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QUALITATIVE FEASIBILITY STUDY OF ALTERNATIVES FOR INTERIM REMEDIATION OF K-65 SILOS

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REPORT

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INTERNATIONAL TECHNOLOGY CORPORATION

QUALITATIVE FEASIBILITY STUDY OF ALTERNATIVES FOR INTERIM REMEDIATION OF K-65 SILOS

Prepared by: IT/ASI

June 1988

Rev. 1

Regional Office
312 Directors Drive • Knoxville, Tennessee 37923 • 615-690-3211

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TABLE OF CONTENTS

5977

1.0 Introduction

- Site Description and History
- K-65 Silo History and Description
- K-65 Silo Waste Characteristics
  - Chemical Characteristics
  - Radiological Characteristics
- Internal Attenuation Layer Selection

2.0 Radon Attenuation Methods

- Venting of Air Space in Silos
- Modification of Existing Radon Treatment System
- Three-foot Rigid Foam Layer on Sludge Surface
- Three-foot Foam Layer on Top of Sludge with Elastomer Seal to Silo
- Permanent or Reversible Gels
- Organic Melts
- Latex Emulsion
- Bentonite
- Cementitious Materials
- Activated Carbon
- Magnesium Sulfate, Silica Gel, etc.
- Other Granular Solids and Combinations
- Transfer of Silo 3 Material into Silos 1 and2

3.0 Silo Dome Support or Combination

- Dome Cover
- Elastomeric Membrane
- Loose Supporting Material Over Radon Attenuation Layer
- Inflated Bladder Within Top of Silo

1.0 INTRODUCTION

5977

SITE DESCRIPTION AND HISTORY

The Feed Materials Production Center (FMPC) was constructed and began operations at the Fernald site in the early 1950s. The U.S. Atomic Energy Commission, predecessor to the U.S. Department of Energy (DOE), established this integrated production complex for processing uranium and its compounds from natural uranium ore concentrates for the needs of the United States government. Initially, uranium ore concentrates, and presently, recycled materials, are converted to either uranium oxides or uranium ingots and billets. They are machined or extruded into tubular form for production reactor fuel cores and target fuel element fabrication.

From 1953 through 1955, the FMPC refinery processed pitchblende ore from the Belgian Congo. No chemical separation or purification was performed on the ore before it arrived at the FMPC. Beginning in 1956 the refinery feed consisted of uranium concentrates (yellowcake) from Canada and the United States.

No uranium ore is currently being received at the FMPC. The basic process performed now is the conversion of uranium-containing residues, uranium hexafluoride, and uranium tetrafluoride to uranium metal.

K-65 SILO HISTORY AND DESCRIPTION

The two K-65 silos, which are on the west side of the FMPC, were constructed in 1951 and 1952. The silos are used for storage of radium-bearing residues, a by-product of the uranium ore processing. The silos are structurally solid with the exception of a 20-foot diameter center section of the dome. At present, two interim stabilization projects are underway to provide radon release control and provide some structural reinforcement to the degrading condition of the dome center section. Phase I, the external foam application results, are reported in Westinghouse's letter TD: 88-056. Phase II, the internal attenuation layer application, is scheduled for fall 1988.

K-65 SILO WASTE CHARACTERISTICS

The current volume of K-65 residues contained in the silos is estimated to be 195,000 cubic feet (8700 MT). The chemical and radiological characteristics of the K-65 residues are summarized in Paragraphs 2.3.1 and 2.3.2 below. The total void volume above the stored residues is estimated to be 87,500 cubic feet (No. 1 of 38,000 cubic feet and No. 2 of 48,000 cubic feet).

Chemical Characteristics

Approximately 40 percent of the K-65 material is composed of silicates (SiO_2). The other constituents that make up 1 percent or more of the residue include calcium, iron, magnesium, and lead. No organic constituents are known to be present in the K-65 residues, although confirmatory data are not available.

Radiological Characteristics

The radiological constituents of the K-65 residue have been estimated to include 11,200 kg of uranium (0.71 percent U-235) and 3000 Ci of radium (Ra-226). The radium concentration is 311 mg Ra-226/ton residue. Radon flux measurements made in October 1984 at 24 locations on each silo ranged from 123 $pCi/m^2/sec$ to more than 3×10^7 $pCi/m^2/sec$. The highest flux values were obtained on surfaces that contained observable cracks.

At present, the radiation exposure rates on the surfaces of the K-65 silo domes are approximately 145 and 185 mrem/hour, and the radon emission levels monitoring results are 45 pCi/liter and 20 pCi/liter, respectively.

INTERNAL ATTENUATION LAYER SELECTION

The internal attenuation layer is intended to reduce the levels of radon gas emitted from the silo residues along with a subsequent reduction in the gamma radiation levels. In addition, this layer was to provide support for the weakened portion of the silo roof; however, roof support can be decoupled from the attenuation layer and independent systems can be evaluated that provide only attenuation or roof support. This report discusses the various methods and combinations of methods proposed to accomplish these tasks.

2.0 RADON ATTENUATION METHODS

VENTING OF AIR SPACE IN SILOS

Summary

Currently, barometric pressure changes result in some release of radon gases from the silo air space. A vent would be installed to control the barometric "pumping" action. The vent would be connected to a closed system or a treatment system to prevent release of radon.

Evaluation Criteria

Application Ease - Installation of a vent system and connection to a separate radon control mechanism could make use of the existing piping and site connections. Structural support of the dome would probably be required in addition to this alternative.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - The technical complexity would be relatively low for the vent system.

One possibility is venting to a sealed pillow tank. The tank would contain the radon gases while controlling the pumping action due to barometric changes. This system would require means to isolate the pillow tank periodically and verify its integrity.

Alternatively, the vent system could vent through a gas dryer and carbon adsorption filter much like the current radon system.

Impact on Final Remediation - The vent system would not significantly impact the final remediation activities.

Public Perception - The vent system alternative should be acceptable from the public perception standpoint. However, "vent" incorrectly implies a release of material. A better name might be "pressure control system".

Environmental and Safety Considerations - A passive vent system would not lower the radon concentration in the silo's air space. Also, internal pressure would be slightly greater than ambient pressure. Releases of radon would be decreased due to control of "puffing". In conjunction with one of the dome-sealing alternatives, the vent system may provide acceptable results.

MODIFICATION OF EXISTING RADON TREATMENT SYSTEM

5977

Summary

The existing radon collection and treatment system would be modified for extended runs, either continuous at lower flow or on an intermittent schedule as required, to prevent radon release from the silos.

Evaluation Criteria

Application Ease - The existing system worked very well for lowering the level of radon gases in the silos, and thus reducing the risk of exposure to workers.

Modifications to the system would be designed to optimize long-term performance with minimal operating and maintenance attention.

Most modifications would be made in the portable building that houses the equipment.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - The existing radon removal system has been proven in service. Modifications would involve changing capacities of equipment and improving the control system.

Impact on Final Remediation - Modification of the radon removal system would not adversely impact future remedial activities.

Public Perception - Public perception of the radon removal system would probably be acceptable. However, this alternative does not provide any structural support of the dome. Public perception may compel steps to prevent dome failure, or to contain any release due to dome failure.

5977

Environmental Safety Considerations - The primary safety considerations with respect to the radon removal system would be monitoring and control of the discharge air.

Another alternative would be required to address the possibility of a dome failure and/or a release.

THREE-FOOT RIGID FOAM LAYER ON SLUDGE SURFACE

Summary

Installation of a three-foot layer of foam to attenuate the radon instead of filling the entire silo simplifies the installation. Drawbacks include shrinkage, difficulty in achieving even application, and upon final remediation, disposal of the low-level radioactive waste that the foam becomes. Sampling would have to be done through a stovepipe or similar device. This method would be much simpler than foaming the entire silo.

Evaluation Criteria

Application Ease - Simpler than full foam.

Exotherms - System is adiabatic; maximum temperature is independent of amount added; will be below degradation temperature.

Dimensional Stability - Some shrinkage will occur.

Technical Complexity - Foam application is common; however, this application will require innovation.

Impact on Final Remediation - Foam will have to be cut out and treated as a low-level radioactive waste. Additional waste volume is created.

Public Perception - The public would probably be receptive of this idea because it resembles the foaming option previously publicized. Their concern of no internal dome support would have to be dealt with.

Environmental Safety Consideration - This method will reduce radon, but not eliminate it.

5977

THREE-FOOT FOAM LAYER ON TOP OF SLUDGE WITH ELASTOMER SEAL TO SILO

Summary

This method would be essentially the same as the three-foot foam layer, except the elastomer would seal the gap formed by shrinkage. Less radon would be released. The application of the elastomer would be more difficult than foam alone.

Evaluation Criteria

Application Ease - More difficult than foam alone.

Exotherms - Same as foam; elastomer should not be significant.

Dimensional Stability - Elastomer seals gap produced by shrinkage.

Technical Complexity - More difficult application.

Impact on Final Remediation - Same as foam; may be more difficult to remove with elastomer seal in place.

Public Perception - The public would probably be receptive of this idea because it resembles the foaming option previously publicized. Their concern of no internal dome support would have to be dealt with.

Environmental Safety Considerations - Would reduce more radon release than foam alone.

5977

PERMANENT OR REVERSIBLE GELS

Summary

Gels are usually installed in a liquid form which become gel-like with time. The use of a pumpable gel would allow the installer to pump a liquid into the silo. The liquid would form a more consistent thickness over the silo before gelling. A reversible gel uses chemical additions either to liquify or gel depending upon the need. The gel would have to be remediated as a radioactive waste or a mixed waste. Additional waste volume is created. These gels may be more expensive than other methods.

Evaluation Criteria

Application Ease - Pumping a liquid into the silo would be relatively simple.

Exotherms - Gels release very little heat; the reaction is relatively slow.

Dimensional Stability - The gel would be flexible enough to adsorb movements of the silo and contents.

Technical Complexity - Choosing the right gel formula may be time-consuming.

Impact on Final Remediation - Permanent gels would be treated similar to foams. The reversible gels would be changed to liquid and pumped out. Both gel types would be treated as radioactive waste.

Public Perceptions - The public may not perceive this option as a "solid" solution. They may still envision walls cracking and gel running out with the sludge.

Environmental Safety Considerations - The gels should provide good attenuation of the radon due to the nature of the gel. Expansion and contraction effects would be minimal. The gel would be a radioactive waste.

ORGANIC MELTS

Summary

Molten organic materials, such as asphalt, petroleum based waxes, and carbowax (PEG), could be used to seal the top of the sludge. The materials would be pumped in as hot liquids and would solidify as they cooled. Some of these compounds have low densities and would float on water, which might be desirable if the sludges are liquid and have low capacity for supporting other materials. Flashing of water may be a problem as the sludges contact the hot melts.

Evaluation Criteria

Application Ease - These materials can be poured but melting and pumping will require heated equipment and traced lines.

Exotherms - Not a problem.

Dimensional Stability - Expansion of silo may open cracks that will result in minor increases in radon leakage.

Technical Complexity - Low.

Impact on Final Remediation - Some organic materials will not be as easily disposed of as mineral-based caps. They might be mixed waste or require incineration.

Public Perception - The public may become concerned over adding hot material and flashing wastewater into the environment.

Environmental and Safety Considerations - These materials will probably provide uniform seal, but may be damaged by debris from dome. Flammability may be a concern.

LATEX EMULSION

Summary

A latex emulsion, similar to latex paint, could be used to attenuate the diffusion of radon from the sludges. This emulsion would contain bentonite or similar clays to provide a thixotropic character. The emulsion would be pumped in and partially cured by lowering the humidity in the silo so that a latex film is formed. Multiple layers of film and emulsion could be built up. This system should be "self-repairing" if damaged by debris from the dome. Acrylic as well as other elastomeric emulsions could be considered.

Evaluation Criteria

Application Ease - This would be one of the easier systems to install. The most difficult aspect would be dehumidifying the silo to cure the film.

Exotherms - Not a problem.

Dimensional Stability - Self-adjusting to expansion cycles and settling.

Technical Complexity - Low.

Impact on Final Remediation - Emulsion may require solidification. May be more difficult to remove than some methods, although not as difficult as foam.

Public Perception - The public may perceive this method to be too simple.

Environmental Safety Considerations - Should effectively seal sludge and tolerate debris from dome and installation uncertainties.

5977

BENTONITE

Summary

Bentonite is effective in attenuating radon because it can retain significant amounts of moisture for extended periods of time.

Application Ease

Bentonite slurry is routinely used in various construction processes, and its handling characteristics are known. Bentonite could be slurried into the silos.

Exotherms - There is no exotherm associated with bentonite.

Dimensional Stability - Volume change of bentonite is dependent on moisture content. Because the environment inside the silo is relatively moist, the bentonite slurry would retain its moisture and therefore would not significantly change in volume.

Technical Complexity - The radon attenuation characteristics of bentonite and other clay materials are well documented. Applications of this type have been previously studied.

Impact on Final Remediation - The bentonite would add volume to the existing waste material in the silos and would require disposal as a low-level radioactive waste.

Public Perception - Public perception should be no different from that of using foam. However, this alternative does not provide support for the weakened section of the dome.

Environmental Safety Considerations - Bentonite is not a hazardous material and would pose no environmental concerns during installation. The effect of dome collapse on the bentonite would require study to ensure that this event would not alter the performance of this material as a radon barrier. If the bentonite were placed so that it was plastic, the material would be "self-healing" in the event of a dome collapse.

CEMENTITIOUS MATERIALS

Summary

Cementitious products, such as concretes, grouts, gunnites, and sodium silicates, could be used to form a cap on top of the sludges to provide an effective radon seal. Multilayer combinations of these materials could be used to form a more effective seal. For example, a thin layer of fast-setting sodium silicate could be used to improve the strength of the sludge surface. A layer of lightweight concrete could serve as the primary radon barrier. This layer might then be coated with gunnite for strength and protection from debris from the dome.

Evaluation Criteria

Application Ease - These materials can be poured or applied by gunning. Poured mixes can be formulated for good flowability so that complete coverage of the sludge surface is assured.

Exotherms - Not a problem.

Dimensional Stability - Expansion of material will have to be considered. Settling and cracking could be a problem.

Technical Complexity - Low for concrete or gunning mixes. Sodium silicate formulations may be more difficult to control.

Impact on Final Remediation - Easier to remove than foam; more difficult than loose, granular material.

Public Perception - The public may become concerned about cracks similiar to those found in driveways.

Environmental and Safety Considerations - Radon attenuation will depend on thickness and integrity of cap. Settling cracks could increase radon leakage.

ACTIVATED CARBON

5977

Summary

Activated carbon is used in the radon removal system to trap the radon until it can decay. Pouring a layer of activated carbon on the top of the sludge could trap the radon. However, in the presence of moisture, radon removal on carbon approaches zero. The silo humidity is saturated and the carbon would not absorb the radon, therefore this technique will not be evaluated further.

MAGNESIUM SULFATE, SILICA GEL, ETC.

5977

Summary

Magnesium sulfate and similar materials act as drying agents and could be applied in a layer between the sludge and the carbon. Theoretically, this method would work. However, too much water exists in the sludge, making this impractical. Therefore, this technique will not be used.

OTHER GRANULAR SOLIDS AND COMBINATIONS

Summary

Many different combinations of granular solids exist that could be used for the radon attenuation. Some of these include sand, gypsum, or flyash. Also, these solids could be layered with each other or with an elastomer to provide an additional seal. The more complicated the system, the more difficult it will be to install. The solids will be difficult to place in a consistent thickness. Gypsum may react with the water to form a plaster-of-paris type skin that may help seal the radon. The addition of an elastomer to improve diffusion resistance would make application and remediation more difficult.

Evaluation Criteria

Application Ease - Solids could be air-conveyed in; maintaining a constant thickness would be difficult. Addition of an elastomer would be much more difficult.

Exotherms - None with solids; elastomer would not add significant heat.

Dimensional Stability - As material absorbs moisture, it may clump and cake, forming cracks. Elastomer may seal these.

Technical Complexity - For solids alone, application in constant layers would be difficult; elastomer application increases complexity.

Impact on Final Remediation - These materials would be easier to remove than the foam but would be radioactive waste. If flyash, gypsum, or lime is used, they could become part of the remediation by assisting in solidification. Elastomer, if installed, would have to be removed separately.

Public Perception - The public may perceive that this material could "sink" into the sludge waste.

5977

Environmental and Safety Considerations - Radon attenuation will depend on thickness. Roof failure into solid bed should not impact radon release if bed is thick enough.

5977

TRANSFER OF SILO 3 MATERIAL INTO SILOS 1 AND 2

Summary

Silo 3 material is a dry metal-oxide, low-level radioactive waste material. This material generates very little radon. It is not much different from the other solids mentioned before, e.g., sand, gypsum, etc., except it is already a radioactive waste material. It could attenuate the radon as well as the other solids. Enough material is present in Silo 3 to fill both silos, providing some roof support. Silo 3 may be emptied. No additional waste is generated. The environmental impact of the transfer would have to be evaluated.

Evaluation Criteria

Application Ease - Similar to other solids, except removal from Silo 3 will have to be evaluated.

Exotherms - None.

Dimensional Stability - A loose, granular solid that should exhibit good stability.

Technical Complexity - Transfer from one silo to another will have to be evaluated.

Impact on Final Remediation - May put all waste in two silos. Does not produce additional waste. Silo 3, if emptied, could be remediated.

Public Perception - The public may have reservations on transfer of material. If Silo 3 can be emptied into other two silos, early remediation of Silo 3 may show progress and relieve some pressure.

Environmental and Safety Considerations - Transfer of waste may have some impact. Radon release would be reduced. If silo is filled, silo support is provided.

3.0 SILO DOME SUPPORT OR COMBINATION

5977

DOME COVER

Summary

A lightweight, self-supporting dome cover could be placed on each silo. This cover would extend over the entire silo and would minimize the environmental consequences of dome collapse.

Evaluation Criteria

Application Ease - The cover could be manufactured and shipped to the site. Final assembly would take place at the site. The dome cover could be set by a crane or assembled in place. These covers can be readily obtained and installed in a relatively short amount of time.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - Using the dome cover as a radon barrier is probably more complex than other alternatives because radon attenuation depends on (1) the material used to construct the dome, and (2) how airtight the dome could be made, particularly with respect to the dome-silo interface.

Assuming the dome cover could function as a radon barrier, the area where the existing concrete dome meets the wall would possibly allow radon to escape because the earth cover at this location is minimal.

However, the dome cover could function as a secondary containment when used in conjunction with a radon barrier placed on top of the K-65 residue. It would minimize the environmental consequences of dome collapse by maintaining the interior of the silo in its present state.

5977

Impact on Final Remediation - If the dome cover is used as a barrier and subsequently became contaminated, it would have to be disposed of as a radioactive waste. However, if the dome cover is used in conjunction with a radon barrier, it may not become contaminated and could be reused or disposed of as ordinary scrap.

Public Perception - Public perception would be positive because the covers would provide additional protection in the event of dome collapse. Also, the dome covers would be visible.

Environmental and Safety Considerations - A dome cover used in conjunction with a radon barrier located on top of the K-65 residue would maintain the present environment of the silo interior if the existing silo dome were to collapse.

5977

ELASTOMERIC MEMBRANE

Summary

An elastomeric membrane could be placed over the existing dome and along the top and sides of the berm where there is limited soil thickness.

Evaluation Criteria

Application Ease - The application is comparable to the recent operation in which a layer of rigid foam was placed on the dome. Removal of existing vegetation on the affected area of the berm would be required.

Exotherms - Not applicable.

Dimensional Stability - Not applicable.

Technical Complexity - The elastomeric membrane seal was proposed to provide a seal between the rigid foam and the silo wall in the original design. Therefore, it is technologically feasible for this application.

If collapse of the center dome portion occurs, the existing temporary cover would provide support for the membrane.

Impact on Final Remediation - The membrane would have no impact on final remediation because it is located completely outside the silo.

Public Perception - Public perception should be favorable, provided the public is made aware that this is a temporary solution.

Environmental and Safety Considerations - This alternative does not provide support for the weakened section of the dome. It could be used in conjunction with other alternatives, such as venting the air space in the silo or a radon treatment system.

5977

LOOSE SUPPORTING MATERIAL OVER RADON ATTENUATION LAYER

Summary

Addition of a "fill" material over other radon attenuation material (such as styrofoam "peanuts", vermiculite, or perlite), could be used to fill the void space over the attenuation layer to provide some silo roof support. The fill material would not necessarily be considered a radioactive waste. The fill material could be used alone, but if so, it may not provide sufficient radon attenuation and would be considered radioactive waste.

Evaluation Criteria

Application Ease - Material is easily handled by air.

Exotherms - None.

Dimensional Stability - As a loose fill, would allow for all silo movements. Material is used as packing for shipping fragile cargos.

Technical Complexity - Simple.

Impact on Final Remediation - Fill over radon barrier could be incinerated. Fill alone would be radioactive waste.

Public Perception - Public perception should be positive if envisioned as a means of internal dome support or cushion. Perception of use of "fill" material alone would be poor considering porosity.

Environmental and Safety Considerations - Would provide some roof support. Final disposal would depend on use; some may be radioactive waste.

5977

INFLATED BLADDER WITHIN TOP OF SILO

Summary

A bladder could be inserted into the void space above the waste material, and then inflated sufficiently to fill the space and provide some support of the dome.

Application Ease

The bladder would need to be inserted through one of the existing manholes. Cutting a larger opening would not be advisable due to existing structural problems with the dome. Therefore, the thickness of the bladder material would be a critical factor in the compactness of the bladder when uninflated.

Mechanical damage of the bladder during installation or damage from possibly exposed reinforcing steel in the dome would be difficult or impossible to repair with the bladder in place, and would destroy the effectiveness of the bladder. Therefore, this alternative will not be considered further.