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CONCEPTUAL DESIGN REPORT K-65 STORAGE SILO RADON MITIGATION AND DOME REINFORCEMENT STUDY (USED AS A REFERENCE IN THE OU4 RI REPORT)

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CONCEPTUAL DESIGN REPORT

K-65 STORAGE SILO RADON MITIGATION AND DOME REINFORCEMENT STUDY

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CONCEPTUAL DESIGN REPORT

K-65 Storage Silo Radon Mitigation and Dome Reinforcement Study

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EXECUTIVE SUMMARY

In response to Item B of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Section of the Federal Facilities Compliance Agreement between the Department of Energy (DOE) and the Environmental Protection Agency (EPA), the Feed Materials Production Center (FMPC) has prepared a Conceptual Design Report (CDR) involving radon emission control and additional dome structural reinforcement for the K-65 Silos. The project described in the CDR involves filling the remaining volume occupied by gas within the K-65 Silos with a polyurethane foam material while providing for safe treatment of the accumulated and continually generated radon gas in the silos.

K-65 Silo radon emission controls are recommended to provide the safest radiological environment possible for personnel that will be working on or near the K-65 Silos during future remediation work. Reinforcement of the K-65 Silo domes is recommended based on the determination that the domes are structurally weak. Moreover, future remedial work on the K-65 Silos would be difficult and costly due to 1) high concentrations of radon gas at the dome surfaces; and 2) special design considerations required by the limited loads allowed by the current structural integrity of the silo domes.

Based upon previous structural engineering evaluations, the feasibility investigation for radon gas control from the K-65 Silos and environmental monitoring data gathered concerning radon flux and radon concentrations in the K-65 area, WMCO recommends that final detailed design for the system to fill the K-65 Silos with foam be completed and operation initiated by September of 1987.

The cost to complete the work outlined in the CDR is estimated at $250,000 and can be completed by October, 1987 pending funding appropriations and DOE and EPA approval by May 29, 1987.

1.0 INTRODUCTION

Westinghouse Materials Company of Ohio (WMCO) operating under its prime contract with the United States Department of Energy (DOE), coordinates activities, including waste management, at the Feed Materials Production Center (FMPC) located in Fernald, Ohio.

As part of the comprehensive waste management and environmental program for the FMPC, specific alternatives are being developed and evaluated for the final disposition of the low-level radioactive waste inventory currently stored at the site. The Waste Storage Areas under evaluation in this program consist of six storage pits, the clear well, the burn pit, two fly ash piles, and adjoining areas (Figure 1.0-1).

This Conceptual Design Report (CDR) outlines the work necessary to fill the remaining volume currently occupied by gas within the two concrete silos in the Waste Storage Area which contain K-65 residues (Figure 1.0-2). The CDR consists of a description of the K-65 Silos and the residues, current structural status, summaries of both the Monsanto-Mound and FMPC Environmental Monitoring Reports as related to radon emissions, a general project description, justification for project design, recommendations and significant factors as related to the project.

The primary objective of the CDR is to present a feasible solution to maintain the K-65 waste storage silos in the most environmentally safe containment mode possible until the site wide Remedial Investigation/Feasibility Study (RI/FS) can be evaluated and alternatives implemented. It is expected that the FMPC is at least 3 years away from implementing any of the alternatives that will be recommended by the RI/FS.

2.0 BACKGROUND

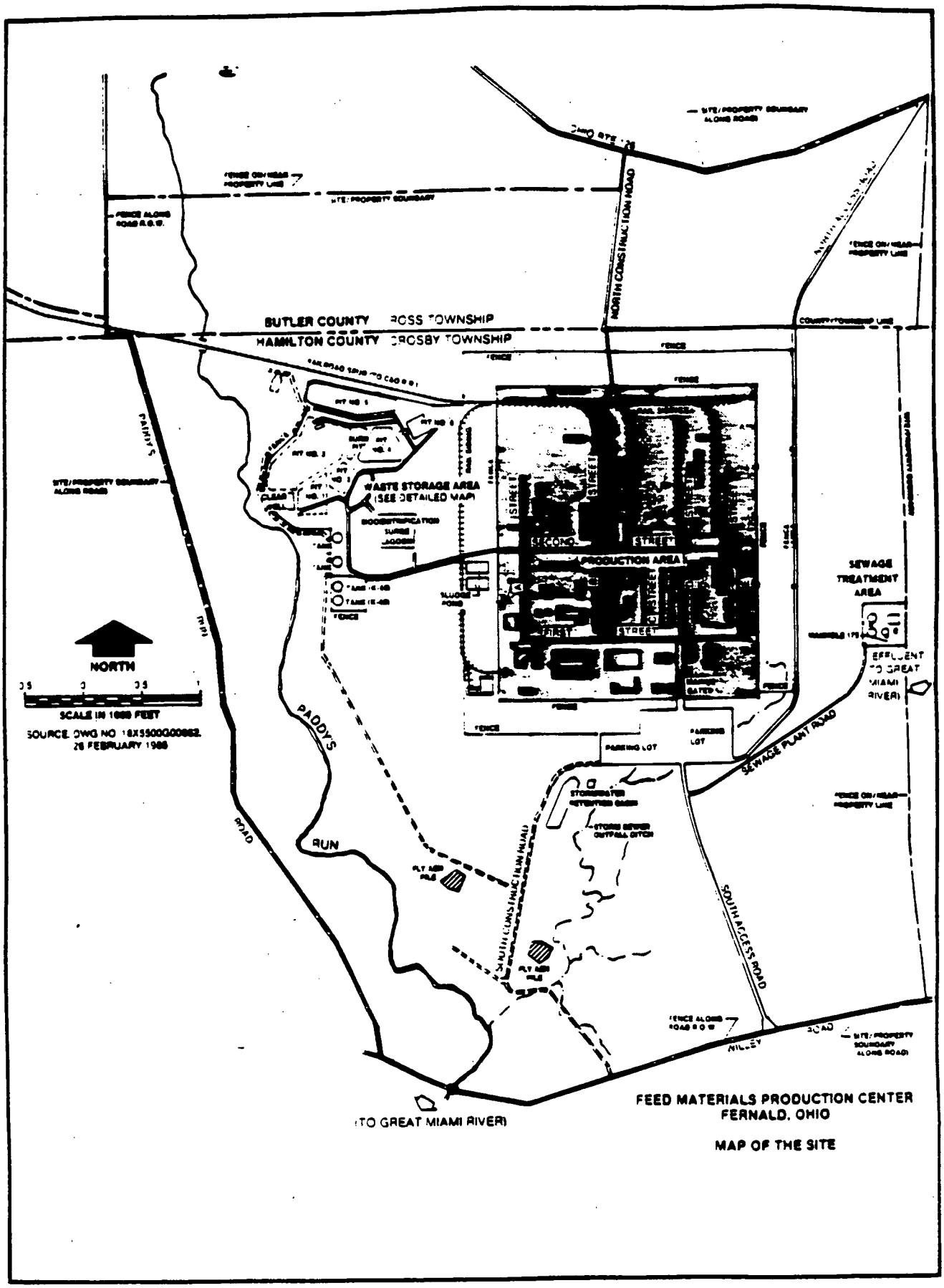
2.1 Historical Information

The two K-65 Silos, located on the west side of the Fernald site, were constructed in 1951 and 1952. The silos are used for storage of radium bearing residues, a by-product of uranium ore processing. The silos are of cylindrical concrete construction, 80 feet in diameter and approximately 27 feet high. The silo domes were originally designed to be 8 inches thick at the dome wall tapering to 4 inches thick at the center. Figure 2.0-1 shows the major structural details of the K-65 Silos.

The walls were post-tensioned reinforced with 0.162 inch diameter wire stressed to 140,000 pounds per square inch (PSI) (with assumed 30% loss, for a design stress of 100,000 PSI). These post-tensioning wires were covered by a 3/4 inch thick gunite coating. The minimum 28-day compressive strength used was 4500 PSI for the dome and walls and 3000 PSI for the floor and footing. The maximum allowable soil pressure was 4000 pounds per square foot (PSF).

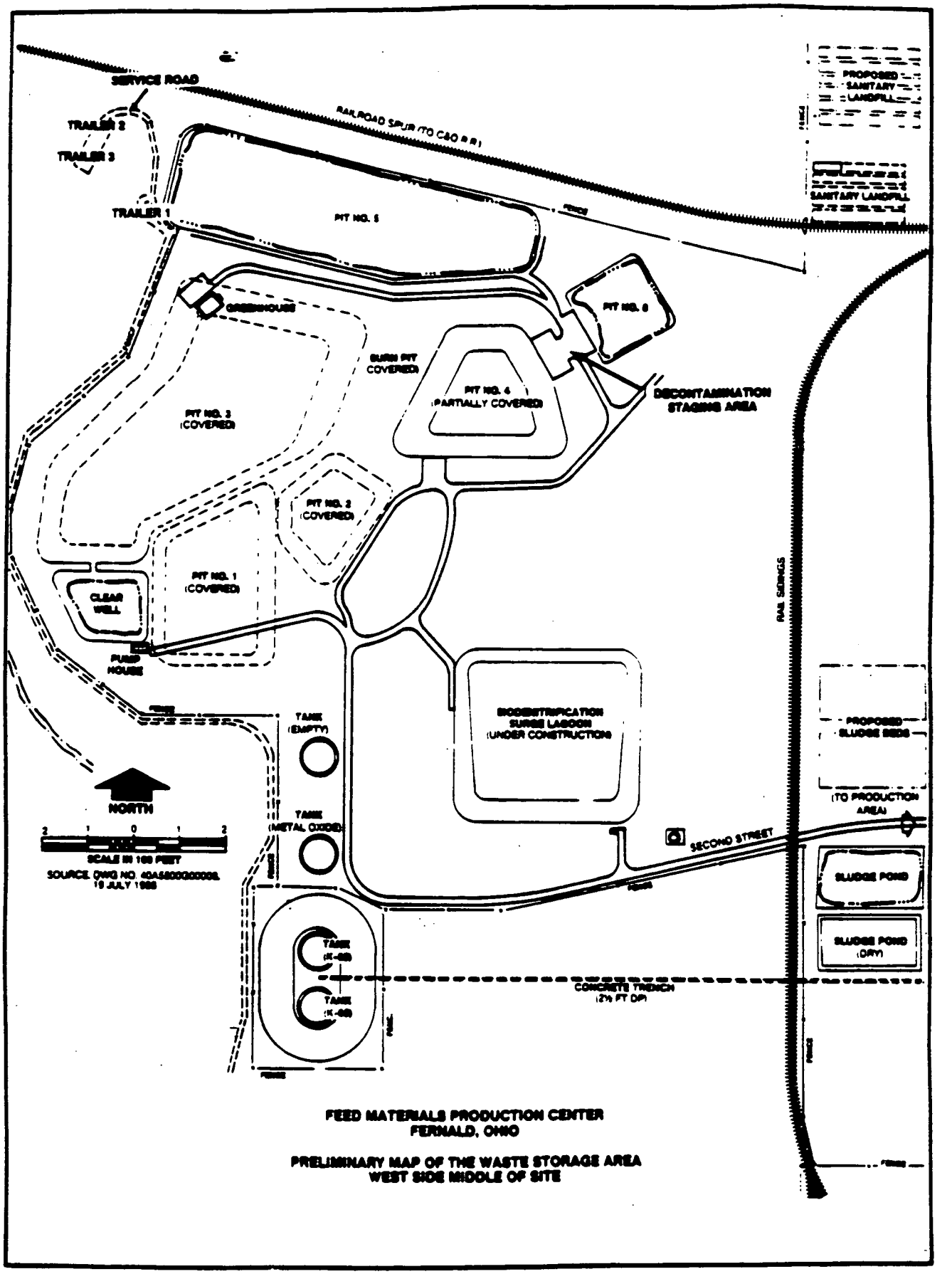
The silos were designed to be loaded with the metal oxides in slurry form at a maximum rate of 8000 gallons per day. The radioactive residues were allowed to settle and the water was decanted, leaving a sludge with a density of 100 pounds per cubic foot (PCF) and angle of repose of 0 degrees. The maximum allowable height of solid material was 23 feet and the water was decanted to a plant to be reused in the production of additional slurry.

In 1963, the silos were showing signs of exterior surface deterioration. Large areas of spalling occurred in the exterior surface gunite coating, particularly on the north silo, leaving post-tensioning wires exposed to weather. Subsequently, patches of the wires became severely corroded and broken. Various options were investigated as remedial actions for the silos. Repairs began in 1964 by first chipping away all loose gunite material and then patching the surface with 3/4 inch coat of cement mortar. After the gunite was repaired, and a waterproofing sealant was applied to the external silo walls, an earth embankment was



MAP OF THE SITE
FEED MATERIALS PRODUCTION CENTER, FERNALD, OHIO

FIGURE 1.0-1



MAP OF THE FMPC WASTE STORAGE AREA

FIGURE 1.0-2

TYPICAL SECTION THRU

K-65 SILO

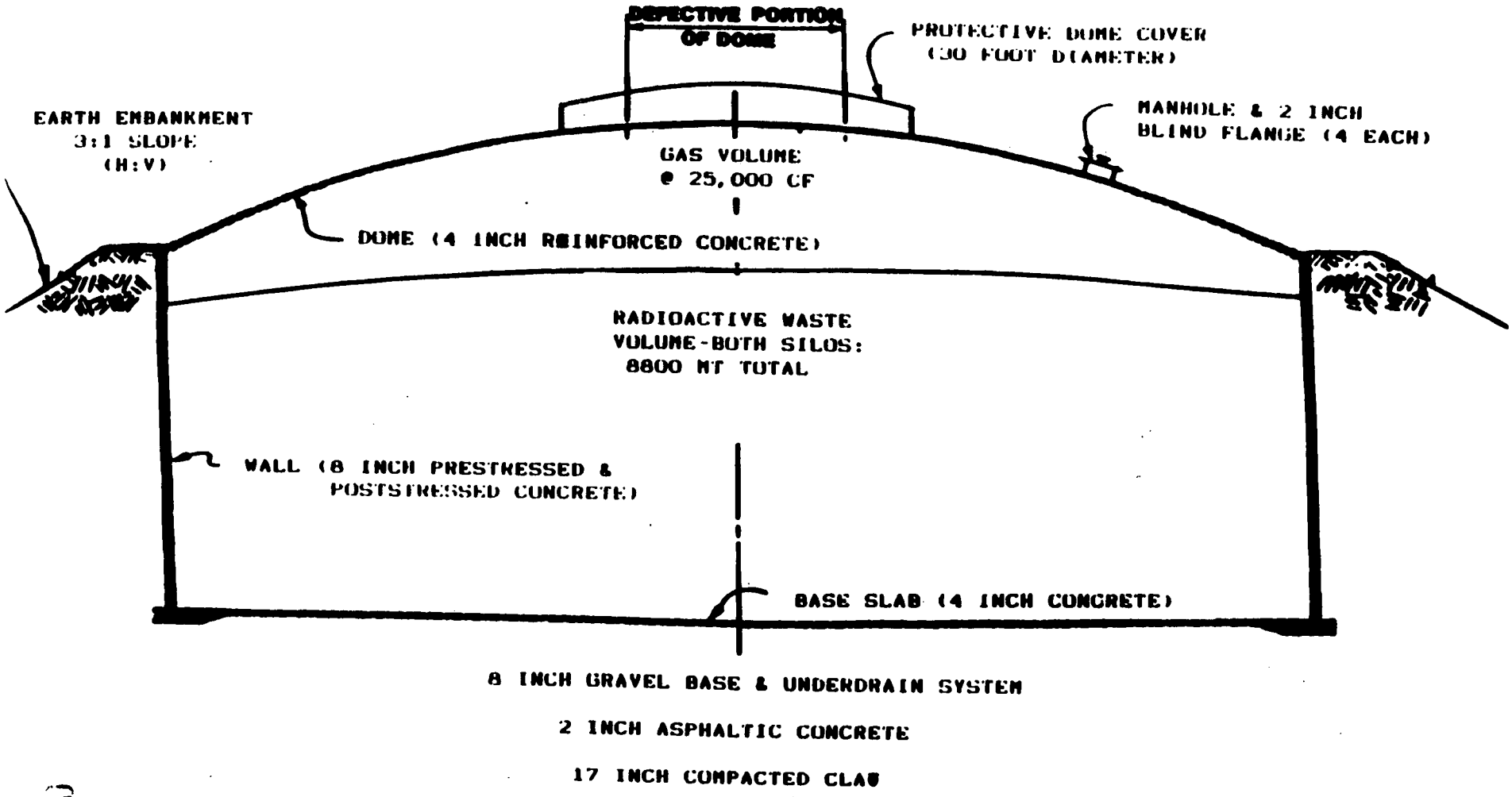


FIGURE 2.0-1

built to the top of the wall on a one and one-half to one (1-1/2:1) slope (horizontal:vertical). The earthen embankment was to provide relief from tensile stress within the walls by counterbalancing the load from the internal contents, since the broken wires were not replaced. A soil was chosen with roughly the same density (125 PCF) as the contents of the silos (100 PCF). Two additional purposes of the embankment were to provide weather protection and to reduce the radon emission from the silos.

In the subsequent years problems with soil erosion on the soil embankment were frequent. The eroded areas were repaired, but with heavy rains the problem reoccurred. In 1983, the embankment was enlarged to achieve a 3:1 slope. No further evidence of large scale erosion has occurred.

2.2 K-65 Silo Waste Characteristics

The current volume of K-65 residues contained in the silos (1&2) at the FMPC is estimated to be 195,000 cubic feet (8800 M.T.). The chemical and radiological characteristics of the K-65 residues are summarized in sections 2.2.1 and 2.2.2 (Reference 1).

2.2.1 Chemical Characteristics

Inorganic constituent analyses for nonradiological elements in the K-65 residue at the FMPC are summarized in Table 2.2.1. Approximately 40 percent of the K-65 waste is composed of silicates (SiO_2). The other constituents comprising one percent or more of the residue include calcium, iron, magnesium, and lead. No data for organic constituents of the FMPC K-65 residues are available.

2.2.2 Radiological Characteristics

The radiological constituents of the K-65 residue at the FMPC have been estimated to include 11,200 kg of uranium (0.71 percent U-235) and 1,652 Ci of radium (Ra-226). The radium concentration is 2.0×10^5 pCi/g. Radon flux measurements made in October 1984

at 24 locations on each silo ranged from 13 $pCi/m^2/sec$ to greater than 3×10^7 $pCi/m^2/sec$. The highest flux values were obtained on surfaces which contained obvious cracks.

3.0 CURRENT K-65 SILO STRUCTURAL STATUS

3.1 Structural Investigation and Analysis

In July of 1985, Camargo Associates, Ltd (Camargo) was subcontracted to perform a nondestructive testing program and structural analysis on the K-65 Silos (Silos 1 and 2) using state-of-the-art testing equipment and computer modeling techniques.

The silo investigation consisted of three phases. The first phase was a computer analysis of the storage silos depicting the original "designed" condition of the silos based on the original construction drawings and specifications.

The second phase consisted of field work that was divided into three areas. These were; the soil exploration study, the "Echo Pulse" system of testing the silo domes, walls and base slabs, and the "Ground-Radar Survey" of the earth embankment around the K-65 Silos. The field work activities were subcontracted by Camargo to Muenow and Associates and Soil & Materials Engineers, Inc.

The third phase was a detailed computer analysis of the K-65 Silos utilizing the results of the initial "designed" computer analysis and the fieldwork data. This work was done by Camargo utilizing three-dimensional modeling programs. The final report of Camargo's study was issued on February 25, 1986 (Reference 2).

Based on their investigation and analysis of the K-65 Silos, Camargo made recommendations and conclusions concerning the silos. A summary of the Camargo recommendations and conclusions are as follows:

1. The base slab and walls at the time of the investigation were structurally stable under the existing static loads being applied

to them and should continue to remain stable for approximately 5 to 10 years.

2. If either the contents of the silos or the silo embankment were to be removed, they must be removed simultaneously or failure of the walls or base slab could result.

3. The center 20 foot diameter portion of the dome top is structurally unsound for a load greater than the existing static dead load and no life expectancy was assigned to it.

4. The application of a three foot thick earth fill load on the dome or the application of tornado suction or pressure loads, would cause a structural failure of the dome.

5. The application of the "defined" synthetic earthquake would induce some additional cracking in the base slab and at the base of the silo wall, but the silo would still be in a serviceable condition. The dome would be unaffected, and should simply move with the ground motions.

6. If a cover is chosen to cover the center portion of each silo dome, the weight should be as light as possible and in no case should it be greater than that allowed by the buckling capacity of the dome (approximately 11,000 pounds).

Additionally, the Camargo report concluded that the dome of the silos were the most critical part of the entire silo structure system. The critical buckling load of the domes was calculated to be approximately 284 PSF for the existing concrete outside the center 20 foot critical dome area. Using a safety factor of 4 the allowable load would be 71 PSF. Inside the critical 20 foot diameter area, the buckling load was calculated to be approximately 104 PSF for the existing concrete. Using a safety factor of 4, the allowable load would be 26 PSF (based on a 2 inch thick area of concrete). The allowable buckling load for the center 20 foot area, therefore, is nearly the same as the dead weight of the dome itself.

3.2 Structural Remedial Actions

In response to the Camargo recommendations, the FMPC had a temporary dome, 30 feet in diameter, designed and installed to span across the weakened portion of the concrete domes. The cover is self supporting and sits on a rolled plate steel skirt. The 30 foot diameter cover is composed of structural steel members which supports 3/4 inch plywood sheeting. The plywood sheeting is covered with a weatherproofing membrane. The dome cover increases the stresses in the existing concrete, but all stresses are within acceptable limits. The dome cover was installed so that containment of the silos contents will be maintained in the event of a center silo dome collapse. This work was completed in January, 1986.

In addition to the dome cover, the installation of an applied fluid neoprene membrane was initiated to cover the existing concrete dome outside the dome cover on the K-65 Silos. The neoprene membrane is designed to prevent water from seeping into the silo dome cracks; thus, limiting further deterioration. It is postulated that the membrane will also inhibit the escape of radon gas and radon daughter products to the environment. This work is currently on hold due to increased radiological concerns stemming from application of the membrane.

4.0 RADON EMISSIONS FROM THE K-65 SILOS

4.1 Summary of the Radon Monitoring Program Report

From September 20, 1984 to February 5, 1985, Monsanto-Mound conducted radon gas monitoring in the environs of the K-65 Silos (Reference 3). The objective of the monitoring program was to assess the extent of increased radon concentrations due to the radium-bearing K-65 residues stored in silos 1 and 2. The radon monitoring program consisted of two subtasks: 1) measurement of radon flux from the surface of the K-65

Silos; and 2) measurement of radon concentrations in the surrounding K-65 Silo environment.

4.1.1 Radon Flux Measurements from the Dome Surfaces

In order to determine the radon gas flux from the surface of the K-65 Silo domes, Monsanto-Mound employed the use of charcoal canisters which were placed on 24 locations on both the K-65 Silos domes. After a period of exposure, the radon-222 content of each canister was then analyzed in the radon laboratory at Monsanto-Mound.

The flux measurements ranged from approximately 13 $pCi/m^2/sec$ to 3 x 10^7 $pCi/m^2/sec$. By comparison, the Environmental Protection Agency standard for uranium mill tailings disposal sites is 20 $pCi/m^2/sec$.

Monsanto-Mound reported that although the measured flux values tended to be higher than those found on inactive mill tailings sites, the surface areas of the tanks are substantially less than those of the tailing sites (ten thousand square feet versus many acres). Monsanto-Mound concluded that the annual radon release from the K-65 Silos is probably less than from the inactive mill tailings sites (200 to 11,500 Ci/yr) and the silos represent a very discontinuous source.

4.1.2 Radon Air Measurements in the Vicinity of the Silos

Time-integrated measurements of radon in air around the K-65 Silos were conducted by Monsanto-Mound utilizing Passive Environmental Radon Monitors (PERMs). After the PERMs were exposed from one to two weeks, the lithium fluoride chips located in each PERM were read and the radon concentration calculated. The results of the radon monitoring between September 20, 1984 and December 5, 1985 ranged from 5.1 pCi/liter near the K-65 Silos to 0.24 pCi/liter at locations farthest downwind along the eastern FMPC site perimeter (approximately 0.75 miles). In comparison, the average background

radon concentration for other locations in the northeastern United States ranges from 0.2 to 0.3 pCi/liter. The radon concentration values measured near the K-65 Silos are below the DOE guideline value of 3.0 pCi/liter above background for uncontrolled areas and 100 pCi/liter value for occupational exposures.

4.2 Summary of the FMPC Radon Monitoring Network

A radon monitoring program has been implemented by the FMPC for the fenceline and offsite environs. The program monitors both radon-222 and radon-220 (thoron) to determine the radiation exposures to humans from both radon and its decay products.

Radon-222 is monitored with track-etch detectors which consist of alpha sensitive plastic detectors mounted inside inverted cups covered by a membrane to prevent radon decay products from entering the cup and being detected. This membrane also sufficiently retards the diffusion of radon to the extent that the short-lived radon-220 does not enter these cups; however, the radon-222 does diffuse through the membrane. A second track-etch cup is also located at each radon monitoring location. The filter over this cup is permeable to radon, allowing both radon-222 and radon-220 to enter the cup, while preventing entry of decay products. Radon-220 concentrations can, therefore, be determined by subtracting the response of the radon-222 cup from that of the radon-222 plus radon-220 cup.

The detector inside each cup is sensitive to alpha particles from radon and its decay products. The alpha particles penetrate the plastic detector leaving tracks which are subsequently etched to produce visible tracks in the plastic. The number of alpha tracks counted per unit area is proportional to the average radon concentrations. The advantages of the track-etch monitoring technique over other radon monitoring techniques are that the monitoring is completely passive, no electrical or mechanical components are involved, and the monitoring is easy to

conduct. Once the detectors are exposed, the vendor of the detectors etches the plastic, visually reads the number of tracks per unit area, and reports the measured concentrations.

Track-etch detectors are a widely accepted method for obtaining accurate measurements of radon concentrations. Measurement standard deviations are generally in the range of 20% for typical environmental concentrations. Results are usually obtained within four weeks from submission of the detectors to the vendor for processing.

The monitoring locations were selected to characterize radon concentrations and potential exposures to humans. The monitoring locations are at the FMPC site boundaries, at two schools, at a local business, and at two residences. The residences serve as background monitoring locations which are in the same meteorological wind patterns as the FMPC site but far enough from the site so as not to be affected by radon emitted from the site. Specific monitoring locations, their distance from the center of the FMPC site, and the direction from the center of the FMPC site are presented below:

Location Number	Type of Site	Distance in km From Center of FMPC	Direction
1	Site Boundary	1.0	N
2	Site Boundary	1.3	NE
3	Site Boundary	0.7	E
4	Site Boundary	1.3	SSE
5	Site Boundary	1.1	SW
6	Site Boundary	0.9	W
7	Site Boundary	1.3	NW
8	Elda School in Ross	4.6	ENE
9	Crosby Township School	3.6	SW
10	Business - Fernald	2.5	S
11	Residence	7.9	W
12	Residence	5.0	ENE

Cups for measuring both radon-222 and radon-220 were installed in 1980. Cups that measure radon-222 only (and therefore allow for determination of radon-220 concentrations when used in tandem with radon-222 plus radon-220 cups) were installed in July, 1986.

During the first quarter of 1987, additional radon-222 and radon-220 monitoring stations are being installed along the FMPC site boundary fence and the K-65 Silos exclusion fence at each of the 16 compass points concentric about the K-65 Silos.

4.2.1 Results from the FMPC Monitoring Data

The established regulations and guidelines limiting concentrations above natural background of radon (Rn-222) and thoron (Rn-220) are presented in 10 CFR 20, Appendix B and DOE Order 5480.1A. Both of these documents limit off-site, non-occupational concentrations of Rn-222 to less than 3 pCi/l. In addition, 10 CFR 20 regulations limit off-site, non-occupational concentrations of Rn-220 to less than 10 pCi/l.

Environmental data obtained at the fenceline of the FMPC and two off-site locations for the most recent available analyses (3rd quarter, 1986) indicate the maximum Rn-222 concentration of 0.7 pCi/l and maximum Rn-220 concentration of 0.7 pCi/l. These maximum values for Rn-222 and Rn-220 are 23% and 7%, respectively of the guidelines and include natural background concentrations of radon.

Environmental data obtained during 1985 for radon concentrations in ambient air were obtained using radon cups without thoron filters, thereby actually measuring both radon and thoron concentrations in 1985. The maximum concentration measured in 1985 was 1.42 pCi/l of radon (Rn-220 and Rn-222) at boundary air monitoring station #6A. This information is continuously gathered and presented each year in the Environmental Monitoring Annual Reports for the FMPC.

Upon evaluation of the available radon monitoring data, interim controls of radioactive emissions from the K-65 Silos are not required to limit off-site, non-occupational concentrations of Rn-222 above natural background.

Methods for controlling occupational exposures to radon are strictly applied to any work activity in the vicinity of the K-65 Silos.

5.0 GENERAL PROJECT DESCRIPTION

The basic plan of the CDR is to fill the remaining void volume in the K-65 Silos with a closed cell, polyurethane foam while providing for safe treatment of the accumulated and continually generated radon gas contained within the silos. Detailed descriptions of both the foam system and treatment/circulating system are provided in Sections 5.1 and 5.2 respectively.

The radon gas treatment/circulating system will be operated prior to injection of the foam into the silos to determine the efficiency of the system to remove and treat radon gas contained in the silos. The treatment of the accumulated radon gas contained within the silos is necessary to minimize the release of radon gas to the environment during the foaming operation. Once satisfactory operation of the treatment/circulating system is obtained, the system will be operated for a continuous period prior to the foaming operation. Satisfactory operation will be based upon gas sample analysis taken upstream and downstream of the treatment system.

Once the gas volume inside a silo has been treated, foam injection will proceed immediately. Determination of when the gas treatment is complete will be based upon radiation measurements of the gas upstream of the treatment/circulating system. During the foam injection, it is anticipated that the radon gas treatment/circulating system efficiency will decrease significantly. The reason for the system efficiency decrease is that the organic gases that are generated during the foaming operation compete with the radon gas for adsorption onto the activated carbon. Based on this knowledge, the anticipated Rn-222 release was calculated using a conservative assumption

of 0% treatment/circulating system efficiency during the initial 2 foot foam application (Appendix II). The calculations in Appendix II show that the maximum downwind dose and Rn-222 concentration occurs at 200 meters from the silos and are 3.5 mrem (whole body) and 13.4 pCi/liter, respectively.

The foam injection will be accomplished by trained subcontractor personnel utilizing a long rigid spray wand to assure that complete filling of the silo volume is obtained. It has been calculated that once an initial 2 foot layer of foam is in place, the radon gas will be almost entirely attenuated by the foam material (Appendix 1). The entire operation of filling a K-65 Silo with foam can be accomplished in one day. The injection of the foam material will be performed in 2 foot layers to assure proper curing of the foam and control over the expansion of the foam.

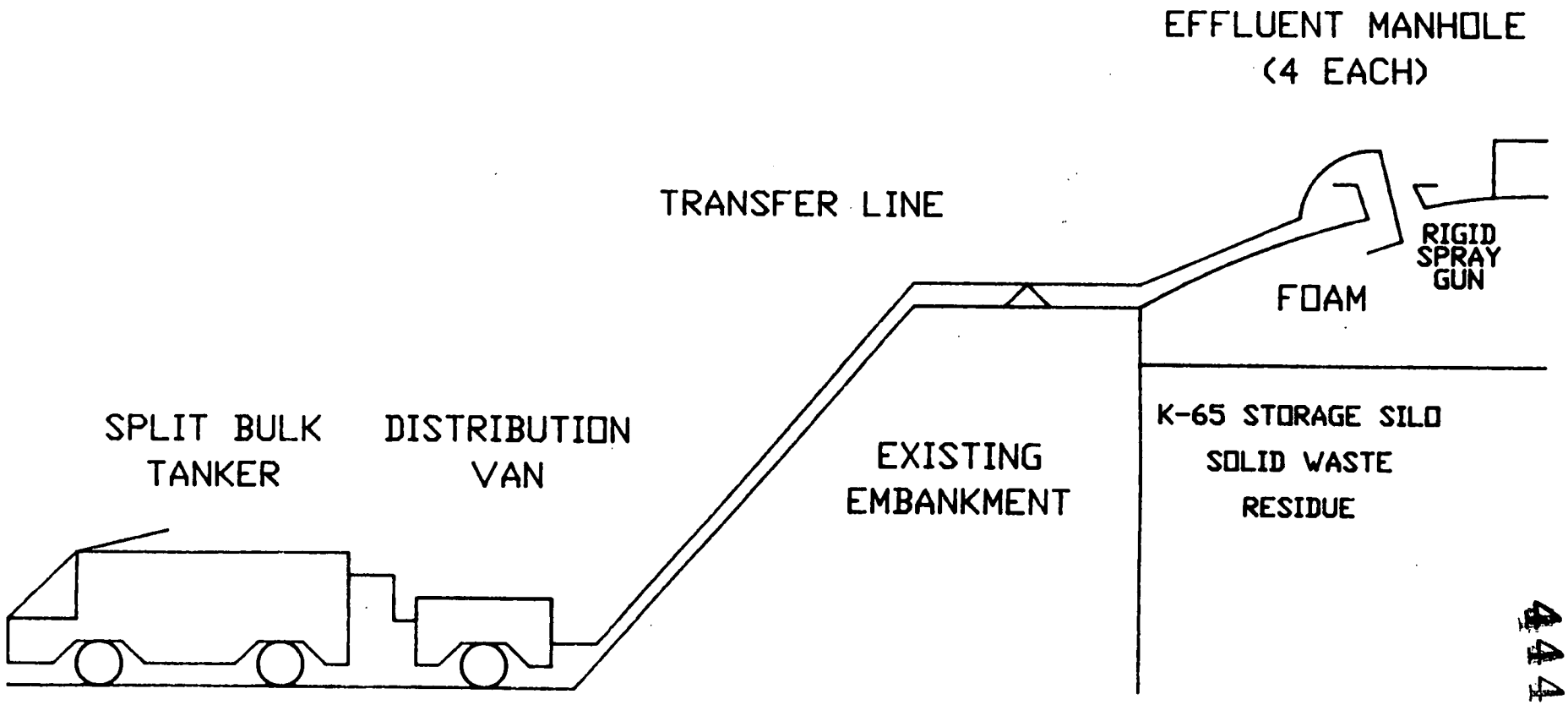
5.1 Foam System Details

The polyurethane foam that is proposed to fill the void space in the K-65 Silos is a rigid closed cell material with an approximate density of 2 to 3 lb/ft^3. The foam material consists of a two component system that upon mixing, reacts and forms a rigid, stable, structure. The density, curing rate and other properties can be controlled by the foam applicators to best suit FMPC requirements and installation restrictions related to the K-65 Silos.

Figure 5.1 is a conceptual sketch of the foam injection operation for the K-65 Silos. The two foam components will be supplied from a split bulk tanker that will transfer the liquid components to a van. The foam flow rate is controlled by the equipment in the van and transferred through a hose up to a portable spray gun on the silos. The liquid foam components are mixed at the spray gun and will be blown into the silos utilizing a fluorocarbon blowing agent. The directional flow of the foam material will be controlled by the subcontractor personnel via the spray gun. The foam material will be injected through each of the 24" effluent manholes located on top of the K-65 Silos.

FIGURE 5.1

PROPOSED K-65 SILO FOAM FILLING SYSTEM



5.2 Radon Gas Treatment/Circulating System

The treatment of radon gas by adsorbtion onto activated carbon has been used successfully in previous applications (References 4, 5). The efficiency of an activated carbon system for removal of radon gas from an air stream depends primarily on the carbon temperature, humidity and gas retention time. Experimental data regarding radon absorption by activated carbon as a function of radon concentrations, air humidity, air flow rates and temperature are available in Reference 4. Essentially, the lower the air humidity, the longer the retention time and the cooler the activated carbon temperature, the more efficient the radon adsorption system. Radon concentration in the air stream does not have any detectable effect on the rate of adsorption for low radon concentrations.

The radon gas control system proposed to treat the radon gas generated and accumulated inside of the K-65 Silos is conceptually illustrated in Figure 5.2. The treatment/circulating system will be designed as a closed system, i.e., the gas will be removed from a K-65 Silo, filtered, the radon adsorbed onto activated carbon and the remaining gas returned into the silo. The reason for the closed system design is to minimize any potential release of radon gas to the environment that would be caused by an open system that is less than 100% efficient for removing radon gas from a bulk gas stream.

The radon treatment/circulating system will first remove gas from within a K-65 Silo and pull the gas through a prefilter then a HEPA filter to remove any particulate matter contained in the gas stream. The prefilter assembly can be specially manufactured to provide for moisture removal from the gas stream. The gas will then be channeled to an activated carbon canister that will adsorb the radon gas component from the gas stream. The remaining gas will be exhausted to the opposite side of the K-65 Silo from which it was removed to provide for optimum mixing within the silo. Note that the ratio of radon gas volume to the bulk gas volume contained in a silo is approximately 2×10^{-11}.

Two sampling ports, one upstream of the prefilter and one downstream of the activated carbon, will be provided to allow a determination of the

treatment/circulating system efficiency. In addition, the downstream sampling port will determine when saturation of the activated carbon canister occurs so that a fresh canister can be put on line. It is estimated that each canister will contain approximately 400 pounds of activated carbon and should be adequate to trap the existing radon activity in a K-65 Silo (22 curies) plus the additional generation during the treatment period.

The prefilter, HEPA filter and blower unit will be housed in a temporary metal shed. The activated carbon canisters will be housed in a separate temporary metal shed within close proximity of the blower unit. Shielding for the radon treatment equipment will be provided by dirt filled low-level waste boxes that exist on site and can be conveniently positioned for shielding purposes. Access to the blower unit may be required for prefilter changeout if too large of a pressure drop develops from particulate loading or if high radiation levels occur. The activated carbon canisters can be isolated by the upstream and downstream valves provided for each canister outside of the metal sheds if saturation of a canister should occur.

The buildup of radioactive daughters in the treatment/circulating system, particularly in the filters and activated carbon, will be shielded by the dirt filled waste boxes. The half-life of the radon daughter particulate material is extremely short, however, and the radiation exposure levels will decrease rapidly after the blower system is shut down.

5.3 Project Costs

The total estimated cost for the CDR is $250,000 (+ or - 20%). The cost breakdown of the major cost items is provided below:

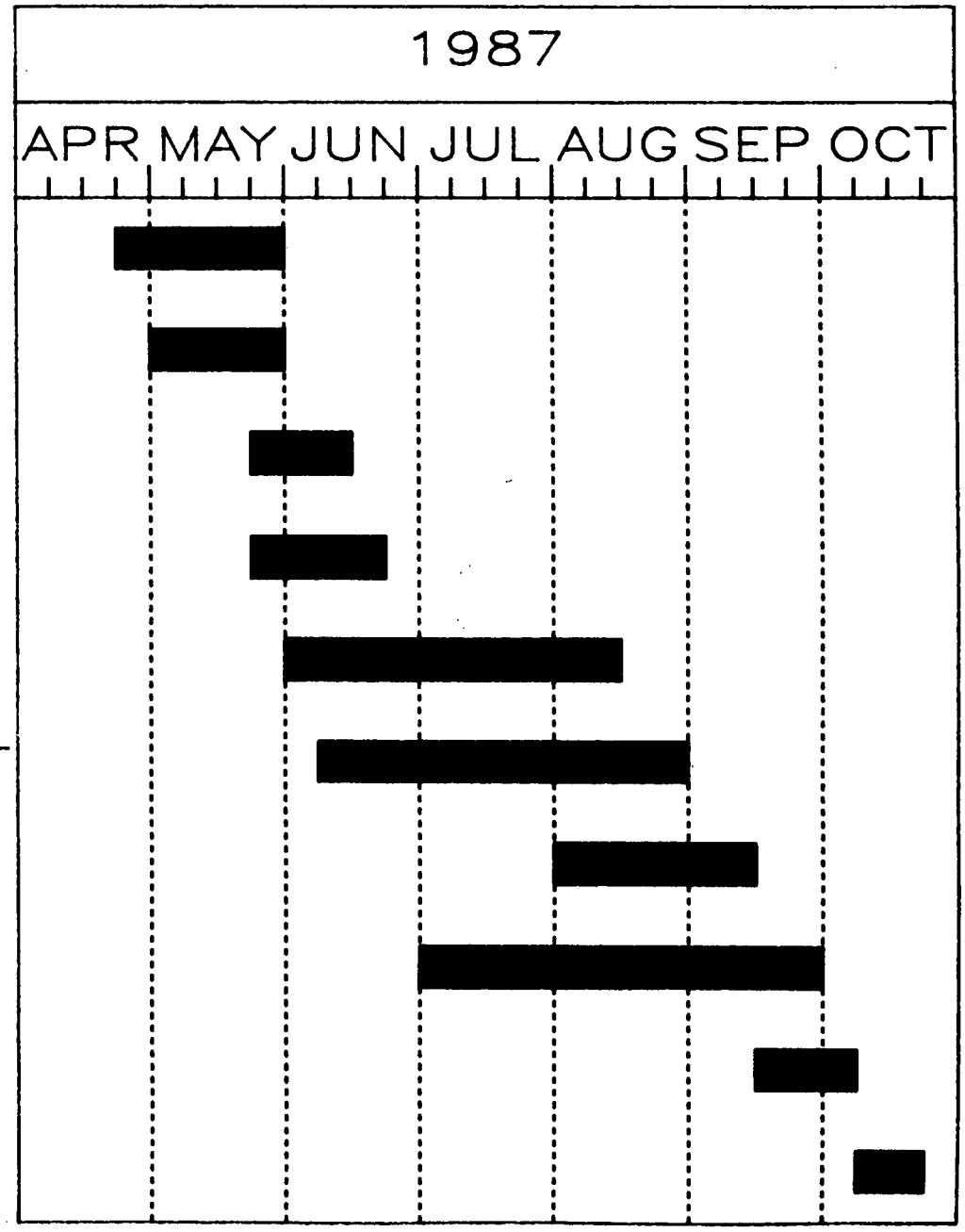
Item	Cost
Design, Construction and Operation of the Radon Gas Treatment/Circulating System.	$ 80,000
Application of the foam material including material costs.	$135,000
Subcontract Administration (RUST)	$ 35,000
TOTAL:	$250,000

5.4 Project Schedule

The K-65 CDR project schedule is illustrated in Figure 5.4. The schedule was developed with the intent to complete the work outlined in the CDR as soon as reasonably achievable due to the high priority the FMPC has placed on remedial actions for the K-65 Silos. The review/approval of the CDR is required by the Department of Energy (DOE), the U. S. Environmental Protection Agency (EPA) and the Ohio EPA. The Camargo evaluation consists of a structural assessment identifying any potential effects or consequences relating to the addition of the foam material into the K-65 silos. The structural assessment will be completed by Camargo Associates LtD., who have performed a recent structural evaluation of the K-65 Silos. The PA document (Project Authorization) will be approved by WMCO personnel and will set up the funding for the project. The field testing and operation of the radon treatment/circulating system will be conducted under a Plant Test Authorization (PTA). A PTA is the mechanism for the FMPC to administratively control equipment and process changes outside the scope

FIGURE 5.4

K-65 CDR PROJECT SCHEDULE



of Standard Operating Procedures (SOP's) through closely controlled test conditions and closely monitored test results. In order to remove the gas from the K-65 Silos for test treatment purposes, a Permit To Install (PTI) may be required from the Ohio EPA to install the treatment/circulating system equipment. A Construction Work Order (CWO) will be issued by WMCO to the construction contractor (Rust Engineering) to obtain and coordinate the services of a firm to perform the foaming operation. The actual radon treatment/venting system operation and foaming operation are scheduled in October, 1987. Injection of the foam material is required while the temperatures are still reasonably warm (60 F) to ensure proper curing of the foam material. The K-65 CDR Project Schedule is dependent upon timely review and approvals of the CDR, PA, PTI, and PTA documents.

6.0 JUSTIFICATION FOR PROJECT DESIGN

6.1 Radon Emission Control

Due to thermal expansion, the gases within the K-65 domes expand and contract daily. As expansion occurs, the additional air volume escapes from the silo causing a greater Rn-222 release than would occur by diffusion alone (Reference 6). For example, it has been determined that for a temperature increase of $10^{o}F$, the volume of air in a silo would increase from 26,770 ft^3 to 27,393 ft^3, an increase of 623 ft^3 or 2.3%. Therefore, it can be estimated that 2.3% of the radon in the air in the silo, or 0.5 Ci per silo, is released due to a temperature increase of $10^{o}F$ in the air in the silo. (Based on the assumption that 22 curies or 3.0×10^{-5} Ci/liter are contained within the air space inside the dome above the residue).

By filling the void in the K-65 Silos with foam, no free volume remains for the radon gas to accumulate. Therefore, the only mechanism for the release of radon gas to the environment is by diffusion through the foam and concrete dome, through the concrete walls and earth embankment or through any cracks between the foam and side walls. It has been calculated that the diffusion of radon gas through an effective height of 2 feet of the foam material will be essentially zero (Appendix 1). In

addition, experimental results detailed in Appendix III shows that total attenuation of radon gas occurs when a positive seal of the foam material is obtained over the radium bearing K-65 residues. Significant radon attenuation was observed even when cracks/leaks were present in the foam. Therefore, the addition of the foam material into the silos is projected to significantly reduce the radon emissions from the K-65 Silos.

In addition, due to the short half life of radon gas (3.82 days), it is estimated that the majority of the radon gas would decay into its particulate daughters and be entrained in the confines of the silo and not released to the atmosphere.

6.2 Structural Reinforcement of the Silo Dome

Due to environmental elements, the K-65 Silo domes have deteriorated and are considered the weakest structural component of the silo system. the placement of the dome covers over the structurally defective center 20 foot portion of the domes was considered only as a short-term remedial solution (1-2 years). Since final remediation plans for the K-65 Silos will take at least 3 years to develop and implement, it is necessary to take additional remedial action to provide for continued safe containment of the K-65 residues.

The addition of the foam material into the K-65 Silo void space is projected to increase the loading limit of the silo domes by a factor of approximately 13. The compressive strength of the proposed 2.0 lb/ft^3 density polyurethane foam is 25 lb/in^2 (3,600 lb/ft^2). In comparison, the critical buckling load for the existing silo domes, outside the critical 20 foot diameter area was calculated to be approximately 2 lb/in^2 (284 lb/ft^2).

6.3 Worker Safety

The present structural condition of the K-65 Silo domes has deteriorated to the point that special design allowances must be considered for all future remediation work. The design allowances include either remote equipment or the construction of additional support platforms to handle heavy equipment that may be required. In any case, it is estimated that future remediation costs could be reduced and worker safety increased if the silos were filled with the foam material to guard against failure of the domes. Minimal work or equipment on the silos themselves is required for the project of filling the silos with the foam.

6.4 Exposure Reduction

Previous radiation surveys of the K-65 Silos before they were sealed (1979) indicate that the gamma radiation levels were 3 to 4 times less than at present. The reason that the gamma radiation levels increased on the silo domes after they were sealed was that the radon gas became trapped in the silo and accumulated in the air space above the residue. As the radon gas decayed into its daughter products, lead 214 and bismuth 214 were formed, both of which are gamma emitters. Therefore, the increased concentration of radon gas within the silos caused higher gamma radiation levels on top of the silo domes. After the treatment/circulating system has been operated it is expected that the radiation exposure levels on top of the silos will be significantly lower for the foaming operation. In time, however, the gamma radiation levels will build back up close to their current readings. The benefit of the foam injection will be the attenuation of radon gas escaping from the silos. The reduction in radon gas emissions will provide a safer working environment and lower radiation exposure due to radon for personnel working on or near the K-65 Silos.

7.0 RECOMMENDATIONS

Based upon the analysis and evaluation of the Camargo report, the Monsanto-Mound report, FMPC environmental monitoring data, the radon control feasibility study and field experience with the silo weatherproofing project, the WMCO recommends the following:

1) Initiate and expedite final detailed design for the system to fill the K-65 Silos with foam, including the temporary radon gas control system.

2) Complete the operation of filling the K-65 Silos by October of 1987.

3) Complete the K-65 Weatherproofing Project after the silos are filled with foam.

8.0 SIGNIFICANT FACTORS

8.1 Radiation Dose Estimates

Major Project Item	Dose (mrem)
Installation and Operation of the radon gas treatment/circulating system (1)	200 mrem
Filling of the Silos (2)	3200 mrem
TOTAL EXPOSURE:	3400 mrem

(1) The only work that will require personnel to stand on the K-65 Silo domes is the actual pipe hookup to one of the effluent manholes. The majority of the radon gas treatment/circulating system work will be conducted off of the K-65 Silos in a much lower radiation exposure area.

(2) The 3200 mrem dose estimate was based on 2 personnel working 8 hours on each silo in a 100 mrem/hr radiation field.

8.2 Environmental Impacts

The environmental impacts associated with the operational stages of the CDR are not expected to exceed any applicable regulations or guidelines for radon releases (Appendix II). The longer term effect of radon release to the environment from the silos will be less due to the reduction in radon emissions.

The placement of the foam material into the K-65 Silos would increase the volume of waste to be disposed of if final remediation of the silos includes residue removal. The polyurethane foam material, however, is non-toxic and is approved for conventional landfill disposal. Moreover, the foam material could be compacted to reduce its volume and hence reduce disposal costs if removal of the foam from the silos is necessary.

8.3 Safety Assessment

The injection of the foam material into the K-65 Silos will be verified by Camargo Associates, Ltd. to model any structural problems that may arise during injection of the foam. In addition, Camargo will be asked to determine safe loading limits on the domes once the foam material is in place. Any structural criteria developed by Camargo will be incorporated into the final project design.

Combustibility characteristics of the rigid urethane foam that is proposed for use in the K-65 Silos varies widely depending upon formulation. Rigid urethane foam can be formulated with flame retardant chemicals which may reduce the possibility of accidental ignition. However, as with other organic materials, rigid urethane foams should be considered combustible and must be protected from open flames and high temperatures. The combustibility of the foam material is not expected to cause any problems for use in the K-65 silos due to the following: 1) the silos are isolated from production operations; 2) the silos have administrative and physical controls for personnel access; and 3) the

foam material will be entirely enclosed within the concrete structure of the silos.

The materials and equipment required to complete the K-65 Silo filling project will not create any unusual safety problems. All work in the area of the silos will be conducted under the cognizance of WMCO Environment Safety & Health (ES&H) Department to assure strict compliance with all radiological procedures. In addition, a detailed safety assessment will be performed by the WMCO ES&H Department and included in the final project design.

8.4 Approval Requirements

The CDR must be reviewed by the FMPC DOE, USEPA and Ohio EPA. Approval to proceed with the project design must be obtained by the end of May, 1987 in order for final project design to be initiated on schedule. Final design will also be submitted for approval to all three organizations before operations are conducted.

8.5 Funding Requirements

Funding for the Camargo structural evaluation, final design, equipment and operation of the CDR will be obtained from the AR budget, (K-65 Remediation).

APPENDIX I

CALCULATION OF RADON ATTENUATION AS A RESULT OF FILLING THE K-65 SILO VOID SPACE WITH A CLOSED CELL FOAM MATERIAL

From Borak's Study (Reference 8), the following values were used:

$[Ra] = 2x10^5$ pCi/g

$p = 1.6$ g/cm^3

$E = 0.2$

l = DIFFUSION LENGTH (TAILINGS) = $[D_0/(P_0*t)]^{0.5} = 150$ cm

To find D_0/P_0, must know t, decay constant for Radon-222;

$t = 2.1 \times 10^{-6}$ 1/sec

Therefore:

$l = [D_0/(P_0\ t)]^{0.5}$

$D_0/P_0 = (l^2) \times t = 4.73 \times 10^{-2}$ cm^2/sec

And:

$J_0 = 2.0 \times 10^5$ pCi/m^{2}sec

Now calculate J_1 from the foam (Reference 7):

$J_1 = J_0\ f\ EXP(-b_1\ x_1)$

Where: J_1 = Radon flux from the surface after attenuation with the foam cover

f = $2/ [(1+Z)+(1-Z)EXP(-2b_1 x_1)]$

Z = $P_o/P_1[(D_o/P_o)/(D_1/P_1)]^{0.5}$

b_1 = $(t P_1/D_1)^{0.5}$

J_o = Radon flux at the surface of the bare tailings pCi/m^2sec

x_1 = Thickness of cover material (cm)

P_1 = Porosity for cover material

D_1 = Effective bulk diffusion coefficient for radon in the foam (cm^2/sec)

From various literature, P_1 and D_1 are given as follows:

P_1 = 0.95

D_1 = 1×10^{-6} cm^2/sec

x_1 was taken from Reference 8:

x_1 = 300 cm

b_1 and f_1 can now be calculated:

b_1 = 1.42 1/cm

f = 0.029

Substituting:

$$J_1 = 0$$

Hence, no diffusion of radon gas will occur through the foam given the listed assumptions.

On the outer edges of the dome, however, the foam height may only be two feet or 61 cm. Now calculate J_1 based on a 61 cm cover thickness:

First calculate exp $(-b_1 x_1)$ to see if the term is 0:

$$b_1 = 1.42 \text{ 1/cm}$$

$$x_1 = 61 \text{ cm}$$

$$\text{EXP } (-b_1 x_1) = 2.6 \times 10^{-38} \text{ or approximately } 0$$

Therefore, 2 foot of foam material will essentially attenuate the radon flux from the silos.

APPENDIX II

CALCULATION OF THE ANTICIPATED RADON RELEASE AND RESULTING DOSES DURING THE K-65 FOAMING OPERATION

Prior to filling K-65 Silos with foam, a radon gas treatment/venting system will be utilized to treat the existing accumulation of radon gas contained within the K-65 Silos. When the operation of filling the silos with foam is undertaken, the efficiency of the treatment/circulating system will be greatly reduced due to the generation of organic gases during foam curing that will compete with the radon gas for adsorbtion.

The calculation that follows, is a worst case estimate of the release in curies that could potentially occur and the resulting dose estimates when a silo is opened and the filling operation is conducted.

The flux rate of radon gas, J_0, from the bare K-65 residues is given in Borak's Report (Reference 8) as:

$$J_0 = 2 \times 10^5 \text{ pCi/m}^2\text{sec}$$

The surface area, A, of a K-65 Silo is approximately:

$$A = 467 \text{ m}^2$$

The release rate, R, from a silo is then:

$$R = J_0 A$$

$$= 9.34 \times 10^{-5} \text{ Ci/sec}$$

The change in the release rate with respect to time is:

$$dR/dt = J_0 A$$

Or

$$dR = J_0 A \, dT$$

Substituting in for A:

$$dR = J_0 [467-2.8t]dt$$

Integrating the above expression over the time interval of 167 minutes gives:

$$R = 0.47 \text{ Ci}$$

Therefore, if all the gas that is generated between the time the foaming operation is initiated and the time a two foot layer is completed escapes, then 0.47 Ci of radon gas will be released to the environment.

The total cummulative release (Ci of radon gas) was evaluated as a function of time using 10 minute time intervals and plotted in Figure II-1. From Figure II-1 it can be seen that the largest radon release occurs during the first 10 minutes of of the filling operating. During the first 10 minutes, the largest surface area is present for radon gas generation and as the filling operation continues the surface area decreases as does the generation of radon gas. After the 167 minute time interval that is required for a 2 foot application of foam is completed the radon gas generation has been essentially attenuated.

FIGURE II-1

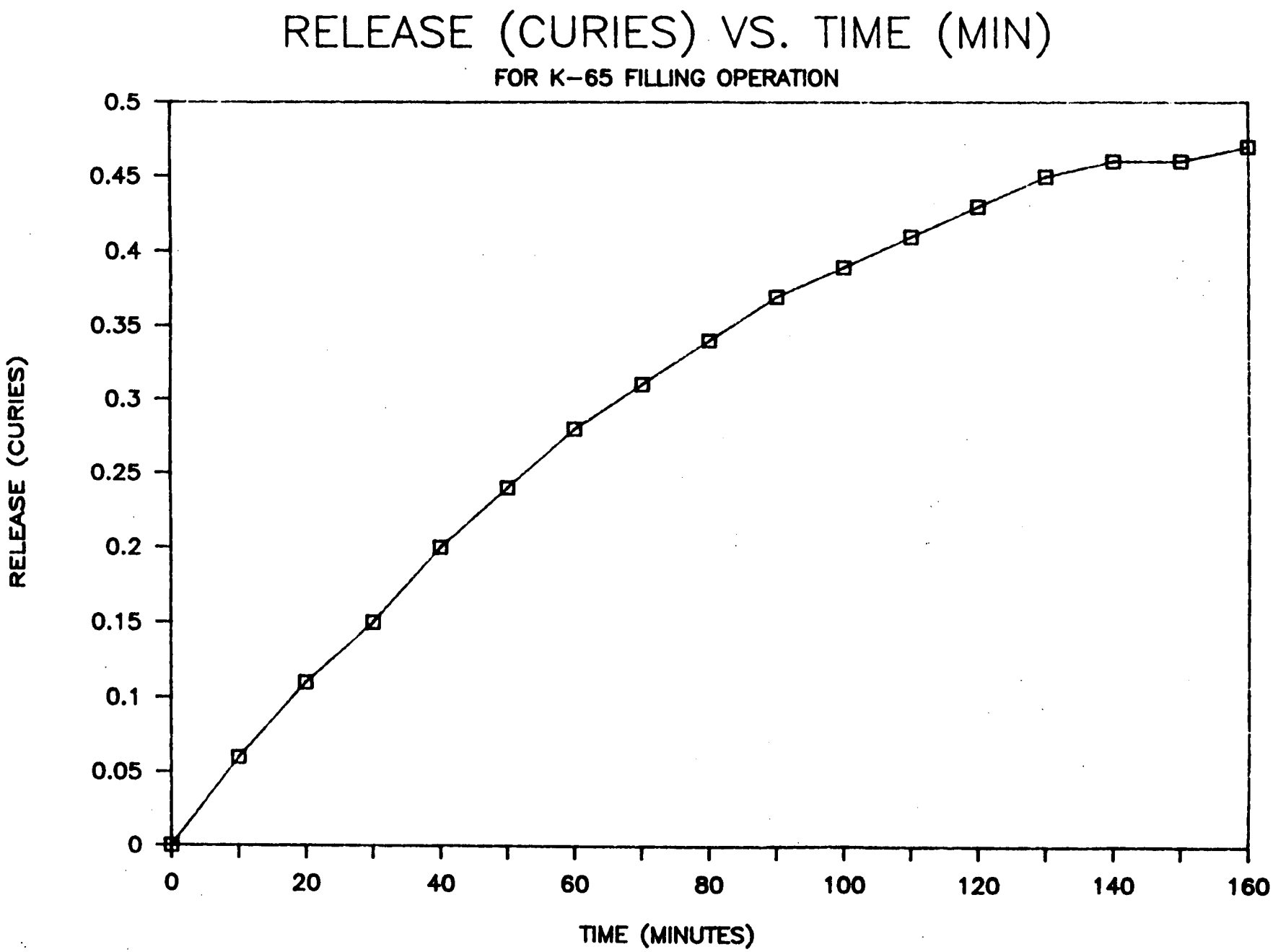


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FIGURE II–2

Rn–222 CONC. VS. DISTANCE FROM SILO

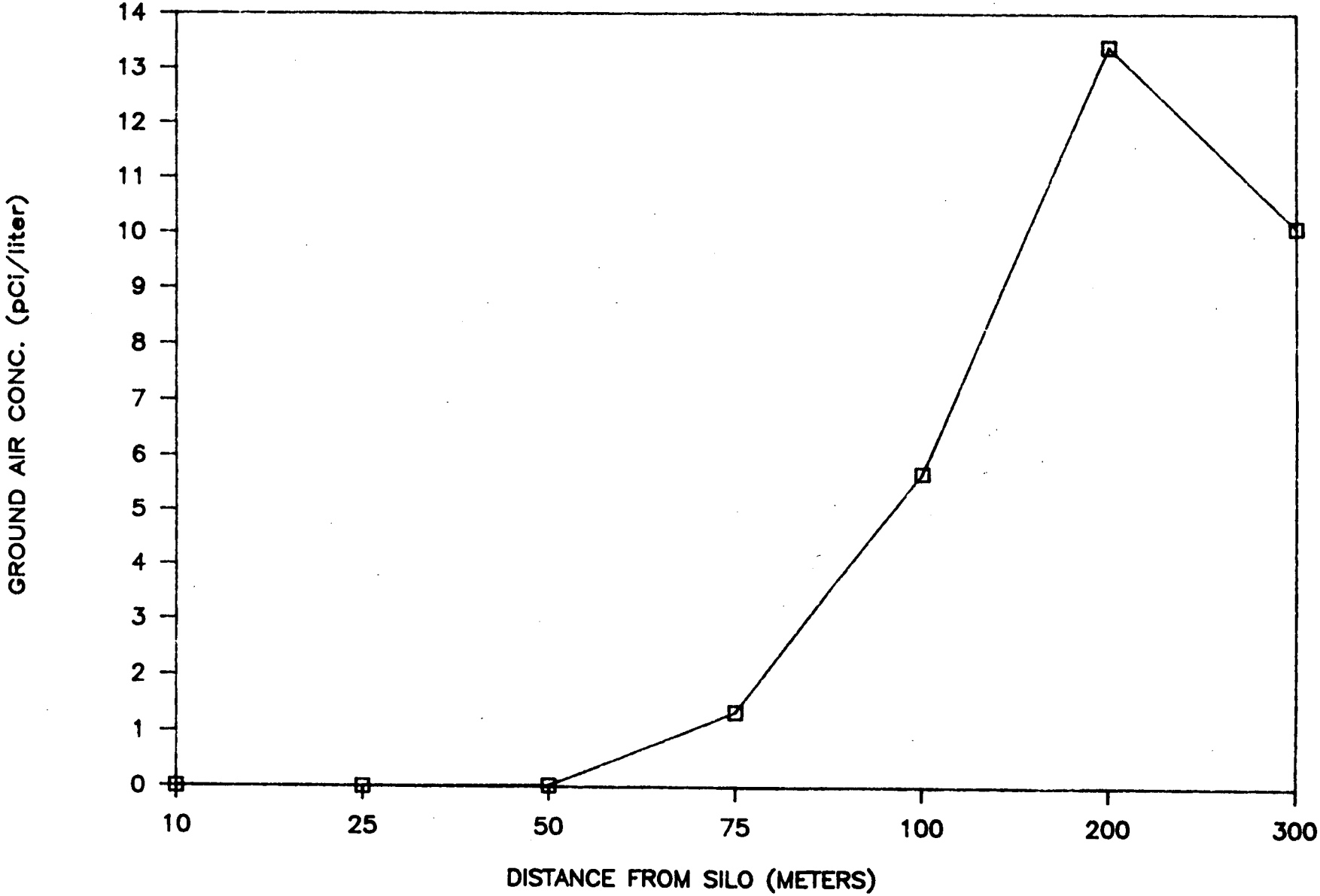
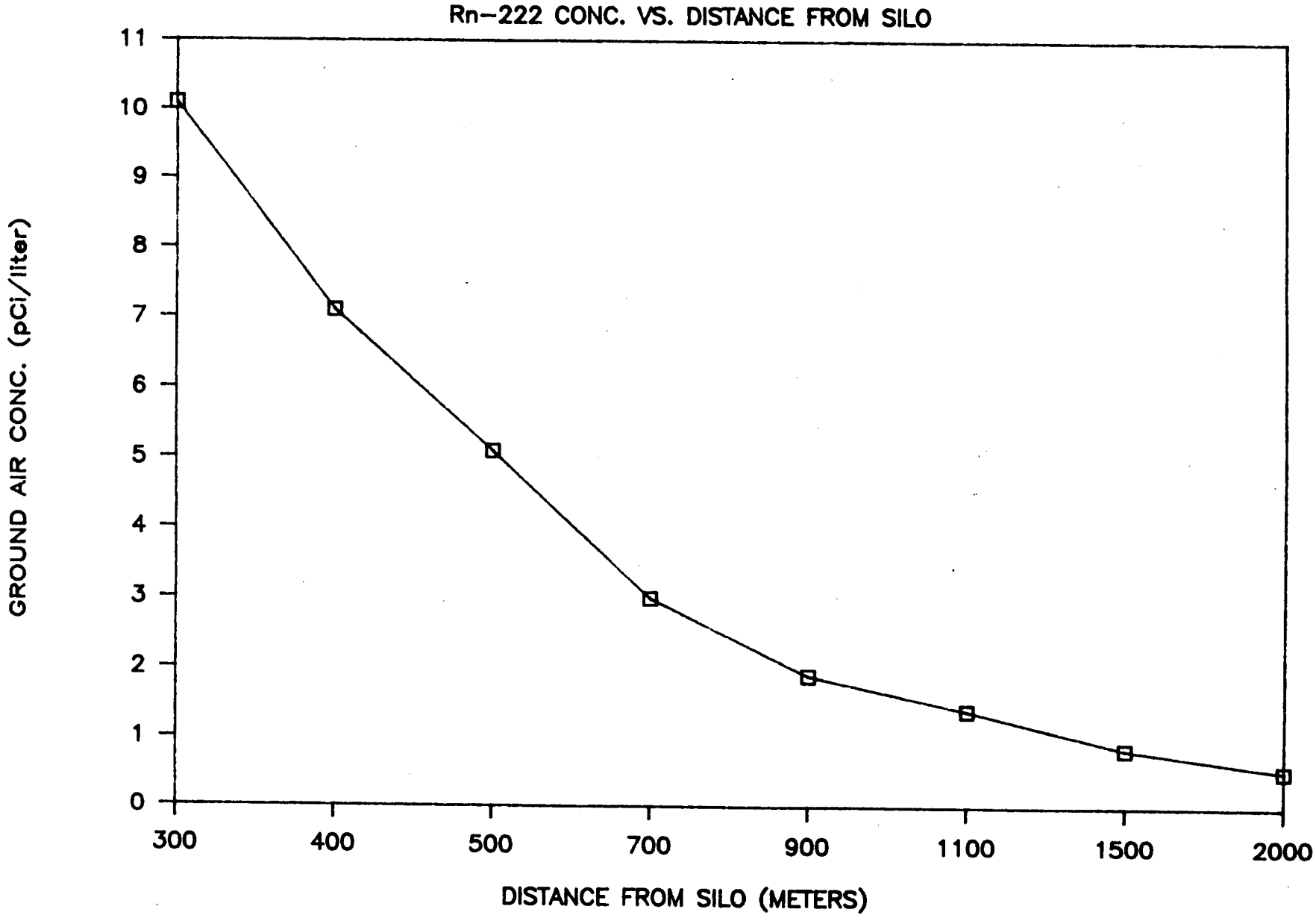


FIGURE II-3


Rn-222 CONC. VS. DISTANCE FROM SILO
GROUND AIR CONC. (pCi/liter)
0
1
2
3
4
5
6
7
8
9
10
11
300
400
500
700
900
1100
1500
2000
DISTANCE FROM SILO (METERS)

The dose estimates resulting from the potential release of radon gas during the K-65 Silo foaming operation were calculated using the computer code Airdos. The following information was given to the computer to model the Radon-222 release from a K-65 Silo during the foaming operation:

Wind Speed = 9 m/sec

Stack Height = 8 m

Effluent Velocity = 1 m/sec

Stack Diameter = 1.2 m

Stability Class = E

Release Rate = 9.35×10^{-5} Ci/sec

The maximum dose that would be incurred by personnel, other than those involved in the foaming operation, due to the 167 minute release of Radon-222 from the K-65 Silos is 3.5 mrem (whole body). The 3.5 mrem exposure assumes that an individual is standing at 200 meters from the K-65 Silo (maximum Radon-222 concentration) during the release in the direction of the plume for 167 minutes.

Figure II-2 and II-3 represent the Radon-222 concentration at various distances in the direction of the plume during the release from the K-65 Silos. It can be seen from Figure II-2 that the maximum Radon-222, 13.4 pCi/liter, occurs in the direction of the plume at 200 meters. Figure II-3 shows that the Radon-222 concentration drops off rapdily as the distance from the K-65 Silo increases to background levels, 0.54 pCi/liter, at 2000 meters.

APPENDIX III

EXPERIMENTAL RESULTS FROM LABORATORY TESTS INVOLVING POLYURETHANE FOAM FOR RADON ATTENUATION

ABSTRACT

A laboratory experiment was performed to determine the effectiveness of a polyurethane foam material to attenuate the diffusion of radon gas. Charcoal canisters were placed over containers that were initially filled with various amounts of radium bearing K-65 residues, then subsequently filled with foam.

The experimental results showed when properly sealed, the polyurethane foam totally attenuated the diffusion of radon gas generated by the K-65 residues.

INTRODUCTION

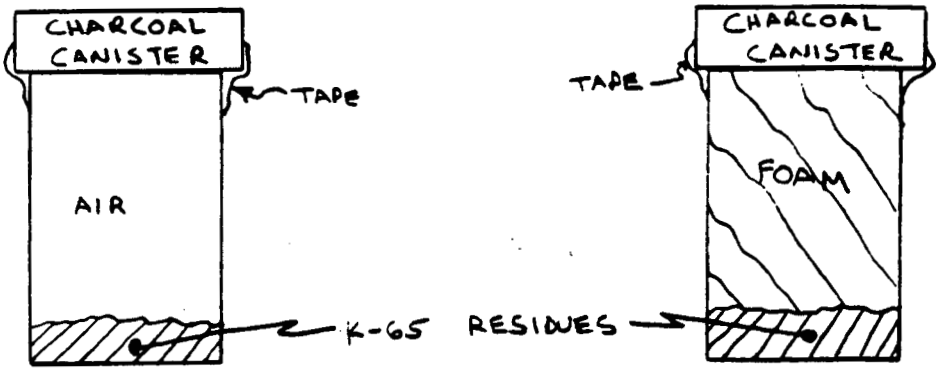
Theoretical calculations (Appendix I) show that a two (2) foot application of a closed cell polyurethane foam over the K-65 residues would essentially attenuate the radon flux from the silos. In order to validate the theoretical calculations, a laboratory experiment was performed to determine the effectiveness of a polyurethane foam material to attenuate the diffusion of radon gas. The effectiveness of the foam to attenuate the diffusion of radon gas was determined by comparing the activity of charcoal canisters exposed to K-65 residues with and without foam present between the residues and the canisters.

The K-65 residues used during the experiment were obtained from a sample that had been taken from K-65 Silo 2 in the early 1970's. The foam material used was obtained from a local hardware store. The foam material used during the test is similar to the proposed closed cell polyurethane foam to be used in filling the K-65 Silos. The charcoal canisters used in the experiment were approximately 2-3/4 inches in diameter by 1 inch high. Charcoal canisters have been used successfully in many applications for the determination of radon flux and provide a relatively easy method for detecting the presence of radon.

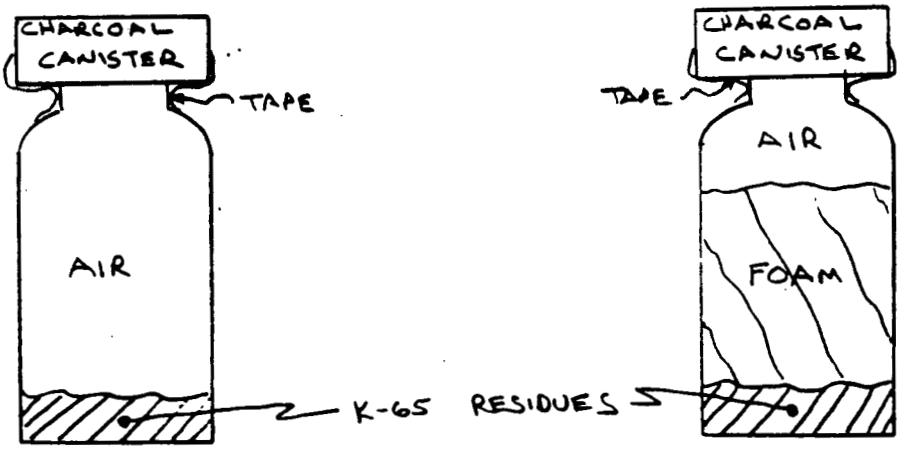
EXPERIMENT DESIGN

The first test was performed using 4, 150 milliliter plastic containers each containing 45, 40, 36 and 26 grams of K-65 residues, respectively. To obtain a base line of expected radon daughter activity that could be adsorbed into the charcoal canisters, a charcoal canister was taped onto the open end of each sample container. The opening in the charcoal canister was faced toward the K-65 residues and the charcoal canister was taped securely to the containers. Approximately 1.5 inches of air space existed between the charcoal canister and the K-65 residues. After 24 hours of exposure to the K-65 residues, the charcoal canisters were removed and counted for beta/gamma activity utilizing a Ludlem rate meter and a pancake probe. In addition, a reference canister, exposed to the laboratory surroundings was maintained to determine if any natural radon was present. The sample containers were then

injected with the polyurethane foam material and new charcoal canisters taped onto the sample containers before the foam cured. The charcoal canisters were exposed to the K-65 residues for various lengths of time, then removed and counted for beta/gamma activity. The following illustration shows the arrangement of the sample containers, foam and charcoal canisters:



The second test was performed using two 1400 milliliter glass containers each containing 100 grams of K-65 residue. The same procedure was followed described previously, by counting the charcoal canisters for adsorbtion of radon gas initially without any foam. Several differences existed, however, between the first test and the second test. After the initial 24 hour exposure of the charcoal canisters to the 100 gram sample of K-65 residues, the samples were injected with foam and the foam allowed to cure before new charcoal canisters were placed onto the containers. The reason that the foam was allowed to cure before the canisters were placed on is that activated carbon has a definite affinity for organic vapors and may have become nearly saturated before adsorbtion of the radon gas began in the first test. In addition, an air space between the top of the foam and the charcoal canisters was maintained. The following illustration shows the arrangement of the glass sample containers in test two:



RESULTS

The results from test one are presented in Table III-1. The sample numbers one through four refer to the residue weight, 45, 40, 36, and 26 grams respectively. The foam column is labeled with either a yes if the container sample contained foam or no if just air was present between the K-65 residues and the charcoal canisters. The exposure time (hours) of the charcoal canisters is listed for each test. The last column in Table III-1 lists the activity in counts per minute (cpm), above background, beta/gamma radiation measured immediately after the charcoal canister was removed from the containers. The charcoal canisters were counted several times after the initial count to verify that the activity was due to radon daughters and not long-lived contamination from the K-65 residues.

The results from test two are presented in Table III-2. The sample numbers five and six both contained 100 grams of K-65 residues in a 1400 milliliter glass container.

The initial tests without any foam present in the containers are marked with a "No" under the foam column in Table III-2. The exposure time for samples five and six were the same for the foam and the no foam tests. The last column, counts per minute (cpm) is the same as in Table III-1.

CONCLUSIONS

From the data presented in Tables III-1 and III-2 it can be seen that in all instances the addition of foam between the K-65 residues and the charcoal canisters attenuated the diffusion of radon gas into the canisters. Samples 1, 3, and 4 in Table III-1 showed evidence of radon gas adsorbing onto the charcoal with the foam in place. The activity from these samples, however, is concluded to have been caused by leakage of the radon gas around the foam or through cracks and not by diffusion through the foam. The reason for this conclusion is that the foam thicknesses present on top of the K-65 residues in test one varied between 1 and 1.5 inches which is the minimum thickness that a seal could be obtained in the 150 milliliter containers. Therefore, it is suspected that positive seals were not obtained for samples 1, 3, and 4.

TABLE III–1

K–65 RADON ATTENUATION TEST #1 RESULTS

SAMPLE #	RESIDUE WT. (gm)	FOAM	EXPOSURE TIME (hrs)	CPM (beta/gamma)
1	45	NO	24	2820
1	45	YES	19	310
2	40	NO	24	2420
2	40	YES	66	0
3	36	NO	24	2280
3	36	YES	24	50
3	36	YES	41	210
4	26	NO	24	1120
4	26	YES	66	290

TABLE III–2

K–65 RADON ATTENUATION TEST #2 RESULTS

SAMPLE #	RESIDUE WT. (gm)	FOAM	EXPOSURE TIME (hrs)	CPM (beta/gamma)
5	100	NO	24	9000
5	100	YES	240	0
6	100	NO	24	9500
6	100	YES	240	0

During test two, the size of the container was increased to allow for additional foam thickness. The weight of the K-65 residues was also increased to increase the radon flux from the residues. The results from test two showed that no diffusion of radon gas occurred through an average foam thickness of 2.2 inches. The use of glass containers in test two allowed a visual observation of the foam seal which appeared to be good.

In conclusion, the results of the tests performed show that a closed cell polyurethane foam, when properly sealed, totally attenuates the diffusion of radon gas. The critical parameter from the data appears to be the integrity of the foam seal over the radon producing residues. Good attenuation was still provided, however, in the cases where a total seal was not obtained.

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