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AT THE
FEED MATERIALS PRODUCTION CENTER

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THE K-65 WASTE STORAGE SILOS AT THE FEED MATERIALS PRODUCTION

Patrick A. Shanks, Robert A. Vogel

ABSTRACT

The Feed Materials Production Center (FMPC) is a DOE facility that produces uranium for the U. S. defense program. In addition to FMPC uranium production facilities, the site also contains waste storage facilities that include two concrete silos known as the K-65 Silos. The two K-65 Silos were constructed in 1951 and 1952 and are filled with radioactive residues from the pitchblende processing beginning in 1952 and ending in 1958. The radiological constituents of the residues include uranium and radium-226 which decays to a radioactive gas, radon-222. This paper will describe the history of the K-65 Silos. Included in the history will be a description of remedial actions taken as a result of deterioration of the silos. The deterioration of the silos includes cracks in the concrete walls and exterior and interior deterioration of the concrete walls and inner dome surface. Several remedial actions have been completed since the 1950's to structurally stabilize the deteriorated concrete silos. Past remedial actions included repairs and weatherproofing of the silo walls, the construction of an earthen embankment surrounding the two silos to counterbalance the forces applied on the silo walls by the residues, and the installation of a dome cap to cover the deteriorated center section of the silo dome. Recent remedial actions include monitoring the pressure and temperature inside the silos, measuring radon concentrations at the silos and the surrounding environment, the construction of a radon treatment system, and the application of a polyurethane foam layer on the exterior dome surface. Future actions include continuously measuring radon at the silos, sampling of the residues, and remediation of the residues and the concrete silos.

INTRODUCTION

The Feed Materials Production Center (FMPC) is a U. S. Department of Energy (DOE) uranium metal production facility located near Fernald, Ohio approximately 32.2 kilometers (20 miles) northwest of downtown Cincinnati. The site covers approximately 425 hectares (1,050 acres) and is used for the production of uranium metal fuel cores, target element cores, and the interim storage of low-level radioactive/hazardous wastes.

FMPC operations began in the early 1950s when the United States Atomic Energy Commission initiated a long-term plan to establish an in-house integrated production complex for processing uranium and its compounds from natural uranium ore concentrates. Current operations no

longer involve processing of uranium ores, but various chemical and metallurgical process steps support the primary mission of supplying uranium metal fuel cores for production reactors at Richland, Washington, and Savannah River, South Carolina. All FMPC operations are administered through the DOE Oak Ridge Operations (ORO) office. As of January, 1986, Westinghouse Materials Company of Ohio (WMCO) operates the FMPC for the Department of Energy (1).

In addition to FMPC uranium production facilities, the site also contains waste storage facilities that consist of six waste pits, two concrete silos (K-65 Silos 1 and 2) two additional concrete silos (metal oxide tanks 3 and 4) a burn pit, the clearwell, fly ash disposal areas 1 and 2, sanitary landfill, and two lime sludge ponds.

RADON AT THE FMPC

The K-65 Silos were filled with radioactive residues in slurry form from the Manhattan Project beginning in 1952 and ending in 1958. The waste material was allowed to settle in the silos and the water decanted through a series of regularly spaced decant valves. The decanted liquid was pumped to a plant to be reused in the production of additional slurry. The majority of the waste residues stored in the K-65 Silos came from the processing of Belgian Congo and Australian uranium ores. The processing of the ores was conducted primarily at the Mallinckrodt Chemical Works near St. Louis and the FMPC refinery.

The waste residues stored in the K-65 Silos contains radium-226 which decays to a radioactive gas, radon-222. The concentration of radon in the head space of the silos has been estimated to be 3×10^7 pCi/l of air. Each head space of the silos contains approximately 34 Curies of radon and 34 Curies of each daughter. Radon seeps out of the silos through cracks in the silo concrete due to thermal heating. Monitors located at the K-65 Silos exclusion fence and the FMPC site perimeter fence continuously measures for radon concentrations. Radon being released from the K-65 Silos has not been detected at the FMPC site perimeter fence monitors to date.

THE K-65 SILOS

K-65 Silos Structural Details

The two K-65 Silos (1 and 2) located west of the production area in the waste storage area of the FMPC, were constructed in 1951 and 1952. The two concrete silos are 24.4 m (80 feet) in diameter by an overall height of 11.0 m (36 feet) which is comprised of approximately 8.2 m (27 feet) high walls and 2.7 m (9 feet) high dome. The 20.3 cm (8 inch) thick concrete cylindrical walls were post-tensioned reinforced with 0.4 cm (0.162 inch) diameter wire and covered by a 1.9 cm (0.75 inch) thick gunite coating. The 10.2 cm (4 inch) thick concrete dome roof is reinforced with 10. 2 cm x 10.2 cm (4 inch x 4 inch) #4 x #4 wire mesh. The 10. 2 cm (4 inch) thick concrete floors of the

K-65 Silos were constructed over an 20.3 cm (8 inch) layer of gravel containing an underdrain system of 5.1 cm (2 inch) slotted pipe draining to a collection tank. Below the gravel is a 5.1 cm (2 inch) layer of asphaltic concrete underlain by 43.7 cm (18 inch) of compacted clay.

K-65 Silos Waste Storage

The estimated metric tons total weight of the waste residues stored in the K-65 Silos is 8,618,256 kg (9,500 tons). Approximately 40% of the waste is composed of silicates (SiO2). The other constituents comprising 1% or more of the residue include calcium, iron, magnesium, and lead. The radiological constituents of the K-65 residues have been estimated to include 11,200 kg (24,692 lbs) of uranium (0.71% U-235) and between 1,600 and 3,700 grams (3.5 to 8.2 lbs.) of radium (Ra-226).

PREVIOUS K-65 SILOS REMEDIAL ACTIONS

Earthen Embankment

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 1.9 cm (0.75 inch) coat of cement mortar. After the gunite was repaired and a waterproofing sealant was applied to the external silo walls, an earthen embankment was 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. 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 three to one (3:1) slope. No further evidence of large scale erosion has occurred.

Structural Investigation

In July of 1985, Camargo Associates, Ltd. (Camargo) was subcontracted to perform a nondestructive testing program and structural analysis on the two K-65 Silos (2). The silo investigation consisted of three phases involving original design computer modeling, field work utilizing an "Echo Pulse" system and "Ground-Radon Survey," and a final computer analysis based on the field data. The pertinent conclusions of the Camargo investigation are summarized 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 five to ten years. 2) The center 6.1 m (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.

In response to the Camargo recommendations, the FMPC had a temporary dome, 9.1 m (30 feet) in diameter, designed and installed to span across the deteriorated portion of the concrete domes. The cover is self supporting and sits on a rolled plate steel skirt. The cover is composed of structural steel members which supports 1.9 cm (0.75 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 outside the deteriorated area and 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. During the membrane installation, however, it was discovered that the silos were capable of building up internal gas pressure due to ambient heating. An inadvertent release of radon occurred and the work was stopped in April, 1986 until an investigation into the pressure build-up could be conducted.

RADON EMISSIONS FROM THE K-65 SILOS

Special Radon Monitoring

From September 20, 1984 to February 5, 1985, Monsanto-Mound conducted special radon monitoring in the environs of the K-65 Silos (3). The objective of the special monitoring was to assess the extent to which radon concentrations in the surrounding area were due to the radium-bearing K-65 residues stored in silos 1 and 2. The radon monitoring by Monsanto-Mound consisted of two subtasks: 1) measurements of radon flux from the surface of the K-65 Silos, and 2) measurement of radon concentrations in the surrounding K-65 Silo environment.

In order to determine the radon 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 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 measurement ranged from approximately 13 $pCi/m^2/sec$ to 3 x 10^7 $pCi/m^2/sec$). By comparison, the Environmental Protection Agency (EPA) 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.

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 1.2 km (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.

Routine Radon Monitoring at the FMPC

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 consisting 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. Also, four RGM radon monitors are positioned around the K-65 Silos exclusion fence which will provide a continuous record of radon concentrations.

The monitoring locations were selected to characterize radon concentrations and potential exposures to humans. The monitoring locations are at the K-65 Silos exclusion fence, FMPC site boundaries, at two local 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.

The 1985 and 1986 FMPC site boundary average concentration of radon-222 were 0.67 pCi/liter and 0.71 pCi/liter respectively. Although the measurements vary slightly from station to station they were not significantly different from one another nor from year to year. Concentrations of radon-222 are also measured at two residences 6.5 and 10.5 km (4.0 and 6.5 miles) from the FMPC and also at two nearby elementary schools. In 1986, the average concentration of radon-222 measured at these locations ranged from 0.6 to 0.9 pCi/liter of air, which does not differ significantly from the 1985 averages (4). The results also indicated that no distinct trend for radon exist in the prevailing wind direction.

Evaluation of Radiation Doses

Determining the dose due to radon emission from the FMPC is an important consideration for the public in the vicinity of the plant. Calculation of dose due to radon emission is not one of the requirements for NESHAP compliance. DOE standards, however, specify that emissions of Rn-222 to uncontrolled areas must be less than 3.0 pCi/l.

During 1986, background radon measurements at locations that are 6.4 and 10.5 km (4 and 6.5 miles) from the FMPC averaged 0.58 pCi/l. A chosen location, which is in the same direction and closer to the K-65 Silos than the nearest residence, recorded an average radon concentration of 0.65 pCi/l. All radon measurements include an error term of about 20%. Therefore, there are no significant differences in radon concentration between background locations and the chosen location in 1986. A dose calculation based on this data does not yield significant results.

In addition to FMPC measurements of outdoor radon concentrations, the Ohio Department of Health (ODH) monitored indoor radon concentrations at nine locations around the FMPC between July, 1985 and July, 1986. These concentrations ranged from 1.1 pCi/l to 12.8 pCi/l with no apparent correlation between average concentration and the proximity to the K-65 Silos. The FMPC Health and Environmental Advisory Committee examined this data and issued a press release indicating that the FMPC is not the source of elevated radon levels found in this study.

In addition to radiation doses due to radon inhalation, exposure assessments were made for external radiation by using a pressurized ionization chamber and thermoluminescent dosimeters (TLDs). The maximum annual exposure was measured at the closest station to the waste materials stored in the K-65 Silos. The data indicating the external exposures to nearby residence was conservatively calculated at 18 mrem in 1986. This is 18% of the DOE standard. It should be noted that the background dose from natural sources measured at several locations surrounding the FMPC was 79 mrem per year.

TEMPERATURE AND PRESSURE MONITORING OF THE K-65 SILOS

Following the attempted membrane installation in April of 1986, the expansion of the gas inside of the K-65 Silos was evaluated. An instrumented flange assembly consisting of two thermocouples and a differential pressure transmitter was installed on each K-65 Silo in March, 1987. Four temperature measurements, the silo dome external surface, the top internal silo gas, the bottom internal silo gas and the ambient temperatures were recorded for each silo. In addition the differential pressure (internal silo gas pressure atmospheric pressure) was also recorded. The temperature and pressure monitoring occurred primarily during April and May of 1987. The temperature data shows that the internal silo gas temperature nearly follows the ambient temperature. Temperature data recorded from K-65 Silo 2 was very similar. In addition, the differential pressure recorded from K-65 Silo 1 versus the time of day for the same period as the temperature measurements was plotted. Neither K-65 Silo is capable of holding significant differential pressure. K-65 Silo 2 shows slightly more fluctuation in the measured differential pressure due to the sealing effect of the membrane application on Silo 2.

CURRENT REMEDIAL ACTIONS

The current remedial action program for the K-65 Silos was developed in response to the Federal Facilities Compliance Agreement (FFCA) between the DOE and the United States Environmental Protection Agency (USEPA) (5). Included in the FFCA are the requirements that the U. S. DOE: 1) implement interim control of radioactive emissions, including radon and radon decay product emissions from the K-65 Silos, and 2) provide interim controls to ensure the structural integrity of the two K-65 Silos. WMCO prepared a Feasibility Investigation (FI) that evaluated alternatives for the control of radon emissions from the K-65 Silos (6). Based upon this evaluation, the FMPC recommended the alternative to fill the void space in the K-65 Silos with polyurethane foam, including a temporary solid media adsorption system to treat the initially displaced radon.

The recommended alternative was further developed by WMCO in the Conceptual Design Report (CDR) (7). The final detailed project design was prepared by Advanced Sciences Incorporated (ASI) in conjunction with International Technology Corporation (IT) (8) based on the FI and CDR.

K-65 Silos Interim Stabilization Project

Initially, the K-65 Interim Stabilization Project developed by WMCO involved internal and external applications of polyurethane foam while providing for safe treatment of the accumulated and continually generated radon contained within the K-65 Silos. The operation of the radon treatment system and exterior foam application was completed on December 6, 1987. The internal foam application, designed to fill the air space above the waste residues inside each silo, was postponed until

the Spring of 1988, due to cold temperature conditions in the Fall of 1987. The total project cost was estimated to be approximately 2.2 million dollars.

Presently, the internal application of polyurethane foam inside the K-65 Silos is no longer being pursued. This decision was made as a result of reviews completed by experts in the polyurethane foam industry of the final design. The result of the industry reviews revealed that filling the silos with polyurethane foam layers could develop into major problems and potentially hazardous situations. The main problem with the final design was the application of the foam layers inside the silos. The operator controlling the foam applicator would have little control of the application. Other problem areas associated with the final design was the exothermic nature and the expansion and contraction properties of the polyurethane foams. These three problem areas were decided to be very difficult to overcome, if not impossible, especially since this task has never been attempted previously, and no data or experience was available for reference.

Due to the cancellation of applying the polyurethane foam layers inside the K-65 Silos, ASI/IT was hired to assist in developing alternatives to this final design. ASI/IT developed a list of seventeen alternatives (9). One of the alternatives was to apply a layer of granular material such as sand over the K-65 Silo residues. The layer of sand would attenuate radon being released from the residues and protect the residues from any spalling concrete from the silo dome. The layer of sand would also provide an additional feature of reducing the emission of gamma radiation from the silos. Presently, WMCO is working on the final design to apply a layer of sand inside the K-65 Silos in order to complete the K-65 Silo Interim Stabilization Project.

Radon Treatment System

The radon treatment system was designed and constructed using the best available technology to safely remove continuously generated radon within the K-65 Silos. The equilibrium radon activity contained within the air space of the K-65 Silos has been estimated to be 37.4 Ci. The primary purpose of operating the radon treatment system prior to the external foam application was to reduce as low as reasonably achievable (ALARA) the whole body radiation dose to personnel performing the foam application and WMCO personnel. Details concerning the construction and operation of the radon treatment system are provided in Reference 10.

External Foam Application

The exterior foam application was conducted in late November and early December, 1987. The foaming consisted of applying a 7.6 cm (3 inch) layer of rigid polyurethane foam to the outer dome surface and a 3.8 cm (1.5 inch) layer to the dome cap. This was followed by a 0.114 cm (45 mil) waterproof, ultraviolet resistant, urethane finish coating.

The following benefits are derived from the external foam application:

- o Weather protection of the K-65 Silo domes
- o Insulation of the silo domes
- o Improvement to the structural integrity of the silo dome due to the rigid foam application
- o Reduction of radon emissions.

The insulation of the silo domes will reduce stresses in the concrete caused by expansion and contraction, and radon emissions caused by heating and expansion of the silo gases. Radon emissions will also be reduced due to the attenuating ability of the rigid foam application. The rigid polyurethane foam material has been independently tested to have a radon diffusion coefficient of approximately 4.0 x 10-6 cm^2/sec (11).

FUTURE K-65 SILOS REMEDIAL ACTIONS

In order to complete the Interim Stabilization of the K-65 Silos, internal filling above the waste residues with sand is proposed. The radon treatment system will be operated prior to the internal stabilization of the silos to minimize the release of radon during the operation. Prior to the internal stabilization, the K-65 residues will be sampled and the data used in support of the currently ongoing sitewide Remedial Investigation/Feasibility Study (RI/FS). Based upon a review of the final remedial alternatives presented in the RI/FS by the U. S. and Ohio

EPAs, a Record of Decision (ROD) is scheduled for early 1991 and will determine the final remedial alternative for the K-65 Silos. The K-65 Interim Stabilization Project will maintain the K-65 waste residues in an environmentally acceptable manner until the final remedial alternative can be designed and implemented sometime in the mid 1990s.

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