

Structural Characterization of the 216-Z-9 Crib Prior to Decontamination and Demolition Using Robot Crawler and High Resolution Photography - 8117

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ABSTRACT

The Department of Energy, Richland Operations Office is preparing to conduct a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) removal action for the decontamination and demolition of the above-grade mining structures and equipment at the 216-Z-9 Crib. An investigation of the condition of the mining complex was initiated to determine constraints necessary for safely conducting the removal of the buildings. While crib headspace chemical analysis and non-destructive analysis of the interior of the buildings was completed to address radiological contamination concerns, the primary concern regarding the removal of the above-grade structures located on the crib cover involves determining the loading capacity and structural integrity of the crib cover slab. Additional concerns included headspace gases and radionuclide contamination. Until the structural analysis was completed, loading limits on the crib cover had been restricted. Photographic documentation revealed the loss of protective tiles and acid resistant coating from the underside of the cover raising a question of concrete stability.

The investigation relied heavily on the use of high resolution photography with high intensity lighting for photographic documentation of the underside of the crib cover,

followed by structural analysis of the documentation by a team of qualified engineers. Deployment of a robot crawler with attached camera and positioning of a fixed camera were integral to this structural characterization effort. Results of the photographic documentation were of sufficient quality to allow for bounding decisions to be made regarding the loading of the crib cover while performing the demolition of the mining structures (glovebox, excavator, bucket) and the associated buildings.

The 216-Z-9 Crib, also known as the 216 Z-9 Recuplex CAW (CA column waste) Waste Disposal Cavern, the Z-9 Trench and the Z-9 Crib was constructed as an engineered trench with an open area beneath a concrete slab. The crib is located near the Plutonium Finishing Plant (PFP) facility, at the Hanford Nuclear Reservation in Eastern Washington State. The crib was used as a disposal site for effluent chemical and radiological wastes from the recovery of uranium and plutonium through extraction or RECUPLEX process, a method that recovered uranium and plutonium from liquid and solid wastes and scraps from other PFP processes. During its operating life, from 1955 through 1962, the Z-9 Crib received liquid wastes totaling approximately four million liters, or one million gallons. Analyses of the crib soil in seven locations to a depth of up to two meters (six feet) beneath the crib floor indicated that the plutonium content of the crib soil ranged from 50 to 150 kg (the highest concentration measured was 34.5 g/L of soil). While performing the structural evaluation of the crib cover, additional characterization information was obtained on the radiological and chemical conditions of the crib and structures.

INTRODUCTION

The U.S. Department of Energy, Richland Operations Office (DOE/RL) and Fluor Hanford (FH) currently are conducting studies to evaluate the 216-Z-9 Crib Soil Removal Structures to support their deactivation and decommissioning (D&D) as part of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) [1] non-time-critical removal action in accordance with the *Action Memorandum for the Plutonium Finishing Plant Above-Grade Structures Non-Time Critical Removal Action* [2]. The soil removal structures extend over the reinforced concrete cover that provides containment for the 216-Z-9 Crib, and are supported by external structural steel beams to minimize the loading on the cover.

Characterization

D&D planning and characterization work has begun on the crib buildings and mining structures. In order to accomplish the D&D, however, analyses are required of the structural integrity of the crib cover, the deactivated ventilation system, combustible gases and other chemical and radiological constituents of the crib atmosphere, and potential air emissions.

Technical issues identified prior to conducting building removal include structural stability of the crib cover and mining apparatus and combustible/toxic gases within the crib area [3]. Based on existing knowledge of the facility and site, concerns over the

structural integrity of the crib slab, which provides support for the mining structures and equipment and also containment for preventing airborne release of contamination, are significant. Recent videotaping and high resolution photography of the underside of the concrete crib cover have shown that many protective tiles have fallen from the cover, indicating areas of the undersurface are unprotected from the acidic environment of the crib atmosphere. Photographic characterization necessary for structural analysis determinations of the underside of the crib cover has been completed [3, 4].

Additional issues to be resolved are associated with preventing radiological contamination and exposure of site workers during the D&D work. These concerns are related to the safety of personnel working on the cover slab or possibly making entry into the trench, as well as the long-term integrity of the concrete cover following building removal. A major source of concern is that hydrochloric acid (HCl) generated from the degradation of carbon tetrachloride has and could continue to degrade the integrity of the undersurface of the concrete cover and /or support columns. Structural issues also include the integrity of the buildings relative to safe demolition practices, continued integrity of the hanger rods to maintain building support loads, and continued integrity of the tile placement that provides protection to the concrete slab and columns.

A facility condition analysis has recently been completed that presents the current understanding of the nature of structural and contamination concerns for the 216-Z-9 soil mining structures and equipment, as well as the condition of the concrete slab that covers the crib. This information will be used to create an approach for performing the removal action for the soil mining structures and equipment, including the establishment of a health and safety program and waste management and disposal alternatives. A qualitative analysis of the structural integrity of the slab itself is also provided. In order to decommission the crib mining structure and the equipment attached to the Z-9 Crib, an analysis of four issues was needed:

- Determine the structural integrity of the crib trench slab for bearing live loads during D&D and also for serving as a containment barrier to control potential alpha airborne emissions for 20 years,
- Determine the nature of the gases generated from radiolytic hydrolysis of water and organics accumulating in the trench area under the cover slab for potential flammable concentrations of gases,
- Determine the use and condition of the electrical equipment and the ventilation system during the D&D effort, and
- Collect the radiological data for additional nuclear safety analyses needed for the D&D work in the glovebox located in the soil packaging building to proceed.

A data quality objectives process was performed to define the data needs associated with determining the structural integrity of the crib cover. The resulting data needs that were identified included comprehensive, high-resolution photography of the underside of the crib cover and visual structural inspection of the buildings and crib cover surface. These data provide information for complete structural analysis by a qualified engineering team. A manned entry into the crib area was considered by the project management team as a

way to obtain the required data. Due to ALARA concerns as well as concerns regarding chemical vapors and structural obstructions, manned entry at this time will be avoided.

Instead, the team acquired a robotic crawler fitted with high intensity lighting, and a high resolution camera was constructed to provide the photographic data for the inspection.

Air samples were taken by filling SUMMA canisters. Analysis of the samples provided a summary of air toxics in the Z-9 Crib air space. Additionally, non-destructive gamma analyses were performed to determine the plutonium inventory within the 216-Z-9 A building structure.

HISTORICAL KNOWLEDGE

The historical knowledge for the 216-Z-9 Crib includes the processing information, and the results of site investigations conducted to characterize the site in the period between the end of waste disposal until the beginning of the current investigations. These studies are explored in detail in *Characterization Information for the 216-Z-9 Crib at the Plutonium Finishing Plant*, by J. Teal [5]. In order to evaluate the potential for a criticality in the crib, DOE/RL collected soil samples from a number of borings from the trench in the early 1970s. Most of the soil taken from the south half of the trench contained 0.5 to 15 grams of plutonium per liter in the top 15 centimeters, and 0.1 to 0.5 grams of plutonium per liter of soil at the 18 to 30 cm depth. Analysis of deeper samples taken at approximately 2.4 meters resulted in 0.03 to 0.1 grams of plutonium per liter of soil. Americium values ranged from 2,000 to 19,000 micro curies of ^{241}Am per liter of soil in the top 15 centimeters, compared with a range of 600 to 5,000 micro curies of ^{241}Am per liter of soil in the 18 to 30 centimeter depth. Deeper samples near 2.4 meters contained 200 to 550 micro curies ^{241}Am per liter of soil. A schematic of the crib structure is presented as Figure 1.

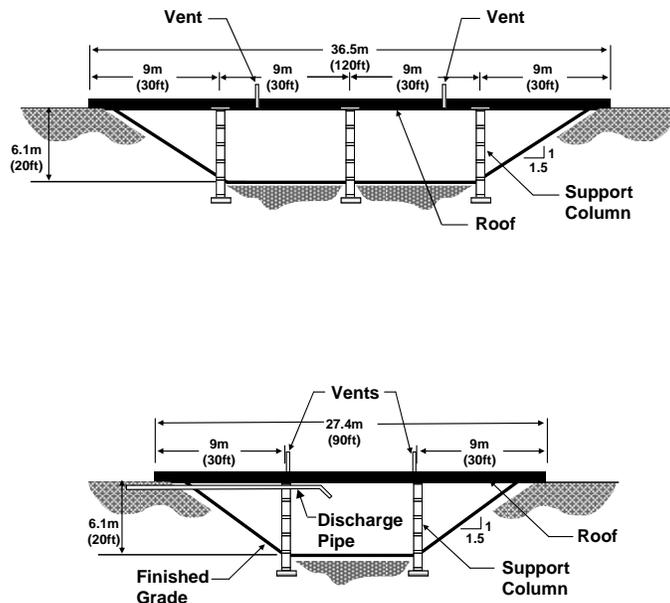


Figure 1. Schematic of 216 Z-9 Crib Structure.

The pH of the soil ranged from three to four over the soil column down to three meters. Moisture in the soil varied from 5% to 15% by weight depending on location. The sludge layer described in the analysis of the soil cores contained up to 45% volatiles, which was assumed to be water for the purposes of calculations. Only trace levels of tributyl phosphate, cadmium, chloride, and nitrate were found in the samples from the soil borings [5,6]. Contaminants in the soil of the Z-9 Crib are described in detail in the *Study of Liquid Effluents and CERCLA Hazardous Constituents Generated and Discharged by the Plutonium Finishing Plant* by Hopkins and Lini [7].

Due to nuclear safety and environmental concerns with the quantity of plutonium in the soil, the decision was made to remove (“mine”) a portion of the crib floor. The 216-Z-9 Crib mining operation lasted from October of 1976 to July of 1978 and removed the top 12 inches of soil from the crib floor. During operations, 28 kg of plutonium were mined from the north half of the crib and 30 kg of plutonium were removed from the south half for a total of 58 kg of plutonium. Soil from each day’s mining was analyzed for moisture, organic, and cadmium content. In addition, each filled canister was assayed for plutonium content. Moisture content ranged between 0.2 and 24.4 wt%, averaging ~ 5 wt%. Organic content of the soils averaged 7.1 wt%, with a range of 0.2 to 46.6 wt% [8]. Cadmium concentrations ranged between less than 0.8 wt% and 0.2 wt%. An estimated 48 to 50 kilograms of plutonium remain distributed throughout the soil, based on the soil analyses [9]. An historical view of the Z-9 Crib mining equipment is presented in Figure 2.



Figure 2. Historical View, Z-9 Crib Mining Equipment

At the time of the soil mining operation, the maximum credible accident as determined by nuclear safety analysis staff and documented in *Final Safety Analysis Report, Contaminated Soil Removal Facility 216-Z-9 Enclosed Trench* (Project HCP-687) [10] was concluded to be collapse of the crib cover. This accident scenario was determined to be a very unlikely occurrence.

Contamination Status of the Above-Ground Structures

Other than the glovebox with interior contamination, the interior of the building has low-level contamination, generally to levels below 2000 d/m as documented in annual radiological surveillances. A series of photographs taken in 2007 inside the buildings on the 216-Z-9 slab indicated no equipment remains outside of the glovebox structure that covers the access port leading to the area below the slab, with the exception of assay equipment, a portable air compressor, its air storage tank, and a supply cabinet [5].

Air Quality Information

No historical analytical information on air quality conditions below the slab has been found to date. The ventilation systems in the buildings associated with the 216-Z-9 Crib are shut down.

Hazardous Contaminants Found in 216-Z-9 Crib Soils

The waste disposed to the crib included significant volumes of organic chemical compounds; additional compounds would have been generated through the degradation of the waste constituents (e.g., carbon tetrachloride, chloroform, tetrachloroethene). Therefore, recent site investigations have included the sampling and analysis of the airspace in the trench to determine the presence and concentrations of volatile organic compounds (VOC). The waste solutions also contained a variety of inorganic chemical compounds as detailed in *216-Z-9 Soil Removal Structures Supplement to the Data Quality Objectives for the Plutonium Finishing Plant Above-Grade Structure*, Hopkins [11].

The mining activity at the 216-Z-9 Crib was performed to recover the first foot of soil, which was very rich in plutonium. The process of soil removal and packaging resulted in soil from the crib contaminating the mining equipment, including the glovebox interior. Other constituents of potential concern identified through historical process knowledge include: americium-241, neptunium-237, plutonium-238, plutonium-239/240, radium-228, strontium-89/90, technetium-99, thorium-232, uranium 233/234, uranium-235, arsenic, cadmium, copper, hexavalent chromium, lead, mercury, nickel, selenium, silver, ammonia, fluoride, nitrate, nitrite, sulfate, acetone, carbon tetrachloride, chlorobenzene, chloroform, methylene chloride, tetrachloroethene, toluene, trichloroethene, tributylphosphate, polychlorinated biphenyl (PCB), oil and grease, and xylene [7].

The majority of the non-radionuclide contaminants of potential concern (COPCs) were eliminated from further consideration in the 216-Z 9 DQO process because only minor

amounts of soil residue, which would provide the source for contamination and exposure or waste designation, are anticipated in the debris matrix. Elevated levels of organic compounds have been ruled out primarily based on the results of recent air samples collected from within the trench.

Criticality Concern

A. E. Smith documents the addition of a cadmium nitrate solution to the crib prior to mining in order to minimize concerns over a critical configuration of the plutonium in the trench [6]. Hanson's 1976 final safety analysis report [8] included a conclusion that "the probability of water reaching the crib in sufficient quantity to cause flooding due to any credible accident or natural phenomena is low, and therefore, the potential for a criticality excursion is very low". The safety analysis report also considered the possibility of a roof collapse.

The configuration of the materials in the soils subsequent to the mining operations should result in an even lower potential for criticality since the soils with the highest concentration of plutonium have been removed from the trench.

A Criticality Safety Evaluation Report (CSER) for deploying the robot into the crib to travel on the surface of the soil indicated that the activities associated with robot operation, equipment removal or manned entry would not result in the formation of the requisite size fully reflective sphere. A fully reflective sphere is considered unfavorable geometry for criticality safety as explained in *Incredibility Analysis for the 216-Z-9 Facility*, Richard 2007 [12].

STRUCTURAL ANALYSIS

The 216-Z-9 enclosed crib, completed in 1955, is an underground excavation with an active floor area of 30 by 60 feet at a mean sea level altitude of 639 feet, 21 feet below the top of the concrete slab cover. The slab is 9 to 12 inches thick, composed of reinforced concrete, and is 90 feet wide by 120 feet long at ground level. The underside of the slab was constructed with an acid-resistant tile facing, due to the low pH of the waste solution. The trench has equally sloping sides, which end at the trench floor. The slab is supported by concrete footings around the perimeter, and six concrete columns located at the corners of the active floor area and midway down each of the 60-foot sides. The columns were built with vitrified tile pipe as a cover to protect the concrete from the acidic waste solution and moist environment. Due to the high salt content and acidic nature of the Recuplex wastes, considerable gassing and soil plugging was expected when the wastes contacted the soil. No waste has been discharged to the 216-Z-9 crib since June 1962.

A key concern for the removal of the 216-Z-9 soil mining structures and equipment is the current and continuing integrity of the concrete slab that covers the crib. Review of this aspect of the facility included a look at the available information for the facility design

and construction, revisions to support soil mining, and observations of current structural components of the slab and building support system.

Facility Design

The crib originally was constructed to contain the large volumes of acidic waste that were generated from the Recuplex process at PFP. The 90 foot x 120 foot (27.4 meter x 36.6 meter) trench cover was designed and constructed to support its own weight plus 50 pounds per square foot (psf) of live load. The concrete slab design included steel reinforcing bar (rebar), as well as acid-resistant tiles on the underside of the cover to protect the concrete from the moist, corrosive air in the trench. The tile facing extended to the concrete footings that surrounded the trench and supported the cover. Six concrete columns support the slab and were completed with vitreous clay pipe covers to protect the concrete.

The original design included five openings – one 62-cm. (24-in.) manhole and four, 10-cm. (4-in.) vent risers. Prior to construction of the mining facilities, ten, 8-inch diameter and eight, 4-inch diameter holes had been drilled through the trench cover (slab) to provide access to the trench floor for soil sampling and neutron pulse measurements. One 10-inch diameter hole was also drilled through the 24-inch manhole cover. The following additional holes were made in the concrete slab to support operation of the Contaminated Soil Removal Facility:

- Two 42-inch diameter, structurally-reinforced risers to permit insertion of the soil excavating equipment.
- Two 20-inch diameter risers to permit installation of the television camera, used to monitor mining activities.
- One 9'5" by 10'9" opening for installation of the mining operator's cubicle.
- One 5'3" by 2'7" opening for conveyor access to the soil packaging hood.
- One 3' by 11'4" opening for installation of the trench entry stairway.
- One 8-inch diameter riser for access to the base of the soil conveyor.
- One 13-inch diameter riser for the ventilation exhaust.

Modifications for Mining

The mining containment building (216-Z-9A) was designed and constructed in compliance with the Seismic-Uniform Building Code, Section 2314, Earthquake Zone 2, Wind-Uniform Building Code, Section 2308 (20 pounds per square foot wind pressure). The structure is located on the east side of the 216-Z-9 Trench with a part of the structure on top of the trench cover. A structural steel system was constructed over and on the trench cover to provide the required support for the additional loads (Figure 3).

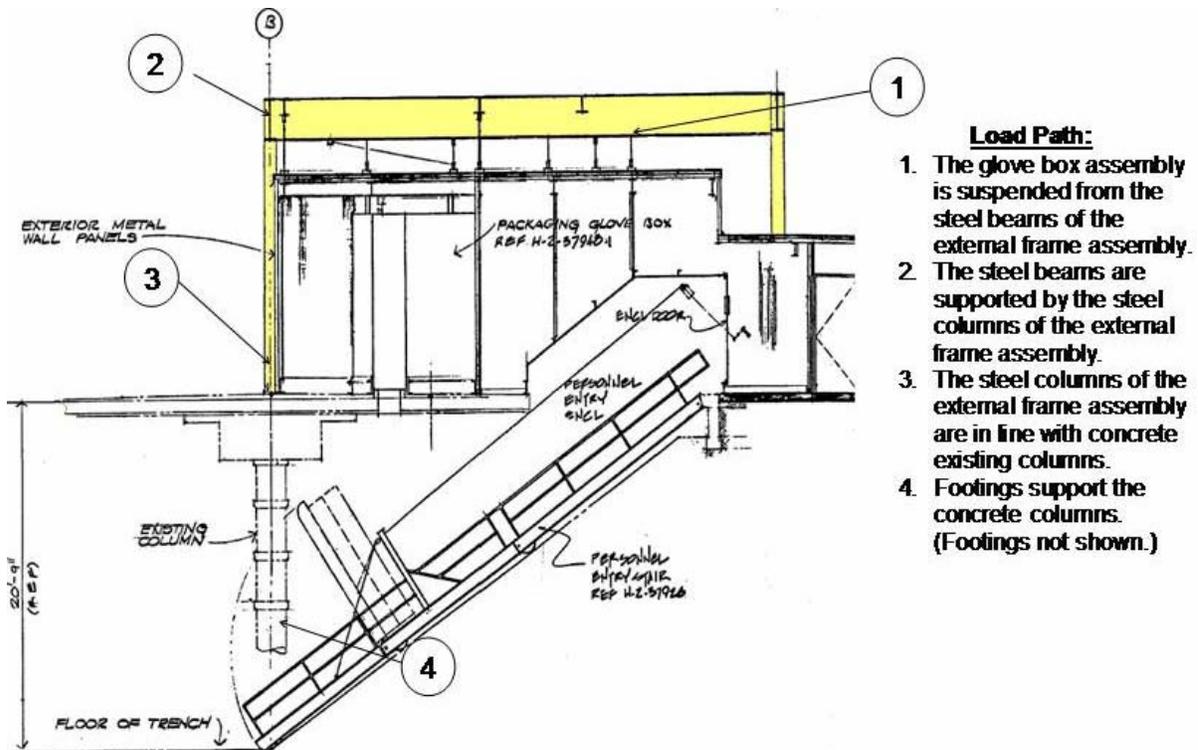


Figure 3. Schematic of Load Bearing structures for Z-9 Crib cover

The structural calculations performed by Vitro in 1975 and the subsequent Battelle review of the calculations in 1976 is the last detailed engineering analyses performed for the 216-Z-9 Crib structure. No structural modifications have been conducted to the slab or supporting structures since that time. The hanger rods attached to the building supporting I beam structure pictured in figure 3 require periodic tensioning to ensure the building load is supported. Otherwise, the building load transfers to the crib cover and could undermine the structural stability of the cover. Records for documenting periodic tensioning of the hanger rods from 1978 through 2006 could not be found. Therefore, an assessment of the hanger rods was performed. All hanger rods with the exception of one were found to be properly tensioned.

Several activities were conducted to assess the continuing integrity of the facilities to determine their ability both to support the removal of the above ground structures and to evaluate the ongoing integrity of the slab. These activities and their results are documented in *Facility Condition Analysis for the 216-Z-9 Crib and Cover Slab to Support Removal of the Above-Grade Soil Mining Structures*, Hopkins, 2007 [14].

This facility conditions report presents the current understanding of the nature of structural and contamination concerns for the crib mining structures and equipment as well as the condition of the concrete slab that covers the crib.

- **Slab Assessment.** In June 2007, a crawler-mounted camera and a fixed camera were inserted into the trench to obtain photographs of the trench floor, the

underside of the slab, and the supporting columns. The goal was to obtain high quality images of the trench interior to enable a qualitative determination by structural engineers as to whether the components of the slab have deteriorated significantly. Figure 4 provides a sample of these photographs showing a panorama of the trench including the mining equipment, operator's cubicle, and the extent of tile separation. The results from analysis of the photographs are included in a structural assessment report.



Figure 4. Composite of High Resolution Pictures of the interior of the Z-9 Crib

Key observations from this report include the following:

- Exposed carbon steel inside the crib area shows signs of corrosion, which appears to only be a light surface corrosion.
- Large expanses of the clay tile, originally cast into or adhered to the interior face of the crib's concrete roof, have fallen off. The vitrified clay tile encasing the columns appears to be undamaged.
- The underside concrete surface that is exposed does not appear to be damaged, based solely on a visual inspection. The concern remains that the concrete may have decayed on this face sufficiently to have lost its bond with the tile and possibly its bond with the reinforcing steel near this face.

In an attempt to verify that the concrete is still competent, without making an entry in to the crib, the top of the slab was surveyed in July 2007, looking for any excessive deflections that might indicate a lack of bond between the reinforcing

steel and the concrete, particularly in the positive reinforcing zone (bottom steel). The resulting elevations did not indicate any deflection or irregularities that present a cause for concern over slab integrity. These results are consistent with a visual inspection of the surface of the slab which also did not reveal any issues of concern.

- I-Beams and Hanger Rods Assessment. A visual inspection of the support beams and the hanger rods that support the mining structures was performed in June, 2007. The structural framing showed no signs of significant structural damage or corrosion. Some of the hanger rods required tightening; however, all are in good condition.

CURRENT SURVEY AND SAMPLING RESULTS FOR 216-Z-9 STRUCTURES AND EQUIPMENT

Radiological surveys, industrial hygiene investigations, vapor samples, and soil-gas samples have been taken from inside the 216-Z-9 Crib and its associated above-ground structures as part of the 2006/2007 characterization activities to support the removal of structures and equipment at the site consistent with the sampling and analysis plan [13].

Radiological Air Sample Analysis

Radiological air sample analyses were collected from the 216-Z-9 Crib on April 29, 2007. All samples showed low alpha concentrations ranging from $3.7\text{E-}14$ to $3.60\text{E-}12$ uCi/ml. Air samples also were taken from select, associated structures in January and May, 2007. All samples showed low alpha concentrations, ranging from $1.60\text{E-}13$ to $5.5\text{E-}11$ uCi/ml.

Radiological Surveys

Radiological surveys have been performed of several items at the 216-Z-9Crib to determine the plutonium content of these materials. Results are summarized below.

- Non-destructive analysis (NDA) measurements were performed in March, 2007 to quantify the contained Pu-239 activity for the 216-Z-9A Glovebox. The In-Situ Object Counting System (ISOCS) measurements of the glovebox were performed from outside of the facility, accounting for the location and size of the glovebox, as well as the building wall construction. The total plutonium inventory for the glovebox was measured as 4.765 grams.
- NDA measurements were performed to quantify the contained plutonium activity for the 216-Z-9 Process Duct. Measurements were performed on the high-efficiency particulate air (HEPA) filters and sections of the duct thought to have higher levels of holdup. The total plutonium inventory for this system was measured as 4 grams, with one gram in the K1-9-1 filter housing and the remainder in sections of the duct.

- An oil sample was collected on August 1, 2007 from the hydraulic system that operated the mining equipment; access was obtained through the 216-Z-9C structure. NDA results for the oil indicate the oil has a TRU specific activity of $1.79\text{E-}02$ nCi/g; total Pu was measured at $4.619\text{E-}09$ grams for the sample, which had a mass of 0.02 kg. Laboratory analysis of two oil samples for PCB provided results of <0.81 mg/kg and <0.84 mg/kg .

Radiological surveys of various areas and smear samples were performed for several jobs associated with the 216-Z-9 facility:

- general housekeeping for 216-Z-9 Crib glovebox building,
- installation of temporary lighting,
- 216-Z-9A building inspection of structural tension rods,
- 216-Z-9A Building initial entry for stairwell inspection,
- 216-Z-9B Building spraying of bleach to down-post contamination area,
- 216-Z-9A building inspection of structural building supports,
- 216-Z-9 riser replacement of flange bolts,
- 216-Z-9 riser flange removal, installation and removal of robot and camera in Z-9 riser flange,
- 216-Z-9 survey of filter boxes,
- follow-up after decontamination of 216-Z-9 Crib contamination area, and
- release of fixed (painted-over) contamination area of 216-Z-9 Crib.

Very little contamination was found above detectable levels. Relatively small amounts of alpha contamination (60-1,500 dpm) were found on the floor and light base in the 216-Z-9 Glovebox Building with somewhat higher alpha contamination levels on the glovebox (12,000-30,000 dpm), the shaft house (1,500 dpm), inside the glove bag associated with the 216-Z-9 riser (1,500 dpm), and filterboxes and concrete in the Contaminated Area (1,200-24,000 dpm). Nearly all detectable alpha was associated with removable contamination [14].

Vapor Surveys and Industrial Hygiene Samples

An industrial hygiene Direct Reading Instrument (DRI) survey for carbon tetrachloride was performed on April 7, 2007. Samples from 14 locations inside the 216-Z-9B Operator's Cubicle were taken from just inside the door to 5 m (16 feet) below the grate. All of the sample results were below the detection limit (0.008 mg per sample tube).

Headspace Samples from the 216-Z-9 Crib

Headspace vapor samples were taken from 216-Z-9 in December 2006, January 2007 and May 2007. All samples were analyzed for a suite of organics. The only detected analytes, and their ranges of detection over the five samples were propane (<10 to 22 PPB V/V), butane (<10 to 33 PPB V/V), carbon tetrachloride (<10 to 52 PPB V/V), methanol (<50 to 14 PPB V/V), acetone and toluene.

RESULTS/CONCLUSIONS

Based on the observations from the photographs and visual inspection of structural beams and hanger rods, the concrete roof of the trench is considered adequate to take the full design loads as established at the time of the mining modification, i.e., a combined live load of 20 pounds per square foot (psf) and up to 6.9 inches of negative pressure, or 50 psf without any vacuum pulled on the underside of the slab. This should be sufficient to meet the needs for the removal activities. Note that the live load should be reduced when a vacuum is pulled. The failure of the tile appears to be a recent development and brings into question the long term stability of the roof. Without a more thorough understanding of the mechanisms contributing to the tile failure, it cannot be assured that the roof structure will continue to provide its confinement function to the crib for more than five additional years. The structural engineering team recommends that the slab be re-inspected at least every five years.

Head space air samples from the crib interior provide sufficient information for the development of an air monitoring plan for the planned D&D work. Similarly, the non-destructive gamma analyses of the 216-Z-9A Building provide sufficient information on the concentration of plutonium in the residual soil remaining in the glovebox and plutonium held up in the filters for continued D&D planning. A removal action work plan is being prepared using the results of these characterization activities.

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