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Decontamination of Hot Cells and Hot Pipe Tunnel at NASA's Plum Brook Reactor Facility

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ABSTRACT

The large scale decontamination of the concrete Hot Cells and Hot Pipe Tunnel at NASA's Plum Brook Reactor Facility demonstrates that novel management and innovative methods are crucial to ensuring that the successful remediation of the most contaminated facilities can be achieved with minimal risk to the project stakeholders.

INTRODUCTION

In the 1950s, the National Advisory Committee for Aeronautics (NACA), NASA's predecessor organization, constructed a test reactor facility in Sandusky, Ohio, intended for research on nuclear powered aircraft. When national goals shifted from the nuclear airplane to the nuclear rocket, the Plum Brook Reactor Facility (PBRF; Fig. 1), became a vital research tool with regard to the development and advancement of the nuclear powered rocket program. Scientists and engineers commenced an experimental program in the 1960s at PBRF to test materials and power systems for space and environmental applications. The PBRF and its seven (7) Hot Cells (HCs) at the PBRF were a key element within the test reactor facility. The HCs were heavily shielded rooms where engineers and technicians could safely analyze irradiated experiments. The two (2) largest cells are shown in Figure 2. Situated beneath the HCs, the Hot Pipe Tunnel (HPT) served as a utility corridor that housed the drain plumbing and air ducts that serviced the HCs.

Fig. 1. NASA's Plumb Brook Reactor Facility – circa 1963.

Fig. 2. Hot Cell 1 and 2 prior to Remediation Efforts.

The HCs and the associated HPT were some of the most highly contaminated surfaces at PBRF. Fixed contamination levels exceeded 11.69 MBq/m² (7,000,000 dpm/100 cm²), while loose contamination exceeded 8.35 MBq/m² (5,000,000 dpm/100 cm²).

HOT CELL 1 DECONTAMINATION

NASA decided to authorize the decontamination of HC 1, the largest and most contaminated area of the facility, to demonstrate whether a HC could be decontaminated to the Remedial Action Limit (RAL). The RAL was defined by two separate and distinct metrics:

1. Total beta contamination, fixed along with removable, had to be less than 25.050 Bq/m² (15,000 dpm/100 cm²) as determined by direct frisk.

2. Removable beta contamination had to be less than 2,505 Bq/m² (1,500 dpm/100 cm²) as determined by smear surveys incorporating standard smear counting techniques.

Initial Plan of Action

HC 1 field activities began on October 31, 2005, with the removal of loose equipment. This was followed by initial decontamination of the HC interior surfaces, removal of electrical wiring from all electrical conduits, removal of fixed equipment, stainless steel liner plate removal, removal of the two observation windows, removal of the HC roof slabs, and the final decontamination of the HC interior surfaces.

Fig. 3. Fixed equipment such as these manipulator arms.

HC 1 contained a significant amount of loose and fixed equipment. Examples of these items are shown in Figures 3 and 4. Some of the major loose equipment inventory included a hydraulically manipulated table, a shielded cask, a transfer tray, lead shielding bricks, and large piles of loose lead shot. Fixed equipment was defined as items extending beyond the surface of the cell, including overhead cranes, manipulator arms, stainless steel liner plates and, lead glass observation windows.

Fig. 4. Loose equipment included items like this work table.

The loose equipment was removed and the initial surface decontamination reduced the smearable contamination levels to a condition that facilitated personnel entry into the HC. The complete liner plate was removed from the floor and the wall. The roof slabs of the HC were removed and decontaminated to free-release standards.

Final decontamination efforts were primarily conducted through the utilization of hand held surface grinders and proved to be largely unsuccessful. The lack of success was primarily attributed to two (2) factors.

1. The results obtained through the use of the surface grinders diminished as the workday wore on due to worker fatigue. Working on scaffolding required operation of the grinders at, or above, chest elevation thereby increasing worker fatigue.

2. The shine, dose rate, emanating from embedded fixed equipment components was significantly elevated, thereby reducing survey reliability and effectively elevated overall dose rates in excess of the RAL.

Field activities associated with the final decontamination efforts for HC 1 to the RAL were suspended on April 12th, 2006. Dose rates within HC 1 remained at, or above, the RAL.

Revised Plan of Action

Following the suspension of work, project stakeholders initially considered abandoning HC decommissioning efforts in favor of total demolition and disposal. This was obviated by the development and acceptance of the following plan of action.

1. Due to the elevated background emanating from embedded fixed equipment, pre-remediation surveys were not to be performed.

2. The use of semi-remote techniques for removal of fixed components would be implemented.

3. Complete removal of embedded fixed equipment components (Fig. 5) as well as previously decontaminated fixed equipment that remained intact was enacted.

4. The vertical and horizontal corners would be decontaminated using a hydraulic hoe-ram in lieu of needle gun scabblers or chipping hammers.

5. The decontamination of the structural surfaces of the HC using mechanically supported and operated scabblers was adopted in favor to using hand held tools.

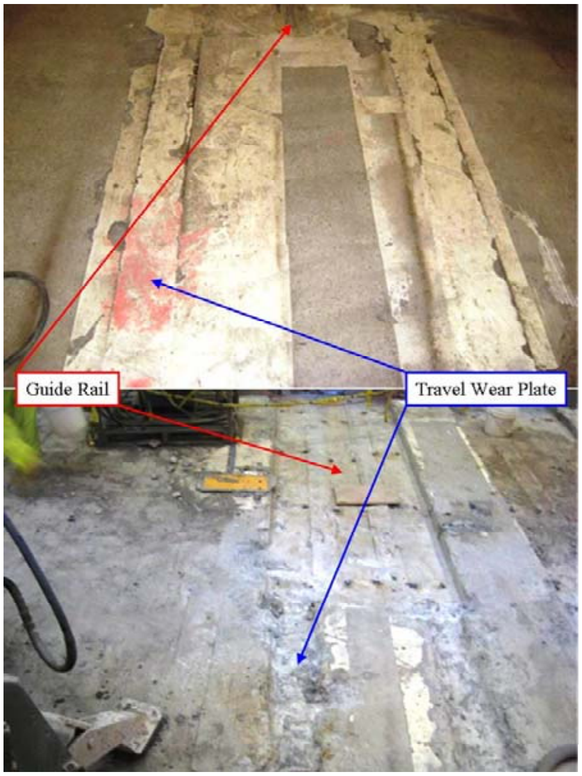

Fig. 5. Example of major steel embed removal includes the guide and wear plates in place for the shield doors

6. A post-remediation survey of the HC would be performed once the results of operational surveys indicated that all surfaces had been successfully decontaminated to a point at, or below, the RAL.

Project stakeholders authorized the recommencement of final decontamination efforts for HC 1 on August 8, 2006, in accordance to the revised plan of action. These efforts began by the removal of major embedded metallic components which included the wear plates and guide rails for the HC door, angle iron protecting the exposed edge at the HC roof slab opening, and embedded sections of the crane rail beams.

The removal of the embedded components left the surfaces of the HC in a “lunar landscape” like condition (Fig. 6). Simply put, the surfaces were so pockmarked that a conventional scabbler head would have been ineffective in removing all of the contamination located in the crevices and depressions on the HC surfaces. Hence, it was determined that the only effective means of decontaminating the HC surfaces would be to utilize remotely operated equipment to chip away at the contaminated concrete surfaces. An electrically powered demolition device was utilized as the tool carrier of choice.

Fig. 6. Example of “Lunar Landscape” like surface resulting from initial remediation approach.

Operational surveys revealed extremely elevated readings around the threaded fitting of many electrical conduit penetrations embedded at the surface of the HC wall. The concrete was removed to expose the fittings in pockets. Each exposed fitting was then removed using thermal cutting methods.

The final, finished product following the decontamination effort was an extremely rough, irregular surface that was scanned during the post-remediation survey. The scan time was greatly increased by the irregularity of the HC surfaces and the efficiencies of the detectors had to be adjusted to accommodate the irregular topography of the HC surfaces to a point wherein it was impractical to “read” anything lower than the RAL accurately.

Documentation pertaining to the post-remediation survey of HC 1 was submitted to NASA for its review and approval on August 31st, 2006. The survey documentation indicated that all surfaces of HC 1 were below the RAL.

Lessons Learned

It is virtually pointless to either attempt to survey an area within a HC to establish those areas in need of remediation or to attempt to physically decontaminate a structural concrete surface until such point in time that all embedded and/or surface mounted metallic components have been removed.

Alternate means of removing the contaminated concrete surfaces, resulting in a smoother finished product more conducive to facilitating final status survey operations, should be researched, studied and evaluated for incorporation into future decontamination work activities.

RE-EVALUATE MEANS AND METHODS

Recognizing the less than desirable performance associated with the HC 1 effort, it was decided that a more productive means-and-methods must be incorporated into the work plan prior to proceeding with the decommissioning of HC 2 through 7 that included over 470 m^2 (4,286 ft^2) of contaminated surfaces.

There was a significant amount of fixed and loose equipment situated in HC 1. This was not the case regarding the physical status of HC 2 through 7 prior to remediation efforts. No loose equipment was located in any of these HC. A minimal amount of fixed equipment remained. The observation windows had previously been removed along with the stainless steel liner plates. The existing physical condition of HC 2 through 7 resembled the condition of HC 1 at the point in time that work activities recommenced after the first suspension.

After analyzing and evaluating alternative means of decontaminating the HC surfaces and considering lessons learned from the HC 1 effort; it was decided to implement the following strategy.

Embedded Items

No attempt would be made to decontaminate embedded metal components in their in-situ condition. These items were to be removed and decontaminated in a designated location. The concrete surfaces around the embedded components were to be hammered out by utilizing a hydraulic hoe-ram. Thermal cutting means would then be utilized to sever any attachment points between the embedded components and the concrete substrate. These embedded items included door receipt pockets, manipulator sleeves, and other common embedded components.

Soft Media Blasting System

Next, a soft media blasting system (SMBS) was substituted for the hand-scabblers for decontaminating the walls, removable roof slabs, and the barrier doors of the HC.

The SMBS removes contaminants by using abrasives bonded in dust suppressing foam. The sponge media particles strike the surface where they flatten and expose the abrasive which cuts into the coating and substrate. As the media rebounds, it creates suction and traps dust and other contaminants that otherwise become airborne. This process (Fig. 7) is known as micro-containment.

Fig. 7. Conceptual representation of the "micro-containment" process.

Up to 95% of the media can be recycled for reuse. Blasted media is collected and processed separating reusable media from oversized and other fine waste.

Hydraulic Wrecking Equipment

Hydraulic hoe-rams and rotary cutters as shown in Figure 8 were used to remove bulk material from floor surfaces. These hydraulically driven tools are powerful, reliable, and efficient. They have been used for many years in confined space demolition projects mounted on many different styles of excavators.

Fig. 8. Scaling drum used to remediate the floors of hot cells and the hot pipe tunnel.

REMAINING CELLS AND THE HOT PIPE TUNNEL

Authorization to proceed with the decontamination and post-remediation surveys of HC 2 through 7 was provided by NASA on September 25, 2006. By March 19, 2007, final decontamination efforts were essentially complete. Removable items, such as roof slabs and barrier doors, were relocated and decontaminated in other locations within the facility. HC 2 through 7 decontamination and post-remediation efforts concluded with the release of the last remaining roof slab after being decontaminated to zero detectable standard by May 16, 2007.

Fig. 9. Steel jacketed concrete plug from the hot pipe tunnel prior to remediation efforts.

The SMBS proved itself to be an effective tool enabling the technician to remove up to 6 mm (0.25 in) of concrete per pass by varying the stay time that the blaster was exposed to the concrete's surface. While decontaminating concrete surfaces, the media was reused numerous times. The reuse rate dropped significantly when decontaminating steel surfaces.

Fig. 10. Remediated plug, free released and to be used as backfill.

Employment of these tools enabled technicians to reduce the residual contamination levels on the HC surfaces to less than 28,000 Bq/m^2 (17,000 dpm/100 cm^2), or one-half of the target DCGL for the HC. Moreover, decontaminating the barrier doors, roof slabs, and the barrier door receipt pockets using the same techniques facilitated the free-release of 226,796 kg (500,000 lbs) of concrete and 45,359 kg (100,000 lbs) of steel. Current plans are to use the concrete material as backfill during site restoration (see Fig. 9 and Fig. 10).

NASA authorized the decontamination and post-remediation survey of the HPT situated below the HC area on March 21, 2007.

Structural decontamination of the walls and ceiling of the HPT which included over 547 m^2 (5,890 ft^2) was completed by July 14, 2007, using the SMBS. Technicians were successful in reducing the residual contamination levels on the HPT walls and ceiling to less than 29,000 Bq/m^2 (17,500 dpm/100 cm^2), or one-half of the target DCGL.

Fig. 11. Actual spot remediation efforts within the hot pipe tunnel.

The floor of the HPT was remediated by utilizing a scaling drum as shown above (Fig. 11). The scaling drum removed an average of 5 cm (2 in) of concrete from the floor slab. This reduced the residual contamination levels to 29,000 Bq/m^2 (17,500 dpm/100 cm^2) over 95% of the tunnel floor area. By July 25, 2007, remediation efforts using the scaling drum were completed. Loose debris was removed and operational surveys conducted. These surveys revealed some areas requiring further spot remediation. All structural decontamination and radiological survey efforts were completed on September 20, 2007.

CONCLUSION

Large scale remediation of substantially contaminated concrete structures can be performed using innovative management and methods to minimize project stakeholders' risk associated with the alternative 'rip and ship' or demolition of the contaminated structure.

Remediation performance associated with the approach deployed for HC 2 through 7 significantly increased in comparison to work performed in HC 1. The homogeneous contour of the remediated surfaces resulting from use of the SMBS greatly enhanced the efficiency of data collection required during the final status survey.

Use of the SMBS does introduce a secondary waste volume; however, project savings resulting from the increased production and survey efficiency far exceed the additional value resulting from marginally increased waste volume.

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