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Going Where No Man Can Go

Casandra W. Robinson
Westinghouse Savannah River Company, Building 773-A, D1110, Aiken SC 29808,
casandra.robinson@srs.gov

Robert H. Smith, Jr.
Westinghouse Savannah River Company, Building 221-H, Aiken SC 29808, robert07.smith@srs.gov

Abstract – This paper discusses the successful remote visual inspection of a contaminated air exhaust tunnel running beneath the Savannah River Site's H-Canyon nuclear material separations facility. The air exhaust tunnel has been in operation since the 1950's, and the portion of the tunnel inspected has not been seen or accessed since startup. Numerous challenges were overcome in the deployment of the vehicle, including an initial 10-ft drop, travelling a long distance through harsh environmental conditions, surviving and recovering from a second vertical drop, turning 90 degrees, and subsequently travelling further. Video of the entire inspection was transmitted back to a control station, and the vehicle was abandoned in place for possible future use.

I. INTRODUCTION

The Savannah River Site (SRS) is a Department of Energy (DOE) facility in South Carolina, and its mission is the management of the nuclear weapons stockpile, nuclear materials, and the environment. SRS began to produce materials used in nuclear weapons in the early 1950's and is currently working towards accelerated cleanup of radioactive waste and closure of facilities that are no longer needed.

In March of 2003, a team from the Savannah River Technology Center, H-Canyon Operations, and H-Canyon Engineering at the Savannah River Site successfully developed and deployed a remotely controlled vehicle into an area that had not been accessed for nearly fifty years. The vehicle was developed in response to a potential problem and to address a DOE concern in that facility.

II. BACKGROUND

H-Canyon is one of two chemical separation facilities built to support the production of nuclear materials, and its main purpose was to reprocess spent uranium fuel and other enriched uranium fuels. H-Canyon began operation in 1955. The building is an 835-feet long, multilevel facility and is referred to as a canyon because of its long, rectangular shape. Radioactive operations are performed inside two parallel smaller canyons, referred to as "Hot" and "Warm" canyons indicating the levels of radiation within them. The radiation rates inside portions of the canyon are lethal at a close distance.

The Hot and Warm Canyons each house a series of cells with concrete walls and cell covers, and all work is performed remotely from a central control room using bridge cranes. To prevent the spread of airborne radioactive contamination, contaminated air is pulled from the Hot and Warm Canyons, through air exhaust tunnels and to a sand filter prior to being released into the atmosphere. The portion of the air exhaust tunnel joining the Hot and Warm canyons is referred to as the crossover tunnel. See Figure 1 for a cross-sectional view of the canyon.

The H-Canyon building also houses two related operational areas: Old HB-Line (OHBL) and HB-Line (HBL). OHBL produced Plutonium-239 (Pu-239) buttons from 1953 to 1960, and it was then upgraded to support NASA in the production of Pu-238 heat sources for deep space exploration of the NASA Galileo, Ulysses, Cassini missions. OHBL also produced Neptunium (Np) oxide during the period that the SRS reactors were operational. OHBL was abandoned in 1984, and its operations were taken over by the new HBL facility. A section of OHBL ventilation duct and a transition point tie-in are located in the air exhaust crossover tunnel. Although portions of the Hot and Warm Canyon air tunnels are inspected annually, the crossover tunnel and OHBL transition point had never been inspected due to extreme access limitations.

III. REASON FOR INSPECTION

Two potential problems related to the OHBL duct were noted: canyon air tunnel exhaust appeared to be

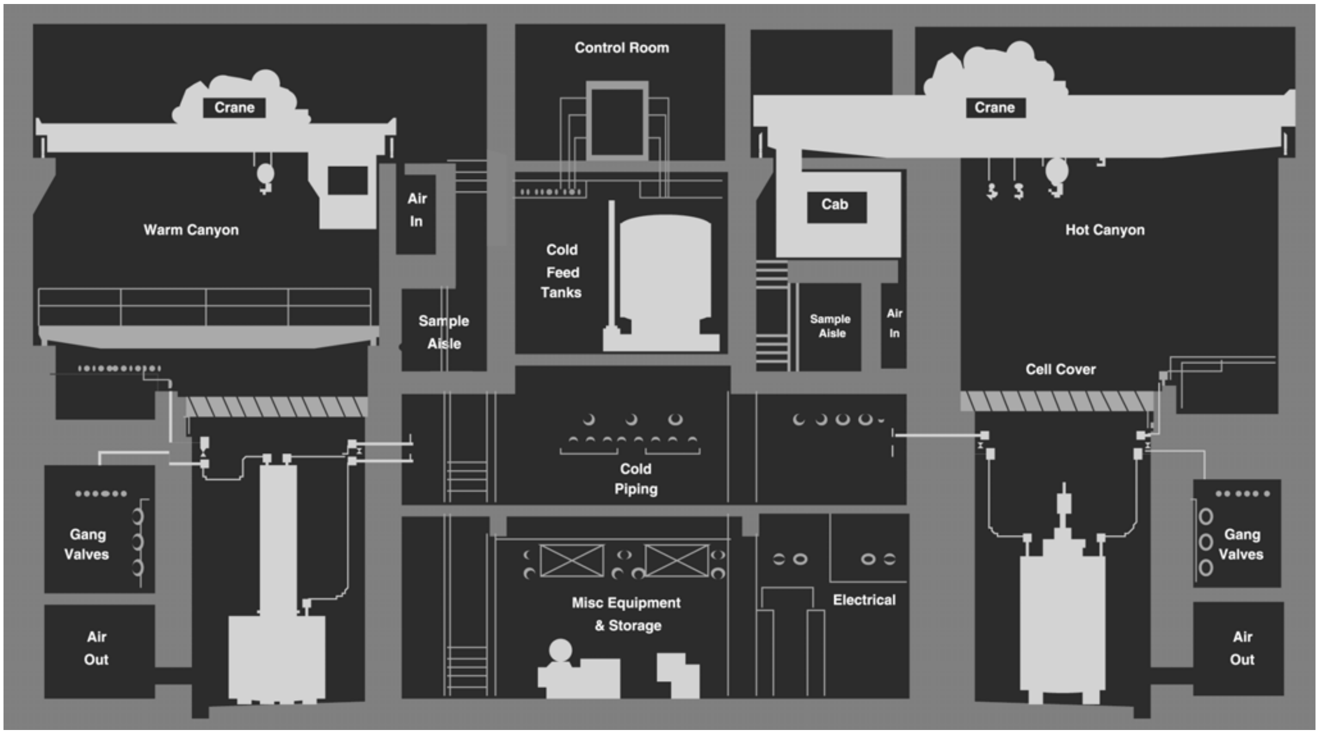

Figure 1. Canyon Cross-Sectional View

leaking into the OHBL duct, and the integrity of the OHBL duct supports was of concern.

The OHBL duct enters the canyon exhaust tunnel on the warm side of the canyon and runs the length of the crossover tunnel. That OHBL exhaust duct then exits the crossover tunnel upstream of the sand filters and delivers flow to a bank of high-efficiency particulate air (HEPA) filters located in a fan house. Within the recent years, high gamma radiation readings were noted in the fan house, and the presence of fission products on the HEPA filters suggests a leak from the canyon exhaust tunnel into the OHBL exhaust duct. This is a concern due to the possibility of an accident or failure of the OHBL duct, which could result in airborne contamination being released at ground level [1] and the habitability of the OHBL and HBL facilities being negatively impacted.

The purpose of this inspection was to determine the source of the in-leakage between the ventilation systems of OHBL and H-Canyon and perform a remote structural inspection.

III. AIR EXHAUST TUNNEL CONDITIONS

The tunnels are 10 ft. x 10 ft. and not only provide the air exhaust path but also contain additional piping and ductwork. The air tunnels are under constant attack from elevated temperatures, humidity, acidic environment with a constant 10 mph air flow. Actual radiation rates in the crossover tunnel have never been measured, but rates exceeding 250 Rem are common in the canyon remote areas, from which air is pulled into the air tunnels. Figure 2 shows the condition of a previously inspected portion of the Warm Canyon air exhaust tunnel.

Accessing the crossover tunnel required remote navigation with over 150 feet of horizontal run, two 10-foot vertical drops, and a number of piping and physical obstructions. The concrete aggregate build up on the floor area presented additional problems with crawler


Figure 2. Photo of Air Tunnel

traction and tether friction. Drawings indicated that at the top edge of the second 10-foot drop, an 8-inch curb spanned the floor of the air tunnel. A final challenge lay in the access port for the tunnel, which is a 1-ft^2 opening.

IV. INSPECTION SOLUTION

The previously mentioned conditions resulted in tight constraints on the design of a remote inspection vehicle. H-Canyon Operations originally requested that the vehicle be deployed into the tunnel through the 1-ft^2 opening, be lowered 10 feet, crawl horizontally 40 feet to the retention curb. At this point, the vehicle's camera would have to be extended over the curb to inspect the tie-in point of the OHBL duct, which lies 10 feet below in the crossover tunnel.

The vehicle shown in Figure 3 was designed within these constraints. To fit through the small access port, it was necessary for the vehicle to be lowered nose-first and be righted after clearing the port. The vehicle was lowered by hand, which meant that weight was an important consideration. Weight was kept below 75 pounds.

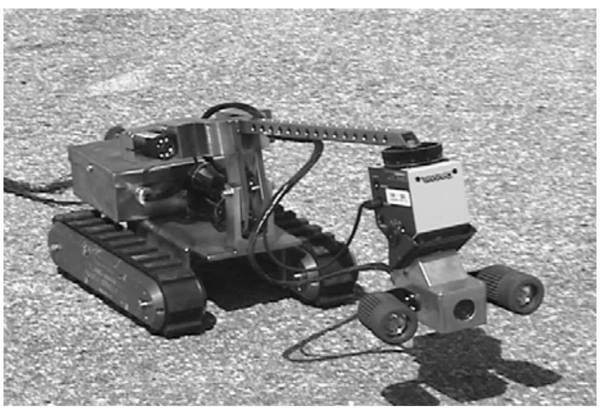

Figure 3. Inspection Vehicle

The vehicle was considered disposable and expected to be abandoned inside the tunnel after the inspection. Unlike development of a reusable vehicle, this design was as simple as possible, and inexpensive components were used. The most expensive component on the vehicle was the drive system, a pair of Inuktun Mini Tracks. These tracks have proven extremely reliable in harsh conditions and unstructured environments. The team chose to use Mini Tracks to ensure the ability to go as far as possible in the tunnel. A platform mounted on the tracks contained a drive camera and a long, adjustable arm with a pan-tilt-zoom camera mounted at the end. The arm was allowed viewing over the curb into the crossover tunnel below. The vehicle was operated from a remote control station located in a safe area approximately 15 feet from the tunnel access port. One operator drove the vehicle, while a second person controlled the cameras and recorded the video.

The vehicle development team decided to extend the design in hopes that the vehicle could crawl over the curb, down the wall, and into the crossover tunnel below to inspect the actual OHBL duct. The ability to get close to the transition tie-in point and see a portion of the OHBL duct would provide evidence of the actual conditions in the crossover tunnel and possibly alleviate the aforementioned concerns. One of the features added for this purpose was a very strong cable to support vertical suspension of the vehicle over the ledge. A second feature was a heavy-duty arm that could possibly help raise the vehicle over the curb.

V. INSPECTION

Each step of the inspection was reviewed in a pre-job briefing to reveal any potential problems and resolve them in advance. The entry port for the vehicle was in a radioactively contaminated area requiring that the vehicle handlers be dressed in protective clothing, including respirators. The handlers lowered the vehicle into the tunnel, righted it using a remote-release pull cord, and placed it on the floor. The handlers remained at the entry port to assist in cable management as the vehicle progressed down the tunnel. A video monitor was supplied so that the handlers could also observe the vehicle's progress.

The vehicle traveled through the tunnel with no difficulty and reached the curb location within fifteen minutes. The video from the vehicle revealed erosion of the walls and ceiling, which subsequently resulted in the buildup of aggregate on the floor. The erosion was caused by years of air, sand, and chemicals flowing through the tunnel. Because of the buildup on the floor, the curb was no longer an obstacle. Figure 4 shows the condition of the walls and the area where the curb was expected to be.

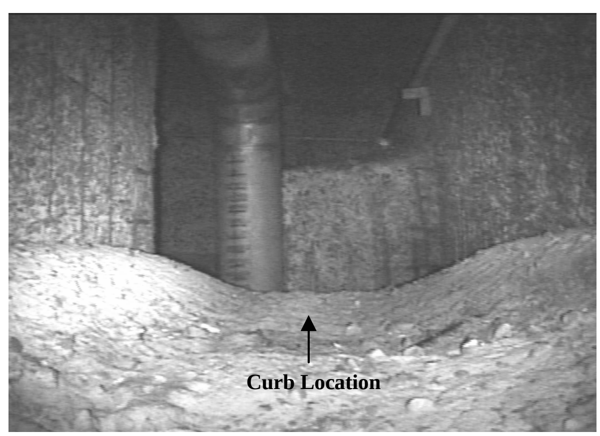

Figure 4: Tunnel Condition Approaching Curb

The area below the ledge was first inspected from above. Then the vehicle was driven over the edge, while the handlers kept a tight hold on the cable to prevent freefall of the vehicle. As it was lowered, the vehicle tracks were driven in an effort to grip the floor and right the vehicle. In less than ten minutes, the vehicle had landed safely on the floor and was able to view the transition tie-in point. Figure 5 shows a portion of the OHBL duct and transition tie-in point. Figure 6 shows two photos of the eroded condition of this transition point.

Figure 5: Portion of OHBL Duct and Transition Tie-in Point

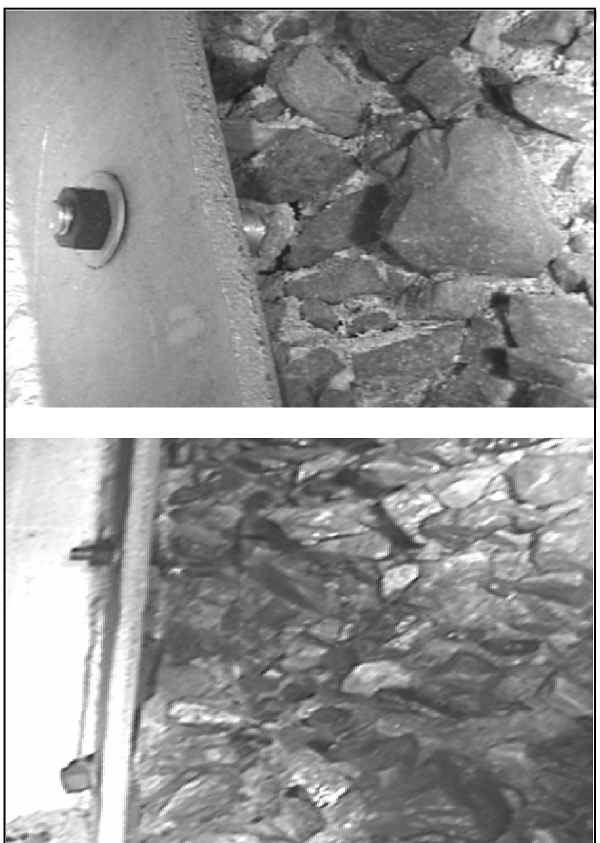

Figure 6: Close Views of Transition Tie-in Point

The vehicle was then driven through the crossover tunnel as far as the cable length allowed. At this point, the team determined that an extension to the cable be made for further travel and additional inspection. The extension was installed, and the vehicle was able to perform an additional 85 feet of tunnel inspection. A portion of the crossover tunnel is shown in Figure 7.

Figure 7: Photo of Crossover Tunnel

VI. RESULTS OF INSPECTION

Successful visual inspection of the OHBL exhaust duct and the transition tie-in point facilitated the structural evaluation of the ducts, support hangers, and tunnel condition. Inspection of the duct transition point also confirmed that the concrete degradation at the duct transition point tie-in is the most likely source of the canyon air in leakage to the OHBL duct. This also addressed concerns from DOE regarding fission product buildup on the OHBL HEPA filters. Additionally, the vehicle was able to inspect the canyon air tunnel sump, the canyon vessel vent header, and additional piping, which had not been previously viewed.

ACKNOWLEDGMENTS

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REFERENCES

1. J. T. Conway, Defense Nuclear Facilities Safety Board, Letter to Jessie Hill Roberson, Assistant Secretary for Environmental Management, Department of Energy, June 26, 2002.