DEACTIVATION OF SPENT NUCLEAR FUEL BASINS USING COMMERCIAL DIVERS

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ABSTRACT

This paper describes the process and tools used to deactivate four aging spent nuclear fuel storage basins at the Idaho National Engineering and Environmental Laboratory (INEEL).

The INEEL baseline plan case for basin deactivation had workers standing at the edge of the basins and on rafts or bridge cranes using long-handled tools to manually scrub basin surfaces. There was significant risk for the workers in this endeavor including skin contaminations, workers falling into the contaminated basin and soft tissue injuries from awkward working positions. Analysis of the safety and radiation dose risks presented by this approach drove the project team to look for safer and more efficient methods to get the work done.

The cost and safety risks associated with the baseline approach were unacceptable to the INEEL. Polestar Applied Technology and the INEEL Integrated Basin Closure staff researched methods used both within the DOE complex and in the commercial nuclear industry to determine how similar basin cleanups were accomplished. Most basin cleanups have been accomplished using traditional methods for scrubbing walls, removing sludge and debris, and applying contamination fixative from the surface. After additional research, the project team concluded that using commercial nuclear trained divers was safer and more efficient than traditional INEEL methods and significantly reduced or eliminated many risks associated with the work.

INTRODUCTION

The Idaho National Engineering & Environmental Laboratory was faced with a major challenge – cleaning and preparing four aging spent nuclear fuel basins for closure by removing sludge and debris, decontaminating surfaces, fixing remaining contamination, and removing water to eliminate a potential risk to the Snake River Plain Aquifer; all in less than 12 months.

The project included cleaning and removing water from the following four basins:

- The Test Area North (TAN) 607 basin, built of epoxy-coated concrete, the largest of the four at 2,953,000 liters. It includes an underwater transfer cart connecting the fuel storage

pool with a vestibule within the TAN hot shop. Until 2001, the TAN basin was used to store fuel and core debris from the Three-Mile Island reactor.
- The stainless steel-lined, 447,000-liter Materials Test Reactor (MTR) canal at the Test Reactor Area (TRA) was used to support reactor operations and store spent nuclear fuel.
- The 95,000-liter, carbon steel-lined Power Burst Facility (PBF) reactor canal was used to support reactor operations and store spent fuel.
- The 43,500-liter unlined concrete CPP-603 basin overflow pit is an isolated portion of the CPP-603 spent fuel basins at the Idaho Nuclear Technology and Engineering Center.

The INEEL baseline plan case had workers standing at the edge of the basins and on rafts or bridge cranes using long-handled tools to manually scrub the basin surfaces. There was significant risk of skin contamination, of workers falling into the basin or sustaining soft tissue injuries from the awkward working position. Analysis of the safety and radiation dose risks presented by this approach drove the project team to look for safer and more efficient methods to accomplish the work.

The safety risks and cost associated with the baseline approach were unacceptable to the INEEL. INEEL Integrated Basin Closure staff and Polestar Applied Technology researched methods used both within the DOE complex and in the commercial nuclear industry to determine how similar basin cleanups were accomplished. Most basin cleanups have been accomplished using traditional methods of scrubbing walls and applying fixative from the surface. After additional research, the project team concluded that using commercial divers was safer and more efficient than traditional INEEL methods and significantly reduced or eliminated many risks associated with the work.

In investigating the use of divers to meet the project objectives, the most noteworthy issue to overcome was the skepticism by many at various facilities – that the divers would receive a lower radioactive dose than workers on the surface.

The dive team is comprised of a Master Diver, a dive tender, a standby diver and a diver in the water; all are qualified divers. In addition there is an engineer assigned whose primary responsibility is to interface with facility operations and to coordinate ongoing activities. The dive team members are experienced nuclear divers with a history of dives in high dose and contaminated areas. As was common in other nuclear dives, before beginning dive activities, all areas to be worked were surveyed by the diver that was to do the work. The potential for finding unexpected debris items during cleanup of the basins was anticipated and direction was given to the divers and the team on actions to be taken. The dive master was in constant voice and video contact with the divers during dive operations and divers were instructed not to pick up anything before obtaining a dose rate. There were no instances in which a diver entered an unsurveyed area or picked up objects that had not been surveyed.

Safety and health is taken very seriously at the INEEL. The Integrated Safety Management System (ISMS) protocol directs that all work be done safely through appropriate prescriptive work planning and execution. This is achieved by implementing formal processes that provide rigor and discipline to work execution. The entire basin deactivation team was intimately involved in work scope definition, hazards analysis, and hazard mitigation throughout the project. All diving operations were performed in a safe, compliant and environmentally responsible manner.

A real-time remote dosimetry system, combined with the thick neoprene dive suits, and the outstanding shielding properties of the water itself resulted in the total dose rate for the divers being very low. The highest dose for a diver during the entire basin cleanup was 453 millirem (mR), far below the individual exposure anticipated in the baseline case for a ‘dry’ worker scrubbing walls as the water level was lowered.

The approach selected improves on standard baseline deactivation methods in several ways:

- Reduces potential for injuries
- Reduces dose to personnel dramatically
- Eliminates potential for airborne contamination
- Reduces cost
- Reduces schedule
- Allows for closer inspection of debris, other materials, and basin surfaces
- Facilitates sharing of lessons learned at other basins.

OVERCOMING SKEPTICISM

In order to obtain the necessary approvals to begin the diver work, it was necessary to educate management and facility personnel on what had been learned during the research into nuclear diving practices. The concept of placing a human in a contaminated liquid environment was initially met with widespread skepticism across the site. Once the benefits of the diver approach were understood and demonstrated, facility management and operations personnel doubt was eliminated and the project received enormous support.

READINESS

Originally, the intent for readiness activities was to perform an overarching Management Self Assessment (MSA) for all four basins and perform a “gap” MSA for the remaining three. In lieu of the gap approach, a MSA was performed individually for each basin. More time and budget should be allocated to allow for management self-assessments before beginning the work and to educate subcontractors on the intricacies of DOE and INEEL safety culture and procedures.

SAFETY

The use of divers eliminated other safety risks as well. The baseline case predicted numerous repetitive-stress soft tissue injuries that would have resulted from awkward working positions. An elaborate scaffolding system was planned in the baseline case as well. Divers eliminated the need for scaffolding and reduced the potential for workers falling into the water.

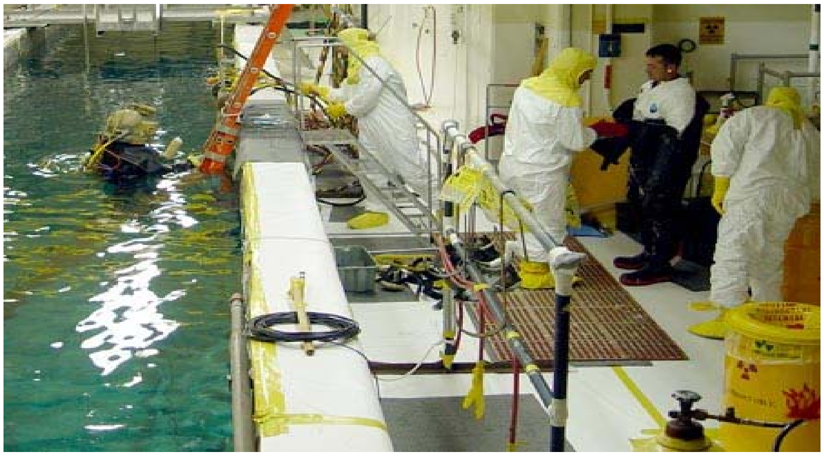

Fig. 1. Tenders assist divers to safely enter and exit each basin.

RADIOLOGICAL CONTROLS

In investigating the use of divers to meet the project objectives, one finding was met with skepticism by many at various facilities – that the divers would receive lower radiation dose than workers on the surface in the baseline case.

The team members are experienced nuclear divers, with a history of diving in high dose and contaminated areas. Before beginning dive activities, all areas to be worked were surveyed by radiation control technicians (RCTs) and the diver. The potential for finding unexpected debris items during cleanup of the basins was anticipated and direction was given to the divers and the team on actions to be taken. The dive master was in constant voice and video contact with the divers during dive operations. Divers were instructed not to pick up anything before obtaining a dose rate. There were no instances in which a diver entered an unsurveyed area or picked up objects that had not been surveyed.

A real-time remote dosimetry system, combined with the thick neoprene dive suits, and the outstanding shielding properties of the water itself, resulted in the total dose rate for the divers being very low. It is conservatively estimated that over nine Rem of exposure was saved by using the diver approach. Table I illustrates the estimated radiation dose savings to workers by using the divers in lieu of personnel performing similar activities using conventional methods.

Table I. Radiation Dose Savings to Workers using Divers over Conventional Deactivation Methods.

	TAN-607	MTR-603	PBF-620	CPP-603	Total Dose (Rem)
Estimated dose for baseline case (person rem)	2.562	1.356	3.480	5.200	12.598
Actual dose received (person rem)	0.824	0.522	0.234	1.739	3.319
Total dose savings (Rem)	1.738	0.834	3.246	3.461	9.279

Each diver was fitted with five dosimeters, one on each limb and one on the torso. The dosimeters transmitted data real-time so the RCTs could monitor the divers while they were in the water. Constant monitoring of the telemetry system prevented unplanned exposures throughout the dives. Whenever any one of the divers' dosimeters reached a predetermined dose rate, the source was immediately identified, surveyed and either removed or worked around. Divers averaged about 6.5 mR per dive and with two dives a day, well below the dose estimated for the baseline case.

Fig. 2. Tenders spray a diver as he emerges from the water for contamination control.

The team completed 411 dives and had only two incidences of skin contamination. The team completed 265 dives before the first skin contamination occurred at 3,000 disintegrations per minute (dpm). The contamination was immediately removed. A second skin contamination occurred at 4,200 dpm. Even though the contamination presented no immediate risk to the diver, the lesson learned was the importance of tenders taking great care during donning and doffing of the dive suits.

An unexpected high dose rate was detected during vacuuming when a very small particle of debris became lodged in the ridges of the sludge vacuum hose. In most instances, the divers were able to dislodge debris trapped in the hose so it could be pulled into the basin filter system. When this proved difficult, the vacuum hose was replaced with a more rigid, smooth hose. Unexpected dose rates also occurred during initial application of the epoxy fixative to the basin floors and walls. At times, as the divers applied the fixative, the divers had to kneel on the basin floor, and elevated dose rates were detected when debris from the floor became stuck in the fixative on the knees or toes of the divers’ suits. Once the suit dried the contamination was easily removed. In subsequent dives, duct tape was placed on the knees and toes of the suits and was removed with the fixative after divers exited the basins. These practices reduced overall dose rates by 90 percent or more.

Other RADCON lessons:

- Underwater AMP-100 radiation detectors performed flawlessly throughout the job. The small probe size makes them ideal for surveying corners, cracks, and other hard-to-reach spaces in the basins and they are compatible with the telemetry monitoring system. Further refinement of the interface with the Winworm telemetry software improved the interface even further.
- Beta dose limits should be set by the radiological engineering group using expected isotopes and an attenuation factor of the dive suits, and the protective clothing that will be worn. This should be done prior to completing the radiation work permit (RWP) for each basin job.
- Make sure enough spare parts are on hand to eliminate delays (e.g., multi-plexers, antennas, and dosimeters).
- A supply coordinator should ensure enough supplies are on hand to avoid the need to scavenge from other departments (e.g., towels, personal protective equipment, absorbents, rad and non-rad bags).
- Wipes of the divers’ suits and airlines were initially between 20,000 and 40,000 dpm. However, contamination levels declined rapidly as the pools were cleaned and the water was filtered. At the end of the job contamination levels remained at 2,000 to 6,000 dpm on dive gear and 2,000 to 8,000 dpm on the floor and stairs of the divers’ work area. These levels are well below the action level of 50,000 dpm specified in the RWP.

OPERATIONS

One-Team Approach

A single team of divers, project engineering and management personnel, and radiation control technicians were used across all four spent fuel basins. The one-team approach helped to ensure smooth operations from start to finish during basin cleanup activities. Much the same way INEEL has realized efficiencies with Decontamination & Decommissioning and Voluntary Consent Order service teams, with similar work at four different facility areas across the INEEL, the one-team approach was the most efficient way to get the work done and ensure that lessons learned at one basin were applied to the others.

In the baseline case, each facility would have been responsible for its own basin with its own teams. The individual facility requirements vary, and an opportunity to realize efficiencies would be lost. It would have been much more difficult to apply lessons learned at each of the other facility basins, resulting in additional cost, time, and exposure for INEEL workers.

Chemical Addition

A chemical was added to the TAN spent fuel basin due to concerns of biological growth in the water. This addition of calcium hypochlorite to maintain the water quality in the TAN basin produced an unanticipated side effect – it turned the water a dark brown color. The color change was due to chlorine in the additive causing metals in the water to precipitate out. Although it didn't hamper the work significantly, the sudden color change was a dramatic difference from the nearly crystal-clear appearance of the basin water after sludge removal was completed.

UNDERWATER FIXATIVE APPLICATION

Applying fixatives for contamination control is being used across the nuclear industry, but it wasn't widely known that some fixatives could be applied underwater. More than 100 types of fixatives were studied to determine which ones would be suitable for the INEEL basins. Thirteen fixatives were eventually tested with the results summarized in a report.

A proprietary two part underwater epoxy was selected for application by the divers. The fixative was applied underwater by divers after extracting basin sludge and removing loose contamination from the basin walls and floors.

It turned out some expectations about fixative application were not met. The epoxy coating is much more difficult to apply under water than house paint in air. It took considerable effort to get a complete coating that passed the dive master's inspection. The divers also had to deal with the bubbled and loose paint layer on some basin walls. The condition of the existing surfaces directly effects the time needed to apply the fixative.

Fig. 3. Divers apply a two part epoxy fixative underwater to eliminate airborne contamination.

The project sought and received a three-year warranty on the fixative coating for each basin. The coating is designed to last 10 years, and the warranty includes periodic inspections, with crews returning to reapply fixative as necessary. This minimizes potential future expenses as the final closure status for the basins is determined.

While applying fixative at TAN, divers found a tiny leak in the basin. The fixative kept disappearing through a three-millimeter crack in the basin wall. Work was temporarily halted while the team patched the leak. The Environmental Protection Agency and state agencies were notified of the leak, and new CERCLA site paperwork is being filed so the site can be properly assessed and dealt with after basin closure. It is highly unlikely that the leak would have been found using the baseline method.

WATER TRANSPORTATION

Water removal, the ultimate goal for the basin closure project, was easier to accomplish at PBF, MTR, and INTEC because they were able to use existing evaporations ponds piped directly to the basins in these locations. However, there were no evaporation ponds available at the TAN facility. After extensive characterization, arrangements were made to transfer the 2.9 million liters of contaminated water from the TAN basin to the TRA evaporation pond, approximately 40 kilometers to the south. Two 23,000 liter tanker trailers were used to transport the water to TRA.

Since the transportation of water required the driver to transverse a state highway, the shipments had to comply with the requirements of a nonradiological shipment. This meant the water had to be less than 2 nCi/ml total activity. This was accomplished by filtering the particulate matter using a 1 micron filter supplied by the divers and an ion exchange system to remove the primary radionuclide culprit; the beta emitter Cs-137.

Water was removed from the basin via a specially designed pumping system that included a submersible pump, multi-bag changeable filter unit, and integrated flow control instrumentation. Operation of the pump was interlocked with level sensing instrumentation in each tanker and was configured to shut off automatically when the trailer reached 90% of capacity. 138 tanker loads were necessary to transfer the TAN water and was completed without any incident of water leakage or spread of contamination. The water transfer took exactly 3 months to complete.

CONCLUSIONS

The approach used by the Integrated Basin Closure subproject is an example of achieving accelerated cleanup goals by working smarter and thinking ‘outside the box.’ It isn’t without its negatives, however. More time and budget should be allocated to allow for management self-assessments before beginning the work and to educate the diver subcontractor on the intricacies of DOE and INEEL safety culture and procedures. Still, the approach improves on standard baseline deactivation methods in several ways:

- Reduces cost

- Reduces schedule
- Reduces dose to personnel dramatically
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A real-time remote dosimetry system, combined with the thick neoprene dive suits, and the outstanding shielding properties of the water itself, resulted in the total dose rate for the divers being very low. It is conservatively estimated that over nine Rem of exposure was saved by using the diver approach in lieu of personnel performing similar activities using conventional methods.

Fig. 4. Test Area North spent fuel basin with fixative applied and water removed.

The overall cost estimate for the baseline case was $1,900,000. This estimate included cleaning of the basin, and removal of debris, sludge and basin water. The diver project saved $300,000 and 4½ months at the TAN basin. The other basins were completed on schedule and within the original budget estimate.