In Situ Decommissioning (ISD) Concepts and Approaches for Excess Nuclear Facilities Decommissioning End State – 13367

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ABSTRACT

The United States Department of Energy (DOE) currently has numerous radiologically contaminated excess nuclear facilities waiting decommissioning throughout the Complex. The traditional decommissioning end state is complete removal. This commonly involves demolishing the facility, often segregating various components and building materials and disposing of the highly contaminated, massive structures containing tons of highly contaminated equipment and piping in a (controlled and approved) landfill, at times hundreds of miles from the facility location. Traditional demolition is costly, and results in significant risks to workers, as well as risks and costs associated with transporting the materials to a disposal site. In situ decommissioning (ISD or entombment) is a viable alternative to demolition, offering comparable and potentially more protective protection of human health and the environment, but at a significantly reduced cost and worker risk.

The Savannah River Site (SRS) has completed the initial ISD deployment for radiologically contaminated facilities. Two reactor (P & R Reactors) facilities were decommissioned in 2011 using the ISD approach through the American Recovery and Reinvestment Act. The SRS ISD approach resolved programmatic, regulatory and technical/engineering issues associated with avoiding the potential hazards and cost associated with generating and disposing of an estimated 124,300 metric tons (153,000 m^3) of contaminated debris per reactor. The DOE Environmental Management Office of Deactivation & Decommissioning and Facility Engineering, through the Savannah River National Laboratory, is currently investigating potential monitoring techniques and strategies to assess ISD effectiveness.

As part of SRS's strategic planning, the site is seeking to leverage in situ decommissioning concepts, approaches and facilities to conduct research, design end states, and assist in regulatory interactions in broad national and international government and private industry decommissioning applications. SRS offers critical services based upon the SRS experience in decommissioning and reactor entombment technology (e.g., grout formulations for varying conditions, structural and material sciences). The SRS ISD approach follows a systems engineering framework to achieve a regulatory acceptable end state based on established protocols, attains the final end state with minimal long stewardship requirements, protects industrial workers, and protects groundwater and the environment. The ISD systems engineering

framework addresses key areas of the remedial process planning, technology development and deployment, and assessment to attain the ultimate goal of natural resource stewardship and protecting the public.

The development and deployment of the SRS ISD approach has established a path for ISD of other large nuclear facilities in the United States and around the globe as an acceptable remedial alternative for decommissioning nuclear facilities.

INTRODUCTION

The DOE has supported the mission of producing special nuclear materials for the nation's weapons stockpile. After the conclusion of the Cold War in 1989, the need for special nuclear materials diminished significantly across the DOE Complex. Over 20,000 facilities were constructed to support nuclear weapons production, testing, and related activities, and DOE has identified over 5,000 of these as excess. Additional facilities may be declared as excess in the future. These excess facilities include production and test reactors, fuel and target fabrication facilities, chemical processing facilities, and gaseous diffusion plants. Some of these facilities are the most massive reinforced concrete structures ever built and are filled with heavily contaminated process equipment. It could take decades for DOE to complete the cleanup of these facilities. [1]

DOE is following a two-phase strategy for facility cleanup: The first is to deactivate the facility to reduce worker risks and maintenance costs. This includes shutting off nonessential safety and security systems, flushing process lines and equipment, and removing dangerous materials. The second is to decommission the facility. This includes decontamination of the facility and equipment (i.e., removal of radioactive and hazardous chemical contamination) and possibly dismantlement. The decommissioning end state is determined separately for each facility. Implementation of this strategy is estimated to consume about $10 billon. [2]

DOE considers ISD to be a decommissioning option for the safe and cost effective disposition of robust nuclear facilities built during the Cold War. The ISD option entails the entombment of especially (but not necessarily limited to) the subsurface portion of these massive nuclear buildings on the DOE enduring sites. This disposition option eliminates the high costs and hazards associated with excavation, demolition, transportation and re-interment of low-level contaminated rubble. It has been estimated that cost reductions of over $2 billion ($2B) are feasible at facilities meeting the criteria for ISD. The DOE decommissioning portfolio includes over 100 large, hardened buildings that could be candidates for ISD. [3]

ISD involves the permanent entombment of a facility and has been adopted by the DOE for a certain class of facilities where this strategy presents a safer and more cost effective closure methodology than complete removal and transport to a disposal facility. Achievement of the "entombed end-state" relies on an established regulatory review and approval process for decommissioning of DOE facilities. The established regulatory framework provides assurance that the risk posed by an ISD facility is within regulatory acceptance criteria. Special emphasis is placed on the fact that an entombed facility is not considered a waste disposal facility; rather it is a decommissioning end-state option.

The SRS was built in the early 1950's with the mission of producing special nuclear materials in a safe, efficient, and environmentally acceptable manner. The special nuclear materials were produced in five production reactors primarily for national defense. After the conclusion of the Cold War in 1989, the need for special nuclear materials diminished significantly across the DOE Complex. Production reactors came off line, defueled, and the facility deactivation process was initiated. These nuclear production facilities became excess and are awaiting final disposition.

The SRS environmental stewardship mission is responsible for waste units, surface and groundwater remediation at deactivation and decommissioning at SRS. The P and R Reactors were the first reactor facilities to implement the ISD approach, funded through the American Recovery and Reinvestment Act.

SRS REACTOR IN SITU DECOMMISSIONING APPROACH

The SRS P and R Reactor Facilities were the first reactor facilities in the DOE Complex to implement the ISD approach, see Figure 1. Deactivation of these facilities were initiated in 2007 and completed in 2010. The primary objective of deactivation was to remove/mitigate hazards associated with the remaining hazardous materials, and thus prepare the buildings for in-situ decommissioning. Deactivation removed the following hazardous materials to the extent practical: combustibles/flammables, residual heavy water, acids, friable asbestos (as needed to protect workers performing deactivitation/decommissioning), miscellaneous chemicals, lead/brass components, Freon®, oils, mercury/polychlorinated biphenyl containing components, mold and some radiologically-contaminated equipment. In addition to the removal of hazardous materials, deactivation included the removal of hazardous energy, some exterior metallic components (representing an immediate fall hazard), and historical artifacts. Deactivation also included the evaporation of water from the two Disassembly Basins located at the two buildings.

Figure 1 – SRS P and R Reactor Facilities before Decommissioning

The ISD approach follows a system engineering process, which fosters the direct interaction-collaboration between project execution and supporting technical organizations. A four step process was applied to assure a comprehensive technical approach; see Figure 2.

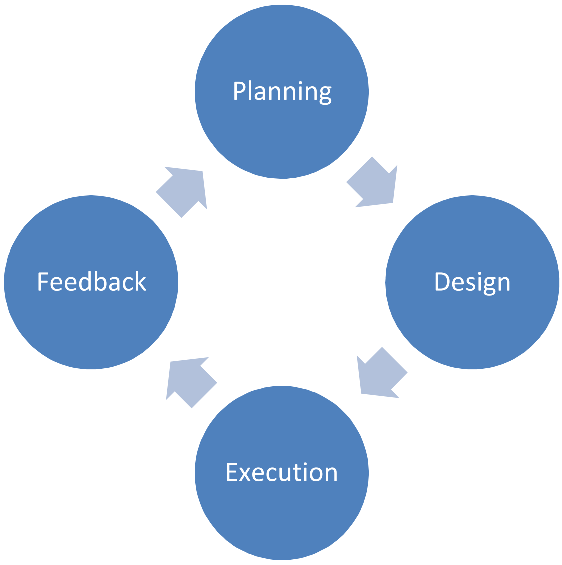

Figure 2 – Reactor ISD Technical Approach

Planning

The ISD approach utilizes the established regulatory framework, providing assurance that the risk posed by an ISD facility is within regulatory acceptance criteria. Special emphasis is placed on the fact that an entombed facility is not considered a waste disposal facility; rather it is a decommissioning end-state option. The regulatory framework for developing P and R Reactor final facility disposition was conducted under the CERCLA process[*]. The entire industrial area is considered an area operable unit. The facility was viewed as the principle contamination threat source contributing to the contamination in this industrial area. A segmented groundwater remedial approach was pursued to contain the principle contamination threat source, to optimize the follow-on groundwater remedial implementation.

Alternatives studies and analysis were completed for each of the two reactor facilities. Results shaped the decommissioning end state definition, which highlighted that the robust, reinforced-concrete structures were appropriate candidates for “in-situ decommissioning” (decommissioning involving minimal demolition of the structure), because the structures would stay relatively intact for up to 500 years provided (1) the gantry cranes for the shield doors were removed, (2) the stacks were demolished, and (3) new concrete roofs were placed over critical areas of the buildings. The typical reactor facility configuration before and after applying the ISD approach is shown in Figure 3.

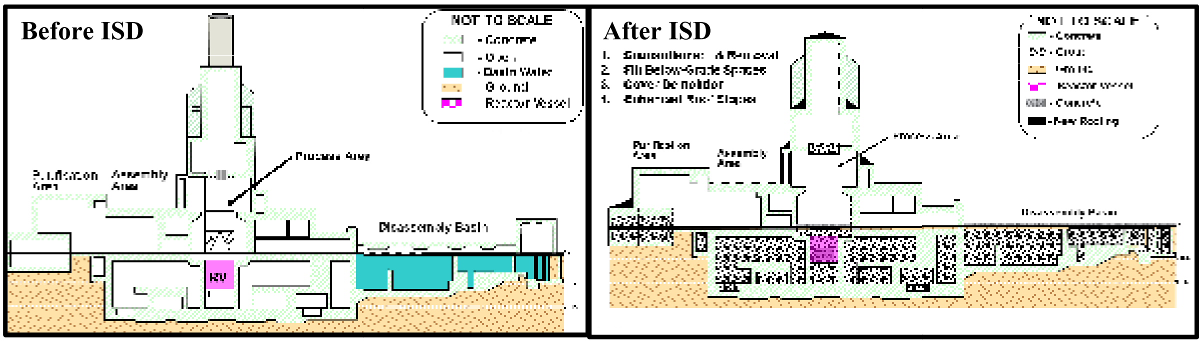

Figure 3 – Typical Reactor Facility Configuration Applying the ISD Approach

P Reactor in situ decommissioning was conducted as an “early remedial action” under CERCLA, while the R Reactor in-situ decommissioning was conducted as a “removal action” under CERCLA. In support of the P Reactor early action, an Early Action Remedial Action Implementation Plan was prepared in late 2009 after issuance of a record of decision for the P Reactor in-situ decommissioning in early 2009. In support of the R Reactor removal action, an Engineering Evaluation/Cost Analysis was prepared. The corresponding action memorandum for the R Reactor removal action was issued in early 2010.

The remedial action intent and end state definition for both P and R Reactors is:

- Minimize human and ecological exposure to unacceptable risk associated with radiological and hazardous constituents that are or may be present;

[*] CERCLA – Comprehensive Environmental Response, Compensation, and Recovery Act, or Superfund, which addresses the protection and cleanup of the environment from known remedial operable units.

- Prevent the migration of radioactive or hazardous contaminants from the building to the groundwater at concentrations that exceed regulatory standards (maximum contaminant levels or preliminary remediation goals) to the extent practical; and
- Prevent animal intruder exposure to radioactive and hazardous contamination.

Design

Overall project technical requirements were developed to address the remedial action intent and end state definition. A key technical challenge was defining applicable fill materials for massive void placement (approximately 100,000 cu. meters per reactor facility) under various conditions. The fill material technical requirements were:

- Compressive strength >0.34 MPa
- Hydraulic conductivity < 1.0E-05 cm/sec
- Flowable, self-consolidating, and self-leveling
- Minimally prone to segregation / settling / phase separation
- Zero bleed water

Laboratory testing was performed to identify candidate formulations and develop final fill material designs. Testing resulted in the development of several hybrid flowable fill grouts. These tailored hybrid flowable fill grouts resulted in considerable savings in labor, materials cost, and placement as opposed to conventional fill materials.

Special fill materials formulated without Portland cement were developed to address high radiation and material compatibility environments in the reactor vessel. Laboratory testing was conducted to identify candidate formulations and develop alternative cement fill material design. Radiolytic analysis and hydrogen gas potential evaluation were also conducted for all fill materials. [4,5]

Execution

Fill material placement strategies were developed to balance fill material bearing capacity, radiological shielding requirements, and residual water management. Laboratory test results were transitioned to engineering requirements for operational execution. [6] Technical consultation was provided to assure compliance with established operational boundary conditions for batching and fill placement of the massive voids within the reactor facilities. The final facility configuration consisted of all below grade areas filled with grout, removal of stack, dismantle and removal of gantry crane, disassembly basin cover structure demolition, and enhanced roof slopes. The P and R closed facilities are shown in Figure 4.

Figure 4 –Closed P and R Reactor Facilities

Feedback

Fill material and entombed system performance is an emerging technical area under development. The entombed system performance incorporates the effects of fill material structural stability and transport characteristics coupled to the durability of the existing reactor facility structure. A sensor network of combined sensor systems is under development through DOE-EM Office of Deactivation & Decommissioning and Facility Engineering to remotely operate and collect on the effects of fill material structural stability and transport characteristics. An initial feasibility demonstration of the sensor network was completed in August 2012. Further testing is planned to refine the sensor network and target a limited field deployment at a future DOE Complex closed nuclear facility. The sensor network was not available to deploy at the closed P and R Reactors.

CONCLUSIONS

SRS successfully implemented the ISD strategy as a safer and more cost effective closure methodology than complete demolition, removal and transport to a disposal facility. Achievement of the "entombed end-state" is a result of an established regulatory review and approval process for decommissioning of DOE facilities. The SRS ISD approach follows a systems engineering framework to achieve a regulatory acceptable end state based on established protocols, attain the final end state with minimal long stewardship requirements, protect industrial workers, and protect groundwater and the environment. The ISD systems engineering framework addresses key areas of the remedial process planning, technology development and deployment, and assessment to attain the ultimate goal of natural resource stewardship and protecting the public. The development and deployment of the SRS ISD approach has established a path for ISD of other large nuclear facilities in the United States and around the globe as an acceptable remedial alternative for decommissioning nuclear facilities.

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