K-25 D&D Challenges - 12170

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ABSTRACT

Decontamination and decommissioning (D&D) of the K-25 former gaseous diffusion plant provides lessons learned applicable to other D&D projects in the DOE Complex. The 175,000-square-meter, 1.6-kilometer-long building is contaminated with highly enriched uranium (HEU), Tc-99, trace quantities of other fission products, asbestos, PCBs, and other hazardous wastes. Safety challenges include deteriorated electrical systems, significant structural degradation, and criticality and exposure risks. The project completely revised the D&D approach after a worker fell through an operating floor and was seriously injured. For protection from deteriorated building conditions, the project reduced the number of workers in the facility, limited their hours in the building, and installed nets and barriers to protect them from falls through weakened floors and from falling material. The new plan involved removing high-risk components, removing motors and compressors, and demolishing the building from the outside with heavy equipment with most of the piping and components inside the building during demolition. The team provided temporary electrical power; reconfigured the criticality alarm system; upgraded security; performed sampling and analysis to locate and characterize HEU deposits and Tc-99; and, to establish “criticality incredible” conditions, conducted a nondestructive assay program and injected foam into equipment and piping as a contamination fixative.

INTRODUCTION

K-25 has been a unique decontamination and demolition (D&D) project with technical execution challenges that provide many valuable lessons learned for other D&D projects in the DOE Complex. The K-25 facility is a former gaseous diffusion building located in Oak Ridge, Tennessee (Fig. 1). The one-of-a-kind uranium enrichment facility was constructed 65 years ago, operated in support of nuclear defense missions, and shut down in 1964 after the highly enriched uranium (HEU) needs were met. Since then, significant structural degradation has occurred that dramatically changed the way the D&D work could be safely accomplished.

With a total area of 175,000 square meters, the building is one of the largest and most complex D&D efforts undertaken to date at a DOE site. The 24-meter-tall, 1.6-kilometer-long building is contaminated with HEU, significant quantities of technetium-99 (with trace quantities of other fission products), and a variety of asbestos, PCBs, and other hazardous wastes. The building’s electrical systems, designed for a peak power capacity of 2,100 MW, also present numerous significant hazards.

Fig. 1. K-25 was built in the shape of a U; major sections are referred to as the east and west wings.

The K-25 Facility contained 3,018 stages of gaseous diffusion process equipment and associated auxiliary systems, broken down into 547 cells and 54 units. Each stage consisted of a converter, two compressors, two compressor motors, and associated piping, with six sets of this equipment per cell and eight cells per building unit. The building contained more than 1,100,000 meters of piping. Following the 1964 shutdown, until 2003 the facility was used for storing a variety of equipment and other items from across the Oak Ridge Reservation. An action memorandum for demolition of the K-25 building signed in February 2002 stipulates that the building must be demolished to slab, and the associated waste must be disposed of.

METHOD

D&D Approach

The first phase of the demolition, hazardous materials removal, started in December 2001 and was completed in June 2005. This phase primarily consisted of the removal of asbestos-containing building material, such as transite panels and insulation, from inside the K-25 building. During this 3.5-year phase, a total of 944 waste shipments were transported to the Environmental Management Waste Management Facility, a CERCLA waste facility located on the DOE Oak Ridge Reservation.

The D&D plan changed entirely in January 2006 when an iron worker fell through the operating floor (upper floor) of the K-25 building and was seriously injured. As this incident demonstrated, the K-25 facility had deteriorated structurally to such an extent that new approaches for access and demolition were essential in order to accomplish the D&D safely. The operating floor was structurally unsafe to work on, and the spalling concrete from the operating floor created hazards on the cell floor below. The potential collapse of a concrete panel through the pipe gallery onto the cell floor presented a formidable hazard to workers, and several corbel beams—integral structural members that supported the cell floor—had deteriorated substantially and were cracking. There was also standing water from rainfall intrusion on every elevation of the building, and water was found in the uranium enrichment process system.

To protect workers from the deteriorated building conditions, the project reduced the number of workers and the hours they worked inside the building. This new plan involved removing high-risk components, unbolting motors and compressors, foaming the process system, and then demolishing the building from the outside using heavy equipment while leaving most of the piping and components inside the building during demolition. To maintain safety, the project team installed nets and barriers and performed major corbel/beam repairs to protect workers from falls through weakened floors and roofs as well as from falling material (Fig. 2). Temporary electrical power was provided, and a new criticality detection system designed and installed to support the necessary D&D work inside the building.

Fig. 2. Worker Protection. The project implemented new D&D approaches and structural reinforcement measures to mitigate the hazards resulting from building deterioration.

Nondestructive assay and segmentation shops were designed and built to support the removal of high-risk components and waste disposition. The project also developed and implemented a robust criticality incredible and characterization program.

RESULTS

The project team had to address many challenges due to the size and deteriorated conditions of the facility. Worker safety and nuclear safety were the two prime considerations in developing this new D&D approach, and both added new challenges for the project team to find unique solutions. Working closely with the regulators, the team found the solutions and implemented programs that allowed the K-25 facility to be demolished safely. Key execution challenges and lessons learned in preparing the building for demolition include the following:

Security

The HEU and related equipment classification required special security handling, including detailed nuclear material control and accountability. Security precautions covered everything from facility access, material handling, and waste handling and packaging to special inspections and accountability of equipment and material.

Potential Nuclear Criticality

An HEU inventory remained in the facility after shutdown. The location of most large deposits of uranium was known and was considered safe from a criticality event in its current location and configuration. However, the location and geometry of the smaller deposits, which amounted to more than half of the total inventory, were not known. The D&D operations therefore had to be analyzed to determine the potential for a criticality event—a task complicated by the deteriorated condition of the facility and the infiltration of water into the enrichment process system. The original criticality detection system was designed and installed for facility operations, not D&D, and it was a 60-year-old system of questionable reliability. The project therefore designed and installed a new criticality detection system customized for the D&D operations, the deteriorated building conditions, and the unknown location and geometry of much of the HEU.

Fire Protection

The K-25 facility was constructed and put into operations without a fire suppression system. A wet system was installed later and was eventually transformed to a dry system. However, this system did not meet today's fire codes, and major portions of the system were not operational at all times. To address this issue, the project developed a fire protection program that accounted for the installed and loose sodium fluoride traps with unknown concentrations of uranium; combustibles throughout the building; emergency egress; the degraded fire suppression system; and the use of foam as a fixative, which was considered a combustible material.

Category 2 Nuclear Facility Safety

Due to the inventory of HEU and the potential for a criticality, the K-25 facility was classified as a Category 2 nuclear facility. Consequently, documented safety analysis and technical safety requirements documents had to be prepared to support the D&D operations. The east wing was downgraded to radiological facility status after criticality incredible was determined and the wing was physically separated from the balance of the facility to permit the start of demolition. The

west wing demolition had to start with the wing as a Category 2 Nuclear Facility until it could be physically separated from the Tc-99-contaminated portion of the wing. Because the foam delivery system was considered a nuclear safety significant system, special operational controls had to be designed into the system and operating procedures.

Waste Characterization and Handling

The enormous size and complexity of the facility posed unique waste characterization and handling challenges. The facility was so large that it was necessary to demolish and ship a portion of it while another portion was being prepared for demolition. Working with the regulators and the waste disposal facility, the project team categorized the facility in over 20 waste profiles and optimized the number of samples for characterization and in order to demonstrate that the waste streams met the on-site waste disposal cell limits. Since portions of the facility did not allow general access during demolition preparations due to the deteriorated conditions, special sorting and handling protocol had to be developed to ensure that selected waste streams were removed from the debris pile for alternative disposal.

Nondestructive Assay

Because of the uncertain location and geometry of much of the residual HEU, the nondestructive assay program had to be certified to cover criticality prevention and to provide adequate nuclear material control and accountability measures.

Foaming of Process Equipment and Piping

The project prepared a foam testing and certification program to:

- certify the foam for criticality control during demolition with small uranium deposits remaining in the process piping and components,
- certify the foam as a void fill for waste burial at the Oak Ridge low-level waste disposal cell, and
- verify that the foam provided adequate contamination control during demolition.

Deteriorated Facility Conditions

The K-25 facility deterioration necessitated a major structural inspection program and a modified D&D approach. This program required the following measures to be taken:

- minimize worker occupancy during building demolition preparation activities;
- install bracing and supports for floor and building integrity to permit work inside the building;
- install nets and barrier to protect the workers from falling objects;
- perform floor loading calculations to support required component removals, maintain emergency egress routes, and allow use of heavy equipment inside the building; and
- remove selected components and hazardous waste during demolition because they were located in areas that were inaccessible during demolition preparation.

Establishing “Criticality Incredible” Before Demolition

Because all the enriched uranium could not be removed during demolition preparation due to the deteriorated condition of the facility, a very extensive “criticality incredible” program was established to prove that a criticality could not occur as a result of demolition activities. The major elements of this program included:

- visual examination of the interior of all process piping and components, where accessible, to inventory all loose uranium in the building;
- verification that components and all process piping with a diameter greater than 3 inches were foamed to ensure that loose uranium could not be relocated during demolition;
- nondestructive assay measurements of all process piping and components to identify locations and inventory of uranium, especially in piping with a diameter less than 3 inches that was not foamed;
- walkdowns and a verification effort to ensure that all large uranium deposits had been removed;
- a sampling program to support enrichment assumptions throughout the building;
- development of a database system to store and manage characterization data;
- establishment of a database that ties together the visual inspection, nondestructive assay results, sampling results, foam activities, and deposit removal efforts by location; and
- preparation of nuclear criticality safety evaluations to substantiate that criticality is incredible during demolition activities.

Tc-99 Contamination

The K-25 building contains some Tc-99 contamination, and a portion of the building contains Tc-99 concentrations exceeding the limits of the Oak Ridge waste disposal facility. While the project strove to maximize the amount of waste disposed of at the Environmental Management Waste Management Facility and minimize the amount requiring shipment to the alternative disposal facility in Nevada (and the associated costs), the characterization program had to prove to the regulators and the disposal facility management that Tc-99-contaminated equipment exceeding disposal limits had been identified and not disposed of at the Environmental Management Waste Management Facility. In addition, a worker protection and contamination control program needed to be developed to protect the workers and ensure that the high concentrations of Tc-99 were not spread to other areas, which would reduce the amount of waste that could be disposed of in the Environmental Management Waste Management Facility.

DISCUSSION

Resolution of these technical challenges, coupled with the unique characterization and D&D program, enabled the project team to conduct extensive modeling and analyses that demonstrated to the regulators that an accidental nuclear criticality was no longer credible. This allowed demolition to proceed without criticality controls. By implementing this demolition approach, the team was able to quickly take the building down safely using large equipment with ultra-high reach demolition manipulators (Fig. 3). Once a

Fig. 3. Revised Demolition Approach. Once the project had demonstrated “criticality incredible” status, large equipment could be used to quickly dismantle the building without the need for additional controls.

segment of the building was down, remote manipulators removed any large equipment or waste that required alternative disposal paths before the debris was loaded for disposal at the Environmental Management Waste Management Facility.

In July 2011, the project team completed demolition and disposal of the K-25 facility west wing and completed preparation of the north wing and 19 units of the east wing for demolition (Fig. 4). Demolition of the east wing commenced in July 2011.

Fig. 4. West Wing Completion. Using the revised approach and control measures, the Bechtel Jacobs project team completed K-25 west wing demolition successfully, efficiently, and safely.