Nuclear Deactivation and Downgrade of Enriched Uranium Facilities at the Y-12 National Security Complex

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ABSTRACT

Buildings 9206 and 9212 at the Y-12 National Security Complex are both Hazard Category 2 nuclear facilities from the Manhattan Project era that supported various missions over the decades, including the processing of enriched uranium. The production mission for Building 9206 ended in the 1990s, while Building 9212 is still an active production facility. The disposition process for contaminated excess facilities is generally described in the U.S. Department of Energy (DOE) Guide DOE O 430.1A, *Life Cycle Asset Management*, which provides guidance on facility surveillance and maintenance, deactivation, decommissioning, and transition in supplemental guides DOE G 430.1-2 through 430.1-5. Historically, production facilities similar to Buildings 9206 and 9212 have not always been cleaned out and deactivated prior to being excessed, which significantly complicates the decommissioning phase. Many legacy facilities were shut down before the formal DOE guidance was established. This paper presents the practical application and implementation of the DOE guidance for the nuclear deactivation of Buildings 9206 and 9212, and summarizes the lessons learned for application across the DOE enterprise.

HISTORICAL BACKGROUND

Building 9206 at the Y-12 National Security Complex (Y-12) was constructed in 1944 for the Manhattan Project as a predecessor to the much larger Building 9212. The purpose of Building 9206 was to perform chemical recycle, metal production, and recovery of highly enriched uranium, as well as to process product from the electromagnetic separation process. From 1944 until 1994, Building 9206 operated to support various production missions for the U.S. Department of Energy and its predecessor agencies. All operations in Building 9206 ceased in 1994 with the stand-down of operations at the Y-12 plant imposed that same year. As a result, a significant inventory of residual uranium-bearing materials and contaminated equipment was left behind in the Hazard Category 2 Nuclear Facility. Restart efforts at Y-12 occurred from the late-1990s through 2010, with priority and resources placed on restarting production capabilities in Building 9212. During this time period, de-inventory and decontamination of Building 9206 were conducted intermittently through various initiatives and funding sources, but in the absence of a clear deactivation and downgrade strategy.

BUILDING 9206

Building 9206, pictured in Figure 1, contains approximately 65,000 gross square feet of floor space. Over the years, Building 9206 housed processes and operations for chemical recycle, charge preparation, highly enriched uranium (HEU) recovery, and enriched uranium (EU) product processing. Most of the uranium that ended up being used in the "Little Boy" atomic bomb was processed in Building 9206. Feed preparation and product processing continued in Building 9206 through 1947, and uranium recovery and reclamation continued through 1951. By 1945 however, most of the building's originally intended processes were being performed in a larger, sister facility—Building 9212. The purpose of Building 9206 began to shift once Building 9212 became operational after the end of World War II (WWII).

Figure 1. Building 9206

After WWII, the Y-12 Plant refocused its mission to reclaiming residual amounts of uranium found on equipment and scrap metal. Building 9206 was the main uranium reclamation facility and housed sanding, grinding, chemistry, and incinerator operations to accomplish the new mission. Throughout its operational lifetime, Building 9206 was involved with processing EU, non-EU, and non-uranium materials, while supporting various governmental programs, missions, organizations, and activities. Accommodating new and diverse missions in Building 9206 required continual modifications to the equipment and processes, as well as building additions.

EU materials operations were continuous in Building 9206 until it ceased all production operations in 1994. The processing areas within the building are high contamination areas due to the varied materials and nature of the operations that were conducted throughout the building's lifetime.

BUILDING 9212

Construction of Building 9212, the sister facility to Building 9206, was completed in 1945 and is pictured below in Figure 2. Once Building 9212 was operational, it became the primary location for EU processing for the electromagnetic separation process. Like Building 9206, Building 9212 was designed as a chemical process building used for feed preparation and product processing. After WWII, Building 9212 was expanded to accommodate the increased production of uranium from the gaseous diffusion plant and to provide the capability to recover and reclaim uranium from waste materials. Over the years, Building 9212 has been expanded with additional wings and support buildings, resulting in the current 9212 Complex. Today, the 9212 Complex occupies more than 450,000 gross square feet. More than 100 different unit operations or processes have been performed in the 9212 Complex over the course of its life. Today, the 9212 Complex performs four primary functions: (1) uranium metal processing, (2) accountability of HEU from Y-12 plant activities, (3) recovery and reclamation of HEU in a form suitable for storage, and (4) serving as the U.S. source of all HEU used in test, research, or propulsion reactors and for isotope production. The 9212 Complex also supports the International Atomic Energy Agency in sampling surplus EU, packaging HEU for offsite shipment, and producing specialized uranium compounds and metal for research reactor fuel.

Figure 2. Building 9212, after construction (left) and the current Complex (right)

Buildings 9206 and 9212 have similar histories, processes, and operations. Both were constructed for the Manhattan Project as chemical processing facilities to process, recover, recycle, and reclaim uranium in support of the electromagnetic separation process. Similar systems, equipment, and chemical processes were included in the building layouts and designs, including the stainless-steel floors.

The amount of nuclear material residing in both facilities drives them to be regulated as Hazard Category 2 Nuclear Facilities. This categorization means that both buildings contain enough special nuclear material for a nuclear criticality to occur, and there is potential for significant on-site and off-site consequences in the event certain facility accident scenarios were to take place. Both facilities must eventually be turned over to the DOE Office of Environmental Management (DOE-EM) for demolition. Before facility turnover to DOE-EM can take place, accountable nuclear materials (both containerized material and removable holdup) must be removed to the extent that the facilities can be downgraded to Hazard Category 3 or radiologically contaminated status. Downgrading Buildings 9206 and 9212 will allow the cancellation of the nuclear criticality safety controls in those facilities, which in turn simplifies the facility turnover to DOE-EM for facility demolition.

EVOLUTION OF DOE ORDERS AND GUIDANCE

At the time that Building 9206 ceased its DOE production mission and was declared to be an excess facility in the early 1990s, the facility disposition requirements, transfer process, and responsibilities for deactivating and transitioning Hazard Category 2 Nuclear facilities were not well-established within the DOE orders and guides, and the regulatory landscape for facility decommissioning was evolving.

In 1994, the Secretary of Energy determined it was inappropriate for DOE to be self-regulating in the performance of decommissioning and that provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) should be applied when appropriate. A working group involving DOE and the Environmental Protection Agency (EPA) was formed to establish the manner of applying CERCLA to decommissioning. The result of this effort was the *Policy on Decommissioning of Department of Energy Facilities Under the Comprehensive Environmental Response, Compensation, and Liability Act,* signed on May 22, 1995, by the Assistant Administrators at EPA's Office of Enforcement and Compliance Assurance and Office of Solid Waste and Emergency Response, and by DOE's Assistant Secretary for Environmental Management. The policy is consistent with, and builds upon, the multi-agency *Guidance an Accelerating CERCLA Environmental Restoration at Federal Facilities*, August 22, 1994.

The 1995 policy established that facility decommissioning activities would be conducted as non-time-critical removal actions under CERCLA, unless the circumstances at the facility make it inappropriate. Use of non-time-critical removal actions was an important first-step in formalizing the facility decommissioning process, by integrating EPA oversight responsibility, solidifying DOE lead agency responsibility, and formalizing State/stakeholder participation in the process.

The DOE Order 430.1A titled "*Life Cycle Asset Management*" was published in 1998, and was superseded by DOE Order 430.1B "*Real Property Asset Management*" in 2003. Both versions of this order discussed the requirement to manage federally-owned facilities through the stages of acquisition, operation, stabilization, deactivation, and eventual decommissioning and demolition.

These early versions of the DOE order also provided a definition for facility deactivation as: "*Placing a facility in a stable and known condition including the removal of hazardous and* *radioactive materials to ensure adequate protection of workers, public health and safety, and the environment, thereby limiting the long-term cost of surveillance and maintenance. Actions include removal of fuel, draining and de-energizing nonessential systems, removal of stored radioactive and hazardous materials, and related actions. Deactivation does not include all decontamination necessary for the dismantlement and demolition phase of decommissioning (e.g., removal of contamination remaining in fixed structures and equipment after deactivation)*."

In 2016, the order was again superseded by DOE Order 430.1C, with the purpose of: "*establishing a data-driven, risk-informed, performance-based approach to the life-cycle management of real property assets to align the real property portfolio with DOE mission needs; acquire, manage, positively account for, and dispose of real property assets in a safe, secure, cost-effective, and sustainable manner*." This current version of the DOE order slightly revised the definition for facility stabilization/deactivation to be: "*an interim process where the facility is placed in a stable, known condition including removal of hazardous and radioactive material to ensure adequate protection of workers, public and environment, thereby limiting the long term surveillance, stabilization, and maintenance costs, while awaiting ultimate decommissioning*."

The order promulgated additional guidance documents pertaining to the management of DOE-owned facilities through the disposition process:

- DOE G 430.1-2, *Implementation Guide for Surveillance and Maintenance during Facility Transition and Disposition (1999)*
- DOE G 430.1-3, *Deactivation Implementation Guide (1999)*
- DOE G 430.1-4, *Decommissioning Implementation Guide (1999)*
- DOE G 430.1-5, *Transition Implementation Guide (2001)*

FEDERAL ROLES AND RESPONSIBILITIES

In 2000, the U.S. Congress established the NNSA as a semi-autonomous agency within the Department of Energy (DOE) responsible for enhancing national security through the military application of nuclear science. With this organizational change, NNSA assumed responsibility for the nuclear security enterprise and associated infrastructure, including Manhattan Project era facilities like Buildings 9206 and 9212. The DOE Guide 430.1-5 issued in 2001 clarified that DOE-owned facilities referenced in the guidance included the newly formed NNSA.

Although the requirements and expectations for life-cycle management of facilities began to be formalized during this time period, a clear delineation of responsibility between NNSA and DOE-Environmental Management (DOE-EM) for transitioning facilities from the production phase to ultimate D&D had yet to be established. In December 2007, the Assistant Secretary for Environmental Management invited the DOE Program Secretarial Offices of Nuclear Energy (NE), Science (SC), and the NNSA to propose facilities and legacy waste for transfer to DOE-EM. In parallel, the Oak Ridge Reservation (ORR) was preparing plans for the Integrated Facility Disposition Project (IFDP) to incorporate environmental clean-up scope owned by NNSA, SC, and NE. The objectives of the DOE-EM transfer invitation at ORR and the IFDP were to identify and commence the process of dealing with the large inventory of excess facilities that had yet to be included as DOE-EM scope. In 2008, DOE-EM conducted numerous walk-downs of the ORR and issued *Assessments of the IFDP at ORNL and Y-12 for Transfer of Facilities and Materials to DOE-EM*. This report summarized the assessments of facilities and materials proposed for eventual transfer to DOE-EM encompassed by the scope of the IFDP, using criteria outlined in DOE Order 430.1B.

The 2008 IFDP walk-downs of the ORR had three main objectives, which were to identify:

1. Conditions to be established by the NNSA for transfer based on criteria in DOE Order 430.1B for facilities and DOE-EM policy for specific materials
2. Facilities that do and do not meet criteria in DOE Order 430.1B for transfer to DOE-EM
3. Facility conditions and materials with a greater-than-normal degree of project risk and liability for deactivation and decommissioning by DOE-EM.

CONDITIONS FOR FACILITY TRANSFER

The general conditions for facility transfer from NNSA to DOE-EM, as documented in the IFDP assessment are:

- Removal of accountable materials, including uranium scrap and uranium compounds, so that the facility hazard category can be downgraded to Hazard Category 3 or Radiological (i.e., Nuclear Deactivation and Downgrade).
- Cleanout of liquid systems, including the removal of bulk process liquids.
- Removal of excess materials, chemicals, tools and equipment, office furniture, personal protective equipment, and loose items.
- Rerouting or decoupling utilities that interface with other facilities. DOE-EM assumes responsibility for isolating the facility from site utilities prior to demolition.
- Characterization of physical, chemical, and radiological conditions prior to transfer.

Once these general conditions are achieved, additional end-point criteria to formalize transfer from NNSA to DOE-EM are developed on a facility-specific basis. Once the facility is transferred, DOE-EM assumes responsibility for:

- Any remaining deactivation activities, such as abatement and removal of asbestos, lead paint, or other hazardous materials
- Final characterization for disposition of waste
- Isolation of building utilities from the site
- Demolition
- Disposal of waste and building debris

The phases of the facility transition process for a Hazard Category 2 nuclear facility from an active production facility, to stabilization, and finally to decommissioning and demolition, along with the roles and responsibilities for NNSA and DOE-EM, are depicted in Figure 3.

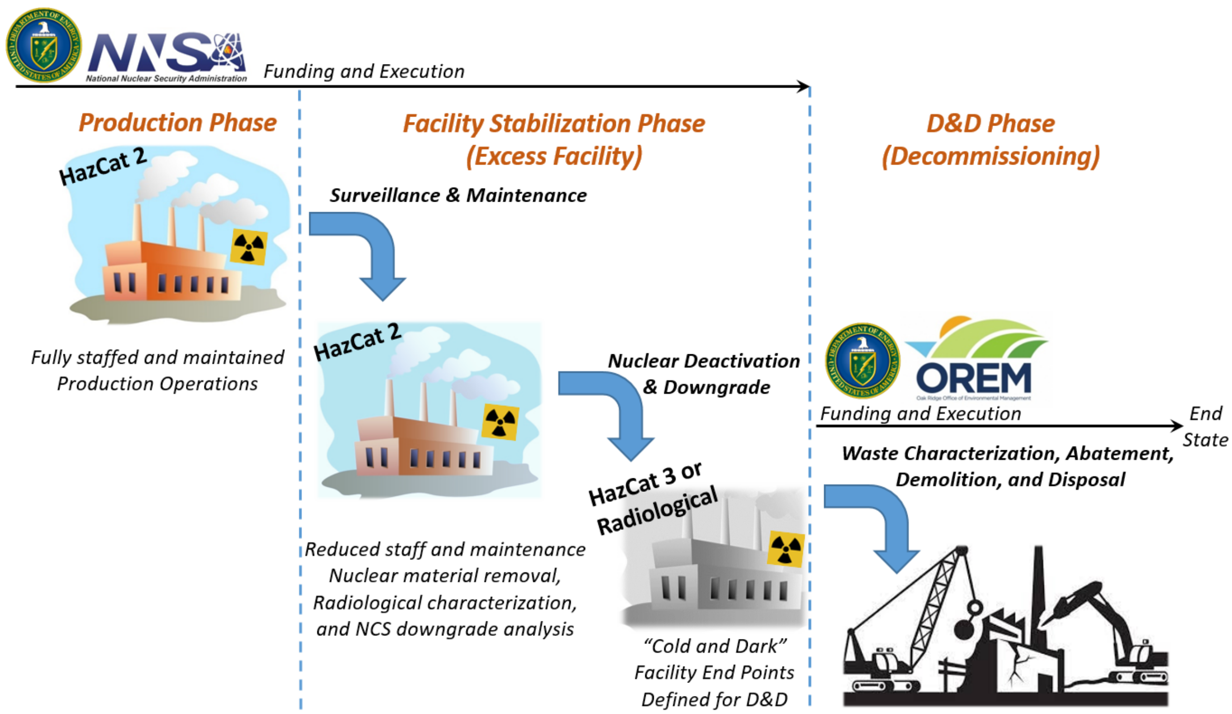

Figure 3. Facility Transition Process

NUCLEAR DEACTIVATION AND DOWNGRADE STRATEGY

As previously discussed, a key criterion for facility transfer from NNSA to DOE-EM is downgrading facilities such as Buildings 9206 and 9212 from Hazard Category 2 to Hazard Category 3 or Radiological status, however the available guidance documents do not provide a specific methodology or strategy for deactivating and downgrading Hazard Category 2 nuclear facilities. Realizing the on-going challenges and costs associated with the long-term surveillance, maintenance, and intermittent deactivation activities in Building 9206, and given the similarities between Buildings 9206 and 9212, the need to develop an exit strategy for Building 9212 became apparent as the priority and path-forward for the future Uranium Processing Facility (UPF) at Y-12 were solidified. In 2014, NNSA re-prioritized plans for the UPF project to focus on ceasing production operations in Building 9212, due to long-term safety and mission risk associated with the aging facility. With this new focus, the exit strategy for Building 9212 would emphasize facility shut-down and deactivation in a proactive manner, with an objective of incorporating lessons learned from the shut-down of Building 9206 that had occurred decades earlier, but in the absence of a clearly-defined nuclear deactivation and downgrade strategy.

Since Buildings 9206 and 9212 share very similar processes and configurations, a similar nuclear deactivation and downgrade strategy would be required to address the significant uranium holdup contained within the facilities, and allow nuclear criticality safety (NCS) controls to be canceled prior to DOE-EM transfer. In 2016, with the development of the Building 9212 Exit Strategy, renewed interest for completing the deactivation of Building 9206 led to the development of a *Nuclear Criticality Safety Strategy for the Downgrade of the 9206 Facility*.

Development of the downgrade strategy required collaboration between multiple organizations, including NCS, engineering, operations, facilities, and infrastructure maintenance, to establish a clear set of criteria that could be used for planning and execution nuclear deactivation work in Building 9206. Implementation of this new strategy in Building 9206 began in 2017, and the same methodology was adapted for system deactivation work in Building 9212 shortly thereafter. The 9212 Exit Strategy was adopted by the NNSA in 2018 and became a funded program in 2019, with the key objectives of completing the nuclear deactivation and facility downgrade of Building 9206 by 2025, while also initiating the transition of enriched uranium production operations and nuclear deactivation of Building 9212.

The steps of the Nuclear Criticality Deactivation and Downgrade Strategy are:

1. Identify and rank systems of nuclear criticality safety (NCS) concern, based on amount of uranium holdup or contamination within each system.
2. Define system endpoint criteria, including isolation of each system and acceptable levels of residual contamination.
3. Obtain non-destructive assay (NDA) data to fill data gaps and plan deactivation work packages.
4. Clean-out/deactivate systems as necessary to achieve desired endpoint and ensure nuclear material cannot migrate between systems by equipment isolation and/or application of fixative. Highly-contaminated components are removed to meet NCS criteria, but systems are left largely intact for eventual demolition by DOE-EM.
5. Perform post-deactivation inspection and analysis of equipment to confirm NCS criteria are met, including NDA and visual inspection with a Borescope as possible.
6. Document basis for the incredibility of an inadvertent nuclear criticality in the 9206 facility once all systems have been deactivated and data collected.

The key objective for nuclear deactivation is ensuring that each isolated/air-gapped system or equipment item remaining in the facility is far below 700 grams of residual uranium-235, with measurement uncertainty applied. This strategy, implemented on a systematic basis, mitigates the nuclear criticality safety risk in the Hazard Category 2 facilities by driving the potential for a nuclear criticality accident to be incredible, thus negating the need to maintain NCS controls and a credited nuclear criticality accident alarm system (CAAS) in the facilities, both of which would significantly complicate future D&D activities.

Although the process systems, transfer criteria, and downgrade strategy are common for Buildings 9206 and 9212, the planning and execution of system deactivation presents unique challenges in each facility. The deteriorating infrastructure, high levels of airborne contamination, potential for worker heat stress, and lack of system configuration documents in Building 9206 significantly complicate the planning and execution of deactivation work in the excess facility. In Building 9212, a majority of the facility is still engaged in active production operations that are tightly-controlled by configuration management procedures, which requires the deactivation work packages to undergo a high level of scrutiny and approval by various stakeholder organizations such as NCS, Facility Safety, Engineering, Radiological Control (RadCon), and Operations. In addition, executing a single system deactivation work package in

Building 9212 usually requires multiple utility systems or an entire wing to be taken temporarily out-of-service, so production outages must be coordinated in advance as part of the deactivation planning process. The dedicated teams in Buildings 9206 and 9212 comprised of representatives from Engineering, NCS, Facility Safety, Infrastructure Maintenance, RadCon, and Operations have adapted to these unique challenges, ensuring lessons learned are incorporated in each successive deactivation work package, and advancing the nuclear deactivation of each facility. At the end of 2021, the deactivation of Building 9206 is forecasted to be approximately 70 percent complete, with a goal to complete facility downgrade by 2025, while the deactivation of the operational, and much larger Building 9212, is forecasted to be approximately 10 percent complete, with a goal to complete facility downgrade by 2034.

CONCLUSION

Buildings 9206 and 9212 are Manhattan Project-era facilities that supported numerous enriched uranium missions over the years, and both are Hazard Category 2 nuclear facilities currently undergoing nuclear deactivation to support eventual decommissioning and demolition. As the missions for Buildings 9206 and 9212 have evolved since their original construction, the requirements, expectations, and responsibilities for the life cycle management of nuclear facilities have also evolved. This evolution in life cycle management has brought into focus the need for addressing nuclear deactivation and downgrade strategies prior to transferring nuclear facilities from NNSA to DOE-EM. Development and implementation of the nuclear deactivation and downgrade strategy for Buildings 9206 and 9212 was a significant step in advancing the facility disposition process. The deactivation and decommissioning of Buildings 9206 and 9212 will reduce risk to the environment, the public, and workers, and will significantly shrink the DOE legacy facility footprint at Y-12, while supporting modernization efforts for future NNSA missions. It is hoped that the historical and strategic information that has been presented will serve to promote facility deactivation, downgrade, and decommissioning as an integral part of future modernization efforts across the DOE enterprise.