Nuclear Criticality Safety Strategy for the Downgrade of the 9206 Facility

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INTRODUCTION

The 9206 facility at the Y-12 National Security Complex in Oak Ridge Tennessee was an operating facility from the mid-1940s through the early 1990s and underwent several changes in mission. Since the 1990s the facility has been engaged in targeted, but limited activities to deactivate the facility with the eventual goal of downgrading the facility from a Hazard Category II Nuclear facility as defined in DOE-STD-1027-92 [Ref. 1]. To categorize a facility as less than Hazard Category II, criticality cannot be credible. The intent is to then hand over the facility to Department of Energy Office of Environmental Management (DOE EM) for eventual demolition. In support of this effort, the Y-12 Nuclear Criticality Safety (NCS) group has developed a strategy for cleanout of the facility systems that would allow for an incredibility argument to be made. This strategy was designed to allow the facility to be downgraded while considering the capabilities of the facility and resources required. This strategy does not include details of the future disposal of material which remains in the facility after downgrade; however, the intent of the options outlined herein is to leave the facility in such a state that harvesting of material is not required for disposal.

Facility History

The original mission of the 9206 facility was to recover enriched uranium from the electromagnetic separation process. After World War II, the 9206 facility received intermediate enrichments of uranium from gaseous diffusion plants as UF_6 which was converted into uranium metal. Supporting these conversion processes, recovery processes were installed to recover and purify uranium contained in the waste processes.

In the late 1960s, the 9206 facility underwent modifications to install denitration and fluid bed systems for the conversion of uranyl nitrate to UF_4. The mission of converting recovered uranyl nitrate from Savannah River Site material back into metal was given to the 9206 facility in 1973. The machine-turning cleaning process was installed in the mid-1980s for recycling uranium turnings. In 1988, shipments of uranyl nitrate from Savannah River Site were stopped. In September 1994, the operations in the 9206 facility were stood down as part of Y-12 response to non-compliances with existing requirements. Significant quantities of holdup remain in the facility processes.

Since 1994 the facility has been engaged in targeted, but limited activities to deactivate the facility such as processing and removing fissile material from the building. Residual holdup remains in the existing systems to varying levels, due to normal release mechanisms, nature of the operations, and upset conditions. In order to transfer the facility to DOE EM, the facility must transition from its current state to a deactivated surveillance and maintenance phase. In this phase, the risks associated with the facility must be lowered to a point where a nuclear criticality is declared incredible and a documented safety analysis is not required to be maintained.

STRATEGY

A technically rational approach to downgrade includes, in order of priority of action: draining of fissile materials from systems, mechanical/physical removal of holdup or components, isolation of system/components to prevent ingress of water and/or fixative to isolate and prevent movement of residual holdup, and a final non-destructive assay (NDA) evaluation in support of downgrade and turnover.

It is noted that for some non-fissile systems/components, holdup is likely at contamination levels and a final NDA evaluation may be the only needed action. Based on these actions, coupled with appropriate management of the facility to prevent wholesale degradation (e.g., structural collapse, water in-leakage), a technical basis for downgrade may be argued. Surveillances to monitor for degradation are entirely in order as part of the methods to manage the facility.

Based on data available at this time, many systems/components are well below a safe mass (700-g ^{235}U per ANSI/ANS-8.1-2014) when considered as a unique entity (no interaction, etc.). While it is prudent to attempt to remove as much holdup as possible, there are diminishing returns for nuclear safety as the above removal approaches are applied (i.e., the risk of criticality diminishes while work exposure continues). A combination of removal, isolation, and/or fixative may be applied to satisfy the downgrade argument.

A more detailed presentation of the NCS strategy for downgrade of the facility is listed in the following steps.

1) Identify systems of NCS concern.

Identify systems of concern based on fissile material present. Systems of concern are identified by review of

existing process information and non-destructive assay measurements. Some systems require more data in order to determine if they are a concern. The criteria for requiring action for any particular system includes systems which at one time processed fissile material, systems with known ^{235}U holdup, and systems without holdup data that were not designed to contain fissile material but may have been exposed to fissile material through potential previous use or upset conditions. It is acknowledged that given the extensive operating history of 9206, holdup may exist in unexpected places. During the deactivation of this facility, personnel should remain vigilant for potential unknown material. Areas of concern should be investigated.

2) Define system end point criteria.

Definition of end point criteria will allow determination of actions likely required to achieve deactivation. The criteria are detailed in the following section.

3) Obtain data in order to plan work

NDA data already exists for many systems in 9206, however much of this data is more than 10 years old. Existing NDA data permits planned removal of existing deposits. However, high quality data is needed for fissile systems for the development of an incredibility argument supporting the required end point for downgrade. This could include NDA, destructive testing, documented visual inspection, etc.

4) Remediate systems as necessary to achieve the desired end point.

Using the data available, remediate systems in order to meet the end point criteria developed in action 2. As part of this remediation effort it is expected that all fissile solutions are drained and all collected fissile material is removed from the facility. In general, efforts should be made to achieve the criteria. Equipment which is removed from the facility as part of the deactivation process does not have to meet the end point requirements.

5) Obtain post remediation NDA as needed.

This action is designed to confirm that systems meet the end point criteria and allow the facility to enter the surveillance and maintenance (S&M) phase with a record of the mass and distribution of holdup remaining.

6) Document basis for the incredibility of an inadvertent nuclear criticality in the facility.

Based on the completion of the strategy steps above, document the basis for incredibility of a criticality in 9206 based on the state of the facility and the management of the facility during the S&M phase to prevent wholesale degradation of the facility (e.g., structural collapse, water in-leakage).

While this strategy does not extend past the downgrade, consideration should be taken for steps beyond downgrade when detailed planning is completed for remediating systems. Systems should be remediated with the potential final disposition (i.e. burial limits) in mind and in such a way that harvesting of fissile material will not be required after downgrade as this could lead to a re-categorization of the facility.

SYSTEM END POINT CRITERIA

Three different sets of system end points were examined in order to determine system end point criteria for downgrade. An overview of each option is discussed below.

System Cleanout Options

Option 1 is to clean out each system such that nature could do no worse. This option calls for the removal of all visible deposits of fissile material and the flushing or wiping of fissile systems with a final NDA to document remaining material. This option is designed to remove all material from the systems that could be mobilized through water ingress and potentially coalesce as 9206 sits in the S&M phase. This option would leave the facility in a state in which it could be argued that criticality would be incredible for all potential upsets which could be imposed on the facility by nature and presents the lowest risk of criticality of any option examined.

Option 2 is to clean out each system and immobilize remaining fissile material. This option calls for the cleaning and isolation of each fissile system such that no more than 700-g ^{235}U (including uncertainty) is located in any single piece of equipment or any collections of connected equipment. A fixative would then be used to immobilize any remaining fissile material in place. The 700-g ^{235}U limit was chosen because it is the ANSI/ANS-8.1- 2014 single parameter subcritical mass limit for uranium systems in mixtures that might not be uniform. This option presents minimal risk of criticality due to the reduced mass in each system and the immobilization of material. Risk mitigation strategies may be required in order to minimize the risk of criticality during upset conditions that could challenge the stability of the fissile material such as a large facility fire. An advantage of this method is that there is precedent for a method similar to this with the downgrade of K-25.

Option 3 is to clean out each system and isolate the remaining material in a robust manner. This option calls for the cleaning and isolation of each fissile system such that no more than 700-g ^{235}U (including uncertainty) is located in any single piece of equipment or any collection of

connected equipment. Once again, the 700-g ^{235}U limit was chosen because it is the ANSI/ANS-8.1-2014 single parameter subcritical mass limit for uranium systems in mixtures that might not be uniform. Robust means of isolation would be used such as welded caps, bolted flanges, etc. to maintain isolation of the fissile material during all but the most extreme upset conditions (facility fire, earthquake). While the overall risk of a criticality is low after cleanout, this option presents the highest risk of criticality of the three options due to the presence of material that could mobilize during upset conditions due to compromised tanks, crushed gloveboxes, etc. Risk mitigation strategies may be required in order to minimize the risk of criticality during upset conditions that could lead to the mobilization of fissile material.

Recommendations for System End Points for Downgrade

After consideration of the options listed, it is recommended that the facility clean systems out as described in option 2 and/or option 3 in order to achieve the goal of downgrading the 9206 facility from a Hazard Category II Nuclear Facility. These options reduce the risk of criticality such that downgrade may be possible without the potential cost associated with option 1. Option 1 is certainly acceptable as the most conservative option and may be used in certain situations, however the cost involved may be prohibitive to be used throughout the facility.

Options 2 and 3 call for the removal of material such that no individual piece of equipment or collection of connected pieces of equipment contains more than 700-g ^{235}U (including uncertainty) as verified by NDA. For option 2, each piece of equipment would be isolated and the remaining material would then be fixed in place using a fixative such as foam or a sealant to prevent the mobilization and coalescence of fissile material. The fixative or sealant should be evaluated for its acceptability from at least a NCS, Fire Protection, and waste acceptance perspective. For option 3, no fixative would be used, however the equipment or collections of connected equipment would have to be isolated using robust means such as welded plates/bolted flanges. It should be noted that much of the current NDA data for systems in 9206 is greater than ten years old and it is recommended that new NDA data be gathered where it may impact the details of cleanout planning for a system. Equipment which was not intended to contain fissile material (nitric acid tanks, etc.) would require no further remediation for downgrade if NDA indicates there is no appreciable amount of fissile material present (<15-g ^{235}U) in an individual piece of equipment and the system is isolated such that fissile material could not enter in the future. 15-g ^{235}U as determined by NDA is currently identified as the arbitrary cut-off for determining the presence of appreciable quantities of fissile material in systems not designed to contain fissile material.

The floors in 9206 present a unique challenge due to the large mass of fissile material which is presumed to be held up under some floors and the potential difficulty in removing that material. Some floors do not have any existing NDA data. It is recommended that the floors be characterized using modern NDA techniques and destructive testing. A deactivation plan may then be developed based on the new data. The recommended system end points described above are presented in Table I.

TABLE I. Overview of Recommended System End Points

System	End point
Systems which processed fissile material	1) Less than 700-g including uncertainty of immobilized ^{235}U per piece of equipment or collections of connected equipment. OR 2) Less than 700-g including uncertainty of ^{235}U per piece of equipment or collections of connected equipment which is isolated in a robust manner.
Systems not designed to contain fissile material but may due to previous use or upsets.	Less than 15-g ^{235}U per piece of equipment. If more than 15-g ^{235}U per piece of equipment is present, then the end point is the same as systems which processed fissile material.
Floors	To be determined after further characterization and deactivation planning.

The reduction of material in each piece of equipment or collections of equipment to below 700-g ^{235}U (including uncertainty) and the immobilization or robust isolation of the remaining material would drastically reduce the risk of criticality in 9206. However, there are credible scenarios during the S&M phase which would lead to uncertainties in the final distribution of material such as building degradation, facility fire, seismic events, or high wind events. It is not expected that a criticality would be likely from these conditions; however, a program designed to mitigate these hazards may need to be credited in order to downgrade the facility. Mitigation strategies may include surveillance and maintenance of the roof and facility structures and a limited fire loading. The ongoing surveillance and maintenance of the facility required by a program designed to mitigate risk associated with building

degradation is expected to prevent extreme equipment degradation that could defeat the measures taken to isolate and fix fissile material.

RECOMMENDATIONS

The following recommendations are made in order to gather information in support of the deactivation and downgrade of 9206:

1) Potential fixatives used to immobilize fissile material should be investigated for applicability in deactivation of 9206 from at least a NCS, Fire Protection, and waste acceptance perspective.

The fixative used may affect different disciplines in different ways such as potentially adding moderation to fissile material for NCS or adding to the facility fire loading for Fire Protection. The long term implications of using foam should also be investigated in relation to the eventual disposition of equipment with fissile holdup from 9206.

2) New NDA surveys should be conducted on equipment or systems where new data may impact the details of cleanout planning.

Much of the existing NDA data available for 9206 systems is older than 10 years. NDA techniques have been refined since then and migration of fissile material may have occurred. Gathering new NDA data is recommended where new data may impact the details of cleanout planning for a particular piece of equipment or system. New data may change specific areas which may need to be addressed due to migration since the last NDA data was taken or may change the decision to conduct cleanout activities or not.

3) Characterization should be conducted of the 9206 floors using both modern NDA techniques and core samples. A plan may be developed for deactivation of the floors once this data is obtained.

The gathering of modern NDA data is recommended in order to have a more accurate picture of the state of the holdup in the 9206 floors. Core samples could then be used to validate the NDA data. The data gathered could be used to develop a plan for deactivation of the floors.

RESULTS

A strategy was developed to pursue the downgrade of the 9206 facility with options for system end points to allow for differing levels of risk and cost. Estimates based on the strategy detailed in this summary indicated large cost savings over the original strategy which involved the complete removal of or extensive cleaning of all 9206 systems before downgrading the facility. Many operating and legacy facilities exist which process or have processed enriched uranium and will at some point need to be decommissioned. The strategy detailed in this summary for the downgrade of the 9206 facility at the Y-12 National Security Center may be adapted and applied to other facilities that have processed enriched uranium.

REFERENCES

1. DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*