Nuclear Operations Application to Environmental Restoration at Corrective Action Unit 547, Miscellaneous Contaminated Waste Sites, at the Nevada National Security Site – 11154

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ABSTRACT

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office has responsibility for environmental restoration at the Nevada National Security Site (formerly the Nevada Test Site). This includes remediation at locations where past testing activities have resulted in the release of plutonium to the environment.

One of the current remediation efforts involves a site where an underground subcritical nuclear safety test was conducted in 1964. The underground test was vented through a steel pipe to the surface in a closed system where gas samples were obtained. The piping downstream of the gas-sampling apparatus was routed belowground to a location where it was allowed to vent into an existing radioactively contaminated borehole. The length of the pipe above the ground surface is approximately 200 meters. This pipe remained in place until remediation efforts began in 2007, at which time internal plutonium contamination was discovered. Following this discovery, an assessment was conducted to determine the quantity of plutonium present in the pipe. This site has been identified as Corrective Action Unit (CAU) 547, Miscellaneous Contaminated Waste Sites.

The quantity of plutonium identified at CAU 547 exceeded the Hazard Category 3 threshold but was below the Hazard Category 2 threshold specified in DOE Standard DOE-STD-1027-92. This CAU, therefore, was initially categorized as a Hazard Category 3 environmental restoration site.

A contaminated facility or site that is initially categorized as Hazard Category 3, however, may be downgraded to below Hazard Category 3 if it can be demonstrated through further analysis that the form of the material and the energy available for release support reducing the hazard category. This is an important consideration when performing hazard categorization of environmental restoration sites because energy sources available for release of material are generally fewer at an environmental restoration site than at an operating facility and environmental restoration activities may result in the complete removal of source material.

INTRODUCTION

The Nevada National Security Site (NNSS) (formerly the Nevada Test Site) is the nation's continental nuclear weapons testing site. In operation since 1952, more than 900 nuclear weapons detonation tests were conducted on the NNSS until detonations were suspended in 1992. To assess and remediate the effects of 40 years of nuclear weapons experiments at the NNSS, a program for environmental restoration was developed. This environmental restoration is conducted by the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office (NNSA/NSO). Oversight of this work is provided by the Nevada Division of Environmental Protection (NDEP) as the state agency with regulatory authority over the remediation effort. Together, NNSA/NSO and NDEP have developed a *Federal Facilities Agreement and Consent Order* (FFACO) to set requirements, expectations, and schedule for remediation activities [1].

The FFACO process defines corrective action site (CAS) as a release site where corrective action is required and provides for the grouping of CASs into corrective action units (CAUs). This process provides structure to the remediation process on the NNSS so that investigation parameters, schedules, and a defined scope of work can be established for each CAS.

In April 2007 during ongoing remediation operations to plug abandoned boreholes on the NNSS, an approximately 200-meter (m)-long piping system containing a previously unidentified quantity of plutonium was discovered. The piping system was connected to a borehole where a nuclear detonation was conducted. Preliminary investigation revealed that the piping system was for a nuclear weapons safety test conducted in 1964 and with the name Player. This system was abandoned after the test and remained untouched until the discovery of residual plutonium contamination in 2007. With this discovery, attempts to plug the borehole were abandoned, and the site became a candidate for inclusion in the FFACO process. A CAU number (547) was established for the piping system to provide for investigation and development of a plan for remediation.

The FFACO process calls for specific steps and documentation during CAU remediation. One of the FFACO methods for documenting remediation involves the development of a Streamlined Approach for Environmental Restoration (SAFER) document. The SAFER is used to document the history, suspected release, method of investigation, and proposed remediation for the CAU. As the process for development of the SAFER began for CAU 547, the investigation phase required that the plutonium present in the piping system be quantified. To meet this requirement, a radioassay system known as *In Situ* Object Counting System (ISOCS) was used to nonintrusively assay the piping system in several locations. The ISOCS and subsequent analysis of the data established that approximately 170 grams (g) of Pu-239 are present within the system.

In addition, during the initial phases of the CAU 547 SAFER investigation, the question was raised by NDEP whether there are other sites on the NNSS that are similar to Player. Because the Player test was a nuclear weapons safety test designed to detonate the weapon chemically without producing a nuclear explosion, it was determined that other safety experiment sites should also be evaluated. A total of 58 safety tests were conducted on the NNSS. Each test was investigated through a document search and a site visit. Eight of these sites were determined to warrant further investigation through ISOCS analysis based on the presence of surface features that could contain plutonium and the description of the test conducted. In addition to the Player site, two safety experiment sites (Mullet and Bernalillo/Tejon[1]) were identified to contain quantities of plutonium requiring remediation. These two sites, along with the Player site, are the three individual CASs that currently constitute CAU 547.

With the remediation of these three sites established as the objective of CAU 547, development of the SAFER for CAU 547 began in early 2009. In the fall of 2009, a question was raised regarding the need to apply nuclear operations requirements to the proposed remediation effort. The SAFER process identified two options for remediation: clean closure (pipe removal and disposal) or close in place (covering of the pipe) with long-term monitoring. Both of these options require that personnel and equipment work in close proximity to the plutonium-contaminated piping system. Based on the quantity of plutonium present, it was determined that the hazard category of the CAU 547 remediation effort must be established in accordance with the requirements of Title 10 of the *Code of Federal Regulations* (CFR) Part 830, Subpart B, "Safety Basis Requirements" [2].

This paper describes the process of applying nuclear facility categorization rules and requirements to the CAU 547 environmental restoration effort.

HISTORY

During the early phases of nuclear weapons testing in the United States, a number of tests were conducted to evaluate the safety of the weapons. The tests were designed with the expectation that little or no nuclear yield would result from the detonation. The Player, Mullet, and Tejon tests were safety tests conducted in August 1964, October 1963, and May 1963, respectively. These safety tests were conducted in a manner that allowed material (plutonium or fission products) generated by the test to be conveyed to the surface of the underground test by piping. At the surface, the piping was connected to various sampling apparatus where data about the radionuclides generated by the test could be assessed. The piping then transitioned back down below the ground, and vented into previously drilled boreholes (in the case of Player and Bernalillo/Tejon) or vented to the atmosphere (in the case of Mullet). Once the tests were complete, any residual radioactive material generated by the test remained in the piping and associated sampling apparatus (e.g., tanks and valves). No cleaning of the piping interior was conducted. At the Mullet site, to accommodate a test at a later date, some of the piping was disassembled and placed alongside the piping that was not disassembled.

CURRENT CONFIGURATION

The current configurations at these sites are similar in most respects, but there are some differences that affect the ability to definitively characterize the plutonium content and the proposed remediation process. Each of the three sites consists of 114-millimeter (mm)-diameter schedule 40 steel pipes that are either welded at joints or bolted together with flanges. The Player site consists of approximately 200 m of piping above grade. Some sections of the piping, however, are covered with soil that was placed during the test and is several centimeters to one

[1] The investigation identified that the plutonium contamination found in the piping system at the Bernalillo site was a result of the Tejon test. The site, therefore, is referred to as the Bernalillo/Tejon site.

meter thick. The Mullet site consists of approximately 120 m of piping above grade, which also is covered in some sections by a thin layer of soil. The Bernalillo/Tejon site also consists of approximately 120 m of piping above grade, with all but 0.6 m of the piping covered by an earthen berm placed before the test. Photographs of these sites are provided in Figures 1, 2, and 3.

Fig. 1. Photograph of the Player site.

Fig. 2. Photograph of the Mullet site.

Fig. 3. Photograph of the Bernalillo/Tejon site.

The Player and Mullet piping systems were each constructed with an expansion loop in the piping at the point where the piping exits the test emplacement borehole. These expansion loops are readily observable in the photographs. Unlike the piping at the Player and Mullet sites, the piping at the Bernalillo/Tejon site runs along the ground with no expansion loop. In addition, the Bernalillo/Tejon piping is covered by a 0.9- to 1.2-m-high berm along almost the entire length of the piping. These features—the expansion loops at the Player and Mullet sites, and the earthen berm at the Bernalillo/Tejon site—limited the locations at which ISOCS analysis could be performed. Four locations were accessible for analysis at the Player site, but only one location was accessible at each of the Mullet and Bernalillo/Tejon sites due to the height of the pipe above the ground (Mullet) and soil covering the pipe (Bernalillo/Tejon).

A characteristic unique to the Mullet site is that loose pieces of piping are present on the ground surface. These pieces were separated from the piping and deposited on the ground surface at some point after the test was completed. This resulted in contamination of the ground surface at the Mullet site and the posting of the entire Mullet site as a contamination area. This also resulted in a reduction of the plutonium inventory within the piping system. These consequences affect both the establishment of the plutonium inventory as well as the ultimate remediation that will be performed at this site.

The Player piping system includes a portion that runs down the side of a crater formed from a nuclear weapons test conducted before the Player test. This portion of the piping is inaccessible due to the steepness of the grade; consequently, no ISCOS analysis was performed on this portion of the piping. This characteristic of the Player site will also likely affect the remediation effort because it will be extremely difficult or impossible to work on this slope without incurring undue risk.

Although the basic configurations of these sites are presently identical—consisting of 114-mm-diameter schedule 40 steel pipes with internal plutonium contamination—there are enough variations among the three sites that both characterization and remediation choices require separate analysis.

REMEDIATION ALTERNATIVES

The remediation alternatives currently being considered for CAU 547 are clean closure and close in place. These two options have been discussed with NDEP in general terms. These alternatives are also the two options being pursued in development of the SAFER. The final SAFER will establish the selected corrective action.

For the purposes of hazard categorization of CAU 547, both options will be analyzed and documented in a safety analysis report. Because a final selection will not be made until the SAFER is complete, the decision to analyze both remediation options will ensure that the nuclear safety analysis will be applicable in either case. These remediation alternatives are briefly summarized below.

Clean Closure

The clean closure alternative consists of uncovering the sections of piping that are above grade but covered by soil piles or berms placed after pipe construction. This will expose the entire run of piping at each site that is above the original grade. The pipe will then be lifted by mechanical means above the ground, enclosed in a containment enclosure, and cut into lengths to allow placement into drums or standard waste boxes. Clean closure will result in the complete removal of piping and contents that were above the original grade before the test. Any piping that extends into the ground below the original grade will be left in place. The sections of the pipe that are removed and cut will be either designated as transuranic (TRU) waste and shipped to the Waste Isolation Pilot Plant in Carlsbad, New Mexico, for ultimate disposal, or managed as low-level waste (LLW) and disposed of at the LLW disposal facility at the NNSS.

Clean closure presents risk to workers during the pipe-cutting operations. The workers could be exposed to plutonium by ingestion, inhalation, and/or direct contact. The potential also exists for release of material that requires the development of safety analysis to identify potential accident scenarios and controls that prevent accidents from occurring or mitigate their consequences. At the completion of clean closure, the site will be left in a clean configuration with no radioactive material present aboveground, which will reduce the long-term risk to workers and the public.

Close in Place

The close in place alternative will involve placing additional soil over the existing uncovered portions of piping. The soil cover will consist of up to 1 to 2 m of soil covering the piping and associated equipment as the long-term protective feature. No removal of piping, equipment, or soil will be conducted at any of the three sites. The soil cover will be capped with geotextile and/or barrier material, such as rip rap, to prevent intrusion into the soil cover and protect against erosion. The soil cover and cap will be engineered and installed to specification to provide a long-term solution to the current unprotected piping configuration.

The close in place alternative will not remove the source term of radioactive material; thus, it will require long-term monitoring to ensure the integrity of the soil cover placed over the contaminated piping and equipment. However, worker risk associated with this alternative is considered significantly less than that associated with the clean closure alternative, because activities involved in the close in place alternative (e.g., installing the soil cover) are much less likely than activities involved in the clean closure alternative (e.g., cutting contaminated pipes) to lead to direct exposure to radioactive particles.

NUCLEAR OPERATIONS APPLICABILITY

To execute either of the proposed remediation alternatives planned for this CAU, a safety analysis is required to demonstrate that the work can be performed safely and in compliance with the safety basis requirements of 10 CFR 830 [2]. The requirements of 10 CFR 830 apply to this CAU because of the quantity of plutonium present at each of the three CASs within CAU 547. An evaluation of each site, proposed remediation alternatives, and the potential for release of radioactive material must be conducted in accordance with the requirements of 10 CFR 830 and the associated DOE standards [3, 4].

10 CFR 830 Requirements

The safety basis process establishes initial thresholds for the maximum inventory of radionuclides that may be present in a facility. The safety basis requirements of 10 CFR 830 [2] require that a facility with the maximum radionuclide inventory above these thresholds be analyzed and categorized as a Hazard Category 1, 2, or 3 nuclear facility. Before making a final facility categorization, however, considerations other than the facility’s radionuclide inventory, such as the presence of physical barriers and the type of activity conducted in the facility, must be addressed.

It should be noted that the quantities of plutonium within the three piping systems vary, but in each case, the concentration (i.e., total curie content of plutonium averaged across the weight of the pipe) is above the TRU waste limit of 100 nanocuries per gram (nCi/g). In addition, the quantity of Pu-239 at each of the three sites is above the Hazard Category 3 threshold of 8.4 g. Therefore, additional analysis is needed before performing final hazard categorization.

Initial Categorization

When the question was first raised regarding the application of 10 CFR 830 requirements [2] to CAU 547, it was necessary to perform an initial hazard categorization of the CAU 547 remediation project. The initial hazard categorization involved the simple process of comparing the inventory of radioisotopes present at the CAU 547 CASs to the limits provide in DOE Standard DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* [3]. For Pu-239, which is the primary isotope present in each of the piping systems, the threshold for nuclear facility designation (i.e., Hazard Category 3) is 8.4 g. Because the quantity of Pu-239 estimated for each of the CAU 547 piping systems exceeded this threshold value but was less than the threshold value for Hazard Category 2 (900 g), the initial hazard categorization established Hazard Category 3 as the initial hazard category for CAU 547.

It should be noted that, although the quantity of Pu-239 estimated for each of the CASs that compose CAU 547 exceeds the Hazard Category 3 threshold value, these CASs are separated from one another by enough distance so that the radionuclide inventories estimated for these CASs do not have to be added together as if they were in a single facility. Also, note that the piping systems are not actively in use and that the CASs are legacy sites undergoing environmental restoration.

Safety Analysis

To determine the final hazard category of each of the CAU 547 sites, a safety analysis will be conducted. The final hazard category will be established in accordance with the requirements of 10 CFR 830 [2], which include the requirement to use the hazard categorization methodology described in DOE-STD-1027-92 [3] in performing hazard categorization.

The hazard categorization techniques described in DOE-STD-1027-92 [3] include those that may be used to reduce the hazard category of a facility or activity from Hazard Category 3 (nuclear) to below Hazard Category 3 (radiological). This is accomplished by revising the Hazard Category 3 threshold values based on an analysis of the physical and chemical form of radionuclides and available dispersive energy sources. This hazard category reduction technique is also described in DOE-STD-1120-2005, *Integration of Environment, Safety, and Health into Facility Disposition Activities* [4], which describes the methodology for performing hazard categorization of environmental restoration activities (see Table 2 of 10 CFR 830, Subpart B, Appendix A). Both DOE-STD-1027-92 [3] and DOE-STD-1120-2005 [4] allow for revising the radionuclide threshold values if a safety analysis demonstrates that the credible release fractions are significantly different from the threshold quantities specified in DOE-STD-1027-92.

The final hazard category of a facility or activity must be determined based on an unmitigated release of material. The final hazard category of CAU 547, therefore, will be determined based on an unmitigated release of radioactive material present at the CAU 547 CASs. The analysis will consider the material quantity, dispersability, and interaction with available energy sources, but will not consider any safety features or practices that prevent or mitigate a possible release from these sites.

The safety analysis will include an examination of the two alternative methods of remediation proposed for CAU 547. The amount of radioactive material that can be dispersed during the remediation activities will be determined as follows. The clean closure alternative assumes that the remediation activities will be conducted on only one segment of the pipe at a given time. This limits the available energy sources for dispersal of radioactive material, because the only energy sources available for dispersal will be the remediation equipment and that equipment will be used in only one location at a time. Similarly, the analysis of the close in place alternative assumes that only one segment of the pipe will be covered at a time. This assumption also will limit the energy sources available for material release.

The safety analysis for CAU 547 will examine dozens of scenarios in which events or accidents could occur. Potential accident scenarios will be identified and analyzed to ensure that no scenario could result in a dose to the worker or public that exceeds the dose limit derived from the threshold values defined in DOE-STD-1027-92 [3].

Final Categorization

The safety analysis will be used to determine whether the CAU 547 remediation project may be downgraded to below Hazard Category 3. If the safety analysis demonstrates that the final hazard category is below Hazard Category 3, then the CAU 547 environmental restoration effort may continue without developing a documented safety analysis (DSA) and the associated implementation requirements. With appropriate safety measures in place to protect workers, e.g., standard safety programs that meet Integrated Safety Management and Occupational Safety requirements, and a radiological protection program that is in compliance with 10 CFR 835, “Occupational Radiation Protection” [5], CAU 547 remediation activities may commence.

SUMMARY

Environmental restoration sites within the DOE complex that have radiological inventories exceeding the Hazard Category 3 threshold values specified in DOE-STD-1027-92 [3] are considered “nuclear facilities,” and thus are subject to the safety basis requirements of 10 CFR 830 [2]. In accordance with the safety basis requirements of 10 CFR 830 [2], the contractor responsible for a DOE nuclear facility must establish and maintain the safety basis for the facility and, in establishing the safety basis, must categorize the facility consistent with DOE-STD-1027-92 [3]. This standard requires that the initial hazard categorization be based strictly on the radionuclide inventory as compared with the threshold quantities listed in the standard.

A facility that is initially categorized as a Hazard Category 1 (nuclear reactors only), 2, or 3 nuclear facility, however, may be downgraded to lower category in final hazard categorization. Final hazard categorization must be accomplished consistent with the process described in DOE-STD-1027-92 [3]. Analysis techniques to be used in final hazard categorization are detailed in Section 4.0 of the standard. If a facility initially categorized as a Hazard Category 3 nuclear facility is determined to be a below Hazard Category 3 radiological facility in the final hazard categorization, then the facility is no longer subject to the safety basis requirements of 10 CFR 830 [2]. It is important for contractors responsible for environmental restoration sites with inventories that exceed Hazard Category 3 thresholds to consider whether the hazard category may be lowered to below Hazard Category 3. Programs required to conduct work at a below Hazard Category 3 facility are much simpler and appropriate for environmental restoration work where the intent is to remove or further mitigate the hazard rather than conduct long-term operations in a permanent structure. There is a significant benefit to demonstrating that work can be conducted as a below Hazard Category 3 facility in terms of cost and schedule.

Corrective Action Unit 547 was initially categorized as a Hazard Category 3 nuclear facility because the quantity of Pu-239 contained in each of the abandoned piping systems present at the three CASs that comprise the CAU exceeded the Hazard Category 3 threshold. However, the potential for release of this material based on the available energy sources present at the locations did not warrant the Hazard Category 3 designation. A safety analysis based on the site configuration and the proposed remediation alternatives will be used to document the final hazard category of CAU 547 as below Hazard Category 3.

Complying with the rules of 10 CFR 830 [2] does not necessarily require full implementation of the requirements for nuclear facility. It may be possible to demonstrate, based on the nature of the facility and the proposed environmental restoration, and through a safety analysis, that work can be conducted as a below Hazard Category 3 facility. This is an important and beneficial allowance in the requirements of 10 CFR 830 [2] that will provide for an accelerated and less expensive remediation in the case of CAU 547.

REFERENCES

1. *Federal Facility Agreement and Consent Order*, agreed to by the State of Nevada; U.S. Department of Energy, Environmental Management; U.S. Department of Defense; and U.S. Department of Energy, Legacy Management (1996; as amended March 2010).

2. *Code of Federal Regulations*, Title 10 CFR Part 830, Subpart B, "Safety Basis Requirements." Washington, DC: U.S. Government Printing Office (2010).

3. U.S. DEPARTMENT OF ENERGY, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, DOE-STD-1027-92, Change Notice No. 1 (September 1997).

4. U.S. DEPARTMENT OF ENERGY, *Integration of Environment, Safety, and Health into Facility Disposition Activities*, DOE-STD-1120-2005 (April 2005).

5. *Code of Federal Regulations*, Title 10 CFR Part 835, "Occupational Radiation Protection." Washington, DC: U.S. Government Printing Office (2010).

DOE/NV--1335