Criticality Accident Alarm System Removal Methodologies

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INTRODUCTION

The Gaseous Diffusion Plants (GDPs) at Portsmouth, OH and Paducah, KY are owned and regulated by the U. S. Department of Energy (DOE) Office of Environmental Management. The Portsmouth/Paducah Project Office (PPPO) manages the DOE cleanup efforts at the two GDP sites. The mission of the PPPO is to conduct safe, secure, compliant, and cost effective environmental legacy cleanup of the Portsmouth and Paducah uranium enrichment sites on behalf of the local communities and the American taxpayer.

The purpose of this paper is to provide methodologies for removing from service a Criticality Accident Alarm System (CAAS) at the GDPs. The presence of a CAAS implies a nontrivial risk of an inadvertent nuclear criticality. The uranium enrichment mission has ended and the facilities are now being deactivated. Once the fissile material has been removed as much as possible in a facility via deactivation and decontamination and any residual fissile material that remains is documented to not pose a criticality hazard, the CAAS may be removed from service.

DESCRIPTION OF THE ACTUAL WORK

In the gaseous diffusion process, isotopic separation was accomplished by diffusing uranium, which has been combined with fluorine to form UF_6, through a porous membrane (barrier). The process utilized the different velocities of the uranium isotopes to achieve separation. The separation of the lighter ^{235}U isotope from the natural isotopic mixture was small, so the process was repeated many times in various cascade stages to obtain the desired degree of ^{235}U enrichment. The enriched uranium presents a nuclear criticality hazard that is mitigated by the use of a CAAS.

Once the criticality hazard is removed via deactivation and decontamination; the resources needed for maintaining, testing, emergency response, procedures, etc. for a CAAS are no longer needed. This results in a significant reduction in the surveillance and maintenance burden for the GDPs.

The Portsmouth GDP operated continuously from the early 1950s until 2001 when the uranium enrichment facilities were placed in cold standby. Portsmouth began producing enriched uranium for commercial nuclear power plants in the 1960s. UF_6 was fed into the system with product enrichment up to 98 wt. % (X-326). The Portsmouth GDP produced Highly-Enriched Uranium (HEU) exceeding 90 wt. % ^{235}U, as well as enrichment typically employed in commercial nuclear power plants (~2 to 5 wt. % ^{235}U). Portsmouth ended production of HEU (>20 wt. % ^{235}U) in 1992 but continued to produce Low-Enriched Uranium (LEU) for use in commercial nuclear power reactors until placed in cold standby in May 2001. The Portsmouth GDP is currently in a Surveillance and Maintenance, Deactivation, and Decontamination and Decommissioning mission. The Portsmouth GDP has sixty-eight (68) active CAAS clusters providing coverage for approximately 200 acres of floor space. The systems were installed in the early to mid-1980s. The CAAS audibly alerts personnel of a criticality by actuating air and/or electronic horns. The depleted UF_6 facilities do not have any operations that require CAAS.

The Paducah GDP began production of enriched uranium in 1952. UF_6 was fed into the system with product enrichment limited to a maximum of 5.5 wt. % ^{235}U. The Paducah GDP ceased production in May 2013 and has transitioned to a deactivation mission. The Paducah GDP has thirty-six (36) active CAAS clusters providing coverage for approximately 125 acres of floor space. The systems were installed in the early to mid-1980s. The CAAS audibly alerts personnel of a criticality by actuating air and/or electronic horns. The depleted UF_6 facilities do not have any operations that require CAAS.

Requirements

The GDP facilities have committed to ANSI/ANS-8.3 *Criticality Accident Alarm System* [1]. ANSI/ANS-8.3 Section 4.2.1 requires;

The need for criticality alarm systems shall be evaluated for all activities in which the inventory of fissionable materials in individual unrelated areas exceeds 700 g of U-235, 500 g of U-233, 450 g of Pu-239, or 450 g of any combination of these three isotopes. … For this evaluation, individual areas may be considered unrelated when the boundaries between the areas are such that there can be no uncontrolled transfer of materials between areas, the minimum separation between material in adjacent areas is 10 cm, and the areal density of fissile material averaged over each individual area is less than 50g/m^2.

Chapter 6 of the Portsmouth GDP DSA flows down the requirement from ANSI/ANS-8.3 stating;

Operations involving fissile material are evaluated for NCS prior to initiation. The need for CAAS coverage is considered during the evaluation process. Coverage is *provided unless it is determined that coverage is not required and that finding is documented in the NCSE. For example, areas containing no more than 700 g of ^{235}U, 50 g of ^{235}U in any square meter of floor or ground area, or areas having material that is either packaged and stored in compliance with 10 CFR 71 or specifically exempt according to 10 CFR § 71.15, can be documented in the evaluation not to require alarm coverage. These exemptions also meet specific criteria or the intent of ANSI/ANS-8.3.*

Chapter 6 of the Paducah GDP Documented Safety Analysis (DSA) flows down the requirement from ANSI/ANS-8.3 stating;

The need for criticality alarm systems is evaluated for all activities in which the inventory of fissionable materials in individual unrelated areas exceeds 700 g of U-235, 500 g of U-233, 450 g of Pu-239, or 450 g of any combination of these three isotopes. Coverage is provided unless it is determined that coverage is not required and that finding is documented in the NCSE or other NCS program document.

Since most of the facilities at the Portsmouth and Paducah GDPs have not been characterized to determine the amount of residual fissile material that remains and the NCSEs still require CAAS coverage, CAAS is installed and maintained as required.

Methodologies

The decision to remove the installed CAAS should be made early in the lifecycle of deactivation. Consideration should be made for the age and reliability of the CAAS, the effect of change on the facility environment (e.g., facility will no longer be heated or cooled), and any future use of the facility. It may be prudent to take no action and keep a CAAS operable even if the current facility condition would not require a CAAS. An example would be a facility that is de-inventoried but will later be used for a fissile material operation. A cost/benefit analysis may be performed to determine the best option for the CAAS. If it is determined the facility will not be used in the future in a way where CAAS would be required, characterization and evaluation of the residual fissile material can enable CAAS removal.

There are at least four methodologies for CAAS removal at PPPO facilities.

1) Demonstrate and document that the individual facility or unrelated areas within a facility contain < 1.0 wt. % ^{235}U. Due to the nature of process at the Portsmouth and Paducah GDPs, uranium chemical forms, and lack of super moderators, uranium compounds with assay < 1.0 wt. % ^{235}U cannot achieve an inadvertent criticality. Process systems containing < 1.0 wt. % ^{235}U are considered non-fissile regardless of the uranium mass present and CAAS is not required. A simple example would be an individual tank containing uranium solution. If the tank can be sampled, analyzed, and documented to contain residual non-fissile material, the tank could then be documented to not require CAAS coverage. Complex interconnected systems will need to be segmented and will need a rigorous Sampling and Analysis Plan (SAP). Segmentation establishes a boundary between the areas such that there can be no transfer of materials between areas.

2) Demonstrate and document that the individual facility or unrelated areas within a facility contain less than 700 g ^{235}U. A facility or area can be de-inventoried and demonstrated to contain < 700 g ^{235}U. This is most practical for facilities (e.g. waste storage facilities, equipment storage pads, laboratories) that house fissile material items in containers or removable equipment items. Thorough facility walk downs are needed to ensure all fissile material items are removed. Process Knowledge (PK) is also key to ensure the facility history is considered so that any facility upsets that may have caused fissile material accumulation, abandoned in-place fissile operations, and/or out-of-service fissile operations are removed. Demonstrating the facility contains < 700 g ^{235}U for large facilities containing installed fissile process equipment can be problematic. The summation of uranium mass from characterization data can quickly surpass the 700 g ^{235}U threshold. Segmentation of a facility may be feasible if it can be accomplished in a practical manner.

3) For those operations where $\geq$ 700 g ^{235}U is present, evaluate the operation and establish controls as needed to ensure the probability of a criticality is so low that a CAAS is not needed. A historic example of this methodology is outdoor UF_6 cylinder storage yards. UF_6 cylinders that contain fissile material are stored at the GDPs. NCS staff have evaluated this operation, established NCS controls in NCSEs, and have documented that CAAS coverage is not required.

4) Demonstrate and document that a criticality is incredible for the residual fissile material contained in an individual facility or unrelated areas within a facility by the nature of the process. Criticality Incredible (CI) can be demonstrated when the condition of a facility or area has been determined by NCS staff to have a qualitative probability of occurrence of a nuclear criticality accident of "incredible". CI is not explicitly defined by any DOE Order or ANSI/ANS standard. Each project must define CI to ensure the project and regulators have a common understanding. For PPPO, CI is achieved when the NCS documentation demonstrates that the residual fissile material will not achieve a critical configuration with no reliance on any NCS administrative or engineered control (other than limiting entry of fissile material) and is applicable to any future condition of the building/area and associated equipment. The scope of ANSI/ANS 8.3 is applicable to all operations involving fissionable materials in which inadvertent criticality can occur and cause personnel to

receive unacceptable exposure to radiation. Fissile material operations that are evaluated and demonstrate that the probability of an inadvertent nuclear criticality is incredible do not need CAAS coverage. For DOE facilities the CI declaration supports downgrading the hazard category (HC) from HC-2 to < HC-3 (e.g. radiological facility).

Criticality incredible evaluations are more stringent than the classic double contingency analysis. The evaluation must demonstrate that an inadvertent nuclear criticality will not occur with no reliance on any NCS administrative or engineered control (other than limiting entry of fissile material). The evaluation must include the present state of the fissile material operation, surveillance and maintenance activities, deactivation activities, demolition activities, and long term disposition of the fissile material (e.g., on-site waste disposal cell). The evaluation must include a discussion of fissile material state which would include scenarios such as migration where the fissile material is displaced from its present location due to activities such as demolition or long term containment deterioration.

Supporting Documentation

The process for getting to the point a CAAS will be removed requires planning, contractor and DOE agreement on method, and documentation. When characterization of the fissile material operation is performed (What do we sample and what do we sample for?), establishment and agreement upon the Data Quality Objectives (DQOs) is key.

Once the DQOs are established, a SAP must be established. The SAP input must be from cognizant stakeholders in the process including Facility Management, Subject Matter Experts (SMEs), NCS Engineers, Nuclear Safety, Characterization Experts, and Systems Engineering. SMEs should include Operations and Maintenance staff that know the history of the facility. Documented PK from the facilities operational records is key. This PK is extremely important to ensure an item that needs to be sampled or removed is "accounted for". This same PK, when documented in the facility operational records and verified by limited characterization may alleviate the need for sampling many items.

Work performance documents are used to methodically obtain the samples from the SAP and document the activity. Approved methods for analysis of the samples must be used to ensure the DQOs are met. Once the sample analyses are complete, an evaluation of the data is performed by the stakeholders. Based on the data, additional actions may require more sampling or additional fissile material removal.

Once the data is analyzed, disposition any fissile material that needs to be removed, and/or segment the facility or area from interacting fissile material operations. Facility walk downs by NCS, Facility Management, and SMEs must verify the threshold for CAAS removal criteria is met. An independent review of the data would be prudent to ensure the threshold is met.

An NCS document will evaluate the new mission and facility conditions and should include the rationale for why the CAAS is not needed based on the data. The Documented Safety Analysis (DSA) and Technical Safety Requirements (TSRs) will also likely require revision to address the new "state" of the operation.

RESULTS

A one-size-fits-all methodology for CAAS removal is impractical for most sites. Each fissile material operation requires an evaluation by cognizant personnel to tailor a methodology that suits CAAS removal for the specific operation. A combination of documented and verified PK, sampling and characterization, and NCS evaluation may be needed for complex operations. The GDPs are large and complex. Comprehensive walk downs of the entire facility and operation are required to ensure all fissile material locations are considered in the analysis.

Obtaining stakeholder (DOE and contractor) review and concurrence on the methodology, DQOs, SAP, and work plan will result in time savings and mitigate the potential for re-work.

ACRONYMS

ANS = American National Standard
ANSI = American Nuclear Standards Institute
CAAS = Criticality Accident Alarm System
CCIPP = Characterization and Criticality Incredible Project Plan
CI = Criticality Incredible
CIDMS = Criticality Incredibility Data Management System
DOE = United States Department of Energy
DQO = Data Quality Objective
DSA = Documented Safety Analysis
GDP = Gaseous Diffusion Plant
HC = Hazard Category
HEU = Highly-Enriched Uranium
LEU – Low-Enriched Uranium
NCS = Nuclear Criticality Safety
NCSE = Nuclear Criticality Safety Evaluation
PK = Process Knowledge
PORTS = Portsmouth Gaseous Diffusion Plant
PPPO = Portsmouth/Paducah Project Office
SAP = Sampling and Analysis Plan
SME = Subject Matter Expert
TSR = Technical Safety Requirement
UF_6 = Uranium Hexafluoride

REFERENCES

1. ANSI/ANS-8.3 *Criticality Accident Alarm System,* (1997).