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A Guide for Facility and Project Managers

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

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P.O. Box 550
Richland, Washington 99352

Project Hanford Management Contractor for the
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A Guide for Facility and Project Managers

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A Guide for Facility and Project Managers

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Executive Summary

The planned Deactivation and Decommissioning (D&D) of once fully supported and operating U.S. Department of Energy (DOE) facilities, present new and unique challenges involving a delicate balance between risk acceptance and progress. Many of the facilities now planned for D&D, contain residual quantities of fissionable materials. As such, criticality safety requirements are a fundamental part of the D&D process. These requirements can be burdensome and expensive, or they can be managed in a graded, methodical, and sensible manner using principles that have been proven to work within the DOE complex.

Prior to engaging in any work involving the movement, storage, or retrieval/cleanup of facilities containing inventories of fissionable materials, it is necessary to establish appropriate criticality safety programs. These programs should incorporate the elements described within ANSI/ANS-8.19-1996, "Administrative Practices for Nuclear Criticality Safety." This document briefly describes the fundamental aspects of such a criticality program in the first section.

Locations and quantities of fissionable materials in facilities facing D&D are often either poorly known or completely unknown. Controls become excessively burdensome when operating with unknowns. Thus, prior to commencing D&D activities, it is essential to establish facility inventories with the highest precision possible. Facility managers and the criticality safety organization must work closely with organizations providing NDA support to ensure that accurate and complete facility characterization is performed. Decisions should only be made after careful consideration of the best available information. This document contains several examples of problems that can result when incomplete information causes managers and safety organizations to make assumptions about the inventory and/or exact location of fissionable materials in D&D operations.

The D&D process has been occurring in fissionable material facilities throughout the DOE complex for many years. As a result, there exists a wealth of information, experience, and technical documentation pertaining to criticality safety controls applicable to D&D projects. This document was prepared in response to a need for a useful, abbreviated, and meaningful compilation of this widely scattered data, and it contains a compilation of lessons learned pertaining to criticality safety and D&D. The information contained within this document was carefully selected to assist Facility and Program Managers in the planning of D&D processes. It specifically addresses the challenges presented by the criticality safety requirements contained within DOE Order 420.1A.

As a facility with fissionable materials moves from operations to D&D, it is important to maintain focus on criticality safety. There are many lessons learned captured in this document specific to criticality safety that can aid facility managers and project managers through the D&D planning process. Major concepts are listed below:

- Involve the criticality safety organization from day one. Given the ever-changing nature of a D&D operation, it is important that sufficient criticality safety resources are available to provide the needed evaluations, as well as an appropriate floor presence, to ensure implementation of the limits.

- It is fundamental that D&D processes in former fissionable material facilities demand a close interaction between Operations, Criticality Safety, and NDA personnel. Very often during the D&D process, the amount and location of fissionable materials is not known, or there is only limited information available. Availability of accurate and timely NDA data is essential to ensuring a successful outcome. The NDA organization, or contractor must be involved early in the D&D planning process, and continue their support of operations and criticality safety throughout the D&D process.

- Criticality safety evaluations written for D&D should be generic and as broad as possible, allowing for the same posting for many areas and processes in the facility. The limits tend to be more conservative, but will reduce the number of non-conformances because the workers will become more familiar and comfortable with the postings because they will rarely change. Managers should ensure that during the development of criticality safety evaluations, operations personnel are directly involved and provide input to the process.

- Care should be used in establishing a point in D&D for declaring criticality incredibility and subsequent removal of the Criticality Alarm System (CAS). This decision should weigh the cost and risk associated with maintaining the CAS against any increased criticality requirements under D&D. It should consider the potential down-time if a discovered condition invalidates the incredibility evaluation (i.e., discovery of previously unknown accumulations of fissionable materials). In some cases, the decision is easy, for example, a relatively new facility with little hold-up may be deemed exempt from criticality alarm requirements much earlier and with very little risk compared to an older facility with greater unknowns. The cost associated with a facility shutdown due to a discovered condition that challenges the incredibility analysis can quickly overwhelm any costs associated with maintaining the system longer than necessary. The costs associated with any increased criticality controls used to establish incredibility should also be considered.

- Until the risk of a criticality accident becomes incredible, it is important for management to continue to have some building or process knowledgeable personnel on all work crews. It is also important that all personnel receive an appropriate level of criticality safety training to perform their work. Even though their work may not normally involve significant quantities of fissionable materials, personnel must know the appropriate action if fissionable material is discovered.

- The installation of unique markings can help protect CAAS equipment and components from damage and inadvertent removal during D&D activities. Red flags and specific paint schemes help warn workers of active equipment. This system has been successfully used in other facilities. In addition, facilities have found it important to move criticality detectors to solid mounting surfaces, such as columns and solid walls. False alarms have occurred because of substantial vibration experienced during D&D from impact devices and dropped equipment. When moving criticality detector heads, ensure head placement is evaluated by the criticality safety organization to ensure changes do not adversely affect coverage.

- Controls to prevent criticality accidents should not depend heavily upon the actions of operations personnel.

- Adequate Characterization of Facilities Scheduled for D&D can Prevent Significant Cost and Schedule Delays.

- It is important to be absolutely sure that criticality incredibility analyses are fully and appropriately implemented before removing Criticality Accident Alarm Systems.

This information represents just a sampling of the lessons learned that are compiled throughout this document that will help facility managers maintain the integrity of their criticality safety program while progressing through D&D activities.

Acknowledgement

The authors are thankful for the support provided by the criticality safety organization from Rocky Flats Environmental Technologies Site (RFETS). We appreciate their time, and the openness of their staff, especially during interviews conducted at their site. In addition, thanks are due to Dr. Robert Wilson, RFETS DOE Criticality Safety Program Manager, for his review and insight into the D&D process. We are also thankful for the support of RFETS staff, most notably Howard Gilpin, and Facility Representatives Joe Sondag and Larry Maghrak. Without their support in gathering information, arranging meetings, and facility access and knowledge, the task of developing this document would have been extremely difficult. Finally, we would like to recognize the contributions of Dr. Jerry McKamy of DOE Headquarters, Ron Lehrschall, Bechtel Hanford, Inc., and Dr. Shivaji Seth, DOE-RL, who also provided timely review and valuable comments.

Several databases were searched for information relevant to this document. The DOE ORPS database was used extensively. Information was utilized from various publications and websites, including the LANL Criticality Safety website and the DOE Headquarters Criticality Safety website. Additionally, information came from the Nuclear Regulatory Commission, the Government of Japan, and the Hanford and Rocky Flats sites. ORPS reports from Rocky Flats, Hanford, Oak Ridge National Laboratories, Savannah River, and Los Alamos National Laboratories were searched for information and personal contacts were made in an effort to retrieve information relevant to criticality safety in D&D activities. While due consideration was given to information from across the DOE complex, those sites with the most maturity in terms of D&D activities are the ones where the greatest amount of information was retrieved. However, this report should be considered a "living document" and as additional information is obtained it will be incorporated.

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Acronyms

AB	Authorization Basis
CAAS	Criticality Accident Alarm System
CSE	Criticality Safety Evaluation
D&D	Deactivation & Decommissioning
HVAC	Heating, Ventilation, and Air Conditioning
NDA	Non-Destructive Analysis
RFETS	Rocky Flats Environmental Technologies Site
SMP	Safety Management Program
SWB	Standard Waste Box
TRU	Transuranic
TSR	Technical Safety Requirements
USQ	Unreviewed Safety Question
WIPP	Waste Isolation Pilot Program
WGE	Weapons Grade Equivalent

Abstract

This document was designed as a reference and a primer for facility and project managers responsible for D&D processes in facilities containing significant inventories of fissionable materials. The document contains lessons learned and guidance for the development and management of criticality safety programs. It also contains information gleaned from occurrence reports, assessment reports, facility operations and management, NDA program reviews, criticality safety experts, and criticality safety evaluations. This information is designed to assist in the planning process and operational activities. Sufficient details are provided to allow the reader to understand the events, the lessons learned, and how to apply the information to present or planned D&D processes. Information is also provided on general lessons learned including criticality safety evaluations and criticality safety program requirements during D&D activities. The document also explores recent and past criticality accidents in operating facilities, and it extracts lessons learned pertinent to D&D activities. A reference section is included to provide additional information. This document does not address D&D lessons learned that are not pertinent to criticality safety.

Introduction and Guidance for Document Use

This document was designed as a reference and a primer for facility and project managers responsible for D&D processes in facilities containing significant inventories of fissionable materials. The document contains lessons learned and guidance for the development and management of criticality safety programs. It also contains information gleaned from occurrence reports, assessment reports, facility operations and management, NDA program reviews, criticality safety experts, and criticality safety evaluations. This information is designed to assist in the planning process and hopefully result in cost savings. A reference section provides information from which safety analyses and programmatic details may be quickly developed. As for any guide, the information within this document was not intended to fit all circumstances or all facilities. Prior to starting the D&D process, each DOE contractor must ensure that appropriate criticality and/or nuclear safety programs are in place, that personnel are adequately trained, and that safety programs adhere to the requirements contained within DOE O 420.1A, or its predecessor documents, as well as the ANSI/ANS Standards affecting criticality safety.

To provide the user of this document with succinct lessons learned and topical areas, the bold heading at the top of each page in the lessons learned section provides an overview of each lesson learned.

Disclaimer:

Sections of this document contain portions of criticality safety analyses developed for use at various DOE sites. These criticality safety analyses are presented for information purposes and as examples only, and they are not to be implemented as they appear here. Criticality safety controls require appropriate basis documentation, reviews and approvals, programs, and training prior to implementation. The sections containing descriptions of criticality safety analyses point to reference documents that may provide additional guidance. Consult your Site Criticality Safety Organization and Nuclear Safety Organization prior to attempting to implement any criticality safety controls in operations.

1.0 Criticality Safety Programs

It is necessary in all operations involving fissionable materials to establish appropriate criticality safety programs that include the elements described within ANSI/ANS-8.19-1996, *Administrative Practices for Nuclear Criticality Safety,* proper administrative controls, and to ensure trained and qualified personnel are available to support operations. This is of particular importance for those activities associated with D&D as in many cases; the inventories of fissionable materials may be uncertain or unknown. Several of the lessons learned examples in this document serve to illustrate this. As in all activities, a graded approach is called for, and many of the reference materials within this document illustrate the appropriate use of a graded approach within a D&D operation. In D&D activities, often analyses conclude that criticality accidents are not credible. However, because of the unknowns associated with fissionable material quantity, form, distribution, and geometry in these operations, appropriate programmatic controls as described within the ANSI/ANS Standards and applicable DOE Orders, Standards, and Guides are essential.

As change is constant during D&D activities, and criticality programs are necessary until the inventory of fissionable materials has been significantly reduced, management must remain engaged through development and enforcement of policy, management assessment, and acceptance of responsibility for safety. Management has a responsibility to provide trained and qualified staff, monitor the health of the program, and provide formal audits and management assessments.

Additionally, significant responsibility resides at the Supervisory level. Supervisors should be trained and qualified in criticality safety, require that his/her staff be trained in criticality safety, participate in the development of adequate procedures, ensure compliance with criticality safety requirements, and require that good conduct of operations practices are utilized in all operations involving fissionable materials.

As conditions are continually changing and the quantities and locations of fissionable materials are difficult to determine, periodic Management Assessment is advised as a tool to establish conditions and identify problems before they emerge. In accord with the principles of Integrated Safety Management, organizations responsible for D&D activities should conduct periodic assessments of the health of their criticality safety programs. Assessment criteria and lines of inquiry designed to fulfill this purpose have been developed by the Department and are published in DOE-STD-1158-2002, *Self-Assessment Standard for DOE Contractor Criticality Safety Programs*. As stated within this standard, "Experience has shown that an acceptable interval for self-assessing the criticality safety program, including all the material in the standard as it applies to a facility, is once every three years." However, particular lines of inquiry should be covered on a more frequent basis. Assessments should be conducted by knowledgeable criticality safety personnel, and should be performed as actual "field assessments," which include tours of facilities, observation of actual work, and personnel interviews.

A series of lessons learned resulted from significant occurrences in 1996-97 at Hanford's Plutonium Finishing Plant. These occurrences (including a major error discovered in a Criticality Safety Evaluation) and the accompanying lessons learned are of use not only for Hanford but for the entire complex. Users of this document should familiarize themselves with these events as described in the report; "The Plutonium Finishing Plant Criticality Safety Program Review", DOE/EH-0571, May, 1998. This document may be found at; http://crit-safety.lanl.gov/ncs/index.htm Problems identified during this review were the result of organizational issues caused by transition to D&D, as well as other factors mentioned in this report. The findings from this review included:

- Inadequate audits of program implementation
- Nuclear Criticality Safety personnel under-staffing
- No self-assessment
- Incomplete review of criticality safety infraction occurrences
- Incomplete knowledge of resource requirements
- Lack of Criticality Safety Engineer training
- No operations participation in Criticality Safety Evaluations.
- Inadequacies in Criticality Safety Evaluations.
- No independent SME review of Criticality Safety Evaluations
- Little facility-specific knowledge on the part of Criticality Safety Engineers.

The lessons learned from that period in Hanford's deactivation and D&D history continue to be valuable to future D&D planning and operations world-wide.

[1]ANSI/ANS-8.19-1996, "Administrative Practices for Nuclear Criticality Safety"

2.0 Lessons Learned from the Historical Criticality Accidents

One must not lose sight of the causes for the several "historical" criticality accidents that have claimed lives, caused injury, and damaged facilities. Preventing future accidents depends upon recognizing and preventing circumstances that have led to the occurrences of several accidents.

There have been twenty-two worldwide criticality accidents that have occurred during the processing of fissionable materials. D&D activities closely resemble those processes, and in many cases, the removal, stabilization, and storage operations that occur during D&D are essentially identical to those processing operations. Many involve fissionable metals, high-density powders, various oxides, fluorides, oxalates, nitrates, and may include fissionable solutions in different chemical forms.

Criticality accidents occur instantaneously without warning and affect those personnel working directly with the materials, and those within approximately 10 to 20 feet of the excursion. For the most part, those who are separated from the excursions by more than 20 feet will receive a non-lethal, but significant dose of radiation. High levels of residual radioactivity may be present, and the possibility of multiple bursts of radiation exists. Thus, it is exceedingly important that operations involving fissionable materials have an adequate working criticality alarm system, evacuation plans and drills, and emergency procedures.

Summary information from the 22 historical process accidents appear below:[2] While not every one of these situations occur in D&D operations, these serve to illustrate the unfortunate results of criticality accidents:

- Twenty-one occurred with the fissile material in solutions or slurries
- One occurred with metal ingots (Siberian Chemical Combine, 1978)
- None occurred with powders
- Eighteen occurred in manned, unshielded facilities.
- Nine fatalities resulted
- Three survivors had limbs amputated
- No accidents occurred in transportation
- No accidents occurred while fissile materials were being stored
- No equipment was damaged
- Only one accident resulted in measurable fission product contamination (slightly above natural levels) beyond the plant boundary.
- Only one accident (Toki-mura, Japan, 1999) resulted in measurable exposures (well below allowable worker annual exposures) to members of the public.

[2]McLaughlin et. al,; "A Review of Criticality Accidents, 2000 Revision", LA-13638, May, 2000.

Frequent Elements and Factors in Criticality Accidents in U.S. Processing Plants[3]

As can be seen from an examination of this list, many of these elements and factors are present every day in D&D operations, particularly ignorance of concentration, poor communication, lack of current knowledge of system configuration, and existence of abnormal situations. D&D operations themselves are abnormal situations.

- Critical configuration of liquids.
- Bulk transfer to unsafe vessel.
- Unintended transfer.
- Ignorance of concentration in intended transfer.
- Valve problems.
- Motive force due to high-pressure air.
- Poor operational communication.
- Lack of current knowledge of system configuration.
- Development of dangerous routine practices
- Errors of commission by operators.
- Errors by supervisors and managers.
- Existence of "abnormal" situations.

[3]R.A. Knief, "Nuclear Criticality Safety, Theory and Practice", American Nuclear Society, Inc., 1993.

3.0 Lessons Learned from Recent Criticality Accidents

Tokai-mura, Japan Criticality Accident, September, 1999.

It is important to understand that even today with over 50 years of experience and numerous lessons learned in criticality safety, accidents resulting in death and serious injury can and still do happen. Operations involving the D&D of fissionable material processing facilities involve the recovery and removal of significant quantities of fissionable materials. Many times these operations are conducted utilizing operations crews unfamiliar with the previous operation and inexperienced in the handling of fissionable materials. Accidents can and do happen, even under the most highly controlled environments. The most recent significant criticality event occurred in Tokai-mura, Japan, September 1999. The Nuclear Regulatory Commission in April of 2000 conducted a review of the event and identified several root causes. Likewise, the DOE conducted a similar review in October 1999, and identified several pertinent lessons learned. The following is information obtained from the NRC's investigation (SECY-00-0085 – *Review of the Tokai-mura Criticality Accident and Lessons Learned*)and the DOE Trip Report (U.S. Department of Energy, *Trip Report of Visit to Tokyo and Tokai-mura, Japan* dated February 29, 2000):

There were three general root causes involved with the Tokai-mura criticality accident: (1) inadequate regulatory oversight; (2) the lack of an appropriate safety culture at the facility; and (3) inadequate worker training and qualification. Each of these conditions may exist in any nuclear facility organization. Facilities slated for D&D are at a particular risk due to schedule pressures, inexperienced operations personnel, and, often, reduced oversight.

1. Regulatory Oversight - The regulatory oversight program for the Tokai-mura fuel processing facility failed to establish and maintain an adequate safety margin.

2. Safety Culture - Deviations from the approved operating procedure began to occur, several years before the company developed a new operating procedure for use (apparently done to improve production efficiency). The manufacturing and quality assurance divisions approved the new operating procedure; however, the safety management division did not. A company spokesman stated to the media that they did not submit the new operating procedure to the regulators because the company knew that the regulators would not approve it.

Within the year prior to the accident, company profits dropped significantly because of competition, and the company laid off about one-third of its work force, a condition very familiar to anyone working in today's DOE complex. Subsequent to the layoff, the company received an order for 18.8 percent enriched specialty fuel, which was produced in small amounts on an infrequent basis, and the company was under pressure to meet the order schedule. Because of the infrequent use of this special process, and the recent layoffs there were no experienced operators available to operate the system. D&D operations often incorporate special procedures or processes that are used on a one-time-only basis. At Tokai-mura, the operators either did not know, or did not heed the unique safety limits applicable to this process because it involved uranium enriched to 18.8 percent U-235.

Furthermore, there was no procedure verification and validation processes, nor were there operator training and qualification checks required by management before authorizing the restart of a process that had not been operated for about 3 years. As previously mentioned, D&D activities differ significantly from operations activities. In total, the company actions represent a significant lack of safety culture. As a result of this accident, the regulator revoked the company's business license.

3. Worker Training and Qualification - If the operators would have been given the fundamental safety knowledge that certain actions could have resulted in a criticality, in all likelihood this event would not have occurred because the operators would have understood the importance of adhering to the safety limits of this process. The training should have stressed the safety controls for this process, which would be to protect against inadvertent criticality. The regulators philosophy was that the system was safe, if it was operated in accordance with the approved procedures.

In addition, *the company did not believe that a criticality accident was a credible event and there were no specific operator training requirements for criticality safety. The operators were also allowed to deviate from the approved procedures to improve production efficiency.* As D&D operations involve unknown or poorly known quantities of fissionable materials, it is common to become complacent and to adopt an attitude similar to the one held at Tokai-mura – "criticality events are not really credible here"..."the facility is no longer operating, our mission is D&D only." At Tokai-mura, had the operators understood the difference between the safety limits for the three to five percent enriched uranium that they usually handled, verses the 18.8 percent enriched material involved with this process, they most likely would not have taken the shortcuts that resulted in this criticality. The people most vulnerable to the consequences of a failure, must be provided with the appropriate safety information.

In addition, the DOE identified the following lessons learned pertinent to D&D:

1. Ensure all levels of involved personnel understand the consequences of criticality accidents

2. Ensure controls are understood and rigorously followed for operations involving fissile materials. This includes having the people whom perform the work understand why the controls are important.

3. Ensure that analyses for fissile material operations that conclude criticality accidents are incredible do not rely significantly on worker actions.

4.0 Operational Lessons Learned

This section contains descriptions of lessons learned gleaned from operational experiences, mostly from the Hanford and Rocky Flats sites. Topics addressed include: criticality alarms, implementation of criticality controls and requirements, facility characterization, training and appropriate safety focus, and legacy issues, among others.

Criticality Incredibility and the Need for Criticality Alarm Systems

The U.S. Nuclear Regulatory Commission Review of the Tokai-mura Fuel Processing Facility Event found that the Licensing Review incorrectly concluded that there was "no possibility of a criticality accident." At the Tokai-mura fuel-processing facility in Japan, the need for adequate criticality detection and alarm systems was not recognized. This lesson learned is directly applicable to D&D activities in the DOE complex.

The following was identified during the NRC Review of the Tokai-mura Criticality Accident April 2000 (SECY-00-0085 – *Review of the Tokai-mura Criticality Accident and Lessons Learned*) and a DOE Trip Report (U.S. Department of Energy, *Trip Report of Visit to Tokyo and Tokai-mura, Japan* dated February 29, 2000):

The regulatory oversight program for the Tokai-mura fuel processing facility failed to establish and maintain an adequate safety margin. The licensing review incorrectly concluded that there was "no possibility of a criticality accident occurrence due to malfunction and other failures." Consequently, no criticality accident alarm was required, or installed, and the facility was not included in the National Plan for the Prevention of Nuclear Disasters. This conclusion relied heavily on the use of administrative controls that were subject to human error.

The resultant belief that a criticality accident was not credible complicated the recovery process. First, there was initial confusion as to whether a criticality had occurred, followed by further uncertainties as to whether the system was still in a critical state. This may have led to three emergency workers receiving an unplanned exposure during their response to the event. Under slightly different circumstances this could have caused recovery personnel to be exposed to any subsequent criticality pulses.

Secondly, since the fuel processing facility was not included in the National Plan for the Prevention of Nuclear Disasters, there was a significant delay in developing and communicating emergency protection measures for the public. Several workers at a nearby lumberyard were not notified to evacuate the area, until approximately 3:00 p.m., although the event began at 10:30 a.m., and officials knew that the system was still critical and could cause significant elevated exposure rates near the facility. In addition, the regulator did not conduct periodic inspections of this process to confirm that it was being operated safely and in accordance with the regulations. In 1997, an opportunity was missed, to correct this flaw, following a fire and a chemical explosion that occurred in another nearby nuclear facility. At that time, the regulator decided that it did not need to conduct any inspections at JCO Co., Ltd because there had not been any reportable events. Lack of an independent inspection program resulted in the regulator not having an early indication of developing adverse performance trends and emerging problems at the facility.

Likewise, the trip report from DOE regarding the accident identified the following:
"Ensure that analyses for fissile material operations that conclude criticality accidents are incredible do not rely significantly on worker actions." In other words, controls to prevent criticality accidents should not depend heavily upon the actions of operations personnel. The controls should be independent of human interaction. Engineered barriers are preferred.

Adequate Characterization of Facilities Scheduled for D&D can Prevent Significant Cost and Schedule Delays.

The original NDA of the 233-S facility process hood assumed the plutonium inventory was located within the piping, vessels, filters, and ducting. This resulted in an estimated 2.8 gram inventory on the process hood floor and was based upon smear survey data. The highest measured values (smear surveys) were then assumed to be uniformly distributed across the entire floor of the process hood to establish an inventory value for the floor.

Prior to engaging in D&D activities, a sample of residual material located on the 233-S process hood floor was collected. Initial non-destructive assay (NDA) of the sample container indicated the presence of substantial amounts of Americium-241. Americium-241 presents a low energy gamma dose rate. Information was received from the NDA personnel indicating a maximum of 20 grams of Plutonium-239 was present in the sample. Further analysis of the new data resulted in the determination of an Unreviewed Safety Question (USQ) and subsequent Unusual Occurrence Report.

The sample was sent to the 222-S Laboratory for analysis. As received by the lab, the sample was a brown/gray dry mixture of sand and dust with some rust-like material dispersed throughout. There were also gray colored flakes that looked similar to paint chips (probably old fixatives). Analysis determined that the 48.6 gram sample contained 6.33 grams of Pu-239. Thus, a single sample of material retrieved from the 233-S Process Hood contained nearly three times the amount of plutonium previously assumed to be present in the entire Process Hood (outside of the vessels and piping). Previous NDA analysis failed to accurately characterize the Process Hood fissile material inventory resulting in a USQ.

Using engineering investigation and change analysis, the cause of the occurrence was determined to have resulted when Non-destructive Assay (NDA) of a process hood sample, obtained in support of ongoing characterization activities, indicated a maximum sample value of 20 grams of plutonium, which exceeded the 2.8 grams assumed in the safety analysis for the fire accident analysis. Because the discovered condition affected the source term assumed in the process cell fire accident scenario, the resultant dose consequences were increased, therefore, an Unreviewed Safety Question (USQ) was declared to exist. Because the increased inventory required reanalysis and it was likely that additional loose material would be found during subsequent decommissioning activities associated with the process hood, the project elected to provide additional conservatism to the safety analysis. The resulting evaluation is expected to bound any future discoveries of loose materials and provide operational flexibility. Accordingly, 2255 grams of plutonium has been evaluated as the new material at risk in the fire accident scenario. This value was previously evaluated in the criticality analysis and is based upon the highest NDA measured value from the process hood (1530 grams plutonium).

Bechtel Hanford, Inc. (BHI) has evaluated the impact of the discovered condition. The potential increased inventory resulted in the creation of a new Safety Evaluation that included a revised criticality analysis, safety analysis and associated dose consequences an Authorization Basis revision. Additionally, the facility installed and maintained a criticality alarm system as a "defense-in-depth" measure. The facility developed and implemented revised Technical Safety Requirements and developed criticality safety postings that were placed throughout the facility.

Programmatic Impact:

The process hood work activities in the 233-S facility were delayed for approximately 5 months at an estimated additional cost of $250,000. Additional costs associated with the discovered condition involved revision of the criticality analysis, installation and maintenance of a criticality alarm system, procedure revisions, developing nuclear criticality safety postings, and training. The total cost of this event likely exceeded $1M.

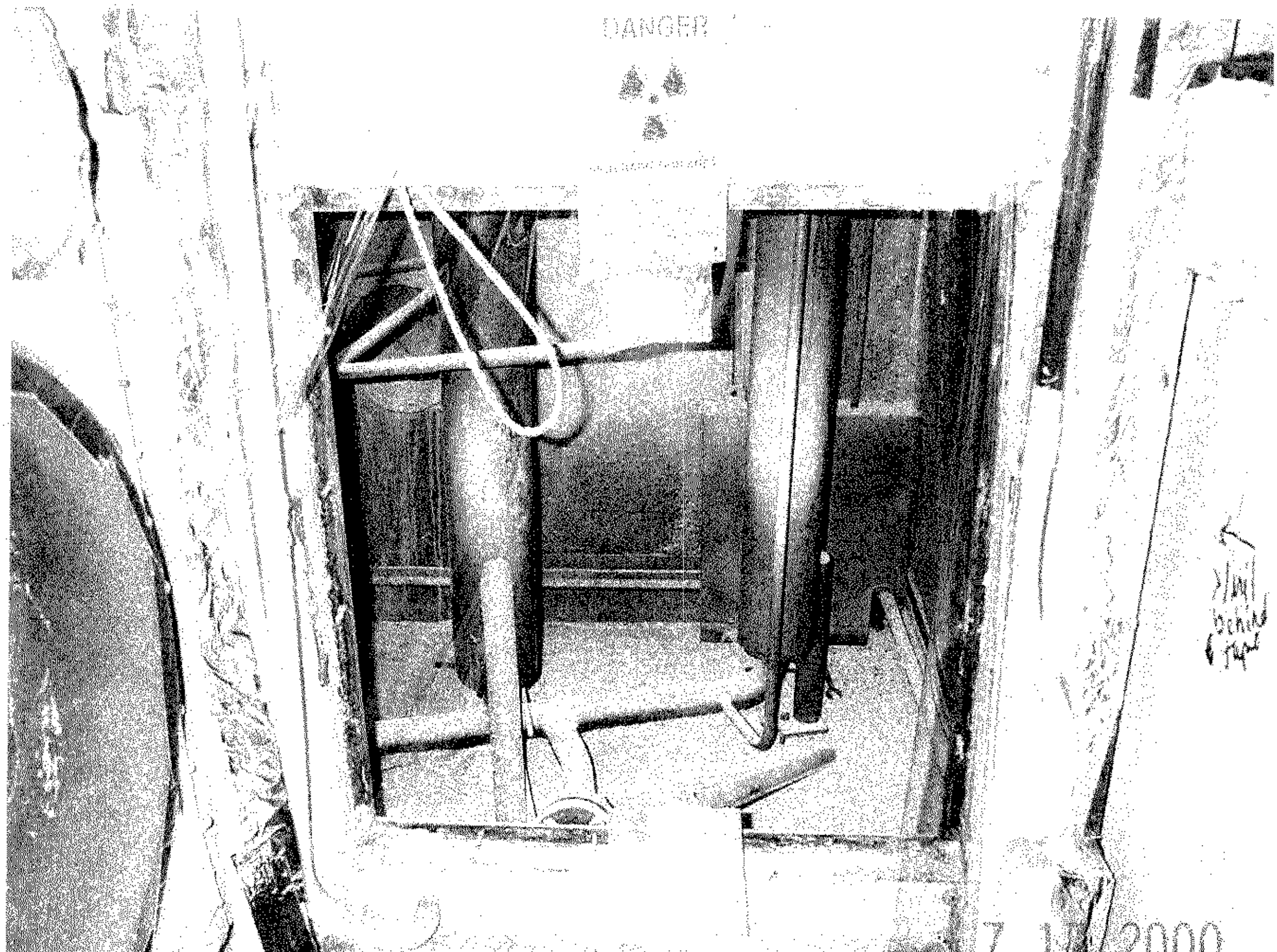


Figure 1: 233-S Process Vessels and Piping

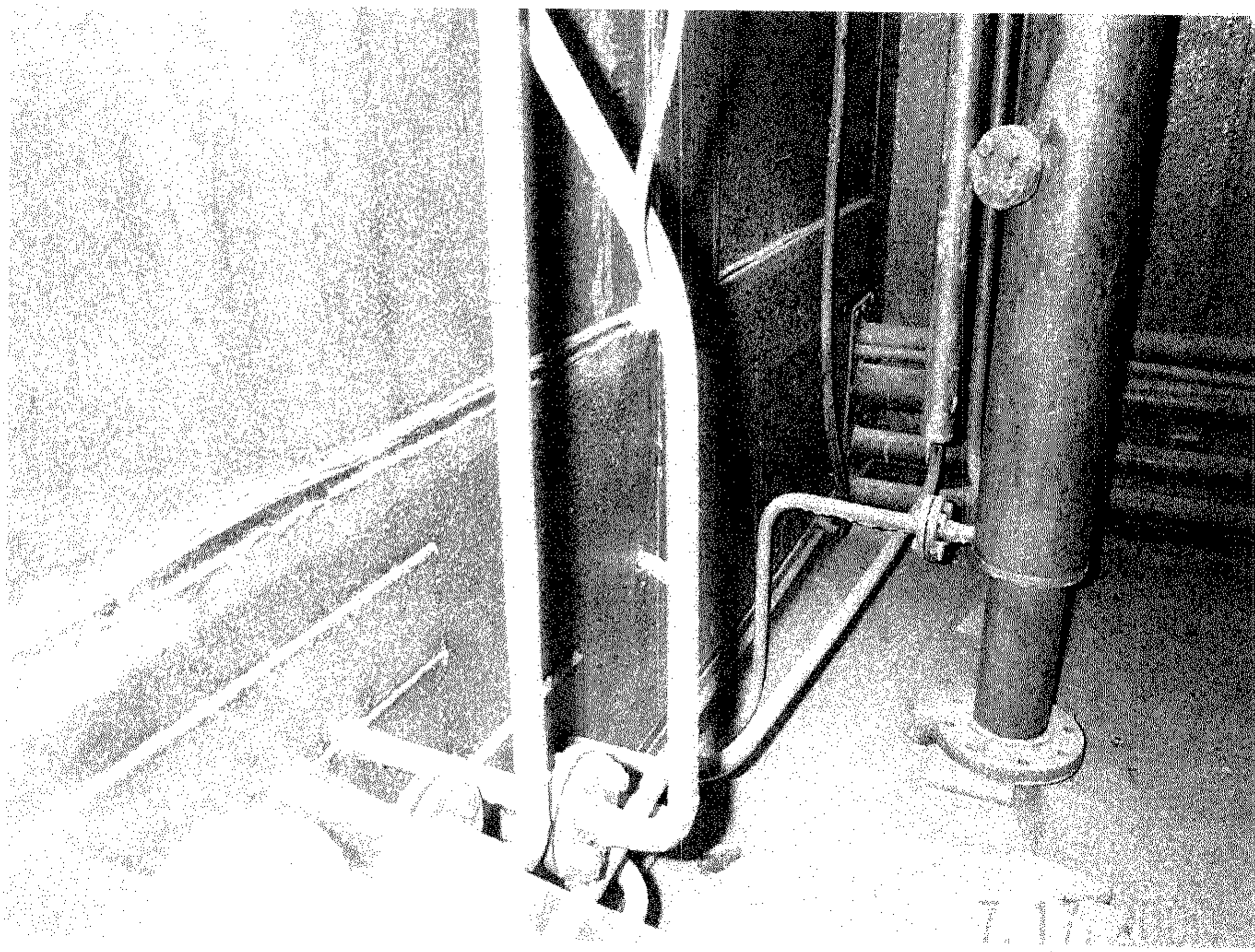


Figure 2: 233-S L-1 Process Vessel and associated piping

Failure to Properly Implement Criticality Requirements may Result in the Loss of Controls Required for Criticality Incredibility

On January 30, 2003, a criticality infraction was declared in Building 776/777 when a drum and Standard Waste Box (SWB) were determined not to meet the pre-requisites of Nuclear Materials Safety Limit 02-039/JSC-042, Revision 2, *Criticality Incredibility Study for Buildings 776/777.* The failure to meet the prerequisites, resulted in the loss of one of the three layers of contingency required for criticality incredibility. Waste drums and Standard Waste Boxes are relied upon heavily in D&D operations. This event points out significant programmatic and administrative problems that resulted from a failure to properly implement criticality requirements.
The specific prerequisite not met in the Criticality Safety Evaluation (CSE) was: "All TRU waste containers (i.e., 55-gallon drums and Transuranic (TRU) waste boxes) loaded prior to April 10, 2002 shall either be removed from Building 776/777 or be confirmed, to at least 95% confidence level, to contain less than 220 grams of fissionable material in each drum or 342 grams fissionable material in each waste box. Confirmation shall be by assay of the whole drum or box (e.g. Safeguards Measurements scan, drum counter, etc.)." The implementation (January 18, 2003) of Technical Safety Requirements Page Change PGC-776-03.0162-RAN, *Building 776/777 BIO Revision, Criticality Incredibility,* relied upon successfully completing the CSE prerequisites prior to declaring the page change implemented and effective. This page change involved removing the criticality accident scenario from the accident analysis, and relying upon the Criticality Safety Management (CSM) Program to maintain criticality incredibility. Since the Authorization Basis concluded that a criticality was incredible, no Technical Safety Requirements (TSR) were introduced and the requirement for an operable Criticality Accident Alarm System (CAAS) and the Administrative Controls for inadequate CAAS annunciation were eliminated.

The event was determined to be an Unreviewed Safety Question (USQ) because the accident analysis assumed full implementation of the CSE and a criticality in the facility was considered incredible. In addition, the analysis did not analyze the scenario to determine dose consequences. Also, since an inadvertent criticality becomes credible when the CSE controls are not met, any criticality would result in a dose consequence and therefore represent an increase. Criticality alarms may be necessary throughout the D&D process for worker protection reasons. This event resulted in significant cost due to downtime (suspended operations) while the condition was being corrected. As described elsewhere in this document, the Criticality Accident Alarm System (CAAS) may be phased out slowly as the facility D&D process progresses. It may not be advisable to rush to deactivate such safety systems prior to engaging in D&D activities. It is important to be absolutely sure that criticality incredibility analyses are fully and appropriately implemented before removing the CAAS. See the next section for more details on this concept.

Care Should be Exercised in Selecting the Appropriate Point in the D&D Process to Declare Criticality Incredible and Remove the Criticality Alarm System.

Often it is possible to produce a criticality analysis that shows that the probability of a criticality in a facility is "incredible" (less than 1e-6/year). Such an analysis allows removal of the Criticality Alarm System (CAAS). Obviously, removal of the system reduces operating, maintenance, and surveillance costs for the facility and should be done as soon as practical. The risks associated with removing the system too early, in terms of both cost and safety, can quickly negate these savings, however. Several factors that must be considered include:

- Costs resulting from the implementation of necessary additional criticality controls to maintain incredibility may be significant: The rigor required to demonstrate incredibility is necessarily greater than that for double contingency. If additional hardware or administrative controls are required to bridge the gap between double contingency and incredibility, the cost of the criticality program can go up. These costs may exceed the savings associated with removing the CAAS.
- Costs due to compensatory measures implemented as a result of discovered conditions: If a condition arises that challenges the criticality incredibility assumptions, associated compensatory measures are often extremely restrictive and costly. Suspension of operations, or even facility evacuation may be required while the situation is being corrected. Idling a major nuclear facility can quickly negate the savings associated with removing the system early.
- Emotional response of workforce: A workforce that has transitioned from nuclear operations to D&D presents a unique challenge. The importance of the CAAS during nuclear operations has become so ingrained in the minds of some workers such that some have a difficult time adjusting to its removal. Attention to continued and open communication with the workforce is important. They need to understand why the CAAS is no longer required, and must become comfortable with the controls that replace it.

Possible negative impact due to delaying CAAS removal: There are also strong reasons to remove the system as soon as practical. Aside from the maintenance and operating costs, there is a non-trivial risk associated with false alarms. The D&D environment is radically different from an operational one. Vibration, RF interference, and potential for physical damage to the system all increase the likelihood of false alarms, and with it increase the possibility of injury to the workers or the facility due to the associated evacuation and extended operation of the CAAS system.

Additionally, the need to maintain a system that by its nature is spread throughout a facility complicates the sequencing of D&D activities. For example, although it might otherwise make sense to perform decontamination activities in one part of a facility while still removing fissionable materials in another part, the need to maintain facility CAAS coverage might make this impractical. The detectors, wiring, and enunciators would need to be moved from the area of decontamination activities, a costly and time consuming process.

Conclusion: A management decision weighing the cost/benefit aspects of removal of the CAAS is necessary. The proper timing for removal of the system is highly facility dependent, a relatively clean facility with limited hold-up could safely remove the CAAS significantly earlier than a facility with the potential for hidden accumulations of fissionable materials. Involvement of criticality safety professionals in the up-front D&D planning, along with consideration of the above, can help define the appropriate timing to minimize risks while maximizing cost savings.

Criticality Safety Experts Emphasize the Need to Maintain a Focus on Criticality Safety During D&D Activities Through Training and Appropriate use of Experienced Personnel, as Criticality Accidents are Still Possible

As a facility transitions from operations to D&D activities there is a potential for personnel to lose focus on criticality safety. Focus can be lost for a variety of reasons including the hiring of new D&D workers with little or no knowledge of criticality safety; loss of operational knowledge and experienced personnel who move to different jobs once D&D commences; the perception that a criticality accident is no longer possible; general reduction in the number of criticality safety personnel; and a general change in culture between operations and D&D. Managers should consider the contributors to the historical criticality safety accidents and their parallels in D&D work activities. The criticality accident at Tokai-mura, Japan also had several causes in common with D&D activities.

To maintain a clear focus on criticality safety during D&D there are some common sense actions that should be taken, such as:

- ensure criticality safety organizations have the resources to provide needed oversight, and;
- ensure criticality safety organizations remain diligent in their oversight role.

To emphasize the need for maintaining a focus on criticality safety through training and the use of experienced personnel one only needs to look to Tokai-mura Japan in September 1999. The NRC identified that inadequate worker training and qualification, inexperienced workers, and a lack of oversight contributed to the event.

- ensure new workers and transitioning workers receive adequate criticality safety training as specified within ANSI/ANS-8.20-1991. Utilize the various re-enactment videos that are available as part of criticality safety awareness/sensitivity training ("It can happen here", RFETS training, "A review of criticality accidents", Tom McLaughlin, LANL, available from DOE-RL, etc.);
- ensure all personnel are trained to identify unexpected conditions that might be encountered during D&D (e.g., additional material, configuration of material, location of material, etc.) and how to react once identified;
- ensure work groups, shifts, and teams have an adequate mix of experienced and new personnel assigned as it becomes easy for all experienced personnel to be assigned to one shift because of seniority reasons;

DOE identified the following lessons learned:

- ensure fundamental understanding of criticality and consequences of criticality accidents by all levels of involved personnel.
- ensure controls are understood and rigorously followed for operations involving fissile materials. This includes having the people whom perform the work understanding why the controls are important.

- ensure sufficient oversight and monitoring of operations involving fissile material by supervisors, management, and regulatory personnel.

Management Must be Diligent in their Identification of Legacy Issues that can Affect D&D Activities

During D&D activities unexpected issues will arise. To minimize the number of unexpected issues and their impact, management must be diligent in identifying legacy issues. Several sites have experienced events related to legacy issues. Below are four specific events and associated lessons learned related to legacy issue in a D&D environment.

RFO-KHLL-SOLIDWASTE-2000-0054:

At RFETS, two wooden TRU waste crates were moved to and stored in a room where TRU waste storage was not allowed. The crates were moved to the room in order to support D&D activities in another area. The D&D crew that moved the crates assumed that all wooden crates were low-level waste.

The two crates in question were legacy crates that were scheduled to be size-reduced. There were no markings on the crates and the associated waste container content logs (Travelers) were not visible. One Traveler was covered with a piece of cardboard and the other Traveler was not on the crate. The workers should have found and reviewed the Travelers before moving the crates. Since the event, all legacy crates were evaluated for appropriate storage and documentation. Training was provided to all D&D supervisors on the procedures and requirements for moving and handling legacy crates.

RFO-KHLL-779OPS-1996-0051:

At RFETS, management requested safeguards personnel to perform gamma scans as part of pre-deactivation activities. From the scans the following problems were identified:

- glovebox with a safety limit of 400 grams had 596 grams of Pu hold-up;
- glovebox posted as "No Fissile Material Allowed" had 174 grams of Pu hold-up;
- glovebox with a safety limit that did not allow Pu anywhere but in four liter containers had 71 grams of Pu hold-up; and
- glovebox with no safety limits for hold-up had 1,000 grams of Pu hold-up.

It is expected that Pu hold-up will be identified as sites move forward with deactivation of Pu facilities. Locating Pu left over from past processes in filters, equipment and vents is a positive step in cleanup and closure. Once located, Pu can be safely removed and packaged for long-term storage. Identification of this material reinforces the need to properly assay and evaluate each glovebox individually before completing "hands on" decontamination activities. Identification of plutonium hold-up in gloveboxes and the steps taken to evaluate and remove the material safely represent a positive model in the era of deactivation, decontamination, and decommissioning of nuclear facilities.

RFO-KHLL-779OPS-1996-0012:

At RFETS, during deactivation activities, safeguards measurements personnel were performing holdup measurements, when a significant quantity of fissile material was identified in a glovebox filter. Based on historical knowledge of the system and the process, it was suspected that the glovebox might have significant amounts of holdup in a variety of locations. Because the holdup was found in an area unreviewed by criticality engineering, no criticality safety limits existed for the holdup material. As a corrective action, criticality safety personnel performed an evaluation and provided immediate guidance regarding the holdup.

The instrumentation used to perform the scan indicated via a spectrum, a qualitative display of the holdup amount. When the filter was initially scanned, there was a "large spectrum visible." This indication of significant holdup was not promptly relayed to management upon completing the scan. As a corrective action, personnel performing the scan, as well as management, were counseled to ensure that information (even preliminary information) is discussed. Preliminary information might not always influence additional actions, however, depending on the circumstances, it can be a vital piece of information. This event highlights the need for clear communication of potential problems to management.

RL-PHMC-CENTPLAT-2003-0004:

Fissile material accumulation was discovered in contaminated equipment located within a canyon storage facility at Hanford's U Plant. The facility was constructed in 1944 as one of three chemical separations plants, but was never used for its original purpose. In 1952, U Plant was converted to the tributyl phosphate process. In 1958, U Plant was placed in standby mode, and since that time it has been used to store contaminated equipment from other facilities.

During demolition planning, a project engineer was reviewing documentation associated with the facility to ensure that characterization activities could support eventual demolition. In the course of review, the engineer observed that a tank in one of the U Plant canyon cells contained a type of material that could exceed the limits for fissile material. The engineer noted that a document described a tank in a canyon cell that contained a "dark green liquid." The engineer's process knowledge from prior experience at the Hanford Site caused him to suspect that the solution contained Pu. Correlating his identification of a questionable residue with a measured radionuclide concentration, the engineer identified that the material was most likely TRU, and performed a rough calculation for the quantity of fissile material present. Based upon data review, it was estimated that the inventory of Pu-239 in the tank could range from 400 to 1000 grams, which was above expectations.

This event emphasizes the need for good planning, in depth documentation reviews, a questioning attitude, and process knowledge. This will ensure that surprises are not encountered and it will allow for the proper implementation of controls.

Management must be Appropriately Equipped to Respond to the Discovery of Unexpected Fissionable Material Holdup

The following information was identified in RFETS , "Discovery of Fissionable Material Holdup", 1-S73-SWCSI-141, Revision O, 08/07/97.

During D&D activities, it is not uncommon to encounter accumulations of fissionable material not previously discovered. This example procedure establishes a response to the discovery of accountable quantities of fissionable materials, and applies to the discovery of fissionable material "holdup," fissionable material accumulations in ductwork, piping, filters, conduits, process equipment, gloveboxes, and etc. Existing facility criticality safety limits may control the presence of fissionable material holdup discovered, but there are cases where a limit may not exist. In addition, persons other than the staff performing NDA measurements or characterization activity may discover holdup.

Operations Management:

Promptly initiate actions to maintain holdup in an undisturbed or stabilized condition to the extent practical while waiting for specific technical guidance from the Nuclear Criticality Safety Organization.

When holdup accumulations are discovered, inform:

- The Nuclear Criticality Safety Organization
- The appropriate Nuclear safety Organization if authorization basis limits (e.g., glove box, duct, building) are exceeded

If personnel other than the staff of the organization performing the NDA measurement discover the holdup, then promptly initiate:

- Any safety controls that might be required
- An NDA assessment.

If no current criticality safety basis applies to the holdup location, then:

- Promptly assess the NDA results, and provide a criticality safety basis in accordance with approved criticality safety guidance.

If an existing criticality safety basis applies to the holdup location, and the holdup exceeds existing criticality safety limits:

- Declare a criticality nonconformance in accordance with procedures
- Inform the Nuclear Safety organization.

If the holdup is within existing criticality safety limits:

- Exit this procedure.

Nuclear Criticality Safety Organization:

Promptly assess the NDA reports, and provide a criticality safety basis in accordance with approved criticality safety guidance. If the situation is an immediate safety issue:

- Initiate procedures for reporting Nuclear Criticality Safety Infractions
- Consider that the condition may represent a PISA
- Provide directions for actions to operations as necessary

When and How to Reduce Criticality Controls in D&D Facilities

There is no simple answer as to when D&D facilities should reduce criticality controls. The criticality program is graded; therefore, controls fall out naturally. To transition the criticality safety program to D&D, the first step is to involve the criticality safety organization from day one. Given the ever-changing nature of a D&D operation, it is important that sufficient criticality safety resources are available to provide the needed evaluations, as well as an appropriate floor presence that will ensure implementation of the limits.

RFETS found the best approach was to deactivate all non-applicable evaluations, limits and postings that were operationally driven. Criticality safety evaluations for D&D were then written as generic and as broad as possible that allowed for the use of the same posting for all gloveboxes in an area. Criticality safety evaluations that did not rely upon criticality drains allowed for the removal of the criticality drains. The criticality safety limits tended to be more conservative, but it reduced the number of non-conformances because the workers were more familiar and comfortable with the postings and the postings rarely changed.

Down-posting of the glovebox should be performed only after it is assured that there will be no more activity in the glovebox, such as decontamination and size reduction. Once gloveboxes no longer require criticality controls, the use of a new indicator, such as a Pink Sheet, used by RFETS, help demonstrate that the criticality controls are no longer required.

RFETS also found that having the Criticality Safety Engineer work closely with the operations organization helped identify upset conditions, actual working conditions, and it made it easier for the criticality safety organization to identify when controls could be removed.

For discussion on establishing "criticality incredibility," see page 23 of this document.

Wherever Possible, Criticality Safety Postings Should Incorporate "Human Factors" Elements in Design, Layout, and Printing*

The practice of criticality safety has traditionally included some degree of reliance on signs placed at strategic locations throughout the work area. These signs, or "criticality safety postings" as they are called, provide concise directions to workers handling fissionable materials. The directions typically include the limiting quantities of fissionable materials that can be handled safety in a specific area, e.g., "TOTAL MAXIMUM MASS: 2500 grams Pu."

Postings are often typed on ordinary 8-1/2" x 11" paper frequently with a small, compact font size in order to convey as much information as possible on a single sheet. Yet with a little additional thought given to human factors in layout and presentation, a considerable improvement in the readability of postings can be achieved. Recently the criticality safety staff at the Department of Energy's Rocky Flats Environmental Technology Site (RFETS) applied human factors principles to criticality safety postings. The criticality safety staff at Project Hanford was favorably impressed with samples of the RFETS postings and elected to further develop and codify its own set of similar posting guidelines.

While color may have been too cumbersome and costly for low volume applications in the past, the current generation of color ink jet printers enables the practical and inexpensive use of color for added informational clarity. Internationally accepted meanings of color are readily adapted to postings. Red characteristically is accepted to mean "stop" or "danger" and is appropriate for limiting quantities. Yellow is used to express caution, while green is used to express a permissive situation.

A large font size is recommended for easy readability in dimly lit areas and by those who might otherwise require reading glasses. The latter can be important in contaminated areas where the proper use of protective clothing makes it difficult if not impossible to use and remove reading glasses.

Casual observation of effective signage suggests that the application or a certain amount of artistic common sense is beneficial in enhancing the sign's ability to transmit information. Certainly it seems intuitive that a well balanced, simple sign is more effective than a cluttered, poorly proportioned one. Following is an example of a criticality safety posting incorporating several of these concepts.

*This entire section is from, M.A. Jensen, E.J. Lipke, B.S. Mo, Fluor Hanford Company, Inc., HNF-8079, Rev.0, April, 2001.

Criticality Safety Posting
Glovebox HC-21A Limit Set C 5500 Grams

ALLOWED FORMS

Plutonium metal, metal corrosion products, oxidized metal, and product quality oxides, e.g., items with BLO, BO, DZO, and PBO in the first field of the label.

MAXIMUM uranium enrichment **50 wt%** ^{235}**U**

MODERATION LIMIT

H/X ≤ 2, except for the sweeps can.

GLOVEBOX LIMIT

MAXIMUM inventory - **5500 grams Pu**

UNIT MASS LIMIT

MAXIMUM unit mass - **5500 grams Pu**

SPACING LIMITS

MINIMUM 10 INCHES between unit masses
AND between any unit mass and other loaded containers.

Spacing limits include containers on HC-2 conveyor.

CSR __________ (initial)

PAF No. _________

Revision No. ______

Criticality Safety Posting

Glovebox HC-21A Limit Set C 5500 Grams

OTHER LIMITS

STACKING of Pu bearing containers or boats **PROHIBITED.**

MAXIMUM 6 SQUARE FEET TOTAL AREA of damp rags.

Clean up noticeable accumulations on the glovebox floor as soon as practical.

Remove fissile material containers prior to HEPA filter change out.

NO LIQUID PERMITTED1
other than 50 ml of non-fissile liquid.

NO FISSILE MATERIALS > 15 g under glovebox.

Note: The sphincter port is considered part of the glovebox.
Containers may be managed as a unit mass in the sphincter port.

Approved: ______________________________ CSR PAF. No. _______

____________ Nuclear Safety Control No. __________

____________ Operations Limit Set ____________

Reference: CPS

Date: ____________

5.0 Criticality Safety Evaluations

This section provides examples of several criticality evaluations used in D&D activities

Example Criticality Safety Limits for Decommissioning a Plutonium Processing Building

Reference: Wachtel, S.J., *CSER 02-011: Criticality Safety Evaluation Report for Decommissioning Building 232-Z*, HNF-11499, Rev. 0, July 2002.

The referenced criticality analysis addresses the D&D of Building 232-Z in preparation for demolition of the building. The D&D process will involve the removal of process equipment, ventilation ductwork, fixtures and utilities. Prior to preparation of the criticality analysis, NDA scans of the process equipment within 232-Z determined the facility contains less than 700g Pu within the remaining equipment, gloveboxes, and ventilation system.

Limits and Controls:

The following administrative controls are typical of those that may be applied to the facility D&D when the remaining inventory of plutonium is well known, the NDA characterization has been completed, and appropriate criticality safety programs exist.

- No additional fissionable material may be brought into the building.

This limits the available inventory of fissionable material and prohibits creation of an unanalyzed condition.

- Fissionable materials shall be handled according to the appropriate destination criticality prevention specifications.

Existing criticality limits and controls may be utilized for handling the waste containers created during the D&D process. No new limits or controls are required.

- Stripcoat decontamination materials shall not be used.

While strippable decontamination coatings may safely be used, this analysis does not permit their use as the D&D process will not require them. Existing criticality analyses for the use of such coatings may be utilized, resulting in significant cost savings in the development of criticality controls.

Example Criticality Safety Limits for Glovebox Cleanout and Equipment Removal

Reference: Erickson, D.G., *CSER 02-013: Criticality Safety Evaluation Report for Glovebox HC-7 Cleanout and Equipment Removal, 234-5Z Building*, HNF-11605, August 2002.

The referenced criticality analysis addresses the cleanout and removal of equipment from a former plutonium processing glovebox. Activities include removal of all loose trash and tools, collection of loose fissionable material, and removal of internal equipment and piping. The glovebox contains up to 5,000 grams of fissionable materials. The form and distribution of the materials are not considered in order to allow for maximum operational flexibility.

Limits and Controls:

The following administrative controls are typical of those that may be applied to the D&D of plutonium process gloveboxes when the inventory of remaining plutonium is well known, NDA characterization has been completed, and appropriate criticality safety programs exist.

- Maximum 5,000 gram fissionable material in the glovebox as holdup on the surfaces, or within the structure, equipment, and piping.

Gloveboxes containing greater than 5,000 grams of fissionable material are considered to be outside the bounds of this analysis.

- Fissionable material collection containers are limited to maximum 1 liter in volume. Exception: One pan exceeding 1 liter in volume may be used for collection of fissionable materials provided that it is less than 5 centimeters deep.

Normal operations only require the Hanford "standard" 0.5 liter slip-lid can for collection of materials. However, no distinction in container type is made.

- Up to 2 liters total combined volume of containers for collection of fissionable material is permitted.

Volume is limited due to the considerable fissionable mass that is permitted in the glovebox.

- Up to a maximum of 1 liter of non-fissile liquids may be present in the glovebox.

Up to 1liter of non-fissile liquids, such as lubricants is permitted for routine maintenance and cleaning operations.

- The Criticality Safety Staff shall validate the glovebox mass prior to implementing this limit set.

This step provides a defense-in-depth verification of the total glovebox inventory.

Process Controls:

- Rags up to 6 square feet total area are allowed for cleaning purposes
- Strippable paints or coatings may not be used.

While strippable decontamination coatings may safely be used, this analysis does not permit their use, as the D&D process will not require them. Existing criticality analyses for the use of such coatings may be utilized, resulting in significant cost savings in the development of criticality controls.

- Introduction of additional fissionable material is not allowed.
- Equipment with void spaces larger than 4-liters total volume shall be covered or configured to preclude liquid accumulation.

Covering or turning over (or other appropriate configuration) equipment with larger void spaces will preclude collection of a potentially critical volume of solution.

- Fissile solution transfer lines shall be rendered incapable of delivering liquids to the glovebox undergoing cleanout (blanked, capped, cut, disconnected, etc.).

Leaks of uncharacterized fissile solutions could provide enough fissionable material to exceed the mass permitted.

Example Criticality Safety Limits for Characterization of Areas/Buildings Containing Unknown Quantities of Fissionable Materials

Reference: J.E. Ham, *Criticality Prevention Specification 224-T Process Cell Characterization Activities*, HNF-7794, Rev. 3, September 2002.

Prior to engaging in active D&D processes, it is necessary to determine the location and quantity of fissionable material within the facility or area. It is common for processes or buildings to be abandoned for years, frequently decades, prior to their planned D&D. Persons with actual firsthand knowledge of the process or facility, are often no longer available to consult about the potential residual inventory of fissionable materials, and it is not uncommon to encounter accumulations of fissionable material not previously discovered. This section establishes a reasonable set of limits and controls for the characterization of such facilities and processes. Additionally, the facility or project manager will need to develop response procedures for managing the discovery of unaccountable quantities of fissionable materials. This limit set example addresses the requirements and restrictions that are applicable to the NDA of areas with unknown quantities of fissionable material.

Refer to the original document for details, before attempting to implement these limits.

Areas with Unknown Quantities of Fissionable Material:

The following operations may be performed in accordance with approved work plans and/or procedures that incorporate the limits and process controls listed in this section for areas with unknown quantities of fissionable material. As always, specific technical guidance from the Nuclear Criticality Safety organization is an essential part of any such operation.

- Radiation and other monitoring
- Installation of radiation or other survey equipment
- Photography
- Neutron activation studies
- Sample swipes
- Installation of monitoring equipment
- Limited Sampling

The following limits provide an example of those appropriate to characterization activities in areas with unknown quantities of fissionable material:

1. Sensors smaller than a soda can are to be spaced 10 inches or more from any vessel larger than 3 liters in volume

2. Equipment larger than a soda can, including robots are to be spaced 24 inches or more from any vessel larger than 3 liters in volume

3. People are to be spaced nominally 3 feet, or more from any vessel larger than 3 liters in volume

4. A 2 liter or a smaller sized bottle of disinfectant or fixative are to be spaced nominally 3 feet or more, from any vessel larger than 3 liters in volume

5. Tanks and equipment known to have less than 450 grams of fissionable material do not have any spacing requirements associated with them

6. No material that can possibly be fissionable or reflective may be moved, rearranged, or otherwise disturbed in a process cell within 3 feet or less of a vessel larger than 3 liters

7. No water or oils may be introduced except as a lubricant for equipment, robots, or pumps

8. No fissionable material is to be introduced

9. Sweeping or dusting may accumulate materials into piles of 2 inches or less, or a volume of 3 liters or less prior to characterization

10. Liquid samples must be contained in volumes of 4.7 liters or less than 5 inches in diameter

11. Silt samples shall be in containers of less than 0.5 liters

12. Vacuums may be allowed with special limits (see original document).

6.0 Non-Destructive Analysis (NDA)

NDA Activities must be Coordinated to Minimize Rework, Personnel Exposure to Additional Risk, and Program Inefficiencies.

The NDA measurements that are taken to support criticality safety, can impact other facility activities, not directly related to criticality safety. Sites have learned that multiple NDA measurements are made throughout the D&D process to support criticality safety. The measurements are often made using different methods with different equipment at different times, (e.g., during waste packaging, waste certification, etc.) and therefore, can result in different NDA values for basically the same material. The different values tend to cause confusion, additional work, and risk (e.g., repackaging material, processing non-conformances, etc.). Therefore, NDA activities and measurement results need to be thoroughly understood and coordinated with each other and with other D&D activities.

As an example, RFETS used three NDA methods that consisted of operators in the field using portable hand held devices (see Figure 4); subcontractors in the field using mobile cart mounted equipment (see Figures 2 and 3); and operators at a remote site performing waste certification for Waste Isolation Pilot Plant (WIPP) using a large stationary NDA device. Inefficiency is encountered when field NDA values differ from remote NDA values. When the remote NDA value is greater than the field NDA value and they exceed the criticality safety limit, a nonconformance is declared and the associated package is transported to a designated area for repacking (i.e., material in the original package is split between multiple packages). The repackaging activity exposes workers to additional risk and is an inefficient way to operate.

However, if during original material packaging, operators do not place enough material into a package, inefficiencies are also introduced (e.g., more packages are required, additional handling of material, etc.). Therefore, in order to minimize the number of boxes (see Figure 1) and drums required to be repackaged and still allow the greatest amount of material to be placed in a box or drum, NDA activities and measurement results must be thoroughly understood and coordinated. In order to balance the two objectives it is necessary to track the number of items requiring repackaging and make adjustments (e.g., add correction factors to field values, evaluate and modify NDA methods and models, change equipment, etc.) until accurate values are obtained.

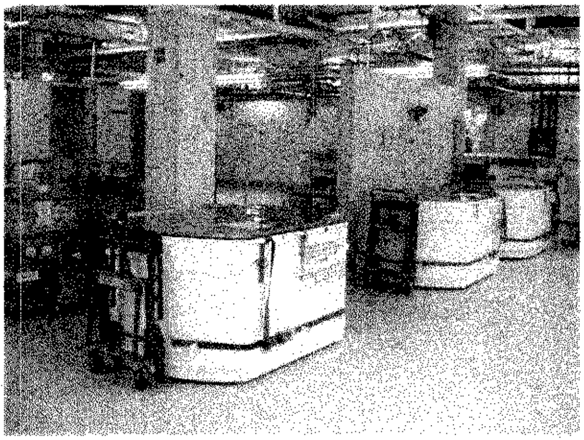
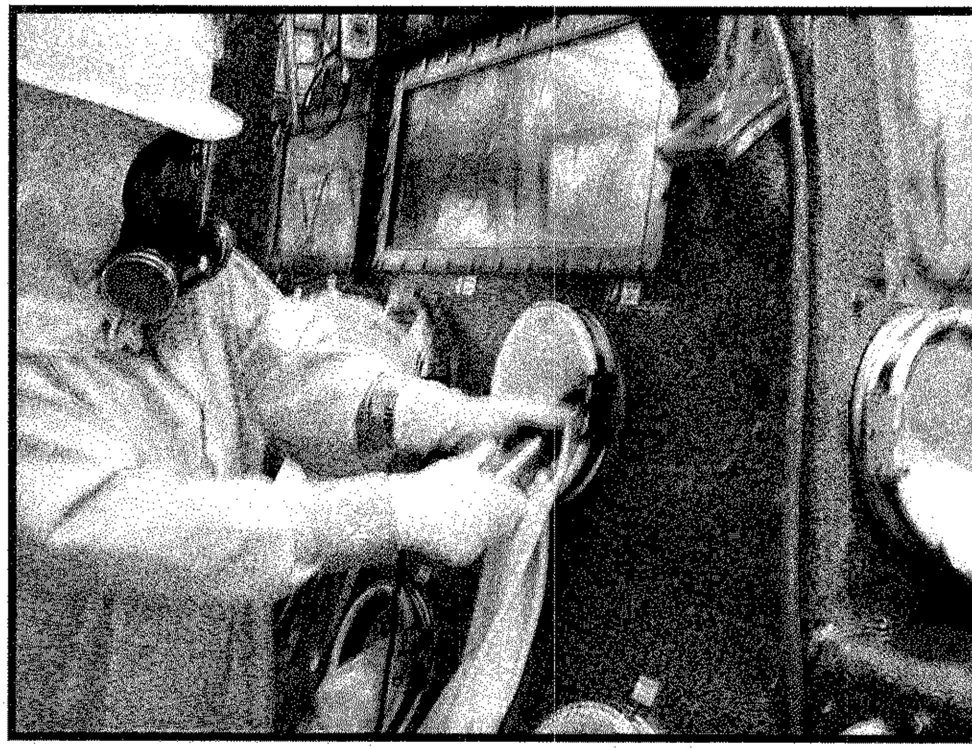


Figure 3: Standard Waste Boxes await disposition



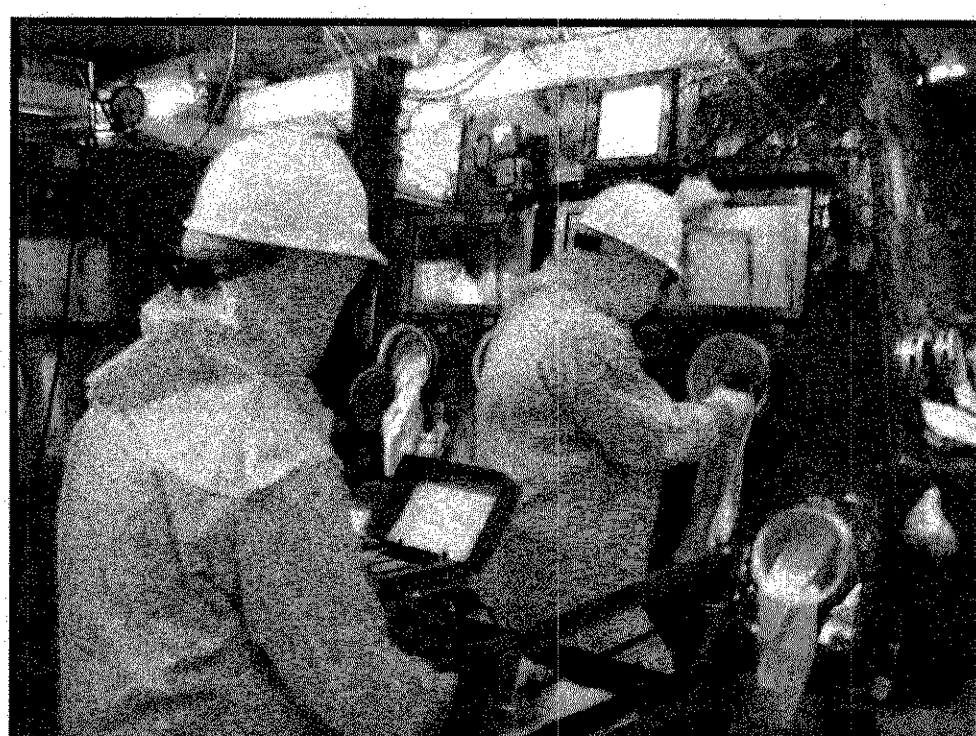


Figure 4: Workers perform an NDA measurement.

Figure 5: NDA equipment mounted on the cart.

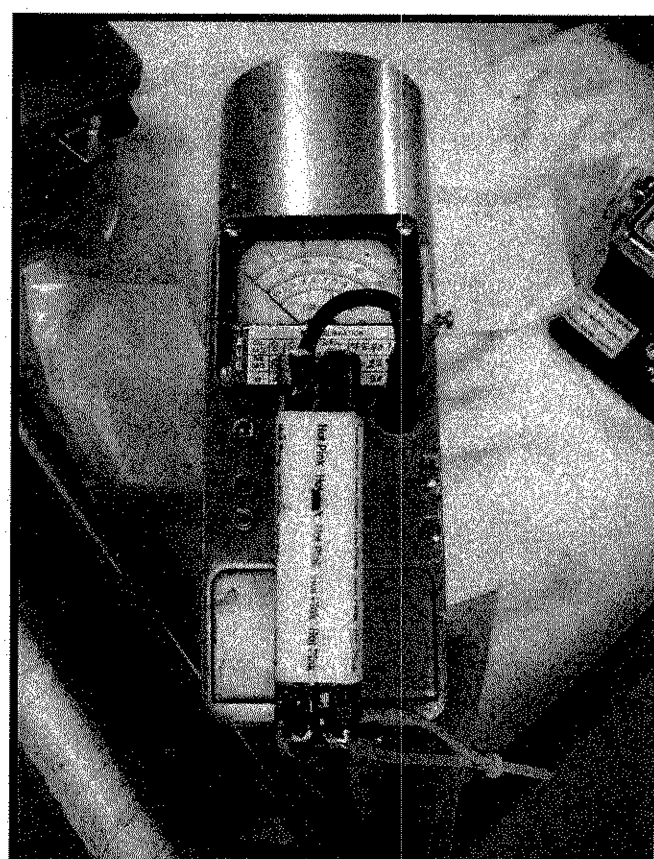


Figure 6: A hand held Ludlum 12-12 NDA instrument.

Management Must Ensure that Personnel are Adequately Trained to Understand the Differences in and use of the Various NDA Numbers Generated During D&D Activities

Management must ensure that personnel are adequately trained to understand the differences and use of numerous NDA numbers generated during D&D activities. The NDA values are generated for different reasons (e.g., Safeguards and Security, Criticality Safety, planning, etc.) and are provided in different formats. Often NDA generated information does not have the pedigree required for criticality safety controls (e.g., two-sigma, 95 percent confidence values) and therefore cannot be used in criticality safety programs. If personnel do not understand the different uses of NDA numbers, problems can and do occur as evidenced at RFETS. The following three occurrences are provided as lessons learned.

RFO-KHLL-PUFAB-2002-0054:

On September 20, 2002, personnel were reviewing data sheets for a waste drum. From NDA scan sheets associated with items in the drum it appeared that the drum was loaded with more than the 200 grams allowed by the criticality safety limit. The traveler for the drum was obtained and reviewed with the NDA scan sheets. From the review, it was determined that the drum was loaded with 270 grams of material. However, the traveler only indicated a value of 194 grams because it was based on nominal scan values, not the 95 percent confidence numbers required by the criticality safety limit.

Prior to items being placed in the drum an NDA group had scanned the items and determined assay values. However, the D&D crew did not have the scanned values when they loaded the drum. Instead, the crew foreman obtained values from a manager who had an e-mail that listed values; however, the e-mail that the manager was referencing was issued only to address Nuclear Material Control requirements for total allowed amounts of attractiveness level C and D material and not for packaging use. Nuclear Material Control requirements are based on nominal scan values. The D&D manager assumed that the values in the e-mail were the 95 percent confidence values and instructed the D&D foreman to use them for packing the material.

During the loading of the drums, the D&D foreman and the employees erred in not ensuring that the required 95 percent confidence values were used for the material being packaged. The crew assumed that information provided to them by the D&D manager was correct and failed to verify it through the required documentation. The D&D manager erred when he provided the D&D crew with the incorrect gram assay values.

The foreman initially questioned the use of the assay values received; however, the manager assured him that they were correct. The D&D manager erred in his failure to adequately understand the intent of the question and assure that his reply was correct, which contributed to this occurrence. If the D&D manager pursued the question on the use of the provided assay numbers, he potentially would have discovered that the direction given to the crew was inadequate and the correct assay values would have been obtained.

Corrective actions included:

- review the incident with all D&D foremen and briefing all D&D crews to ensure they verify 95 percent confidence numbers for packaging;
- modify the NDA Scan Sheet to better label the column containing the 95 percent confidence numbers used for packaging; and
- ensure that procedures provided adequate direction for use of correct gram estimation values, and that values are adequately documented for criticality safety purposes.

Management must ensure that personnel are adequately trained to understand the differences and use of multiple NDA numbers generated during D&D activities. NDA values are generated for different reasons (e.g., Safeguards and Security, Criticality Safety, planning, etc.) and are provided in different formats. Often the information generated does not have the pedigree required for criticality safety controls (e.g., two-sigma, 95 percent confidence values) and therefore cannot be used in criticality safety programs. If personnel do not understand the differences and use of NDA numbers, problems can occur.

RFO-KHLL-PUFAB-2002-0056:

On October 7, 2002, RFETS management was notified that NDA measurements of a SWB exceeded the 325-gram limit. The NDA scan indicated that the SWB contained 695 grams (two-sigma, 95 percent confidence number).

Review of the gram estimation source document for the SWB revealed that waste had not been properly gram estimated when loaded. The waste packaging crew foreman obtained NDA values from an NDA Summary Holdup letter for the building. The information used by the foreman was entitled "Max Grams/sq. ft." The foreman mistakenly read this to be the total gram value assigned to the glovebox. A verifier in the process checked the numbers entered on the waste traveler, but only verified that it was under the gram limit, not that it was correct or accurate.

Corrective actions included:

- revise an operations order (written to provide guidance to waste teams on gram estimation) to require that any missing or unclear information regarding 95 percent confidence be immediately brought to the attention of management prior to packaging the item;
- establish an independent review process for waste packages;
- assign one or two individuals from each crew to be "experts" for the gram estimation process (Assigned experts received enhanced waste process training that included methods and process for gram estimation, responsibilities, and independent verification);
- add Transuranic (TRU) waste experts to a technical response team, and have them available to respond to questions from waste teams as they perform work; and
- assess work crews to ensure training was completed and understood.

RFO-KHLL-PUFAB-2002-0057:

On October 16, 2002 a drum containing TRU waste was shipped from Building 707 to Building 569 to be assayed. On October 18, 2002, Building 707 Facility Management was notified of a potential non-compliance with the assumptions of the facility AB. The drum contained Material at Risk that exceeded 250 grams of Weapons Grade Equivalent (WGE) Plutonium (Pu). The drum was packaged by D&D workers, and was transferred from Building 707 to Building 569, for assay on October 16, 2002. The assay results determined that the drum contained 300 grams WGE Pu, which exceeded the 250 grams WGE Pu assumed in the Building 707 Decommissioning Basis for Interim Operation accident analysis.

The direct and root cause of the drum being over packed was attributed to personnel error, and inattention to detail by the D&D worker, whom performed the gram estimation of the packaged material that was placed into the drum. During the drum packaging process, several of the items that were placed into the drum had gram estimations performed on them by a D&D worker using "LUDLUM 12-12 GRAM ESTIMATING" under procedure PRO-552-GRAM. During the gram estimation process, the D&D worker erred in his performance of the estimations, which allowed for the drum to be loaded in excess of the 200 gram packaging limit per procedure PRO-4-D99-WO1100. With the inaccurate gram estimations listed on the drum traveler, the drum was transferred across the 707 dock, which exceeded the analyzed 250-gram Authorization Basis limit for Building 707 dock. During gram estimating under PRO-552-GRAM many packages of materials had been correctly and conservatively gram estimated. The procedure has limitations on which materials can be gram estimated and incorporates multiplication factors into the final estimation values that are obtained in attempt to achieve a 95 percent confidence value for the materials. Due to the worker who performed the gram estimation permanently leaving the site prior to the completion of this occurrence report, it can only be surmised that the employee either failed to follow the LUDLUM 12-12 Gram Estimating procedure or failed to place the correct gram estimations onto the Estimated Pu Gram Worksheet.

Corrective actions included:

- Develop and give a briefing on Gram Estimations to the D&D personnel. The purpose of the briefing is to describe the methods available and the process for gram estimation of TRU and TRU mixed solid waste, and to ensure that waste containers remain within the authorized criticality safety limits for fissile materials; and
- D&D Management handpick a limited group of personnel that will be allowed to perform the Ludlum 12-12 Gram Estimations; these individuals were provided additional training on the estimation process. Additionally, D&D Management has limited the use of the Ludlum 12-12 gram process and initiated the use of more specific procedural processes as additional methods to reduce the potential for packages to be over packed.

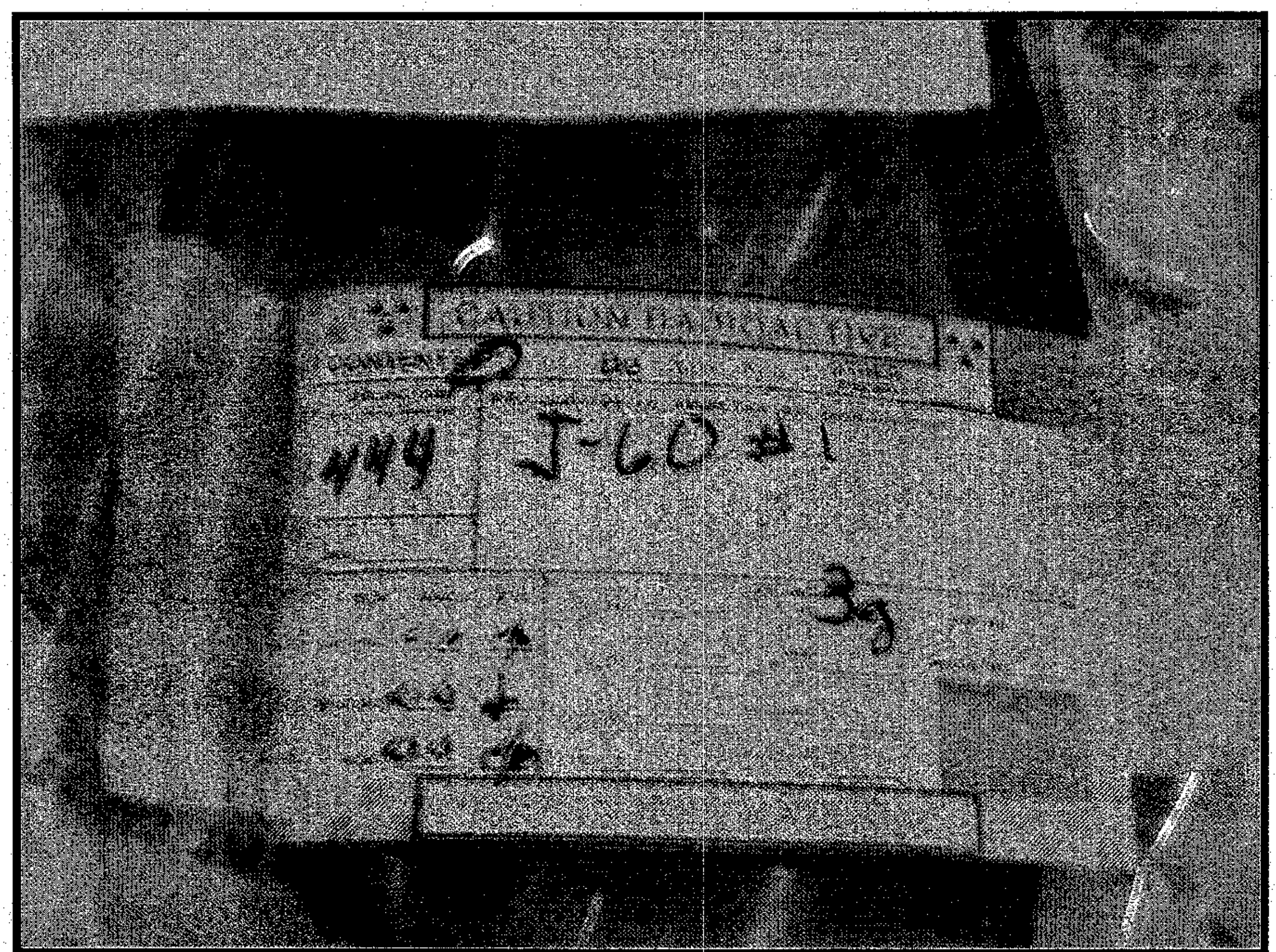


Figure 7: A typical packaging label that identifies the gram values from the NDA.

7.0 General Lessons Learned for NDA Use

NDA procedures must contain appropriate rigor and specificity

NDA procedures must contain the rigor and specificity to ensure repeatable performance and provide a record of work performed. Processes controlling NDA must include Quality Assurance expectations concerning the application of standards-based processes, peer review of calculations, and appropriate use of standards spanning the range of measurements. The technical basis for NDA applications must be adequately established.

Procedures must document the process in sufficient detail to ensure repeatability and ensure that NDA activities may be completed without close supervision and oversight by the scientists themselves.

Adequate measurement controls must be in place for instrumentation. Measurement of a standard should be completed daily, and checks of resolution and energy calibration should be completed and tracked as part of this measurement. The suggested regular performance tests described in ASTM E181-98 for NaI and HPGe instrumentation should be added to NDA practices.

NDA Equipment must be appropriate for the type of measurement being performed

The portable NDA equipment used at a Hanford facility was discovered to not be technically capable of determining whether material was TRU or non-TRU. The use of standards for calibration of portable detectors to determine whether an item is TRU or non-TRU must meet best practices. The use of standards that were normally much higher in Pu content (appropriate for supporting safeguards measurements) than appropriate for the low values that mark the TRU/non-TRU criteria contributed to this problem.

Reported measurement uncertainties should include more than the statistical uncertainty

Reported measurement uncertainty should not just include the statistical uncertainty. Facilities should evaluate the use of bounding conditions on distance measurements, material assumptions, isotopics, etc… so that the "most" and "least" reported NDA values could also include these uncertainties. Also, some uncertainties, such as calibration factor uncertainty, could be added and propagated with the counting statistics uncertainty. Conforming to standard practices involves propagating more than the counting statistics for uncertainty measurement (See section 11 of ASTM E181-98 or section 5.5 of ANSI N15.20 for a list of potential error sources and their typical contribution to total measurement uncertainty). Every effort should be made to include the mean and standard deviation values in reported results. (Often the NDA characterizations provide a very conservative bounding value and semi-quantitative discussions of uncertainties, but no mean or best estimate). This is important not only for NCS, but also for authorization basis reasons (e.g., proper estimation of release in case of fires, taking account of uncertainties).

NDA equipment must be appropriately calibrated after maintenance, repair, or movement

Requirements should be specified for calibration verification after maintenance, repair, or movement of the NDA system. To conform to common practices, the calibration should be verified when such activities are completed. Procedures should specify such a requirement. Additionally, procedures should specify a requirement for the use of the same filters for calibration and for assay.

Additional requirements for NDA Programs

1) Facilities need trained NDA staff familiar with the waste forms and fissile material processes that produced the waste forms;
2) NDA staff must understand the pitfalls of the various measurement techniques and equipment;
3) All waste packages and containers must be assayed/measured at the time of initial packaging with appropriate allowances for bias and uncertainty;
4) Where possible, facilities should incorporate the use of both gamma and neutron assay capability as there is no single method that is universally accurate.

8.0 Criticality Safety Detection and Alarm Systems

Programs and Procedures should be in Place to Establish Compensatory Measures for Criticality Accident Alarm Systems in Temporary High Noise Areas Created During D&D Activities

Criticality Accident Alarm Systems detect excessive radiation indicating that a criticality accident has occurred. The system alerts personnel within the coverage area with an alarm that will prompt timely evacuation, thus limiting radiation exposure. However, during D&D activities there is a real potential for sustainable high noise areas that can prevent audible alarms from being heard. Noise generated during D&D activities, come from equipment not commonly used during the operational phase of the facility. Such devices include nibblers, reciprocating saws, air chisels, pump operations, powered vehicles, jackhammers and etc. ANSI/ANS-8.3-1997, Section 4.3.8 states, "In areas with very high audio background or mandatory hearing protection, visual signals or other alarm means should be considered."

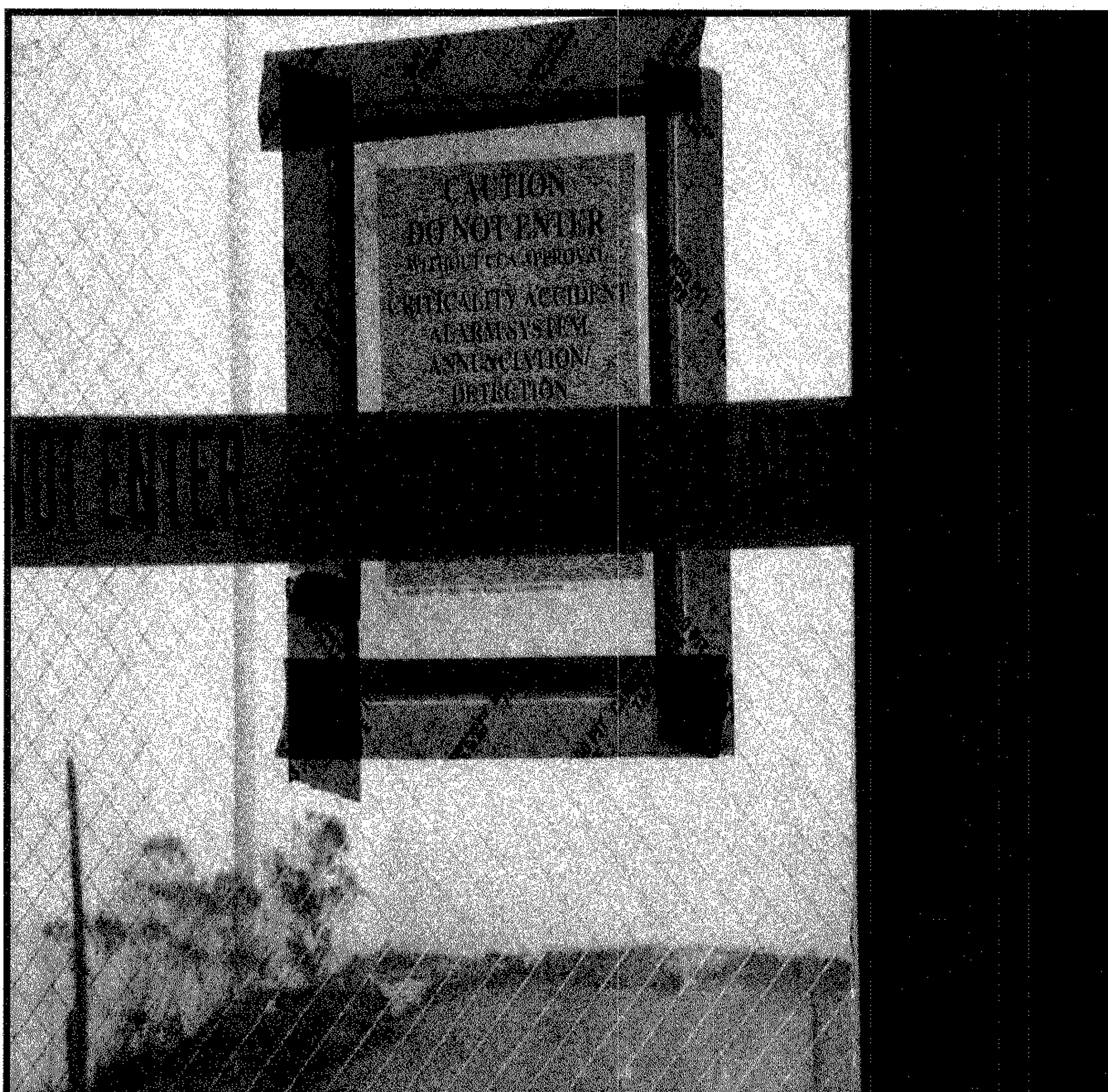
Thus, inadequate alarm annunciation requires compensatory measures to be taken. Compensatory measures identified below have been used successfully in the past at RFETS:

- **Radio Headsets** - To receive alarm signals (see Figure 6)
- **Wireless or Wired Two-Way Headsets** – These are used to communicate between a dedicated notifier and a worker in an effected area
- **Noise Cancellation Headsets** – These headsets provide hearing protection and amplify certain frequencies of sound (e.g. voice, alarms). Headsets compensate for high noise only.
- **Dedicated Teams** – Team size is limited to a maximum of six and must be documented on a roster. Each team will have a dedicated notifier, who has the single function to notify the team, of the need to evacuate.

Procedures and programs should contain requirements for evaluating high noise readings for CAAS compensatory measures for the affected area, posting rooms and HVAC plenums when inadequate alarm annunciation exists (see Figure 7), instructing personnel on the correct use of compensatory measures, announcing the initiation of temporary high noise activities, ensuring compensatory measures are in place during the entire job, and training of personnel.

Figure 8: A radio headset that enables workers to hear the criticality safety alarm in high noise areas.

Figure 9: A CAAS deficiency posting.



Example Technical Safety Requirement (TSR) Administrative Control for Inadequate Criticality Accident Alarm System (CAAS) Audibility or Annunciation (Rocky Flats Environmental Technology Site):

5.7 Inadequate CAAS Annunciation

Implement Nuclear Criticality Safety Manual compensatory measures prior to entering areas with inadequate CAAS annunciation.

Applicability: These requirements are applicable to areas with inadequate CAAS annunciation.

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. AC 5.7 requirements for inadequate CAAS annunciation are not met.	A.1 Correct the deficient CONDITION. **OR** A.2 Conduct a controlled evacuation of the AFFECTED AREA. **OR** A.3 SUSPEND OPERATIONS in the 371/374 COMPLEX.	IMMEDIATELY 2 hours 2 hours

SURVEILLANCE REQUIREMENTS:

None Required

BASES:

AC 5.7	Requirements for criticality notification hardware (i.e., LS/DW speakers, criticality beacons) and inadequate CAAS annunciation postings are covered by LCO 3.4. ADMINISTRATIVE CONTROLS for inadequate CAAS annunciation areas (e.g., compensatory measures that permit access) are covered by AC 5.7. AC 5.7 ensures that workers entering an inadequate CAAS annunciation area have an approved method of notification and are prepared to respond (evacuate) if a criticality occurs. The compensatory measures in the Nuclear Criticality Safety Manual use alternate detectors or notification methods that are considered adequate to notify workers of a criticality.
ACTIONS A.1, A.2, and A.3	If the LS/DW System does not meet audibility requirements and a criticality beacon is not visible, the CAAS cannot reliably notify workers of a criticality. The CAAS annunciation capability may also be inadequate as part of a permanent CAAS audibility/visibility non-compliant configuration. If it is DISCOVERED that the AC 5.7 required compensatory measures are not met by personnel in the AFFECTED AREA, the facility shall either correct the

deficiency or conduct a controlled evacuation of the AFFECTED AREA or SUSPEND OPERATIONS in the 371/374 COMPLEX.

If AC 5.7 requirements for the inadequate CAAS annunciation CONDITION are not met, ACTION A.1 requires IMMEDIATELY correcting the deficient CONDITION associated with the AC 5.7 requirements. Correcting the deficiency in a timely manner re-establishes compliance with AC 5.7. However, entry into CONDITION A must be documented as part of AC NONCOMPLIANCE tracking and trending under TSR 3.0.4.

If AC 5.7 requirements for the inadequate CAAS annunciation CONDITION are not met, ACTION A.2 requires conducting a controlled evacuation, removing workers from areas where the CAAS annunciation capability is degraded. During or following evacuation of the AFFECTED AREA, if AC 5.7 compensatory measures are re-established, the evacuation requirement can be removed. The evacuation of the AFFECTED AREA ensures that personnel in the 371/374 COMPLEX are only located in areas where they can

(continued)

BASES:

ACTIONS A.1, A.2, and A.3 (continued)

be informed that a criticality event is occurring if they do not have compensatory measures implemented. The 2-hour COMPLETION TIME was selected as a reasonable amount of time to notify workers in the AFFECTED AREA, to place any work being conducted in the area in a safe configuration, and then to exit the area.

If AC 5.7 requirements for the inadequate CAAS annunciation CONDITION are not met, ACTION A.3 requires SUSPENDING OPERATIONS in the 371/374 COMPLEX. As above, if AC 5.7 compensatory measures are re-established, the SUSPEND OPERATIONS ACTION does not need to be performed. The REQUIRED ACTION to SUSPEND OPERATIONS ensures that activities that could lead to a criticality event are not performed while areas exists in the facility that do not have an OPERABLE CAAS. The adequacy of this REQUIRED ACTION is based on a documented determination by Criticality Safety (Reference 22) that a criticality event is incredible while operations are suspended. The 2-hour COMPLETION TIME was selected as reasonable to notify workers and SUSPEND OPERATIONS.

CAAS Detector Placement should be Evaluated Prior to the D&D Process to Ensure Changes do not Adversely Affect Coverage

When criticality safety equipment is planned to be moved or covered to protect it during D&D activities, or if large pieces of equipment (e.g., glove boxes, tanks, etc.) that could affect the function of the CAAS are moved or staged, it is imperative to engage the criticality safety organization to ensure the function or performance of the criticality safety equipment will not be degraded. DOE O 420.1A invokes the ANSI/ANS-8.3-1997 Standard "Criticality Accident Alarm System" requirements. These requirements must be carefully considered during the D&D process to ensure continued compliance.

Procedures should contain requirements to review the impact on CAAS coverage for D&D activities. The criticality safety personnel must work closely with operations in planning work, and they should be aware in advance of any planned changes that could affect the CAAS coverage. An annual review of CAAS coverage should also be performed.

Reference: RFETS Joint Criticality Safety Program Assessment, FY02-070-KHAP, March 2002

Example "Step-out Criteria" that Defines when Criticality Accident Alarm Systems (CAAS) are no Longer Required (Rocky Flats Environmental Technology Site).

Discontinuation:

Ultimately, the Criticality Accident Alarm Systems must be shut down and removed. Therefore, the TSR Applicability statement also contains criteria for when the requirements can be discontinued. The requirement for an OPERABLE Criticality Accident Alarm System may be discontinued when a criticality is determined to be incredible by a DOE approved Criticality Safety Evaluation. The requirement for annunciation (audible or visual) may be discontinued in an AFFECTED AREA when the maximum foreseeable absorbed dose in free air will not exceed 12 Rad.

9.0 Conduct of Operations

During D&D Activities, Equipment Performance May be Compromised in Unique Ways as Evidenced at RFETS when a CAAS Detector Head Cord was Inadvertently Damaged by Movement of a Fork Truck

During D&D activities it is important to ensure that CAAS components are protected from damage. During D&D new and unique ways of damaging equipment present themselves as evidenced at RFETS when a detector went into trouble alarm when the detector cord was inadvertently pulled out of the detector head during movement of a fork truck from its charging station.

The worker operating the fork truck was trained and qualified, and because he was aware that the charger and a few small items were directly behind him, a spotter was being utilized at the right rear side of the fork truck. The spotter's main concern was focused on the items directly behind the fork truck. The driver was also aware that the alarm boxes were directly on the front side of the fork truck and he was watching carefully so as not to hit the boxes when pulling away from the wall. However, he failed to notice that a detector cord was hanging down about 12 inches between the alarm boxes. The cord was the same thickness and color as the guard around the fork truck light. As the worker pulled away from the wall, the fork truck light guard caught the cord, pulling it out of the detector. (see Figure 8 and 9)

A non-conservative decision was made when the fork truck was permanently relocated to the subject area for storage and charging. A Standard Work Package was utilized and a walkdown was performed prior to moving and relocating the equipment. It was determined that Industrial Hygiene and Safety was not involved in the move and obstructions were not adequately evaluated prior to placing the fork truck in the subject area. Subsequent to the event, the facility management evaluated the need for a protective shield to be placed over the detectors and relocating the fork truck storage and charging station to another area.

During D&D new equipment, tools, and machinery are used. In addition, activities once never thought of during operation will occur. Therefore, facilities must be diligent in evaluating their impact, specifically on the CAAS. The evaluation process should include specific triggers that will require evaluating CAAS impacts. Impacts that should be evaluated include but are not limited to attenuation of radiation to detector heads, damage to equipment and components, potential inadvertent activation of equipment, inaudibility of alarms, blockage of beacons, and inadvertent removal of equipment.

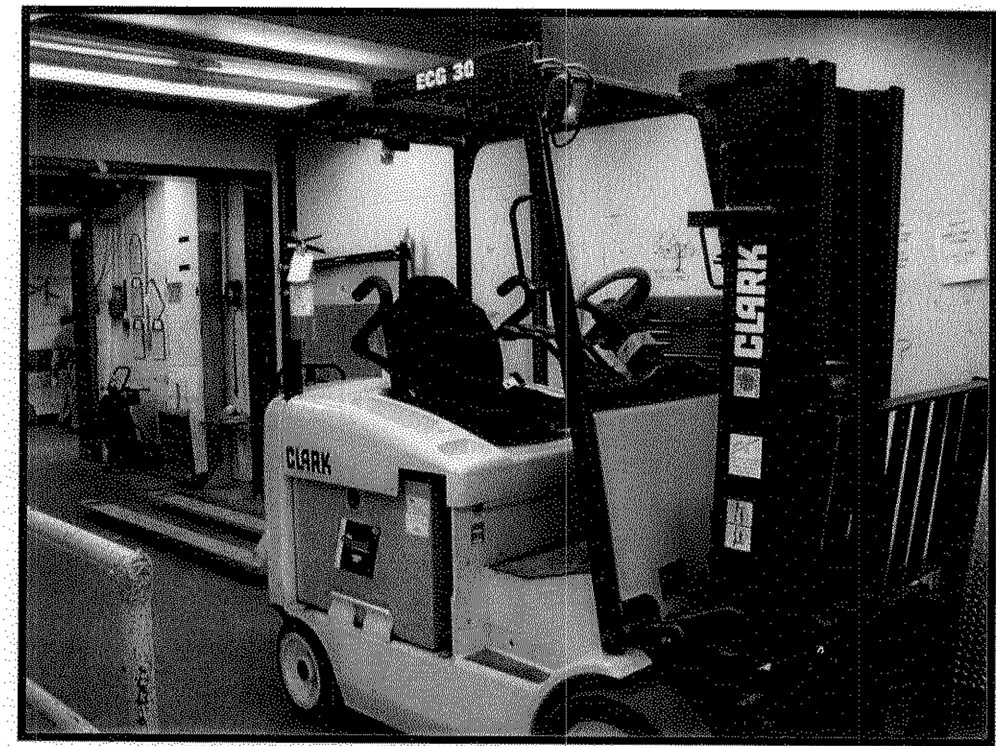


Figure 10: Fork truck that was involved in the occurrence.

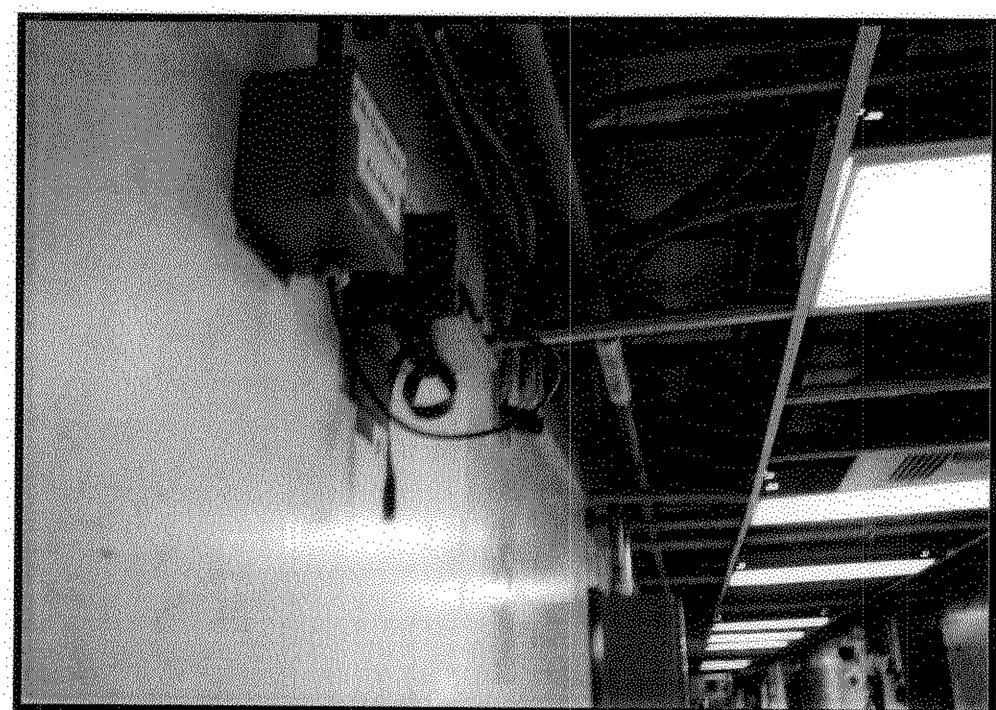


Figure 11: A CAAS system that was damaged.

During D&D Activities Equipment Performance May be Compromised in Unique Ways as Evidenced at Hanford when a Criticality Alarm System was Inadvertently Activated by a Pipe-fitter and Modifications to the Criticality Alarm System were Made without the Knowledge of Criticality Safety Personnel

Although the following event, Occurrence Report RL-PHMC-PFP-2001-016, occurred during construction rather than D&D, the lessons learned are very much applicable to today's world of D&D in the DOE complex.

On April 5, 2001, the Criticality Alarm System was inadvertently activated. Plant personnel evacuated the facility per plant response procedures. Construction personnel indicated that they had inadvertently struck a conduit run from one of the criticality alarm system detectors in Room 642 of Building 2736-ZB immediately before the alarm. All radiological surveys were negative, indicating no criticality had occurred. Subsequent investigation found the alarm was inadvertently activated by a unique combination of conduit placement and interaction with a drill being used in close proximity by construction personnel.

The pipe-fitter who inadvertently struck the conduit with his arm just prior to the alarm was trying to install a 12" x 12" half-inch steel plate to the wall directly behind and slightly above the first criticality detector junction box. This activity involved drilling four anchor holes in the concrete wall using a roto-hammer drill powered through a "white-box" (Drillco DS-69A, a safety device designed to interrupt power to the drill if the bit contacts conduit or rebar embedded in the concrete). He was drilling a hole when he accidentally bumped the criticality detector junction box causing the horizontal conduit to separate from its fitting, leaving a half-inch gap between the conduit and the fitting. He stopped work, laid the drill on top of the plywood detector enclosure, stepped off his ladder and walked away. At this point, the criticality alarm sounded.

The impact this event had on the facility was substantial, in that all facility personnel were evacuated for several hours, and due to the extended operation of criticality horns, approximately 30 horns required repair/replacement.

As part of the investigation of this event, additional unauthorized or poorly controlled work activities were identified:

- On April 6, 2001, facility personnel found that a plywood box had been built over criticality detector set Z9-1 in Room 642 of Building 2736-ZB as a construction barrier. The shielding effect of this material on the performance and function of the detectors had not been reviewed by Criticality Safety personnel prior to its installation. Follow-up calculations performed by the Criticality Safety Representative and a Criticality Safety Engineer confirmed that the barrier did not adversely impact the operability of the detectors.
- During retest of the Criticality Alarm System April 6, 2001, Criticality Alarm Horn Z7-14 was found to have been re-positioned when fall protection railing was installed on the roof of Building 2736-Z by construction personnel. This

unauthorized modification resulted in the horn being "inoperable" (i.e. - it could not be heard by a stationed observer).

- The following are Lessons Learned from this event ("D&D" can be substituted for the word "construction" throughout):
- Construction activities require diligent tracking of specific tasks being performed and communication between crafts, supervision, points-of-contact, and engineering to minimize risk to existing equipment and systems. Vulnerability of systems, especially safety systems such as criticality alarms, must be assessed before, during, and after construction activity.
- To strengthen control and allow closer oversight of construction work activities, establish early in the project a mechanism for review and approval of construction activities on a daily basis. This mechanism should include review and approval by a facility project coordinator and the associated construction superintendent. Any deviations to the approved work plan should require approval by representatives of the same entities that originally approved the plan.
- Facility hazards and areas of active system interface concern should be highlighted on the daily activity plan. This information should be used in the morning pre-job meeting to inform crafts of areas of concern. In addition, if additional activities were planned during the day over and above what was authorized, they should receive the same scrutiny as the ones identified earlier and could include additional briefings on areas of concern.
- When criticality safety equipment is planned to be moved or covered to protect it during D&D activities, or if large pieces of equipment (e.g., glove boxes, tanks, etc.) that could affect the function of the CAAS are moved or staged, it is imperative to engage the criticality safety organization to ensure the function or performance of the criticality safety equipment will not be degraded.
- Modifications to existing active systems should be scheduled as early in the project as feasible, to minimize potential damage or inadvertent activation during construction activities. For example, if it were known that before the project was to begin, that the criticality detectors needed to be moved, then this would prevent construction workers from having to work around active detectors for several months. If the detectors were moved early in the project activity, problems identified in Occurrence Report RL-PHMC-PFP-2001-016 may be avoided.

Simultaneous D&D of Adjacent Facilities can Create Configuration Control Challenges as Evidenced at RFETS when a Criticality Detection Head for an Operating CAAS was Inadvertently Removed when an Adjacent Facility's System was being Deactivated

During D&D activities facility configuration control is still a vital aspect of plant operations. The controls can become difficult during D&D when equipment is shared between facilities or there exists unique interfaces. Because of a unique interface and other contributing causes (e.g., inattention to detail) an active criticality detector head was inadvertently removed. Specifically, the following event occurred at RFETS:

On February 13, 2003, a criticality detection head for the Building 707 criticality annunciation alarm system was inadvertently disconnected. Technicians were removing detection heads from Buildings 776/777 because a Criticality Incredibility Study indicated that they were no longer required; however, the technicians inadvertently disconnected a Building 707 detection head because it happened to be physically located in Building 777. Building 707 and Building 777 are adjacent buildings connected by a corridor. The detection head was reinstalled back to its normal configuration (see Figure 10)

The event emphasizes the need to ensure that unique interfaces are well known, understood, and controlled. As presented elsewhere in this document, the use of unique identifiers and markings (e.g., red flags) on all active equipment might have prevented this event.

Figure 12: Door separating Building 707 and Building 776/777 with detector mounted just behind. Detector for Building 707 (mounted in Building 776/777) that was inadvertently removed.

During D&D Activities, the Electrical Configuration of a Facility is Under Constant Change. It is Therefore Essential for Management and Personnel to be Cognizant of Electrical Loads in Order to Maintain Operability of Credited Safety Systems as Required by the Authorization Basis.

During D&D activities the electrical configuration of a facilities are under constant change. It is therefore essential for management and personnel to be aware of electrical load limits in order to maintain operability of credited safety systems per Authorization Basis requirements. Loss of electrical system configuration can occur as evidenced by the following event at RFETS.

RFO-KHLL-771OPS-2002-0022:

On December 22, 2002, an electrical breaker tripped resulting in a two hour and twenty minute loss of power to a building CAAS panel. During the outage the battery backup activated and powered the panel; however, CAAS Criticality Beacons were rendered inoperable because of a lack of battery backup power. This resulted in CAAS annunciation not being available per Technical Safety Requirements.

The CAAS system shared a breaker with several other loads including heaters. Maintenance and electrical personnel checked and verified that the system could support all known loads. However, over time additional loads were added to the system that exceeded the trip point of the breaker. Personnel responsible for the system were not cognizant of the additions.

Banks of portable heaters were being powered through the subject breaker. Maintenance and electrical personnel monitored and regulated the loads on the breakers as much as possible, to maintain proper amperage. Two days prior to the event, management approved the use of an additional portable heater (for the day) in an abandoned maintenance shop. When the heater was plugged into the system, the breaker maintained the load with no problems. The additional heater was to be unplugged at the end of the day; however, it was overlooked and was left plugged in over the weekend. During the night, the weather turned cold and the original banks of heaters, plus the additional heater in the old maintenance shop, cycled "on" at the same time and overloaded the system.

A review of this event determined that the breaker had not tripped when the additional heater was initially plugged in because the weather was warmer and the original banks of heaters had not yet cycled to "on" and overloaded the breaker.

During D&D activities, the electrical configuration of a facility is under constant change. It is therefore essential for management and personnel to be aware of electrical load limits in order to maintain operability of credited safety systems per Authorization Basis requirements.

Unique Markings can Help Protect CAAS Equipment and Components from Damage and Inadvertent Removal During D&D Activities

DOE sites have found that the use of unique identifiers on CAAS equipment and components during D&D activities have helped to prevent equipment damage and inadvertent removal. Facilities have implemented the use of Red Flags and specific paint schemes to warn personnel that the equipment and components are active and requires protection (see Figure 11, Figure 12, and Figure 13). Facilities have also used a process where Green Flagged structures, systems, and components can be removed. Facilities have also found it important to move criticality detectors to solid substantial mounting surfaces such as columns and solid walls during D&D activities. Criticality detectors have alarmed because of substantial vibration experienced during D&D such as with the use of impact devices and dropped equipment.

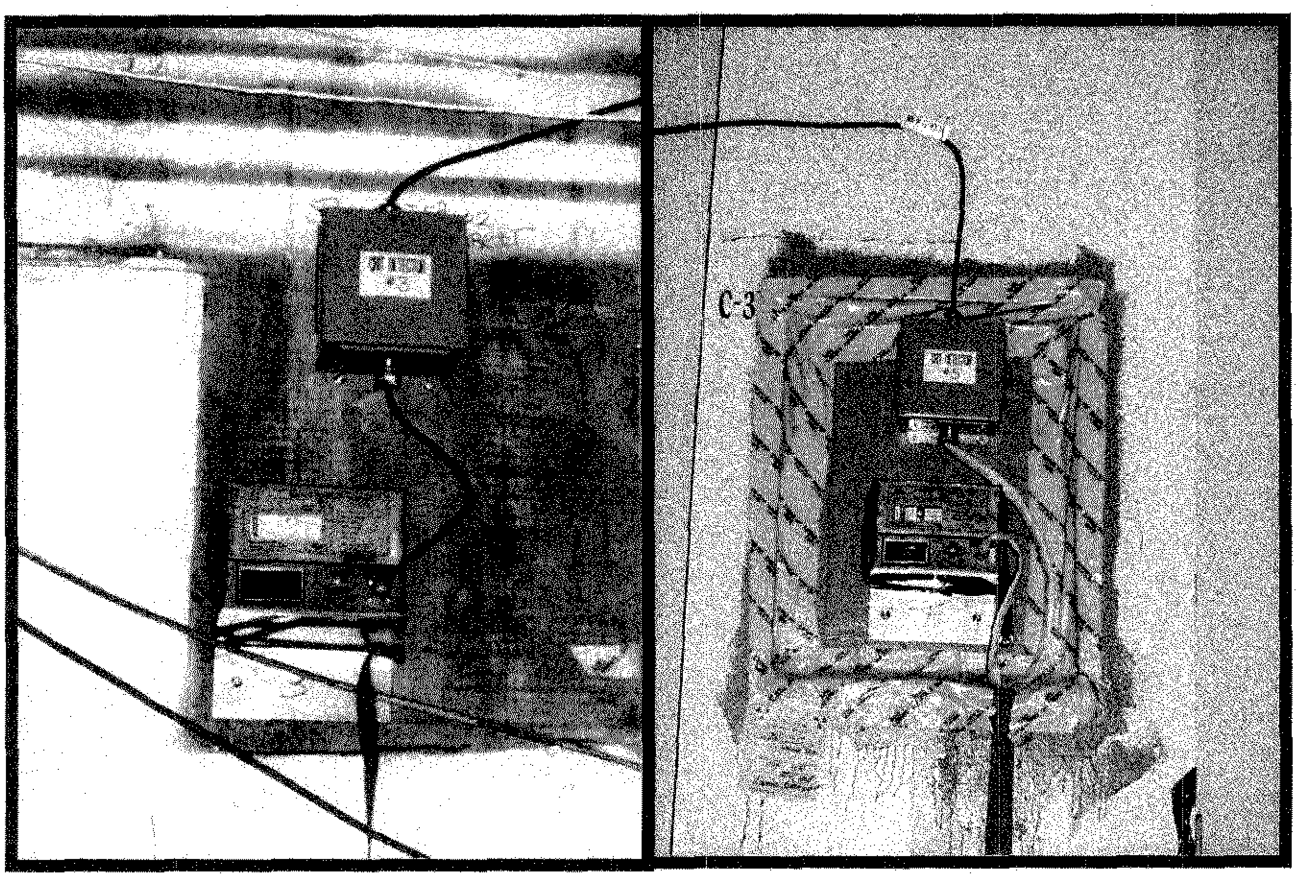


Figure 13: Criticality detectors at Rocky Flats mounted on solid surfaces with unique identifiers (red flags).

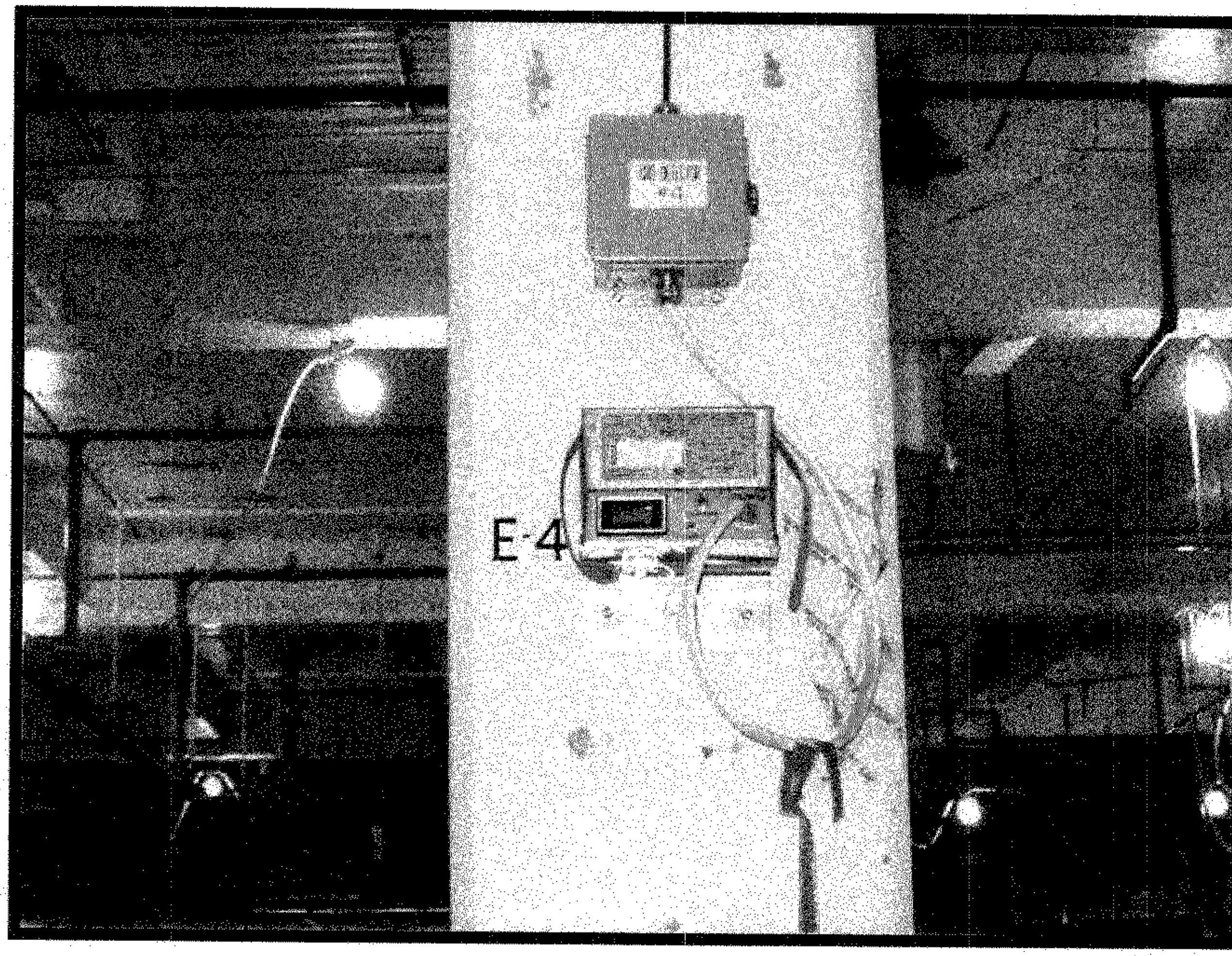


Figure 14: Criticality detectors at Rocky Flats mounted on solid surface with unique identifiers (red flags).

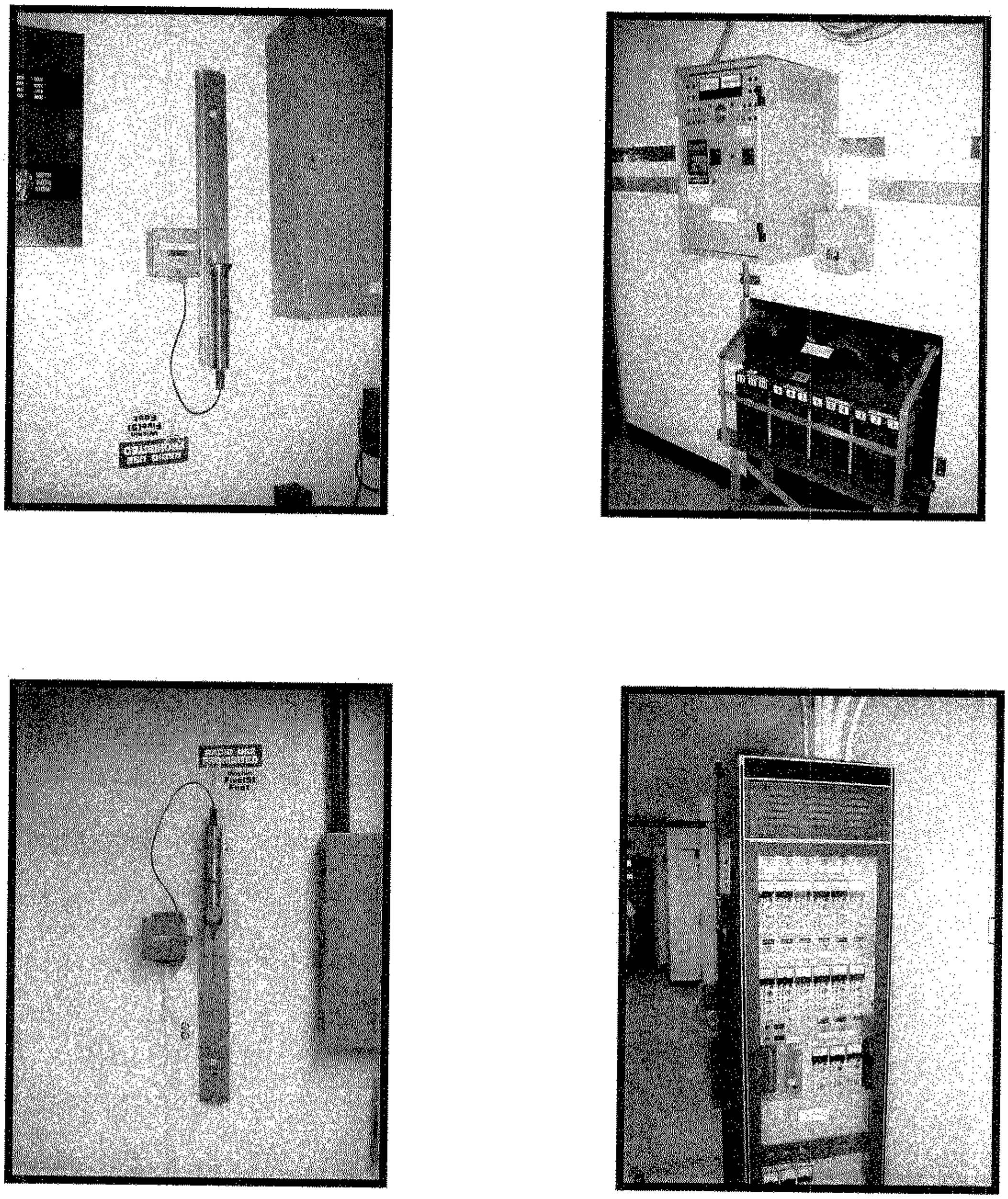


Figure 15. Typical CAAS used at the Hanford Site (Plutonium Finishing Plant) requiring protection during D&D.

10.0 Miscellaneous Lessons Learned

Related Criticality Safety Events from Outside of the DOE Complex

Criticality safety events are not unique to the DOE complex and often occur in Nuclear Regulatory Commission (NRC) licensed facilities. Several events, captured from NRC Event Notification Reports, are provided below to help heighten management awareness of potential problems.

NRC Event Notification Report for May 1, 2000, Portsmouth Gaseous Diffusion Plant:

While the chemical operations personnel performed decontamination operations on three forklifts, they discovered slit in the seat cushions. Since the cushions were geometrically unfavorable, this was a loss of one control (geometry) of the double contingency program. The second control, physical integrity of overhead piping, was maintained.

The chemical operations personnel discovered an unattended waste drum with its lid ajar. This condition could have potentially resulted in the accumulation of an unsafe volume of solution in the drum, had a leak developed in the overhead storage system, which contained uranium-bearing solution. This was a loss of one control (volume) in the double contingency control program. The second contingency (physical integrity of the storage system) was maintained.

Event Notification Report for August 16, 1999, Siemens Power Corporation:

A laboratory supervisor reported to a criticality safety specialist that the results of a new method of sampling material (microwave dissolution) to determine uranium content significantly exceeded the results of the normal method. The normal method of sampling was found to be low by a factor of three. It was determined that the normal method of preprocessing laboratory samples, did not put all of the uranium solids into solution, and the standard used to calibrate NDA equipment did not adequately reflect the material and geometry of the material when counted.

Event Notification Report for September 25, 2002, Westinghouse Electric Company, Commercial Fuel Fabrication Facility:

The scrubber ventilation ductwork containing gross contamination was stacked without proper spacing. The scrubber ventilation system ductwork was non-operational and was being removed. The criticality safety limit for floor storage of material with "gross contamination" required a 12-inch or greater spacing requirement.

Event Notification Report for April 20, 1999, Paducah Gaseous Diffusion Plant:

A HEPA vacuum cleaner was discovered with its vacuum hose wrapped around it. Double contingency was not maintained because the hose was not adequately spaced from the vacuum (spacing was a contingency). The purpose of the requirement was to prevent fissile material, which may be present inside the hose due to a clog, from interacting with the material, which may be present inside the cleaner.

Conclusion

As facilities containing residual fissionable material inventories move from operations to D&D, it is important to maintain focus on criticality safety. There are many lessons learned captured in this document specific to criticality safety that can aid facility managers and project managers through the D&D planning process. Major concepts include:

- Involve the criticality safety organization from day one.
- D&D processes in former fissionable material facilities demand a close interaction between Operations, Criticality Safety, and NDA personnel.
- Criticality safety evaluations written for D&D should be generic and as broad as possible.
- Care should be used in establishing a point in D&D for declaring criticality incredibility and subsequent removal of the Criticality Alarm System (CAS).
- Until the risk of a criticality accident becomes incredible, it is important for management to continue to have some building/process knowledgeable personnel on all work crews. It is also important that all personnel receive an appropriate level of criticality safety training to perform their work.
- The installation of unique markings can help protect CAAS equipment and components from damage and inadvertent removal during D&D activities.
- Controls to prevent criticality accidents should not depend heavily upon the actions of operations personnel.
- Adequate Characterization of Facilities Scheduled for D&D can Prevent Significant Cost and Schedule Delays.
- It is important to be absolutely sure that criticality incredibility analyses are fully and appropriately implemented before removing Criticality Accident Alarm Systems.
- Ensure criticality safety organizations have the resources to provide needed oversight.
- Ensure criticality safety organizations remain diligent in their oversight role.
- Management must be diligent in identifying legacy issues.

This information represents just a sampling of the lessons learned that are compiled throughout this document that will help facility managers maintain the integrity of their criticality safety program while progressing through D&D activities. An Appendix to this document contains references and website links that the reader may find useful. This Appendix contains sources of additional information and lessons learned.

Appendix – Reference Material and Web Links

References:

- ANSI/ANS-8.19-1996, Administrative Practices for Nuclear Criticality Safety
- ASTM E181-98
- ANSI N15.20
- DOE-STD-1158-2002, Self-Assessment Standard for DOE Contractor Criticality Safety Programs
- U.S. Department of Energy, Trip Report of Visit to Tokyo and Tokai-mura, Japan dated February 29, 2000
- McLaughlin et. al,; A Review of Criticality Accidents, 2000 Revision", LA-13638, May, 2000
- R.A. Knief, Nuclear Criticality Safety, Theory and Practice, American Nuclear Society, Inc., 1993
- Nuclear Materials Safety Limit 02-039/JSC-042, Revision 2, *Criticality Incredibility Study for Buildings 776/777*
- Technical Safety Requirements Page Change PGC-776-03.0162-RAN, *Building 776/777 BIO Revision, Criticality Incredible*
- RFETS Joint Criticality Safety Program Assessment, FY02-070-KHAP, March 2002
- Occurrence Report, RFO-KHLL-PUFAB-2002-0054
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- RFO-KHLL-SOLIDWST-2003-0005, *Level 3 Criticality Infraction, Non-compliance to the Criticality Incredibility Prerequisites, Positive Unreviewed Safety Question(USQ)* Notification Report.
- 2003-03-01, Infraction/Deficiency Report
- RFETS, PRO-1426-707-CRIT-COMP, *CAAS System Deficiency Compensatory Measures, Building 707*
- RFO-KHLL-PUFAB-2002-0039, Cord to Criticality Detector #14 Damaged by Fork Lift
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- Wachtel, S.J., *CSER 02-011: Criticality Safety Evaluation Report for Decommissioning Building 232-Z*, HNF-11499, Rev. 0, July 2002

- Erickson, D.G., *CSER 02-013: Criticality Safety Evaluation Report for Glovebox HC-7 Cleanout and Equipment Removal, 234-5Z Building*, HNF-11605, August 2002
- J.E. Ham, *Criticality Prevention Specification 224-T Process Cell Characterization Activities*, HNF-7794, Rev. 3, September 2002
- NRC Event Notification Report for May 1, 2000, Portsmouth Gaseous Diffusion Plant
- NRC Event Notification Report for August 16, 1999, Siemens Power Corporation
- NRC Event Notification Report for September 25, 2002, Westinghouse Electric Company, Commercial Fuel Fabrication Facility
- NRC Event Notification Report for April 20, 1999, Paducah Gaseous Diffusion Plant
- FY00-201-AB771, *RFETS Annual Criticality Safety Assessment of Buildings 771/774*, November 2000
- FY01-045-707, *RFETS Annual Criticality Safety Assessment of Building 707*, January 2001

- **Web links:**

SECY-00-0085 - Review of the Tokai-mura Criticality Accident and Lessons Learned

http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2000/secy2000-0085/attachment1.pdf

"The Plutonium Finishing Plant Criticality Safety Program Review", DOE/EH-0571, May, 1998. This document may be found at http://crit-safety.lanl.gov/ncs/index.htm

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