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Author(s): Kenneth E. Thomas
Bruce W. Erkkila
Phillip M. Rinard
Neil R. Zack
Calvin D. Jaeger

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Design Impacts of Safeguards and Security Requirements for a US MOX Fuel Fabrication Facility

Bruce H. Erkkila, Phillip M. Rinard, Kenneth E. Thomas, and Neil R. Zack
Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Calvin D. Jaeger
Sandia National Laboratories, Albuquerque, NM 87185 USA

Abstract

The disposition of plutonium that is no longer required for our nation's defense is being structured to mitigate risks associated with the material's availability. In the 1997 Record of Decision, the US Government endorsed a dual-track approach that could employ domestic commercial reactors to effect the disposition of a portion of the plutonium in the form of mixed oxide (MOX) reactor fuels. To support this decision, the Office of Materials Disposition requested preparation of a document that would review US requirements for safeguards and security and describe their impact on the design of a MOX fuel fabrication facility. The intended users are potential bidders for the construction and operation of the facility. The document emphasizes the relevant DOE Orders but also considers the Nuclear Regulatory Commission (NRC) requirements. Where they are significantly different, the authors have highlighted this difference and provided guidance on the impact to the facility design. Finally, the impacts of International Atomic Energy Agency (IAEA) safeguards on facility design are discussed. Security and materials control and accountability issues that influence facility design are emphasized in each area of discussion. This paper will discuss the prepared report and the issues associated with facility design for implementing practical, modern safeguards and security systems into a new MOX fuel fabrication facility.

Introduction

This paper is a summary of a document[1] prepared for the Office of Materials Disposition of the Department of Energy (DOE). The DOE document was a follow-up document to "Safeguards and Security Considerations for a Mixed Oxide Fuel Fabrication Facility,"[2] which reviews US requirements for safeguards and security as applied to a mixed-oxide (MOX) fuel fabrication facility and the facility design implications of these requirements. The intended users of the DOE document are potential bidders for the construction and operation of the facility.

The document prepared for DOE emphasizes the relevant DOE Orders. During the preparation of the document there was an indication that materials control and accountability (MC&A) may fall under the NRC regulatory process. Accordingly, where the requirements are significantly different, the NRC requirements are highlighted.

Although the Orders are reviewed for completeness, the areas that influence facility design are emphasized. Many of the security requirements have a direct bearing on facility design; however, many of the requirements for MC&A in both the DOE and NRC regulations are more administrative in nature. While many of the materials accounting requirements do not directly contribute to the building design, careful attention must be given to the measurement, monitoring, and data-gathering requirements for the facility. These aspects of a near-real-time accounting system can play an important role in planning processing operations and floor-space requirements within the process and storage areas. Throughout the document the authors have tried to point out how a requirement for safeguards and security might impact the design of the building and internal operations features.

Materials Control and Accountability

Based on the graded safeguards section of DOE Order 5633.3B, the MOX facility would be subject to Category I safeguards and security requirements through the point in the process at which plutonium oxide is blended with uranium oxide to about 5% plutonium. After this point in the process, the materials would be subject to Category II, or perhaps Category III, requirements depending on the quantities of materials in-process. Other nuclear materials will also be present in the facility; these require less stringent controls but still must be accounted for. In principle, it may be possible to design the facility to separate the areas having different safeguards and security requirements; however, operational considerations may preclude such separation.

Typically, a MOX fuel fabrication facility will be subdivided into three material balance areas (MBAs): feed storage, product storage, and process. The facility must be designed with controls so that all transfers of materials between MBAs are recorded and based on measured values. Each MBA shall be equipped with accountability stations that contain a computer, barcode readers, and electronic balances. Stations are located for recording transfers and measurement information at critical points in the processing operations. Nondestructive assay (NDA) instrumentation may also be located in the MBA and interfaced to an accountability station for the performance of accountability measurements.

Measurement capability must be specified in the facility design. The existence of an on-site analytical laboratory, as well as the location of NDA instruments within the process areas must be considered. An appendix in the document discusses NDA measurement options.

Storage areas will include the receiving vault, feed plutonium oxide vault, the product assembly vault, and the in-process (lag storage) vault. Separate storage areas shall be provided for uranium-bearing materials. Each of these areas shall be designed as a vault or vault-type room with a minimum number of penetrations of the safeguards containment. The design shall facilitate implementation of international safeguards containment and surveillance by instrumenting vault penetrations to allow detection and recording of transfers of special nuclear material (SNM) into or out of these areas.

The process MBA will be located primarily inside glove boxes. Although these glove boxes provide little containment from a safeguards perspective, the process glove boxes themselves shall be located in controlled-access rooms. To support normal facility operations and shut-down during emergency conditions, the facility locations where nuclear materials will be handled shall be designed to permit SNM to remain in-process during conditions when personnel are not present. Appropriate automated monitoring, detection, and access-control systems shall be in place in these areas to detect and assess unauthorized entry to areas containing nuclear materials.

The facility and process shall be designed to have the capability to detect and assess unauthorized removals of SNM from authorized locations. This capability shall interface with physical protection systems and other systems and provide notification of non-normal conditions to security forces. Detection and monitoring applications shall consider the use of tamper-indicating devices, portal monitors, waste stream monitors, area radiation monitors, sensors, and data anomaly assessment programs. All solid, liquid, and gaseous waste streams will be monitored for the presence of SNM as these streams leave the material access area (MAA). The design shall implement, where practical, automated methods for completing daily administrative check requirements. Automated detection and assessment methods shall be incorporated into facility data gathering and calculational software to detect and assess anomalies and unauthorized access.

Physical Protection

The facility must be designed to provide protection and control of safeguards and security interests (e.g., SNM, vital equipment, classified matter, property, and facilities). Physical protection consists of a number of components that detect, delay, and respond to adversary attack. These components are implemented in a graded manner and must effectively protect the facility assets for the MOX fuel fabrication activities. The MOX fuel fabrication facility, as a Category I facility, must have an MAA located inside a protected area (PA). Controls must be designed into these perimeters to limit access to authorized personnel and to detect contraband upon entry to the facility and SNM upon exit from the facility. Particular attention must be given to design of vehicle portals as well as to the screening of packages for SNM.

Threat. Physical protection systems shall be designed and installed at facilities to assist in denying hostile actions posed by an adversary or a group of adversaries that could result in loss of material, sabotage at the facility, or unacceptable impact on the health and safety of the public.

Physical Protection Design. In designing physical protection systems, the concept of defense-in-depth shall be applied to the protection of facilities and materials and shall include a series of subsystems within an integrated safeguards and security protection program. To provide defense-in-depth, the physical protection systems must consist of subsystems that include, but are not limited to: access control, barrier denial, intrusion detection, assessment, communications, and response force.

In conjunction with materials control and other safeguards and security activities, the MOX fuel fabrication facility should be compartmentalized to limit access to only those who need to be in a specific area. Consideration should be given to not only the processes but also the traffic flow of personnel and material within the facility. The form and composition of the SNM will change during the MOX fuel fabrication processes. If the activities are adequately compartmentalized, this may provide for graded safeguards and a more cost effective system.

Personnel Access. For personnel to have hands-on access to Category I (or Cat II material that can be accumulated to make up a Cat I quantity) SNM, they must possess a Q clearance; for Category II and III SNM, they must have at least an L clearance. Enrollment in the Personnel Security Assurance Program (PSAP) will help reduce the insider risk threat. It is envisioned that during the design, construction, and operation of the MOX fuel fabrication facility, personnel from the consortium who are uncleared, and perhaps also foreign nationals, will require access to the MOX fuel fabrication areas. If classified and/or sensitive activities are ongoing near the proposed MOX operating areas or if the areas are located within high-level security areas, this may affect operations and increase security requirements. At a minimum it would also require additional efforts to complete access authorization approval and escort requirements.

NRC Requirements for MC&A

Much of the NRC regulations for MC&A are similar to the DOE requirements. However, several sections of the NRC regulations are different from DOE requirements and may have significant impact of facility design.

Requirements for LEMUF. The limit of error on the materials balance or material unaccounted for (LEMUF) is set at the 95% confidence interval (two sigma on the MUF). NRC requires that LEMUF for this type of material processing facility be equal to or less than 0.5% of additions or removals, whichever is greater. Therefore, measurements of additions and removals must have an associated (one sigma) uncertainty of about 0.25%, including sampling error. A further assumption is that the uncertainty on the materials in process is small compared to the uncertainty on the throughput; therefore, in-process materials must be minimized, and where they cannot be minimized, good NDA methods will be employed. Based on the limit of error of the inventory difference (LEID) requirement and the measurement uncertainty requirements to meet this requirement, the materials balance for the processing MBA will most likely be derived from the results of chemical assay (isotope dilution mass spectrometry) of the feed plutonium oxide and the sintered pellets. This is substantially more restrictive than the LEID performance requirement in the DOE Order.

Control of Scrap. A feature of the NRC regulations that does not appear in the DOE Order is control of scrap materials. If the scrap cannot be measured to better than 10%, then it cannot remain on inventory longer than 6 months. Glove-box sweepings and other cleanup materials may meet the definition of scrap and are usually poorly measured; this material shall be recovered within the six-month time frame, or good-quality measurements (probably by NDA) will have to be employed. Facility design shall incorporate measurement requirements for scrap materials.

Process Monitoring. The NRC regulations contain a general requirement to monitor all internal transfers, storage, and processing of strategic SNM, similarly to DOE requirements. The NRC regulations continue with more specific requirements for types of material, and detection quantities and probabilities. The major flows of plutonium-bearing materials in a MOX fuel fabrication facility are subject to this requirement; materials not subject to the requirement are the uranium materials, scrap in small pieces, and small throughput processes.

The process monitoring section specifies unit process production quality control with loss detection capability. This means that within the processing MBA of the MOX fuel fabrication facility, the MBA would be subdivided into unit processes. Input and output plutonium masses must be determined for each unit process. Thus, facility design must incorporate NDA of in-process materials and, in some cases, glove box monitoring systems for plutonium holdup.

The performance measures for process monitoring have no parallel in the DOE Order. To meet the requirement, the MOX fuel fabrication facility's accounting system must be able to accommodate data input and materials balance closures by unit process, as well as by MBA. The system must also track holdup, maintain detailed measurement and measurement-control information, and record material-tracking information, such as operator identification, bar codes, container identifications, locations, and time. Accountability and monitoring stations must be incorporated into the facility design to provide timely loss detection.

Item Monitoring Performance Requirements. The facility operator must verify on a sampling basis the presence and integrity of items with a 99% probability of detecting item losses totaling 2 kg of plutonium within 30 calendar days for items in a vault, three working days for items located elsewhere in the MAA. Given that each item of feed plutonium oxide will contain at least 2 kg of plutonium, then 99% of the items will be inspected each month for those materials in a vault, and those items that are in-process will be inspected every three days. To satisfy the item monitoring requirement for the anticipated large inventory of the MOX fuel fabrication facility, automated item monitoring shall be designed into the vaults. Such a capability can be accomplished through the use of an inventory pallet with image capability and radiation monitoring capability; this pallet could be designed to continuously monitor materials in storage.

International Safeguards

There are no prescriptive requirements for international safeguards as there are in the DOE Orders and NRC regulations. Here, one must refer to the application of the US/IAEA Safeguards Agreement (INFCIRC/288) to the MOX fuel fabrication facility. There are requirements under the Agreement for an accounting system, periodic reports, measurements, measurement control, etc., that have already been discussed from the DOE or NRC viewpoints. However, the IAEA will inspect the facility and audit its records for the purpose of verifying US statements and declarations about the function and holdings of the facility.

International experience has shown that a modern MOX fuel fabrication facility must be as automated and instrumented as possible to meet the IAEA verification goals with minimum impact on facility operations (an appendix in the source document lists background materials). This includes automation of materials handling and transfer, as well as automation of data collection, storage, and analysis. Automation has the advantage of reducing radiation and hazard exposure to personnel, makes the movements of materials more predictable, and provides a means of recording and monitoring these movements. IAEA data must be acquired and stored on media that are under the control of the IAEA.

A capability important to the operation of the MOX fuel fabrication facility is the ability to quickly satisfy the IAEA measurement and sampling requirements for physical inventory verifications and interim inspections while minimizing process downtime. It may be necessary to locate sampling stations at several strategic locations in the process to minimize the number of movements of material for inspections. In addition, the conveyor/transport system must have the capacity to handle the additional movements necessitated by verification. Minimization of storage in the process vaults will help this situation.

To accommodate these IAEA inspection activities, the following need to be considered in the facility design:

- space to house measurement equipment,
- sampling stations within the process lines,
- transfer capacity,
- shared use of facility equipment,
- office and meeting space, and
- equipment storage space.

The IAEA uses containment and surveillance to monitor the activity at a facility when inspectors are not present. Containment for the MOX fuel fabrication facility would likely be the MAA boundary, the vault walls, and the in-process storage area walls. Surveillance would be applied in storage areas and at penetrations in the containment, particularly the entrances and exits through the MAA and the vaults. The surveillance equipment would record movements across the containment boundary and movements of materials within the storage areas. Surveillance equipment may be remotely monitored. Recent safeguards developments permit the transmittal of surveillance information (images, radiation readings, etc.) to the IAEA for viewing on-demand, in addition to storing information on-site for review by the inspector.

Conclusion

A modern plutonium-handling facility should incorporate as much automation, instrumentation, and computerized support as possible to meet the requirements of NRC, DOE, and the IAEA. All routine aspects of moving and handling the materials should be automated, from receipt of the feed material to loading of the assembly transports. Data gathering for MC&A should be automated, as well, making use of bar-code readers and integration of measurement equipment, particularly balances, to the computer system. Thus, careful consideration will have to be given to the number and location of MC&A stations, measurement equipment, etc., in the design of the facility. In addition, many of the monitoring and inventory operations are most effective when automated and continuous. If these features of a modern safeguards and security system are not designed into the facility, it may not be possible to meet DOE and NRC regulations or IAEA safeguards criteria without expensive and time-consuming facility shutdowns and increased personnel radiation exposure. In some cases, retrofitting may be needed but may not be possible.

References

1. B. H. Erkkila, P. M. Rinard, K. E. Thomas, N. R. Zack, and C. D. Jaeger, "Design Impacts of Safeguards and Security Requirements for a US MOX Fuel Fabrication Facility," Los Alamos National Laboratory document LA-UR-97-4691 (November 1997).
2. C. E. Cliche and K. E. Thomas, "Safeguards and Security Considerations for a Mixed Oxide Fuel Fabrication Facility," Los Alamos National Laboratory document LA-UR-97-2940 (July 1997).