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NUCLEAR MATERIAL MINIMIZATION THROUGH PACKAGING AND REMOVAL OF EXCESS SEPARATED PLUTONIUM INVENTORIES

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ABSTRACT

The pace of fuel cycle research with plutonium materials worldwide has decreased significantly over the last two decades resulting in excess legacy plutonium materials that can be used in weapons of mass destruction (WMD). Recent Nuclear Security Summits have highlighted the need for a global commitment to minimize excess weapons usable separated plutonium inventories. The United States Department of Energy-National Nuclear Security Administration (DOE-NNSA) has been leading the effort with partners globally to facilitate removal and disposition of legacy plutonium. In recent years, DOE-NNSA Office of Material Management and Minimization (M3) and its partners have worked collaboratively with six countries and the European Commission to develop and implement plans to characterize, stabilize, and package excess separated plutonium materials for removal and ultimate disposition. Since much of the infrastructure for working with plutonium in these research facilities had been dismantled, the handling of legacy plutonium materials to facilitate stabilization and repackaging for transport has entailed the development of new glove box facilities in many of the partner countries. In addition, since significant quantities of separated plutonium predicate the use of Category 1 transport of these materials, DOE-NNSA has worked closely with transport companies, and U.S. and international regulatory authorities to facilitate protocols for secure maritime transport of the plutonium materials. This paper will describe the DOE-NNSA M3 role in the removal and minimization of separated plutonium material. DOE-NNSA M3 facilitates the isotopic characterization of the plutonium materials, development of the packaging process flow sheets, design and development of the necessary glove box infrastructure for packaging operations, procedure development, and training of personnel. In addition, the paper will highlight the 9975 plutonium package certificate validation process with the regulators and review the safeguards protocol practiced in the plutonium packaging, storage, and transport activities. Finally, the paper will describe the key considerations in developing a transport strategy and the attributes of the operational plan. The paper will use the examples of plutonium minimization campaigns completed with Sweden, Italy, Belgium, Switzerland, Germany and Japan to highlight the lessons learned.

INTRODUCTION

Civilian separated plutonium inventories worldwide are on the rise and recycling and/or disposition of plutonium continues to be a challenge. Civilian separated plutonium falls into two categories:

1. Separated plutonium associated with research and legacy facilities, and
2. Separated plutonium associated with commercial nuclear power.

Research and legacy plutonium is a small subset of the global plutonium inventory, however, it is considered highly vulnerable because it is portable and in forms that are particularly attractive. Hence elimination of research and legacy plutonium is a high priority.

The DOE-NNSA's Office of Material Management and Minimization (M3) mission includes minimization of vulnerable nuclear materials from civilian sites. The Gap Program was initiated in 2004 to address high enriched uranium (HEU) not covered by the U.S. Origin and Russian-Origin nuclear material removal programs. In 2010, the necessary environmental approvals for the removal and disposition of separated plutonium were obtained. Since then, the DOE-NNSA/M3 Office has partnered with six countries and ten different facilities to eliminate legacy plutonium inventories. The approach to the plutonium packaging and transport takes into account safely handling, stabilizing, packaging, transporting, and dispositioning of the separated plutonium.

APPROACH

The approach to the plutonium characterization, stabilization, packaging and transport has been fairly consistent throughout all of the plutonium minimization campaigns. Figure 1 provides a high level roadmap of the approach. Initially the legacy separated plutonium inventories are reviewed with the partner country to identify the legacy separated plutonium materials that may be eligible under the Gap program.

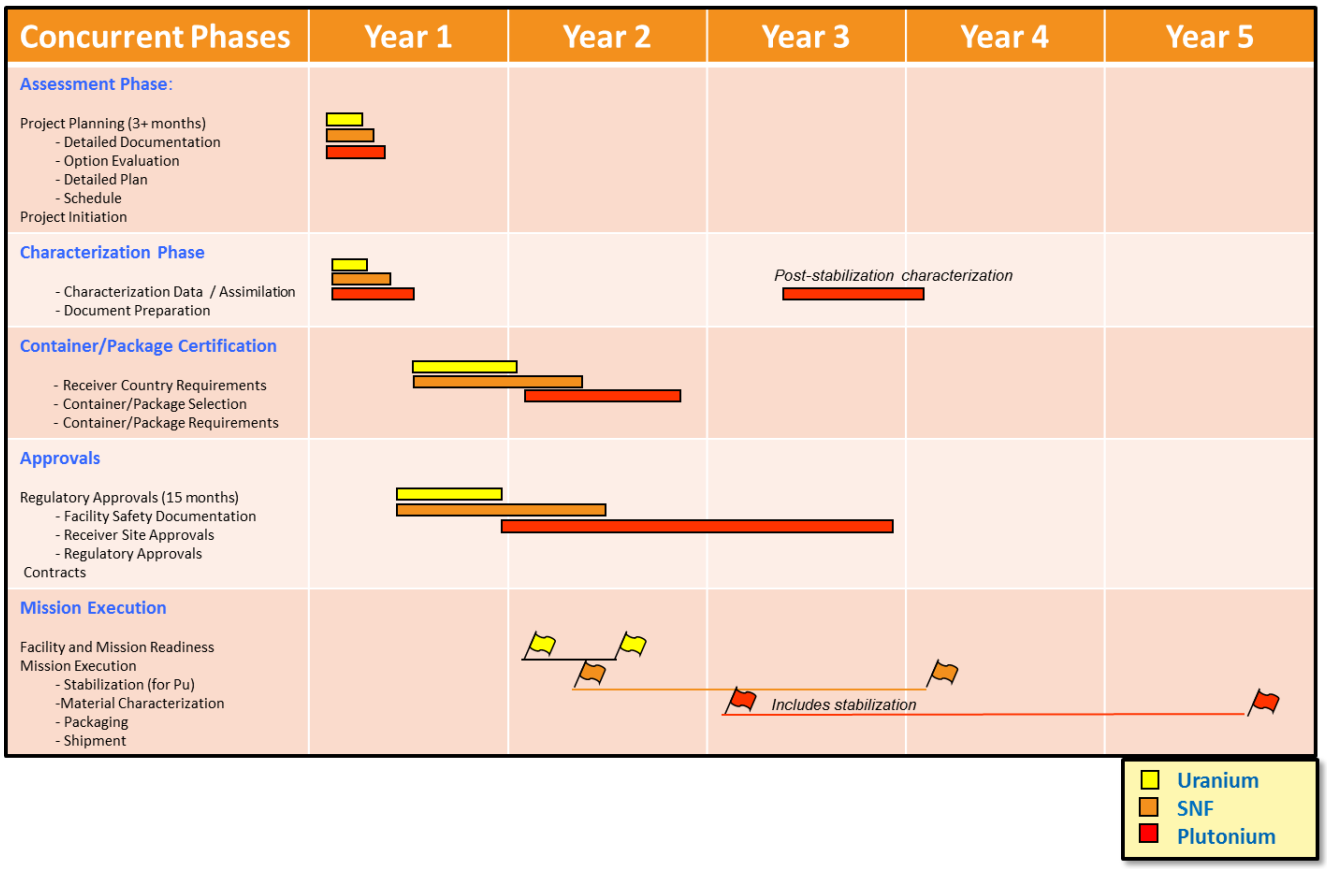

Figure 1 High Level Roadmap of Gap Removal Approach

Considerations include the quantity, type, and characteristics of the material, the location, storage condition, attractiveness level, ability to meet receipt facility criteria and availability of disposition path. A subsequent assessment phase is initiated where a detailed documentation of the plutonium materials characteristics is developed, the stabilization and packaging options are evaluated, and a detailed plan and high level schedule are generated. It is during this assessment phase that details of the host country capabilities are determined including facilities and personnel competency. Existing infrastructure in the partner country to stabilize and safely package plutonium materials and package them safely sometimes requires incremental upgrades to facility and infrastructure. However in most of the partner countries the lack of infrastructure drives the need for the design, construction, installation and operation of new gloveboxes for plutonium stabilization and packaging. The plutonium packaging and transport campaigns required new equipment for characterization and stabilization regardless of whether new gloveboxes were needed. Some of the key pieces of equipment included a high temperature furnace, multiple weighing scales, grinding / crushing instrument, sieves, and thermogravimetric analysis (TGA) equipment. The installation of new gloveboxes and/or new equipment within the gloveboxes required revisions or upgrades to the facility safety bases documentation and appropriate safety committee and/or regulatory approvals. Additionally, it required development of procedures and a training program to qualify the glovebox operators and plutonium workers.

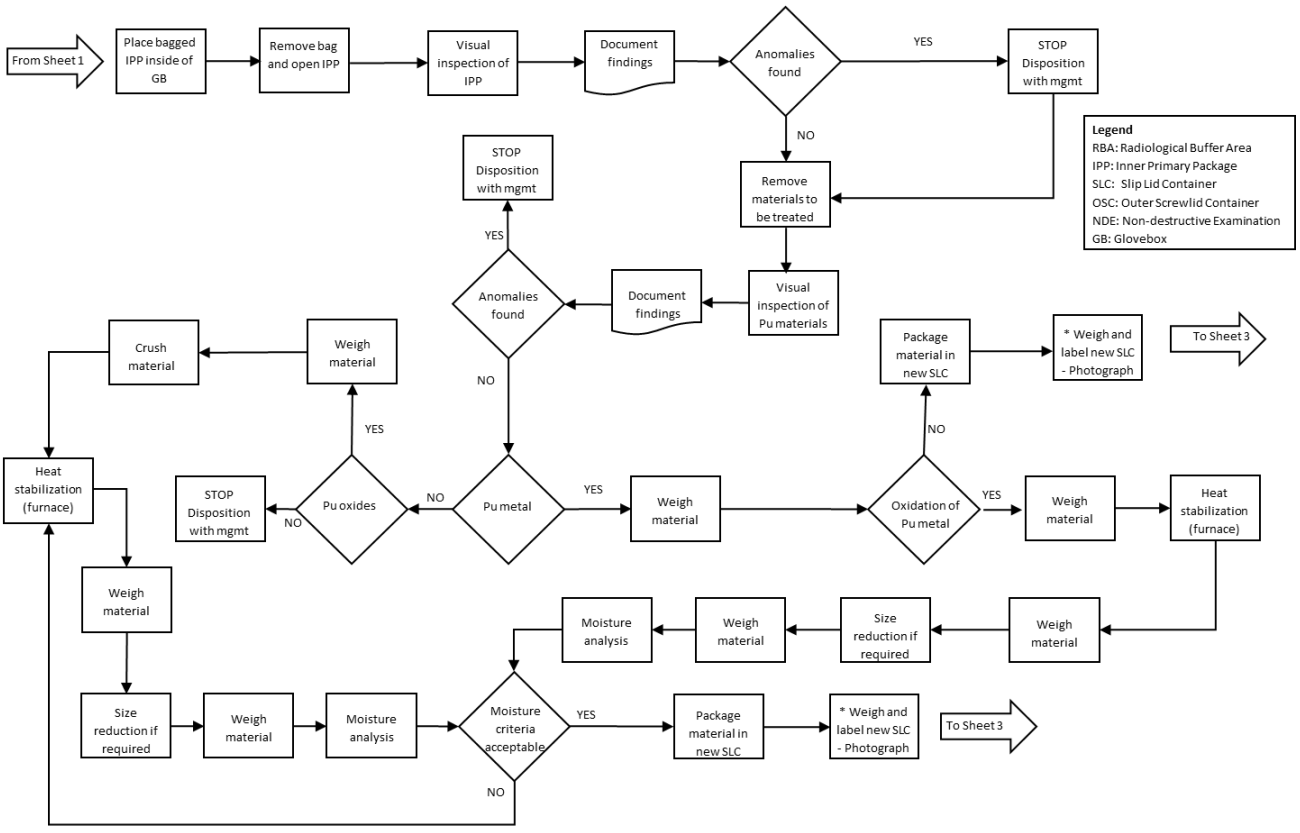

Figure 2. Example Flowsheet of Plutonium Materials Treatment

Concurrent to the assessment phase, the host country is required to prepare a detailed assessment of the description and storage history of the plutonium materials. Historical characterization data from the host country is also assembled. Additional characterization of the materials is performed in order to obtain as much information about the materials prior to their treatment and packaging. A unique flowsheet is developed for the movement, processing, and packaging of plutonium material for each partner country. An example of a flowsheet for processing the material is provided in Figure 2.

The regulators and key stakeholders at the packaging site are engaged throughout the planning process. Typically, during the course of the overall project a number of regulatory approvals are required including facility safety basis documentation, receiver site documentation, and transport approvals. Figure 3 is a representation of the documentation required to be prepared by the packaging site (PS) in the partner country. There are three main sets of documentation that the packaging site must prepare that require a review and approval by the receiving site (RS). First, prior to hot operations the packaging site develops the documentation that provides assurance that they comply with the receiving site acceptance criteria (AC).

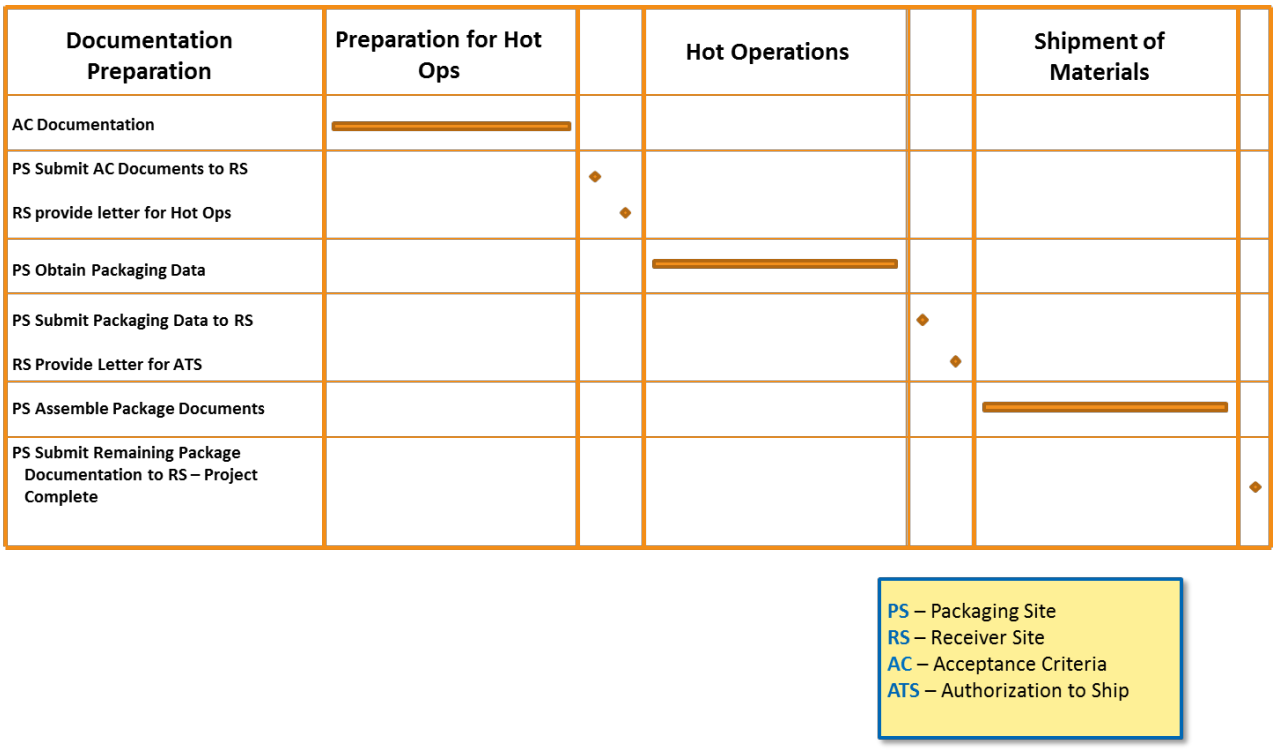

Figure 3. Representation of Documentation Required From Packaging Site in Partner Country

The Acceptance Criteria is a documentation package that the packaging site has to submit to the receiving site and obtain approval prior to commencement of the hot operations. It includes a description of:

- Plutonium material to be packaged
- Compliance with a prescriptive stabilization processes
- Equipment being used for processing including the acceptable performance of the equipment
- Containers and shipping packages to be used
- Procedures used for processing and packaging the plutonium materials
- QA program.

Key elements of the hot operations include stabilization, material characterization, and packaging. The packaging site will collect data during the hot operations campaign that includes materials form and characterization data including photographs and moisture content of stabilized material, materials accountability data including measurement uncertainties, 9975 shipping package data sheets, dose measurements, etc. This data is assembled by the packaging site and provided to the receiver site for data validation and approval.

Finally a collection of all the completed procedures and the raw data from the PS is compiled and sent to the RS for project completion.

MATERIALS CHARACTERIZATION

A number of techniques are used for characterization of the plutonium materials during the processing operation at the packaging site. Those types of characterization include:

- Thermogravimetric analysis (TGA)
- In-Situ Object Counting System (ISOCS)

Plutonium oxides from the partner countries are required to be stabilized prior to packaging. This stabilization requires that the plutonium oxide materials be heated with an oxidizing atmosphere in a furnace to 950°C for a minimum of 2 hours. Stabilization drives the volatile impurities and moisture off the plutonium oxide materials to ensure they can be shipped safely. The TGA is used to measure the moisture content of plutonium oxide materials after stabilization to ensure they are <0.5 wt% moisture. This requirement was originally defined in the DOE-STD-3013 for stabilization of plutonium oxides for storage within a 3013 [Ref. 1] and has been adopted as part of the packaging criteria for the Gap plutonium materials program.

The ISOCS is a non-destructive assay measurement done on the Gap materials container configuration prior to placement within the 9975 package for shipment. This measurement is done to gain an understanding of what isotopic distribution is within the container, which is required to ensure it meets the requirements of the 9975 SARP and the receiving facility requirements.

SHIPPING PACKAGE CERTIFICATION

Each partner country utilized the robust Type B 9975 Shipping Package for transport, Figure 4 which was selected for a variety of reasons. The 9975 shipping package is a robust Type B package specifically designed for the transport of plutonium in both metal and oxide form. It is designed and built to DOE, DOT, and IAEA standards and requirements. It is approved for U.S. domestic

shipments of Pu metal and oxide and has been demonstrated with the land transport of >6000 packages in the United States. To support the M3 Gap plutonium materials remove program, an addendum was developed and approved for use of a slip lid / screw lid container configuration, Figure 5, with nitrogen over gas within the primary containment vessel. This container configuration, also known as the Gap materials configuration, has been used extensively for the plutonium oxide transports in partner countries as well as the Competent Authority Certificate approval for international ocean transport.

The DOE-NNSA/ M3 team worked closely with the partner country at the packaging facility as well as the Regulatory Authority to ensure all appropriate reviews of the 9975 Safety Analysis Report for the Package (SARP) [Ref. 2] were completed and the U.S. certificate validated.

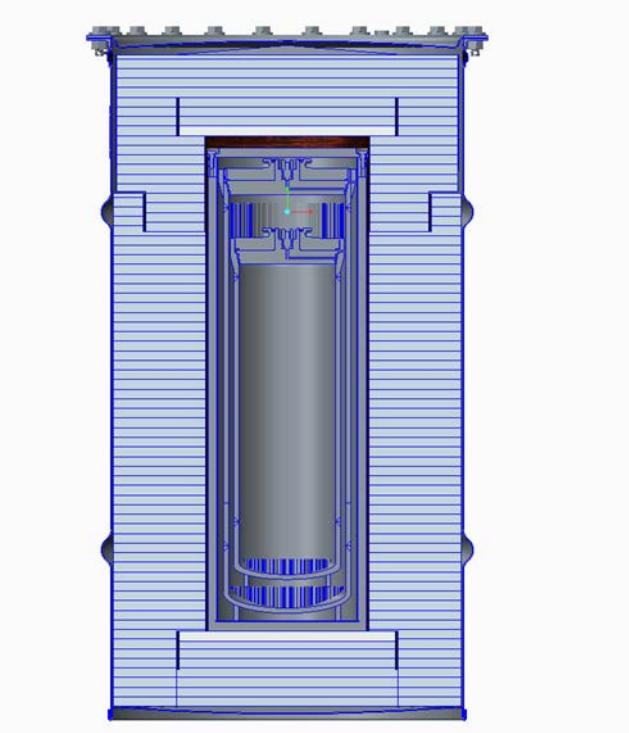

Figure 4 Type B 9975 Shipping Package

Figure 5 Typical Can-Bag-Can Configuration

TRANSPORT STRATEGY

The transport strategy was developed in conjunction with each partner country to ensure the appropriate safety and security regulations were observed and consistent with IAEA standards for a category 1 transport. Calibrated equipment was loaned to each partner country for packaging the Gap materials within the 9975 shipping packages. This approach ensured that the partner country packaged the materials in compliance with the receiver site requirements and per the 9975 SARP.

Figure 6 shows the leak tester, a portion of the equipment, loaned to the partner country for validating that the containment vessels are sealed properly.

The Gap materials were packaged in containers which were placed within the 9975 shipping packages. The 9975 shipping packages were then placed within a cargo restraint transporter (CRT), Figure 7. A total of five 9975 shipping packages can be placed within a single CRT. The DOE-NNSA/M3 Team provided assistance with development of the procedures and training to ensure efficient and effective loading operations.

- Leak tester
- Pump
- Line conditioner
- Orifice
- Nitrogen lid cover and wand
- Vacuum grease & lint free cloth

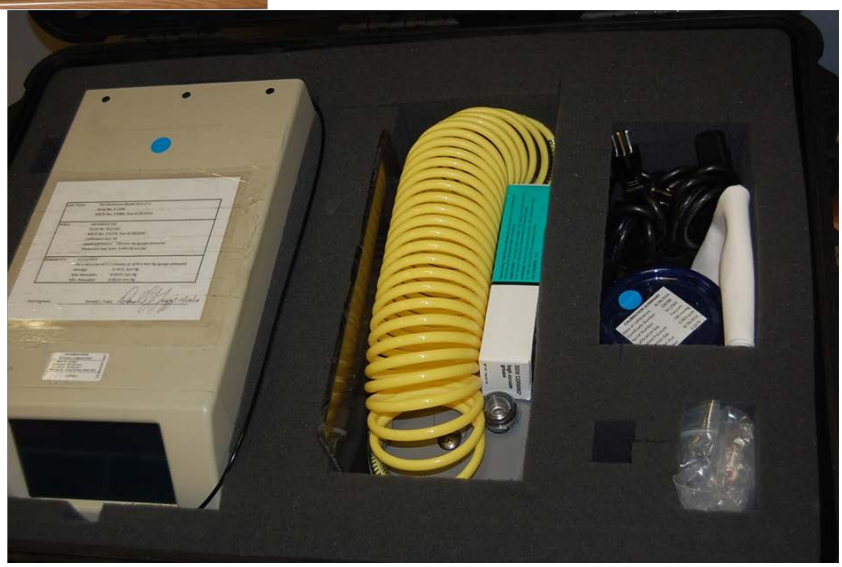

Figure 6. Leak Test Kit Loaned to Partner Countries

The CRT pallets are then tied down with dedicated slings and fastened to special anchorage systems within ISO containers. Fastening of the CRT pallets to the ISO containers was designed to meet not only land transport requirements but also very strict maritime transport regulations for a Category 1 shipment, Figure 8. These regulations included dynamic load requirements.

In all packaging and transport cases the work was executed in compliance with the highest security standards and regulations. The preparation for physical protection and emergency plans was lengthy and complex. However, the partnership between the DOE-NNSA/M3 Team and each partner country team ensured the transport of the materials was safely completed with an enhanced degree of safety and security measures, as required for a category 1 transport.

Figure 7. Cargo Restraint Transporter

Figure 8. Land Transport with ISO Containers and Typical Maritime Transport Vessel

CONCLUSIONS

Recent Nuclear Security Summits have highlighted the need for a global commitment to minimize excess weapons usable separated plutonium inventories. The United States DOE-NNSA Office of Material Management and Minimization (M3) has worked with partners globally to facilitate packaging, transport and disposition of legacy plutonium materials. Since 2010, the M3 team and its partners have worked collaboratively with six countries and the European Commission to develop and implement plans to characterize, stabilize, and package excess separated plutonium materials for transport and ultimate disposition. Additionally, since the quantities of separated plutonium predicated the use of Category 1 transport for these materials, DOE-NNSA worked closely with transport companies, and U.S. and international regulatory and security authorities to facilitate protocols for secure maritime transport of the plutonium materials. Plutonium minimization

campaigns were completed with Sweden, Italy, Belgium, Switzerland, Germany and Japan and announced at the 2012, 2014 and 2016 Nuclear Security Summits.

REFERENCES

[1] DOE Standard Stabilization, Packaging, and Storage of Plutonium-Bearing Materials, DOE-STD-3013, March 2012

[2] Safety Analysis Report for Packaging Model 9975, S-SARP-G-00003, Revision 4, December, 2015

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