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Author(s): D. Dennis Wilkey, Warren T. Wood, and
Charles D. Guenther

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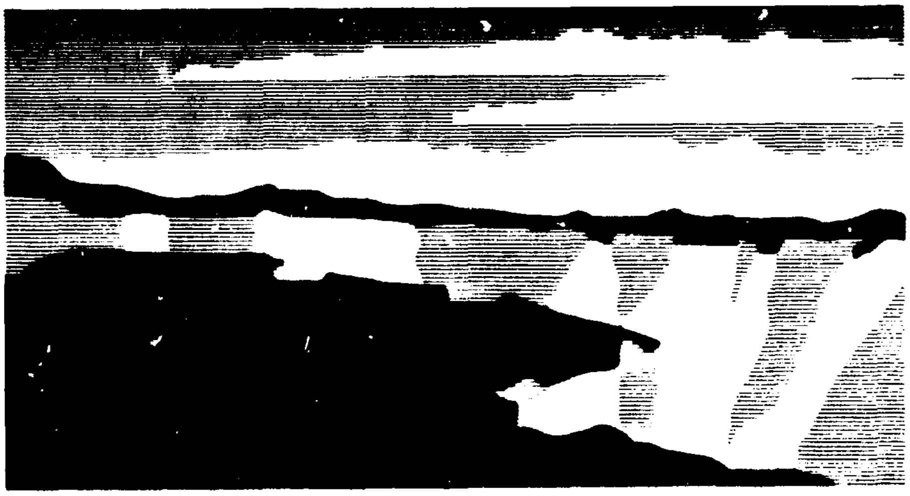

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LONG-TERM PLUTONIUM STORAGE: DESIGN CONCEPTS*

D. Dennis Wilkey and Warren T. Wood
Los Alamos National Laboratory
Los Alamos, NM 87545 USA

Charles D. Guenther
Fluor Daniel, Inc.
3333 Michelson Drive
Irvine, CA 92730 USA

ABSTRACT

An important part of the Department of Energy (DOE) Weapons Complex Reconfiguration (WCR) Program is the development of facilities for long-term storage of plutonium. The WCR design goals are to provide storage for metals, oxides, pits, and fuel-grade plutonium, including material being held as part of the Strategic Reserve and excess material. Major activities associated with plutonium storage are storing the plutonium inventory, material handling and storage support, shipping and receiving, and surveillance of material in storage for both safety evaluations and safeguards and security. A variety of methods for plutonium storage have been used, both within the DOE weapons complex and by external organizations. This paper discusses the advantages and disadvantages of proposed storage concepts based upon functional criteria. The concepts discussed include floor wells, vertical and horizontal sleeves, warehouse storage on vertical racks, and modular storage units. Issues/factors considered in determining a preferred design include operational efficiency, maintenance and repair, environmental impact, radiation and criticality safety, safeguards and security, heat removal, waste minimization, international inspection requirements, and construction and operational costs.

INTRODUCTION

The DOE weapons complex is consolidating nuclear materials as a result of major changes in its mission. There is now an increasing need to store nuclear material inventory on a medium to long-term basis. Long-term storage on a scale of 50 or more years has not been addressed in the weapons complex.

This paper is a summary of a functional analysis of storage concepts performed for the DOE Weapons Complex Reconfiguration (WCR) Program. The analysis was led and facilitated by personnel in the Fluor Daniel, Inc., WCR Office. Contributors included personnel from Los Alamos National Laboratory, Sandia National Laboratories, Westinghouse Savannah River Site, Westinghouse Idaho Nuclear Company, EG&G Rocky Flats Plant, Scientech, and DOE-HQ (DP-40). Although primarily concerned with plutonium storage, many of the conclusions can be applied to storage of enriched uranium and other nuclear materials.

STORAGE CRITERIA

The following is a discussion of the basic criteria set by DOE for the long-term plutonium storage facility.

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Provide storage for up to 40,000 plutonium items for up to 50 years. The number of items and the proposed active lifetime of the facility are unprecedented. With 40,000 stored items, there is conflict between minimizing the number of individual storage locations to reduce the size and cost of the facility and maximizing accessibility of individual items to improve operating efficiency and material accountability. The number of items also affects the monitoring of special nuclear material (SNM) attributes at the storage location and, therefore, is directly related to physical inventory requirements. Monitoring systems that require hard wiring to each location are not feasible due to the effort and cost of maintenance and replacement over the lifetime of the facility. The duration of the storage period requires that equipment in the vault must be easily replaced, and the design must facilitate safety inspections of the integrity of the storage containers and material.

Stored items include metals, oxides, pits, and fuel- and power-grade plutonium, including material being held as part of the strategic reserve and excess material. The inclusion of pits places special maximum temperature limits for the storage area. These limits will require a more complex, high-volume air flow system. The inclusion of both strategic reserve and excess materials complicates third party inspections of the excess materials (see following item).

Design must be sufficiently flexible to allow for third party inspections. This is generally interpreted to require segregation of strategic reserve material from the rest of the inventory. Providing for third party inspection may result in duplication of systems, if completely separate vaults are required.

Maximize use of remote and/or automated handling of plutonium storage and shipping containers. This is driven by increasingly stringent radiation exposure limits and the desire to decrease exposures even further. This requirement led to designs in which all operations in the vault could be performed by automated or remotely controlled equipment. If a design concept precluded manned entry to the vault, capability had to be provided for removal of failed equipment for repair outside of the vault.

Full compliance with all applicable codes, regulations, and DOE Orders. This requirement did not impact the five design concepts judged to be acceptable; however, it contributed to the elimination of some of the others where compliance was judged to be questionable or costly.

Minimize waste generation and limit environmental impact. Both of these requirements had a negative impact on those concepts that used water cooling systems due to concerns over leaks and disposal of contaminated water. Waste minimization also affected those designs for which the decontamination and decommissioning effort was more extensive or costs were judged to be higher.

FUNCTIONAL ANALYSIS

The proposed plutonium storage vault concepts were analyzed in three steps: 1) development of a functional description of a plutonium vault based on functional requirements and constraints; 2) compilation of a list of vault design concepts to be considered; and 3) evaluation of the design concepts against the required functions and constraints. In the course of the review, 19 storage concepts were identified and evaluated resulting in a set of 5 concepts judged to meet the functional requirements.

The primary required functions for a storage vault were identified as receiving incoming storage packages, moving packages to storage positions, retrieving packages from storage, moving packages to work or shipping stations, and shipping packages to external locations. Implicit in these required functions is the capability to identify storage packages and their locations at all times.

Constraints on performance of the required functions include providing criticality safety and contamination confinement, limiting radiation exposures, limiting environmental impact, removing heat, allowing for facility and equipment maintenance, meeting safeguards and security requirements, enabling third party inspections, maximizing passive safety, and providing for decontamination and decommissioning.

STORAGE CONCEPTS

Of the 19 storage concepts initially considered, 10 were eliminated in the evaluation because they were judged not to meet the functional requirements. The remaining nine were reduced to five by combining similar design features. The basic design characteristics of the remaining five concepts are discussed below.

1. Warehouse Storage

The vault is separated into bays by concrete walls. Unshielded containers are hung on walls in a horizontal array. An automated guided vehicle (AGV) moves containers to or from storage locations. Active air cooling is required for this design.

Advantages. This is the most common type of SNM storage vault, and there is substantial experience in design and operation of such facilities. Storage locations are readily accessible, facilitating removal of items and physical inventories that could be performed in place. Individual bays can be isolated allowing material segregation to limit spread of contamination and enable third party inspections of portions of the inventory.

Disadvantages. Radiation levels in filled bays preclude manned entry to deal with problems and reduce operational flexibility. A safety-class, active, high-volume cooling system would be required to remove heat and assure that temperatures of stored items remain below an allowable maximum. This increases the complexity of the filtered contamination confinement system. Many storage locations could be contaminated by a single leaking container, unless the vault is divided into many small compartments. Security surveillance of all storage locations in vertical arrays with narrow aisles is more difficult and expensive than for horizontal arrays, and the technology for continuous monitoring of SNM attributes is less developed. AGV technology would require further development before application to this design.

2. Water-Cooled Vertical Sleeve

Eight to twelve containers in a rack are stored in a vertical sleeve extending through the concrete floor of the vault. A remotely operated crane moves containers to or from storage locations. Cover plugs provide shielding and security. Beneath the floor, the sleeve extends into a pool of water.

Advantages. There is substantial experience within the complex in using pool type storage for nuclear materials. The technology for remotely operated cranes is fully developed. Storage in individual sleeves limits most contamination incidents to a single sleeve and facilitates third party inspection of a portion of the inventory because individual sleeves can be presented to inspectors. Sleeve plugs increase security and allow people to enter the facility. Security surveillance of a large number of sleeve covers can be performed with a single monitoring device in a horizontal array. Existing technology for continual monitoring of SNM attributes can reduce physical inventory requirements. Water cooling allows the use of low-volume air flows for heat removal, which simplifies the design of the filtered confinement system. Passive cooling is possible with this design if heat pipes can cool the pool.

Disadvantages. Individual containers are less accessible for inventory, shipping, or safety evaluations because an entire sleeve must be removed to unload an item. Pool storage requires purchase and installation of water treatment equipment and continual maintenance of water chemistry and periodic inspections for leaks or corrosion. Decontamination and decommissioning efforts will be more complicated and costly for a water-cooled facility. The most significant concern for water-cooled storage is the potential environmental impact resulting from a leak or the need to dispose of contaminated water.

3. Air-Cooled Vertical Sleeve

Vaults with an air-cooled vertical sleeve are identical to vaults with a water-cooled vertical sleeve except that the sleeves extend through the floor into an air bath. This design originally included active air cooling; however, a recent design study indicates that a passive air cooling system could also be used.

Advantages. The technology for remotely operated cranes is fully developed. Storage in individual sleeves limits most contamination incidents to a single sleeve and facilitates third party inspection of a portion of the inventory because individual sleeves can be presented to inspectors. Sleeve plugs increase security and allow people to enter the facility. Security surveillance of a large number of sleeve covers can be performed with a single monitoring device in a horizontal array. Existing technology for continual monitoring of SNM attributes can reduce physical inventory requirements. Maintenance and the potential for adverse environmental impact are reduced in comparison to water-cooled systems. If passive air cooling can be used, benefits would include simplification of the filtered confinement system as well as safety advantages.

Disadvantages. Individual containers are less accessible for inventory, shipping, or safety evaluations because an entire sleeve must be removed to unload an item. Air cooling may require an active, high-volume cooling system to remove heat, which complicates the design of the filtered confinement system.

4. Air-Cooled Horizontal Sleeve

Eight to twelve containers in a rack or tray are stored in a horizontal sleeve extending through the concrete wall of the vault bay. A remotely operated stacker/retriever moves containers to or from storage locations. Cover plugs provide shielding and security. This design requires active air cooling.

Advantages. Storage in individual sleeves limits most contamination incidents to a single sleeve and facilitates third party inspection of a portion of the inventory because individual sleeves can be presented to inspectors. Sleeve plugs increase security and allow people to enter the facility. Maintenance and the potential for adverse environmental impact are reduced in comparison to water-cooled systems.

Disadvantages. Individual containers are less accessible for inventory, shipping, or safety evaluations because an entire sleeve must be removed to unload an item. Air cooling requires an active, high-volume cooling system to remove heat, which complicates the design of the filtered confinement system. Concerns about security surveillance of storage locations and monitoring SNM attributes in large horizontal arrays are the same as for the warehouse storage concept.

5. Single Container in a Floor Well

A shallow well in concrete holds a single container in dry storage. A metal cover provides shielding, security, and heat transfer. Remotely operated cranes move containers to or from storage. LANL consultants demonstrated that passive air cooling is an option for this design, provided that there is sufficient separation between wells.

Advantages. The technology for remotely operated cranes is fully developed. Storage in individual wells limits most contamination incidents to a single stored item. The vault can be easily separated into bays or rooms to facilitate third party inspection of a portion of the inventory, although this could negatively impact heat removal capabilities. Well covers provide increased security and heat transfer and allow people to enter the facility when needed. Security surveillance of a large number of wells in a horizontal array can be performed with a single monitoring device. The large mass and surface area of the floor slab allow the use of low-volume air flows for heat removal, which simplifies the design of the filtered confinement system. Passive cooling may be possible with simple venting of the confinement building.

Disadvantages. Due to storage of items in individual floor wells, the area of the vault is much larger than for the other four storage concepts. Although this is somewhat countered by the lower height required for the building, it is likely that construction costs would be substantially higher.

CONCLUSIONS

The analyses reported here found five designs that can meet the major functional requirements for long-term storage of plutonium. The exercise demonstrated that functional analysis is an effective and efficient method for pooling diverse areas of expertise to evaluate complex systems.