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DEFENSE NUCLEAR FACILITIES SAFETY BOARD

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March 10, 2005

The Honorable Samuel W. Bodman
Secretary of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Bodman:

On March 10, 2005, the Defense Nuclear Facilities Safety Board (Board), in accordance with 42 U.S.C. § 2286a(a)(5), unanimously approved Recommendation 2005-1, *Nuclear Material Packaging*, which is enclosed for your consideration. This recommendation addresses issuance of a requirement that nuclear material packaging meet technically justified criteria for safe storage and handling outside of engineered contamination barriers.

After your receipt of this recommendation and as required by 42 U.S.C. § 2286d(a), the Board will promptly make it available to the public. The Board believes that the recommendation contains no information that is classified or otherwise restricted. To the extent this recommendation does not include information restricted by the Department of Energy (DOE) under the Atomic Energy Act of 1954, 42 U.S.C. §§ 2161-68, as amended, please arrange to have it promptly placed on file in your regional public reading rooms. The Board will also publish this recommendation in the *Federal Register*. The Board will evaluate DOE's response to this recommendation in accordance with Board Policy Statement 1, *Criteria for Judging the Adequacy of DOE Responses and Implementation Plans for Board Recommendations*.

Sincerely,

John T. Conway
Chairman

Enclosure

c: Mr. Mark B. Whitaker, Jr.

RECOMMENDATION 2005-1 TO THE SECRETARY OF ENERGY
Pursuant to 42 U.S.C. § 2286a(a)(5),
Atomic Energy Act of 1954, As Amended

Dated: March 10, 2005

Background

In Recommendation 94-1, *Improved Schedule for Remediation in the Defense Nuclear Facilities Complex*, the Defense Nuclear Facilities Safety Board (Board) urged the Department of Energy (DOE) to improve the packaging and storage conditions of its large inventory of nuclear materials once used for weapons manufacture. In particular, the Board recommended that DOE place plutonium metals and oxides in storage configurations meeting DOE's standard for long-term storage (DOE-STD-3013-2004, *Stabilization, Packaging, and Storage of Plutonium-Bearing Materials*). Some sites applied Recommendation 94-1 to excess materials only. The Board has continued to evaluate whether other categories of nuclear materials are stored in a safe manner.

DOE has made progress in the stabilization and storage of its excess nuclear materials. The storage requirements for other categories of nuclear materials, however, are not as well defined and controlled. Specifically, DOE Order 5660.1B, *Management of Nuclear Materials,* does not address safe storage requirements. Other than two narrowly focused standards—DOE-STD-3013-2004 and DOE-STD-3028-2000, *Criteria for Packaging and Storing Uranium-233-Bearing Materials*—there is no explicit DOE-wide requirement to ensure the safe storage of nuclear materials. Currently, the technical adequacy of packaging—the combination of containers and other components providing a contamination barrier—for nuclear materials, including liquids, is dependent on the safety bases of individual facilities. Typically, facilities have credited engineered features, such as the confinement structure and ventilation system, for protecting offsite individuals and collocated workers. For facility workers, however, the controls are generally administrative, such as continuous air monitors, personal protective equipment, periodic contamination surveys, and other aspects of the radiological control program, in conjunction with proper evacuation training. In accordance with DOE Standard 3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analysis* (DOE-STD-3009-94, Change Notice 02), accidents that pose the risk of significant radiological exposure to workers, such as a breached nuclear material storage package, should be prevented or mitigated using safety-significant controls. The preferred hierarchy of controls favors engineered, preventive features over administrative controls.

Establishing packaging requirements for nuclear materials within the DOE complex requires consideration of a diverse population of material types for storage for uncertain periods of time. From a safety standpoint, nuclear material packaging must protect against a number of challenges that could breach the container and release radioactive material. Many of the materials of concern generate gases that result in container pressurization and may be pyrophoric or highly reactive. The container design must take into account corrosion, oxidative expansion of stored metal, effects of radiolysis, diurnal pumping and damage due to impacts from drops and tooling during handling. The Board's recent review of nuclear material packaging at

Lawrence Livermore National Laboratory (LLNL) revealed that many of these insults had not been fully considered when packaging choices were made for nuclear materials not covered by Recommendation 94-1. In fact, many of these current packaging configurations are similar to the inadequate configurations addressed in Recommendation 94-1, and are documented as being susceptible to eventual failure in the report of the Recommendation 94-1 Materials Identification and Surveillance Working Group, entitled *Summary of Plutonium Oxide and Metal Storage Package Failures* (LA-UR-99-2896).

In general, the hazards posed by nuclear materials covered under DOE's Implementation Plan for Recommendation 94-1 are the same as those for nuclear materials not considered excess. When nonexcess materials are removed from glovebox confinement for interim storage, relocation to another work station, assay, or other purposes, the packages are susceptible to the same types of failures as those addressed in Recommendation 94-1. The longer the materials are stored, the greater are the chances that the packaging will fail, especially if the packaging has not been designed appropriately for the actual duration of storage. The Board found that approximately 15 percent of the nonexcess items at LLNL's Plutonium Facility are stored in packaging more than 5 years old. Some of the older items, previously declared excess, remain in their existing packaging while awaiting stabilization and packaging under DOE-STD-3013-2004. This situation emphasizes the need to establish a technical basis for packaging, such as designating the time period for which a particular container is confirmed to perform its function adequately, in conjunction with tracking the age of containers in use.

Two recent events serve as further reminders of the importance of using packaging that is properly designed for its function:

- An August 5, 2003, event at Los Alamos National Laboratory's (LANL) Plutonium Facility resulted in multiple workers receiving plutonium-238 uptakes as a result of the degradation of a package stored longer than planned. This event is documented in a DOE Type B investigation report (HQ-EH-2004-1). The release of material and the resulting contamination and worker uptakes were due, in large part, to the inadequate packaging of plutonium being stored and handled outside of a glovebox.

- An October 6, 2004, incident at LLNL involved the accidental drop of a package containing salt-bearing plutonium oxide. This event is documented in an Occurrence Reporting and Processing System report (OAK--LLNL-LLNL-2004-0046). Although no plutonium was released, this event highlights the need to specify robust packaging requirements for materials handled outside of a glovebox.

State of Nuclear Material Packaging

DOE-STD-3013-2004 sets forth requirements for a robust storage configuration for long-term storage of plutonium-bearing materials. The requirements ensure containment through a combination of material form, packaging design, and surveillance of containers. However, the robust, welded configurations in the standard may not be desirable when a short storage period is anticipated pending use of the material.

There are no equivalent requirements for interim storage. As part of its response to Recommendation 94-1, DOE finalized guidance for the storage of plutonium-bearing materials not packaged for long-term storage under DOE-STD-3013. This guidance, identified in a January 25, 1996, memorandum from Deputy Secretary of Energy Curtis entitled *Criteria for Interim Safe Storage of Plutonium-Bearing Solid Materials*, provides a technically justified approach to safe packaging and storage of plutonium-bearing materials for a period of up to 20 years. Although these Interim Safe Storage Criteria (ISSC) were not intended to apply to materials in working inventory, much of the guidance remains germane to storage of all nuclear materials outside of approved engineered contamination barriers (e.g., gloveboxes or certified shipping containers).

The ISSC were only implemented for selected excess materials and were never formally issued as part of the DOE Directives System. In practice, the sites use a wide variety of packages, many of which do not meet the ISSC. According to the lessons learned from the DOE Type B investigation of the worker uptakes at LANL, packages containing radioactive material should be assumed unsafe until proven otherwise or the materials are repackaged to current standards. Yet sites continue to rely on container types that have been used historically, but have no technically justified safety or design basis. These container types are generally forms of packaging typically used in non-nuclear applications (e.g., paint cans, food pack cans). Thus, they are not designed to protect against the hazards of the nuclear materials they contain for the duration of storage.

Several commonly used containers and their potential inadequacies are briefly summarized in an attachment to this Recommendation. Many other containers are in use for specialized applications.

Remaining Problems

In response to the Board's May 20, 2002, correspondence on safety of nuclear materials storage, the National Nuclear Security Administration (NNSA) established the Inactive Actinide Working Group (IAWG), with the goal of developing a comprehensive approach to the characterization, packaging, and storage of a subset of nuclear materials. As presented in a February 7, 2003, letter from NNSA to the Board, the IAWG was to meet this goal through the development of three strategies for the following: acceptance and retention of nuclear materials, material characterization and storage adequacy, and disposition. The Board has been observing the IAWG's efforts and has made three observations.

First, a key product of the IAWG effort will be the strategy for material characterization and storage adequacy. Based on discussions with IAWG participants, the delivery of this strategy has been delayed, in large part because of disagreements among member sites on the requirements necessary for justifying adequate storage. The Board believes these requirements should provide for sufficient characterization based on an appropriate combination of analysis and process knowledge to determine the appropriate packaging. Characterization information should also be used to develop a surveillance program prioritized according to expected material and container risk (including, for example, material type, material form, and the age and type of container).

Second, in a June 2000 report entitled *A Strategic Approach to Integrating the Long-Term Management of Nuclear Materials*, DOE recognized the need to update the existing DOE Order on nuclear materials management. In particular, this report urged improvements to the nuclear materials management process. However, neither the current Order nor the report explicitly considers storage safety. The Board believes that DOE should require a technical basis for nuclear material packaging and storage safety. Efforts to meet this requirement should take advantage of the knowledge about storage adequacy being developed by the IAWG, as well as existing guidance, such as the ISSC.

Third, the IAWG strategy does not include other program offices in the defense nuclear complex, such as the Nuclear Energy, Science, and Technology (DOE-NE) facilities involved in defense nuclear activities. Currently, materials and activities in transition between the facilities of different program offices have the potential to be overlooked. For example, operators at the Savannah River Site have begun converting the neptunium-237 solutions covered under Recommendation 94-1 to oxide and placing the oxide in packaging intended for 1 year of storage at that site prior to offsite shipping. The long-term storage of large quantities of neptunium oxide has not been performed previously in the complex, and the technical basis for ensuring the safety of such storage is incomplete. Nonetheless, these materials will be transferred to DOE-NE for use, where they may continue to be stored in their existing packaging for a period of up to 20 years. In addition, the Board has learned that DOE-NE intends to assume more direct control of activities involving plutonium-238, which have to date been performed at NNSA sites. The significant radiological hazards associated with this material necessitate appropriate storage containers for the expected storage period. The Board believes the requirement for a technical basis for nuclear material packaging and storage should encompass all program offices in the defense nuclear complex. DOE may wish to consider implementing this requirement for all program offices, including those outside of the defense nuclear complex.

The Board is encouraged by other efforts currently under way to improve nuclear material packaging. As a result of discussions between the Board's staff and LLNL, the Livermore Site Office, in a December 3, 2004, letter, directed LLNL to develop a technical basis for the adequacy of storage packages as part of a Special Nuclear Materials Storage Plan covering "all packaging activities." LLNL replied in a letter of January 31, 2005, outlining the required activities, milestones, and funding to develop and implement an approved packaging and storage program. Implementation of the plan is contingent upon the availability of key personnel and funding. Likewise, the proposed Documented Safety Analysis (DSA) for the LANL Plutonium Facility requires the use of a proposed facility packaging standard and designates material containers as a safety-related component. However, the new DSA has been awaiting NNSA approval. In general, these efforts represent an improvement, but they do not represent a comprehensive DOE-wide effort, and significant differences remain in the quality of the efforts at individual facilities.

Recommendation

Nuclear material packaging provides the primary containment boundary to protect facility workers during storage and handling activities. The Board believes the development of technically justified criteria for packaging systems for nuclear materials is necessary on a DOE-wide level. Therefore, the Board recommends that DOE:

1. Issue a requirement that nuclear material packaging meet technically justified criteria for safe storage and handling. Packaging should, in general, provide a robust barrier between facility workers and the stored nuclear materials once they are removed from an approved engineered contamination barrier. It may be appropriate to include this requirement in an updated nuclear materials management Order.

2. Identify which nuclear materials should be included in the scope of the above requirement and then determine the technically justified packaging criteria needed to ensure the safe storage and handling of those materials. The scope need not include waste materials, fully encapsulated forms, or de minimus quantities such as analytical laboratory samples. The criteria should account for the nuclear material form and properties, expected future use, and duration of storage. It may be appropriate for this information to be included in a packaging Manual.

   The ISSC may provide the beginning of a sound technical foundation for developing such criteria. Although some modifications may be necessary to make the ISSC more applicable to short-term storage, the Board believes the basic ISSC principles—for example, the requirement for a minimum of two contamination boundaries for high-hazard materials such as plutonium, assurance that leak-tightness is maintained for materials requiring a sealed environment, ability of the containers to withstand maximum expected internal pressures, and protection against common insults such as drops—should be maintained. The criteria should also include provisions for surveillance programs to verify that the container and any limited-life components are performing in a manner consistent with the duration of storage.

3. Prioritize implementation of the improved nuclear material packaging requirement consistent with the hazards of the different material types and the risk posed by the existing package configurations and conditions.

John T. Conway, Chairman

Attachment

ATTACHMENT

Selection of Commonly Used Nuclear Material Packaging

Food-Pack Cans

Food-pack cans are thin-walled tinned carbon steel containers used in the food industry. No additional manufacturing or structural requirements have been specified for application with nuclear materials. These cans typically rely on a double-crimped metal-to-metal closure with a thin layer of sealing compound to provide leak-tightness. Historically, many sites have reported failures of food-pack cans. Lawrence Livermore National Laboratory (LLNL) has reported anecdotal evidence suggesting that none of its food-pack cans have failed to the point of detectable contamination outside the container (UCRL-ID-11733). However, this same report states further that some degree of oxidation was observed in all of the examined food-pack cans containing plutonium metal, suggesting the lack of an airtight seal. Leakage of oxygen through nonairtight food-pack cans has been responsible for a number of container failures reported at other sites, due to oxidative expansion of plutonium metals (LA-UR-99-2896).

Improvements have been made to the technology, including better sealing equipment, as discussed in a May 1984 report entitled *The Effectiveness of Corrective Actions Taken to Preclude Events Involving Tin Cans and Plutonium* (RHO-HS-SA-59 P). Some evidence suggests, however, that these containers still may not be adequate for prolonged storage of nuclear materials. Approximately half of the sampled lot of food-pack cans sealed 10 to 14 years earlier at the Hanford Plutonium Finishing Plant using the improved methodology failed leak testing, and nearly all showed further indications of a potential lack of seal (LA-UR-99-3053).

Additional testing performed at Pacific Northwest National Laboratory confirmed that the performance of food-pack cans is highly dependent on the quality of the seal (PNL-5591). During these tests, 33 industry-standard food-pack cans were sealed according to federal specifications. The testing revealed leak rates ranging from less than 10^{-5} cubic centimeters per second (cc/sec) to more than 2 cc/sec. These findings should receive due consideration when food-pack cans are used for storage applications in which a hermetic seal is required. LLNL continues to use food-pack cans as inner and outer containers for the storage of plutonium metal and oxide, and other sites may be storing nuclear materials previously packaged in food-pack cans.

Paint Cans

Paint cans are thin-walled cans with a press-fit lid that are commonly used to store paint. They have been used as both inner and outer containers for the storage of some nuclear materials, including plutonium metal. The press-fit lid is typically placed by hand using a mallet, which results in a questionable seal lacking any evidence of quality control. According to a January 16, 1987, LLNL site report entitled *Incident Analysis/Plutonium Burn in Storage Can*, oxidation was found to be common for plutonium metal stored in paint cans (memorandum from R. H. Condit to K. Ernst). The report goes on to calculate that a 4 micron gap integrated across the seal area would be sufficient to permit complete oxidation of 100 grams of plutonium metal in 1 year. A leak of this size can reasonably be assumed to be present in the press-fit closure; therefore, the adequacy of these cans for nuclear material storage applications requiring a seal cannot be ensured. Although LLNL reports that ingress of air is expected because the lid and rim of the can are not designed to be airtight (UCRL-ID-117333), paint cans remain approved for use for certain applications at the laboratory. Other sites may also be storing nuclear materials that were previously packaged in paint cans.

Taped Slip-Lid Cans

Slip-lid cans are thin-walled cans with a loose-fitting cover that is often taped. While convenient and inexpensive, the use of these containers has resulted in several breached storage packages, including the plutonium-238 package that led to the Type B event at Los Alamos National Laboratory (LANL). Many nuclear material packages consisting of nested taped slip-lid cans remain at the Department of Energy's defense nuclear facilities. By design, these cans were never intended to serve a containment function. Furthermore, except for tape, a mechanical closure is absent, resulting in a container that may not be able to provide even gross retention of the materials within. The effectiveness of tape in performing this sealing function over time and under high radiation conditions is poorly understood. For this reason, the Interim Safe Storage Criteria (ISSC) specifically prohibit crediting slip-lid cans as one of the two required contamination barriers. Yet several sites continue to use this type of packaging. For nonmetallic plutonium, including items containing plutonium-238, LANL plans to rely on stainless steel taped slip-lid cans only as an inner container; currently, however, a large number of items remain at the laboratory in nested slip-lid cans. Moreover, several varieties of slip-lid cans continue to be approved for use as inner and outer storage containers for certain materials at LLNL.

Hagan Can

LANL's Comprehensive Nuclear Material Packaging and Stabilization Plan approves the use of a standard container known as the Hagan can, a robust, screw-top container with an O-ring seal and filtered vent. The Hagan can generally meets the expectations of the ISSC and has undergone testing to certify its performance (Wickland and Mataya, PATRAM 98, 1998). However, drop testing was performed at a height lower than the expected maximum storage height; therefore, additional analysis or testing is required. Under the proposed Documented Safety Analysis for LANL's Plutonium Facility, the Hagan can is classified as a safety-significant engineered feature. The Hagan can appears to be an appropriate outer package for nuclear material storage, although, as recognized by LANL, the service life of the Viton (an organic fluorocarbon compound) O-ring requires verification through a surveillance program. Currently, Hagan cans are widely used only at LANL; however, their use may be under consideration at other sites.

Conflat Can

A can fabricated with a Varian-type Conflat flange results in a hermetically sealed, robust container that can be used to store plutonium metal. A copper gasket on a bolted flange closure is designed to maintain a long-term hermetic seal against oxidation of plutonium metal. This closure type has been standard in the high-vacuum industry for many years and has been certified to maintain a leak-tight seal under various temperature and pressure conditions. The Conflat can is identified in LANL's Comprehensive Nuclear Material Packaging and Stabilization Plan as the inner container for the storage of plutonium metal. The use of Conflat cans for storage of other nuclear materials requiring a sealed environment may also be appropriate. Conflat cans have been used periodically at some sites for special storage applications, but their use is not widespread or uniform.

Metal Drums

Several sites commonly use U. S. Department of Transportation (DOT) Type A containers and similar types of metal drums for overpacking of packages of nuclear materials for onsite transportation and storage. These containers have been certified as Type A radioactive material packages per DOT specifications. For transportation purposes, this certification usually is limited to a single year. The use of these containers for interim storage beyond the certification period appears appropriate, but consideration should be given to periodic inspection and replacement for limited-life components, such as lid gaskets. The *Criteria for the Safe Storage of Enriched Uranium at the Y-12 Plant* (Y/ES-015/R2) allow interim storage of enriched uranium materials for a period of up to 10 years in DOT Type A or Type B containers.

Y-12 Prolonged Storage Container

The Y-12 Y/ES-015/R2 criteria specify the use of stainless steel cans similar to food-pack cans for prolonged low-maintenance storage for up to 50 years. While the reliance on a single robust barrier for the storage of enriched uranium may be appropriate, it is unclear whether the requirement to maintain mechanical and seal integrity during normal handling includes protection against drops. In addition, a lid sealant compound is specified in the appendix to Y/ES-015/R2, but no discussion of its longevity is provided. While fewer radiological hazards and less chemical reactivity are associated with enriched uranium than with plutonium and some other nuclear materials, further testing of these containers would better demonstrate their reliability for long-term storage. Currently, the Y-12 container specification is planned for use only at the Y-12 National Security Complex.

Plastic Bags and Bottles

Historically, plastic bags have been relied upon to provide contamination control for a limited period. Bag materials, which include polyethylene, polyvinyl chloride, and related polymers, play an important role in the overall packaging system. Their principal use is for contamination control during the "bagout" operation, when the nuclear material container is removed from the glovebox. Unfortunately, some types of bags have proven to be detrimental to the integrity of packages left in storage for prolonged periods of time. For example, the radiation-induced degradation of polyvinyl chloride bag material led to the production of hydrochloric acid, which in turn contributed to the corrosion and eventual failure of containers that occurred during the Type B event at LANL. The choice of material also impacts the generation of radiolytic gas and effectively defines the service life of a package when the outer container is not leak-tight. In repackaging campaigns at LLNL, as well as at other sites, such as Hanford, bags commonly have been found to be in a discolored or otherwise degraded state (UCRL-ID-117333 and WHC-SD-TRP-067). While plastic bags have been in use for a long time, little quantitative information exists on the effects of time, temperature, and radiation field exposure on maintenance of an effective contamination barrier. It is recognized that plastic bags may be necessary for contamination control, but they should not be relied upon as a long-term contamination barrier.

In some cases, plastic bottles (e.g., safe bottles) have been used for the storage of solutions containing nuclear materials, especially enriched uranium, outside of processing equipment. While bottles are constructed of thicker plastics than are bags, they undergo the same chemical and radiolytic degradation with time and must be compatible with the chemical properties of the contained liquids. Furthermore, whereas bags provide only contamination control, bottles are relied upon to provide a complete contamination barrier, including structural integrity. Any reliance on plastic bags or plastic bottles for extended periods of time should be informed by the available knowledge of polymer degradation, in combination with information gleaned from surveillance programs.