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Title: TECHNICAL CONSIDERATIONS AND POLICY REQUIREMENTS FOR PLUTONIUM MANAGEMENT

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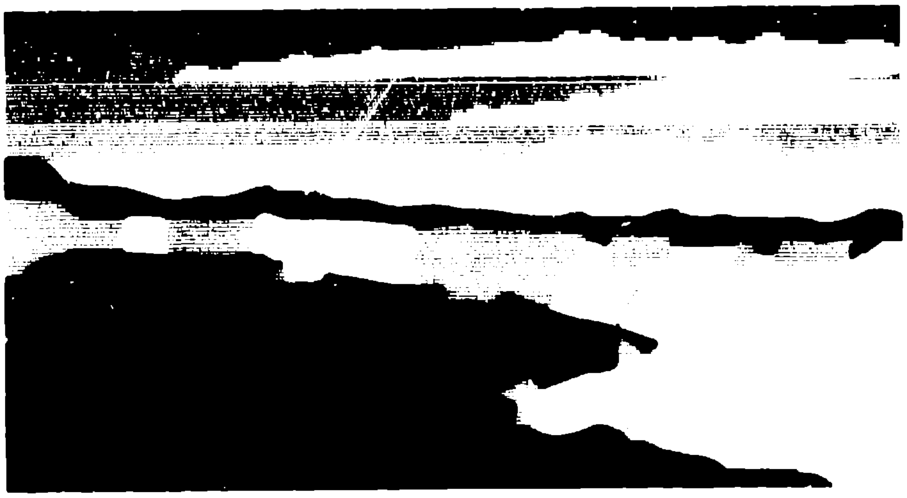

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Technical Considerations And Policy Requirements For Plutonium Management

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ABSTRACT

The goals for plutonium management have changed dramatically over the past few years. Today, the challenge is focused on isolating plutonium from the environment and preparing it for permanent disposition. In parallel, the requirements for managing plutonium are rapidly changing. For example, there is a significant increase in public awareness on how facilities operate, increased attention to environmental safety and health (ES&H) concerns, greater interest in minimizing waste, more emphasis on protecting material from theft, providing materials for international inspection, and a resurgence of interest in using plutonium as an energy source. Of highest concern, in the immediate future, is protecting plutonium from theft or diversion, while the national policy on disposition is debated. These expanded requirements are causing a broadening of responsibilities within the Department of Energy (DOE) to include at least seven organizations. An unavoidable consequence is the divergence in approach and short-term goals for managing similar materials within each organization. The technology base does exist, properly, safely, and cost effectively to extract plutonium from excess weapons, residues, waste, and contaminated equipment and facilities, and to properly stabilize it. Extracting the plutonium enables it to be easily inventoried, packaged, and managed to minimize the risk of theft and diversion. Discarding excess plutonium does not sufficiently reduce the risk of diversion, and as a result, long-term containment of plutonium from the environment may not be able to be proven to the satisfaction of the public.

INTRODUCTION

As a result of the Strategic Arms Reduction Treaties and unilateral offers and agreements made by Presidents Bush, Gorbachev, and Yeltsin, the United States and Russia will retire many thousands of nuclear weapons within the next decade. This will remove many metric tons of plutonium from military control. Plutonium is one of the essential elements of nuclear weapons, and physical controls on the access to plutonium historically have been the primary barrier to theft and/or proliferation of nuclear weapon material. Not so obvious today is the fact that surplus plutonium also exists in the form of raw metal and oxide, residues, transuranic (TRU) and low level waste (LLW), contaminated facilities and equipment, and spent nuclear fuel, each of which also represents a significant source for diversion. With the end of the cold war, the management of these categories of materials is fragmented; and, consequently, they are at increasing risk for loss of management control.

A recent National Academy of Sciences study on the "Management and Disposition of Excess Weapons Plutonium"[1] is quoted as saying that, with regard to the weapon-related materials: "The existence of this surplus material constitutes a clear and present danger to national and international security." This report defines the need to safeguard and more comprehensively manage surplus inventories until permanent disposition options can be selected. The state of technology to address this inventory will be explored.

DISCUSSION

Recently, numerous studies have been published concerning the management of plutonium.[1-4] This fact indicates the keen interest that the international community places on managing this material safely and properly. Over the 50 years since the discovery of plutonium, the main use for plutonium in the U.S. was in national defense. A second major use of plutonium has been as an energy source in advanced fuel programs. At the time of the discovery, all plutonium work was conducted under self-imposed secrecy, as a result of the recognition that it was possible to produce a powerful explosive through the rapid fissioning of plutonium by neutron bombardment. This precedent was maintained during the cold war, and very little actual information concerning the use and inventories of weapons plutonium was published. Numerous physical security measures were deployed to protect against the diversion of either information or the actual material outside the nuclear weapon community. This was accomplished fairly easily because all the material was handled under the jurisdiction of the Department of Energy Office of Defense Programs (DOE/DP), and Office of Nuclear Energy (DOE/NE).

The New Requirements

The end of the cold war has brought about a significant change in how plutonium inventories are managed. First, the Secretary of Energy began an initiative to increase the quality of ES&H management within Department facilities.[5] This step exposed the nuclear defense community to a broader range of oversight organizations, most of which are outside the Department. At the same time, Congress established the Defense Nuclear Facilities Safety Board (DNFSB), with the charter to evaluate the performance of the Department of Energy (DOE) in the execution of its safety and health obligations.[6] This became a very public vehicle for bringing scrutiny on the Department's nuclear operations. Congress and the Department established the Office of Environmental Remediation and Waste Management (DOE/EM) with the charter to clean up excess cold war nuclear facilities and sites.[7] This resulted in the transfer of a significant amount of plutonium to the new DOE/EM in the form of residues, waste, and contaminated equipment and facilities. The DOE/EM Office is heavily involved in the privitization of facility clean up functions, and most of the new contractors are unaware of the historical basis of nuclear material management. The Secretary announced the "Openness Initiative" wherein previously classified information was released for public consumption. This included the disclosure of quantities of plutonium that exist in the defense inventories.[8] Congress recognized the fact that plutonium would become an inventory challenge and initiated the DOE Office of Material Disposition (DOE/MD) to evaluate permanent disposition options for excess weapons materials. An additional dimension to the charter of DOE/MD was the opening of relations with the Russian Federation and the discussion of plutonium stabilization and disposition.[9] In 1995, the President announced that the U.S. would place 200 metric tons of special nuclear material under the International Atomic Energy Agency (IAEA) safeguards program.[10] This action exposed the DOE facilities to the potential for international safeguard controls over material. During 1994, two weapons DOE Complex-wide plutonium safety assessments were made; one by the DNFSB and the other by the Assistant Secretary for Environmental Safety and Health.[11,12] The latter assessment resulted from a 1993 Presidential initiative on nuclear nonproliferation and DOE's effort to develop strategies for the eventual disposition of excess fissile materials.[12,13] Both of these assessments identified the imminent dangers to workers, environment, and the public associated with the ever-deteriorating state of nuclear material packages, infrastructure, and nuclear facilities. This list of significant changes and actions has generated an increasingly more complex list of requirements for material management and facility operations. Globally, the new requirements include:

1. Theft protection of materials -- The DOE published a minimum set of requirements and procedures for the control and accountability of nuclear materials.[14] In addition, a set of international standards has been proposed concerning storage, protection, and accountability of spent nuclear fuels in surface and geologic storage.

2. Long-term ES&H management -- The DOE strengthened the role of its Office of Envirnoment, Safety and Health (DOE/EH) in performing its self-assessment responsibilities and has engaged other government organizations in jointly performing ES&H oversight to include the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and others.

3. Cost of Material Management -- The Department is embarking on the development of a uniform approach for the packaging and storage of excess nuclear materials and has published a standard for the handling of materials that have a plutonium (Pu) content of >50%.[15] The Department is also working on a packaging and storage standard for lower-concentration materials.

4. Waste Management -- The responsibility for the management and minimization of waste is distributed among a number of offices. Managing the source-term for materials considered for discard is the key to controlling the release of plutonium to the environment. The EPA, as well as state and local agencies, also have a role in the management, handling, transportation, and disposal of mixed waste.

5. Military Applications and Nonproliferation -- Nuclear weapons continue to represent an aspect of national defense. The control of nuclear weapon technology and information, as well as the identification of the spread of such technology, is essential.

6. Energy Production -- Countries having nuclear capability are evaluating the use of excess plutonium and enriched uranium in future power production. A number of national studies have evaluated this approach and support it.[1,2,3] The current policy of the U.S. is not to reprocess and recycle spent nuclear fuels.

7. National Policy -- The national policies concerning the use of plutonium in the fuel cycle, disposal of plutonium, control of weapon information, and other aspects of the problem, are in a dramatic state of flux. Understanding and managing these policy changes is an essential requirement.

These requirements are the major issues that are changing the organizations involved with and the approaches to managing nuclear materials. Establishing a uniform basis for managing these materials must take into account these requirements Whereas in the past, most of the weapon nuclear materials were managed by the DOE/DP and DOE/NE, the significant changes discussed above have caused a rapid distribution of responsibility to include as many as seven DOE organizations, thus exacerbating the problem. Figure 1 shows the various organizations who have responsibility over materials, technology, information, and/or operations involving nuclear materials. The *X*s in the table indicate where each organization plays a role in implementing the various requirements. The very fact that so many *X*s occur indicates the need to develop a uniform policy and approach for nuclear material management.

Program Requirements for Nuclear Material Management

Organization	Theft	ES&H	Waste	Cost	Military	Energy	Policy
DOE/DP	*X*	*X*		*X*	*X*		*X*
DOE/NE					*X*	*X*	*X*
DOE/EM	*X*	*X*	*X*				*X*
DOE/MD		*X*	*X*			*X*	*X*
DOE/NN	*X*			*X*	*X*	*X*	*X*
DOE/EH		*X*	*X*				*X*
DOE/PO	*X*	*X*	*X*	*X*	*X*	*X*	*X*

Figure 1: Department of Energy organizational relationship versus program requirements for nuclear material management.

Of the new categories of requirements, the one involving the greatest concern is the Theft (anti-theft) requirement. In an effort properly to evaluate this category, the DOE Order on the Control and Accountability of Nuclear Materials[14] can be used to express the forms of plutonium according to their theft attractiveness. Figure 2 is a extracted from the DOE Order in terms of the Attractiveness Categories and the materials categories. On the far right side of the figure are listed the typical materials existing within inventories and how they are categorized within the definitions of the DOE Order. From a theft and proliferation standpoint, weapon assemblies and components are the highest and are therefore noted at level A in the figure. Plutonium pits, freshly separated plutonium metal and oxide, and recycled metal and oxide are slightly lower in attractiveness, and therefore fall into attractiveness level B. Residues, unirradiated fuel and some TRU wastes fall into attractiveness level C. Spent nuclear fuel and most (TRU) waste both fall into attractiveness level D. Finally, HLW and LLW fall into the lowest level of attractiveness, level E. Added at the bottom of the figure, althouth not specifically noted in the DOE Order is a category titled "other". Within this category exists material such as Nevada Test Site Debris. Although this is relatively difficult to obtain, never the less, it represents a source of plutonium for theft or diversion. In fact, in the old test locations, the materials have likely cooled sufficiently such that the nuclear materials are relatively desireable.

The plutonium weapon components, separated metal and oxide, and small portions of the residues are currently under the jurisdiction of the DOE/DP and are managed in a fashion consistent with national defense security activities. Similarly, the storage, protection, and accountability of spent nuclear fuel falls under the jurisdiction of the IAEA and is managed in a consistent fashion. It is the materials that fall in the categories of residues, TRU waste, and LLW that are managed in a number of organizations that have less of an integrated focus. Of particular concern is the fact that the American Nuclear Society Special Panel on Protection and Management of Plutonium[3] reported that spent nuclear fuel is a continuing proliferation risk, that burial of spent nuclear fuel is not adequate to protect it from proliferation, and that spent nuclear fuel becomes more attractive over time because of the die-out of short-lived daughter products. These facts were reinforced by Dr. Glenn T. Seaborg in his plenary talk to the American Nuclear Society on October 30, 1995.[16] In looking at Figure 2 and in reading reference 13, one clearly concludes that if spent nuclear fuel represents a continuing proliferation risk, then residues and

Attractiveness Level	Materials Categories	Typical International and DOE Materials
A	Weapons: assemblies and test devices	Weapon assemblies and some components such as some pits.
B	Pure Products: Pits, major components, buttons, ingots, recastable metal, directly convertible materials	Most pits, freshly separated metal and oxide (IAEA) and recycled metal and oxide (DOE)
C	High-Grade Materials: Carbides, oxides, solutions >25 g/l, nitrates, fuel elements, alloys.	Unirradiated fuel, Weapon Manufacturing Residues, Some TRU Waste
D	Low Grade Materials: Solutions 1-25 g/l, process residues requiring extensive reprocessing, moderately irradiated materials	Old Spent Nuclear Fuel, Some Weapon Manufacturing Residues, Most TRU Waste
E	All Other Materials: Highly irradiated forms, solutions <1 g/l,	New Spent Nuclear Fuel, High Level Waste, Low Level Waste.
Other	Difficult to access materials	Nevada Test Site Debris

Figure 2: Nuclear Material Safeguards Categories.[14]

waste (TRU and LLW) also represent a continuing proliferation risk. Therefore, consistency in nuclear materials management is becoming increasingly important.

Consequently, it is worthwhile to look at the history of categorization of these materials. During the cold war period, the United States hosted a program of nuclear weapon fabrication that included the making of new plutonium in reactors and, simultaneously, the recycle of manufacturing residues. The value of new plutonium was calculated based on the cost of nuclear reactor and separation canyon operations. The cost of recycle was then compared to the cost of new plutonium, and a decision was made concerning the discard of residues. Those with a cost of recovery that exceeded the cost of new plutonium were categorized as waste and packaged for disposal. Those with a cost of recovery less than new plutonium were saved for recycle. This concept was referred to as the "Economic Discard Limit." In addressing the priority for residue recycle, the residues with large plutonium content, and therefore most easily recovered, were selected for recycle first. The lower-concentration residues were stored for future recovery. This approach was referred to as "High-Grading." The decisions were based on available budget and not limited based on whether appropriate technology was available for processing. Clearly this approach was flawed in that it is the lower-concentration residues that contain undesirable characteristics and constituents that are today causing storage difficulties. These difficulties include container failures, corrosion, pressurization, and general loss of containment.[17]

Of special interest is the fact that the basis for discard of nuclear materials was based on an economic evaluation and did not take into account the cost of waste management nor did it take into account the cost of future safeguards. This means that the basis for Material Accountability and Safeguards and the basis for discarding the material as waste were not coordinated. Therefore, some materials having a realtively high attractiveness were not deemed recyclable and were discarded.

The New Goals, Taking Into Account The New Requirements

Clearly today, the goals for plutonium handling have changed dramatically. The focus of the past was on the use of plutonium in nuclear weapons and advanced fuels, while the emerging needs revolve more around the elimination of the current packaging hazards, as well as around the safe isolation and stabilization of material. With regard to the excess residues, waste, facilities, and equipment, figure 3 illustrates this change in paradigm and, therefore, states the basis for the new goals.

In recognition of this new paradigm, DOE has abandoned the concept of "Economic Discard Limits"[18] and is in the process of preparing an approach referred to as the "Plutonium Discard Methodology" (PDM), which takes into account a number of criteria including technology availability, waste minimization, diversion risk, health and safety of processing, and cost.[19] In addtion, the DOE has prepared an approach for defining when safeguards provisions are to be terminated on discardable nuclear materials.[26] It is a concentration based criteria and provides for an absolute concentration calculation for safeguards termination. In order to evaluate the impact of this new paradigm, and both the PDM and termination criteria, it is essential to evaluate the status of plutonium inventories and then to evaluate the status of technology needed properly to address isolation and stabilization requirements.

Old Paradigm	New Paradigm
• Pu had great value.	• Pu is a liability.
• Pu was purified.	• Bulk residue is purified.
• Pu is the product.	• Bulk residue is the product.
• "Economic Discard Limit" Economy is practiced	• "Zero" Hazard Discharge Economy is practiced
• TRU waste was accepted.	• Benign discharge is most desired.
• Exceptions were granted to rules.	• Full compliance to rules is expected.

Figure 3. The paradigm shift in the management of plutonium.

Status of the Residues (The First Problem Area)

Many plutonium residues and reprocessing wastes are complicated mixtures of different compounds. This means that maintaining accurate accountability records and proper safeguards is difficult. In many residues, there is little fissile content in large-bulk inventories of material. Therefore, handling and packaging strategies are not obvious. Although the problems associated with plutonium residues were recognized by the sites, there is now a heightened awareness within the DOE and a basis for action, addressing the problems associated with the legacy plutonium residues within U.S. Defense Complex, has been prepared.[20,21] The significance of the residue problem is illustrated by the recently completed plutonium ES&H vulnerability study[12] which revealed that there are more than 50,000 at-risk packages of plutonium stored in various configurations throughout the DOE Complex. Of the 26 metric tons (MT) of plutonium identified as potentially at-risk during this assessment, most exist in a variety of unstable and reactive solid matrices with varying degrees of ES&H vulnerabilities. For example, at three major locations within the DOE Complex, there are large quantities (more than 100,000 gal. total) of solutions containing plutonium and other transuranics having high likelihood for causing environmental contamination and worker safety problems. Figure 4 indicates the distribution of residues around the DOE Complex.

Facility	Total Number of Items
Rocky Flats Environmental Test Site	27,679
Hanford Reservation	8,404 *
Los Alamos National Laboratory	9,470
Savannah River Plant	3,794
Argonne National Laboratory (West)	2,360
Lawrence Livermore Nat'l Laboratory	2,299
Mound Facility	236
Argonne Nat'l Lab. East/New Brunswick	9,898
Oak Ridge National Laboratory	622
Sandia National Laboratories	117
Lawrence Berkeley Nat'l Laboratory	473
Total	**65,352**

*Does not include equipment holdup and in-process solutions

Figure 4. The number of residue items located at various DOE facilities.[12]

Declaring these items as waste and directly disposing of them is being considered. None of the current fissile material is in a form that could be packaged directly for waste disposal and the U.S. has not yet opened a TRU or HLW repository, despite decades of effort. Recent studies[1] conclude that direct disposal does not adequately address the theft and diversion problems. These constraints suggest that it could be prudent and economically attractive to separate the radioactive material from the bulk materials and thereby provide a robust long-term storage form. To meet the standards that will be required for long-term storage, current technologies[22, 23] will need to be adapted and, in some cases, new technologies will need to be developed to isolate plutonium. In addition, these technologies must be in total compliance with the 1992 Federal Facilities Compliance Act and the 1993 Executive Order mandating major waste reductions at all federal facilities[25, 26], particularly with regard to TRU and mixed waste generation. To ensure success, a technology base has to be maintained and new technologies have to be developed and demonstrated to manage the inventories of fissile materials. Consequently, actinide processing and handling technology, in conjunction with enhanced waste treatment technology, is essential to the successful development of a national strategy for fissile material disposal. In particular, developing criteria for suitable material storage forms and processes to manufacture these forms will enable the proper decisions to be made.

Status of Technologies for Addressing the Residue Problem

There are demonstrated technologies that can be immediately applied to reduce the short-term safety concerns resulting from inadequately stored residues. Approaches must be considered for ultimate disposal of excess fissile material. Fabrication into reactor fuel or immobilization in glass are two possibilities. No schedule for implementation of fissile material disposition has been set by either Congress or by the Clinton Administration. Because a national policy has yet to be formulated, long-term retrievable storage is required. Since much of the material is in solution form and in dilute degradable matrices, processing/stabilization is required to prepare it for safe storage.

1. TRU Residue Processing

On the basis of our current knowledge of residues, only properly prepared oxide and metal are considered suitable for long-term storage. Because oxide and metal are a relatively small portion of the residue holdings in terms of net weight, an assessment was completed of the entire residue inventory to identify vulnerabilities. The overall priorities for stabilization were assigned as follows:

- Items that present an unusual radiation or release hazard;
- Items that are corrosive and can breach their current containers;
- Items that are combustible or can easily form combustible mixtures;
- Reactive/unstable mixtures such as organics in contact with radioactive material, calcium metal, or solutions in interim containers.

At Los Alamos, a multistaged sampling program, for vault holdings, was designed in an effort to assess the status of packaging against the above criteria. Every container was visually inspected and handled in order to evaluate container integrity. Suspect packages were removed from the vault shelves and repackaged. In a second phase, 160 items were selected at random and totally unpackaged in order to evaluate package integrity. In phase three, 220 old packages were selected in an effort specifically to evaluate the effect of age on package integrity. Finally, every item that is brought up for processing undergoes an evaluation for package integrity simultaneous with the actual residue stabilization effort.

All vault items are categorized, based on hazard reduction, for processing as shown in the figure 5. Therefore, the risk-reduction approach will be to process and stabilize these items so that they can be properly converted to stable oxides for long-term storage.

Residue Category	Identified Hazards	Remediation Approach
Solutions	Containment, Radiolysis, Criticality, Control of Solution Chemistry	Ion Exchange, Solvent Extraction, Precipitation, Direct Calcination
Salts		
Pyrochemical	Reactive Metals, Corrosion, Gas Generation	Oxidation, Reduction, Distillation
Sand, Slag, and Crucible	Reactive Metals, Corrosion	Size Reduction, Pu Separation
Ash	Radiolysis, Gas Generation	Calcination, Pu Separation
Metals	Oxidation, Radiolysis	Repackaging
Oxides	Radiolysis, Pyrophoricity, Dispersibility	Calcination, Repackaging
Combustibles	Radiolysis, Gas Generation, Flammability	Volume Reduction, Matrix Destruction, Pu Separation
Noncombustibles	Radiolysis of Packaging Materials, Gas Generation	Volume Reduction, Pu Separation

Figure 5. Processing approach by general category.

The goal is ultimately to isolate radioactive materials and other hazards from the bulk matrix; produce only a LLW (or better) during processing; and to store the radioactive material in a safe, acceptable form pending final disposition. To accomplish this goal, we must be able to treat effectively the spectrum of radioactive residues and to continue to develop and demonstrate enhanced recovery, stabilization, and assay capabilities. As examples of the type of capability improvement, we continue to lower detection limits for assay instruments and to develop residue processing operations for the improvement of the actinide recovery efficiencies, using better separation and waste treatment technologies.

To eliminate these immediate corrosive and reactive hazards, several existing technologies have been identified and can be implemented to reduce the risk involved with these residues. In order to reduce the life-cycle cost of radioactive material management and the long-term liability of handling and storing energetic materials, the final state of material must meet the storage criteria. The only proven method to achieve this stability is to separate the plutonium or other radioactive material from the bulk matrix, discard the bulk material as a certified waste form and store the radioactive material as a metal or oxide. In essentially all cases, methods exist for remediating residues. However, these methods were developed and optimized to purify plutonium, rather than to produce a safe storage form with minimium waste. Consequently, in order to meet the new goals, it will be desirable to adapt proven technologies for plutonium separation and advanced waste treatment. These modified and new methods should be implemented to ensure that the processing of plutonium residues has the least impact on the environment and worker safety as is technically and economically possible.

2. Separation Techniques

- **Salts** -- Pyrochemical salts and sand, slag, & crucible represent a signficant fraction of the residue inventory in the DOE Complex. Potential hazards associated with these salts include corrosion of the container, gas generation from radiolysis of moisture with the salt or the packaging materials, and the presence of reactive metals.

  Processing techniques have been developed that use carbonate to oxidize the reactive metals in pyrochemical salts. Tests for water decomposition by reactive metals have been conducted to document the efficiency of this process. In all cases using this chemical oxidation procedure, no hydrogen evolution above the baseline was observed. Chemical oxidation alone would meet the stabilization requirements, but plutonium separation is required to facilitate the safe disposal of these salts as waste. A distillation process is under development that will extensively reduce the need to use aqueous processing flowsheets to remove plutonium from this matrix. A recent trade study commissioned by the Department of Energy's Nuclear Material Stabilization Task Group, taking into account waste minimization, radiation exposure, disposal costs, and schedule, found that salt distillation would be the most efficient process to facilitate the disposal of the majority of the pyrochemical salt inventory.

- **Solutions** -- Plutonium nitrate and chloride solutions are currently being stored in configurations that were not designed for extended storage. The solutions are stored in plastic bottles, stainless steel and plastic-lined tanks, and process piping. These solutions, which range from 0.25 to 300 gm Pu/*l*, represent some of the most significant vulnerabilities to the worker. Control of the solution chemistry to prevent unanticipated concentration or precipitation of neutron absorbers, such as boron, is required. There is no question that solutions are not suitable for safe interim storage and must, therefore, be solidified as expeditiously as possible. Several processing techniques have been or are under development within the DOE Complex to meet specific site requirements for the stabilization of these solutions. Well-demonstrated precipitation techniques may be the most efficient. A flowsheet involving the Pu (III) oxalate precipitation followed by magnesium hydroxide precipitation of the filtrate has been demonstrated for the stabilization of Rocky Flats nitrate solutions containing high levels of plutonium (> 6 gPu/*l*). This technology effectively stabilizes the solution, while minimizing processing exposure and waste generation.

A vertical calciner is being developed by Hanford personnel for the direct conversion of plutonium nitrate solutions to a stable, storable solid. In this process, small amounts of plutonium-bearing solutions are metered into a continuously heated and stirred bed of solids. Calcination proceeds through rapid evaporation of liquid, slowly drying to solids, denitration, and initial heat treatment of stable plutonium dioxide. This process is known to work on solution concentrations ranging from 15 to 500 gm/*l*.

- **Combustibles and Noncombustibles Treatment** -- Currently, pyrolysis, electrochemical oxidation, and hydrothermal processing are being tested as advanced methods of processing combustible wastes. As an example, a pilot-scale pyrolysis experimental setup was designed and constructed to test the viability of this approach. Materials commonly used in glovebox applications were pyrolyzed. All of the materials were reduced significantly in mass to dry, solid, black materials. Introducing a few conventional technologies (e.g., a cold trap and an activated carbon filter to capture the organics, and a catalytic converter to oxidize carbon monoxide to carbon dioxide), will allow pyrolysis to be readily deployed in a manner compliant with environmental regulations.

  In addition, it is possible, with a select variety of combustible and noncombustible items to remove the plutonium by first freezing the material and then crushing it to increase surface area. The plutonium on the surface can then be removed by simple washing. Therefore, safety concerns about potential fire or explosion hazards due to radiolytic-hydrogen generation or high flammability can be reduced. Bench scale tests on polypropylene filters, which were used as pre-filters in the rich-residue ion-exchange process line at the Los Alamos Plutonium Facility were performed using ultrasonics, and advanced dissolution agents as a method for dislodging particulates. Batch experiments were run on crushed filter material in order to determine the amount of Pu removed by stirring, stirring and sonication, and stirring and sonication with the introduction of Pu-chelating water-soluable polymers or surfactants. Significantly more Pu is removed using sonication and sonication with chelators than is removed with mechanical stirring alone.

As leaner residues are scheduled for processing, improved solid treatment methods will be required to reduce the volume of TRU (>100 nCi/g) waste. This is important because of the large cost difference between TRU and LLW. Also, physical solid-solid separation methods, such as magnetic separation, are being implemented to reduce the initial volumes of the low-level residues, such as ash and graphite.

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Waste Treatment (The Second Problem Area)

Waste exists in solid, liquid, and gaseous forms. For the most part, gaseous forms are treated via scrubbing and filtering, and are therefore not considered a problem in waste management. The principal issues include treating liquid and solid wastes as well as certifying waste products.

Liquid Waste

This treatment effort must meet all applicable state and federal regulations for radioactive and hazardous waste. Generally, the most pressing issues involve characteristics other than radioactive materials, such as nitrate content or heavy metal content. In addition, there are considerable cost savings incurred by minimizing waste wherever possible. At Los Alamos, for example, it is planned to implement acid recycle in order to lower the volume of solid waste produced at the TA-50: Low-Level Waste Treatment Plant. Also, chelating extractants will be deployed to reduce the radioactivity discharges from the liquid waste stream in order to comply with the proposed 0.5 μCi/*l* discard limits being considered for the Liquid Waste Treatment Facility.

Solid Waste

Improved methods, such as advanced soaps, plasma-based, and electrochemical decontamination techniques will be tested and implemented to remove plutonium from the solid residues, such as plastic filters, dirt and blacktop, and other items that do not meet the current waste acceptance criteria. These technologies can also be used to reduce the volume of secondary radioactive solutions that are inevitable during processing operations.

Nondestructive Assay (NDA) Methods

Because of the nonhomogeneous and dilute nature of the residues, better assay methods are required to ensure good accountability of fissile material. Improved NDA techniques will also ensure that the waste forms can be properly certified for final disposal. NDA methods are attractive because they can be done in-line and do not require chemical sampling of the matrix. Furthermore, they can be computerized to ensure repeatability and reduce operator exposure.

CONCLUSIONS

With the end of the cold war, the goals for plutonium management have changed dramatically. The focus is now on the safe packaging and storage of plutonium until such time as ultimate disposal can be achieved. It is imperative that plutonium be safeguarded against theft and diversion. Recent studies have asserted that materials, such as spent nuclear fuel, may represent an unacceptable diversion risk if disposed of in their present form. By using the DOE Orders on Nuclear Material Safeguards, it is clear that plutonium bearing residues, and many waste materials (TRU and LLW) are at least as attractive as spent nuclear fuel, and, therefore, must be safeguarded in a rigorous fashion. This implies that direct discharge of residues and some waste items into repositories is likely unacceptable. A prudent approach is to separate the plutonium from the bulk matrices, discard the bulk as certified waste, and, pending disposition, to store plutonium as an impure oxide. The necessary technology base exists and can be quickly deployed.

DISCLAIMER

The views expressed in this paper are solely those of the authors. The views are based on the evaluation of numerous references concerning the management of plutonium, most of which are DOE citations. Despite this, the views do not necessarily reflect the views of the U.S. government or of any of its agencies.

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