CONF 930205--9

WSRC-MS--92-501

DE93 007448

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ABSTRACT

Recent changes in world politics have resulted in the United States reducing its nuclear weapons and stopping plutonium production. Prior plutonium production, dismantling warheads, and decontamination and decommissioning some facilities have produced plutonium-bearing materials which must continue to be managed. As each lot of material is processed, the processor must decide whether to remove the plutonium before discarding the material or to discard it without plutonium removal. DOE has developed a new method of making this decision, called the Plutonium Removal Limit System (PRLS). The system is based on defining a plutonium concentration above which the cost of disposing of plutonium-bearing materials will be less if plutonium is recovered and below which the cost will be less if plutonium is discarded (following suitable waste treatment). This method minimizes the overall cost to DOE for disposing of the existing inventory of plutonium-bearing materials.

The method was used to analyze the plutonium-discard limit for all categories of plutonium-bearing materials currently at each site. This analysis indicated the need to standardize the way sites make the remove-versus-discard decision. For this purpose, a set of departmental plutonium removal limits was developed. DOE expects to approve implementing this new method at all facilities handling plutonium-bearing material in FY 93.

INTRODUCTION

While DOE was processing weapons-grade plutonium, a fraction of it ended up as scrap and residues. This scrap, designated plutonium-bearing material, occurs in forms ranging from very small amounts of plutonium on contaminated rubber gloves to insoluble salts, ash, or casting dross with relatively high plutonium assays. In many cases, it was more difficult and costly to recover plutonium from these materials than to produce new plutonium. Therefore, for many years, the plutonium-bearing materials frequently were placed in storage rather than be processed to recover plutonium. Also, at most sites, only material containing less than 0.1% of plutonium could be packaged for waste disposal. Therefore, even low-assay materials that might have been considered waste frequently were allowed to accumulate.

The current total bulk weight of plutonium-bearing materials is ~190 metric tons. Significant quantities exist at four DOE materials-processing sites, as shown in Table 1.

Place Table I here.

When a DOE site has to decide on disposing of plutonium-bearing materials, it normally has two choices. It can dispose of materials directly to a repository (after appropriate classification, treatment, packaging, etc.) or it can process the material chemically to remove part of the plutonium before disposing of the remaining material. In the latter case, the removed plutonium would be added to the national asset reserve and stored as high-assay plutonium. Currently, the official policy for making this decision is based on a method called the Economic Discard Limit (EDL). The EDL was used to determine whether or not removing plutonium from a material would provide it at less cost than producing new plutonium in a reactor.

In recognition of the changes in the world and the fact that DOE has more plutonium than currently needed, DOE recently chartered a task team to review current EDL calculations and make recommendations for changes. The task team developed a concept that changed the focus from recovering plutonium for weapons to determining how to dispose of plutonium-bearing materials most economically.

DISCUSSION

New Discard Methodology

The PDL study task team set out to establish a new plutonium-discard method that was precise, centrally controlled, provided for site flexibility, could be implemented easily, ensured regulatory compliance, and minimized costs.

DOE's future processing of existing plutonium-bearing materials mostly will be for safe management, not for recovering plutonium. However, the new discard-limit concept is based on the philosophy that plutonium is a national asset that has some value as a future reactor fuel and that may be needed for future weapons systems. This philosophy recognized that future plutonium production, responding to future needs, would be expensive.

The new system, called the Plutonium Removal Limit System (PRLS), is based on determining whether it is more economical to remove plutonium before discarding the material or to discard the material directly. For a given DOE site and plutonium-material category, the most economical option depends on the plutonium concentration in the material. In general, it is less expensive (per unit of plutonium) to recover plutonium from highly-concentrated material and to discard low-concentrated material. The plutonium concentration at which the two costs are equal is defined as the Plutonium Removal Limit (PRL), as illustrated in Figure 1. Plutonium-bearing material that has a concentration above the PRL would not be discarded, while that with less than the PRL would be considered waste and would be designated for eventual disposal in a waste repository.

Place Figure 1 here.

To make this decision, a PRL value must be calculated for each category of plutonium-bearing materials. This is accomplished by balancing recovery and disposal costs with the plutonium's value, using the equation in Figure 2.

Place Figure 2 here.

The left side of the equation includes all of the cost terms involved if the plutonium is removed. Term 1 includes all costs of the removal process. For example, it would include the cost of operating an existing facility, the amortized cost of a new facility, if required, and the cost of preparing and shipping the material to another site for processing, if that were required. The second term recognized that any processing will generate new waste, and the cost of disposing of this waste needs to be included. The third term recognizes that no process has 100% yield, and that even after processing, some original plutonium will remain (e.g., as undissolved material) and must be discarded. Both the second and third terms include all of the costs associated with treatment and disposal of generated waste. The fourth term provides credit for the value of plutonium that is recovered during processing. Currently, this credit is estimated at $50 per gram, which is the computed value of plutonium when it replaces uranium in a power-producing reactor.

The fifth term, on the right side of the equation, includes all costs that would be incurred by directly disposing of the material. This could include, if applicable, costs for stabilizing, certifying, packaging, shipping, and the WIPP disposal fee.

Specific PRLs for Aqueous Processing Systems at Current Sites

The predominant processing option for most of the plutonium-handling sites is aqueous processing. It is possible to derive a specific equation applicable to sites using aqueous processing by assuming the following:

- Only new liquid, process wastes are generated by the plutonium-removal processes.
- Residuals from the original residues, remaining after plutonium removal, accurately can be estimated by reducing the initial bulk, by calculating the yield factor, and by assuming the residual contains the original plutonium concentration.
- Only existing processing facilities will be used.

- The density of waste in the processing operation is 1 Kg per liter.

Based on these assumptions, the general equation can be written as

$$BC_R + fBC_{w2} + (1-y)gBC_{w1} - yPv \leq g\,BC_{w1} \qquad \text{(Eq.1)}$$

where
- B = initial bulk residue of plutonium-bearing material, kg
- P = total plutonium in initial bulk, g
- v = unit value of plutonium, \$/g
- y = ratio of plutonium weight removed to total plutonium weight
- f = ratio of new liquid waste generated by plutonium removal to initial bulk, 1 per kg
- g = ratio of volume of residue after dilution for disposal to the initial weight, liter per kg
- C_R = unit cost to remove plutonium to a storable form, \$ per kg of initial bulk
- C_{w1} = unit cost to directly discard residues, \$/1 of treated bulk
- C_{w2} = unit cost to dispose of waste generated during plutonium removal, \$/1 of bulk as shipped to a repository

Also by definition

$$g = (P/B)/PDL \qquad \text{(Eq. 2)}$$

where PRL equals the concentration of waste as it is shipped to a repository (grams plutonium per liter of bulk).

Combining the two expressions, solving for the P/B concentration, and setting the minimum P/B equal to the PRL yields these aqueous-related equations

$$PRL = (P/B)\ \text{min} \qquad \text{(Eq. 3)}$$

or

$$PRL = (C_R + C_{w2}f)/y(v+C_{w1}/PDL)) \qquad \text{(Eq. 4)}$$

The constants in the above equation depend on the various site's cost and efficiency in processing or discarding plutonium-bearing materials. If a site can process a given type waste more cheaply and efficiently (i.e., generating a minimum amount of waste) than it can discard those materials, the PRL's value would be small, and low-concentration materials would be processed to remove the plutonium. Conversely, if the processing was costly and inefficient, and the disposal was less expensive, then only very high-assay materials would be processed. In general, if plutonium is relatively easy and inexpensive to remove, the disposal method would dictate removing plutonium; whereas, if the plutonium is difficult or expensive to remove, the disposal method would dictate discarding the material.

Plutonium-bearing materials are divided into several categories, as shown in Table 2, with each having similar basic composition and plutonium content.

Place Table II here.

Each site provides constants for aqueous processing and waste-treatment steps that could be used in PRL calculations for each material category. Because the sites have not measured yields, waste-generation rates, and costs for all categories and processes, the values were estimates.

Departmental (DOE) PRLs

The value of PRLs calculated by the plutonium-handling sites varied widely. This variation partly is due to processing differences among sites and to differences in the way the sites allocate costs. Resolving these differences was not achieved easily. Therefore, to ensure consistent treatment of plutonium-bearing materials, it was proposed that each site use a standard departmental PRL as the criterion for removal or disposal decisions.

Initial departmental PRLs were developed based on current aqueous, plutonium-removal processes with costs and process parameters chosen as those representing the current complex's best capabilities. The recommended values, by material category, are shown in Table 2. These departmental PRLs were developed based on a blend of SRS's and the Rocky Flats Plant's processing capabilities, and they represent existing residue processing and waste treatment. Table 2 also compares the actual, average concentration of residues in the plutonium-bearing materials and shows if the plutonium in each category would be removed before the material is discarded, depending on whether the plutonium concentration is above or below the PRL.

Where applicable, the sites are expected to use the departmental PRLs. Departmental PRLs are not all-encompassing and are not to be applied rigorously when clearly inappropriate. For example, neither the PRL method nor departmental PRLs should be applied to plutonium-bearing materials which don't have processing technology or capabilities. Plutonium-bearing materials that have been declared waste due to non-economic considerations also are not subject to the PRL method. Applying departmental PRLs also is inappropriate in cases where new capital facilities are required or where shipments of material stabilized between sites are required to allow processing.

Plutonium Discard Limit (PDL)

One factor that significantly affects PRL calculations is the assumption of how much plutonium will be contained in each waste drum shipped to a repository. This determines the value of the Plutonium Discard Limit (PDL) (expressed as grams of plutonium-239 per liter of bulk volume).

The PDL may vary widely, as shown in Table 3. The maximum concentration of plutonium-239 accepted by WIPP, defined by the Waste-Acceptance Criteria or WAC, is 200 gram Pu-239 per drum of bulk.

Place Table III here.

There are several factors that could cause a facility to ship drums of plutonium-bearing materials that have concentrations below the WAC. For example, an allowance may be made for inaccuracy in measuring the drum's content, shipping criteria might be more stringent than the WAC, or the material already might exist at a low concentration.

Similarly, the concentration might be set by Department of Transportation limits rather than WIPP limits. In the latter case, the amount of heat in each container might be the limiting item. The departmental PRLs were calculated, using a PDL of 0.25 for materials in categories 1 through 12 and 0.8 for all other categories.

Regulatory Compliance

The By-product Rule, 10CFR 962.3 (May 1, 1987) provides that DOE will comply with the Resources Conservation and Recovery Act (RCRA), et al., for hazardous components of radioactive, mixed-hazardous waste. It is DOE's commitment to comply with RCRA for mixed-hazardous waste. However, the applicability of RCRA to all plutonium-bearing materials is not clear. A DOE-wide group, under the Office of Environmental Compliance, is evaluating strategies for the applicability of RCRA to manage materials that are scrap but contain valuable source materials or special nuclear materials that can be reclaimed.

Safeguards and Security

The proposed change in the disposal limit may have the net effect of increasing the amount of special nuclear material eligible for disposal. Applying DOE Order 5633.3, Control and Accountability of Nuclear Material, to this material raises a variety of safeguards and security issues that must be addressed. Even if material is below the PRL, it can not be discarded unless it is defined to be Attractiveness Level E (not desirable for producing an improvised nuclear device) or unless discarding it is approved by the Office of Safeguards and Security and the applicable program office. Once material has been declared waste, safeguards may be terminated.

There are no provisions for terminating security requirements when material has been declared waste. However, if the material is Attractiveness Level E, it normally will be a Security Category IV which requires protection similar to measures already provided at interim waste-storage sites. However, if more attractive plutonium-bearing materials were to be discarded, the security provisions normally associated with plutonium-storage vaults might have to be extended to waste sites.

Waste Minimization

The PRL method is based on process and treatment options that tend to reduce the volume of waste that will be sent to a waste repository, such as the WIPP, as well as the waste's plutonium content. However, it is not possible to minimize both waste and cost, simultaneously. It is feasible to derive an equation for the PRL that would minimize waste to WIPP rather than minimize cost. A derivation based on the same concepts used in the cost-minimization method results in the following PRL equation:

PRL (vol-min) = f (PDL)/Y (Eq. 5)

where PRL (vol-min) is the PRL that results in the minimum-waste volume being sent to WIPP, and the remaining symbols are defined as they were for the cost-minimization method.

The results of calculating PRLs with this equation (using the same constants used for the department PRLs) and applying the results to the current inventory of plutonium-bearing materials are shown in Table 4. Minimizing the amount of waste sent to WIPP requires that the plutonium in most categories be removed prior to disposal. Table 4 shows the total cost (incremental, not including storage) and the space requirements in WIPP for various options, using actual inventory data as of September 30, 1991.

Place Table IV here.

Table 4 shows that:

- Using a PRL based on minimum-waste volume would decrease the amount of waste sent to a waste repository such as the WIPP by 1/4 relative to a PRL based on minimum cost, but would increase the cost of disposing of the materials by $561 million (50%).
- Discarding all materials in categories 1 through 12, rather than applying a cost-based PRL would increase the cost only slightly and would increase the waste sent to WIPP by 50%.
- Directly discarding all plutonium-bearing materials considered in this study rather than removing the plutonium from some, would increase the total cost by $120 million and would more than double the amount of waste sent to a waste repository such as WIPP.

Table I. Distribution of Plutonium-Bearing Materials at DOE Sites

DOE Site	Residue Weight, MT
Rocky Flats Plant	99
Los Alamos National Laboratory	81
Hanford	5
SRS	3
Total	188

Table II. Recommended Values for Departmental PRLs

Discard No.	Category	Recommended PRL (g-Pu/kg-bulk)	Avg Conc (g-Pu/kg-bulk)	Remove or the Plutonium?
1	graphite	50	10	discard
2	combustibles	51	8	discard
3	ash	50	64	both
4	heels	42	65	both
5	SS&C	11	19	both
6	insul, filters	54	21	discard
7	ceramics (LECO)	43	22	discard
8	non-SS metal	51	4	discard
9	glass	44	6	discard
10	Pb rubber	49	0.8	discard
11	sludge	42	44	both
12.a	MSE salts	52	50	both
12.b	ER salts	48	63	both
12.c	DOR salts	53	61	both
13	Pu/U	152	530	remove
14	Pu/Th	401	530	remove
15	Pu/Be	191	29	discard
16	Pu/Np	136	570	remove
17	Pu/Zr	0	0	
18	Pu/Al, Scr Alloy	141	290	remove
19.a	non-spec Pu	412	970	remove
19.b	anode heels	412	930	remove
20	>85% oxide	415	870	remove
21	<85% oxide	111	370	remove

Table III. Typical Values of Plutonium Discard Limit

Typical Circumstance	Pu Loading g/Drum	PDL g/l*
WIPP waste-acceptance criteria	200	1.00
maximum with accuracy allowance	165	0.80
average concentration of categories 1 to 12	45	0.25
concentration limited by heat	15	0.08

*Assumes that a liter of waste is 1 kg mass and that each drum holds 200 liters

Table IV. Comparison of Cost and Volume for Various Process or Discard Decision Alternatives

	Relative Costs** ($mil)	Min WIPP Vol Required (cu ft x 1000)
departmental PRLs	1,120	379
departmental PRLs (vol-min)	1,681	277
direct discard all residues (cat 1-12)	1,168	578
direct discard all PBM* (cat 1-21) 1,251	1,251	900

*plutonium-bearing materials
**incremental cost

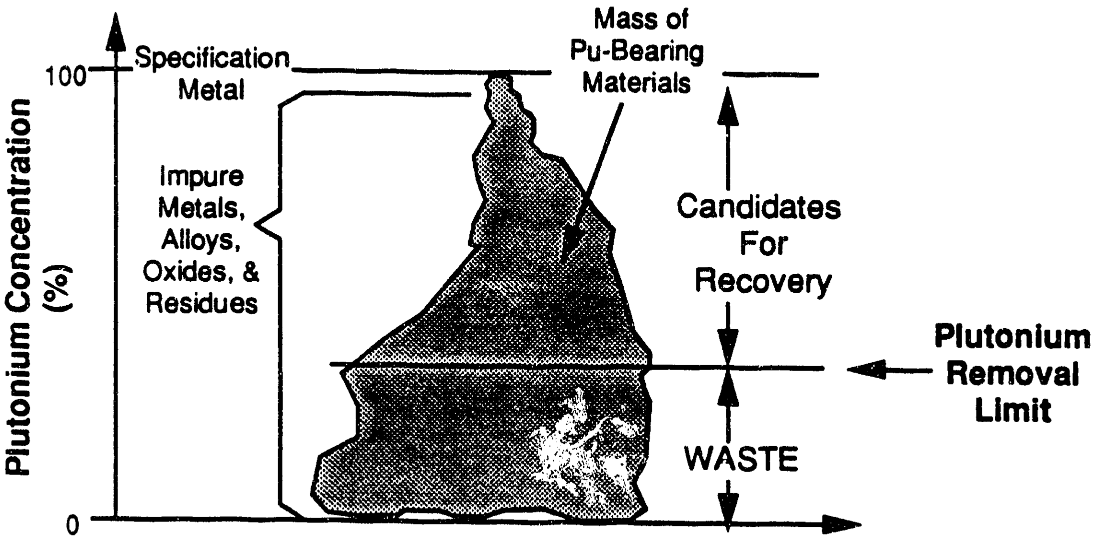

Figure 1. Application of PRL

$$\underset{①}{\begin{pmatrix}\text{Plutonium}\\ \text{Removal}\\ \text{Costs}\end{pmatrix}} + \underset{②}{\begin{pmatrix}\text{Discard Costs}\\ \text{for New Re-}\\ \text{moval Process}\\ \text{Wastes}\end{pmatrix}} + \underset{③}{\begin{pmatrix}\text{Discard Costs}\\ \text{for Remaining}\\ \text{Original}\\ \text{Residues}\end{pmatrix}} - \underset{④}{\begin{pmatrix}\text{Value of}\\ \text{Plutonium}\\ \text{Removed}\end{pmatrix}} \leq \underset{⑤}{\begin{pmatrix}\text{Discard}\\ \text{Costs for}\\ \text{Original}\\ \text{Residues}\end{pmatrix}}$$

Figure 2. Decision Equation For PDL Determination

END

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