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**Evaluation of Rocky Flats Plant Stored
Plutonium Inventory at the
Idaho National Engineering Laboratory**

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Lockheed
Idaho Technologies Company

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ACRONYMS

BE	best estimate
GM	Geiger-Muller survey meter
ID	inventory difference
INEL	Idaho National Engineering Laboratory
NDA	nondestructive assay
NOL	normal operating loss
PAN	passive-active neutron assay
RFP	Rocky Flats Plant
RWMC	Radioactive Waste Management Complex
RWMIS	Radioactive Waste Management Information System
TRU	transuranic
TSA	Transuranic Storage Area
UB	upper confidence bound

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1. INTRODUCTION

The purpose of this document is to evaluate reported inventories of plutonium contained in stored transuranic (TRU) waste generated by the Rocky Flats Plant (RFP). From 1970 to 1989, this waste was shipped to the Idaho National Engineering Laboratory (INEL) and placed in aboveground retrievable storage at the Radioactive Waste Management Complex (RWMC)-Transuranic Storage Area (TSA). This evaluation was initiated to address potential uncertainty in quantities of stored plutonium reported in the Radioactive Waste Management Information System (RWMIS). The RWMIS includes radionuclide information from generators that shipped TRU waste to INEL for storage. Recent evaluations¹ performed on buried TRU waste (1954-1970) resulted in significant revision to the original reported values of plutonium, americium, and enriched uranium. These evaluations were performed based on Rocky Flats Plant (RFP) Inventory Difference (ID) records.

This evaluation for stored TRU waste was performed to: (1) identify if significant discrepancies exist between RWMIS reported values and RFP ID records, (2) describe the methodology used to perform the RWMIS evaluation, (3) determine a Best Estimate (BE) and 95% Upper Confidence Bound (UB) on the plutonium inventory, (4) provide conclusions based on this evaluation, and (5) identify recommendations and/or actions that might be needed.

1.1 Background

Information provided in the buried TRU waste evaluation indicates that plutonium inventory differences have occurred for several reasons.¹ The largest contribution to ID is believed to be unmeasured discards sent to the INEL. This is due to the historical lack of adequate nondestructive assay (NDA) capabilities for measuring the mass of plutonium in a variety of waste forms and containers. Use of NDA techniques for drums began in 1964. Over the years, improvements in NDA capabilities have occurred. Techniques used for assaying post-1970 wastes have included 90-second passive gamma measurements, 20-minute segmented gamma measurements and passive-active neutron (PAN) counting. In some cases, radiochemical analysis was performed to obtain radionuclide information.

Until 1978, no NDA systems existed for waste boxes. Measurements were made using a Geiger-Muller (GM) survey meter and converting the measured value of radiation into an estimate of plutonium mass. A PAN system for boxes was available in 1978. At present, no quantitative information is available concerning the historical accuracy, precision, or error associated with the various NDA techniques used at RFP. Other sources of ID include equipment and ductwork holdup, and understated quantities of Pu in the drum backlog.

The total TRU mass reported in RWMIS² is 823 Kg, which includes a significant amount of U-233. The RWMIS Pu mass (Pu-238, -239, -240, -241, and -242) in storage from 1970-1989 is

680 Kg. It should be noted that this value includes 25.8 Kg of Pu placed in storage from retrieval of buried waste (pits 11 and 12) that occurred in 1974-1979.

2. EVALUATION METHODOLOGY

Two evaluations were performed to determine stored RFP waste plutonium quantities based on recently declassified ID and Normal Operating Loss (NOL) records previously provided by RFP personnel. The evaluations are described below.

The information sources used here provide no additional information on the quantities of Americium-241 and enriched uranium in the stored waste beyond that given in RWMIS.

2.1 Best Estimate

A best estimate (BE) of the RFP stored plutonium inventory was developed using ID, NOL, and RWMIS values. Waste from RFP was placed in storage from 1970-1989.

Several events have occurred over the years that required a modification to the procedure used to estimate the buried plutonium inventory based on cumulative ID and NOL records. These events include the transition from burial of TRU waste to storage operations; retrieval of buried TRU waste from SDA Pits 11 and 12 from 1974 to 1979; and interruption of waste shipments from RFP in October 1988 by the Governor of Idaho. These events affected the amount of plutonium placed in storage and required that a modified approach be used in calculating a best estimate for stored RFP plutonium.

The ID is determined based on a plant-wide Pu balance using the following formula:

$$(1) \text{ ID} = \text{Beginning Inventory} + \text{Receipts} - \text{Shipments} - \text{NOL} - \text{Ending Inventory}$$

or rearranging (1):

$$(2) \text{ ID} + \text{NOL} = \text{Beginning Inventory} + \text{Receipts} - \text{Shipments} - \text{Ending Inventory}.$$

The NOL should reflect the quantity of Pu shipped to INEL in RFP TRU waste. Table 1 provides an overview of the yearly ID and NOL values, RWMIS Pu mass values for RFP waste shipments, and cumulative values. The cumulative NOL totals, based on RFP records, require adjustment due to the effect of the previously mentioned events on "true" totals of Pu received from RFP for storage. For example, waste continued to be generated (and consequently NOL values) at RFP in 1988 and 1989 even though restrictions were imposed on shipment of the waste to INEL. Using the RFP NOL values without adjustment would result in an overestimation of mass of Pu shipped to INEL.

A comparison of the NOL values for 1970-1987 was made with the RWMIS (shipment record) for 1970-1987. The RWMIS values for the years 1974 to 1979 were adjusted to remove Pu mass contained in waste drums retrieved from Pits 11 and 12. Results of this comparison indicated that very good agreement (within 2.2%) existed between the NOL and RWMIS records. It is believed that the NOL value for 1970 includes Pu that was ultimately buried. Therefore, when calculating a best estimate for the stored Pu, it was decided that the RWMIS Pu mass

Table 1. Year-by-year stored Pu inventory data.

Fiscal year	Inventory difference ^a (Kg)				Normal oper. loss (Kg)		RWMIS (Kg)	
	Reported annual	Cumulative	Adj. (2/3) annual	Adjusted cumulative	Reported annual	Cumulative	Reported annual ^b	Cumulative
1970	83.2	83.2	55.5	55.5	38.7	38.7	5.7	5.7
1971	191.7	274.9	127.9	183.4	23.5	62.2	14.3	20.0
1972	(31.1)	243.8	(20.7)	162.7	12.5	74.7	33.3	53.3
1973	(197.8)	46.0	(131.9)	30.8	24.1	98.8	24.3	77.6
1974	(44.6)	1.4	(29.7)	1.1	26.3	125.1	35.6	113.2
1975	(46.5)	(45.1)	(31.0)	(29.9)	51.4	176.5	41.3	154.5
1976	(51.2)	(96.3)	(34.1)	(64.0)	29.2	205.7	21.0	175.5
1977	3.3	(93.0)	2.2	(61.8)	35.1	240.8	40.3	215.8
1978	17.3	(75.7)	11.5	(50.3)	20.4	261.2	33.4	249.2
1979	(9.3)	(85.0)	(6.2)	(56.5)	14.6	275.8	14.8	264.0
1980	31.4	(53.6)	20.9	(35.6)	15.3	291.1	20.2	284.2
1981	41.0	(12.6)	27.3	(8.3)	18.3	309.4	19.9	304.1
1982	37.3	24.7	24.9	16.6	48.5	357.9	42.9	347.0
1983	39.5	64.2	26.3	42.9	51.3	409.2	44.5	391.5
1984	29.5	93.7	19.7	62.6	61.2	470.4	56.7	448.2
1985	5.8	99.5	3.9	66.5	64.8	535.2	71.6	519.8
1986	4.8	104.3	3.2	69.7	95.1	630.3	83.8	603.6
1987	12.3	116.6	8.2	77.9	33.4	663.7	46.5	650.1
1988	2.6	119.2	1.7	79.5	34.5	698.2	15.7	665.8
1989	23.3	142.5	15.5	95.0	15.7	713.9	13.7	679.5

a. Parentheses around inventory difference values represent a gain.

b. Reported annual for years 1974 through 1979 include waste retrieved from Pits 11 and 12.

values would provide a better estimate for 1970 and thus were used rather than the NOL value. For 1988 and 1989, the RWMIS values were also used rather than the NOL values due to the restrictions imposed on shipments of the waste to INEL during those two years. These data are summarized in Table 2.

The ID is believed to exist because of unmeasured Pu discards contained in waste shipped to the INEL for storage (due to improving NDA capabilities for all waste forms); equipment and ductwork holdup; and understated Pu quantities in the drum backlog. The ID can be expressed as:

$$(3) \text{ ID} = (\text{Backlog} + \text{Holdup}) + \text{Unknown Pu quantity shipped to TSA.}$$

Past studies performed by Rocky Flats personnel have estimated that (Backlog + Holdup) constitute approximately one-third (33.3%) of the total ID. Therefore, the remaining two-thirds (66.7%) of the total ID would be the estimate of the unmeasured quantity of Pu contained in waste shipped to the TSA for storage. However, for stored waste, this is believed to be a conservative approach since assay systems were widely used at RFP for measuring Pu content beginning in 1966. Additionally, significant gains (in reduction of ID) occurred due to 1969 fire cleanup operations, startup of size reduction operations to recover Pu held up in equipment, cleanout of the Pu Recovery Building 771 ventilation system, and reduction of drum backlog. This information suggests that more Pu may be contained in backlog and holdup than previously estimated. This fact, coupled with the use of assay systems, would indicate the portion of the ID applied to the stored waste should be lower. Unfortunately, no data exists at RFP to indicate a more appropriate estimate for unmeasured Pu that may have been shipped to INEL for storage based on improvements in assay capabilities and more recovery of Pu from holdup and backlog.

Therefore, a conservative best estimate for the cumulative Pu mass in RFP stored TRU waste for 1970-1989 is:

$$\begin{aligned} (4) \text{ BE} &= \text{NOL} + (0.667)(\text{ID}) \\ &= (1970 \text{ RWMIS}) + (1971-1987 \text{ NOL}) + (1974-1979 \text{ RWMIS for} \\ &\quad \text{retrieved waste}) + (1988-1989 \text{ RWMIS}) + (0.667)(1970-1989 \text{ ID}) \\ &= [5.7 + 625.0 + 25.8 + 29.4] + (0.667)(142.5) \\ &= 685.9 \text{ Kg} + 95.0 \text{ Kg} \\ &= 781 \text{ Kg.} \end{aligned}$$

The RWMIS value for 1970 to 1989 is 680 Kg Pu in stored waste received from RFP. The best estimate represents a 15% (101 Kg) potential increase in Pu inventory.

2.2 Upper Confidence Bound

Uncertainty exists in the best estimate of the actual amount of stored Pu due to random variability in the generation process and errors in the measurement process. To account for this uncertainty, an upper bound of at least a 95% upper confidence limit on the actual amount of stored Pu was constructed. The approach used to estimate this upper bound was as follows. Using year-by-year data, the variance of the best estimate for the RFP Pu material stored at the

Table 2. Data used to arrive at best estimate.

Fiscal year	RFP NOL (Kg)	RWMIS (Kg)	Retrieved (Kg)	(2/3) ID (Kg)	Annual sum ^a (Kg)
1970		5.7		55.5	61.2
1971	23.5			127.9	151.4
1972	12.5			(20.7)	(8.2)
1973	24.1			(131.9)	(107.8)
1974	26.3		0.5	(29.7)	(2.9)
1975	51.4		2.4	(31.0)	22.8
1976	29.2		4.1	(34.1)	(0.8)
1977	35.1		8.1	2.2	45.4
1978	20.4		10.6	11.5	42.5
1979	14.6		0.1	(6.2)	8.5
1980	15.3			20.9	36.2
1981	18.3			27.3	45.6
1982	48.5			24.9	73.4
1983	51.3			26.3	77.6
1984	61.2			19.7	80.9
1985	64.8			3.9	68.7
1986	95.1			3.2	98.3
1987	33.4			8.2	41.6
1988		15.7		1.7	17.4
1989		13.7		15.5	29.2
TOTAL	625.0	35.1	25.8	95.1	781.0

a. This column is the sum of the previous columns and is shown only to provide detail on calculation of best estimate. The individual entries do not represent annual best estimates; in fact, some of the individual entries are negative due to periodic adjustments made to Pu inventory records at RFP.

TSA during the 19 years from 1970 through 1988 is calculated as shown in equation (6), the standard deviation as in equation (7), and the upper bound as in equation (8):

$$\begin{aligned}
 (6) \text{ Var(BE)} &= [(.667)^2 \times \text{Var(ID)}] + \text{Var(NOL)} \\
 &= [(.667)^2 \times (20)^2 \times \text{Var(mean ID)}] + [(20)^2 \times \text{Var(mean NOL)}] \\
 &= [(.667)^2 \times (20)^2 \times 255.7] + [(20)^2 \times 25.4] \\
 &= 55,662 \text{ Kg} \quad (7) \text{ Std. Dev. (BE)} = (55,662)^{0.5} \\
 &= 236 \text{ Kg}
 \end{aligned}$$

$$\begin{aligned}
 (8) \text{ UB} &= \text{BE} + [1.729 \times \text{Std. Dev. (BE)}] \\
 &= 781 + (1.729 \times 236) \\
 &= 1189
 \end{aligned}$$

The variance of NOL is calculated using RWMIS values for 1970, 1988, and 1989, and including the retrieved waste quantities with the NOL for the years 1974 through 1979. The data are presented in Table 2. The upper bound is at least a 95% confidence limit on the actual amount of Pu from RFP stored at the TSA because process variability and measurement error cannot be separated due to incomplete data. Thus, somewhat inflated estimates of the variances of the mean ID and the mean NOL are used, resulting in a conservative upper bound. While it is understood that the 2/3 factor is an estimate with associated error, changes to this factor result in small changes to the variance of the best estimate.

3. CONCLUSIONS AND RECOMMENDATIONS

The results of this evaluation indicate that a much less significant potential inventory difference exists with Pu in INEL stored TRU waste, as compared to Pu in buried TRU waste. The new best estimate for the buried TRU waste, which was based on plant-wide Pu balance, was more than three times larger than the previously-reported estimate, which was based on the Lee-to-Soule letter.³ For the stored TRU waste, the best estimate of 781 Kg provided here is only 15% higher than the estimate provided by RWMIS, the reported plutonium inventory. This 15% difference could easily be due to measurement errors, process variability, and/or the inadequacy of the assumed one-thirds/two-thirds ID split. Thus, there is no real evidence to suggest that a substantially larger amount of Pu than previously reported exists in the stored TRU waste from RFP.

3. REFERENCES

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