PLUTONIUM INVENTORY DIFFERENCES AT THE ROCKY FLATS PLANT AND THEIR RELATIONSHIP TO ENVIRONMENTAL RELEASES

by

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Introduction

This report examines the plutonium inventory accounting at the Rocky Flats Plant and its relation to quantitative estimates of plutonium releases to the environment. In order to understand the accounting problems, it may be useful to first read my companion report, "Overview of Rocky Flats Operations," for a better understanding of the nature of the work conducted at Rocky Flats.

Before proceeding, it should be noted that this analysis has been severely limited by the Department of Energy's (DOE's) refusal to release the following two categories of data: a) with rare exceptions inventory difference data for specific material balance areas and buildings, and b) rates of plutonium processing, or production. With respect to the first, DOE has released only the total site-wide inventory differences on an annualized basis, i.e., summed over each year. With respect to the second, as has been said best by L.L. Zodtner and R.F. Rogers, two of Dow Chemical Company's own material accounting experts, "Quantities of material unaccounted for may be large or comparatively small, but these figures by themselves are meaningless unless they are tied to rates of production or rates of processing." [Zodtner and Rogers, 1964]. DOE continues to over-classify MUF related information. See, for example, Dow, Explanation of Material Unaccounted For, "71" Plant, 1954, which demonstrates DOE is still classifying small quantities of plutonium in nitrate solutions and oxides, rather than releasing these data when declassifying documents.

To appreciate the limitations this lack of data places on an analysis of inventory difference data, imagine wanting to analyze errors made in the personal checking accounts of 100 individuals, but being given access only to the arithmetic sum of the known errors made by all 100 people over one year intervals. Obviously one could say a great deal more if one also had access to the checkbooks and monthly bank statements of each individual. And of course one could better judge the significance of the errors made if one knew how much money was in each individual's account and how this changed over time.

In not releasing detailed plutonium accounting data, DOE's concern appears to be with protecting the mass of plutonium in individual pits. DOE argues that if detailed inventory difference data or plutonium processing rate data were made public, one could calculate the plutonium mass in individual weapons, or weapon components, i.e., weapon pits. This is not true with regard to much of the data DOE has redacted. DOE contends that revealing the plutonium mass of individual pits to a proliferant or potential adversary would be harmful to U.S. national security. In my view this is not the case. Significant information about plutonium, including its critical mass in various concentrations and configurations is readily available in the scientific literature. The fully reflected spherical critical mass of alpha and delta phase weapon-grade plutonium, for example, is publicly revealed to be about 4.4 kilogram (kg) and 5.8 kg, respectively [Zvacek, 1994, 3456701]. The approximate amount of plutonium needed to make nuclear weapons is already well known [See, for example, Cochran and Paine, 1995]. Knowing the plutonium mass in any individual U.S. weapon would not be useful to a proliferant or adversary in developing an efficient nuclear weapon, or in countering our own weapons, without also knowing many other engineering design details of the weapon which should, and do, remain classified [see Zvacek, 1994, 3456702]. Calculating approximate masses of plutonium in U.S. nuclear weapons from historical plutonium processing rates also would not be useful to a proliferant or adversary.

Inventory Difference

Before jumping into the formal definition of Inventory Difference (ID), as used at Rocky Flats and other DOE facilities, it may be useful to give a couple of informal examples.

The Example of the Jeweler

Suppose you took a bar of gold to a jewelry maker and asked him to make a ring. Together you both weighed the gold bar and agree that it weighed 1.00 ounce. A month later you return. The jeweler hands you a finished ring and a small bag of leftover gold filings. Together you and the jeweler weigh separately the ring and the filing. The ring weighs 0.80 ounce and the filings weigh 0.19 ounce. There is an inventory difference of 0.01 ounces, i.e., 1.00-0.80-0.19=0.01.

You ask the jeweler for the other 0.01 ounce of gold—the other one percent. He says he does not have the inventory difference of 0.01 ounce, that it represents a normal loss in making the jewelry. The jeweler claims the "material unaccounted for" or "inventory difference," was not kept by him, but some of it remained in the scrap from casting the ring, which he discarded, some of it stuck in the grooves of his jewelry files, and some of it is in the dust on the floor.

Because the inventory difference is a small percent of the gold the jeweler processed, you may choose to believe his story. Were the losses larger, you might think that the jeweler was downright sloppy, or even a crook. If he were working with nuclear weapon-usable material, you might demand that he do better.

The Example of the Armored Car Company

Armored car transportation companies carry large sums of money between banks and other institutions. They transport paper money in bills of different denomination and coins. The bills and coins of each denomination typically have been separately counted and wrapped by the institution from which they have been picked up. The transportation company also counts the money to confirm how much money is picked up and handed over, to insure that no one is cheating on the accounts, and to insure that its drivers are not stealing from the company. Some companies find it is necessary to count all bills of five dollar denomination and larger to protect against someone substituting one dollar bills for larger denomination bills and pocketing the difference. But it is not profitable to count the change and the one dollar bills. These are weighed instead of counted. Average weights for a dollar bill, a penny, a nickel, a dime, etc., are used to estimate the total value of the money on hand. Because the assigned average weights do not necessarily reflect the real weights, this procedure usually results in a small inventory differences between the what appears on the written receipts and the amount of money estimated by weighing the bills and coins.

This inventory differences can be positive (an apparent loss of money) or negative (an apparent gain in money). A negative inventory difference (an apparent gain in money), for example, could occur if the coins were actually newer, and therefore heavier on average, than assumed. When the inventory difference is small the company most likely would assume the difference is due to uncertainties in the measurement and estimating process. If the inventory difference revealed an apparent small loss of money, the company would likely reason it is not worth recounting the money because of the cost involved. If the inventory difference revealed an apparent gain of money, the company would have no incentive to recount the money

As can be seen from this example, inventory differences can be positive (an apparent loss) or negative (an apparent gain).

We now turn to the more formal definition of inventory difference, for a mathematical description of what we have discussed in these two examples.

Formal Definition of Inventory Difference

Inventory difference (ID) is a term used in accounting for two categories of materials used in the nuclear industry: source and special material (SS), and special nuclear material (SNM). Plutonium and highly-enriched uranium (HEU) are special nuclear materials. ID is defined as:

$$ID = BI + Rec - EI - S - OR$$

where

BI	=	Beginning Inventory, or material on hand at the beginning of an accounting cycle
Rec	=	Receipts, or material received from outside the accounting group
EI	=	Ending Inventory, or material on hand at the end of an accounting cycle
S	=	Shipments, or material removed to another account group or off site location
OR	=	Other Removals and Discards

- Measured Discards, or Normal Operating Loss (NOL)
- Accidental Losses
- Radioactive Decay
- Write-off
- Degraded

DOE Order 5633.3A defines the "inventory difference" as the "book inventory" minus the "physical inventory." This definition is the same as given above, in that "book inventory" is (BI + Rec - S - OR) in the above formula. "Book inventory" is the quantity of material present at a given time as reflected by accounting records. The "physical inventory" is the quantity determined to be on hand by first physically ascertaining its presence and then using techniques that include measuring, sampling, weighing, and analysis [DOE, 1994, p. 107]. Measured discard, or Normal Operating Loss (NOL), is a loss of material, determined by measurement or by estimate on the basis of measurement, which, whether in the form of solids, liquids, or gases, has been discarded. It should be noted that unmeasured discards and equipment holdup are not included in the terms to the right of the equal sign in the equation above. Therefore, these categories contribute directly to ID.

For plutonium, radioactive decay usually refers to the radioactive decay of Pu-241 into Am-241. The radioactive decay of other plutonium isotopes represents such a small amount that it can be ignored. Write-off is a removal from the record of a known quantity of material, usually restricted to SS material which will be used in such a manner as to lose its identity as a nuclear material, per se, such as SS material incorporated into an instrument. Accidental loss is the irretrievable and inadvertent loss of a known quantity of special nuclear material as a result of an operational accident. Quantities reported as accidental loss must be determined by measurement or estimated on the basis of measurement. Degraded is the blending of two or more quantities of SS material (containing the same element, but containing different percentages of a specific isotope) to the extent that one or more of the original quantities may no longer be identified as being of the original type of material.

The term "inventory difference" (ID) replaces the previously used term "material unaccounted for" (MUF). The term "book inventory difference" (BPID) was used prior to MUF. All three terms (BPID, MUF, and ID) are defined by the same formula.[1] [Rockwell, December 12, 1979, p. 4]

IDs are calculated for individual "material balance areas" (MBAs) covering discrete time periods. The IDs for different discrete time periods can be summed to arrive at a cumulative ID for a longer period. For example, monthly IDs an be added to arrive at a yearly ID. Similarly, IDs for different MBAs can be summed to arrive at a cumulative ID for a larger area. For example, IDs for different MBAs in a building during the same time period can be added together to arrive at an ID for the entire building, and then the various building IDs can be summed to arrive at a plant-wide ID. The frequency of inventories varies. Typically, the more often one takes inventories, the smaller the ID, but the less time is available for production. About 1987 at Rocky Flats, the frequency was ["History of Inventory Differences at Rocky Flats Plant," ca. January, 1987]:

[1] Although they may differ in sign, that is, the quantitative values representing a loss of material are sometimes expressed as positive (plus) values and sometimes as a negative (minus) values.

Frequency	Number of MBAs
Monthly	46
Bimonthly	35
Quarterly	1
Biannual	4
Annual	15
Six Years	1
Total Number of MBAs	102

In 1976 at Rocky Flats there were about 100 MBAs used in MUF record keeping, 16 of which handled large amounts of plutonium [Hoffman, 1976].

Plutonium Accounting at Rocky Flats

> *Unexplained inventory differences continue to be a major deficiency in the operation of plutonium production processes at Rock Flats. Since 1980 there have been five major incidents of this type involving metallurgical operations in Buildings 707-776-777. Each time this happens the entire AL [DOE Albuquerque Operations Office] system is held hostage while we attempt to resolve the dilemma of meeting our production commitment and maintaining adequate control over DOE's special nuclear materials. …*
>
> *The common thread in the investigation of all these incidents has been the failure of production personnel to follow procedures for plutonium accountability. I am convinced that the direction for reversing this trend can only proceed from conveyance of management's unequivocal resolution not to tolerate further unacceptable performance.*

R.G. Romatowski
Manager,
Albuquerque Operations Office
Department of Energy
April 13, 1983

Plutonium processing and accountability were designed and patterned after operations at Los Alamos Scientific Laboratory (now called the Los Alamos National Laboratory (LANL)). Separate accountability systems were established at Rocky Flats in 1952 for plutonium, enriched uranium, depleted uranium and the Assembly Operation. The Rocky Flats site-wide annual plutonium inventory differences are reproduced in Table 1 and Figure 1. The site-wide cumulative inventory difference is reproduced in Table 1 and Figure 2.

To better interpret the inventory difference data, it is useful to divide the Rocky Flats Plant operations into five periods [Here, I am recounting and elaborating on a similar presentation made by Douglass, 1994]:

1. Initial phase FY 1952 - FY 1964
2. Transitional phase FY 1964 - FY 1966
3. Production phase FY 1966 - FY 1989
4. Curtailment phase FY 1990 - FY 1991
5. Transition/EM Restoration FY 1992 - present

We are interested only in the first three phases, which covers the period of plutonium processing and pit manufacturing by the first two contractors, Dow Chemical Company (1952-1975) and Rockwell International, Inc. (1975-1989).

Initial Period, FY 1952-FY 1963

Some important characteristics of the initial phase regarding MUF, Normal Operating Loss (NOL), and measurement systems were [“Chronology of RFP’s MUF,” 1976; Douglass, 1994]:

1. Beginning in March 1952, the amount of plutonium processed gradually grew to almost one tonne per year in FY 1957, and then grew rapidly to about 18 t per year in FY 1962.
2. The cumulative MUF increased from 0 to 665 kg.
3. The MUF as a percent of throughput was a few percent during the period 1955-1959 (and perhaps earlier), peaking at about 8 percent in 1956.
4. There were no good measurements of scrap/waste.
5. There were no discard limits.
6. There were significant process and equipment hold-ups associated with startup operations.
7. With the exception of sludge, all other plutonium wastes (dry box waste, graphite, processing equipment, duct work, etc.) were shipped to the Idaho burial grounds (beginning April 22, 1954) as unmeasured discards having less than accountable amounts of plutonium. The total volume of all wastes and sludge shipped to Idaho was 789, 623 cubic feet.

At Rocky Flats during the initial phase of operations there were no measurement systems capable of accurately measuring plutonium waste, nor were there any discard limits [Rocky Flats Plant Nondestructive Assay Instrumentation History Nuclear Material Accountability, ca. 1993]. A study of plutonium accountability published by Zodtner and Rogers on January 6, 1964 [discussed below] identified numerous areas where plutonium accountability was unsatisfactory. In particular, the study found large significant areas of “unaccountability” for certain wastes categories, notably used filters shipped off-site, graphite and dry boxed waste (processing equipment duct work, pipe, etc.), oxide loss from thin walled warhead components, and errors in measured discard of liquid waste.

The Zodtner and Rogers report presents a curve of the four quarter running total of MUF for the period FY 1955-FY 1963. The report also shows on the same page the four quarter running total of the plutonium processed, apparently measured in terms of the total mass of plutonium casting charges, and the MUF as a percent of throughput, also where throughput apparently is measured in terms of the total mass of the casting charges. Although the numerical values have been redacted from the ordinates (i.e., the vertical scales) of these two graphs, there is sufficient information presented in the report to permit one to calculate the scale values. In Figures 3-5, I have reproduced the Zodtner and Rogers graphs with the quantitative values included on the vertical scales. As seen from Figure 4, beginning in March 1952 the amount of plutonium processed (i.e., in casting charges) gradually grew to almost one tonne per year in FY 1957, and then grew rapidly to about 18 t per year in FY 1962. As seen from Figure 5, the MUF as a percent of throughput was as high as 8 percent in 1956, and averaged about five percent from FY 1955 through FY 1958, and about one percent from FY 1959-FY 1963.

Transitional Period, FY 1964-FY 1966

Some important characteristics of the transitional period were ["Chronology of RFP's MUF," 1976; Douglass, 1994]:

1. There was a large volume of plutonium processed.
2. Cumulative MUF increased 435.4 kg over three years (from 665.3 kg at end FY 1963 to 1100.7 kg at end FY 1966).
3. Increased equipment and process hold-up.
4. Initiation of procedures to better segregate scrap and to retain high-level scrap for reprocessing.
5. The backlog of plutonium residues increased significantly.
6. Installation of nondestructive analysis (NDA) equipment.
7. Reluctance to believe the NDA measurements taken with new equipment.
8. Scrap and waste continued to be shipped with estimated plutonium values.
9. Total volume of all waste and sludge shipped to Idaho was 294,339 cubic feet.

In 1964 a drum counter was developed, and standardization begun, to measure the plutonium content in solid type residues, waste and scrap. It was initially used to monitor drums of residue scheduled for write off as a measured discard. A helix counter was also installed in 1964. In 1965 a can counter was developed to radiometrically assay the content of in-process residues in one gallon containers where standards existed. Both drum and can counters were placed into routine production operation for nine types of residue categories in 1966 [Young, 1977, p. 38]. During the transitional phase there was considerable reluctance to "believe" the newly developed NDA measurements of scrap/waste discards, and therefore estimates of plutonium content continued to be used for accountability purposes.

Production phase, FY 1967 -FY 1989

Some important characteristics of this third period were [“Chronology of RFP’s MUF,” 1976; Douglass, 1994]:

1. Large fluctuations in annual MUF values.
2. The cumulative MUF increased 110 kg over 23 years, from 1101 at the end FY 1966 to 1212 kg at the end FY 1989.
3. NDA measurements of all discards.
4. Better segregation of plutonium scrap categories.
5. Improved accountability for plutonium.
6. Total volume of all waste and sludge shipped to Idaho was 1,159,038 cubic feet

It appears that major changes in the plutonium process, particularly in measurement techniques and in waste handling, that were started around FY 1966 [Young, 1977, p. 17], had a significant impact on MUF. There were large fluctuations in annual MUF, ranging from -197.8 kg in 1973 to +191.7 kg in 1971. The MUF fluctuations during this period were not completely random. The cumulative MUF reached a maximum value of 1345 kg in 1971. The string of MUF gains from FY 1973-1976 were attributed primarily to cleanup resulting from the 1969 fire, equipment size reduction activity, and six-month clean-up inventories in Chemical Operations and working off backlog [Young, 1977, p. 62] (See Figure 6).

The upward trend in MUF from 1966 through 1971 was attributed to a combination of a) biases in measurements, b) the method of accounting for the May 1969 fire, and c) process holdup. The downward trend in MUF from 1971 to June 30, 1974 was attributed to a) processing of scrap whose inventory values were understated, b) close out of the May 1969 fire account, size reduction of process equipment, and d) tank clean outs [“Chronology of RFP’s MUF,” 1976].

In 1971 L.D. Hazelton, Manager, Nuclear Materials Control, Dow Chemical Company, Rocky Flats Division, noted, “Historically plutonium MUF losses have been generated in Metallurgical Operations with gains occurring in Fabrication.” [L.D. Hazelton, memo to W.H. Hauschild, et al., “Plutonium MUF Study - Building 707,” August 18, 1971]

Curtailment Phase, FY 1990-FY 1991

Some important characteristics of the fourth period were [Douglass, 1994]:

1. Curtailment of operations.
2. Clean out of plutonium in ducts.
3. Safety issues were addressed and upgrades installed
4. Hold-up materials were added to the inventory.
5. The cumulative MUF decreased 9 kg over the two year period, from 1212 to 1193 kg.

Cumulative MUF

The cumulative inventory difference at the Rocky Flats Plant for plutonium through June 1994 was 1191 kg [Table 1 and Figure 2]. In other words the ID represents a decrease from the "book inventory" by 1191 kg. "The value of the cumulative Pu MUF for the RFP operations has been and is a major concern for ALO [DOE's Albuquerque Operations Office] and Dow Chemical" ["Chronology of RFP's Plutonium Material Unaccounted For (MUF)," 1974]. As can be seen from Table 1, most of the cumulative MUF derived from operations during the initial and transitional period.

As seen from the formal definition of ID at p. 3 above, a major contributor to MUF may be due to errors on estimating normal operating losses (NOL). In fact, according to Rockwell, the largest single contributor to MUF appears to be the unmeasured discards shipped to Idaho for burial ["Chronology of RFP's MUF," 1976]. The historical NOL for Rocky Flats is shown in Table 2 and Figures 7 and 8. As seen by comparing Tables 1 and 2, the cumulative MUF and cumulative NOL for Rocky Flats are about the same, both just over one metric ton. As discussed under " Plutonium Wastes at Rocky Flats" below, estimates of plutonium concentrations in waste at Rocky Flats prior to 1964 were highly uncertain. "The measuring and sampling of these wastes is a difficult problem, and the record shows that the credit taken for measured discards has been inadequate." [Kudera, 1994]. I agree with Rockwell that most of the cumulative MUF is due to poor estimates and measurements of the plutonium in waste [For further elaboration, see also, Kudera, 1994].

A more recent discussion of some of the possible contributions to the cumulative MUF at Rocky Flats was compiled by Roberts, et al., in 1994, who claim:

> An independent study of the amount of plutonium shipped from Rocky Flats to the Idaho National Engineering Laboratory (INEL) has been conducted by INEL personnel, Rocky Flats contractor personnel, and DOE personnel. It has been estimated that the inventory of waste drums shipped to INEL for burial is understated. The actual amount of the understatement has been estimated at 600 to 800 kilograms of plutonium. [Roberts, et al., 1994, p. 9]
>
> In addition to the material shipped to INEL and the material in residues, it is estimated that another 200 to 300 kilograms of plutonium is held up in process and duct systems. [Roberts, 1994, p. 10]
>
> …cleanup and decommissioning could easily result in the 200 to 300 kilograms of material being either left as nonremovable or removed from process systems and equipment by the end of decommissioning and decontamination of the facilities. [Roberts, 1994, p. 11]

The potential sources of the 1191 kg cumulative plutonium ID at Rocky Flats through June 1994, as estimated by Roberts, et al., is summarized in Table 3. The cumulative ID for plutonium is expected to decrease somewhat by materials that will be recovered during decontamination of buildings and equipment [DOE, 1994, p. 108].

The 1964 MUF Study by Zodtner and Rogers

The very existence of a significant MUF should trigger immediately an investigation as to its cause. As noted in a 1986 ID investigation report, “The question central to the inventory difference resolution is: Has the inventory difference been accounted for?” [Weston, 1986, see Enclosure, Summary]. Apparently, the first effort to understand the causes of the huge inventory differences at Rocky Flats was a study conducted by Zodtner, and Rogers over a decade after the plant began operations [Zodtner and Rogers, 1964]. This study remained classified for thirty years. Some highlights of their report, in their own words, are as follows:

> 1.0 Introduction:
>
> The plutonium losses experienced during the entire history of the Rocky Flats plant have been significant. These losses have never been explained or properly justified and this study was conducted to determine their source and causes. From available data, several possible causes of these losses were determined.
>
> 2.0 Investigations Conducted:
>
> The plutonium operations at Rocky Flats have been continually plagued with material unaccounted for (MUF). These losses have occurred almost every month, and exhibited large variations which may possibly have been due to inventory error.
>
> In order to get a better understanding of the accountability and process handling of plutonium, the history was reviewed from the very start of operations to June 30, 1963. The accountability procedures, the processing, and the handling of residues were reviewed.
>
> ……..
>
> 2.5 Fire Loss - Building 71:
>
> The Building 71 fire which occurred on September 11, 1957 resulted in a plutonium loss as set forth below:
>
> Inventory in Room 180 before fire 62,515 grams

Undamaged Items Removed	29,857	
Recovered through processing	24,356	
Measured Discards	2,315	
Total Recovered		56,528
Fire Loss		5,987 grams

This gives a contribution to MUF of 6.0 kg.

2.6 Ventilation:

….

The total amount of plutonium lost via stack release was only 0.44 grams during the entire period of operation at Rocky Flats.

3.0 Summary and Conclusions:

We have considered all receipts, shipments, measured removals and unmeasured removals. Some of the figures involved are accurate and some are estimates based on meager data, but the final resulting figures give the best available picture of what happened to some of the plutonium.

Following is a summary of items which the study indicated are contributors to MUF:

Thin wall WR [War Reserve] returns - oxide loss	40.0 kgs.
Button receipt SS factor bias	*
Error in measured discard of liquid wastes	39.0
Radioactive decay loss	*
Building 71 fire loss	6.0
Final filter bank holdup	0.6
Building 76 prefilter and duct holdup	2.2
Building 71 prefilter and duct holdup	7.2
Used filters shipped off-site	128.9
Building 71 miscellaneous dry box waste discarded	18.0
Building 76 miscellaneous dry box waste discarded	16.7
Building 76 washables discarded	26.6
Building 76 graphite discarded	254.0
Total “explained” MUF	579.1 kgs.

[“*” denotes classified data. These two entries necessarily total 39.9 kg]

If we deduct the above “explained “ MUF of 579.1 kgs. From the total MUF of 663.5 kgs., there remains 84.4 kgs. Which is lost without suitable explanation. Eighty-four kgs. appears to be a substantial quantity of plutonium;

> however, it is less than [CLASSIFIED] of the [CLASSIFIED] and would appear to be a reasonable loss.
>
> ….

"Unexplained" MUF plagued the Rocky Flats management throughout the history of Rocky Flats operations. For example, as noted in 1971 by Dow employee H.E. Bowman, "Historically, MUF has been a problem with us since the beginning of operations in 1952." [Bowman, 1971]. Also, as noted in handwritten "Working Closeout Notes" attached to a 1981 DOE safeguards survey of Rocky Flats, "IDs - record for year is deplorable Out-of-control losses, gains, lost items largely unexplained." In a subsequent note, the word "deplorable" has been crossed out and replaced by "less-than-admirable" [DOE, 1981].

MUF Associated With Fires at Rocky Flats

> *It has come to my attention that there may have been times when fissile material accountability differences have been regarded by operations personnel as solely an accountability problem. I would like to stress that accountability differences may, and in the case of large differences do, represent a criticality safety and environmental protection concern.*
>
> Jack R. Roeder
> Assistant Manager for Safety and Safeguards
> DOE, Albuquerque Operations Office
> September 18, 1985

The September 1957 Fire

The MUF associated with the 1957 fire was estimated to be 6.027 kg of plutonium, a material loss [Dunn, 1977, p. 12; see also Voillequé, 1995, pp. 4-8 and Kudera, 1994]. Voillequé estimates the pre-fire filter bank plutonium inventory plus that carried to the filter bank during the fire was in the range of 180 to 1,200 g of plutonium (Pu-239 and Pu-240) [Voillequé, 1995, p 22].

The May 1969 Fire

According to Rockwell, following the May 11, 1969 fire:

> Intense recovery and cleanup efforts took place over a period of three years following the fire. A book inventory of the plutonium in the fire area was calculated by the automated Nuclear Materials Control System as of May 11, 1969. This book value was used as a beginning inventory for the removal and recovery operation which followed. All removals and normal operational losses were credited to a separate fire account (MBA 0595-76) established immediately after the fire. [Young, 1977, p. 56]

A MUF gain from the clean-up and recovery operation was reported to the AEC/ERDA on official records as of October, 1972. The reported MUF was -103.469 kg of plutonium, a material gain [Young, 1977, p. 57; and Dunn, 1977, p. 12].

While there was a reported MUF gain, Rockwell International in 1977 acknowledged that there was also a contributing loss out of the building: "It is known that 0.0125 grams (856 microcuries) of plutonium escaped the confines of the building involved in the 1969 fire, but none of the material is believed to have reached beyond the plant boundaries." [Dunn, 1977, p. 10; see quote above].

MUF Associated With the 903 Pad Release

The following is a summary describing plutonium accounting associated with the storage of plutonium contaminated waste at the 903 pad [Young, 1977, pp. 54-56]:

> Between 1959 and 1969 approximately 5,230 drums of machining coolant oil contaminated with plutonium were accumulated and stored in an outside storage area on plant site, now known as the 903 storage area. Approximately 5,000 gallons of contaminated oil containing an estimated 85 grams of plutonium leaked into the soil. In October 1969 an asphalt pad was placed over the area to contain the contaminated soil. [This early release estimate of 85 g of plutonium is inconsistent with later, much higher, estimates of the total off-site release based on soil sampling; see Cochran, Overview of Rocky Flats Operations, 1996]
>
> In January 1967 a disposal project was started. Most of the drums were in various stages of corrosion so the liquid was transferred into good drums for transfer to Building 774, Waste Treatment Facility. The disposal process included filtration and solidification of liquids. Filters used in the process were drum counted in Building 771 and each batch of filtered solution was sampled prior to solidification. Emptied drums (4,672) were drum counted prior to packaging for shipment off-site to burial.
>
> A summary of the recovery activity follows:

Description	Method of Determination	Pu SS Net Wt. (grams)
1) Salvage material	Drum count	594
2) Coolant Oil Solidified	Sampled & Analyzed	2,471
3) Emptied drums	Drum count	5,152
		8,217

> Detailed accountability records are not available to determine what quantities of plutonium if any were written-off as an NOL when the drums were removed from the production area to the outside storage area. Accountability personnel in charge of the records at the time (recalling from memory) indicate that no NOL credit was reflected on Accountability records at the time. Credit would have been taken as an NOL write-off for items 1) and 2) above when they were processed through the drum counters. Accountability records fail to reflect if appropriate NOL credit was taken for 2,471 grams of organic solids shipped off-site burial during the disposal process period. [end of quote from Young, 1977, pp. 54-56]

Radiological Assessment Corporation (RAC) recently estimated a total of 9 to 18 kg of plutonium were in the drums and from 40 to 1,800 grams of plutonium leaked out into the soil.

Plutonium Waste at Rocky Flats

In January 1964 there were an estimated 95,000 cubic feet of classified plutonium-239 waste at Rocky Flats [Report on Disposal of Classified Radioactive Wastes," 1964]. Over 2,600 tons of contaminated waste was shipped to INEL for burial from 1954 through end-FY 1963 [Kudera, 1994].

In 1977, Rockwell estimated that the following amounts of waste had been shipped for retrievable or non-retrievable storage,

	No. Shipped	Ft^3
Drums (55, 40, & 30 gallon)	269,786	1,983,211
Boxes (standard and non-standard)	12,212	1,359,879
Cartons (including filters and drums)	18,290	1,132,979
TOTAL	300,288	3,476,069

Included in this waste was an estimated 490.662 kg of plutonium [Dunn, 1977, p. 14]. The 490 kg of plutonium represents most of the 499 kg NOL of plutonium through 1976. The NOL of plutonium through 1987 had risen to 938 kg.

According to Young, "Over the years there were only a few isolated and well identified cases of write-offs and accidental losses for nominal amounts. This leaves the measured discards (NOL) portion of the removal function as the weakest and undoubtedly the greatest contributor to MUF." [Young, 1977, p. 61]

On December 7, 1993, DOE issued a press release indicating that between 600 kg and 900 kg more plutonium than the previously estimated 366 kg was shipped to and buried at the Idaho National Engineering Laboratory's (INEL's) Radioactive Waste Management Complex (RWMC) between 1954 and 1970 [DOE 1993]. In 1995 INEL presented a best estimate of

1,102 kg and an upper estimate of 1,455 kg of plutonium from Rocky Flats from 1954 through 1972 buried at the INEL Subsurface Disposal Area (SDA) [INEL, 1995]. INEL's presented a best estimate of 781 kg of plutonium in stored transuranic (TRU) waste shipped from Rocky Flats between 1970 and 1989 [Clements and Einerson, 1995].

Conclusion

The important conclusions that I draw from the Rocky Flats MUF data fall into two categories: a) those related to the failure of Dow Chemical Company and Rockwell International to properly account for and control nuclear weapon-usable fissile material; and b) those related to what can and cannot be said about the magnitude of environmental releases of plutonium in light of the very large inventory differences at Rocky Flats.

Failure to Provide for Adequate Fissile Material Accounting and Control

Dow Chemical Company was grossly negligent in its failure to adequately account for plutonium (and highly-enriched uranium) inventories during the initial period of operation of Rocky Flats—during the period from April 1953, when the first shipments of plutonium nitrate arrived on site from Hanford, through FY 1963 (June 1963). For over a decade, Dow did not systematically measure the plutonium in residues and scrap, set no limits on the plutonium content in scrap, failed to conduct frequent clean-out inventories of equipment and processes lines, and as a consequence allowed the cumulative plutonium inventory difference to climb to 665 kg—equivalent to the amount of plutonium in the pits of some 220 modern nuclear weapons.

For at least five years the plutonium inventory difference was running at several percent of throughput (as high as 8 percent in 1956), compared to less than one percent in later years after some of the inventory problems were brought under control. For a decade, Dow did not try to systematically address the reasons the inventory differences were so large. As noted in a 1964 internal Rocky Flats MUF study, "The plutonium losses experienced during the entire history of the Rocky Flats plant have been significant. These losses have never been explained or properly justified and this study was conducted to determine their source and causes." [Zodtner and Rogers, 1964]

In 1964, more than a decade after the plant started operations, Dow finally started addressing the inventory difference problem. But during a three year transitional period, the cumulative plutonium inventory difference climbed another 435 kg, or the equivalent of what is in about 150 modern nuclear weapons.

Even during the five year period, FY 1980-FY 1984, when Rockwell International was operating the plant, the site-wide plutonium inventory differences were running 30 to 40 kg per year. Even in 1989, the last year of plant operations under Rockwell management, the plant was still experiencing "larger than usual inventory difference losses" and "troublesome inventory difference trends." [Rockwell International, 1989]. There is no doubt that these MUF values could have been lowered substantially, had Rockwell conducted more frequent clean-out inventories and taken other steps to improve measurement and accounting practices.

Relevance of MUF to Off-Site Releases

There were four major *known* sources off-site plutonium releases: a) routine filtered stack emissions, b) the 1957 fire, c) the 1969 fire, and d) the 903 Pad. Of course there were surely other releases that were smaller, simply missed, or went unreported. Over the years a number of investigators have made estimates of the releases from one or more of these known sources. Efforts to quantify these releases continue, as new data will derive from ongoing dose reconstruction and plaintiffs' experts analyses. The summary below does not address these new analyses or data, but is limited to previous estimates. These earlier estimates typically fall below the following values [Cochran, "Overview of Rocky Flats Operations, 1996]:

Source of Release	Estimated Release	Technique
Routine Filtered Stack Emissions	< 0.001 g Pu	from stack monitoring data
1957 Fire	< 25 g Pu	from stack, veg. & air data
1969 Fire	< 0.3 g Pu	from stack monitoring
903 Pad	< 1,900 g Pu	from soil concentration data

These estimates can be compared to the "Material Unaccounted For," which for Rocky Flats is cumulatively on the order of 1,200,000 grams (i.e., 1,200 kg). The cumulative plutonium MUF is over one billion times the estimated stack emissions based on stack effluent measurements. Although most of the MUF is due to a combination of poor estimates and measurements of waste and residues, bookkeeping errors, and process and equipment holdup, the bottom line is that one cannot distinguish between these MUF contributions, theft, emissions that are not monitored, and errors in measured emissions to the environment. For this reason estimates of routine emissions based on stack gas monitoring provide at best only a lower limit estimate of routine plutonium emissions. Actual releases could be orders of magnitude higher.

Several estimates of the amount of plutonium released to the environment associated with the 1957 fire have been derived from a combination of stack, air, soil and vegetation monitoring data. These estimates vary considerably, with 25 grams of plutonium being the highest upper bound on the release of estimates to date. The MUF associated with the fire is about 6,000 grams, which is 240 times larger. The large spread in the release estimates reflects the poor quality of the environmental monitoring, and consequently the large uncertainties in the estimates. A much larger estimate of the upper bound on the release still would be consistent with the very large MUF associated with the fire.

The largest estimated off-site plutonium releases were those associated with the improper management of drum waste at the 903 Pad. Subsequent drum measurements indicate that the amount of plutonium in the drums was between 9 kg and 18 kg. What would be of greater interest is the amount that leaked into the ground. An early contractor estimate was that 85 grams leaked into the soil. Subsequent estimates have a range if 40 to 1,800 g. It is clear from these estimates that the plutonium content of the drums and what blew off-site is highly uncertain.

It is a shameful legacy of the contractor operations of the Rocky Flats Plant that internal accounting and off-site environmental measurements of plutonium did not receive the attention they demanded from the very start of Rocky Flats operations in 1952.

At Rocky Flats the uncertainties in estimated plant releases, reconstructed radiation doses and public health effects, when derived from off-site contamination measurements, are very large. The upper end of these estimates no doubt will be consistent with the very large MUF values at Rocky Flats—that is, with what we do not know about the whereabouts of much of the plutonium. The plutonium release estimates could be increased by orders of magnitude and still be consistent with the MUF.

Finally, it should be noted that while these conclusions are based upon an analysis of the plutonium MUF, the enriched-uranium MUF was similarly very large—in fact, also too large—and given that the Rocky Flats contractors could not keep adequate track of plutonium and uranium, it stands to reason that they probably did not keep adequate track of the numerous hazardous chemicals used in the production processes at the plant as well.

Signed:

Date:

References

1. H.E. Bowman, “Measurement and MUF Problems,” May 21, 1971 [Cook 14Dec94 Request for MUF 4472191].

2. ChemRisk, “Estimating Historical Emissions From Rocky Flats,” Task 5 Draft Report, November 1992.

3. “Chronology of RFP’s Material Unaccounted For (MUF),” August 16, 1976.

4. T.L. Clements, Jr. And J.J. Einerson, Evaluation of Rocky Flats Plant Stored Plutonium Inventory at the Idaho National engineering Laboratory,” Idaho National Engineering Laboratory (INEL) Lockheed Idaho Technologies Company, September 1995, [Cook 14Dec94 Request for MUF 4329805].

5. Thomas B. Cochran, “Overview of Rocky Flats Operations,” October 1986.

6. Thomas B. Cochran and Christopher E. Paine, “The Amount of Plutonium and Highly-Enriched Uranium Needed for Pure Fission Nuclear Weapons,” NRDC Revised April 13, 1995.

7. DOE, Nuclear Safeguards Branch, Safeguards and Security Division, Albuquerque Operations Office, “Nuclear Materials Safeguards Survey of Rockwell International Energy Systems Group Rocky Flats, April 30 1981 [See Cook 14Dec94 Request for MUF pp. 4301697 and 4301708].

8. DOE, Fact Sheet, “Buried Waste at INEL May Contain More Plutonium than Previously Recorded, December 7, 1993 [Cook 14Dec94 Request for MUF, 4329774; see also pp. 4329775-4329789].

9. DOE, Fact Sheet, DOE Openness Press Conference, June 27, 1994.

10. Douglass, Viewgraphs, Rocky Flats, June 21, 1994.

11. Dow Chemical Company, “Explanation of Material Unaccounted For, “71” Plant,” June 1954 [Cook Request for MUF from Build 881, 3432529].

12. Dow Chemical Company, “A Report on Radiation Problems Related to Plutonium Fabrication Operations at the Rocky Flats Plant,” Albuquerque Operations Office, USAEC, prepared by Rocky Flats Division, Dow Chemical Company, January 1968.

13. Dow Chemical Company and Rockwell International, various monthly ID Summary Reports during the period, 1975-1979.

14. Dunn, Manager, Nuclear Materials Controls, Rockwell, Rocky Flats Plant, internal letter to E.R. Young, "Possible Declassification of MUF," June 22, 1977.

15. Hazelton, memo to W.H. Hauschild, et al., "Plutonium MUF Study - Building 707," August 18, 1971.

16. R.B. Hoffman, Letter to Robert R. Fredlund, November 1, 1976 [Cook 20Sep95 Request 750 Safeguards, See p. 3458185].

17. Idaho National Engineering Laboratory (INEL) Lockheed Idaho Technologies Company, "A comprehensive Inventory of Radiological and Nonradiological Contaminants in Waste Buried in Subsurface Disposal Area of INEL RWMC During the Years 1952-1983, INEL-95/0310 [Cook 14Dec94 Request for MUF 4329796].

18. D.E. Kudera, "Rocky Flats Plant Estimation of Plutonium Loss to Burial," March 17, 1994 [Cook 14Dec94 Request for MUF 4329764].

19. H. Robert Meyer and Jill Weber, Radiological Assessment Corporation, "Estimating 903 Area Releases," Rocky Flats Health Advisory Panel Meeting, September 12-13, 1996.

20. "Report on Disposal of Classified Radioactive Wastes at Commercial (Licensee) Burial Grounds," accompanying a memo to Edward J, Block, Assistant General Manager for Operations, AEC, and K.F. Hertford, Manager, Albuquerque Operations, January 13, 1964.

21. Roberts, et. al., "A Discussion of Inventory Difference, Its Origin and Effects," EG&G, Rocky Flats Inc., Revision 4, August, 1994.

22. Rockwell, "Classification of Rocky Flats Plant Inventory Difference (ID) Data," Rockwell International, Rocky Flats Plant, December 12, 1979.

23. Rockwell International, "Rocky Flats Technology Office MC&A Team Report," December 6, 1989 [Cook 14Dec94 Request for HQ MUF 4302564].

24. Rocky Flats Plant Nondestructive Assay Instrumentation History Nuclear Material Accountability, ca. 1993 [Cook 14Dec94 Request for MUF, 4329754].

25. Jack R. Roeder, letter subject: "Accountability and Safety Functions in Fissile Material Operations," for Safety and Safeguards, September 18, 1985 [Cook 14Dec94 Request for MUF 4303396].

26. R.G. Romatowski, Manager DOE's Albuquerque Operations Office, memo to J.R. Nicks, and J.E. Dorr, "Special Nuclear Material Inventory Problems," April 13, 1983.

27. Paul G. Voillequé, "Estimating Airborne Releases of Plutonium During the 1957 Fire in Building 71," in Radiological Assessment Corporation (RAC), "The Rocky Flats Dose Reconstruction Project, Phase II, DRAFT, May 1995.

28. W.F. Weston, "Resolution of Aqueous Recovery Inventory Difference (MBA 1375-30)/Recommendations," March 10, 1986 [Cook 14Dec94 Request for MUF, see p. 4311606].

29. E.R. Young, Director Safeguards and Security, Rockwell International, "Rocky Flats Plutonium History of Material Unaccounted For (MUF)," January 21, 1977, Appendix 2 to "Classification of Rocky Flats Plant Inventory Difference (ID) Data," Rockwell International, Rocky Flats Plant, December 12, 1979.

30. L.L. Zodtner and R.F. Rogers, "Study of Unaccounted For Plutonium Losses," Dow Chemical Company, Golden, Colorado, January 6, 1964.

31. Stephen V. Zvacek, "Minutes of the 89th Weapons Contractor classification Conference," Sandia National laboratories, March 8-10, 1994 [Cook 5Sep95 request WC3 Meeting Mins 345685].

Table 3. Possible Contributions to the 1191 kg Cumulative Plutonium ID Through 1994, as Estimated by Roberts, et al., 1994.

Sources of ID	Pu (kg)
Waste Shipped Offsite	600-800
Material Measurements Onsite	200-300
Equipment and Process Holdup	
Process piping (14,350 m in Bld 371)	4.3
Gloveboxes (190 in Bld 771)	up to 50
Process Ductwork (about 16,000 ft)	20-30
Process Tanks (190 in Bld 771)	30-40
Process Equipment	up to 100