SEC Petition Evaluation Report
Petition SEC-00030

Report Rev #0 | Report Submittal Date: 4-7-2006

Subject Expert(s):	Karin Jessen, Craig Little, Robert Meyer, Tim Vitkus
Site Expert(s):	Roger Falk, Jim Langstead, Eugene Potter, Ken Savitz, Al Wolff
Independent Technical Reviewer:	Dan Stempfley

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Qualification Date	DOE/AWE Facility Name
SEC-00030	83.13	06-16-2005	Rocky Flats Plant

Feasible to Estimate Doses with Sufficient Accuracy?

Single Class				Multiple Classes				Determination Established for All Classes			
Yes	X	No		Yes		No	X	Yes	X	No	

Petitioner Class Definition

All represented members, past and current of USWA Local 8031 and its predecessors who have worked at all of the facilities at Rocky Flats between the time period of April 1952 and February 15, 2005.

Proposed Class Definition

All employees of DOE, DOE contractors, or subcontractors who have worked at the Rocky Flats Plant from April, 1952, through February, 2005.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
NONE			

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
NONE	

ORAU Lead Technical Evaluator: (Document Owner)	Signature on file *Karin Jessen*	April 7, 2006 *Date*
Peer Review Completed By:	Signature on file *Brant Ulsh*	April 7, 2006 *Date*
SEC Petition Evaluation Reviewed By:	Signature on file *Jim Neton*	April 7, 2006 *Date*
SEC Evaluation Approved By:	Signature on file *Larry Elliott*	April 7, 2006 *Date*

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Evaluation Report Summary: SEC-00030, Rocky Flats Plant

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 USC (EEOICPA) and 42 CFR 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner Requested Class Definition

Petition SEC-00030, qualified on June 16, 2005, requested that NIOSH consider the following class: *All represented members, past and current of USWA Local 8031 and it's predecessors who have worked at all of the facilities at Rocky Flats Plant between the time period of April 1952 and February 15, 2005.*

NIOSH Proposed Class Definition

Based on its research, NIOSH expanded the petitioner-requested class to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. This proposed class includes all employees of DOE, DOE contractors, or subcontractors (regardless of union membership) who worked at the Rocky Flats Plant (RFP) in Golden, Colorado, from April, 1952, through February, 2005, and who were employed for at least 250 aggregated work days either solely under the employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements). The class was expanded (Section 9.0) to include non-union employees because NIOSH determined that all employees were similarly or identically exposed, and therefore, cannot be disaggregated from the union workers with respect to their work and exposures.

Feasibility of Dose Reconstruction

Per EEOICPA and 42 CFR § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose incurred by any member of the class; or (2) estimate radiation doses more precisely than a maximum dose estimate. Information available from the site profile and additional resources is sufficient to estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period.

Health Endangerment Determination

Per EEOICPA and 42 CFR § 83.13(c)(3), a health endangerment determination is not required because NIOSH has determined that it has sufficient information to estimate dose for the members of the proposed class.

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SEC Petition Evaluation Report for SEC-00030

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees of DOE, DOE contractors, or subcontractors who have worked at the Rocky Flats Plant from April, 1952, through February, 2005. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

This report does not provide any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH. This report does not make the final determination as to whether or not the proposed class will be added to the SEC (see Section 2.0).

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 CFR 83, and the guidance contained in the Office of Compensation Analysis and Support's *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

2.0 Introduction

The EEOICPA and 42 CFR 83 require NIOSH to evaluate qualified petitions requesting the Department of Health and Human Services (HHS) to add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether or not it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[1]

42 CFR § 83.13(c)(1) states: *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class, or if NIOSH has established that it has access to sufficient information to estimate the radiation doses of members of the class more precisely than an estimate of the maximum radiation dose.*

Under 42 CFR § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also make a determination whether or not there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high level exposure has not been established, then NIOSH is required to specify that health was endangered for

[1] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 CFR 82 and the detailed implementation guidelines available at www.cdc.gov/niosh/ocas.

those workers who were employed for at least 250 aggregated work days either solely under the employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document the evaluation in a report. For development of the evaluation report, NIOSH relies on its own dose reconstruction expertise as well as technical support from Oak Ridge Associated Universities (ORAU). Upon completion, the report is provided to the petitioners and to the Advisory Board on Radiation and Worker Health. The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose decisions on behalf of HHS. The Secretary of HHS will make final decisions, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this final decision process, petitioners may seek a review of certain types of proposed decisions issued by the Secretary of HHS.[2]

3.0 Petitioner Requested Class/Basis and NIOSH Proposed Class/Basis

Petition SEC-00030, qualified on June 16, 2005, requested that NIOSH consider the following class: *All represented members, past and current of USWA Local 8031 and it's predecessors who have worked at all of the facilities at Rocky Flats Plant between the time period of April 1952 and February 15, 2005.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible. NIOSH considered the following information and affidavit statements sufficient to qualify SEC-00030 for evaluation.

> Periods of inadequate monitoring, lack of monitoring, and/or changes in methodology and procedures over the history of the Rocky Flats Plant which make accurate dose reconstruction over time impossible. Examples include: no routine lung counting until the late 1960s, no monitoring for neutron radiation prior to the late 1950s, and neutron measurements found in error until the 1970s, and the impossibility of accurate dose assessment for high fired oxide exposure.
>
> The petitioner asserted by affidavits that energy employees at RFP have either had their doses inaccurately reported or had unmonitored exposures.

The information and affidavit statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petitioner-requested basis are addressed in Section 7.5.

NIOSH expanded the petitioner-requested class for the purpose of this evaluation to include all employees of DOE, DOE contractors, or subcontractors (regardless of union membership) who

[2] See 42 CFR 83 for a full description of the procedures summarized here. Additional internal procedures are available at www.cdc.gov/niosh/ocas.

worked at the Rocky Flats Plant (RFP) in Golden, Colorado, from April, 1952, through February, 2005. The class was expanded to include non-union employees because NIOSH determined that all employees were similarly or identically exposed, and therefore, cannot be disaggregated from the union workers with respect to their work and exposures.

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed data sources to determine the availability of information relevant to determining the feasibility of dose reconstruction for the class of employees proposed for this petition. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following sections summarize the data sources identified and reviewed.

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to serve as a supplement to, or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. As part of this evaluation, the following TBDs were reviewed:

- *Technical Basis Document for the Rocky Flats Plant – Introduction*
  ORAUT-TKBS-0011-1, Rev. 00; April 20, 2004

- *Technical Basis Document for the Rocky Flats Plant – Site Description*
  ORAUT-TKBS-0011-2, Rev. 00; January 10, 2004

- *Technical Basis Document for the Rocky Flats Plant – Occupational Medical Dose*
  ORAUT-TKBS-0011-3, Rev. 00; February 9, 2004

- *Technical Basis Document for the Rocky Flats Plant – Occupational Environmental Dose*
  ORAUT-TKBS-0011-4, Rev. 01; June 29, 2004

- *Technical Basis Document for the Rocky Flats Plant – Occupational Internal Dose*
  ORAUT-TKBS-0011-5, Rev. 00 PC-1; December 13, 2005

- *Technical Basis Document for the Rocky Flats Plant – Occupational External Dose*
  ORAUT-TKBS-0011-6, Rev. 00; January 20, 2004

4.2 ORAU Technical Information Bulletins (OTIBs)

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. An ORAU Procedure provides specific requirements and guidance regarding EEOICPA project level activities including the preparation of dose reconstructions at particular sites or categories of sites.

NIOSH reviewed several OTIBs describing the dosimetry program at RFP as well as a methodology for using co-worker data to fill in gaps in monitoring information for some employees and time frames:

- *OTIB: Maximum Internal Dose Estimates for Certain DOE Complex Claims*
  ORAUT-OTIB-0002, Rev. 01 PC-2; May 7, 2004

- *OTIB: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*
  ORAUT-OTIB-0006, Rev. 03 PC-1; December 21, 2005

- *OTIB: A Standard Complex-Wide Correction Factor for Overestimating External Doses Measured with Thermoluminescent Dosimeters*
  ORAU-OTIB-0008; Rev. 00; November 7, 2003

- *OTIB: A Standard Complex-Wide Correction Factor for Overestimating External Doses Measured with Film Badge Dosimeters*
  ORAU-OTIB-0010; Rev. 00; January 12, 2004

- *OTIB: Analysis of Coworker Bioassay Data for Internal Dose Assignment*
  ORAUT-OTIB-0019, Rev. 01; October 7, 2005

- *OTIB: Use of Coworker Dosimetry Data for External Dose Assignment*
  ORAUT-OTIB-0020; Rev. 01; October 7, 2005

- *OTIB: Assignment if Missed Neutron Doses Based on Dosimeter Records*
  ORAUT-OTIB-0023, Rev. 00; March 7, 2005

- *OTIB: Supplementary External Dose Information for Rocky Flats Plant*
  ORAU-OTIB-0027; Rev. 00; May 19, 2005

- *OTIB: Application of Internal doses Based on Claimant-Favorable Assumptions for Processing as Best Estimates*
  ORAU-OTIB-0033; Rev. 00; April 20, 2005

- *OTIB: Use of Rocky Flats Neutron Dose Reconstruction Project Data in Dose Reconstructions*
  ORAU-OTIB-0050; Rev. 00; December 13, 2005

- *Procedure: Occupational X-ray Dose Reconstruction for DOE Sites*
  ORAU-PROC-0061; Rev. 00; December 1, 2004

4.3 Facility Employees and Experts

Throughout the evaluation process, additional information was obtained via phone and e-mail as well as through a July 6, 2005, telephone conference with several of the RFP TBD authors and subject matter experts who previously worked at RFP, including several former employees who were radiation monitors, chemical operators, and managers. These communications are documented under SEC-00030, Non-Submitter Communications, SECIS IDs: 42, 48, 51 through 60, and 2002.

4.4 Previous Dose Reconstructions

NIOSH reviewed its dose reconstruction database, the NIOSH OCAS Claims Tracking System (NOCTS), to identify dose reconstructions under EEOICPA that might provide information relevant to the petition evaluation. Table 4-1 provides a results summary of this review for the April, 1952, through February, 2005 timeframe. (Data available as of: February 8, 2006)

Table 4-1: No. of Rocky Flats Claims Submitted Under the Dose Reconstruction Rule

(April , 1952, through February, 2005)

Description	Totals
Total number of claims submitted for energy employees who meet the proposed class definition criteria	1096
Number of dose reconstructions completed for energy employees who were employed during the years identified in the proposed class definition	623
Number of claims for which internal dosimetry records have been obtained for the identified years in the proposed class definition	997
Number of claims for which external dosimetry records have been obtained for the identified years in the proposed class definition	1038

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. NIOSH also reviewed the interviews conducted with the claimants. The interviews provided some information that might be useful for dose reconstructions (i.e., work locations, hours worked, and hazards encountered, such as fires in the gloveboxes). Of the total number of claims (1096), only 46 claims have no external monitoring data available, 87 claims have no internal monitoring data, with 12 claims not receiving a response from the site.

4.5 NIOSH Site Research Database

The NIOSH site research database was reviewed for documents to support the evaluation of the proposed class. Some information is available for the RFP regarding dust sampling, air monitoring, urinalysis data, the radiological control program, medical monitoring, process materials, and process description as referenced in this evaluation report.

4.6 Other Technical Sources

The Neutron Dose Reconstruction Protocol (NDRP) reassesses the neutron doses to workers who worked in the plutonium production buildings between 1952 and 1970. The document describes the methods and technical basis used for: (1) reassessing doses for workers not monitored for neutron exposures; or (2) reassessing doses for monitored workers by re-reading films and plates. (ORISE-05-0199)

4.7 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following documents submitted by the petitioners (SECIS ID: 8448, received 02/15/05; SECIS ID 8892, received 05-24-05):

- *Advisory Board on Radiation and Worker Health*, Vol. I, July 1, 2002; Pages 206-214
- *Historical Neutron Dosimetry at Rocky Flats*, May 18, 1994; presentation by Roger Falk
- *Investigation Team Report*, March 15, 2001
- *Report on the Radiation Protections Review at the Rocky Flats Plant*, December 1, 1993; Defense Nuclear Facilities Safety Board
- *Trip to Review Feed Characterization for Rocky Flats Plant Building 707 Thermal Stabilization Process*, January 20, 1994; Defense Nuclear Facilities Safety Board
- *Consent Order Incorporating Agreement between U.S. Department of Energy and Kaiser-Hill*, L.L.C. memo from Department of Energy to Kaiser-Hill Company, L.L.C.
- *Preliminary Notice of Violation and Proposed Imposition of Civil Penalty, $385,000*, July 17, 2001, from the Department of Energy to Kaiser-Hill Company, L.L.C.
- *Lifetime Dose Limitation and Neutron Dose Reconstruction-MTS-193-94*, July 26, 1994, Interoffice Correspondence
- Summary of Events, 1952-1988
- Radiological Improvement Reports (RIRs) 1998-2003
- Twenty-two affidavits from workers

5.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize RFP radiological operations from April, 1952, to February, 2005. From available sources, NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing the process through which the radiation exposures of concern may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is meant only to be a summary of the available information. Radiological operations are discussed in more detail in ORAU-TKBS-0011-2, *Technical Basis Document for the Rocky Flats Plant - Site Description*.

5.1 Rocky Flats Plant and Process Descriptions

The U.S. Atomic Energy Commission announced its decision on March 23, 1951, to build the Rocky Flats Plant in Colorado. Ground-breaking occurred in July of 1951 for what is now building 991. In general, the primary missions and general activities at the plant remained essentially the same from the time the plant opened until 1989, when the U.S. Department of Energy (DOE) suspended plutonium operations. The RFP had two major missions – production of plutonium triggers (or “pits”) for nuclear weapons, and processing of retired weapons for plutonium recovery. From the beginning, the plant was a manufacturing facility. Plutonium triggers are components of fission bombs, used to initiate the second-stage fusion reaction in hydrogen bombs. The plant received plutonium from production sites (Savannah River and Hanford), and from retired warheads and residues. Parts were formed and machined from plutonium and uranium as well as from beryllium, stainless steel, and other non-radioactive materials.

In 1984, the site was proposed as a Superfund Site and, in 1989, it was included on the National Priorities List for clean-up of environmental contamination. In December, 1989, DOE suspended plutonium processing to review and upgrade the plant’s safety systems. EG&G, Inc., assumed operation of the site on January 1, 1990, working toward the resumption of operations in the plutonium buildings. With the President’s 1992 announcement of cancellation of the W-88 Trident Warhead Program, the Rocky Flats production mission ended permanently. In 1993, the Secretary of Energy formally announced the end of nuclear production at Rocky Flats. In 1994, the last defense production-related shipment was sent from Building 460. Kaiser-Hill managed the RFP, which closed in October, 2005.

There have been only three basic pit designs since the beginning of plant operations, with the manufacturing of the first two designs phased out within the first five years of production. The first two designs were solid units made mostly of uranium. Design changed around 1957 to focus primarily on plutonium. (ORAUT-TKBS-0011-2)

The SEC-00030 evaluation addresses the entire time period of the RFP. Table 5-1 summarizes the site's development.

Table 5-1: Rocky Flats Plant Development Chronology

Years	Buildings	Comments	Plant Population
1951-1954	991, 771, 444, 881	By April, 1952, production operations reportedly had begun, but no production or shipment details are available for 1952 or the first part of 1953. By 1954, the plant was fully operational, with about 700,000 square feet of building space.	Employment grew steadily during this time. In 1951, there were 133 people.
1955		A major facility expansion began, referred to as Part IV construction.	
1956-1957	447, 776, 777, 883, 997, 998, 999 and the expansion of Bldgs. 444, 881, 771	These additions were directly related to the change of the weapon concept to a hollow unit and anticipated production increases. A few years later, roughly coincident with the onset of the Cold War, RFP became the primary manufacturer of pits under the single-mission concept.	
Mid 1960s	559, 779, 865	These additions were research and development facilities focusing on effects of time and field conditions on weapons.	By 1964, the workforce reached a level of about 3,000 people that remained stable for about 15 years.
Early 1980s-1990	371, 460	By 1990, total building space had grown to about 2.5 million square feet.	Significant upturn in employment, with a peak of 5,990 in 1984.
1990s-2006		Pu processing ceased in 1990. The announcement of the curtailment of nuclear weapons components for submarine-based missiles ended nuclear production. Decontamination and Decommissioning phase. Site closed in 2005.	Announcement in workforce reduction to ~4,000 by October, 1995.

5.2 RFP Functional Areas

Rocky Flats operations included the following functional areas:

- Component Manufacturing and Assembly
- Material Recovery and Purification
- Research and Development
- Waste Processing
- Plant Support

To manufacture a fissionable product, RFP developed facilities, equipment, and personnel to conduct precision metalworking and to assemble fissionable and non-fissionable materials. Key non-fissionable components were made of beryllium, aluminum, and stainless steel.

Early work at the plant involved both U-235 and Pu-239 as fissionable materials. Enriched uranium contract work was transferred to the Oak Ridge Reservation in 1964. Americium-241 recovery began in 1957, functioning as a step in the plutonium recovery process and producing a marketable product. Use of beryllium in full-scale production operations began in 1958. Stainless steel component work began in 1966. Stainless steel operations (known as the "J Line") took place in Building 881 until 1984, when they moved to Building 460. (ORAUT-TKBS-0011-2)

5.2.1 RFP Component Manufacturing and Assembly

Originally, the plant had four operational areas – A, B, C, and D Plants – identified according to four primary types of work. The A Plant included Building 444 operations, which involved the fabrication of depleted uranium (DU) parts. Later known as Building 881, the B Plant recovered enriched uranium (EU) and manufactured enriched uranium components. The C Plant, later Building 771, housed plutonium operations, and the D Plant in Building 991 was the center of final product assembly operations.

The RFP originally received DU from Paducah, Kentucky, and later, from the Feed Materials Production Center in Fernald, Ohio, as feed material in the form of ingots in sealed cans. An external dosimetry TBD produced by the Rocky Flats site states that recycled uranium (RU) was present at Rocky Flats in relatively small quantities (RFETS, 1998). The TBD states that, of the 8,029 metric tons of DU metal received, "only 2.1 metric tons (received from the Fernald facility) is known to have been derived from the recycle process." The cited transuranic (TRU) and technetium (Tc) content provided by Fernald for that shipment was 2.8 parts per billion (ppb) plutonium, 389 ppb neptunium, and 8550 ppb technetium. The report also states that this shipment was "defined by Fernald as 'low enriched' material (containing slightly more than 0.7% U235)…." Although this material was not truly depleted uranium, "the site considered this material to be DU and included it in the mass balance ledger for that material type." It has not been identified whether this material was ever processed as DU. If a worker is identified to have been involved with processing low enriched uranium, the dose reconstructor would include the contribution of the RU contaminants.

Regarding enriched uranium, the TBD states that "HEU [highly enriched uranium] metal of the purity required for the weapons program would not have recycle contaminates because of the processing steps to establish the enrichment and therefore is considered de minimis." The report cites a shipment of 200 kilograms of recycled highly-enriched uranium in the form of uranyl nitrate in 1955 from the "Idaho facility" and states contaminant levels of 0.007 ppb plutonium, 2.5 ppb neptunium, and 9.12 ppb technetium. This level of contaminants would not substantially affect the level of radiation dose of any exposed workers.

Thorium

Beginning in 1952, thorium was used on site in quantities small enough that effluents were not routinely analyzed for Th. Thorium quantities varied from as little as none to as much as 238 kilograms (kg) in a given month. The principle use was fabrication of metal parts from natural thorium metal (Th-232) and from various thorium alloys. Thorium oxide might have been used as a mold-coating compound in limited experiments. Thorium compounds were used in analytical procedures. In addition, twice between 1964 and 1969, thorium "strikes" were performed to remove gamma-emitting Th-228 from U-233 metal needed for fabrication of test devices. The strikes involved a fluoride precipitation and filtration process using natural thorium. Photon radiation from Th-228 decay products would have been monitored by standard gamma dosimetry badges in use at the plant. In addition, thorium was used as a stand-in for plutonium or uranium components in development programs.

Tritium

Tritium was present at the RFP beginning in approximately the mid-1960s. The tritium was associated with, and the result of, the receipt and reprocessing of contaminated weapons components returned to the site. The disassembly and reprocessing of these components introduced tritium into air and wastewater streams, and in several documented cases, resulted in site environmental releases.

5.2.2 RFP Material Recovery and Purification

Manufacturing produced wastes consisting of fissionable and non-fissionable materials; associated lubricating and cleaning compounds; and other materials such as rags, slags, clothing, tools, and paints. Wastes were stored in barrels in the 903 Area just outside the main fence. In the late 1960s, waste oils were eventually treated by fixation in concrete and shipped off site for burial. Clean-up of the 903 Area resulted in some potential for worker exposure to airborne plutonium from disturbance of contaminated soil.

Plutonium Recovery and Purification

When Building 771 became operational in 1953, operations included plutonium recovery (from weapons manufacture, and later, from weapons recycling), plutonium purification, and plutonium component manufacturing. Eventually, operational capacity reached 12 kg per day. In 1965, an expanded production area added five dissolution lines, increasing plutonium recovery by a factor of 20. In 1968, the decision was made to replace Building 771 recovery operations. However, the new Building 371 was plagued with problems from the outset. Building 371 was shut down in 1985 before achieving full-scale operation.

Originally, plutonium at the RFP came from Hanford as plutonium nitrate in small stainless-steel flasks packaged in cylindrical steel carrying cases. Later, plutonium was received from Hanford in the form of buttons. Occasionally, plutonium nitrate feed was received from the Oak Ridge Reservation. In 1959, these shipments were reduced, and most of the plutonium feed to recovery and purification operations was from recycled material from site returns, the foundry, or waste products from the recovery operation. Some plutonium that went through the system at this time came from outside sources in the form of plutonium dioxide. Later shipments of plutonium consisted of metal buttons from the Savannah River Site.

The RFP produced components from other metallic radionuclides on a limited basis for incorporation in pits for special-order operations. The inclusion of these radionuclides (neptunium-237, americium-241, plutonium-238, and curium-244) as tracers into the makeup of the pits enabled research elsewhere. The Special Recovery area processed the plutonium tracer materials. Eventually, leftover tracer materials had to be removed from the plutonium streams, which became part of Special Recovery operations. Special Recovery operations included the Oralloy and Part V Leaching lines, in which surface impurities were removed from enriched uranium and plutonium components.

The recovery process was often described in terms of functional divisions (i.e., "fast" and "slow" recovery operations). The fast cycle processed plutonium nitrate solution, turning the liquid to a powder and then to metal. The slow cycle received materials with higher concentrations of impurities that required a greater degree of pre-processing before entering the fast-cycle metal conversion process.

Before the implementation of the molten salt extraction (MSE) process in 1968, almost all plutonium-bearing materials went through slow recovery operations. These materials had to be converted to plutonium nitrate via the slow cycle and then introduced into the fast cycle line for conversion to a solid and reduction to metal. With the MSE process, some of the essentially-pure plutonium metal (e.g., metal from site returns) went through MSE to remove americium in-growth, and then directly to plutonium foundry operations in Building 777 for casting and subsequent processing into plutonium components.

Uranium Recovery and Purification

Building 881 was built in 1952 and housed enriched uranium component manufacturing, including machining and fabrication of parts. In 1954, when the chemical recovery line began enriched uranium recovery from metal residues created in the manufacturing processes, Building 881 housed all enriched uranium operations, from casting to forming, machining, assembly, recovery, and purification.

Americium Recovery

There was a pressing need to deal with the americium in the plutonium handled at RFP, because in-growth of Am-241 from Pu-241 decreases the effectiveness of the plutonium and creates a gamma exposure problem. The plant had a backlog of americium-containing sludge generated from a plutonium recovery process. As a result, an americium line began operation in 1957 in Building 771. From the late 1950s until the late 1970s, Am-241 was recovered and purified for resale. The demand for americium declined in the late 1970s, and the Am-241 removed in the plutonium purification process went to Building 774 to be processed as radioactive waste.

In 1967, the MSE process became the feed source for americium purification. In MSE, molten americium-bearing plutonium came into contact with molten NaCl-KCl-$MgCl_2$ salt. Oxidation reduction reactions with the salt separated the americium from the plutonium by equilibrium partitioning. There were alpha-contamination personnel exposure problems associated with the hydroxide precipitation step, and in 1973 it was replaced with a cation-exchange procedure. The entire process underwent another major change in 1975 when the ammonium thiocyanate steps were eliminated and the americium was recovered from the anion effluent by oxalate precipitation with subsequent calcination to form the more stable oxide. Americium recovery and purification operations shut down in 1980, and work was limited to that required to extract americium from plutonium metal in site returns.

5.2.3 RFP Waste Processing

When Building 774 was built in 1952, its primary purpose was to support Building 771 by treating its radioactive aqueous waste. The general mission of the waste operations was to reduce the volume of wastes. Liquids transferred to Building 774 were subjected to pH adjustment and sent through a precipitation step to remove radionuclides. The resulting slurry was sent to vacuum filters. The solids removed from the filters were combined with cement or another solidifying agent and shipped to long-term storage as transuranic (TRU) mixed waste. The aqueous waste from this first stage went through the process again. Before 1973, aqueous wastes from this process went to either the solar evaporation ponds or to the "B" series of holding ponds, depending on the concentrations of radioactivity. Maintenance and eventual clean-up of the solar ponds introduced potential worker exposure scenarios.

Around 1965, an evaporator was installed in Building 774 to treat liquids that had accumulated in the solar evaporation ponds. Water and volatiles evolved from the evaporation process were discharged to the atmosphere. The concentrate from the evaporator was fed to a double-drum dryer, on which the salt solution dried for removal by a scraping blade. Water vapor and volatiles from the dryer went through a scrubber and de-mister before venting to the stack, with the liquids from the scrubber and de-mister returning to the aqueous treatment process. The evaporator was removed from service in 1979, and liquids from the second stage of treatment and the solar ponds were transferred to Building 374.

Building 374 went into operation in 1980 as an integral part of the new plutonium recovery facility, Building 371. Building 374 was designed to handle wastes generated in Building 371. The processes used in Building 374 were essentially the same as those used in Building 774, with more efficient equipment. Building 374 was also designed to provide greater safety of operation through improved containment, control systems, and separation of workers from operations.

While most hazardous and radioactive wastes were shipped off site for disposal, approximately 178 inactive waste sites existed within the plant boundaries as production operations were completed in the late 1980s, some of which had been used for burial, incineration, and land application.

Liquid sanitary waste operations were kept separate from the liquid process waste operations to prevent contamination of the sanitary waste streams. Holding tanks upstream from the treatment plant were sampled to check for plutonium contamination. Standard waste treatment was provided. Final disposition of sludges has changed over the years. From 1954 to 1968, 100 tons of sanitary sludges were disposed of in on-site trenches (T-2 through T-8). At that time, some floor drains in the manufacturing buildings were not isolated from the sewage treatment plant, and the sanitary sludge became contaminated with uranium and plutonium. A second landfill that opened in 1968 received sludges until 1969. At that time, the sludges were declared low-level radioactive waste and shipped off site to approved disposal sites.

There were instances of on-site burial of contaminated materials, most notably soils contaminated by the 1969 fire, and other soils excavated during clean-up of the laundry waste outfall formerly located on the north side of Building 771. In the early years of plant operation, laundry waste was discharged directly to Walnut Creek. The released water met then-current standards for concentrations of plutonium and uranium. On December 21, 1973, the release of laundry waste to Walnut Creek ended.

The original RFP landfill, on the south side of the plant, opened in 1952 and closed in August, 1968. An incinerator was in operation at that time in Facility 219 on the west access road. With a few exceptions, non-radioactive combustible waste was burned in the incinerator and the resultant ashes were buried adjacent to the incinerator. It is estimated that fewer than 100 grams of depleted uranium were incinerated in general plant waste between 1952 and 1968.

5.2.4 RFP Research and Development

In the mid-1960s, research and development (R&D) work became a larger part of the activities at the plant as Buildings 779, 559, and 865 were constructed and brought on-line. Much of this R&D work focused on examining site returns to determine the effects of time and field conditions on the weapons, including corrosion and other forms of deterioration.

Rolling of EU foil was conducted in 1964 in Building 331. Interviews suggest that this area was also used for the development of DU and uranium alloy casting techniques.

Building 779, a Pu R&D facility, studied the chemistry and metallurgy of Pu and its interactions with other materials.

Building 865 served as an R&D facility primarily for manufacturing processes using uranium and beryllium.

Work for Others

Rocky Flats conducted Special Order work for other facilities in the weapons complex, the DOD, or other Federal departments or agencies. Most Special Order work did not involve materials other than types used in production activities. The tracer work was an exception. Neptunium-237 tracer work associated with uranium and plutonium components took place in Buildings 771 and 881. Exact dates of production and later recovery of this tracer (from recycled materials) are not readily available; however, it is thought to have occurred from the mid-60s to late 70s. There was considerable effort devoted to keeping tracer materials separate from the regular production material streams, and Special Recovery operations focused on recovering the materials.

5.2.5 RFP Support Organizations

The plant had a number of support organizations. One of the support organizations included the Criticality Laboratory, or Nuclear Criticality Safety Group, which was responsible for identifying and directing control of the potential for criticalities. This group was at the plant beginning in 1953 and in the early years performed its work in the areas where production materials were handled. The *in situ* experiments were always sub-critical; neutron count rates were observed as criticality was approached. In later years, the Nuclear Safety Group conducted its work in Building 886, which was commissioned in 1965. The group conducted about 1,600 critical mass experiments using EU, including Pu in solutions (800 tests), compacted powder (300), and metallic forms (500). After 1983, criticality experiments were not conducted with solid materials; they were conducted primarily with uranyl nitrate solutions, which were reused. Building 886 housed the Critical Mass Laboratory, some offices, and a small electronics and machine shop.

Additional information regarding RFP functional areas can be found in ORAUT-TKBS-0011-2.

5.2.6 Summary of Key RFP Facilities

Table 5-2 summarizes the key processes as well as the buildings and dates of operation[a]. All processing buildings were demolished as of October, 2005.

Table 5-2: RFP Key Facilities, Operations, and Dates of Operation Start-up

Buildings	Facilities	Date of Start-up of Operations
371	**Plutonium Recovery Facility:** Pilot scale operations conducted. Due to engineering design problems production processes in this building never operated. Actual building use began in 1976. Used for material storage and processing (Plutonium Stabilization and Packaging System) until 1989. Monitoring data for radionuclides are available for the life of this building.	1976
374	**Process Waste Treatment Facility:** Brought on line in 1978 to process waste for many of the production buildings, including 122, 123, 443, 444, 460, 559, 707, 774, 776, 778, 779, 865, 881, 883, and 889.	1978
444/445	**DU and Beryllium Metallurgy:** DU processing operations have included casting and machining. Beryllium operations began in 1958; blanks received from commercial supplier were machined. BE casting ended in 1980. Production plating laboratory began operating in 1981 and ended in 1990. Tritium stripping began in 1987 and U foundry shut down in 1989.	1953
447, 448	**Building 447**: A manufacturing building for a variety of U and Be parts, either for production, special orders, disposal, or recovery. Building 448 was for shipping, receiving, and storage.	1956
460	**Consolidated Manufacturing Facility:** Non-nuclear facility for war reserve and special-order parts and assemblies.	1984

Table 5-2: RFP Key Facilities, Operations, and Dates of Operation Start-up		
Buildings	**Facilities**	**Date of Start-up of Operations**
559	**Plutonium Analytical Lab:** Supported Pu processing operations. Principal mission was analyzing gaseous, liquid, and solid samples to quantify major components, including isotopes, alloying agents, and impurities. Provided analytical support to SNM management projects as well as production. Pu analytical laboratory operations are a possible source of tritium emissions from processing product. Approximately once per month, Pu oxidation conducted on remaining sample analyses prior to shipping the $Pu0_2$ to another process on the plant.	1968
566	**Laundry Facility:** Designed as laundry facility for clothing and respirators contaminated with radioactive materials.	unknown
701	**Waste Treatment Research and Development Facility:** Research and development facility used to design, build, and evaluate bench-scale and pilot-scale waste handling and treatment processes.	1965
705	**Coatings Laboratory:** Coatings laboratories and associated offices. No evidence of radioactive materials used in Bldg. 705 was found. Operations included vapor deposition, Be vapor deposition, parts cleaning, Be parts cleaning, polishing, sand blasting, and water cooling.	1966
707/707A	**Plutonium Fabrication Operations:** Bldg. 707 was originally a manufacturing facility for casting, fabricating, and assembling finished plutonium parts (as well as parts made of other materials) into nuclear weapons components. Operations suspended in 1989, but activities related to the restart of PU operations, nuclear facility maintenance, and later D&D operations occurred post-1989. Bldg. 707A was added as part of a 1972 modification. These buildings have also been used for thermal stabilization, inspection, brushing, and repackaging of Pu. Pu was stored in the building on an interim basis.	1972
771/774	**Pu Recovery and Liquid Waste Treatment Building:** Bldg. 771 was designed for Pu recovery from scrap/residue materials. Recovery operations were terminated in 1989. The facility was also used for the interim storage of large quantities of SNM and waste; laboratory analysis; HEPA filter counting; low specific activity counting; and conduct of risk reduction activities (low-level tank draining, bottle venting). The building also solidified ion-exchange resins through cementation and utilizes microwave vitrification for solid residue treatment. Bldg. 774 was used for low-level liquid waste treatment operations. These buildings have been demolished.	1953
776/777	**Pu Manufacturing and Assembly Complex:** Until 1970, this complex was the major Pu fabrication and assembly facility. Operations in the building were shut down for several months after the 1969 fire and the production operations remained shut down. Large amounts of Pu had been stored at the facility. Operations after the 1969 fire included testing and inspection, disassembly of site returns, special projects, plutonium recovery (pyrochemical operations: electro-refining, molten salt extraction, direct oxide reduction, and salt scrub processes) (HAER). Waste operations (initiated in 1969 to support disposition of equipment damaged by the fire as well as waste generated in the clean-up efforts) were on-going. The Supercompactor and size-reduction facilities were used to minimize the total volume of radioactive waste at the complex. Bldg. 776 housed drums containing Pu residue and supported drum-venting activities to prevent the build-up of hydrogen gas. Bldg. 777 was a foundry operations and coatings facility.	1957
778	**Building 778** was a support building for the Pu processing buildings (776, 777, and 707). It was located directly south of Buildings 776 / 777 and was connected to these buildings, as well as Building 707, by enclosed walkways. Over its history, Bldg. 778 was used mainly as a protective clothing (Anti-C) laundry for all the Pu process buildings, a locker room and shower area, and maintenance shops.	

Table 5-2: RFP Key Facilities, Operations, and Dates of Operation Start-up

Buildings	Facilities	Date of Start-up of Operations
779	**Pu Development Building:** This building was constructed for Pu research activities involving process chemistry technology, physical metallurgy, machining and gauging, joining technology, and hydrating operations. All activities were terminated in 1989, although D&D activities occurred through the mid-1990s. The facility had been used for storing SNM and waste. Glovebox activities in support of Pu storage included inspection, metal brushing, and repackaging. Limited laboratory activities included waste characterization and minimization, stockpile reliability evaluations, and surface analysis.	1965
865, 867, 868	**Research and Development of Uranium and Beryllium:** Material and process development and metallurgy laboratory. High Bay area of Building 865 supported production through research and development. Most work was done with DU, Be, Cu, tungsten, stainless steel, and other steel alloys. Processes included metal casting, machining, rolling, heat-treating, and isostatic pressing. Grit Blasters in Bldg. 865 were for surface cleaning of parts containing DU. Bldgs. 867 and 868 contained filter plenums for process exhaust routed from Bldg. 865.	1970
881	**Laboratories, maintenance shops, and plant support facilities**: The original building was designed and built for processing enriched U. Small quantities of other radioactive materials such as ^{233}U and Pu were also handled.	1953
883	**Beryllium and Uranium Machining Facility:** Machining facility for both enriched and depleted U. The building was divided into an A side and B side. The A side rolled enriched U while the B side rolled depleted U. In 1966, the A side of Building 883 was converted to Be rolling. Depleted U rolling continued on the B side. Be machining stopped in mid-1970s, and from 1980 through 1985, there was increased processing of depleted U.	1957
886	**Critical Mass Laboratory/Nuclear Safety Facility:** This building contained a critical mass laboratory that had been used to conduct criticality experiments in support of process operations. Most experiments were conducted using highly-concentrated and enriched uranyl nitrates solutions. Solid uranium and Pu were also used. Criticality experiments were conducted until 1987. More than 1,600 criticality experiments were performed. Materials used in the experiments (uranyl nitrate metal powder) were re-used. Short-lived fission products were produced and none were indicated as having been released to the work or outdoor environment. The isotopes decayed rapidly and were contained until stable.	1965
910, Solar Ponds, 207A, B, and C	**Reverse Osmosis Facility:** Bldg 910 was constructed in 1977. Solar Pond 207A constructed and put into use in 1957. It was used to store and evaporate low-level contaminated waste containing nitrates and radioactive substances (laundry wastewater containing Pu and U). Solar Ponds 207B and 207C were put into service in 1960.	1957
991	**Building 991** was used for weapon assembly, and later, storage and shipment of waste. Emissions data include: ^{238}Pu, $^{238/239}Pu$, ^{241}Am, $^{233/234}U$, and ^{238}U. Building 991 also provided access to underground storage vaults 996, 997, and 999.	1952
995	**Sanitary Sewage Treatment Facility**	unknown

[a] http://www.globalsecurity.org/wmd/facility/rocky_flats.htm

5.3 Characterization of Radiological Exposure Sources from RFP Operations

5.3.1 Alpha Particle Emissions

Alpha particle emissions from the radioactive source materials handled at the RFP presented the most significant radiological protection challenge in the prevention of internal deposits (alpha particles do not present an external exposure hazard). The main alpha-emitting plutonium isotopes associated with the weapons-grade plutonium handled at the RFP were Pu-239 and Pu-240. Pu-239 emits a 5.16 MeV alpha emission with a lower abundance 5.46 MeV emission. Similarly, ^{240}Pu emits alphas at 5.17 MeV and a lower abundance emission at 5.12 MeV. Depleted uranium, comprised predominantly of the isotope U-238, also was a source of internal alpha exposure. U-238 emits alpha particles that are either 4.20 or 4.15 MeV.

5.3.2 Beta Radiation Fields

Beta radiation fields are usually the dominant external radiation hazard in facilities requiring contact work with unshielded forms of uranium. This was the case at the RFP for EU and DU work. For uranium enrichments up to 30%, the beta radiation field is dominated by contributions from U-238 decay products. Thus, for DU, 2.29 MeV (Emax) beta particles are from Pa-234m, the most energetic contributor to the beta exposure. The uranium foundry operations at the RFP produced “skull” that resulted in high beta dose rates. Large foundry ingots were generally handled by lifting devices, but machined uranium parts were handled with gloved hands. The RFP did have problems with elevated beta dose rates from contamination on leather gloves worn during foundry operations.

5.3.3 Neutron Exposures

The most problematic form of uranium from a neutron generation standpoint, UF_6, was not present at Rocky Flats. Neutron exposures become significant in processes involving kilogram quantities of plutonium. Neutrons originate from three sources:

1. Spontaneous fission of even isotopes of plutonium

2. Alpha-neutron reactions with low-atomic-number elements, including oxygen and fluorine in plutonium compounds and impurities in metals

3. Neutron-induced fissions

Because of strict criticality controls, most forms of plutonium have very little neutron-induced multiplication. Induced fission seems to be a problem only in metal (1 kg or more) or in very large, high-density arrays of plutonium oxide with an additional moderator.

Plutonium compounds created during the plutonium manufacturing process, such as PuF_4 and PuO_2, can produce high neutron dose rates through alpha-neutron reactions with fluorine and oxygen. Fluorinator glove boxes typically have the highest neutron dose rates in a plutonium processing line. Although PuO_2 is the preferred form because of its chemical stability, the oxide emits almost twice as many neutrons as pure metal. (DOE STD-1128-98)

5.3.4 Photon Exposures

Low energy photons from Pu are generally stopped by the metal sides of the glove boxes, where the majority of the Pu was handled. However, some photons do escape through material release, open glove ports, non-leaded windows and from oxide coated on the interior surfaces of the gloves, especially when they are pulled outside the glovebox for storage. Twenty five percent of the photon exposure spectra from freshly-separated plutonium is assumed to be from <30 keV photons. (Langstead; SEC-00030 Non-Submitter Communication, SECIS ID: 55)

Examples of workplaces that would typically have spectra with significant low-energy photons include:

- Weapons assembly and disassembly areas
- Plutonium machining areas
- Plutonium processing facilities in areas where the primary hazard is from the product
- Laboratories performing work with plutonium or americium

^{234m}Pa is a decay product in the ^{238}U (depleted uranium) decay chain and emits a 2.29 MeV beta particle. Thus, a significant quantity of photons resulting from Bremsstrahlung radiation are produced and contribute photons of intermediate energy (30 - 250 keV). Bremsstrahlung radiation can contribute up to 40% of the photon dose from uranium metal (DOE-STD-1136-2004). This decay product grows-in fairly rapidly and is present in equilibrium quantities for most depleted uranium that was processed at RFP. It is appropriate to use the default assumption for depleted uranium that 50% of the dose is contributed by photons in the 30 - 250 keV photon energy range and 50% of the dose is a result of exposure from photons in the >250 keV photon energy range.

Although enriched uranium has significantly less in-growth of ^{234m}Pa, ^{235}U and its decay products emit a 185.7 keV photon 57% of time and a 143.8 keV photon 11% of the time. These photons dominate the measured photon energy spectra. Thus, for enriched uranium, it is appropriate to use the default assumption that the entire photon dose is a result of exposure in the 30 - 250 keV photon energy range. This is a claimant-favorable assumption. (ORAUT-TKBS-0011-6) The default assumptions are shown in Table 5-3.

Table 5-3: Default Photon Energies for RFP Materials

Energy	Plutonium	Enriched Uranium	Depleted Uranium
<30 keV	25%*	0%	0%
30-250 keV	75%*	100%	50%
>250 keV	0%	0%	50%

***** Langstead; SEC-00030 Non-Submitter Communication, SECIS ID: 55

5.3.5 Incidents and Fires

An extensive review of the Rocky Flats accident history occurred during Phases 1 and 2 of the environmental dose reconstruction. Researchers evaluated classified and unclassified accident-related databases and documents. Thousands of small-scale releases and accidents were identified over the 40-year operating history. Many events reviewed during the investigation resulted in releases that passed through filtered building ventilation systems.

Fires were a continuous hazard when working with Pu. For example, RFP data indicate 623 reportable fires (most were small) between January, 1955, and December, 1974. Of those fires, 387 occurred in Pu processing areas.

There were 164 reported fires between 1966 and the 1969. Of these fires, 31 involved Pu, of which 10 occurred in Buildings 776 and 777. Of the remaining 133 fires, 17 occurred in Buildings 776 and 777. There is no reliable estimate of the number of Pu fires not reported to the Fire Department. (ORAUT-TKBS-0002)

<u>September 11, 1957 Fire</u>

The September 11, 1957, fire (Voillequé, RAC Report 10) began when metallic plutonium casting residues spontaneously ignited in a glovebox in Room 180 of Building 71 (later Building 771). The fire spread to an exhaust filter plenum, Rooms 281 and 282, consuming a considerable quantity of filters and damaging the ductwork and fan system. No major injuries were reported in this fire.

Smoke from a burning glovebox, detected in a building hallway, led two watchmen to discover flames extending 18 inches from a Plexiglas window on a glovebox at approximately 10:10 p.m. on Wednesday, September 11, 1957. The fire started in a can of plutonium turnings in the “fabrication development line” in Room 180 (first floor) of the plutonium processing and fabrication building (Building 771). Because large quantities of plutonium were handled and stored in this area, people were delayed in fighting the fire until they could don adequate radioactive contamination protection. Attempts to fight the fire with carbon dioxide from hand extinguishers and a 100-pound cart were ineffective. A water spray nozzle was effective, although there was considerable uncertainty at the time about the potential for criticality.

During this time, the fire spread to the filters, which introduced hot gases through the ventilation booster system (pre-filter plenum) and the main exhaust duct. Fires in the box exhaust booster filters and main filter plenum on the second floor might have started around this time, but were not discovered until 10:28 p.m. An explosion of collected flammable vapors in the main exhaust duct at 10:39 p.m. resulted in spreading plutonium throughout most of the building. The Building 771 exhaust fans shut down at about 10:40 p.m. when power was lost. The only draft would have been that created by the natural updraft of the stack and through 100 feet or so of horizontal ductwork that leads to the base of the 150-175 foot stack. Supply fans might have created a positive pressure inside the building for about one-half hour. The fire in Room 180 was controlled at 10:38 p.m., but rekindled several times. The main filter fire was controlled at 2:00 a.m., and the fire was officially declared out at 11:30 a.m., Thursday, September 12, 1957.

1965 Glovebox Drain Fire

In 1965, a plutonium fire occurred during a maintenance operation on a plugged glovebox drain in Buildings 776 and 777 (Voillequé, RAC Report 6). The fire vented to the room air and spread throughout the buildings through the normal ventilation system. About 400 employees, many without respirators, were potentially exposed to airborne plutonium dioxide. Body counter measurements indicated that 25 employees received 1 to 17 times the permissible lung burden. Lung concentrations greater than 0.008 µCi were found in fifteen employees.

The fire lasted for one-half to one-and-a-half minutes and was extinguished with carbon dioxide. It vented to the room atmosphere and combustion products were widely spread by the normal ventilation pattern. Residues of the fire and a drain leg removed from an adjacent lathe were analyzed. The analyses indicated that, during the fire, a chemical reaction occurred between plutonium and carbon tetrachloride. The burning of plutonium in air is generally nonviolent and described as smoldering. The reaction of plutonium and carbon tetrachloride can be violent. Plutonium contamination was spread through a major portion of Building 776 and through 25,000 square feet of Building 777. Major areas of the buildings were cleaned up by Monday morning, October 18, and nearly all production operations resumed at that time (ChemRisk, 1992; ORAUT-TKBS-0011-2).

May 11, 1969, Fire

A major plutonium fire started in a glovebox in the North Foundry Line in Building 776 on Sunday, May 11, 1969 (Voillequé, RAC Report 9). The fire burned for several hours, spreading through combustible materials in several hundred interconnected gloveboxes in Buildings 776 and 777. The first indication of a fire was an alarm in the Fire Station in the North Foundry Line at 2:27 p.m. The Fire Department responded promptly, but upon arrival the fire was moving rapidly through the Foundry Conveyor Line. The fire spread through an interconnecting conveyor to the Center Fabrication Line. It was brought under control about 6:40 p.m., but continued to burn or recur in isolated areas through the night. On Monday morning, a fire was discovered in a glovebox on the South Foundry Line; it was quickly extinguished, causing little damage.

The dense smoke, crowded conditions, and presence of large quantities of combustible material in the form of Plexiglas windows and Benelex-Plexiglas shielding made the fire difficult to fight and extinguish. The fire did not breach the building roof, and ruptured only a minor part of one exhaust filter system. As a consequence, most of the smoke and essentially all of the plutonium remained in the building. One fire fighter received a significant internal body burden of plutonium**.** There is no evidence that a criticality incident occurred. The damage to Buildings 776 and 777 and equipment was extensive. In addition to actual fire and smoke damage, the buildings were grossly contaminated with plutonium. Adjacent buildings sustained minor exterior and interior contamination. Building 771 was grossly contaminated during this fire when water used to extinguish the fire ran down the tunnel connecting Buildings 776 and 777.

6.0 Summary of Available Monitoring Data for the Proposed Class

Historically, the main purpose of the RFP radiation monitoring programs has been to assure that each worker's exposure to radiation was kept below the annual prescribed occupational exposure limit in effect at that time. Because of this aim, personal radiation dosimetry data in the early years were seldom collected for workers who were considered to have low potential for exposure. External penetrating and shallow exposures to particulate and photon radiation were monitored using radiation-sensitive materials housed in personnel badges worn by workers. In the 1950s, the RFP practice for internal monitoring was to monitor workers only if they were expected to be exposed to 10% or more of the limit (called "tolerance"). Later, the goal was to operate at less than 10% of the radioactive concentration guides (RCG) and to investigate conditions if an air sample exceeded 100% of the RCG.

6.1 RFP Internal Monitoring Data

The available RFP internal monitoring information indicates that RFP workers with the potential to receive intakes primarily of plutonium, americium, enriched uranium, or depleted uranium were monitored accordingly. The primary intake mode would have been chronic or acute inhalation or through breaks in the skin (wounds). The primary bioassay data are the urinalysis data, the activity of the radionuclide of interest excreted in the urine following an inhalation or wound intake, the lung count data, and the activity of the radionuclide present in the lungs after an inhalation intake.

The intake exposure record for a worker consists of records of the bioassay data and reports of involvement in incidents, accidents, or special situations.

Details regarding the various analyses used and the associated minimum detectable activities are presented in the *Technical Basis Document for the Rocky Flats Plant - Occupational Internal Dose*, ORAUT-TKBS-0011-5.

Other techniques for evaluating occupational uptakes were in use at various times at Rocky Flats. Techniques included a wound counter, nasal smears, and fecal samples.

Nasal smears served as supplementary data to verify that an intake had occurred, and provided data to determine the concentration of Am-241 in the inhaled plutonium mixture.

Fecal sampling was performed intermittently while site operations were active and served primarily as a means to verify an intake and evaluate clearance rates. In general, these fecal bioassay data are not as germane to dose reconstruction, with urinalysis and lung/body counting providing the primary data, but may be used as supplementary data for validation of acute intakes and some of the input assumptions.

In addition, during the site's decommissioning, fecal sampling was used to quantify a suspected intake and to assign dose, in addition to routine urinalysis and air monitoring. Intakes during decommissioning were the result of cumulative exposure over time from routine job activities. Examples of suspected intake incidents were personnel or clothing contamination, continuous air monitor (CAM) alarms, and instances where the ambient airborne radioactivity environment was higher than expected (e.g., while work was performed in containment enclosures). A fecal sample was typically requested by internal dosimetry health physicists when a worker may have incurred an internal dose greater than 100 mrem from either an incident or cumulative airborne exposure.

Airborne radioactivity sampling results during decommissioning were used to track derived air concentration (DAC) hours and, in some cases, used by the site to assign dose in lieu of fecal sampling if an intake was suspected. The DAC-hour tracking was required whenever supplied-air or powered-air purifying respiratory protection was required.

Air monitoring was performed in work areas throughout the site's history. As reported by Putzier, the intent of the air sampling was multi-purpose. First and foremost was to ensure that ambient air radionuclide levels were below the RCGs, and to trend the effectiveness of engineering controls over time. Initial air sampling stations were within the work area but later changed to both collect samples for analysis and to continuously monitor the effluent air. Continuous air monitors (CAMs) and selective alpha air monitors were used for notifying of a potential release in a work area via an alarm. Several attempts were made during the production history to do specific workplace and worker monitoring, but with limited success. With the start of site decontamination and decommissioning activities and improved personnel monitoring equipment, individual workers were monitored using lapel-type air samplers. The data from these samplers were used to trigger further evaluation if an intake was suspected (e.g., fecal sampling).

In addition to workplace air and stack effluent monitoring, environmental air monitoring stations were established in 1952 at numerous locations around the site. Air monitoring stations were also placed at off-site locations at this time and were operated throughout the site's history.

The air monitoring data collected from 1952 to 1969 provided gross alpha activity rather than radionuclide-specific results. After 1969, results were reported specifically for Pu-239/240. An evaluation of the available air monitoring data was conducted during a public exposure study of Rocky Flats performed during the 1990s. It was reported and referenced in the Occupational Environmental Dose TBD (ORAUT-TKBS-0011-4). The study was conducted in two phases: Phase I identified the radionuclides of concern; Phase II provided an assessment of plutonium air pathway exposure. The results of this study determined that the data from the period 1952 until 1960 were of limited value in estimating Pu-239/240 air concentrations because the long-lived alpha component of the result could not be determined (i.e., the result included both the long-lived alpha component and interferences from naturally-occurring radon progeny). From 1960 until 1964, measurements were made in a manner that enabled estimation of the long-lived alpha component, and therefore, an estimate of the Pu-239/240 concentration (i.e., by performing counts of gross alpha activity within four hours of sample collection and again one week later). However, these data were also considered of limited use in estimating plutonium air concentrations because they were reported as one on-site number rather than individually for each monitoring station. From 1964 until the initiation of radionuclide-specific analyses, the total long-lived gross alpha activity was reported for individual on-site samplers. Similarly, the Phase I study also estimated air concentrations for Am-241, EU, DU, and H-3.

Based on NIOSH's review of the RFP internal dosimetry information and documentation for this SEC evaluation report, it was determined that internal dosimetry information is available for the proposed worker class defined in this report, which is representative of the internal exposures received by individuals during their RFP work. Internal monitoring is discussed in further detail in Section 7.2.

6.2 RFP External Monitoring Data

The methods for, and concepts of, measuring occupational external doses to workers evolved over time from the beginning of RFP operations. The RFP external beta-gamma dosimetry evolved from the use of film badges, during the early years of plant operation, to the use of thermoluminescent dosimeters (TLDs) in 1969. In the early years of plant operation, RFP neutron dosimetry consisted of neutron track plates; these plates were replaced with Nuclear Track Type A film in 1957. In 1971, the RFP replaced the NTA film with albedo neutron TLDs. In 1983, the Panasonic UD-809 dosimeter was introduced at RFP to measure neutrons; algorithm updates were made to this dosimetry system in 1990 and 1993. In 1964, the dosimetry badge was incorporated into the security badge, which ensured that each individual wore dosimetry. This design was maintained until the early 1990s, when the security badge was separated from the dosimetry and individuals unlikely to receive occupational radiation exposure greater than 100 mrem per year were no longer issued dosimeters.

The determination of the badge exchange frequency was based on the potential for external dose and the necessity to control dose to administrative limits. Badges were exchanged at various frequencies. Early dosimetry was exchanged on a weekly basis, which later became semimonthly and monthly. In later years, dosimetry was exchanged on semimonthly, monthly, and quarterly frequencies. In the 1990s, exchange frequencies went to monthly, quarterly, and semiannually.

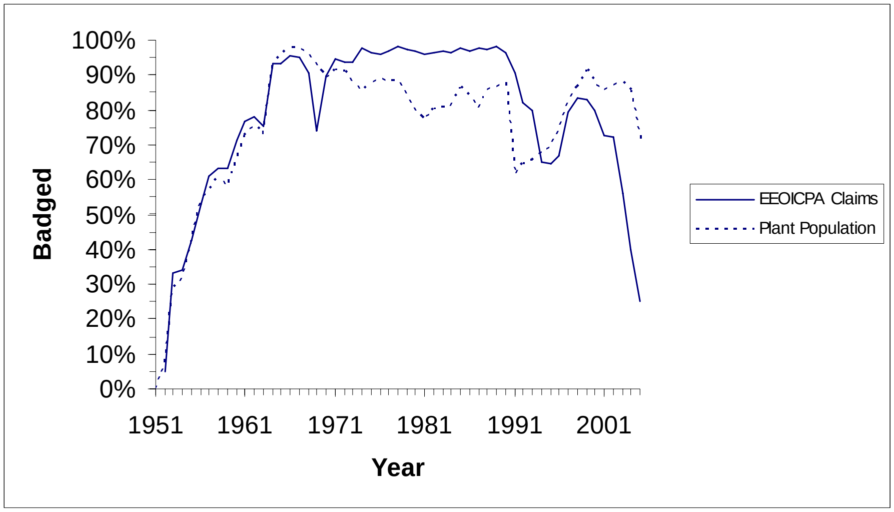
The exchange frequency for an individual can be determined by reviewing the external dose record, if individual dosimeter readings were maintained. After 1976, the dose record will show a dosimeter reading for each exchange. For earlier years, the dose has been combined into quarterly records. (ORAUT-TKBS-0011-6)

Exchange frequencies used before 1976 were determined by reviewing original dosimetry laboratory worksheets, many of which have been assembled as part of the NDRP. Dosimetry laboratory worksheets from 1951 through 1970 were reviewed, and an exchange frequency was determined, along with the building and dosimeter type (photon, beta, or neutron). It was necessary to evaluate the job category because the worksheet did not indicate job assignment. Dosimetry worksheets are not readily available from 1970 to 1976, so exchange frequencies were extrapolated forward for those years. This provides a claimant-favorable assumption when determining missed dose. (ORAUT-TKBS-0011-6)

After about 1990, many individuals at RFP who did not work in radiological areas were not badged. The site Radiological Protection Organization determined that these individuals were unlikely to exceed 100 mrem occupational exposures in a calendar year.

Figure 6-1 shows the number of workers badged over various years. The solid line is derived from EEOICPA claimant files; the broken line shows the results of a similar analysis performed on the RFP electronic files for the entire plant population. The difference is due to discrepancies in termination dates in the electronic files. These dates are verified as claimant files are reviewed, providing a better understanding of the badging process as well as a more accurate individual claimant record.

Figure 6-1: Percent of RFP Workers Badged for Dosimetry



Based on NIOSH's review of the RFP external dosimetry information and documentation for this SEC evaluation report, it was determined that external dosimetry information is available for the proposed worker class defined in this report, which is representative of the external exposures received by individuals during their RFP work. External monitoring is discussed in further detail in Section 7.3.

6.3 RFP Wound Count Data

After the advent of the wound counters in 1954 (alpha monitor) and 1957 (NaI gamma/X-ray monitor), any wounds that occurred in a work area involving Pu were monitored for Pu contamination. Wounds occurring in uranium work areas were monitored selectively. The records usually included an incident report, a wound count data sheet, a medical decontamination report, and a medical treatment report, depending on the era and circumstances. The primary data are the urinalysis results, the identification of the mode and date of intake, and whether there was residual Pu at the wound site. Three annual dosimetry reports are available for wound counts for 1984, 1985, and 1986. All potential intake pathways are analyzed and considered for a radiological dose reconstruction performed under the EEOICPA. When doing a dose reconstruction, intakes resulting from wounds are reflected in urine and/or fecal concentration data. Wound monitoring is discussed further in Section 7.2.1.3.

The wound counter was used for assessing whether a wound occurring in a work area was contaminated with plutonium. Reviewed documentation indicated that the wound counter was primarily a tool for assessing first if contamination was present (with data reported as counts or disintegrations per minute), for providing a means of evaluating decontamination effectiveness, and then for performing follow-up wound-site monitoring. Improvements to the wound counter (beginning in 1957) enabled more quantitative measurements as well as the estimation of contamination depth through gamma/X-ray rather than alpha measurements.

6.4 RFP Air Sampling Data

Air samples were taken in various locations within buildings where the possibility of airborne contamination existed, but were not employee-specific. In later years, lapel air sampling was used for certain workers and jobs and was employee-specific. Air monitoring is discussed in further detail in Section 7.2.1.4.

6.5 ICRP Default Absorption Type and Particle Size Comparison

Dose coefficients for absorption Type F, Type M, and Type S, currently used by the ICRP 66, were compared with coefficients for Class D, W, and Y compounds, respectively, as defined in ICRP 30. The dose coefficients generated by models of ICRP 30 were based on default particle size of 1µm (AMAD) recommended in that document. The dose coefficients generated by models in ICRP 66 were based on the default particle size of 5µm, as recommended in that document. The absorption type selected during internal dose reconstruction is based on bioassay data, or as otherwise determined to be claimant favorable, and the ICRP 66-recommended default particle size is applied.

(Begin: Roger Falk; SEC-00030 Non-Submitter Communication, SECIS ID: 56) Note that when an intake is assessed based on urine bioassay or lung-count measurements, the particle size is not a significant factor except for the GI tract, for which a large particle size is claimant- favorable. This effect is illustrated in the following tables.

Table 6-1 presents the committed equivalent dose to selected organs based on urine excretion of 1 pCi/day at 1 year after an acute intake of Pu-239, for solubility types M and S and for particle sizes 1 and 5 µm AMAD. The assessment was made using the IMBA code with the default ICRP parameter values used by the dose reconstruction project (except for the 1 µm AMAD particle size).

Table 6-1: Effect of Particle Size for Selected Organs for Intakes Assessed from Urine Data

Organ	Type M, CED (rem)		Type S, CED (rem)	
	1 µm AMAD	5 µm AMAD	1 µm AMAD	5 µm AMAD
Kidneys	3.76	3.98	8.68	8.64
Liver	192	203	427	425
RBM	43.4	46.0	99.5	99.1
Bone Surface	911	966	2010	2000
SI	1.61	1.70	3.48	3.48
ULI	1.61	1.71	3.68	3.64
LLI	1.61	1.72	3.47	4.00
Colon	1.61	1.72	3.60	3.80
Lung	18.9	19.9	940	1030
BB sec	32.2	49.3	765	1440
bb	27.0	22.9	72.8	73.3
Gonads	12.1	12.9	27.1	26.9
Remainder	1.63	1.73	3.76	4.36

Table 6-2 presents the committed equivalent dose to selected organs based on a lung count result of 1000 pCi of Pu-239 at 1 year after an acute intake, for solubility types M and S and for particle sizes 1 and 5 µm AMAD. Again, the assessment was made using the IMBA code with the default ICRP parameter values used by the dose reconstruction project (except for the 1 µm AMAD particle size).

Table 6-2: Effect of Particle Size for Selected Organs for Intakes Assessed from Lung Data

Organ	Type M, CED (rem)		Type S, CED (rem)	
	1 µm AMAD	5 µm AMAD	1 µm AMAD	5 µm AMAD
Kidneys	2.81	3.86	0.0518	0.0548
Liver	143	197	2.55	2.69
RBM	32.4	44.6	0.594	0.628
Bone Surface	680	935	12.0	12.7
SI	1.20	1.65	0.0208	0.0221
ULI	1.20	1.66	0.0211	0.0231
LLI	1.21	1.67	0.0219	0.0254
Colon	1.20	1.66	0.0215	0.0241
Lung	14.1	19.3	5.61	6.55
BB sec	24.1	47.8	4.56	9.10
bb	20.1	22.1	4.35	4.65
Gonads	9.11	12.5	0.161	0.171
Remainder	1.22	1.68	0.0224	0.0276

Use of a 1 µm AMAD particle size is more claimant favorable than use of a 5 µm AMAD particle size when the intake is assessed from air concentration data. Table 6-3 illustrates this point for intakes of 1000 pCi airborne ^{239}Pu.

Table 6-3: Effect of Particle Size for Selected Organs for Intakes Assessed from Air Conc. Data

Organ	Type M, CED (rem)		Type S, CED (rem)	
	1 µm AMAD	5 µm AMAD	1 µm AMAD	5 µm AMAD
Kidneys	0.0224	0.0154	0.0274	0.00145
Liver	1.14	0.785	0.135	0.0713
RBM	0.259	0.174	0.0314	0.0166
Bone Surface	5.43	3.73	0.635	0.336
SI	0.00956	0.00658	0.00110	0.000585
ULI	0.00957	0.00661	0.00112	0.000611
LLI	0.00961	0.00666	0.00116	0.000673
Colon	0.00959	0.00663	0.00114	0.000638
Lung	0.112	0.0769	0.297	0.174
BB sec	0.192	0.191	0.242	0.241
bb	0.161	0.0884	0.234	0.123
Gonads	0.0726	0.0500	0.00855	0.00452
Remainder	0.00970	0.00669	0.00119	0.000732

Because of the data hierarchy used for dose reconstructions (lung and urine data taking precedence over air concentration data), it is expected air concentration data will rarely be used when assessing RFP workers at risk of workplace intakes. However, air concentration data will likely be used when assessing environmental intakes for unmonitored workers. (End: Roger Falk; SEC-00030 Non-Submitter Communication, SECIS ID: 56)

7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by EEOICPA and 42 CFR § 83.13(c)(1). Under this Act and rule, NIOSH must establish whether or not it has access to sufficient information to either: (1) estimate the maximum radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the radiation doses to members of the class more precisely than a maximum dose estimate. If NIOSH has access to sufficient information for either case, then it would be determined that it was feasible to conduct dose reconstructions.

In making determinations of feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class (identified in Section 9.0 of this report). If not, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure NIOSH can estimate either the maximum doses members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class (summarized in Section 7.7). This approach is specified in the SEC Petition Evaluation Internal Procedures (OCAS-PR-004) available at www.cdc.gov/niosh/ocas. The next four major subsections examine:

- the sufficiency and reliability of the available data. (Section 7.1)
- the availability of information necessary for reconstructing internal radiation doses. (Section 7.2)
- the availability of information necessary for reconstructing external radiation doses. (Section 7.3)
- the bases for petition SEC-00030 as submitted by the petitioner. (Section 7.5)

7.1 Sufficiency of RFP Data

7.1.1 Pedigree of RFP Data

7.1.1.1 Health Information System (HIS20) Data:

(Begin: Ken Savitz; SEC-00030 Non-Submitter Communication, SECIS ID: 57) Rocky Flats was operated for the Department of Energy from 1952 to 2005. Workers were monitored for occupational radiation exposure during the history of the site and the records were retained in various forms over that period. As computer systems evolved, the exposure data was migrated from earlier databases. The Health Information System (HIS20) from Canberra Industries was the last system at RFETS for the retention of occupational radiation exposure data. This system is an Oracle-based relational database. The system that preceded the HIS20 system was also an Oracle system developed by

RFETS computer specialists. The Radiological Health Records System (RHRS) was used by the Radiological Health Department from about 1991 until 1999. This system was the initial source of the data for the HIS20 database.

HIS20 External Dosimetry Data

Once the data was migrated from RHRS to HIS20, it was soon discovered that there were very few results prior to 1976. A document discovered later revealed that, during a previous migration to RHRS, results from 1952 to 1976 were summed into a single value representing an individual's prior external radiation exposure history. This value was called the 'lump sum' exposure. In about 1997, the Radiological Health Department recovered a dataset that contained individual annual external exposure data. This dataset contained total annual deep dose measurements for individuals uniquely identified by plant ID, social security number, birth date, and name. A project was initiated to load this information into the HIS20 system. For the individuals who were in the HIS20 system, a comparison was made of the 'lump sum' to the sum of the annual doses in the dataset. In addition to the electronic investigation, a group of health physics files for both active employees and inactive employees were reviewed to validate the dataset and to provide guidance on the proper method for loading the data. The following rules were imposed on the project:

- For those individuals for whom the totals were the same, the 'lump sum' was deleted, and the annual doses were inserted.

- If the total was less than the 'lump sum', the annual doses were inserted, and the difference was retained in a single record representing the period from the earliest monitoring date to the end of 1976.

- If the total was greater than the 'lump sum,' the annual doses were inserted.

- If the 'lump sum' skin dose was different from the 'lump sum' deep dose, the skin dose record was retained and identified as representing the period from the earliest monitoring date to the end of 1976.

Since there was no way to discern the neutron dose, the neutron value in HIS20 was set to 'null' and the deep dose was applied to the gamma component.

The beginning and ending monitoring dates for the annual dose records were set to the hire date and to the termination date for the years in which those dates applied. All other years were set to January 1st and December 31st for the monitoring period. Altogether, a total of 55,288 annual exposure records for 7,840 individuals were loaded.

In addition, there were a number of records that were not migrated due to the absence of a social security number. It appeared that this data value was not available from an earlier radiological records system since it was linked to a human resources computer system that provided the demographic information. There were also individuals who were identified as missing completely from the database. This omission appeared to be related to individuals who had been hired and left the site before 1976. As was the case with the radiological database, the human resources systems had undergone similar migrations and modifications over time. One of the outcomes of this evolution was the removal of individual's records who were no longer employed and not receiving benefits. Fortunately, records were maintained by the human resource staff that contained the individuals who had been removed from their database system. From a search of this data, about 1200 additional individuals were identified by plant ID, name, and birth date and were incorporated into the HIS20 system.

Another significant modification to the HIS20 database was the incorporation of the Neutron Dose Reconstruction Project (NDRP) data from ORAU. This data consisted of neutron values for employees who worked in specific buildings between 1952 and 1970. Since the NDRP program did not always identify the original gamma dose, it was determined that only the difference in the original neutron dose and the recalculated neutron dose would be incorporated into HIS20. This data was included as an annual neutron dose value for each individual in the study. This dose value was also included as an increase to the skin exposure. There were a total of 23,386 NDRP neutron dose records for 5244 individuals.

Finally, modifications were made to the electronic record in HIS20 whenever discrepancies were discovered by the radiological health staff in an individual's health physics file. Periodically, requests for an employee's health physics file would be received for various reasons, including EEOICPA requests. It was the policy of the radiological health department to review the electronic record from HIS20 and compare it to the hardcopy health physics file. If, for example, there was still a lump sum for years prior to 1976, the staff would correct the data by including the annual exposure data from the annual exposure report(s).

The policy was to correct dates and exposure data as necessary. However, if there was exposure data in the electronic record that was not contained in the health physics file, that data would be retained with an explanation. (End: Ken Savitz; SEC-00030 Non-Submitter Communication, SECIS ID: 57)

HIS20 Internal Dosimetry Data

(Begin: E. W. Potter; SEC-00030 Non-Submitter Communication, SECIS ID: 58) The main sources of internal dosimetry data in the HIS20 database were:

- *Data transferred from the RHRS (Radiological Health Records System) database.* The RHRS database was populated from data in the Health Sciences Database (HSDB), which was the earliest-known electronic database system at the site. Most of this data was hand-entered from paper records. There was a documented verification of the data uploaded to RHRS. Lung count information was hand-entered into RHRS by internal dosimetry personnel. This generally only included the date and time of a count and some demographic data (height, weight, count type, etc.) but may not have included calculated activity, uncertainty, or decision level. The upload of the HSDB data resulted in duplicates, consisting of both an original result and a rounded result. The Health Physics Database (HPDB) came between HSDB and RHRS and this is the most likely origin of the duplicates that are referred to below came from; one from HSDB and one un-rounded result from HPDB. The rounded result was used to calculate the systemic burden prior to 1989.

  In the late 1990s, the obviously-rounded duplicates were removed using an algorithm. This left some less-obvious duplicates in the database. Some of the remaining duplicates were removed on a case-by-case basis, but some remain. Another known issue is that some of the data is marked with a "no calculation" code inappropriately. This code was used to indicate that the data value should not be used to recalculate the systemic burden. This is an artifact of removing duplicates in the data created by rounding during the systemic burden era. There is also data that was not intended to be used to calculate the systemic burden for other reasons that is similarly marked (e.g., DTPA-influenced results, invalid results). Potential intake events were also marked in the HSDB with a code that indicated the date the systemic burden calculation was to use as an intake date, and this date may not necessarily correspond to an actual urine result. Committed doses calculated from the systemic burden and lung burden data were uploaded from RHRS. As a result, many employees have large doses assigned to calendar year 1993, which are really from all intakes in prior years. Doses assigned after 1989 were individually calculated and hand-entered by internal dosimetry personnel either into RHRS or into HIS20 after its implementation.

- *Bioassay data transferred from the Building 123 Laboratory Information System (LIMS) used from about 1988 to 1997.* Before 1988 or so, the Building 123 laboratory used the Laboratory Information System (LIS). The data from this system was probably hand-entered, not transferred electronically. The dates for LIS are not certain. Originally, the bioassay data was collected in lab notebooks, etc., and transferred to cards that were maintained in the individual files. It is believed that nearly all of this data was also hand-entered into a database. During 1996-1998, an extensive effort was made to upload this data from the on-site bioassay laboratory (shut down in 1997) so that the LIMS could be retired. The data was checked by internal dosimetry personnel to ensure that it had uploaded properly.

- *Electronic data deliverables from off-site laboratories (mainly the IT/Quanterra/Severn-Trent lab in Richland, WA).* The site started using Quanterra for bioassay sample analysis around 1994 or 1995. Hard copy records were always furnished, and at some point, the site started to require electronic data deliverables that were supplied on diskettes. This resulted in a six-months to one-year gap in the electronic records. The Oak Ridge Lab was also used for a short while around 1994-1995; this data was not immediately uploaded. The data on the electronic data deliverable diskettes was eventually uploaded and verified by internal dosimetry personnel. The known gaps in the urine and fecal data are in the modern era when hard copies were sent to the individual dosimetry records. These records are available to dose reconstructors. In addition, these gaps occurred when more than one laboratory was analyzing the samples, so electronic bioassay results should be available for all periods for the purpose of co-worker studies.

- *Bioassay data obtained from General Engineering Laboratories, in Charleston, SC (also known initially as General Physics).* Starting around 1998-1999, this data was received electronically and routinely uploaded and verified by internal dosimetry personnel.

- *Data from the Building 122 lung counters (1995-2004) and the lung count trailer (2004-2005).* This data was transferred electronically by radiological health personnel. Even though both of the counters and HIS20 used Canberra Industries software, the transferred data generally only included the date, time, and type of count. It did not include details of the count (results, decision level, etc.) unless the result was "positive" (e.g., a peak of interest was identified). However, the results were stored in HIS20 with units of micro-Ci with four decimal places. There was generally verification that the upload had taken place and any upload errors (unknown identifiers, etc.) were corrected. (End: E. W. Potter; SEC-00030 Non-Submitter Communication, SECIS ID: 58)

7.1.1.2 Comprehensive Epidemiologic Data Resource (CEDR) Data:

Comprehensive Epidemiologic Data Resource (CEDR) is a working data file set prepared by the Los Alamos National Laboratory. The following description of the data set was pulled from CEDR. Note that details are provided for both external and internal data contained in CEDR. However, NIOSH is using external data from the HIS20 database instead of CEDR because HIS20 is a primary data source. Also note that the description refers to workers employed from 1951-1979; however, RFFACW02_BIOASSAY was updated on April 1, 2002, with data for additional years (up to 1988).

Description from CEDR:

This working data file set, prepared by the Los Alamos National Laboratory, Occupational Medicine Group, consists of six working files prepared for mortality studies of workers employed at the Rocky Flats Plant (RFP) during the years 1951-1979.

Data were obtained in various formats and media from Rocky Flats departments and other agencies. Demographic data were collected from two primary sources of records provided by the RFP Personnel Department. Supplemental data were obtained from RFP Health Physics records. Death information was abstracted from death certificates obtained from various states. External ionizing radiation exposure and plutonium bioassay data were provided by the RFP Health Physics Department. The external ionizing radiation data from hard copy records through 1978 were computerized by the Epidemiology Section at LANL.

The six files in the RFFACW02 data file set are segregated by type of data: demographic, external ionizing radiation exposure, and plutonium-239 bioassay results. Data pertaining to an individual that appear in one or more files may be linked by the individual identification number assigned to each worker.

Number of Data Files: 6
Cohort Size: 9537
Providing Organization: Los Alamos National Laboratory, Occupational Medicine Group, Epidemiology Section
Races: All
Sexes: Both
Diseases: All causes of death
Exposure Type: External ionizing radiation and internal
Exposure Agent: Whole-body doses and plutonium-239 and americium-241 and uranium
Methods: Film badges, thermoluminescent dosimeters (TLDs), urine bioassay, and mathematical calculation

1. *RFFACW02_PERSON:* This working file contains demographic information, including race, sex, birth date, limited work history information, and death information, such as cause-of-death, date of death, and state of death for 9,537 males and females hired between 1951 and February, 1979. The file includes 1,563 females, 7,973 males, and one with unknown sex. Race was determined for 99% of the workers. Death information was last obtained in 1992 from the National Death Index (NDI). Mortality data were available from the NDI from 1979 through 1990. Earlier death information was obtained from the Social Security Administration (SSA) and other sources, including the Colorado Department of Motor Vehicles and active tracing. There are 1,423 deaths identified in this working file. Cause-of-death information (ICDA8) is not available for six deaths.

This file also includes dosimetry data from 1981 that has been superseded by the data in the other four files in this working data file set.

2. *RFFACW02_ BIOASSAY:* This working file contains results of urine bioassay measurements for gross alpha, uranium, enriched uranium, depleted uranium, plutonium-239, and americium-241 through 1989. The file contains 300,261 records for contractor personnel and hires after 1979. Data include the date of the sample, type of analysis, activity of each isotope, and estimated body burdens for plutonium-239 and for americium-241. These data were not edited by LANL. [NOTE: The BIOASSAY file was entered into CEDR on Apr 21, 1994 and updated on April 1, 2002 with data for additional years (up to 1988)].

3. *RFFACW02_ RFEXTRAD:* This working file contains external ionizing radiation exposure data. There are 62,375 records for 9,015 workers for the years 1951 through 1978. The variables include year of monitoring, and annual whole-body penetrating dose (in millirems) incurred while working at RFP. These data have been edited extensively with the help of the RFP Health Physics staff.

4. *RFFACW02_ RFLTA:* This file contains values recorded at RFP for "lifetime accumulated other" external ionizing radiation exposure received from a facility other than the RFP. There are 9,015 readings for 9,015 individuals. These data were coded from hard copy records provided by RFP and are available for 1965 through 1978. These data have been edited with the help of the RFP staff.

5. *RFFACW02_ RFTLD:* This file contains 360,388 records of badge readings for external radiation for the last quarter of 1976 through 1989. In addition to records for RFP workers, readings are present for contractor employees and workers hired at RFP after 1979. These data were provided in computerized form by RFP in 1990 and have not been edited.

6. *RFFACW02_ RFWB:* This file contains americium and plutonium whole-body counts. The file contains 79,761 records for contract employees and workers hired after 1979. These data were never used by the LANL Epidemiology Section in any analyses, and no documentation exists at LANL as to the units or meaning of data in this file.

<u>BIOASSAY Urinalysis Data and RFWB Lung Data</u>

Urinalysis data for uranium and plutonium from 1952 to 1988 were extracted from a Microsoft Access table named RFFACW02_BIOASSAY. There were just over 300,000 records in the urinalysis database. Four cases had a date prior to 1952: one each in 1950 and 1951, and two that appeared to be date errors (years incorrectly entered as 1911 and 1923).

In most cases, both the uranium and plutonium results were recorded as dpm/24 hr. However, the depleted uranium units are date-dependent: through April, 1964, the units were μg/24 hr; from May 1964 to 1988, the units were dpm/24 hr. Micrograms of uranium were converted to dpm by a 0.89 multiplier determined from the isotopic abundances specified for depleted uranium in IMBA. Once converted to dpm, the uranium data were assumed to be entirely U-234.

All of the uranium and plutonium urinalysis results were recorded either as positive numbers or zeros. In general, a zero entry meant the result was less than some reporting level; however, after April 6, 1970, actual results were reported, even negative values, according to Technical Basis Document for the Rocky Flats Plant – Occupational Internal Dose. The RFP TBD for Occupational Internal Dose (ORAUT-TKBS-0011-5) states, "After April 6, 1970, all results >= 0.00 dpm/24-hr sample were reported. Negative results were reported as zero through 1989. After 1989, the actual negative value was reported." Zeroes were reported in 176,900 records, a little over half of the results for all measurements. The TBD states that uranium and plutonium urinalysis data with a "1" flag in the "nocalc" column of the database (about 2,500 records out of roughly 300,000) should be (and were) excluded from analysis because the data did not meet quality objectives.

In vivo Am-241 lung data from 1965 to 1988 were extracted from a Microsoft® Access table named RFFACW02_RFWB. There were just fewer than 80,000 Am-241 records in the lung database. From 1965 through 1971, all results (about 4,000) were reported as zero, with no explanation of what those values might have meant. Therefore, no analyses were performed on those data. Furthermore, ORAUT-TKBS-0011-5 mentions that the Am-241 activities were quantified only if a known plutonium incident occurred. However, the TBD also says that results were sometimes recorded (in counts per minute) when no known incident had occurred. Some results were also recorded in micrograms or nanocuries. After 1971, positive values began to appear but there still were no exclusion instructions for when 0 values were reported. (See the "nocalc" discussion above.) Therefore, 0 results were treated as zeroes because no better information was available. Calculations of the lung plutonium values recorded with the Am-241 lung data were determined by using the Am-241 data and an assumed concentration of 1000 ppm (by weight) of Am-241 in the plutonium.

In both the urinalysis and lung counting data sets, badge numbers (column "ID") are associated with most records. However, in the urinalysis data, 55,200 records had a "0" in the badge-number column. It was not determined what a "0" badge ID meant other than, perhaps, to identify unbadged personnel. For the urinalysis data, about 34,000 of the "0" badges were plutonium records, 15,000 were gross alpha ("A"), and 6,000 were "U". It was decided to treat "0" badge numbers as one individual when counting the number of unique individuals in any period. The "sdate" column provided the date of each analysis in YYMMDD order.

7.1.2 Credibility and Consistency of RFP Data

7.1.2.1 Credibility and Consistency of RFP External Dosimetry Data:

External dosimetry is available for most Rocky Flats workers. Although the petitioners have expressed concerns with the reliability of this data, to date no evidence other than numerous worker affidavits has been provided that would support these concerns. In response to a letter to the petitioner dated March 16, 2006, requesting reports or citations supporting allegations of fraud in recording and reporting worker dosimetry results, the petitioner directed NIOSH to Freedom of Information Officer Lisa Bressler. Ms. Bressler informed NIOSH that a search for "all abnormal dose records that have resulted in a criminal and/or internal investigation at the Rocky Flats Site for the past 50 years," as suggested by the petitioner, would take 2-4 months. Officer Bressler also directed us to a few other DOE and Kaiser-Hill personnel. NIOSH is currently continuing conversations with these additional personnel, but an early opinion offered is that they are not aware of any findings of criminal and or fraudulent activities regarding dosimetry records. (Lisa Bressler; SEC-00030 Non-Submitter Communication, SECIS ID: 59)

External dosimetry data from the HIS20 database were compared against the original hardcopy records for a number of individuals (approximately 25 worker-years worth of data so far). No evidence of systematic errors or significant differences between the electronic and hardcopy data was observed. The following observations were noted from this comparison: (1) there is substantial agreement between HIS20 and hardcopy (2) there is no evidence of systematic underestimation of dose by HIS20 (3) in the few instances where HIS20 and the hardcopy do not agree, HIS20 usually gives the slightly higher number. These comparisons support the use of data from HIS20 to generate external co-worker data for use in dose reconstructions of unmonitored individuals. The HIS20 database is a primary data source (individual dosimetry records maintained by the site), as compared to secondary data sources such as CEDR. There is generally less concern regarding the credibility of primary data sources, although an examination of the pedigree of secondary data sources can be helpful in establishing their credibility. The availability of individual external dosimetry data, both for a great majority of EEOICPA claimants, and for use in co-worker data to support dose reconstruction for unmonitored workers, leads NIOSH to conclude that sufficient data exists to reconstruct external doses for all members of the proposed class for 1952 to the present.

7.1.2.2 Credibility and Consistency of RFP Internal Dosimetry Data:

Two comparisons were made to establish the credibility and consistency of internal dosimetry data:

1. Data retrieved from the CEDR database were compared to the internal dosimetry data found in the HIS20 database. No evidence of systematic errors or significant differences between the two databases was observed.

2. HIS20 data was compared with original hardcopy records for a number of individuals. No evidence of systematic errors or significant differences between the HIS20 database and hardcopy data was observed.

These comparisons support the use of data from CEDR to generate external co-worker data for use in dose reconstructions of unmonitored individuals. The availability of individual dosimetry data both for a great majority of EEOICPA claimants, and for use in co-worker data to support dose reconstruction for unmonitored workers leads NIOSH to conclude that sufficient data exists to reconstruct external doses for all members of the proposed class for 1952 to the present.

7.1.3 RFP Data Sufficiency Conclusion:

NIOSH has investigated the pedigree of the external dosimetry data from the HIS20 database and performed comparisons between this data and original hardcopy records. Similarly, NIOSH also investigated the pedigree of internal dosimetry data found in the CEDR and HIS20 databases, compared the CEDR data to HIS20 data, and finally compared HIS20 data to original hardcopy records. No evidence of censoring or data manipulation that would cast doubt on the integrity of the data for use in dose reconstruction or in the generation of co-worker dose distributions was found.

7.2 Internal Radiation Doses at RFP

The principal source of internal radiation dose for members of the class was airborne releases of several primary plutonium isotopes found in weapons-grade plutonium—comprised of 99.6 weight percent of plutonium-239/240 and 0.36 weight percent of plutonium-241—for which the isotopic make-up is well known. The other radionuclides of concern (ROCs) for workers' internal dose were americium-241 and uranium in both depleted and enriched isotopic abundances. (ORAUT-TKBS-0011-5).

These radioactive materials could have become airborne as a result of: machining operations, chemical processing and recovery operations, re-suspension from contaminated surfaces, remediation activities, and most significantly, fires. The airborne source term could then be inhaled by individuals in the building work areas and a fraction deposited in the respiratory tract with varying systemic transport. Furthermore, inhalation of material was possible within the site environs outside of the various buildings due to: routine releases of radioactive materials through building ventilation stacks; releases resulting from non-routine incidents; and re-suspension of contaminated soils (ORAUT-TKBS-0011-4). Other modes of uptake in addition to inhalation of airborne material were: transport of contamination directly to the bloodstream via a wound; or ingestion into the body by transfer from contaminated surfaces via hand to mouth.

The site employed a variety of personnel protective and engineering controls to minimize worker exposure. These controls included: protective clothing; respiratory protection for workers with the potential for exposure using supplied air, full- or half-mask respirators; building ventilation systems; glove boxes; contamination self-monitoring stations; and hooded machining areas (Putzier, 1982). However, both chronic and acute uptakes did occur over the history of operations. Most uptakes would have been chronic in nature with acute uptakes due to non-routine episodic events, such as the fires or other incidents. The workers known to have been involved in an incident where an acute uptake could have occurred should have site records available documenting their involvement in the occurrence/incident. Otherwise, individual monitoring records can be evaluated for trends indicative of an acute intake and coupled with site documentation/records and/or co-worker data to evaluate the potential exposures.

Review of RFP processes and operations indicates that the ROCs would have been present in a number of physical and chemical forms. In conjunction with the form and/or operation, the solubility of the ROCs encountered by the workers, and ultimately the estimated dose to the organ of concern, would vary from somewhat soluble to highly insoluble. The plutonium compounds in most metal-working operations were insoluble (Type S). An exception to this solubility classification for plutonium metal was if the metal was associated with a solvent, and therefore, more soluble (Type M). In the case of the larger fires that occurred in Buildings 771 and 776/777, and other events both at Rocky Flats and other plutonium facilities, it was determined that the plutonium, in an oxide form as a result of fires, exhibited higher lung retention than what was predicted by accepted dosimetry models (Mann, 1967). Therefore, plutonium in this form is considered highly insoluble (Type Super S). This condition may also exist for other small fires that occurred at the site. Plutonium in the chemical processing operations could have been either Type M or S or a combination of the two, depending on the specific process. The particle size assumed for a given uptake will also impact the assigned dose to the organ(s) of interest, with particle size impacting regional respiratory tract deposition, and ultimately, systemic transfer. The specific particle sizes and distributions of airborne materials may not be known for all situations. However, adequate technical bases exist for bounding particle size relative to the respirable fraction, and associated solubilities are available from ICRP publications and published scientific studies for deriving claimant-favorable assumptions during dose reconstructions (see Section 6.5).

Related to the weapons-grade plutonium was the presence of americium-241—the immediate progeny of plutonium-241—resulting as a purified by-product following plutonium recovery, or as a result of in-growth as the plutonium metal matrix aged. The solubility type of the recovered, purified americium-241 is considered to be Type M, as documented in ICRP 68. When incorporated as part of the plutonium metal matrix, the solubility class and particle size assigned would correspond with that of the accompanying plutonium with consideration of an initial more-rapid clearance of a more-soluble component of Am-241 relative to the overall intake composition (PNNL-MA-860).

At the onset of site operations, uranium was the primary ROC until the mid- to late-1950s as uranium operations declined and plutonium operations continued to increase (ORAUT-TKBS-0011-2). Uranium compounds were present in enriched (EU) and depleted (DU) isotopic abundances. Uranium work included casting, machining, and recovery in specific buildings; some of which were further subdivided for work with DU or EU, respectively. In the 1980s, there was extensive DU work in the making of tank armor and armor-piercing munitions tips. The solubility of uranium is also dependent on its physical or chemical form, ranging from Type F to Type S. Specific information on the uranium compounds present when intakes may have occurred is incomplete as is information on uranium particle sizes. However, claimant-favorable assumptions regarding solubility type may be derived during dose reconstructions, similar to those for plutonium (see Section 6.5).

Lastly, there have been a number of special projects involving small quantities of other radionuclides. Small quantities of thorium-232 were used in the fabrication of metal parts as early as 1952, as mold-coating compounds, and in analytical procedures. Thorium-228 was noted as being removed from uranium-233 metal in thorium "strikes" during the mid- to late-1960s. Limited amounts of neptunium-237, curium-244, americium-241, and plutonium-238 were employed as tracers into the make-up of Special Order pits to assist research taking place at other facilities, for plutonium-238 as Zero Power Reactor fuel elements, and extraction of americium-241 for special applications. None of these other radionuclides were present at Rocky Flats in high enough quantities to contribute significantly to internal dose potential.

7.2.1 Process-related Internal Doses at RFP

The following subsections summarize the extent and limitations of information available for reconstructing the process-related internal doses of members of the proposed class.

7.2.1.1 Urinalysis Information and Available Data

Rocky Flats began routine *in vitro* urinalysis at the onset of site operations in 1952 for workers with the potential for intakes of radioactive material (Putzier, 1982; ORAUT-TKBS-0011-2). The urinalysis program methodologies were continuously evolving over the course of the plant's history (ORAUT-TKBS-0011-5). In addition to improvements in the methods for separating interfering ROCs, the methodology changes allowed for quantification of individual isotopes—beginning in 1973 and fully-implemented by 1978—and improved the minimum detectable activities (MDAs). The RFP relied almost exclusively on urinalysis to monitor its workers' exposures through 1964. After 1964, urinalysis was combined with lung counting to monitor intakes (see Section 7.2.1.2).

Urinalysis for each worker was scheduled either routinely or as a specific request following a suspected or actual intake. The urinalysis sample extraction procedure used depended on where the employee worked. The samples were chemically extracted for the specific ROCs and precipitated for counting. Prior to the refinement of the chemistry procedures and the addition of counting systems that enabled separation of the various alpha energies to quantify individual isotopes, a number of interferences were noted. Additionally, if an employee worked in both plutonium and uranium areas, or one of the Special Project areas during a given monitoring period, a non-specific gross alpha analysis was performed. The activity was then assigned as either enriched uranium through 1963 or as plutonium after this period until the gross alpha method was discontinued (about 1973). Results of analyses for each worker were recorded on a Urinalysis Record Card through 1969, after which a database system was put in place, the Health Sciences Data System – Urinalysis Detail Report. An assigned systemic body burden was then calculated from the data.

Urinalyses were also performed in cases where workers had the potential for exposure to tritium. The TBD states that the specific tritium urinalysis methodology has not been reviewed but that the method probably involved liquid scintillation counting of samples (ORAUT-TKBS-0011-5). The actual bioassay result and an uncertainty value were reported for each monitored worker. The MDA of the procedure also has not been calculated for the period from when tritium bioassay began in the 1970s through the 1980s. However, the procedures for recovering tritium from a liquid sample and counting the sample are well known, as are the accompanying MDAs, which can be conservatively estimated if needed for dose reconstruction.

NIOSH has access to more than 300,000 urinalysis results for the period from 1952 to 1989. The records during the decommissioning phase are also available. The internal dosimetry program in place during the decommissioning phase ensured that all employees who were trained as Radiological Workers and who accessed contamination areas participated in the routine bioassay program (RFETS, 2003). The records available will enable dose reconstruction for the monitored workers. Distributions of these data may also be applied as co-worker data for unmonitored workers when appropriate. Specific considerations for dose reconstruction using bioassay data are provided in project Technical Basis Documents and Technical Information Bulletins and include provisions for issues related to varying MDAs, reporting of values that were less than the MDA, uncertainties, possible interferences from other radionuclides in the chemical extraction procedure, and non-radionuclide-specific analyses.

A Technical Information Bulletin is under development that will provide for application of these data as co-worker data for determining the best estimate of intakes for unmonitored workers and for accounting for potential missed doses (ORAU-OTIB-0038 draft). Another Technical Information Bulletin under development and concerning the use of urinalysis data addresses the reconstruction of dose for workers who may have had an intake of Type Super S plutonium oxide prior to the implementation of lung counting in 1964 (ORAU-OTIB-0049 draft). This is an issue because the material (due to its insolubility) would exhibit higher lung retention than solubility class S. Thus, this material may not have been excreted at concentrations greater than the MDA. Therefore, the activity deposited in the lung and the corresponding dose would be underestimated if solubility type S is assumed to calculate intakes. The dose reconstruction can account for a potential Type Super S material intake by using empirically- and analytically-observed parameter values in the ICRP 66 lung model, and can account for missed dose, as discussed in Section 7.2.

7.2.1.2 Lung Counting Information and Available Data

In 1964, the site implemented lung counting using gamma spectroscopy for workers with the potential for intakes of plutonium. Lung counting allows for increased precision in estimating the quantities of inhaled intakes. The procedures and detection equipment used improved over time. These improvements resulted in lower MDAs and improved resolution of photopeaks used in the quantification process. These improvements further led to the site's ability to perform lung counting specifically for depleted uranium quantification beginning in 1978. (Putzier, 1982).

The basis for quantifying plutonium lung depositions using gamma spectroscopy relied on measurements of Am-241, the direct progeny of Pu-241. Results would then be quantified and converted to a percent of the maximum permissible body burden only after confirmation that the counts observed were the result of a lung deposition. There were a number of assumptions that were required in the original site's calculation that also impact contemporary dose reconstruction. The assumptions include the initial fraction of Pu-241 in the Rocky Flats plutonium isotopic mixture at the time of the intake, the initial Am-241 concentration at the time of intake, and estimation of the intake date if the lung count was not the result of a specific, known event. Interferences for quantifying plutonium lung deposition that would, in most instances, result in an overestimate of the intake were: intakes of uranium prior to improvements in resolution of the gamma spectroscopy system; skin contamination or plutonium intakes that were not associated with the lung deposition; and build-up of plutonium within the skeletal system. A specific issue raised by the SEC-00030 petition involves measurements of intakes of Type Super S plutonium. The Type Super S designation relates to the chemical compound's solubility classification and would not degrade the measurement capability via gamma spectroscopy.

Lung counting for DU began in 1978 for special cases in which lung deposition was suspected; such evaluations became routine beginning in 1983. The method involved measuring one of the short-lived, immediate progeny of uranium-238, thorium-234, with secular equilibrium assumed. The counting data would then be converted to an activity either in special cases or once the detection of thorium-234 was confirmed by a secondary photopeak. As the measurement systems improved, reporting of the lung count data for DU became routine. Beginning in 1995, the conversion to activity was automatically performed. Interferences in the DU lung count data should only be from natural, environmental uranium-238. Methods for discerning natural from occupational uranium deposition are provided in the TBD.

There are approximately 80,000 lung count records available for use in reconstructing doses through 1989. The numbers of records available post-1989 have not been tallied at the time of this report. These records will be useful to support reconstructions using the bioassay records and also as complementary data for dose reconstructions for workers employed after 1964 who may have had intakes of Type Super S plutonium. A review of lung count procedures is provided in the Rocky Flats Occupational Internal Dose TBD (ORAUT-TKBS-0011-5). Gamma spectroscopy calibrations will normally account for effects from geometry, source-to-detector distance, and attenuation. As discussed earlier in this section, the gamma spectroscopy system, calibration, and counting procedures evolved over time.

7.2.1.3 Application of Co-Worker Data for Internal Dose Reconstruction

From the onset of operations, the RFP's monitoring program ensured that those workers who could potentially receive intakes had routine bioassays for evaluating possible internal exposures. Non-routine monitoring was also performed when an intake was suspected as a result of discrete events. This monitoring has resulted in a database with over 300,000 urinalysis and 80,000 lung count records covering the period from 1952 until 1989. During the more recent decommissioning phase of the site, urinalysis, lung counting, and fecal monitoring records are available. Site air monitoring records are also available.

These data have been evaluated and intake models have been developed. These models, coupled with claimant-favorable inputs, may be used to reconstruct doses for unmonitored workers or to fill data gaps where records may have been lost, incorrectly recorded, or where assigned doses may have been underestimated. Section 7.2.3 provides further detail.

The application of co-worker bioassay and *in-vivo* data is used to assign intakes of radionuclides for the purpose of assigning doses to workers who were either unmonitored and should have been, or for partially monitored workers. Analyses of coworker internal dosimetry data, including the results and deviations from the process, are documented in a site-specific TIB or a site profile.

In general, participation in a bioassay program involves workers who have the largest potential for exposure. While there are exceptions to this generality, such as accidents involving unmonitored workers, it is unlikely that an unmonitored worker would have received a larger dose than the most highly-exposed monitored worker at a site. Statistical methods used to calculate co-worker intake values assume that bioassay results for groups of workers have a lognormal distribution.

To determine co-worker intake rate values from bioassay, the 50th-percentile (median) and 84th-percentile bioassay results are calculated for specific periods from the available data. The R^2 fit parameter is also calculated as an indicator of reasonableness-of-fit for each distribution of bioassay results. Co-worker intake rates are determined from the resultant two data sets, and the geometric standard deviation (GSD) of the coworker intake distribution is calculated by dividing the 84th-percentile intake(s) and/or intake rate(s) by the 50th-percentile intake rate(s).

This statistical method eliminates the need to define the minimum detectable activity or amount (MDA) for uncensored data sets (that is, data sets that include all values regardless of statistical significance). Where the data sets are censored, there may be insufficient information for performing a fit to obtain the 50th- and 84th-percentile values. These censored data often are recorded as zeroes, numbers preceded by a less-than symbol (<), or as a code such as "ND." In such cases, a method for substituting a range of values for that censored data may be used if the reporting level or cutoff value is specified or can be determined. This method is only to be used for cases where the fitting of the positive data yields unsatisfactory results. If the reporting level cannot be determined, the data may need to be used without modification. In some cases, such as when monitored individuals typically had a measurable body burden from natural or manmade sources, substituting a range of values below the reporting level could be inappropriate.

7.2.2 Ambient Environmental Internal Radiation Doses at RFP

Ambient environmental internal exposures due to inhalation of radioactive materials resulting from routine releases of radioactive materials through building ventilation stacks, non-routine incidents, and re-suspension of contaminated soils could contribute to internal radiation dose. Such exposures could have impacted both monitored and unmonitored workers.

The following subsections summarize the extent and limitations of information available for reconstructing the ambient environmental-related internal doses of members of the proposed class.

7.2.2.1 Ambient Environmental Internal Dose: Monitored Workers

In the case of exposure assessments for monitored individuals, any ambient environmental exposures will be accounted for in the assignment of the process-related dose (based on individual monitoring data or the assignment dose from co-worker data). Therefore, no additional dose from ambient environmental internal exposures would be assigned unless: (1) the ambient environmental dose is assigned (in addition to process-related dose) to ensure claimant-favorability in the dose reconstruction; or (2) the ambient environmental dose is representative of the internal exposures for those individuals (assigned as the process-related dose for a monitored individual with no, or low, potential for internal exposures).

7.2.2.2 Ambient Environmental Internal Dose: Unmonitored Workers

Ambient environmental exposure would have been the primary internal exposure pathway for the unmonitored worker. The Occupational Environmental Dose TBD (ORAUT-TKBS-0011-4) provides methods for estimating potential intakes using the air monitoring data discussed above. For the period 1952 until 1964, the TBD relies on the air concentrations calculated through atmospheric dispersion modeling conducted for the Phase II study for estimating annual intakes; for later years, it uses measured concentrations from site air samplers. Although site air samplers continued to be monitored through the site decommissioning phase, the TBD recommends using the highest concentrations observed during the prior 20-year period as a claimant-favorable assumption. Other claimant-favorable assumptions can be made for particle size, breathing rates, exposure time, respirable fraction, solubility classes, and for accounting for variations for certain parameters that can be applied for site workers employed during events such as the large fires and other known releases.

7.2.3 Internal Dose Reconstruction

There are numerous scenarios involved with the SEC-00030 petition that must be independently evaluated prior to determining if the internal dose for each scenario can be reconstructed using claimant-favorable assumptions. These scenarios are a result of the broad historical timeframe of the site, the multiple monitoring programs in place over the site's history, the presence of multiple ROCs, and varying forms of the ROCs. Table 7-1 provides 16 combinations of worker categories and ROCs. The demarcation of 1964 was selected because it coincides with the advent of the lung counter. Up to 1964, the primary data for dose reconstruction will be urinalysis data, after which the urinalysis data may be analyzed together with the lung counting data.

NOTE: The determination whether claimant-favorable overestimates of potential internal dose can be performed for each worker category/ROC combination is discussed in turn. In the discussions below, the numbers to the left refer to the corresponding scenario number in the Table 7-1 cells.

Table 7-1: RFP Internal Dose Scenarios by Worker Category and ROCs
(Scenarios are numbered 1-16)

Worker Category	**Internal Dose Radionuclides of Concern (ROCs)**			
	Uranium	**Plutonium**	**Uranium plus Plutonium**	**Miscellaneous Transuranics/Thorium/ Tritium**
Monitored / Terminated Pre-1964	1	2	3	4
Unmonitored / Terminated Pre-1964	5	6	7	8
Monitored / Employed through or after 1964	9	10	11	12
Unmonitored / Employed through or after 1964	13	14	15	16

Monitored/Terminated Pre-1964

1) Uranium was the primary ROC during the early years of RFP production activities, with enriched uranium predominating. As plutonium was phased in, the uranium and plutonium production areas were separated and, in most cases, employees worked within a specific facility for security reasons. From the onset of site operations, uranium workers were monitored for internal intakes via urinalysis. Although bioassays were intended to monitor for occupational exposure, any environmental intakes would also contribute to, and therefore be accounted for, in the bioassay result. The urinalysis records, most of which reported gross activity during this time period, provide the necessary data for reconstructing the uranium internal dose of the monitored worker using the current dose reconstruction models.

Claimant-favorable assumptions can be made regarding uranium isotopic abundances, solubility class (Type F, M, and S), and default particle size distribution of 5 μm AMAD (in the absence of documentation of another specific applicable value) in order to maximize the dose to the organ(s) of concern. Missed dose to a monitored worker may have resulted if a zero or less-than-MDA value was assigned for a specific urinalysis, if a dosimetry record was missing, or if there were gaps in routine monitoring of an individual worker who was normally monitored. Missed dose may be accounted for during reconstruction in several ways. For cases where the urinalysis record lists a zero or less-than-MDA value, a conservative intake may be input that corresponds to the MDA for an overestimate, or more realistically, at a fraction of the MDA. Otherwise, a co-worker data distribution from the specific time period corresponding to a missed dose period may also be applied. (ORAUT-TKBS-0011-5)

2) The early plutonium production workers were also monitored for intakes via urinalysis. These records, combined with claimant-favorable assumptions, enable dose reconstruction. As discussed for uranium, early urinalysis analytical processes recorded results as gross activity concentrations rather than radionuclide-specific results. A worker's building assignment(s) history, when available in records, may be used during dose reconstruction to discern whether the gross alpha activity result may be input solely as plutonium isotopes. Without specific worksite history, it would be claimant-favorable to assume plutonium activity due to the greater inhalation dose conversion factor. Positive urinalysis results (i.e., greater than the MDA) may be modeled using claimant-favorable solubility characteristics to calculate the intake and resultant dose.

Most published research findings have shown that intake models using urinalysis data overestimated the intakes measured post-mortem. The exception was the determination that the retention time and deposition fraction of Type Super S plutonium in the pulmonary region of the lung exceeded the model predictions as a result of reduced solubility. As a result, the reliance solely on urinalysis data and biokinetic models without accounting for the Type Super S characteristics could result in significant missed dose if an intake of Type Super S was suspected due to a worker's involvement in an incident. Therefore, additional considerations are necessary to reconstruct doses involving the respiratory tract. A Technical Information Bulletin is currently being prepared that evaluates the *in vivo* and urinalysis data for a number of well-documented cases involving intakes of Type Super S plutonium (ORAUT-OTIB-0049 draft). These data were used to develop claimant-favorable lung dose adjustment factors that will be applied to the dose calculated from the standard model using the Type S parameters. Alternatively, the dose may be reconstructed using the claimant-favorable assumptions discussed in the Occupational Internal Dose TBD. Supplementary records to support reconstruction for monitored workers may include fecal sampling records, wound monitoring records, and occupational/environmental air monitoring records.

Dose contributions from the in-growth of Am-241 may also be required. The two primary factors to consider are the weight percent of Am-241 present in the plutonium at the time of intake and the solubility characteristics. The additional in-growth of Am-241 is readily accounted for based on an assumed or known intake time. In general, the americium is considered to share the solubility characteristics of plutonium. Claimant-favorable assumptions regarding the weight percent of Am-241 present at the time of the intake may be input (ORAUT-TKBS-0011-5). The Occupational Internal Dose TBD provides the approaches necessary for accounting for these multiple variables during dose reconstruction for inhalation exposure and internal exposures from wounds (ORAU-OTIB-0049).

3) Some monitored workers may have been exposed to both uranium (enriched uranium during the early site years) and plutonium, either occupationally or from environmental exposures. The site's urinalysis method reported gross alpha activity during the earlier years, as previously discussed. The records reported activity as enriched uranium until 1963 and plutonium after then. However, if a worker's building assignment work history records are incomplete or indicate work was performed in both plutonium and uranium facilities, uncertainties in radionuclide intake assignment may be addressed by performing the dose reconstruction as either a uranium or plutonium intake, or a mixture thereof, and selecting the most claimant-favorable assumption to estimate or maximize the dose. Other dose-maximizing assumptions may also be applied regarding solubility type and missed dose. (ORAUT-TKBS-0011-5 and ORAUT-OTIB-0049 draft)

4) Some workers may have been exposed to de minimis levels of contaminants in recycled uranium. Of these, only thorium is listed in the site history documentation for this time period. The inventory quantities were small relative to plutonium and uranium so that they were considered insignificant from a monitoring standpoint. Intakes that may have occurred would have contributed to the gross alpha urinalysis result, and hence, would be captured in the dose reconstruction, although these small exposures are unlikely to have a major impact on the dose. For workers whose records suggest such an intake, the urinalysis gross activity results would be modeled as a thorium intake to ensure claimant-favorability and to ensure all potential dose was accounted for in the individual dose reconstruction. (ORAUT-TKBS-0011-5)

<u>Un-monitored/Terminated Pre-1964; Uranium and/or Plutonium</u>

5–7) Workers whose job responsibilities had low potential for exposure may not have been monitored routinely, or at all, depending on the period and policy in place. However, intakes could have occurred from site incidents, environmental exposure, or non-production work assignments in production facilities. Internal dose reconstruction for workers without monitoring data applies to the air concentration modeling data that has been developed to account for environmental intakes. These models also include provisions for increased annual intake resulting from the 1957 fire. A model was developed for the pre-1964 air concentrations rather than using actual air monitoring results because of the limited availability of usable, actual air-concentration data. Internal dose reconstruction methods for monitored workers will be applied using co-worker data for individuals who were not monitored but should have been based on their job assignments and duties (i.e., who have missing or unavailable internal monitoring data). The dose reconstruction methods and data to be applied in these cases are specified in (ORAUT-TKBS-0011-4, ORAUT-TKBS-0011-5, ORAUT-OTIB-0038 draft, and ORAUT-OTIB-0049 draft)

8) As with the monitored workers described in Scenario 4 above, thorium was the only additional ROC present at the site prior to 1964. However, the small quantities present at the site would not be major contributors to a worker's dose. Co-worker gross alpha data could be assigned with a thorium intake percent fraction ranging from 0 to 100% to ensure claimant-favorability and to ensure that all potential dose was accounted for in the individual dose reconstruction if there is information in a claim indicating a potential intake. (ORAUT-TKBS-0011-5)

Monitored/Employed through or after 1964

9-11) Post-1964 workers were monitored via urinalysis, lung counting, wound counting and, during the latter years, by fecal sample if an intake was suspected. Plutonium was the dominant ROC after 1964, with uranium again present during the 1980s. Urinalysis remained the primary routine bioassay monitoring method and these data are available. The urinalysis data, combined with the other monitoring data and claimant-favorable assumptions, allow completion of maximizing dose reconstructions. Claims involving pre-1973 records, which preceded radionuclide-specific urinalysis, will require claimant-favorable assumptions regarding radionuclide intake in the event there is no documentation of work areas, lung/wound count records, or documentation of involvement in an event with a specified ROC. However, in most cases, any intakes would likely be the result of plutonium. After 1973, radionuclide-specific analyses would eliminate the need to assume the ROC. Post-1973 records will also include the period when uranium work was reintroduced at the site.

Dose reconstructions involving a possible intake of Type Super S may be evaluated by comparing urinalysis and lung count records. Cases without accompanying lung count data can be evaluated and the doses reconstructed using the urinalysis records and claimant-favorable assumptions as described in Scenario 2. Lung count data will also assist reconstructions for workers who may have been exposed to uranium because, beginning in 1978, measurement system capability allowed for quantification of uranium lung burdens.

Monitored worker missed dose may readily be factored into the reconstruction by assigning intakes corresponding to the respective MDAs (or a fraction thereof, as detailed in TBDs), together with other claimant-favorable assumptions, for those periods when a urinalysis record or lung count does not have a positive result. Additionally, co-worker data may be applied for monitoring record data gaps. (ORAUT-TKBS-0011-5 and ORAUT-OTIB-0049 draft)

12-16) Workers involved with the Special Projects may have records providing specific bioassay results for H-3 or the miscellaneous alpha emitters (Th-232/228, Np-237, Pu-238, Am-241, and Cm-244, as applicable), or alternatively, gross activity results. Even if there was some potential for exposure to the very low levels of these contaminants in recycled uranium, the assumption that gross alpha results reflect Pu-239/240 is claimant-favorable. (ORAUT-TKBS-0011-4, ORAUT-TKBS-0011-5, ORAUT-OTIB-0038 draft, and ORAUT-OTIB-0049 draft)

Unmonitored/Employed through or after 1964

13-16) Reconstruction of the unmonitored radiological workers is feasible using a number of available data sources. The primary data source will be co-worker data from routine urinalysis and lung counting. Because these data represent those individuals with the greatest potential for exposure, they will provide claimant-favorable input values for unmonitored workers. Application of the data assumptions during dose reconstructions relative to a specific ROC and its chemical and physical characteristics can follow the same premises used for monitored workers. Co-worker data may be further supplemented for environmental exposure using the developed air-concentration models and available air monitoring that has been analyzed and plotted over time (taking into account incidents that have contributed to increased air concentration during specified periods). Environmental data are available for assigning assumed intakes for those workers whose job assignments did not involve activities within controlled areas. These data evaluations and models are provided in ORAUT-TKBS-0011-4, ORAUT-TKBS-0011-5, ORAUT-OTIB-0038 draft, and ORAUT-OTIB-0049 draft.

7.2.4 Feasibility Conclusion for Estimating Internal Doses

NIOSH has established that it has access to sufficient information to either: (1) estimate the maximum internal radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the internal radiation doses to members of the class more precisely than a maximum dose estimate.

7.3 External Radiation Doses at RFP

Work operations at Rocky Flats were separated into two primary radiation environments: plutonium and non-plutonium processing areas. In the early years, workers were separated in their work by security restrictions. Later, they were separated in their work by work assignment. Few workers alternated routinely between the work environments. Some maintenance and support personnel (i.e., radiation monitors) did alternate between the primary radiation environments, but they routinely received low dose.

In both radiation environments, radioactive sources were also used for instrument calibration, waste assay, radiography, and other functions. These sources included Cs-137, Sr-90, Co-60, and Cr-252. Exposure contribution from these sources was limited due to their low activity or enclosure in a shielding device.

7.3.1 Process-related External Radiation Doses at RFP

The following subsections summarize the extent and limitations of information available for reconstructing the process-related external doses of members of the proposed class.

<u>7.3.1.1 Radiation Exposure Environment</u>

In the plutonium processing areas, the primary sources for external radiation exposure were low-energy photons from plutonium and Am-241, a progeny of the Pu-241 present in weapons-grade plutonium (WGPu). Also present were neutrons from spontaneous fission of even isotopes of plutonium, alpha-neutron reactions, and (not many) neutron-induced fissions.

In the non-plutonium processing areas, the primary concern for external radiation exposure was due to high-energy beta emitters from uranium progeny and impurities. During processes such as melting and casting, these daughter elements may concentrate on the surface of the castings and equipment, producing elevated beta dose rates. Photon doses from uranium were typically a small fraction of the beta doses; however, storage of large amounts of uranium can create low-level gamma radiation fields. (DOE-STD-1128-98)

Beta and Photon Characterization

Plutonium produces very few highly-penetrating gamma rays because they occur at such a low emission probability. Most photons from plutonium are from low-energy X-rays that are easily shielded. The primary source of external photon exposure is the decay of Am-241, which produces a 60 keV photon with 37% probability of emission per alpha disintegration. Am-241 is the beta decay progeny of Pu-241, which is present in WGPu. The Am-241 in-growth in the plutonium increases with time, and hence, increasingly contributes its higher energy photon component to the total exposure. The Pu-241 decay beta is of low energy (0.022 MeV) and is completely shielded by thin rubber gloves and various other materials. (DOE-STD-1128-98)

The gamma spectrum to which RFP workers were exposed has been reconstructed by considering the decay characteristics for concentrations of weapons-grade plutonium, enriched uranium, and depleted uranium (ORAUT-TKBS-0011-6). For the reconstruction, these radionuclides were all considered to be freshly-separated materials decayed for 10 and 30 years, respectively. Those decay times provided an understanding of the material to which workers were potentially exposed. Plutonium was almost exclusively handled in glove boxes, which provided shielding from the materials. Depleted and enriched uranium were routinely handled in the open with no shielding. The field calculations performed in the study assumed large pieces of material (infinitely thick with respect to the photon path length in that material) and 1/16-inch stainless steel as the shielding provided by the glovebox. (Typically, shielding of 1/8-inch was used, which makes the 1/16-inch assumption claimant-favorable.) Plutonium processed at the RFP varied in age from freshly-separated material to wastes stored on site for many years.

Pa-234m is a decay product in the U-238 (depleted uranium) decay chain and emits a 2.29 MeV beta particle. A significant amount of photons resulting from Bremsstrahlung radiation are produced, which contribute photons of intermediate energy (30 - 250 KeV). Bremsstrahlung radiation can contribute up to 40% of the photon dose from uranium metal. This decay product grows-in rather rapidly and was present in equilibrium quantities for most of depleted uranium processed at the RFP. It can therefore be assumed that 50% of the dose is contributed by photons in the 30 - 250 KeV photon energy range, and 50% by photons in the >250 KeV photon energy range for depleted uranium.

The beta spectrum from uranium is highly dependent on the quantity of daughter products in the uranium which, in turn, depends on the enrichment level of the uranium. Daughter products from depleted uranium grow into secular equilibrium relatively quickly (~30 days) and can be conservatively assumed to be present at these levels. The assumption of equilibrium of Th-234 with U-238 for lung count measurements is reasonable for most inhalation situations involving depleted uranium because the most likely source of airborne uranium is air-oxidized uranium, which implies an aging process. Even after a thorium strike, 50% equilibrium is achieved after 24 days and 90% after 80 days.

Enriched uranium has much less in-growth of Pa-234m, but U-235 and its decay products emit a 185.7 KeV photon 57% of time and a 143.8 KeV photon 11% of the time. These two photons dominate the measured photon energy spectra. It is appropriate to assume that the entire photon dose from enriched uranium is a result of exposure in the 30 - 250 keV photon energy range. For enriched uranium, the reconstruction assumed that all photon doses were a result of exposure to the 30 - 250 keV photon energy range, which provides an overestimate for external dose reconstruction.

Neutron Field Characterization

Neutron exposures become significant in any process involving kilogram quantities of plutonium. Experience has shown that alpha-neutron reactions and spontaneous fission are the only important sources of neutrons. Because of strict criticality controls, most forms of plutonium have very little neutron-induced multiplication. Induced fission seems to be a problem only in metal (1 kg or more) or in very large, high-density arrays of plutonium oxide with an additional moderator. Plutonium compounds created during the plutonium manufacturing process (e.g., PuF_4 and PuO_2) can produce measurable neutron dose rates through alpha-neutron reactions with fluorine and oxygen. Fluorinator glove boxes typically have the highest neutron dose rates in a plutonium processing line. Neutron fields varied from rather unmoderated Pu containing a high-energy component to any level of moderation. Most neutrons produced by plutonium have energies less than 20 MeV, with the majority of energies being less than 5 MeV. (DOE-STD-1128-98)

With assistance from researchers from Pacific Northwest National Laboratory (PNNL), health physics staff performed neutron dose assessments at the RFP in 1988. The results are expected to be applicable prior to 1988 given the materials routinely used and processed at the RFP. These 1988 assessments used multi-sphere neutron measurements in representative high-neutron dose situations. The neutron dose measurements were taken at production locations with mock-ups in which plutonium parts were in a glovebox where measurements could be performed, and also at waste storage locations (Brackenbush, 1989).

The neutron energy spectrum for PuF_4 produces an average energy of about 1.1 MeV. The neutron energy spectrum for plutonium–aluminum alloy produces an average energy between 1.5 and 2 MeV. The average energy for PuO_2 produces a continuum from 1 MeV to 2.5 MeV. Maximum neutron energies observed from plutonium-beryllium mixtures were around 12 MeV.

With neutron shielding in place similar to that experienced by workers in that area, measurements lasting several days were required to acquire a dose sufficient for accurate results. The neutron spectra were determined from the multi-sphere measurements and presented in the PNNL report. (Brackenbush, 1989).

7.3.1.2 History of Whole Body External Monitoring

In 1951, the RFP collaborated with Oak Ridge National Laboratory (ORNL) to implement their dosimetry program. The RFP began monitoring personnel for external radiation exposure in 1952, beginning with the operating group in Building 991. At the time, Building 991 was the only building on site in operation. (Putzier, 1982)

The RFP dosimeter was similar to a design being used at ORNL and Los Alamos Laboratories. It consisted of a stainless-steel holder with two open windows. The larger window was shielded on the inside of the holder by cadmium with dimensions of about 1x27x33 mm. The bottom window was unshielded. The back of the holder was also shielded by 1 mm of cadmium. This first dosimeter contained X-ray film sensitive to beta and gamma emissions. This dosimeter was capable of monitoring exposure to Am-241 (with the 60 keV photon) which was prevalent even in early operations. The film was developed using standard hand-dip darkroom techniques (i.e., developer, rinse, fixer, and drying) specific for the brand of film in use. The densities of the various sectors (areas of film under different filters) were measured with the densitometer instrument. This dosimeter had no designed filter for beta. From inception until May, 1953, the beta-gamma film elements were processed by Los Alamos Laboratories. The RFP assumed processing of the dosimeters in June, 1954. (Putzier, 1982)

This first dosimeter also contained an element sensitive to neutrons. This element, known as a neutron track plate, was a piece of glass about 2.5 cm square. The glass was coated with an emulsion on one side. The neutron track plates were interpreted by using a microscope to measure track lengths. The neutron track plates were interpreted by Los Alamos Laboratories until 1956. In 1956, the RFP introduced a new neutron element and contracted with Health Physics Services to process the neutron and beta-gamma elements. The new neutron element was referred to as NTA film. Health Physics Services processed the dosimeter for two years while the RFP started their own in-house processing (using about 10 workers in Building 771 as a pilot). By 1958, the RFP was processing all of their dosimeters. (Baker, 2002)

The dosimeter design and structure remained constant until 1964 except for the addition of a brass filter on a portion of the open window. The brass filter gave one-half the filtration of the cadmium filter and was used to distinguish 60 keV photons from the lower-energy component. In 1964, a new plastic holder was introduced to replace the stainless-steel holder. A personal nuclear accident dosimeter (PNAD) element was also added to the badge configuration in 1964 (ORAUT-TKBS-0011-6). The PNAD was not used for routine dosimetry (Baker, 2002). Also in 1964, the security badge was incorporated in the dosimetry badge, which ensured that each individual wore a dosimetry badge (Putzier, 1982). This design was maintained until the early 1990s when the security badge was separated from the dosimeter and individuals unlikely to receive occupational radiation exposure greater than 100 mrem were no longer issued dosimeters (ORAUT-TKBS-0011-6).

By 1971, the RFP had planned for, and fully adopted the use of, thermoluminescent dosimeter (TLD) chips for both beta-gamma and neutron dosimetry. Three Harshaw TLD 700 model elements (chips) were used to record exposure from beta and gamma fields. A TLD 600 chip (which measured both beta-gamma and neutron response) was used to monitor exposure to neutrons. The neutron response was determined by subtracting the response of the TLD 600 chip from the TLD 700 gamma response.

The RFP processed these dosimeters, which remained in use until 1986. All Harshaw dosimeters were processed using manual Harshaw model readers. (Putzier, 1982)

In 1983, in addition to the Harshaw chips, the RFP began using Panasonic dosimeters to monitor workers engaged in higher-exposure-risk activities. The Panasonic UD-802 dosimeter was used to monitor for beta-gamma exposure; the Panasonic UD-809 dosimeter was used to monitor neutron exposure. Each Panasonic dosimeter type contained four elements/filter arrangements which permitted evaluation of response to a range of irradiation environments. In 1987, external dosimetry of all RFP workers was transitioned to the use of the Panasonic dosimeter models UD-802 and UD-809.

The external dosimetry program for whole body monitoring passed the Department of Energy Laboratory Accreditation Program (DOELAP) in 1991. Obtaining DOELAP accreditation requires a site to measure and accurately report exposure from external radiation (DOE-STD-1111-98). While accreditation has only been in place since 1992, the RFP had used similar dosimeter designs prior to that time.

Since 1991, only workers identified as having potential for occupational exposure to radiological hazards were routinely monitored by whole body dosimetry. Workers who were not monitored were not considered to have the potential for exposure to external radiation (shallow, penetrating, or neutron) greater than 100 mrem per year.

7.3.1.3 History of Extremity Monitoring

Extremity dosimeters were used at RFP beginning in 1952, employing a film badge dosimeter designed by Oak Ridge National Laboratory. This dosimeter was similar to the whole body dosimeter in use at the time, but modified with a brass filter similar to the body badge. The extremity dosimeter was worn on the wrist (Baker, 2002, Putzier, 1982). The only workers monitored with extremity dosimeters were those who performed tasks in which the extremity dose was considered to be significantly greater than the whole body dose. (Rocky Flats, 2001)

In 1971, the RFP began using a wrist dosimeter designed in-house that used the same Harshaw chips (TLD-600 and TLD-700) used for whole body beta-gamma and neutron monitoring. The 1971 extremity dosimeter contained four Harshaw chips. Both chip types were incorporated to enable neutron and photon dose determination. Before 1971, wrist dosimetry at the RFP did not record a neutron response.

In 1991, the RFP implemented a custom-designed model of the Panasonic model UD-813 dosimeter (UD-813AS11) in a plastic wrist holder, and discontinued the use of the Harshaw wrist dosimeter. This wrist dosimeter (used until January, 2005) contains two Li-6 borate elements (sensitive to neutrons) and two Li-7 elements (insensitive to neutrons), which enables neutron dose measurement as well as gamma and beta Two of the elements are under a thin open window to provide for beta and low-energy photon dose measurements. This Panasonic extremity dosimeter passed DOELAP performance testing in 2000 (Baker, 2002; Rocky Flats, 2001).

The RFP has not used finger-ring dosimeters on a routine basis. Studies showed the use of finger rings did not provide satisfactory results (Putzier, 1982). Doses to the hand were estimated by multiplying the dose measured by the wrist dosimeter by a hand-to-wrist ratio. For RFP workers who were not monitored with extremity dosimetry, the wrist (or forearm) dose was assigned the same dose as the measured skin (shallow) dose, and the hand dose was assigned the same value. Where an extremity dosimeter was worn, but the resulting value was less than the skin dose measured by the whole body dosimeter, it was assumed that the extremity dosimeter was not worn. In such cases, the skin dose was assigned as the wrist dose. When the extremity dosimeter result exceeded the result (dose) recorded by the whole body dosimeter, the extremity measurement was assigned to the wrist. Then, a hand-to-wrist ratio was used to estimate the dose to the hand. Several studies were performed over time to determine the hand-to-wrist ratio. Different values were determined and used for different buildings and some job categories. (Baker, 2002)

7.3.1.4 Neutron Dosimetry Study and Dose Reconstruction

As stated previously, neutron dosimetry was implemented in 1952. However, a pilot study performed in 1994, and the NDRP completed in 2005, identified some issues related to the RFP neutron dosimetry program which are addressed in the referenced reports, and in information included in this section (both studies are discussed in ORISE 05-0199). Some workers were not monitored for neutron exposure during the period 1952 through 1970. For some plutonium workers, neutron monitoring was not provided until the early 1960s. Their recorded dose may not have included significant contributions from neutron exposure. These workers included most of the employees working in Building 771. From a review of available records, it appears that less than 20 of these employees were monitored for neutron exposure, and that monitoring was only during the period October, 1956, to September, 1957. Operations in Building 771 involved chemical processing of plutonium in acid solutions which typically can result in significant neutron fields from the alpha-neutron reaction with light elements. For some other workers in the period from 1967 through 1970, the NTA film badges were issued but not evaluated. It is also appears that no shielding of neutrons was used before the mid-1960s. (ORISE 05-0199)

As the RFP neutron dosimetry program was upgraded starting in 1967, the following improvements were made: (1) implementation of quality assurance oversight; (2) implementation of a system to prioritize films to be evaluated microscopically; and (3) implementation of a program to assign "notional" neutron doses to personnel whose NTA films were not evaluated. Neither the 1994 nor the 2005 study looked at neutron dosimetry from 1971 forward. The RFP transitioned to the Harshaw LiF TLD for neutron monitoring in 1971. (Baker, 2002)

As a result of the 2005 study, neutron dosimetry and dose results were re-evaluated and reconstructed. Results of 5317 workers were examined. Doses were reconstructed for 4676 workers. 825 workers received an increased dose of 5 rem or more. The techniques used in the reconstruction study are presented in the *Neutron Dose Reconstruction Protocol,* ORISE 05-0199.

(Begin: Roger Falk; SEC-00030 Non-Submitter Communication, SECIS ID: 56) There were few sources of neutrons at Rocky Flats that were not associated with plutonium operations. Although UF_4 was processed at RFP, the neutron yield for uranium fluoride is approximately one hundred thousand times less than the neutron yield for plutonium fluoride per unit mass. The chemistry of uranium processing performed in Building 881 (until 1964) produced significantly less neutron exposure than similar plutonium processing.

The NDRP did evaluate all neutron dosimetry elements available. These did include personnel with home building assignments in non-plutonium buildings (e.g., Buildings 21, 22, 23, 34, 44, 81, and 86). These individuals were identified as workers who performed occasional work in the plutonium production areas. Thus, these individuals included non-plutonium workers and roving workers. The neutron-to-photon ratio developed for "All Others" is based on the entire set of neutron films, and thus, includes non-plutonium and roving workers. It does include the higher neutron-exposure plutonium workers and provides a claimant-favorable value to apply to non-plutonium and roving workers.

The NDRP and the ORAU team technical documentation (ORAUT-OTIB-0050) provide time-varying (and location-varying for the NDRP data) neutron-to-photon ratios. Application of these results to dose reconstruction is documented in ORAUT-OTIB-0050 and the dose reconstruction instructions. (End: Roger Falk; SEC-00030 Non-Submitter Communication, SECIS ID: 56)

7.3.1.5 Dosimetry Records

Data and documents covering external dosimetry, and related records covering the entire operational period of the RFP, are readily available.

There is a large set of records on RFP external dosimetry and external monitoring available from the onset of the monitoring program. Initially, through the early 1960s, external dosimetry data were handwritten and reported manually. In the 1960s, the RFP began storing dosimetry data on mainframe computers. Starting in 1976, the following databases were developed to maintain dosimetry and other health physics data:

- HSDB (Health Sciences Database) – 1976 to 1990
- RHRS (Radiological Health Records System) – 1990 to 1999
- HIS-20 (Health Physics Information System, Canberra Industries) – 1999 to present

The RFP typically summed the deep gamma dose and the neutron dose into a "penetrating" value. The neutron and deep gamma numbers were not retained and only the penetrating value remains.

Data obtained prior to 1976 were stored in these databases; however, the data were entered on an annual basis. In years through 1958, data is available in the paper record by quarter even though dosimeters might have been exchanged more frequently. Hand dose, as described in Section 7.3.1.3, was also maintained. Hard copy reports are available for the period 1959 through 1963, which contain details for each measurement for a monitored worker. In 1964, data appears to have been maintained by quarter. Starting in 1976 and through the current time period, individual dosimeter results were maintained with assigned- and ending-dates. These dates can be used to ascertain the monitoring frequency. (ORAUT-TKBS-0011-6)

The RFP data are also available without worker identification in the Department of Energy Comprehensive Epidemiologic Data Resource (CEDR). These datasets were recently used to generate exposure distributions for the RFP co-worker population for workers who were potentially exposed to occupational radiation but were not monitored, not monitored during all time intervals, or where records are not available.

The exchange frequency for an individual can be determined by reviewing the external dose record, if individual dosimeter readings were maintained. After 1976, the dose record will show a dosimeter reading for each exchange. For earlier years, the dose has been combined into quarterly records for which the exchange frequency has been lost, although it is reasonable to assume badges were exchanged at least quarterly (ORAUT-TKBS-0011-6).

Exchange frequencies before 1976 were determined by reviewing original dosimetry laboratory worksheets, many of which have been assembled as part of the Neutron Dose Reconstruction Project (NDRP). Dosimetry laboratory worksheets from 1951 through 1970 were reviewed, and an exchange frequency was determined (which includes the building and dosimeter type [photon, beta, or neutron]). It was necessary to evaluate the job category because the worksheet did not indicate job assignment. Dosimetry worksheets are not readily available from 1970 to 1976, so exchange frequencies were extrapolated forward for those years (Baker, 2002).

7.3.1.6 Application of Co-Worker Data for External Dose Reconstruction

The application of co-worker external data is used to assign doses to workers at DOE sites who have little or no individual monitoring data. These workers generally are in one of the following categories: (1) the worker was unmonitored and, even by today's standards, did not need to be monitored [e.g., a non-radiological worker]; (2) the worker was unmonitored, but by today's standards would have been monitored; (3) the worker may have been monitored, but the data are not available to the dose reconstructor; or (4) the worker may have partial information, but the available information is insufficient to facilitate a dose reconstruction. Analyses of co-worker external dosimetry data, including the results and deviations from the process, are documented in a site-specific TIB or site profile.

Development of site-specific data summaries and distributions involve a careful examination of the various data sources with the objective of identifying the most complete and accurate data set available. Prior to the analysis of the selected data and the development of summary statistics and dose distributions, a sampling of the data is compared to claim-specific data submitted to NIOSH by the DOE sites. The comparison also provides information needed to adjust the site-wide data sets to account for missed dose, partial year data, etc. Should significant issues arise during the course of this comparison that shed doubt on the accuracy or completeness of the site data selected for analysis, additional evaluations will take place to ensure that a valid data set has been selected.

Selected co-worker datasets are analyzed for the purpose of developing annual 50th and 95th percentile doses. Prior to calculating the percentile doses, the doses are adjusted to account for missed dose based on the badge exchange frequency and the dosimeter limit of detection (LOD). For example, the median annual reported dose might be zero at a particular site and in a particular year, but it would be inappropriate to assign a dose of zero as a median value because of the potential for missed dose, which must be included in the dose estimates to claimants. Specifically, one-half of the maximum annual missed doses are added to the reported annual doses, except for reported positive doses, in which case the maximum missed dose is reduced by the dose corresponding to one badge exchange (because it is not possible that all individual badge results were zero if a positive annual dose was reported). The 50th and 95th percentile annual penetrating and shallow doses are then derived by ranking the data into cumulative probability curves and extracting the 50th and 95th percentile doses for each year. Additional details on the incorporation of missed dose in the site co-worker data are provided in site-specific TIBs.

7.3.2 Ambient Environmental External Radiation Doses at RFP

Releases to the environment of weapons-grade plutonium, enriched and depleted uranium, tritium, and natural thorium have all occurred during the RFP operational period. Since these isotopes are not strong gamma or energetic beta emitters, there is little external dose consequence. In addition, releases from incidents would not increase the ambient dose rates appreciably due to the large proportion of the total environmental external dose coming from naturally-occurring radioactivity. This can be seen by comparing ambient gamma measured at the site perimeter stations with the on-site stations. The on-site stations were an average of 9% higher than the perimeter stations, equating to approximately 10 mrem/yr. (ORAUT-TKBS-0011-4)

Annual environmental reports from 1975 through 1994 contain environmental TLD data, which can be used to estimate external dose. Prior to 1975, external dose was determined by film badges, which are not suitable for monitoring environmental doses.

The 1994 Rocky Flats Site Environmental Report (RFETS, 1994) is the last annual report from the RFP site. This report contained on-site air-concentration measurements used to estimate intakes, but did not provide ambient external dose measurements. After 1993, the external dose measurements were no longer reported. On-site air-monitoring data continued to be reported in quarterly environmental monitoring reports through 1998. After 1998, only perimeter measurements were reported.

For external dose after 1993, the current TBD assumes the mean for all years for which measurements have been reported (1973 through 1993) for each year between 1994 and October, 2005, when the plant closed. (ORAUT-TKBS-0011-4)

For intakes after 1998, the current TBD assumes that the maximum intake over the 20-year period preceding 1998 applies. Currently, some limited on-site monitoring data (from approximately two samplers) available from the Colorado Department of Public Health and Environment is being reviewed with the intent to substitute that information for the 20-year maximum value.

Ambient environmental external doses are assigned to account for any doses potentially received from stack releases of other radiation sources that may have been subtracted from an individual's dosimeter readings and could have contributed to their external radiation dose. Such exposures could have impacted both monitored and unmonitored workers.

The following subsections summarize the extent and limitations of information available for reconstructing the ambient environmental-related external doses of members of the proposed class.

7.3.2.1 Ambient Environmental External Dose: Monitored Workers

Based on information in the RFP Site Profile, and in the procedure, *External On-site Ambient Dose Reconstruction for DOE Sites* (ORAUT-PROC-0060), on-site ambient should be included, in addition to the assigned external dose, for time periods where individuals may have been exposed to elevated ambient environmental external doses, or when the ambient environmental external dose has not been otherwise accounted for in the assignment of individual external doses (applicable to pre-1977 and post-1999 exposure periods).

7.3.2.2 Ambient Environmental External Dose: Unmonitored Workers

Ambient environmental exposures would have been the primary external exposure source for the unmonitored worker. The Occupational Environmental Dose TBD (ORAUT-TKBS-0011-4) and the procedure, *External On-site Ambient Dose Reconstruction for DOE Sites* (ORAUT-PROC-0060), provide methods for estimating potential ambient environmental external doses. External dose reconstruction methods for monitored workers will be applied for individuals who were not monitored, but should have been based on their job assignments and duties (i.e., who have missing or unavailable external monitoring data).

7.3.3 RFP Occupational X-Ray Examinations

As part of the requirements for RFP employment, entrance, exit, and periodic physical examinations may have been performed on employees. These physical examinations could include radiographic examinations of the lungs and, for some employees, the lumbar spine.

Before approximately 1986, many production workers would receive single-view chest X-rays on a nearly annual basis. After that date, the frequency of routine chest X-rays varied widely: none for office personnel, every 5 years for respirator wearers, and annually for beryllium workers and asbestos workers over age 45 and with a 10-year history of asbestos exposure. Because chest X-rays were not consistently performed on a strict annual basis due to missed exams or changing policies, and because an exam would not have been provided more frequently than annually, it is claimant-favorable to assume an annual chest X-ray for all workers. (ORAUT-TKBS-0011-3)

Between 1952 and 1974, workers could have received spinal X-rays during their initial employment medical examination. This X-ray series consisted of a 14-in by 17-in. anterior-posterior (AP) view and a 10-in by 12-in. lateral (LAT) view of the lumbosacral spine. To be claimant-favorable, workers whose start date falls within this range could be assumed to have received the spinal X-ray. (ORAUT-TKBS-0011-3)

Photofluorography (PFG) may also have been performed at RFP. Although no specific records or protocol exist showing PFG was performed, evidence does exist indicating the disposal of a PFG machine in 1968. Since doses from PFG are typically higher than standard PA chest radiography, NIOSH will use default dose values that assume an annual chest PFG in addition to regular chest X-rays for all years prior to 1968 could be used to assure claimant favorability. (ORAUT-OTIB-0006)

7.3.4 External Dose Reconstruction

Through December 2005, 1076 EEOICPA claims from RFP workers had been submitted to NIOSH. Of those 1076 claims, dose reconstructions have been completed for 588 claims. These claims cover the entire range of RFP operations and include claims with external monitoring data.

There is an established protocol for assessing external exposure when performing dose reconstructions for the RFP claims (discussed in the following subsections):

- Photon Dose
- Electron Dose
- Neutron Dose
- Unmonitored Individuals Working in Production Areas
- Medical X-ray

7.3.4.1 Photon Dose

Film dosimeters required the use of workplace-specific calibration factors, so it was necessary to know the facility in which the individual worked. The Dosimetry Department determined this by using facility assignment rosters, and issuing and retrieving badges to each major facility. Individuals sometimes worked in other facilities on temporary or overtime assignments that the Dosimetry Department could not detect. Area-specific calibration factors were necessary to evaluate readings from X-ray/gamma dosimeters used in the plutonium areas and the beta/gamma dosimeters used in the uranium areas. If a dosimeter was exposed in a different field, this could not be detected, which introduced a source of uncertainty.

TLD systems use more tissue-equivalent detection elements that do not require a field-specific calibration factor. This source of uncertainty is minimal with these dosimeters.

The claimant-favorable assumption is that the photon dose is a result of exposure in the 30-250 keV photon energy range (for Pu, this is 75%; for EU, this is 100%; for DU, it is 50%). When performing a dose reconstruction, dose conversion factors are used to calculate the exposure to photon radiation, coupled with information supplied from site dosimetry records, area monitoring, and personal monitoring for the claimant (when available). The energy fraction used in the dose reconstruction represents the amount of measured and missed dose applied to the appropriate energy range. Potential missed dose can be assigned to a potential dosimeter cycle to provide a claimant-favorable estimate of the external missed dose.

The NDRP-reported gamma dose only includes those gamma doses that were in some way used to estimate neutron dose; they are usually less than the DOE dosimetry reports from the site. In some cases, the gamma dose in the NDRP evaluation files is greater than the penetrating gamma dose reported in the DOE site dosimetry files. In that event, the greater dose will be used for dose reconstructions with maximizing and best-estimate approaches. The smaller dose may be used when using minimizing approaches. (ORAUT-OTIB-0027)

Pre-1960: Some dosimetry records indicate the dose determined by film darkening under each dosimeter element, as well as the recorded skin and penetrating dose values. The dosimeter could not effectively measure the 60 keV photon; thus, penetrating dose was calculated. The sum of the low energy (<30keV photons or >15keV electron) and the photon doses (30-250 keV and/or>250 keV photon, as applicable) exceeds the original reported skin dose. Thus, by implementing the methodologies discussed in ORAU-OTIB-0027, dose reconstruction can be calculated from the reported penetrating and skin doses.

1960-1970: The three-element film dosimeter used at the RFP from 1960-1970 had an open window (OW), a cadmium (CD) filter, and an additional brass (BR) filter providing half of the filtration of the CD. The brass filter was added to more accurately measure the 60 keV photons. This dosimeter was phased out during 1970. Based on review of each dosimeter element, as well as the recorded skin and penetrating dose values, and estimate of >15keV electrons, <30keV photons, 30-250 keV photons, and >250 keV photon dose, dose reconstruction can be calculated from the reported penetrating and skin doses, which were calculated as a sum of the three windows. The penetrating dose was calculated using 35% OW plus the other two windows. (ORAUT-OTIB-0027)

1970-present: The RFP started using TLDs to measure photon dose in 1970. The TLD materials used were much more tissue-equivalent and the response much less energy-dependent. Dosimeters were calibrated to more appropriate photon energies and filter design was more advanced. It is believed that these dosimeters performed substantially better than film. Although various chip and filter combinations were used, data provided in DOE dosimetry files does not generally include dose from individual components similar to the various categories from the film era (CD, OW, BR). (ORAUT-OTIB-0027)

7.3.4.2 Electron Dose

Beta radiation fields are usually the dominant external radiation hazard in facilities requiring contact work with unshielded forms of uranium. This was the case for enriched and depleted uranium work at the RFP. Large foundry ingots were generally handled by lifting devices, but machined uranium parts were handled with gloved hands. The RFP did experience elevated beta dose rates from contamination on leather gloves worn during the foundry operations. Extensive research in the areas of dosimeter wear location, electron energy spectra, and film response currently requires conversion of dose readings to shallow dose, which is an overestimation of the true shallow dose. This assumption is claimant-favorable for RFP workers. (ORAUT-TKBS-0011-6)

7.3.4.3 Neutron Dose

Missed doses are assigned using the Limit of Detection (LOD)/2 method. This method involves the assignment of a dose equal to the LOD divided by 2 for each dosimetry measurement that is recorded as zero, below the limit of detection, or below a reported threshold. Workers who were unmonitored for external radiation exposure are not assigned missed dose using the LOD/2 method; rather, they are assigned either (1) external on-site ambient doses (if they were non-radiological workers and would not have been exposed to workplace radiation sources); or (2) unmonitored doses (using co-worker studies or some other approach) if a potential for exposure existed. (ORAU-OTIB-0023)

ORAUT-OTIB-0050 describes the methodologies for calculating neutron dose that apply to workers at the RFP plutonium facilities during the period from 1952-1970. Data from 1977 to the present will be used to determine the neutron-photon ratio for the period from 1970-1976. All NIOSH worker data from 1977 to the present were analyzed to determine a neutron-photon ratio for claims involving these years of operation.

7.3.4.4 Unmonitored Individuals Working in Production Areas

In the early 1950s, only groups expected to receive doses greater than 10% of the Radiation Protections Guideline (called the "threshold dose") received dosimeters. During this time, the Radiation Protection Guideline was 3 rem per quarter. Thus, the missed dose estimate for unbadged individuals working in radiological controlled areas would be one half of 10% of three rem per quarter, or 600 mrem per year. When assigning the doses, a lognormal distribution will be assumed, with the upper 95% dose estimate used for these individuals or 1.2 rem per year. (ORAUT-TKBS-0011-6).

7.3.4.5 Medical X-ray

The frequency of X-ray examination varied significantly for RFP workers. A protocol for frequency of a single posterior-anterior (PA) view chest X-ray as a function of job category was not established until approximately 1986. Between 1952 and 1974, all workers received spinal X-rays during their initial employment medical examination. The medical files did not always document each X-ray taken until the mid-1970s. A claimant-favorable approach to the estimation of the X-rays taken would assume lumbosacral spine X-rays if the claimant started work between 1952 and 1974. An annual chest X-ray is assumed for all claimants, as well as AP and LAT lumbar spine X-rays at the start of employment for all individuals employed from 1952 to 1974 (ORAUT-TKBS-0011-3). This potential overestimation of the X-ray use will compensate for the few "retakes" that may have been necessary in individual cases for which the initial X-ray was of poor quality.

7.3.5 External Dose Reconstruction Feasibility Conclusion

NIOSH has established that it has access to sufficient information to either: (1) estimate the maximum external radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the external radiation doses to members of the class more precisely than a maximum dose estimate.

7.4 Dose Reconstruction Outcomes

NIOSH reviewed its dose reconstruction database, NIOSH OCAS Claims Tracking System (NOCTS), to identify dose reconstructions under EEOICPA that might provide information relevant to the petition evaluation.

The NOCTS data do not fully address the feasibility issues for this class, which is extensive and diverse in its history of exposures, monitoring experiences, and records availability. However, the data clearly show that dose reconstructions can be successfully completed using the methodological approaches shown in Table 7-2 for all years at the RFP. The data used for the dose reconstructions include data from internal and external sources, as discussed in Sections 7.2 and 7.3 of this report. Each claim in the table is only counted once and each claim is categorized based on the earliest start date of RFP employment.

Table 7-2: RFP Dose Reconstruction Outcomes by Methodological Approach

(Timeframe: 1952-2005) (Results as of: July, 2005)

Methodological Approach	1950s [a]	1960s	1970s	1980s	1990s	2000s	Totals
Not Entered[b]	9	5	1	0	0	0	15
Full Internal and External	1	0	1	0	0	0	2
Full Primarily External	0	1	0	0	0	0	1
Full Primarily Internal	1	1	0	0	0	0	2
Overestimate Primarily External	0	0	4	2	2	0	8
Overestimate Internal and External	28	94	75	104	38	5	344
Overestimate Primarily Internal	2	0	0	1	1	0	4
Underestimate Primarily External	21	14	1	3	0	0	39
Underestimate Primarily Internal	18	20	8	3	0	0	49
Underestimate Internal and External	10	7	1	0	0	0	18
Completed Totals	90	142	91	113	41	5	**482**
Unsubmitted Totals[c]	172	200	67	65	16	3	**523**

a. Decade columns list the number of dose reconstructions completed for the corresponding methodological approach.
b. "Not Entered" = Dose reconstruction completed, but type of dose reconstruction not entered.
c. "Unsubmitted Totals" = Claims that have not been sent to the Dept. of Labor.

7.5 Evaluation of Petition Basis for SEC-00030

The following subsections evaluate the assertions made on behalf of petition SEC-00030 for the Rocky Flats Plant. Twenty-two specific statements were made by workers on behalf of the petition. Nine statements are directly addressed in Section 7.5.2. The remaining 13 statements are generally addressed in Sections 7.5.1 and 7.5.3.

7.5.1 Evaluation of Major Topics Detailed in Petition SEC-00030

The following major topics were detailed in petition SEC-00030. Italicized statements are from the petition; the comments that follow are from NIOSH.

7.5.1.1 High Fired Plutonium Oxides

SEC-00030: *Exposure to a unique form of plutonium referred to as high fired oxides or super class Y materials that are metabolized differently and have self-shielding properties which make accurate assessment of dose impossible. In addition, the uniquely small particle size of high fired oxides – as small as 0.12 um Activity Median Aerodynamic Diameter (AMAD)- makes current dose models inaccurate. Dose models in use at Rocky Flats use a particle size of 1.0 um AMAD and underestimate high fired oxide doses by a factor of 1-2. Current models in use by NIOSH – International Commission on Radiological Protection (ICRP) 66 – use a particle size of 5.0 um AMAD and underestimate these doses by a much as a factor of 10. High fired oxides were generated from the Building 771 fire in 1957, the Building 776 fires in 1965 and 1969, numerous other smaller fires, and multiple high temperature processes in furnaces, incinerators and production process areas used in multiple plutonium buildings at Rocky Flats. A detailed accounting of these activities is included in our petition. The impossibility of accurate dose assessment for high fired oxides exposure is summarized in more detail on the following pages* [of the petition].

NIOSH agrees that there is evidence of high-fired Pu oxides at the Rocky Flats Plant. The presence of such materials does not, however, affect the feasibility of dose reconstructions.

One issue the petitioner has focused on is the "extreme nature of high fired oxides." The concern is that "Super Class Y material" (also discussed in this report as Type Super S material) was released during the various fires that occurred at the site. The concern is the relative insolubility of Type Super S, which limits the sensitivity of standard bioassay techniques. While this is a non-trivial issue, it is not a feasibility concern. Forms of Pu that are more soluble than Type Super S are assumed for maximizing dose reconstructions for cancers in non-respiratory tract organs. This results in claimant-favorable dose estimates for non-respiratory tract organs. For respiratory tract claims that have POC <50% using Type S material, NIOSH will assume type Super S, and will calculate lung doses using the methodology outlined in ICRP 66, together with empirically-observed solubility and retention parameter values as described in ORAUT-OTIB-049

Another issue raised by the petitioner is the difference between the potential particle size of high-fired oxides and the particle size assumption used in NIOSH dose reconstructions. This is not a feasibility concern. When an intake is assessed based on urine bioassay or lung count measurement, the particle size is only a significant factor for reconstructing doses to organs of the GI tract, as demonstrated in

Section 6.5 of this report. In these cases, however, the NIOSH assumption of a particle size of 5.0 um AMAD is claimant favorable.

The petitioner also asserted that high-fired Pu oxide particles would be ceramicized, and that this would lead to "self-shielding," which would challenge the ability of lung counting to detect Pu inhalation intakes. However, since Pu lung counting relies on the detection of the 60 keV gamma radiation from the Am-241 daughter, it is not plausible that any significant self-shielding would occur. From first principles, even if the Am-241 were encased in a solid ceramic sphere of 0.12 μm diameter (the size that the petitioner asserts should be used for the particle size), the chance of the resultant gamma ray from the Am-241 daughter being shielded by the sphere is approximately 3×10^{-4}, or 0.03%. Even under the worst-case assumptions made in this scenario (spherical particle with Am atom in the center), this shielding potential is trivial and would not affect the ability of the lung counter to detect a Pu lung burden.

7.5.1.2 Inability to Link Exposures to Specific Incidents or Events

SEC-00030: *Inability to link exposures to specific incidents as evidenced by the Building 771 worker exposure issue as recently as 2000/2001. In this incident, workers received undetected exposures through chronic long-term exposures below the threshold of workplace monitors that were discovered only by happenstance. Without a date to enter into the equation for bioassay results, an accurate dose assignment is impossible.*

Undetected or unmonitored intakes occur at many DOE facilities and are not a concern for the feasibility of dose reconstruction. Estimates of the unmonitored dose can be made using either co-worker data or using the proximate recorded doses for the specific worker of interest occurring prior to and following a period of unmonitored dose. OCAS-PR-004 describes several different options for calculating unmonitored dose in various situations. A definitive intake date, while helpful, is not necessary for dose reconstruction. In cases where a definite intake date cannot be ascertained, claimant-favorable assumptions (e.g., assuming that the intake occurred on the first day of work with radioactive materials) are made to estimate the maximum possible internal dose.

7.5.1.3 Periods of Inadequate and/or Lack of Monitoring

SEC-00030: *Periods of inadequate monitoring, lack of monitoring, changes in methodology, and inconsistency in procedures over the history of the Rocky Flats site which make accurate dose reconstruction over time impossible. Examples include: no routine lung counting until the late 1960's, no monitoring for neutron radiation prior to late 1950's and neutron measurements found in error until 1970's.*

It was recently determined that neutron doses may have been under-reported or over-reported for certain individuals hired prior to 1968. Process workers who were exposed to neutrons may not have been monitored for neutrons from 1953 until about 1958. In addition, the neutron film used to monitor employees in the late 1950's and early 1960's may not have been read properly, thereby either missing some neutron exposure or reporting more neutron exposure than was actually received. The issue appears to be limited to neutron exposures prior to 1968.

The basic principle of dose reconstruction is to characterize the occupational radiation environment to which a worker was exposed using available worker and/or workplace monitoring information. In cases where radiation exposures in the workplace environment cannot be fully characterized based on available data, default values based on reasonable, claimant-favorable scientific assumptions are used as substitutes. EEOICPA recognized that the process of estimating radiation doses would require dealing with uncertainties and limited data, and thus, methods were established for arriving at reasonable, claimant-favorable estimates of radiation dose received by an individual who was not monitored or inadequately monitored for exposures to radiation, or for whom exposure records are missing or incomplete. To the extent that the science and data involve uncertainties, these uncertainties are typically handled to the advantage, rather than to the detriment, of the claimant. NIOSH has used the best available science to develop the methods and guidelines for dose reconstruction. As described in detail in the following sections, the lack of routine lung counting prior to the 1960's does not preclude dose reconstruction because urinalysis and fecal sampling results are available. Neutron doses from early time periods can be addressed using neutron/gamma ratios.

The issue of inaccuracies in measured neutron doses has been addressed in the Neutron Dose Reconstruction Protocol, and these results are being used by NIOSH in dose reconstructions for affected energy workers (ORISE 05-0199). With the release of this protocol, it is possible that results from previously-assigned neutron doses could change. This issue only affects non-compensable claims with employment periods prior to 1977, where the current overestimate approach would cause the POC to be greater than 50%. Prior to 1977, the neutron and photon dose was reported as a single penetrating dose. Neutron-to-photon ratios are available to separate the two radiation types. In addition, the Neutron Dose Reconstruction Project has reassessed the number of neutron tracks. The current overestimate approach is to assign the penetrating dose as 100% photon and 100% neutron dose. In addition, the organ dose conversion factors (DCFs) have been increased to a value of 2. This approach has been found to provide an overestimate of the expected Neutron Dose Reconstruction Project findings for a claim. For claims with employment periods after 1976, the external dose is reported as cycle data, not summary data. Neutron and photon dose are reported separately and can be assessed without complications.

7.5.1.4 Unmonitored Exposures Surfacing throughout Time

SEC-00030: *As recently as 2004, a former worker from the 1950's was monitored under a DOE former worker radiation program and was found to have a significant internal deposition that had gone undetected and unrecorded for nearly 50 years.*

The dose reconstruction methods applied for Rocky Flats incorporate processes to account for unmonitored and missed internal dose in a claimant-favorable manner (see response in Section 7.5.1.2). If available monitoring data identifies positive bioassay results, the data will be reviewed and considered in the internal dose evaluation. If an individual was monitored and had no positive bioassay results, the potential missed internal dose will be evaluated in light of the minimum detectable activity (MDA) for the selected bioassay method (in-vivo or in-vitro). As indicated in the Rocky Flats Internal Dosimetry TBD (ORAUT-TKBS-0011-5), the bioassay MDAs improved (i.e., decreased in value) over time from the 1950s to the present, which could account for the situation described by the former worker above. However, the total potential intake will be accounted for through the application of the dose reconstruction methods in the Internal TBD. Although the RFP utilized a program in which the highest exposure-potential employees were individually monitored, it is recognized that not all employees were monitored. The established protocol for assessing internal dose when performing dose reconstructions in this situation includes the use of co-worker data, or the application of methods that assign a maximum plausible internal dose based on the maximum internal exposure from multiple isotopes (assigned as an acute exposure on the first day of employment), or based on maximum plausible air concentrations in the associated work area (assigned as a chronic exposure over the entire employment period).

7.5.1.5 Negative Effects of Site Closure on Accuracy of Dose Reconstruction

SEC-00030: *As a closure site, Rocky Flats presents unique challenges for dose reconstruction in that the entire infrastructure will be eliminated and with it the subject matter experts that provide information and clarification for dose reconstruction questions. No one will be left that understands the data. Currently the Rocky Flats dosimetry department answers calls on a regular basis in support of dose reconstruction where data is missing, or part of a file is missing, in particular with the change in 1989 from systemic burden to dose, when the Radiation Control Manual was implemented. When Rocky Flats is gone, there will be no one left who understands these nuances, making accurate dose reconstruction impossible*.

NIOSH does not have any reason to expect that the closure of the site will adversely affect the feasibility of dose reconstructions. Subject matter experts, including former Rocky Flats dosimetry personnel, are currently available and will continue to be available. NIOSH is making full use of these individuals' experience and knowledge. Furthermore, individual dosimetric data is being supplied by the Department of Energy to NIOSH for use in dose reconstruction. Extensive holdings of Rocky Flats dosimetry program documents are being maintained by the Department of Energy; NIOSH has access to these documents as needed.

7.5.1.6 Worker Recall Monitoring Program

SEC-00030: *With closure, worker recall monitoring programs are going away. The contract has ended for the former worker recall program through Oak Ridge where workers were called back every three years. The Rocky Flats program that recalls active employees on an annual basis will go away at closure. Currently there is nothing in place to replace these important activities.*

Although the Worker Recall Monitoring Program may be going away, the continuation of this program has no bearing on the EEOICPA radiological dose reconstruction program. This worker outreach program, formerly known as the Former Radiation Worker Medical Surveillance Program at Rocky Flats was initiated informally in the early 1980s by Dr. Robert Bistline. He was associated with the Medical Department, and saw an opportunity to bring back former workers with known internal lung depositions, workers with residually-contaminated wounds, and/or workers who had received chelation treatments to minimize potential long-term depositions. This project officially started in the fall of 1994 and concluded in the fall of 2004. The importance of this work is in the body of data collected on long-term exposures (via lung count and urine excretion). The data these former workers provided has helped the scientific community to better understand the biokinetics of plutonium and americium. The program's purpose was to grasp the opportunity to gather data and information on a large, relatively stable former workforce. The results of this study were officially released in June, 2005.

During the early years, the program focused more on individuals with the highest internal depositions and the oldest individuals. During the latter years of the project, everyone was eligible for at least a single visit. The criteria for determining whether individuals qualified as repeat participants were whether they had received 20 rem or more of exposure (external plus internal) and whether there was some reason to believe that a potential existed for missed dose.

Bioassay results from recall programs can help refine estimates of dose from internally-deposited radioactive materials. However, the ability of NIOSH to perform dose reconstructions is not predicated on the continuance of such programs. When these data are available, NIOSH will consider them in dose reconstructions, but monitoring and other data collected from the period during which the worker was employed, together with NIOSH's procedures for the assignment of unmonitored doses, are sufficient to conduct dose reconstruction.

7.5.1.7 Plutonium Linked to Cancer

SEC-00030: *Exposure to plutonium has been causally linked to more than 20 types of cancer was well as lung fibrosis. Plutonium exposure, in particular to high-fired oxides and their related ailments endanger the health of the members of this Rocky Flats class of workers. DOE and the federal government have recognized the causal role of plutonium exposure in these specific cancers as evidenced in the Energy Employees Occupational Illnesses Compensation Program Act (EEOICPA) which designates a list of cancers currently linked to radiation exposure. Additionally, the effects of synergism of exposures to different toxins are not known. In particular the effects of combination exposures where an individual has both plutonium and toxic chemical exposure, such as carbon tetrachloride, trichloroethylene, nitric acids, and numerous other toxic chemicals used at Rocky Flats. Synergism has been documented, for example, for the combination of plutonium exposure and cigarette smoking. The result is that a person who was exposed to plutonium and also smoked is 10 times more likely to contract lung cancer than a person who was not expose to plutonium and smoked.*

For the purpose of the SEC Evaluation of this petition under the requirements of the EEOICPA, Part B (currently being administered by the Department of Labor), and 42 CFR Part 83, NIOSH considers the feasibility of estimating radiation doses with sufficient accuracy. If radiation doses cannot be estimated with sufficient accuracy, then NIOSH also considers whether such radiation doses may have endangered the health of members of the class of employees. Neither the feasibility of radiation dose reconstruction nor the associated determination of health endangerment involve the effects of smoking or exposure to toxic chemicals. The effects of smoking (for lung/respiratory tract cancers) are considered by the Department of Labor (DOL) in the evaluation of probability of causation for employees who receive a dose reconstruction from NIOSH. DOL also considers the exposure of a worker to the combination of toxic chemicals and radiation under Part E of EEOICPA.

7.5.2 Evaluation of Specific Petitioner Statements in SEC-00030

Nine specific statements made by workers on behalf of petition SEC-00030 are addressed below. The italicized statements are from the petition; the comments that follow are from NIOSH.

7.5.2.1 Incident in 1957 Involving a Chemical Operator

SEC-00030: *A chemical operator in June 1957 was involved in an explosion resulting in an exposure to plutonium nitrate and 50 percent hydrogen peroxide. The only protective clothing he had on was white coveralls and safety glasses. He spent a week in medical and never knew the levels of contamination of his body. However, his last body count in 2003 showed 12 body burdens.*

Dose reconstructions are intended to estimate the radiation doses associated with incidents as well as exposures that occur through routine radiological conditions. There are numerous records of similar incidents at RFP contained in the information supplied by the Department of Energy. Careful evaluation of the bioassay and lung-counting record would show whether there was an excretion level indicating an intake had occurred. Any external dose above the relevant limit of detection would have been reflected on the external dosimetry. The application of potential external or internal missed dose, calculated in accordance with the Rocky Flats TBDs and dose reconstruction supporting documentation, can be used to reconstruct dose incurred by the individual.

7.5.2.2 NDT Technician's Dosimetry Badge Placement

SEC-00030: *An NDT* [Non-Destructive Testing] *Technician, who worked in Buildings 777, 991, 707 and 444, X-rayed pits and other nuclear materials in high radiation areas. He wore a lead apron and gloves. The dosimetry badge was required to be worn under the lead apron. He now has cancer of the esophagus.*

Lead aprons were available and used for a limited number of tasks at RFP. For most years, workers were instructed to wear badges under the lead apron to measure dose to the torso. In 1992, this policy was changed to instruct workers to wear the dosimeter outside the lead apron to better measure the dose to the head, neck, and arms. Field studies to determine the dosimeter response in both locations were performed. The results of these studies were used to develop bias corrections for dose reconstructions.

7.5.2.3 Unmonitored Exposures for a Clerk Packer in Buildings 444 and 883

SEC-00030: *A clerk packer who worked in Buildings 444 and 883 was exposed to high radiation areas and never wore respiratory protection when handling parts. In fact, they used to eat and drink in their work areas. He now has cancer in the nasal pharynx, which then went into the lymph nodes of his neck. These exposures were unmonitored and unrecorded.*

This situation can be addressed adequately and fairly through dose reconstruction. Potentially unmonitored dose would be assigned by the claimant-favorable application of co-worker data. Employees working in Building 444 handled depleted uranium (DU); employees working in Building 883 handled DU and enriched uranium (EU); employees in both buildings were on a monitoring program. Intakes from eating and drinking would be reflected in bioassay results. Intakes resulting in urine concentrations below bioassay detection limits would be accounted for by the assignment of internal missed dose. It is NIOSH policy that doses are not adjusted to account for the use of respiratory protection, which would reduce the intake of radiological materials and reduce internal radiation doses. Therefore, in cases in which respiratory protection was in fact used to protect a worker from a radiological intake, this NIOSH policy would result in a claimant-favorable overestimate of the worker's radiation dose.

7.5.2.4 Unmonitored Exposures for a Handyman in T-609K Trailer

SEC-00030: *A handyman working in the T-690K trailer was informed that the trailer he was in charge of became contaminated. He did not wear a dosimeter or any respiratory protection while working in this area. He was later asked to submit a fecal sample a year after the event. The sample was sent to an off site subcontractor laboratory and the results invalidated by Internal Dosimetry. This is another example of unmonitored exposure.*

This appears to be a situation in which doses can be reconstructed. Generally, RFP conducted a follow-up bioassay and/or lung counts when someone was potentially contaminated; however, instances of unmonitored doses associated scenarios as described could have occurred. For the scenario described, NIOSH would first examine the bioassay data in question, if available. If these data were not available or valid, NIOSH would evaluate any subsequent bioassay data for this worker, which typically would be sufficient to establish an overestimate of any doses associated with the contaminated trailer. If there were no subsequent bioassay data for this worker, then a claimant-favorable overestimate of unmonitored internal dose would be applied using co-worker data.

7.5.2.5 Exposures to a Chemical Operator/Nondestructive Assay Worker

SEC-00030: *A chemical operator/nondestructive assay worker was expose to very high radiation level packages of plutonium oxides, salts, americium, etc. and was often required to wear double lead aprons and 60 or even 90 mil leaded gloves, yet he still had numerous "No Current Data Available" dosimeter badge reports. So his exposure was going unrecorded. After being sent to a low-level exposure job at the solar ponds he was informed that he had received a positive inhalation and that it must have come from his days as a worker in Building 771.*

As addressed in ORAUT-TKBS-0011-6, Section 6.5.3, a blank record likely indicated that badge exchange was missed. The individual would then wear the badge for an additional exchange period (or more) before it was exchanged and processed. When the badge was processed, the dose would be credited to the latter exchange period and the first exchange period would contain one the following: (1) no reading; (2) the entry "No Current Data Available"; or (3) a zero, if the then-current computer system required a number in that field. The dose reconstruction missed-dose process will assign a dose to the blank or zero fields, resulting in a claimant-favorable double counting of dose for those periods. If a worker were on a quarterly badge exchange, this would result in missed quarterly results, even though the individual was continuously badged and the dosimetry record provides a complete record. From these records, it is not possible to determine if a badge was contaminated, lost, damaged, or unreturned, but the dosimetry program did recognize the necessity for a continuous record and did address lost badges. In the later years, the program became much more procedural. Procedures do exist for a graded response to lost badge dose estimation (4-J88-RDE0053 and 4-J98-RDE-0071).

7.5.2.6 Unrecorded Contamination Incidents and Effect of Dosimeter Storage Location

SEC-00030: *An employee describes how certain contamination events would require the removal of clothing and how these events would not be recorded. He also describes that radiation was coming through a wall where he hung his dosimeter. He has been diagnosed with a glioblastoma multiform brain tumor, an exceedingly rare form. He also reports having met a former Rocky Flats guard who has the same form of tumor. Efforts are being made to track down the former guard to obtain information on his work history.*

Uptakes of radioactive material resulting from contamination events would be reflected in bioassay results, even if the particular events went unrecorded. On-site ambient dose is assessed separately from dosimetry dose and would be included in the employee's assessment.

If the employee's dosimeter were stored in a location where it was exposed to radiation, this exposure would cause his dosimeter badge to register additional dose that he didn't actually receive. The NIOSH dose reconstruction would incorporate this overestimate of his dose, benefiting his claim under EEOICPA.

7.5.2.7 Employee Fire Experiences in Buildings 771 and 776

SEC-00030: *An employee describes his experiences with both the Building 771 and 776 fires. He also presents a list of people he worked with who either died of cancer or have had cancer.*

A large percentage of the staff who worked at RFP during the fires in these buildings in 1957 and 1969 was involved in one way or another with the fire or the clean-up. This is a recurring story in dose reconstruction telephone interviews with claimants from these two buildings.

The NIOSH dose reconstructions enable the Department of Labor to identify cases of cancer among RFP employees that were likely to have been caused by radiation exposures at RFP. By design, the Department of Labor's determinations of this likelihood err greatly on the side of finding a cancer to have been associated with radiation exposure at the facility. Similarly, the NIOSH dose reconstructions are designed to err on the side of overestimating the employee's radiation dose, rather than underestimating dose, further increasing the identification of cancer cases possibly associated with radiation exposures.

It should be understood, however, that cancer is a common illness that has many possible causes. One out of every three to four Americans is likely to have at least one case of cancer in his or her lifetime.

7.5.2.8 Unreported and Unrecorded Incidents

SEC-00030: *A surviving spouse describes her husband's work activities and job titles. He left Rocky Flats in March 5, 1989, and died of colon cancer on March 9, 1989. She has records of unreported and unrecorded incidents her deceased husband was involved in.*

The information of this surviving spouse presumably would be provided to NIOSH as a result of the telephone interview NIOSH conducts with claimants during the dose reconstruction process. This information would be considered by NIOSH in reconstructing her husband's exposures and doses.

Although such claimant information can facilitate the dose reconstruction process, NIOSH has a wide variety of informational sources from RFP upon which it develops these dose reconstructions.

7.5.2.9 Crystals on the Floor in Building 123

SEC-00030: *An affidavit submitted by the petitioner states that, as a Janitor in 1982, 6-12 crystals were found on the floor in Building 123. If the crystals were in good shape, they would be discharged and reused. In addition, the foreman would advise the dosimeter worker that the dose shown was too high to possibly be correct, and the worker was advised to change or delete the reading.*

It is possible that these crystals were read before they were dropped, but some crystals could have been dropped before being read. Systems were in place to interpret a badge with a missing crystal, and badges contained duplicate crystals. In these cases, a dose could be estimated from the readings from the remaining crystals. These situations were investigated, and the procedures for doing so were formalized in 4-J88-RDE-0053, *TLD Data Investigation and Abbreviated External Dose Reconstruction*, and 4-J98-RDE-0071, *Extended External Dose Reconstruction*. The results of these investigations were documented in the worker's Health Physics file and may or may not have been communicated to the employee at that time. Since instances where badges were missing crystals were investigated, NIOSH contends that this issue does not prevent NIOSH from performing dose reconstructions of sufficient accuracy. Therefore, NIOSH contends that this issue does not have SEC implications.

7.5.3 Evaluation of General Concerns Raised in Petition SEC-00030

The following subsections address general concerns raised in the discussion of petition SEC-00030.

7.5.3.1 Use and Effects of Lead Aprons

Lead aprons have been used in various types of high dose work, including drum movements, material repackaging, storage vault work, solution transfer, and material bag-outs. The lead aprons were front and back sleeveless, with a minimum lead equivalency of 0.45 mm lead thickness. (Wesley, 1997)

The use of lead aprons was job-specific and often determined by Radiological Engineering in conjunction with facility operations. The use of lead aprons was based on a qualitative assessment of expected dose rates, physical constraints and restrictions of the job, and expected neutron to gamma ratios. When neutron radiation was expected to dominate the work, use of lead aprons was usually avoided since lead is ineffective in reducing neutron dose, and whatever shielding benefit might be obtained for the gamma radiation component would probably be offset by the increase in time from wearing the apron. In jobs where Pu materials are unshielded, and gamma dose rates were expected to dominate (such as bag-out and transfer of concentrated Pu solution in polyethylene bottles), use of lead aprons does reduce gamma dose to the torso. (Wesley, 1997)

The effects of lead aprons on whole body gamma and neutron dose were measured in 1992 by RFP External Dosimetry in conjunction with a study performed to determine the proper location for wearing the whole body TLD. It was found that TLDs underneath the aprons read 16-90% higher neutron dose than those outside the apron. In addition, the study also found that the maximum attenuation of gamma radiation of various penetrating energies (shallow, lens of eye, and deep) ranged from 0-15% for the TLDs shielded underneath the lead apron. Therefore, a determination was made to wear the TLD underneath the apron. (Wesley, 1997)

Prior to the 1992 study, the plant practice was to wear the TLD taped to the outside of the lead apron unless specifically directed otherwise. This was to ensure that the TLD monitored the maximum dose expected to be received by a portion of the whole body.

The results of these field studies on the effects of lead aprons on recorded external doses allow for corrections to external doses assigned in dose reconstruction. These results are currently being incorporated into the Rocky Flats external dose TBD. While the use of lead aprons may require appropriate adjustment of recorded external doses, it does not raise a concern about the feasibility of dose reconstruction.

7.5.3.2 Improper Control Badge Storage

A concern has been raised that some dosimeter control badges were stored in areas of elevated radiation prior to 1977. Such a situation could result in the personnel dosimeters being over-corrected for background radiation. To remedy such a problem, NIOSH would adjust the ambient environmental dose NIOSH assigns during dose reconstruction. However, substantial research on this topic does not support the general concern.

From the start of RFP radiological operations until January, 1976, it appears that dosimeter background was determined from either laboratory blanks or control dosimeters stored on the storage boards with the dosimeters. There was some discussion that, in that period, storage boards may have been moved to lower dose locations because the background dose from the facility was unacceptably elevated. To evaluate this issue, a records review and interview program were initiated. Approximately 18 boxes of external dosimetry program records were reviewed. These records included weekly and monthly status reports from the 1950s, 1960s and 1970s, and some technical documents generated during that period. Approximately 500 pages of documents were identified as potentially relevant to this issue. No evidence of an identified high background radiation level was found. No evidence of action to reduce storage board background was found. Interviews were conducted with four retired dosimetry program managers. Each of these individuals was asked if they recalled this issue or actions taken in response to such a problem. None of the four recalled storage board background as a problem. Most recalled that elevated storage background was not significant and did not affect the dosimetry results. From this review, it is concluded that elevated ambient levels of external radiation were not a problem at Rocky Flats during the 1951-1976 time period. From 1977 to February, 2000, a plant-wide standard background was subtracted. For dosimeters collected in March, 2000, through 2003, badge storage background dosimeter results were used. These background dosimeter results were averaged over a five-quarter rolling period. The initial results of this process indicated a background that is a 14% increase over the calculated site average (standard deviation = 16%).

7.6 Other Issues Relevant to the Petition Identified During the Evaluation

During the feasibility evaluation for SEC-00030, a number of issues germane to this evaluation were discussed in public meetings involving the petitioners, Working Groups of the Advisory Board on Radiation and Worker Health (the Board), NIOSH, and contractors supporting the dose reconstruction program and the Board. A brief summary is provided below of some of these issues and how they have been addressed in this evaluation.

- ISSUE: The approaches regarding solubility need to be reviewed, particularly for Type “S” or “Super-S” plutonium compounds whose high insolubility may lead to more exposure to gastrointestinal and respiratory tract organs. The sensitivity of the bioassay methods was not adequate to detect incidental intakes of insoluble compounds, and also the bioassay methods applied at that time were not appropriate.

  APPROACH: This is discussed in Section 7.2.1.1. The adequacy of the sensitivity or application of the old bioassay methods is not an intractable issue for retrospective dosimetry because the dose reconstructions are based on the higher of the actual measured value or the MDE (or its surrogate). Indeed, a lack of sensitivity in early bioassay monitoring measurements will likely result in a very claimant-favorable dose reconstruction for affected workers unless there are more recent and better data to bound the dose reconstruction.

  NIOSH will provide for examination by the Board ORAUT-OTIB-0049 and all supporting case data and analysis files, including United States Transuranium and Uranium Registries (USTUR) autopsy cases used in support of the Super S plutonium approach. NIOSH will also provide the procedure for addressing the GI tract doses from Super S plutonium exposure, which is currently under development.

- ISSUE: Uncertainties are not addressed in the TBD regarding the Am-241 assay of plutonium processed at RFP and how lung counting was calibrated to these values, especially in view of different Am-241 proportions at different processing steps and different plutonium ages.

  APPROACH: This issue is discussed in Sections 7.2.1.1 and 7.2.1.2. This topic is addressed more extensively in Attachment B of ORAUT-TKBS-0011-5. If the information regarding Am-241 is not apparent in the available records, a claimant-favorable approach is to assume the initial ppm Am-241 to be 100. This value represents freshly-purified plutonium (within zero to five months, depending on the efficiency of the purification). Although some guidance is given regarding the intake date if it is not well documented in the record, the dose reconstructor has general guidance to consider a claimant-favorable intake scenario when there is ambiguity in the record.

  The health physicists working at RFP were well aware of the problems of lung counts for workers possibly exposed to freshly-purified plutonium with minimal, if any, americium. The issue is mitigated by the ingrowth of americium at a rate of approximately 20 ppm per month. Therefore, in the early 1970s, Rocky Flats implemented the practice to re-count workers involved in possible inhalation (PI) incidents: (1) at 90 days post-incident if the ppm Am of the representative incident material sample was 200 to 500; and (2) quarterly for one year if the ppm Am was less than 200 ppm. In addition, urine and fecal samples were requested for the next three days following the incident for less than 200 ppm Am. This information is contained in the body count reports and bioassay records for any affected claimant/worker. At least annual routine lung counts were provided to workers most likely potentially-exposed to purified plutonium (i.e., process operators in Building 771). Table 7-3 demonstrates the difference between assuming an initial ppm Am of 0 or 100 diminishes significantly over time. No further action is required.

Table 7-3: Ingrowth of Americium-241

(For plutonium with 0.5% Pu-241 by weight with initial parts per million Am-241 of 0 ppm and 100 ppm)

Time (years)	ppm Am at Time		Ratio
	Initial ppm = 0	Initial ppm = 100	$(ppm_0=100)/(ppm_0=0)$
0.25	59	159	2.69
0.5	118	217	1.83
0.75	175	275	1.57
1	236	336	1.42
2	460	560	1.22
3	673	772	1.15
4	876	975	1.11
5	1069	1168	1.09

- ISSUE: Interpretation of NTA film data and correction of recorded dose for workers who were not included in the NDRP is not evident.

  APPROACH: This issue is discussed in Sections 6.1, 7.3.1.3, and 7.3.1.4. Neutron Track Plates (NTP) were used at the RFP. The NDRP located 757 track plates that were evaluated by that program. Los Alamos Scientific Laboratory documents describing Nuclear Track Plate characteristics and the analysis techniques used for Dow Chemical (RFP) are available. It is clear that Neutron Track Plates were used and the timeframe has been identified.

  A technical description of this neutron dosimetry system will be added to the ORAUT-TKBS-0011-6 based on the technical material available. The TBD will be revised to incorporate a description of the NDRP and describe the results obtained by this program. The inclusion of non-plutonium and roving workers in the NDRP will be addressed as well. The neutron-to-photon ratio developed for all others is based on the entire set of neutron films, and thus, includes non-plutonium workers and provides a claimant-favorable value to apply to non-plutonium and roving workers. The TBD will be updated to include the varied neutron spectra encountered during exposure to uranium, criticality experiments, calibration sources, and the neutron generators that existed at Rocky Flats. Some issues are still outstanding such as the justification for using the NTA film calibration factor for glass-track dosimeters in view of the problems with the latter, and the use of one or two neutron calibration spectra to cover all neutron energy spectra in the varied RFP workplaces. However, these are not issues concerning the feasibility of dose reconstruction.

- ISSUE: There is a need to use neutron-to-photon ratios and/or film/TLD comparisons to correctly determine past neutron doses. Workers were exposed to neutrons in the NTA film period at lower energy levels than the dosimeter is capable of measuring. It is important to generate correction factors for under-monitored workers or for monitored-worker missed dose. This is especially important for non-Pu workers covered by the NDRP Report, and workers involved with the Pu tetraflouride and Pu machining operations during the early period.

APPROACH: This issue is discussed in Sections 7.3.4.1 and 7.3.4.3. The bias correction factors presented in ORAUT-TKBS-0011-6, Section 6.7.3.4, are used to address the human factors issues associated with limited personnel reading large numbers of neutron films. The NDRP for non-plutonium workers (the "All Others" neutron-to-photon ratios developed by the NDRP) provide a dose reconstruction tool for these claimant files. Unmonitored energy range neutrons (those below the film detection energy threshold) are currently addressed in ORAUT-TKBS-0011-6, Section 6.7.3.3. A significant bias correction factor has been identified and is applied in dose reconstructions. ORAUT-OTIB-0050 provides time-varying (and location-varying for the NDRP data) neutron-to-photon ratios. Application of these results to dose reconstruction is documented in ORAUT-OTIB-0050 and the dose reconstruction instructions. These results, as well as more recent extremes, will be included in the ORAUT-TKBS-0011-6 revision.

- ISSUE: The site profile, while incorporating methodologies for assignment of missed dose, has not adequately bound exposure conditions, compensated for calibration errors and technical deficiencies, and addressed possible data integrity issues, including possible zero entries in the dose records when badges were not returned, all of which may contribute to missed dose.

  APPROACH: NIOSH has developed ORAUT-OTIB-0050, which describes how to use the NDRP data for individual dose reconstructions. NIOSH continues to pursue obtaining the Job-Exposure Matrix developed by Dr. James Ruttenber. In addition, NIOSH is pursuing co-worker data, which is not dependent on Dr. Ruttenber's data. NIOSH has provided the Board with an analysis regarding the completeness of external exposure data and will provide a description of the co-worker database and/or analysis files. This is being developed using actual data, which consists of 360,000 bioassay data and covers all years. In addition, NIOSH has indicated it is not clear that "…the practice of recording zeros when badges were not turned in…" was consistent across all time periods. NIOSH will investigate how the radiation protection group approached investigation of suspect badge results and the outcomes of such investigations.

- ISSUE: Only "roll-up" penetrating doses exist for individuals prior to 1976. It is not clear how the neutron and photon doses will be determined from the roll-up dose.

  APPROACH: NIOSH plans to use the neutron-to-photon approach used in the NDRP and outlined in ORAUT-OTIB-0050 for pre-1971 determinations, and for 1971-1976.

- ISSUE: A group of results from July thru October, 1984, appear to indicate a reporting problem with the dosimetry algorithm used to calculate dose equivalents.

  APPROACH: NIOSH has determined that the problem with the algorithm resulted in the recording of neutron doses that were evaluated as zeroes as measured doses (i.e., greater than zero). This problem would result in overestimates of the neutron doses actually received during this brief period.

7.7 Summary of Feasibility Findings for Petition SEC-00030

This report evaluated the feasibility for completing dose reconstructions for employees at the Rocky Flats Plant between April, 1952, and February, 2005. NIOSH found that the monitoring records, process descriptions, and source term data available are sufficient to estimate radiation doses with sufficient accuracy for this class of employees. NIOSH did not identify any groups of employees at the facility during this time period for which it would not be feasible to complete dose reconstructions.

Table 7-4 summarizes the results of the feasibility findings for RFP for each exposure source from April, 1952, through February, 2005.

Table 7-4: Summary of Feasibility Findings for SEC-00030
(April, 1952, through February, 2005)

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal	X	
- Urinalysis (*in vitro*)	X	
- Airborne Dust	X	
- Lung (*in vivo*)	X	
External	X	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

As of February 8, 2006, a total of 1096 claims have been submitted to NIOSH for individuals who worked at RFP. Dose reconstructions are complete for 623 individuals (~57%).

A review of a portion of completed claims captured a wide variety of job titles. Examples of job titles include: janitor, production foreman, chemical operator, laboratory technician, laundry laborer, HR administrative assistant, engineers, firefighter, security guard, laboratory technicians, foundry foreman, and assembler. Years of service range from 180 days to 36 years.

Upon reviewing each of these dose reconstructions, appropriate data relevant to the employee's radiation exposure was used, including internal dosimetry (e.g., urinalysis results), external dosimetry data (e.g., film badge readings), workplace monitoring data (e.g., air sample results), workplace characterization data (e.g., type and amount of radioactive material processed), and descriptions of the type of work performed at the work location. The specific methods used for each dose reconstruction vary, depending on the type of work done. When dose information is not available, or is very limited, or the dose of record is very low, NIOSH may use the highest reasonably-possible radiation dose based on reliable science, documented experience, and relevant data to complete dose reconstruction. In other instances, NIOSH may not need to fully complete a dose reconstruction because a partial dose reconstruction results in an estimated dose that produces a POC of 50% or greater. Criteria and guidelines for making this determination are established by EEOICPA and the Probability of Causation Guidelines (42 CFR 81).

8.0 Evaluation of Health Endangerment for Petition SEC-00030

The health endangerment determination for the class of employees covered by this evaluation report is governed by EEOICPA and 42 CFR § 83.13(c)(3). Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. This evaluation, however, determined that it is feasible to estimate with sufficient accuracy the radiation doses for members of this class. Therefore, a determination of health endangerment is not required.

9.0 NIOSH Proposed Class for Petition SEC-00030

Based on its research, NIOSH expanded the petitioner-requested class to define a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees of DOE, DOE contractors, or subcontractors (regardless of union membership) who worked at the Rocky Flats Plant (RFP) in Golden, Colorado, from April, 1952, through February, 2005.

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