SEC Petition Evaluation Report
Petition SEC-00192

Report Rev #:1 Report Submittal Date: September 30, 2013

Subject Expert(s):	Daniel Stempfley, James Bogard, Elizabeth Brackett, Paul Ruhter, Tosh Ushino, Mutty Sharfi, Chris Miles
Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00192	83.13	August 23, 2011	February 9, 2012	Rocky Flats Plant

Petitioner-Requested Class Definition

All workers employed at Rocky Flats from April 1, 1952 to December 31, 2005.

Class Evaluated by NIOSH

All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors with the potential for tritium, thorium, uranium-233 and associated progeny, and/or neptunium-237 exposures while working at the Rocky Flats Plant in Golden, Colorado, during the period from April 1, 1952 to December 31, 2005.

NIOSH-Proposed Class(es) to be Added to the SEC

All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Rocky Flats Plant in Golden, Colorado, from April 1, 1952 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE Facility Name	Petition Status
SEC-00030	83.13	Rocky Flats Plant	Two classes added to the SEC: - Apr. 1, 1952 through Dec. 31, 1958 - Jan. 1, 1959 through Dec. 31, 1966
SEC00192, Rev. 0	83.13	Rocky Flats Plant	Evaluation specific to tritium: No class added to the SEC

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
SEC Petition Evaluation Report for Petition SEC-00030	Rocky Flats Plant

ORAU Lead Technical Evaluator: James Bogard

ORAU Peer Review Completed By: Daniel Stempfley

Peer Review Completed By:	[Signature on File] *LaVon B. Rutherford*	9/30/2013 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on File] *J. W. Neton*	9/30/2013 *Date*
SEC Evaluation Approved By:	[Signature on File] *Stuart L. Hinnefeld*	9/30/2013 *Date*

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Evaluation Report Summary: SEC-00192, 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 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 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-00192 was received on August 23, 2011, and qualified on February 9, 2012. The petitioner requested that NIOSH consider the following class: *All workers employed at Rocky Flats from April 1, 1952 to December 31, 2005.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. As a result of the initial qualification of petition SEC-00192, and the identification of issues associated with the incomplete analysis of tritium during the original evaluation for Rocky Flats petition SEC-00030, NIOSH evaluated the following class for Rev. 0 of this SEC-00192 evaluation report: All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors with the potential for tritium exposures while working at the Rocky Flats Plant in Golden, Colorado, during the period from April 1, 1952 through December 31, 2005.

As a result of the presentation of Rev. 0 of this SEC-00192 evaluation report to the Advisory Board, and the subsequent review by the Board working group, the petitioner and NIOSH, additional issues were identified that required further evaluation. Therefore, the class evaluated by NIOSH in Rev. 1 of this report has been expanded to include: All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors with the potential for tritium, thorium, uranium-233 and associated progeny, and/or neptunium-237 exposures while working at the Rocky Flats Plant in Golden, Colorado, during the period from April 1, 1952 through December 31, 2005.

NIOSH-Proposed Class(es) to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has obtained documentation and data for the worst-case tritium exposure scenario at RFP for any worker, working in any area, over the applicable time period under evaluation. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate tritium radiation doses with sufficient accuracy. However, in the process of subsequent classified and unclassified document reviews and interviews (after initial presentation of Rev. 0 of this evaluation report to the Advisory Board), NIOSH identified issues that prevent estimation with sufficient accuracy exposures to thorium, uranium-233 and associated progeny, and neptunium-237. Therefore, NIOSH is proposing the following class be added to the SEC: All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Rocky Flats Plant in Golden, Colorado, from April 1, 1952 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Feasibility of Dose Reconstruction

NIOSH finds it is not feasible to estimate internal exposures with sufficient accuracy for all workers at the site from April 1, 1952 through December 31, 1983 due to insufficient data. With the exception of this class, per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) 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 (2) estimate radiation doses more precisely than an estimate of maximum dose. Information available from the site profile and additional resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the evaluated class under plausible circumstances during the specified period (January 1, 1984 through December 31, 2005).

The NIOSH dose reconstruction feasibility findings are based on the following:

- NIOSH finds that it is likely feasible to reconstruct occupational medical dose for Rocky Flats workers with sufficient accuracy.

- Principal sources of internal radiation for members of the proposed class included exposures to tritium, thorium, uranium-233 and associated progeny, and/or neptunium-237. The modes of exposure for all four radionuclides of concern were ingestion and inhalation.

- The potential for tritium exposures existed from the beginning to the end of RFP operations, and was associated with, and the result of, the receipt and reprocessing of tritium-contaminated weapons components returned to the site. Based on the assessment presented in this evaluation, NIOSH concludes that there are sufficient data and knowledge of processes and operations to support bounding the associated tritium dose using the methods and information presented in this evaluation.

- Thorium exposure was related to fabrication of metal parts from natural thorium or thorium alloys, use of oxide (“thoria”) as a mold coating compound, use in compounds in analytical procedures and research and development, and use as a substitute for U or Pu components in research and development. NIOSH has evaluated the available personnel and workplace monitoring data and has determined that these data are insufficient for estimating internal thorium exposures. In the absence of adequate *in vitro* or *in vivo* bioassay, NIOSH would employ source term data. However, NIOSH lacks sufficient source term data that are inclusive of the throughput amounts of thorium (i.e., they only represent a snapshot in time in regards to quantities); these data do not support estimating potential internal exposures to thorium during the period of RFP thorium operations from April 1, 1952 through December 31, 1966.

- Uranium-233 and associated progeny exposure was related to receipt and processing of U-233 residues. Processing involved thorium strikes to extract Th-228, which was containerized and shipped to Idaho National Laboratory. The uranium was then converted to a peroxide and ultimately reduced to U-233 metal. In its review of available bioassay records for individuals identified as having worked in U-233 processing areas, NIOSH has determined that uranium bioassay data may not be available for all potentially-affected individuals. In additional, these same workers were also potentially exposed to Th-228. NIOSH lacks thorium bioassay data for Rocky Flats personnel. Furthermore, NIOSH has determined that workplace air monitoring and contamination surveys for U-233 processes are insufficient for dose reconstruction purposes. Without uranium and thorium bioassay results, NIOSH has concluded that it cannot estimate with sufficient accuracy the potential internal exposures to U-233, U-232, and Th-228 which the proposed class may have received from 1964 through 1983.

- Neptunium-237 exposure was associated with, and the result of, preparation of pure neptunium oxide, metal and metal alloys, and the recovery of Np-237 from a variety of residues, including sand, slag, crucibles, casting skulls, and alloys. Processes included dissolution, anion exchange, precipitation, filtration, calcination, conversion to fluoride, and reduction to metal. Fabrication steps such as casting and rolling were also sometimes performed for the production of high-purity metal shapes and foils. Evidence points to a number of specific tasks performed at the request of other DOE laboratories from 1962 until around 1983, involving a few grams to a few hundred grams of neptunium. NIOSH has evaluated the available personnel and workplace monitoring data and has determined that these data are insufficient for estimating internal neptunium exposures. In the absence of adequate *in vitro* or *in vivo* bioassay, NIOSH would employ source term data. However, NIOSH lacks sufficient source term data that are inclusive of the throughput amounts of neptunium (i.e., they only represent a snapshot in time in regards to quantities). These data do not support estimating potential internal exposures to neptunium during the period of RFP neptunium operations from January 1, 1962 through December 31, 1983.

- The principal sources of external radiation doses for members of the proposed class were evaluated in the SEC-00030 Rocky Flats Plant Evaluation Report. SEC-00030 concluded that all external dose except neutrons could be estimated with sufficient accuracy. This revision of SEC Evaluation Report SEC-00192 was initiated based on NIOSH's subsequent research and determination that internal radiation exposures to U-233, thorium, and Np-237 could not be reconstructed; consequently, NIOSH has determined that there is no need to assess external exposures and the ability to reconstruct dose at RFP beyond what has already been presented and assessed in SEC-00030.

- Pursuant to 42 C.F.R. § 83.13(c)(1), NIOSH determined that there is insufficient 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 of members of the class more precisely than a maximum dose estimate.

- Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed Rocky Flats during the period from April 1, 1952 through December 31, 1983, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is required because NIOSH has determined that it does not have sufficient information to estimate dose for the members of the proposed class from April 1, 1952 through December 31, 1983.

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in the proposed class may have accumulated substantial exposures through chronic and/or episodic intakes of thorium, uranium-233 and associated progeny, and neptunium-237. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under their employment or in combination with work days within the parameters established for other SEC classes.

For the period January 1, 1984 through December 31, 2005, a health endangerment determination is not required because NIOSH has determined that it has sufficient information to estimate dose for the members of the evaluated class.

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<u>ATTRIBUTION AND ANNOTATION</u>: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluator: James Bogard, Dade Moeller. The rationales for all conclusions in this document are explained in the associated text.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors with the potential for tritium, thorium, uranium-233 (and associated progeny), and neptunium-237 exposures while working at the Rocky Flats Plant in Golden, Colorado, during the period from April 1, 1952 through December 31, 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 make 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 also does not contain the final determination as to whether 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 C.F.R. pt. 83, and the guidance contained in the Division of Compensation Analysis and Support's (DCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, DCAS-PR-004.[1]

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[2]

42 C.F.R. § 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.*

[1] DCAS was formerly known as the Office of Compensation Analysis and Support (OCAS).
[2] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at http://www.cdc.gov/niosh/ocas.

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that 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 those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for one or more other SEC classes.

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioner(s) and the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order 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 a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[3]

3.0 SEC-00192 Rocky Flats Plant Class Definitions

The following subsections address the evolution of the class definition for SEC-00192, Rocky Flats Plant. When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of the petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

[3] See 42 C.F.R. pt. 83 for a full description of the procedures summarized here. Additional internal procedures are available at http://www.cdc.gov/niosh/ocas.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00192 was received on August 23, 2011, and qualified on February 9, 2012. The petitioner requested that NIOSH consider the following class: *All workers employed at Rocky Flats from April 1, 1952 to December 31, 2005.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Rocky Flats workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00192 for evaluation.

The petitioner affidavit states:

> *I attest that there were occasions when I was not monitored. When I worked in the 700 complex, one of my duties was to work on site returns. I clearly remember one incident at a down draft table. I was given the incorrect measurements and when the machine tool reached the given measurement the shell was breached. I remember that I had a nasal smear taken after the breach. I have requested a copy of this nasal smear report numerous times but have not received it. I was later told that I was probably exposed to tritium gas. I have no bioassay for tritium exposure.* (Affidavit, 2011)

Based on its review of Rocky Flats Plant past research and data capture efforts, specifically as it relates to the SEC-00030 RFP evaluation, NIOSH determined that it has access to personnel or area monitoring data for Rocky Flats workers specifically applicable to tritium starting from the time of the tritium incident that occurred in 1973. However, NIOSH also determined that a review of tritium records and data was necessary for all time periods. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that tritium radiation exposures and radiation doses were not adequately monitored at Rocky Flats Plant, either through personal monitoring or area monitoring. The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class because NIOSH has determined there is evidence of possible tritium exposures warranting evaluation beyond that performed for SEC-00030. Subsequent to the presentation of Rev. 0 of this SEC-00192 evaluation report to the Advisory Board, the Board-assigned working group and petitioner identified other issues beyond tritium requiring additional response. NIOSH's follow-up research identified further issues as well. Therefore, the class evaluated by NIOSH in this report was expanded to include: All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors with the potential for tritium, thorium, uranium-233 and associated progeny, and/or neptunium-237 exposures while working at the Rocky Flats Plant in Golden, Colorado, during the period from April 1, 1952 to December 31, 2005.

3.3 NIOSH-Proposed Class(es) to be Added to the SEC

Based on its research, NIOSH has obtained monitoring data and bioassay data for the worst-case tritium exposure scenario that support its ability to bound the tritium dose at the Rocky Flats Plant over the site's entire covered operational period. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate tritium radiation doses with sufficient accuracy. However, in the process of responding to issues raised during the review and evaluation of Rev. 0 of this SEC-00192 evaluation report, NIOSH's research confirmed issues that prevent estimating with sufficient accuracy exposures to thorium, uranium-233 and associated progeny, and/or neptunium-237. Therefore, NIOSH is proposing the following class be added to the SEC: All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Rocky Flats Plant in Golden, Colorado, from April 1, 1952 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As is standard practice, NIOSH completed an extensive database and Internet search for information regarding Rocky Flats Plant. The database search included the DOE Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet effort included searches of the OSTI OpenNet Advanced system, OSTI Information Bridge Fielded system, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) system, the DOE Office of Human Radiation Experiments website, the DOE-National Nuclear Security Administration-Nevada Site Office system, the Defense Technical Information Center (DTIC), the DOE Comprehensive Epidemiologic Data Resource (CEDR), the DOE Hanford Declassified Document Retrieval System (DDRS), National Archives and Records Administration sites (NARA), the Nuclear Information and Records Management Association (NIRMA) database, the Oak Ridge Institute for Science and Education (ORISE) database, and the University of Colorado Norlin Library. Attachment 1 contains a complete list of databases/libraries searched as well as a summary of Rocky Flats Plant documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

In addition to the database and Internet searches listed above, NIOSH identified and reviewed numerous data sources to determine information relevant to determining the feasibility of dose reconstruction for the class of employees under evaluation. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following subsections summarize the data sources identified and reviewed by NIOSH.

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 supplement, 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. The Site Profile for a small site may consist of a single document. As part of NIOSH's evaluation detailed herein, it examined the following TBDs for insights into Rocky Flats Plant operations or related topics/operations at other sites:

- *Rocky Flats Plant– Introduction*, ORAUT-TKBS-0011-1; Rev. 01; November 30, 2006; SRDB Ref ID: 30012
- *Rocky Flats Plant – Site Description*, ORAUT-TKBS-0011-2; Rev. 01; February 1, 2007; SRDB Ref ID: 30013
- *Rocky Flats Plant – Occupational Medical Dose*, ORAUT-TKBS-0011-3; Rev. 01; April 23, 2007; SRDB Ref ID: 31376
- *Rocky Flats Plant – Occupational Environmental Dose*, ORAUT-TKBS-0011-4; Rev. 02; April 23, 2007; SRDB Ref ID: 31377
- *Rocky Flats Plant – Occupational Internal Dose*, ORAUT-TKBS-0011-5; Rev. 02; August 17, 2007; SRDB Ref ID: 34365
- *Rocky Flats Plant – Occupational External Dose*, ORAUT-TKBS-0011-6; Rev. 02 PC-1; October 20, 2010; SRDB Ref ID: 89284

4.2 Technical Information Bulletins and Procedures

A Technical Information Bulletin is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. A Procedure provides specific requirements and guidance regarding EEOICPA project-level activities, including preparation of dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following Technical Information Bulletins and procedure as part of its evaluation:

- *OTIB: Tritium Calculated and Missed Dose Estimates*, ORAUT-OTIB-0011; Rev. 00; June 29, 2004; Oak Ridge Associated Universities; SRDB Ref ID: 19430
- *TIB: Tritium Calculations with IMBA*, OCAS-TIB-002; Rev. 00; April 22, 2003; National Institute for Occupational Safety and Health (NIOSH); SRDB Ref ID: 22407

- *Procedure: Occupational Onsite Ambient Dose Reconstruction for DOE Sites*, ORAUT-PROC-0060; Rev. 01; June 28, 2006; Oak Ridge Associated Universities (ORAU); SRDB Ref ID: 20213

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed 48 former RFP employees and subject experts. NIOSH performed individual in-person interviews, telephone interviews, email interchanges, and worker outreach meetings in Colorado to obtain additional information regarding tritium, plutonium and neptunium exposures and monitoring at RFP.

- Personal Communication, 2003, *Personal Communication with* [redacted]; Email interchange; July 30, 2003; SRDB Ref ID: 25014

- Personal Communication, 2007, *Personal Communication with* [redacted]; In-person Interview by ORAU staff; May 15, 2007; SRDB Ref ID: 92798

- Personal Communication, 2008, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; May 14, 2008; SRDB Ref ID: 44428

- Personal Communication, 2009, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; February 2, 2009; SRDB Ref ID: 59674

- Personal Communication, 2012a, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 12, 2012; SRDB Ref ID: 116217

- Personal Communication, 2012b, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 12, 2012; SRDB Ref ID: 116218

- Personal Communication, 2012c, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 13, 2012; SRDB Ref ID: 116008

- Personal Communication, 2012d, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 13, 2012; SRDB Ref ID: 116009

- Personal Communication, 2012e, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 21, 2012; SRDB Ref ID: 116210

- Personal Communication, 2012f, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 21, 2012; SRDB Ref ID: 116211

- Personal Communication, 2012g, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 22, 2012; SRDB Ref ID: 116666

- Personal Communication, 2012h, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; June 26, 2012; SRDB Ref ID: 117164

- Personal Communication, 2012i, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; July 9, 2012; SRDB Ref ID: 116671

- Personal Communication, 2012j, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; July 9, 2012; SRDB Ref ID: 116672

- Personal Communication, 2012k, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; July 18, 2012; SRDB Ref ID: 116677

- Personal Communication, 2012l, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; August 10, 2012; SRDB Ref ID: 117245

- Personal Communication, 2012m, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122515

- Personal Communication, 2012n, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122516

- Personal Communication, 2012o, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122517

- Personal Communication, 2012p, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122550

- Personal Communication, 2012q, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122551

- Personal Communication, 2012r, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122553

- Personal Communication, 2012s, *Personal Communication with* [redacted]; In-person Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122666

- Personal Communication, 2012t, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122667

- Personal Communication, 2012u, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122668

- Personal Communication, 2012v, *Personal Communication with* [redacted]; In-person Classified Interview by ORAU staff; November 6, 2012; SRDB Ref ID: 122669

- Personal Communication, 2013a, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 15, 2013; SRDB Ref ID: 122627

- Personal Communication, 2013b, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 15, 2013; SRDB Ref ID: 122628

- Personal Communication, 2013c, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 16, 2013; SRDB Ref ID: 122624

- Personal Communication, 2013d, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 18, 2013; SRDB Ref ID: 122625

- Personal Communication, 2013e, *Personal Communication with* [redacted]; In-person Interview by ORAU staff; January 22, 2013; SRDB Ref ID: 122623

- Personal Communication, 2013f, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 22, 2013; SRDB Ref ID: 122629

- Personal Communication, 2013g, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 23, 2013; SRDB Ref ID: 122626

- Personal Communication, 2013h, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 31, 2013; SRDB Ref ID: 122670

- Personal Communication, 2013i, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; January 31, 2013; SRDB Ref ID: 122671

- Personal Communication, 2013j, *Personal Communication with* [redacted]; In-person Interview by ORAU staff; February 5, 2013; SRDB Ref ID: 122466

- Personal Communication, 2013k, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 4, 2013; SRDB Ref ID: 122805

- Personal Communication, 2013l, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 4, 2013; SRDB Ref ID: 122806

- Personal Communication, 2013m, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 4, 2013; SRDB Ref ID: 122807

- Personal Communication, 2013n, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 5, 2013; SRDB Ref ID: 122808

- Personal Communication, 2013o, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 14, 2013; SRDB Ref ID: 122907

- Personal Communication, 2013p, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 7, 2013; SRDB Ref ID: 123337

- Personal Communication, 2013q, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; March 11, 2013; SRDB Ref ID: 123762

- Personal Communication, 2013r, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; July 18, 2013; SRDB Ref ID: 126995

- Personal Communication, 2013s, *Personal Communication with* [redacted]; Telephone Interview by ORAU staff; August 20, 2013; SRDB Ref ID: 127272

- Personal Communication, 2013t, *Personal Communication with* [redacted]; email to ORAU staff; September 18, 2013; SRDB Ref ID: 127751

- Worker Outreach Meeting, 2012a, *Colorado Worker Outreach Meeting with former RFP Workers 10:00 AM session*; Public outreach meeting by ORAU and NIOSH staff; May 24, 2012; SRDB Ref ID: 117357

- Worker Outreach Meeting, 2012b, *Colorado Worker Outreach Meeting with former RFP Workers 1:15 PM session*; Public outreach meeting by ORAU and NIOSH staff; May 24, 2012; SRDB Ref ID: 117358

- Worker Outreach Meeting email follow-up interchange, 2012c, *Colorado Worker Outreach Meeting with former RFP Workers 10:00 AM session*; Email follow-up with a participant at the public outreach meeting by ORAU and NIOSH staff; Meeting: May 24, 2012, email follow-up interchange: May 25 and 29, 2012; SRDB Ref ID: 118770

Collective Summary of Information Gathered from RFP Interviews

The interviews listed above are referenced, as applicable, within the text of this evaluation report. The collective summary of the information from the interviews and meetings indicate the following:

Tritium Related Information

Six of the interviews were with former employees who worked at RFP prior to the 1973 tritium incident.

- As a normal practice, RFP did not handle or process tritium and did not expect to have tritium-contaminated materials on site (other than tritium targets for neutron generators).

- Although they may not have been as effective, instruments for monitoring for tritium existed from the very early years at the site, including sniffers, vibrating reed instruments, and air bubblers.

- The site performed environmental monitoring for tritium, including the periods prior to the 1973 incident, with no positive results that personnel could recall.

- There were limited tritium bioassay samples performed at RFP prior to the 1973 incident; there were no known positive bioassays other than those associated with the 1973 incident.

- Radiological surveys were performed at the site that included periodic tritium smears.

- The 1973 incident involved tritium-contaminated materials from Livermore (described as pits and scrap materials) and resulted in personnel exposures, which resulted in a program change regarding tritium at the site.

Thorium Related Information

- Interviews related to thorium were focused on thorium strikes, which were directly related to U-233.

U-233 Related Information

- Interviews related to thorium were focused on thorium strikes, which were directly related to U-233.

- Some interviewees said that multiple thorium strikes may have occurred before U-233 processing;

- Other interviewees had heard about the presence of thorium on site, but did not know what a thorium strike was.

Np-237 Related Information

- Neptunium bioassay may have been performed in the Building 771 (operations area) laboratory prior to the early 1980s.

- There were written manuals for the Building 123 HS&E laboratory that were published and exchanged between the laboratories located in different buildings; however, outdated procedures were not archived prior to the early 1980s.

- Gross alpha analysis was used for early assessments of uranium and plutonium exposures and was not intended as a screening analysis for workers exposed to other radionuclides.

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (referred to as NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of September 12, 2013)

Table 4-1: No. of Rocky Flats Claims Submitted Under the Dose Reconstruction Rule	
Description	**Totals**
Total number of claims submitted for dose reconstruction[1]	1963
Number of dose reconstructions completed for energy employees who worked during the period under evaluation (April 1, 1952 to December 31, 2005) (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	1519
Number of additional claims identified as SEC Pulled (i.e., pulled from NIOSH by the Department of Labor for final approval).	82
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	1507
Number of claims for which tritium bioassay records were obtained for the identified years in the evaluated class definition	128
Number of claims for which thorium bioassay records were obtained for the identified years in the evaluated class definition	2
Number of claims for which uranium[2] bioassay records were obtained for the identified years in the evaluated class definition	1028
Number of claims for which Np-237 bioassay records were obtained for the identified years in the evaluated class definition	1
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	1638

[1] Table 4-1 totals comprise all RFP claims listed in NOCTS, including those that may be covered by other existing SECs.
[2] Although one focus of this evaluation is U-233, it is unlikely there will be U-233 bioassay identified; it is more likely that bioassay would be identified as uranium.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. 4106 documents in this database were identified as pertaining to Rocky Flats. These documents were evaluated for their relevance to this petition. The documents include historical background on air monitoring, urinalysis data, the radiological control program, process materials, and process description.

4.6 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following document submitted by the petitioners:

- *Affidavit from* [redacted]; October 31, 2011; DSA Ref ID: 115186, pdf p. 7 (Affidavit, 2011)

- *Email from* [redacted]; September 29, 2012 and October 1, 2012; Subject: Rocky Flats worker interviews; DSA Ref ID: 119323

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

NOTE: This SEC-00192 Evaluation Report (ER) focuses on RFP worker exposures to tritium, thorium, U-233 and associated progeny, and neptunium. However, during the feasibility evaluation for SEC-00192 Rev. 0, NIOSH concluded that a review of SEC-00030 issues and their subsequent resolutions and closures should be documented in this report. This review is provided in Section 7.5. This report is specific to the assessment of tritium, thorium, U-233 and associated progeny, and neptunium. For discussions and assessments that cover RFP exposures above and beyond those exposures, refer to the SEC-00030 Evaluation Report. Discussion of topics beyond those discussed in Section 7.5 will not be included in this ER.

The following subsections summarize tritium, thorium, U-233, and neptunium operations at the Rocky Flats Plant (RFP) from April 1, 1952 to December 31, 2005, and the information available to NIOSH to characterize those particular processes and radioactive source quantities. From available sources NIOSH has attempted to gather process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 Rocky Flats Plant and Process Descriptions

The Rocky Flats Plant was located in Golden, Colorado on a 384-acre site, surrounded by a ~6000-acre buffer zone (RFP Overview, 2001; RFP Overview, 2011). The workforce grew from a little over 100 people at the beginning of the site's covered period to just over 6000 in 1990. After the site ended operations and entered its remediation phase, the workforce began to decrease from the 1990 employment levels until site closure in 2005. While the previous Rocky Flats Plant SEC evaluation, SEC-00030, assessed potential exposure issues (see Section 7.5 of this report), other issues have been brought up during discussions with the Board working group and petitioner requiring additional research and evaluation. Consequently, this SEC-00192 evaluation focuses on those operations/activities with the potential for tritium, thorium, U-233, and neptunium exposures; therefore, only those locations and operations with the potential for those exposures will be discussed in this report.

As previously discussed in the SEC-00030 ER, RFP site construction began in 1951 and initial radiological operations began in April 1952. The primary missions and general activities at the plant initially began with uranium production and shifted in the 1960s to plutonium production, which continued through 1989 when the U.S. Department of Energy (DOE) suspended plutonium operations. From the beginning, the plant was a manufacturing facility making and recycling nuclear and non-nuclear components for a portion of the U.S. nuclear weapons arsenal.

In 1989, DOE suspended plutonium processing to review and upgrade the plant's safety systems. Although the site continued to prepare for restart after the 1989 shutdown, the Rocky Flats production mission ended permanently in 1992 and entered a site clean-up and remediation phase. In 1993, the Secretary of Energy formally announced the end of nuclear production at Rocky Flats. In 1994, the last defense production-related shipment left the site. The RFP site remediation was completed and the site officially closed in October 2005.

Table 5-1 summarizes the site's development.

Table 5-1: Rocky Flats Plant Development Chronology and Population Over Time			
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.	Approximately 1200 (ChemRisk 3&4, 1992, Figure 3-4, p. 50)
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 the 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.	Approximately 1500 (ChemRisk 3&4, 1992, Figure 3-4, p. 50)
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.	Plant population had grown to over 10,000 (including contractors and subcontractors) by the very early 1990s (Personal Communication, 2013t). Announcement in workforce reduction to ~4,000 by October, 1995. As of 1999, there were 280 DOE employees and 3410 contractors at the RFP site (RFP Overview, 2001).

5.1.1 Tritium Related Operations

Rocky Flats dealt with pits or primary triggers for three different weapons types/pits over its history. The first two, which are the designs associated with pure fission devices (like those used in the "Fat Man" and "Little Boy" weapons), were handled through 1957 until those designs were phased out for improved, boosted fission or thermonuclear designs. The latter designs may have incorporated materials like tritium; however, operations involving coupling tritium with pits were performed at other sites (ChemRisk 3&4, 1992, p. 45.). Since 1958, pit designs at RFP remained relatively the same (ChemRisk 3&4, 1992, p. 47). Around the time of this change at RFP, the AEC began revising the weapons program so that each site focused on specific operations instead of maintaining the same production operations at multiple sites. RFP dropped most of its uranium operations as a part of this program change and became primarily focused on the plutonium pit operations (in the late 1950s and early 1960s). The program changes included construction and transformation of facilities to handle returned plutonium pits (including methods to remove Am-241 from the weapons-grade plutonium). Although it appears that the main focus of site operations shifted at the end of 1957 (ChemRisk 3&4, 1992, pp. 45-61; RFP Operations Overview, 1996, pdf pp. 11-12), NIOSH's follow-up research findings indicate that tritium-contaminated material in a form similar to the Lawrence Livermore Laboratory (LLL, now LLNL)[4] materials associated with the 1973 incident, as well as pits in the form of returns contaminated with tritium, were in existence in the MED/AEC complex in the early 1950s, although there is no documented indication that those materials existed at RFP prior to 1957, and most likely, not until the late 1960s. As discussed in the 1994 ChemRisk report for Rocky Flats, a conservative assumption would be that the release of tritium from similar operations could have occurred since the time that RFP plutonium operations commenced in 1953 (LLNL Parts, 2012; Review, 2012b; ChemRisk 5, 1994, Page 119).

The main plutonium sources at RFP during the late 1950s included plutonium from Hanford and Savannah River Site (SRS), and pits from retired nuclear weapons from the Pantex Plant (ChemRisk 3&4, 1992, pp. 45-61; RFP Operations Overview, 1996, pdf pp. 11-12). Although the transuranic radioactive materials on site could have been responsible for the generation of tritium as a result of neutron interactions (mentioned below), the site deemed that the most significant source of personnel exposure was tritium-contaminated materials associated with plutonium returns.

RFP also took over the AEC's manufacture of stainless-steel tritium reservoirs in 1964. This occurred when the AEC shifted the contract from the American Car and Foundry Corporation in Albuquerque to RFP because of contract and economic reasons (ChemRisk 3&4, 1992, p. 54). It should be noted that although RFP manufactured these highly-technical components, they sent the tritium reservoirs to other locations for final assembly; therefore, although it was related, this work did not constitute a tritium activity at RFP (Tritium Reservoirs, 2012).[5]

The nature of the weapons work at Rocky Flats, and the specific weapons materials involved, resulted in the handling of tritium sources and the potential cross-contamination of materials, such as the materials associated with the 1968, 1973, and 1974 incidents discussed in the following section. The site's assessment indicates that these potential sources existed from the beginning of plutonium operations at the site through the end of site operations (ChemRisk 3&4, 1992; ChemRisk 5, 1994, p. 119; RFP Overview, 2001, pdf p 5). This tritium was associated with, and the result of, the receipt and reprocessing of contaminated weapons components and related waste or return products/materials sent to the site from other AEC/DOE facilities. The disassembly and reprocessing of these components had the potential to introduce tritium into air and wastewater streams, and in several documented cases, resulted in site environmental releases (Worker Outreach Meeting, 2012b).

[4] Lawrence Livermore Laboratory is now called Lawrence Livermore National Laboratory (LLNL). The historical source documents used for this evaluation refer to LLL; this report will refer to LLNL from here on.
[5] Classified references at OSTI supporting the conclusions of this document include: (1) P.L. Sturgill, "SP-949SL Fill Fitting Weld. (U)", LMfg-85-008, Rockwell International , 1985, and (2) R.W. Nokes, "Characterization of the SP830. (U)", CD71-101, Dow Chemical Company , Jan. 05, 1971.

Other Potential Tritium Sources

Another known tritium-related operation was associated with neutron generator targets starting in 1963 (Tritium Release, 1973, pdf p. 68). As reported in a 1973 incident follow-up report, the site had two types of Cockcroft-Walton neutron generators, one incorporating a sealed-tube target and one incorporating a drift-tube target. Neutron generators were located in five different locations on site (Neutron Generators, 1973): Building 886 (1963-1987) (Critical Mass Lab, 2011; Tritium Release, 1973); Building 991 (1969-1976) (Building 991, 2011; Tritium Release, 1973); Building 881 (1969-the late 1980s) (Analytical Reports, 1985-86; Building 881, 2011; Tritium Release, 1973); Building 444 (1969-1971) (Building 444, 2011; Tritium Release, 1973); and Building 123 (1964-1980s/1990s) (Building 123, 2011; Decommissioning, 1997; Tritium Release, 1973). As of the 1973 incident assessment, the site had purchased 241 Ci of tritium containing targets. Based on documentation from the site (Target Changes, 1971) regarding sealed-tube type neutron generators, maintenance could only be performed by a factory-authorized maintenance person in order to keep the warranty on the equipment valid. This was specific to maintenance on the head where the tritium target was installed (in a glass tube at a vacuum). Users/operators did, however, handle and replace the tritium targets in the drift-tube type units. Tritium contamination was also a concern in the neutron generator support systems, specifically the vacuum-pump system and the cooling-water system (Tritium Release, 1973).

There was also the potential to produce tritium at the site under normal conditions considering the various radioactive materials present (Tritium Release, 1973). Other sources discussed in the RFP Tritium release document (Tritium Release, 1973) were assessed but determined not to be a significant source or contributor to the overall tritium source term at Rocky Flats (Tritium Release, 1973).

Table 5-2 summarizes the key processes with the potential for tritium exposures. All processing buildings were demolished as of October 2005.

Table 5-2: RFP Key Facilities with Potential Tritium Exposures
(This table spans four pages)

Buildings	Facilities	Date of Start-up of Operations	Comments
122	**Medical Services Facility:** This facility included a radiological decontamination facility with the potential for tritium contamination.	1953	Tritium Release, 1973, Fig VI-1, indicates Bldg 122 and 123 were in the waste transfer stream that had a potential for tritium exposures. Also see reference: Building 122, 2011, Facility Description.

Table 5-2: RFP Key Facilities with Potential Tritium Exposures (This table spans four pages)			
Buildings	**Facilities**	**Date of Start-up of Operations**	**Comments**
123	**Analytical Health Physics Laboratory:** This facility contained a neutron generator with tritiated targets.	1953	Tritium Release, 1973, Fig VI-1, indicates Bldg 122 and 123 were in the waste transfer stream that had a potential for tritium exposures. Tritium Release, 1973, pdf p. 75, indicates Bldg 123 neutron generator tritium source exposures for dosimetry studies. Reference: Building 123, 2011has a facility description.
374	**Waste Water Facility:** Waste waters contaminated with tritium were evaporated in this facility.	1970s	ChemRisk 3&4, 1992, p. 130, indicates tritium exposure.
440	**Modification Center Receiving:** Received tritium-contaminated scrap.	1960s	Tritium Release, 1973, Fig 1-1 p. 98, indicates Bldg 440 received scrap. ChemRisk 3&4, 1992, pp. 55-57 shows Bldg 440.
444	**DU and Beryllium Metallurgy:** This facility contained a neutron generator with tritiated targets. Titanium stripping began in 1987; the U foundry shut down in 1989.	1953	Tritium Release, 1973, Fig 1-1, indicates Bldg 444 as a potential location with tritium exposures. Tritium Release, 1973, Fig VI-1, indicates Bldg 444 was in the waste transfer stream that had a potential for tritium exposures. Reference Tritium Release, 1973, pdf p. 75, indicates Bldg 444 neutron generator tritium source exposures.
559/561	**Plutonium Analytical Lab:** Pu analytical laboratory operations are a possible source of tritium emissions from processing product. Building 561 contained the exhaust plenums for Building 559.	1968	Tritium Release, 1973, Fig VI-1, indicates Bldg 559 was in the waste transfer stream that had potential for tritium exposures. ChemRisk 3&4, 1992, p. 130.
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. These operations had the potential for tritium contamination. Bldg. 707A was added as part of a 1972 modification.	1972	Tritium Release, 1973, Fig VI-1 indicates Bldg 707 was in the waste transfer stream that had potential for tritium exposures. ChemRisk 3&4, 1992, p. 130
771/774	**Pu Recovery and Liquid Waste Treatment Building:** Bldg. 771 was designed for Pu recovery from scrap/residue materials. Bldg. 774 was used for low-level liquid waste treatment operations. Both had the potential for tritium contamination.	1953	Tritium Release, 1973, Fig 1-1 indicates Bldg 771 was where oxide residue was sent. Indicates 774 was location of Storage Tank 207. Tritium Release, 1973, Fig VI-1, indicates Bldg 771 and 774 were in the waste transfer stream that had potential for tritium exposures. ChemRisk 3&4, 1992, p. 130.

Table 5-2: RFP Key Facilities with Potential Tritium Exposures (This table spans four pages)			
Buildings	**Facilities**	**Date of Start-up of Operations**	**Comments**
776/777	**Pu Manufacturing and Assembly Complex:** This complex was the major Pu fabrication and assembly facility. 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 and had the potential for tritium contamination. Bldg. 777 was a foundry operations and coatings facility and also operated as a disassembly and scrap-weighing location with the potential to be the source of the most significant tritium releases at the site (i.e., the highest percentage of the site's overall tritium releases).	1957	Tritium Release, 1973, Fig 1-1 indicates Bldg 777 weighed scrap. Tritium Release, 1973, Fig VI-1, indicates Bldg 776 was in the waste transfer stream that had potential for tritium exposures. ChemRisk 3&4, 1992, p. 130.
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. In the 1950s and 1960s, 778 had a cafeteria in the west end and offices in the east end of the building (Personal Communication, 2013t). It had the potential for tritium contamination.	1957	Tritium Release, 1973, Fig VI-1 indicates Bldg 778 was in the waste transfer stream that had potential for tritium exposures. See also reference Building 778, 2011.
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. Glovebox activities in support of Pu storage included inspection, metal brushing, and repackaging. Hydriding operations performed at the facility to recover plutonium also resulted in tritium releases.	1965	Tritium Release, 1973, Fig 1-1 indicates Bldg 779 was location of Hydriding Lab and waste tank dump to offsite. Tritium Release, 1973, Fig VI-1, indicates Bldg 779 was in the waste transfer stream that had potential for tritium exposures. ChemRisk 3&4, 1992, p. 130.
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 with a potential tritium waste stream. Buildings 867 and 868 contained filter plenums for process exhaust routed from Building 865.	1970	Tritium Release, 1973, Fig VI-1, indicates Bldg 865 was in the waste transfer stream that had potential for tritium exposures.
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 U-233 and Pu were also handled. The facility contained a neutron generator with tritiated targets.	1953	Tritium Release, 1973, Fig 1-1, indicates Bldg 881 as a potential location with tritium exposures. Tritium Release, 1973, Fig VI-1, indicates Bldg 881 was in the waste transfer stream that had potential for tritium exposures. Tritium Release, 1973, pdf p. 75, indicates Bldg 881 neutron generator tritium source exposures.

Table 5-2: RFP Key Facilities with Potential Tritium Exposures
(This table spans four pages)

Buildings	Facilities	Date of Start-up of Operations	Comments
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. Some indication of work with tritium shells (breaking up shells).	1957	Tritium Release, 1973, Fig 1-1, indicates Bldg 883 as a potential location with tritium exposures. Tritium Release, 1973, Fig VI-1, indicates Bldg 883 was in the waste transfer stream that had potential for tritium exposures.
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. More than 1,600 criticality experiments were performed. 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. The facility contained a neutron generator with tritiated targets.	1965	Tritium Release, 1973, Fig VI-1, indicates Bldg 886 was in the waste transfer stream that had potential for tritium exposures. Tritium Release, 1973, pdf p. 75 indicates Bldg 886 neutron generator tritium source exposures
889	**Equipment Repackaging and Decontamination Facility:** Potential for tritium contamination.	Late 1960s	Tritium Release, 1973, Fig VI-1, indicates Bldg 889 was in the waste transfer stream that had potential for tritium exposures. See also reference Decontamination, 1997.
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. There was the potential for tritium contamination at these locations as the collection point for other facility discharges.	1957	Tritium Release, 1973, Fig 1-1, indicates Pond 207A as a potential location with tritium exposures. Tritium Release, 1973, Fig VI-1 indicates the 207 ponds were in the waste transfer stream that had potential for tritium exposures.
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. The facility contained a neutron generator with tritiated targets.	1952	Tritium Release, 1973, pdf p. 75, indicates Bldg 991 neutron generator tritium source exposures.
995	**Sanitary Sewage Treatment Facility:** There was the potential for tritium contamination at this location as the collection point for other facility discharges.	unknown	Tritium Release, 1973, Fig VI-1, indicates Bldg 995 was in the waste transfer stream that had potential for tritium exposures.

5.1.2 Thorium Related Operations

Thorium was present at Rocky Flats Plant facilities starting from the beginning of operations in 1952, at least through 1975, with quantities varying from 0 or gram quantities to 238 kilograms in any one month at the site (ChemRisk 3&4, 1992, pdf p. 136; Thorium Bounding, 2008; RFP, 1976). The site used thorium in various ways including:

- Fabrication of metal parts from natural thorium or thorium alloys

- Use of oxide ("thoria") as a mold-coating compound

- In compounds used in numerous analytical procedures and research and development programs.

- As a substitute for U or Pu components in various research and development activities and programs.

- The removal of Th-228 (referred to as a thorium strike performed during U-233 processing – to be discussed in that section of this report).

- Mg-Th alloy work is being assessed and addressed as part of a follow-up being performed outside the scope of this evaluation; therefore, further discussion of that operation is not included in this report.

While the consensus of the contributors and authors of the thorium reference documents was that the quantities and concentrations of thorium on site over the years at RFP were minimal, there was the potential for thorium exposures to certain populations on site. The available documentation supports the existence of thorium on site in the early 1950s through the development of internal and external thorium-monitoring processes (Monthly Reports, 1956-1957; Monthly Progress Reports, 1953-1963; Monthly Progress Reports, 1958).

Table 5-3 summarizes the key processes with the potential for thorium exposures. All processing buildings were demolished as of October 2005.

Table 5-3: RFP Key Facilities with Potential Thorium Exposures			
Buildings	**Facilities[1]**	**Date of Start-up of Operations**	**Comments**
331	**Plant Garage: Building 331** was the location of shearing small quantities of thorium. Handled ~240 kg (3 80 kg ingots).	1960	Thorium Bounding, 2008, indicates thorium exposure.
334	**Maintenance Shop: Building 334** was the location of shearing small quantities of thorium.	unknown	ChemRisk 3&4, 1992, p. 136, indicates thorium exposure.
771	**Special Recovery Laboratory: Bldg. 771** was used for some small scale thorium work of an unspecified nature, using a few kilograms of thorium.	unknown	ChemRisk 3&4, 1992, p. 136, indicates thorium exposure.
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 U-233 and Pu were also handled. The facility contained a neutron generator with tritiated targets.	1950s and 1960s	ChemRisk 3&4, 1992, p. 136; RFP, 1994b, pg 164, indicates thorium exposure.
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. Handled ~240 kg (3 80 kg ingots).	1960	Thorium Bounding, 2008, indicates thorium exposure.

[1] Inventory numbers are included in Table 5-3; however, these numbers are not reflective of RFP throughput for any particular time period or year at the site. Inventory numbers for U-233 are provided in Table 5-5.

5.1.3 U-233 Related Operations

The U.S. government evaluated materials that could serve as alternative sources of nuclear fuels for weapons and reactors. One of the alternative sources identified was uranium-233. U-233 was produced as a transmutation of thorium when thorium is placed in a reactor neutron flux. It was also concluded that U-233 could be more easily separated from thorium than U-235 could be separated from U-238. While there were many advantages to the thorium fuel cycle, a major disadvantage was the generation of U-232, which was a contaminant in the production of U-233. U-232 has decay products that emit highly-energetic gammas, which pose a significant personnel external radiation hazard (Buildings 9205 and 9212, 1964; Building, 9202, 1974; ORNL, 1998, pdf pp. 17-20; RFP, 1965b; Thorium U-233 Symposium, 1958). One solution for removing the source of the highly-energetic gammas was to remove the Th-228, which occurs at a point in the decay scheme before the primary sources of the highly-energetic gammas. This Th-228 removal process was called a “thorium strike” (Dow, 1965, pdf p. 13).

Shipments of U-233 residues were sent from Oak Ridge to RFP for processing. Based on the available documentation, U-233 operations and refining also took place at Hanford, SRS, INEEL, ANL-W, LANL, and LLNL (which also used fuel from several commercial nuclear power plants). Several other national laboratories had small research quantities of U-233 (SRDB 117226). Available data indicate that RFP activities involving U-233 residue processing occurred between 1964 and 1983 (Dow, 1972; RFP, 1999).

5.1.4 Np-237 Related Operations

Neptunium processing at Rocky Flats included preparation of pure neptunium oxide, metal and metal alloys, and the recovery of Np-237 from a variety of residues (Conner, 1981, pdf p. 6). Processes employed included dissolution, anion exchange, precipitation, filtration, calcination, conversion to fluoride, and reduction to metal. Fabrication steps such as casting and rolling were also sometimes performed for the production of high-purity metal shapes and foils. Neptunium was recovered from residual materials including sand, slag, crucibles, casting skulls, and alloys (Np-Sn, Np-U, and Np-Zr).

The first special-order request for neptunium processing at Rocky Flats came from Lawrence Radiation Laboratory (now Lawrence Livermore National Laboratory, LLNL), which required high-purity neptunium with gamma-emitting impurities removed. Techniques for purifying neptunium (including the removal of other actinides) were developed as a result of this project. The project also called for preparation of Np-Pu alloys, which were prepared by co-reducing Np and PuF_4 mixtures with calcium metal. This technique led to a capability for producing pure Np metal that could be cast with Pu or U to form alloys. The first Np-Pu alloy was produced in 1964, and several kilograms of Np metal were produced in subsequent years for preparing U and Pu alloys. Other specific projects that involved Np processing included the preparation of high-purity neptunium oxide for the Oak Ridge National Laboratory isotope pool, neptunium metal foils for the Savannah River Plant, and neptunium metal disks for use in the liquid-metal, fast-breeder-reactor, neutron dosimeter program (Conner, 1981, pdf pp. 6-7).

Some early neptunium work was conducted in open hoods, but most was performed in "alpha containment" glove boxes in general-purpose research facilities. The first hydrofluorination equipment used for neptunium consisted of a glove box used to load NpO_2 into reaction "boats," and several open hoods enclosing the front portion of the hydrofluorination furnaces. A second system used for this purpose was smaller and enclosed in a glove box, limiting batch sizes to 110 g of NpO_2. These first hydrofluorination systems (which were originally designed for applications other than neptunium processing) were subsequently replaced with a glove-box-enclosed system specifically designed for converting small batches ($\leq$100 g) of NpO_2 to NpF_4 (Conner, 1981, pdf pp. 20-23).

A typical glove box for aqueous Np processing consisted of a "wet" section (for aqueous processes) and a "dry" section (for calcining precipitates and weighing powders) separated by an air lock. Each section had separate air inlet and exhaust filters. A door in the air lock was used to pass equipment and material between the wet and dry sections. A ⅛-inch-thick lead sheet was bonded to the stainless steel portion of the glove box and ¼-inch leaded glass was placed over the glove box windows as a shield against gamma radiation from the neptunium and its impurities (Conner, 1981, pdf pp. 7-8). Radiological impurities in neptunium included other actinides, primarily Pu isotopes. Occasionally, neptunium contaminated with thorium (typically 200 ppm – 2,000 ppm) was processed. One 343-g batch of NpO_2 with 3% thorium by weight was processed (Conner, 1981, pdf p. 18).

Neptunium metal was produced by reduction of NpF_4 with calcium metal and iodine in a sealed reaction vessel (Conner, 1981, pdf pp. 24-26). This thermite process, used to produce 10 g - 400 g batches of Np, was initially performed in the same area as the first hydrofluorination runs using the same glove box and hoods employed for loading the hydrofluorination "boats." The operation was later moved to reduction furnaces enclosed in glove boxes. Vessels for four charge sizes were used: 15 g scale (for charge sizes containing 10 g – 15 g of Np), 50 g scale (16 g – 50 g of Np), 100 g scale (50 g – 110 g of Np), and 500 g scale (125 g – 400 g of Np).

Neptunium metal-casting techniques were similar to those for plutonium because of the similar melting points of the two elements. A tilt-pour casting technique was used for metal shapes with thicknesses exceeding 0.040 inch. Injection casting was used for thicknesses of 0.010 inch (Conner, 1981, pdf p. 29). Hot-rolling of Np ingots heated to 310 ^{0}C was initially used to produce foil thicknesses <0.010 inch; however, once process development was completed, injection casting proved superior and replaced rolling for Np foil production. Hot rolling required care to avoid problems such as edge-cracking of the ingots, and the high temperature required for pre-heating and rolling the ingot resulted in vaporization of the silicon oil, which condensed on the glove box walls, windows, and equipment inside the box (Conner, 1981, pdf pp. 33-34).

5.2 Tritium Exposure Sources, Radiological Programs, and Incidents

NOTE: This SEC-00192 Evaluation Report (ER) focuses on RFP worker exposures to tritium, thorium, U-233 (and associated progeny), and neptunium. However, during the feasibility evaluation for SEC-00192 Rev. 0, NIOSH concluded that a review of SEC-00030 issues and their subsequent resolutions and closures should be documented in this report. This review is provided in Section 7.5. This report is specific to the assessment of tritium, thorium, U-233 (and associated progeny), and neptunium. For discussions and assessments that cover RFP exposures above and beyond those exposures, refer to the SEC-00030 Evaluation Report. Discussion of topics beyond those discussed in Section 7.5 will not be included in this ER.

Tritium is a radioactive isotope of hydrogen with a mass number of 3. It has a half-life of 12.262 years and emits an 18 keV E_{max} (~6 keV E_{avg}) beta particle, with no other emissions. In the form of tritiated water (HTO), it will distribute uniformly throughout water-based body fluids. Because of the low energy of the beta particle, the dose is primarily an internal exposure concern where the dose to the whole body is equivalent to any particular organ dose.

The potential for tritium exposures from RFP operations involving tritium-contaminated materials (e.g., materials associated with the 1968, 1973, and 1974 incidents) existed from the beginning of operations to the end of operations in 1989 (ChemRisk 3&4, 1992; ChemRisk 5, 1994, p. 119; RFP Overview, 2001, pdf p 5). This tritium was associated with, and the result of, the receipt and reprocessing of tritium-contaminated weapons components returned to the site. For the most part, in cases prior to 1973, the site did not consider tritium a potential source of exposure as an equipment/material contaminant; therefore, there was not a significant monitoring program prior to the 1973 incident.

Other known tritium sources, associated with neutron generator targets, were brought on site beginning in 1963 (Tritium Release, 1973, pdf p. 68). As of the 1973 incident assessment, the site had purchased 241 Ci of tritium-containing targets. The site's assessment concluded that the release of the entire amount of tritium from all of the targets would be necessary to produce a significant exposure from the targets (a scenario that is not evident from the available information) (Release Investigation, 1973). The site concluded, and NIOSH concurs, that this source is not a significant tritium source from the perspective of a bounding exposure at RFP.

As part of its evaluation of tritium sources, the site also reviewed operations with the potential to produce tritium as a result of radiation interactions. The site concluded that the most likely and significant source of this tritium was associated with radiation interactions involving materials such as plutonium, boron, beryllium, and nitrogen. Two estimates were provided based on two evaluations performed in the early 1970s. The first estimate based on this source term determined that approximately 0.2 Ci/yr could have been produced with a worst-case production rate of 3.2 Ci/yr (although the worst-case conditions were considered unrealistic) (Tritium Release, 1973, pdf p. 70). A follow-up estimate was based on the assessment of six possible sources with a result of 5.4E-12 Ci/day (approximately 2.0E-9 Ci/yr), which was much closer to the site's measured background levels at the time (Tritium Release, 1973, pdf p. 70). The site's conclusion was that this was not a significant tritium production/emissions source at RFP from the perspective of personnel chronic exposures (Tritium Monitoring History, 1973). NIOSH evaluated this issue and concurred with the site's conclusion.

In response to the Board review of Rev. 0 of this SEC-00192 evaluation report, NIOSH conducted a follow-up research and evaluation effort to respond to issues identified during the Board's review. As part of the follow-up, additional document data captures and personnel interviews were performed (classified and unclassified). In addition to follow-up on the existence of tritium on site and associated personnel exposures, the effort also focused on the specific areas of tritium bubbler sampling, shipping container tritium surveys, and sampling analysis performed in Building 123. These follow-up efforts were performed to validate the tritium bounding method for the SEC-00192 RFP ER (which uses information from the 1973 tritium incident as the maximum exposure scenario), and to provide more precise estimates of doses due to tritium.

5.2.1 Exposure Sources from Tritium Operations

Based on its assessment of RFP operations, NIOSH has concluded that the operations that could have resulted in the most significant personnel exposures to tritium were associated with the receipt and processing of scrap plutonium and returned/retired plutonium pits from other sites. The site received this scrap material and other "special materials" from other sites for the purpose of recovering and recycling usable plutonium. This is the type of material that resulted in the 1973 incident that produced the highest recorded tritium contamination levels at the site. The 1973 tritium-contaminated scrap was received from LLNL and processed over a period of time from April through September of 1973. As a result of the tritium contamination incident, RFP reviewed and revised its material receipt process. RFP records from 1970-1974 indicated that approximately 290 shipments were delivered to RFP (Review, 2012a). Of these shipments, RFP considered the four from LLNL the most likely to have been contaminated with tritium. The estimated levels of tritium contamination in each of the four shipments was: April 1969, 57 Ci; March 1971, 50Ci; December 1971, 29 Ci (Tritium Release, 1973, pdf pp. 68-71); March 1973, 500-2000 Ci. Other potential sources of tritium at RFP were also evaluated and determined to be very small in comparison to the 1973 incident levels (Tritium Release, 1973). This is exemplified in the tritium incidents that resulted in the most significant personnel tritium exposures at the site. The plutonium operations were performed in specific buildings, including Buildings 771 and 776/777. As indicated in the available documentation, the operations associated with the receipt and processing of returns and scrap did not change significantly over the early years until after the tritium incidents of 1973 and 1974.

Evaluation of 1,700 LANL 'site return' pits, retrieved from stockpile for Stockpile Laboratory Test (SLT) Evaluation, normal retirement, or with possible defective or unusual conditions, showed little or no tritium gas in the 18-month period in 1979 and 1980. Tritium gas concentrations in these pits ranged from <15 $\mu Ci/m^3$ to 468 mCi/m^3, with most in the 150 mCi/m^3 - 350 mCi/m^3 range.[6]

Plutonium from site returns was reclaimed by acid dissolution, but parts involved in boost testing were reclaimed by a hydriding process in the Building 779A Hydriding Laboratory. Tritium levels monitored for a 40-day period in 1974 in a glovebox used for hydriding ranged from 50 $\mu Ci/m^3$ to 300 $\mu Ci/m^3$. All other gloveboxes and the glovebox exhaust showed background (10 $\mu Ci/m^3$) levels.[7] Radiography to determine the structural integrity of internal components was a routine part of Stockpile Laboratory Testing and was sufficient to determine that tritium contamination was likely in a pit returned for SLT evaluation in 1984. This pit was returned to LANL for disassembly.[8]

Building 771 was the initial and primary RFP facility constructed for plutonium operations from 1953 through 1957 (when Buildings 776/777 were placed in operation to handle the increased workload). In 1957, RFP installed an americium line in Building 771 to remove Am-241 that had grown into weapons-grade plutonium due to plutonium decay; the americium operation was most likely to involve scrap materials and returns. The americium was considered a significant contaminant in the plutonium from a weapons perspective. The americium product was a major money-maker at the site for some time based on its commercial use in items like smoke detectors. Both buildings (771 and 776/777) experienced fires that resulted in the shift of some operations to other locations. A Building 771 fire in 1957 resulted in the shift of some work to 776/777 (ChemRisk 3&4, 1992), and a Building 776/777 fire in 1969 resulted in the shift of some work to 707 (ChemRisk 3&4, 1992, p. 73).

Although changes in the individual plutonium purification process at RFP occurred over the years, the overall process remained unchanged until 1975, specifically as it related to engineering or plant configuration changes that would affect or control associated tritium exposures (Building 771, 1994). The primary airborne control implemented at the site was the use of HEPA filtration, which was

[6] W.G. Scherer, "Summary Report of LANL Site-Return Pits for July 1979 through December 1980. (U)" CD81-2164, Rockwell International. (Classified Document, OSTI); cited in Review, 2012b, J.S. Bogard, "Review of Classified Documents in OSTI (deleted version)(U).
[7] R.P. DeGrazio, "Tritium Information from August 1 – September 9, 1974. (U)", CD74-3726. (Classified Document, OSTI); cited in Review, 2012b, J.S. Bogard, "Review of Classified Documents in OSTI (deleted version)(U).
[8] A.E. Hodges, III, Report no. CD84-1298, Rocky Flats Plant , March 5, 1984. (Title and document are classified, OSTI); cited in Review, 2012b, J.S. Bogard, "Review of Classified Documents in OSTI (deleted version)(U).

implemented from the beginning of operations in 1953 (ChemRisk 3&4, 1992, p. 66). RFP implemented administrative controls for tritium after the 1973 incident until engineering controls could be implemented in the processes to control potential exposures to tritium-contaminated scrap and materials; the engineering controls were completed in 1975.

Since the beginning of plutonium operations in 1953, RFP continuously upgraded its plant and systems to address the recycling of on-site and off-site scrap materials and returns as well as to align its operations with the different pit designs that RFP handled over the years. These upgrades included installation of the americium line in Building 771 that was associated with the weapons-recycling process. The most significant known source of tritium at RFP was the contaminated scrap materials received from LLNL from 1969-1973 (ChemRisk 3&4, 1992, p. 241; ChemRisk 5, 1994, p. 116). It is assumed that unmonitored levels of tritium are consistent with the 1973 incident levels, which involved the processing of tritium-contaminated materials at RFP over the period from April – September 1973 (i.e., the current maximum basis for tritium at RFP during any period).

5.2.2 Tritium Radiological Programs

Based on the available information reviewed by NIOSH for this evaluation, there were no reported detectable personnel exposures to tritium at RFP prior to the 1973 incident (Neutron Generators, 1973; Personal Communication, 2012a; Personal Communication, 2012f; Personal Communication, 2012g; Worker Outreach Meeting, 2012a). The 1973 incident introduced significant levels of tritium to the RFP that resulted in detectable personnel exposures. Although tritium was present at RFP prior to 1973, it was contained in sealed sources or was believed to be present at levels that did not constitute an exposure concern. Following the 1973 incident, a more rigorous bioassay program was implemented to monitor for potential tritium exposures (Urine Sampling, 1973).

A routine monitoring program was implemented that required that one-tenth of the urine samples taken as part of the Pu and Am monitoring program would be analyzed for tritium (Tritium Monitoring, 1974); however, in September 1975 this program was discontinued "… since not a single sample has measurable tritium during this testing period (1973-1975)". Consequently, the tritium monitoring program was changed to a job-specific program. The program basis document stated that RFP "… does not routinely handle tritium containing materials" (Sampling Program, 1981). The document identified the operations that would be involved in tritium sampling program, which included:

- Operations of neutron generators Building 887 (tritium/tritide targets)
- Operations of Gas Chromatograph Building 881 (tritiated foils)
- Operations of Special Disassembly Systems Building 777 (sealed sources containing tritium)
- Operations in Tritium Surveillance Laboratory Building 777 (incoming shipments)

As a result of these new criteria, workers were identified for participation in a tritium bioassay program typified in RFP memos available to NIOSH (Special Tritium Samples, 1983; Tritium Bioassay Results, 1982). As shown in Table 6-1, NIOSH also has access to RFP sample results for the post-1973 incident period (Tritium Bioassay Results, 1979; Tritium Bioassay Results, 1980; Tritium Bioassay Results, 1981; Tritium Bioassay Results, 1982).

The criteria for job-specific monitoring were subsequently reiterated in RFP procedures and technical basis documents (EG&G, 1991; Routine Bioassay, 1992; Tritium Procedure, 1986). The RFP requirement was that jobs that involved <1 mCi of tritium would not require any tritium bioassay. Jobs that involved >1 mCi of tritium would require a pre-job urinalysis, a weekly urinalysis if the job lasted longer than one week, and a post-job urinalysis, all to be analyzed for tritium. The program also included air sampling and smear surveys of ongoing operations (Tritium Procedures, 1979; Tritium Reports, 1979-1985; Tritium Reports, 1983-1984; Tritium Reports, 1984-1986; Tritium Results, 1974-1982; Tritium Results, 1976-1983; Tritium Smears, 1979; Tritium Smears, 1980; Tritium Smears, 1981).

5.2.3 Tritium Incidents

The most significant tritium exposure incidents being assessed in this evaluation were associated with events from 1968, 1973[9], and 1974, with the 1973 incident being the most significant from the perspective of the amount of tritium involved/released. No documented tritium incidents have been identified relating to the neutron generator targets, but none of those sources were capable of producing the levels associated with the 1968, 1973, and 1974 incidents.

A 500-600 Ci tritium release occurred from a Rocky Flats special project in 1968 (details cannot be relayed due to the classified nature of the work) (Incident Summary, 1976; ChemRisk 3&4, 1992, p. 243). The site's report indicated that there was no significant off-site impact as a result of this incident. Based on NIOSH's review of the information associated with the 1968 incident, as compared to the 1973 incident where releases and personnel exposures did occur, there was no detectable environmental or workplace impact in 1968 because of differences in the chemical form (H3 versus HTO). These differences were the result of the two plutonium-recovery operations at RFP. Normal site returns (the bulk of RFP's reprocessing effort) were processed by acid dissolution in Buildings 776/777. Special returns like the ones from LLNL were processed by hydriding the plutonium in the Building 779A Hydriding Laboratory. The hydriding process for recovering plutonium (presumably having no tritium) involved burning the resulting gases before filtering and release to the atmosphere. Release of any tritium from this process is almost certainly as tritiated water from the final combustion of these gases. So when tritium was present in boost-tested parts, as in the case of the material processed at RFP[10] in 1973, it went up the stack as tritiated water, which very quickly got into the groundwater around RFP and was subsequently detected. The processing of normal site returns by acid dissolution of the plutonium involved no combustion stage so any existing tritium would have been vented out the building exhaust stack without a chemical change. The other evaluated incidents (i.e., the 1968 and 1974 incidents), resulted principally from the failure of tritium reservoirs during disassembly leading to the release of elemental tritium which, in turn, takes much longer to become incorporated into environmental water (Tritium Release (1968), 2012; LLNL Parts,

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[9] Also in 1981: "Investigation Report of Tritium Release Incident, January 6, 7, 1981," Internal letter from K.G. Tallman to R. E. Yoder, CD89-2188, January 16, 1981. (.CRF00079052$, Denver Federal Center)

[10] Classified documents supporting this conclusion include the following: (1) "Extracts from Classified Section of Draft Report to Committee Investigating Rocky Flats Tritium Release (U)," Extracts from CD73-4775, pp 6-7, October 9, 1973 (Extracted from Rocky Flats Classified Document .CRF00041936%); and (2) "Investigation of the Tritium Release Occurrence at The Rocky Flats Plant – Extract," pp. 18-19, October 29, 1973 (Extracted from Rocky Flats Classified Document .CRF00536785R).

2012)[11]. Based on NIOSH's review of the available documentation, there is no other evidence that tritiated plutonium in any significant quantity was ever found in the normal site returns which were recovered by the acid-dissolution method.

In the 1973 incident, tritium-contaminated scrap from LLNL was sent to Rocky Flats for processing (Release Investigation, 1973; Release Investigation, 1974; ChemRisk 3&4, 1992). The material was processed in Building 779A at the site. As a result of the processing, tritium was released to on-site basins and ponds, to the Great Western Reservoir, and to the atmosphere (as a result of hydriding and oxidizing operations). The recovery products were also routed through other locations at the site resulting in the spread of tritium contamination to other worker areas on site. Based on the assessment of the incident, it was estimated that between 500-2,000 curies of tritium-contaminated materials were shipped from LLNL to Rocky Flats for processing.

There were varying levels of tritium exposures based on the site's assessment (Exposure Data, 1973). This incident was initially detected by the Colorado State Department of Health as a result of environmental monitoring around the site. The site had the capability to perform personnel and area monitoring for tritium; however, because it did not handle or process tritium, there was no belief that routine monitoring was needed. Although the site had developed a method of detecting tritium in urine in 1961, the method was maintained on standby and not routinely used to monitor personnel. The site commenced liquid scintillation tritium bioassay monitoring techniques in 1972.

Coincidentally, the site had shifted to a more job-specific sampling program in 1972-1973 because of the lack of positive results and the need to analyze plutonium samples at the site (Tritium Sampling History, 1973). In conducting its environmental monitoring around the site, the Colorado State Department of Health (CDH) identified significantly-elevated tritium levels in waterways surrounding the site. Records indicate that CDH had been conducting environmental monitoring since 1969 (Incident Summary, 1976). The site disputed that it was the source of the tritium until it was finally confirmed later in the year. Since the 1973 incident, the RFP implemented significant improvements in the amount and types of personnel and area monitoring for tritium. NIOSH has reviewed the available CDH environmental monitoring data (which it has found only for 1970-1974) to assess the sequence of events the data represent (Surveillance, 1970-1974). NIOSH determined that the data are representative of an incident occurring in the mid-1973 period with no other indication of a release (such as that in 1973) during the period that CHD was performing environmental monitoring.

The 1974 incident (ChemRisk 3&4, 1992, p. 247) involved the release of approximately 1.5 Ci of tritium from the exhaust system of Building 777. The source of the tritium contamination in the incident was identified to be the opening of an un-surveyed shipping container (called a "pressure cooker") received from Battelle that was found to be contaminated (Building 777 Investigation, 1974). No significant environmental or personnel impact from this incident was identified by the Colorado State Department of Health or RFP as a result of this incident (Building 777 Investigation, 1974).

[11] Classified documents supporting this conclusion include the following: (1) "Investigation Report of Tritium Release Incident, January 6, 7, 1981," Internal letter from K.G. Tallman to R. E. Yoder, CD89-2188, January 16, 1981 (.CRF00079052$, Denver Federal Center); and (2) "Classified Section of Draft Report to Committee Investigating Rocky Flats Tritium Release. (U)",CD73-4775, October 9, 1973 (.CRF-00041936%, Denver Federal Center).

5.2.4 SEC-00192, Rev. 0 Tritium Follow-up

A review of all RFP-related SRDB documents was performed to determine if any documents existed in that dataset that could expand on any of the issues raised by the Board regarding tritium. The documents relating to tritium monitoring at RFP were identified, including some tritium bubbler results, and some indication of tritium contamination surveys. There are multiple documents regarding four significant incident-related tritium releases that occurred in 1968, 1973, 1974, and 1977 (Building 777 Investigation, 1974; Investigation, 1977; Release Investigation, 1973c; Tritium Releases, 1968; Tritium Release, 1973; Tritium Releases, 1976-1983; Tritium Releases, 1987; Tritium Report, 1973). There are also post-1977 documents that confirm continued monitoring of tritium releases and residual tritium as a result of these four earlier releases. There is also an SRDB document that provides information on post-1977 stack releases occurring in 1981 and 1986; both releases were considered small with no impact to site personnel or the immediate surrounding area (Tritium Releases, 1987). While some of the documents corroborated the classified interview issues addressed later in this report (i.e., bubblers and tritium contamination surveys), it does not appear that any of the new information supports the notion that there were any tritium levels that exceeded the 1973 incident.

As stated in Revision 0 of the SEC-00192 ER, RFP operations that were related to, or had potential exposure impacts associated with tritium included neutron generator operations (i.e., the use of tritiated targets), and returned pit operations. Subsequent classified interviews identified shipping container handling as a potential exposure source. The following was learned:

- The follow-up effort corroborated in at least one interview (Personal Communication, 2013o) and in two documents (RFP, 1994a; Review, 2012b) the point made in Revision 0 of the SEC-00192 ER that the stainless steel reservoir operation was a construction operation before the introduction of tritium, which occurred at other sites. RFP was responsible constructing the reservoirs and shipping them to other locations where they were filled/used.

- The follow-up effort corroborated that the neutron generator tritium target sources did not represent a source larger than the one represented in the 1973 tritium incident.

- The tritium-contaminated pits and shipping containers are considered directly related because the shipping container tritium was a result of tritium from the pits loaded in the containers. Because of potential classification issues the assessment of this issue will be addressed later in this report under the more general term Shipping Containers rather than the term Pits.

- A follow-up effort was directed to determine if there are any other scenarios with the potential to exceed the SEC-00192 RFP ER, Rev. 0 bounding approach. These scenarios are assessed as part of the pre-1973 tritium shipping container exposure evaluation in this report.

The indications found in the available documentation, and provided by the majority of interviewees, were that RFP did not work with tritium as a normal or usual process, and therefore, did not expect it on site. The RFP radiological program did very little monitoring for tritium prior to the 1973 incident because they felt they had limited tritium exposure potential. Changes to the program related to tritium monitoring were implemented as a result of the 1973 incident. It has been corroborated that tritium bubbler monitoring did exist on site as part of the usual RFP air monitoring program before and after the 1973 tritium incident (Personal Communication, 2013o); however, the current information does not indicate how long before the 1973 incident bubblers existed on site.

As indicated in Rev. 0 of the SEC-00192 ER, the site implemented a routine tritium bioassay program after the 1973 tritium incident, but discontinued the routine program in 1975 due to lack of positive bioassay results. The program was subsequently implemented on an as-needed or as-identified basis. This implementation process was corroborated in at least one personnel interview performed during this follow-up effort (Personal Communication, 2013o).

5.3 Thorium Exposure Sources, Radiological Programs, and Incidents

Thorium is a soft ductile metal that is also radioactive. It is a long-lived radionuclide that emits alpha particles as part of its radioactive decay. It is found in nature and is commercially used in welding rods, lantern mantles, alloys, and optical glass. When inhaled, the radionuclide delivers dose to a person's lungs before it is assimilated and deposited in the bone.

The potential for thorium exposures from RFP operations existed from the beginning of RFP operations, through the mid-1960s with most thorium inventories off-site by the mid-1970s (ChemRisk 3&4, 1992, pdf p. 136; RFP, 1976; Thorium Bounding, 2008). The Thorium operations were related to special projects, of which limited information and documentation is available because of classification issues associated with the operations and materials.

5.3.1 Exposure Sources from Thorium Operations

Based on the research and review of related thorium operations at RFP, NIOSH has identified that there were thorium related operations with personnel exposure potentials (ChemRisk 3&4, 1992, pdf p. 136; RFP, 1976; Thorium Bounding, 2008). These operations included:

- Fabrication of metal parts from natural thorium or thorium alloys – 3 thorium metal ingots sent to RFP from W.R. Grace for experiments on forming and shaping thorium metal as well as canning the resulting products.

- Use of oxide ("thoria") as a mold coating compound – for a brief period at RFP, experiments involving the use of thoria as a mold coating compound for weapons-grade uranium and plutonium.

- Compounds used in numerous analytical procedures and research and development programs – RFP coordinated with Oak Ridge in several thorium laboratory experiments including use of thorium as a titrating agent, in separation studies, in impurity analyses, and in the conversion of thorium oxide to thorium metal.

- Used as a substitute for U or Pu components in various research and development activities and programs – RFP received pre-shaped/formed thorium parts from Y-12 for use in experiments because of the rarity and higher cost of the Pu and U parts.

- The removal of Th-228 (referred to as a thorium strike performed during U-233 processing – Th-228 at RFP was related to the U-233 operations and existed in the U-233 as the progeny of the U-232 contaminant in the U-233. This operation is discussed further in the U-233 section of this report.

5.3.2 Thorium Radiological Programs

There are some indications that RFP acknowledged the potential for personnel thorium exposures associated with operations and the need to develop personnel internal/external monitoring for the work as early as 1954 (SRDB 24631, page 165). The development of the thorium analysis methods continued through the 1950's and into the 1960's (Monthly Reports, 1956-1957; Monthly Progress Reports, 1958; Monthly Reports, 1960-1961). While some sporadic personnel monitoring results exist for some RFP personnel, no known routine thorium monitoring programs existed at RFP (Thorium Bounding, 2008, pdf p. 4). NIOSH has collected some thorium specific personnel and area monitoring data in the process of its research for the development of this evaluation report (Dosimetry History, date unknown, pdf p. 11; ChemRisk 3&4, 1992, pdf p. 136; Monthly Reports, 1956-1957, pdf p. 116-125); Monthly Progress Reports, 1958 pdf p. 50; Monthly Reports, 1960-1961, pdf p. 8, 72, 96-112); Logbook, 1966-1969, pdf p. 6; Special Analyses Logbook, 1960 [starting pdf p. 20 for 1960, including urine samples starting p. 25]). While some data were available, it was determined that at least some of the results contained in the data were inconclusive (SRDB 25698). It was also determined that gross alpha would not necessarily be representative of the personnel thorium exposures (ChemRisk 3&4, 1992, pdf p. 136).

5.3.3 Thorium Incidents

There are no known thorium incidents in the documentation available to NIOSH.

5.4 U-233 Exposure Sources, Radiological Programs, and Incidents

Uranium-233 is a fissile radioactive isotope of uranium that is part of the thorium fuel cycle. U-233 is produced by neutron irradiation of Th-232. U-233 has a half life of 159,200 years. It is part of the neptunium decay series, decaying via alpha emission to Th-229. U-233 and its progeny are primarily considered internal dose hazards, similar to the naturally-occurring uranium isotopes, U-234, U-235, and U-238.

Production of U-233 also results in the unavoidable production of uranium-232, a problematic contaminant with a half life of 72 years. U-232 decays via alpha emission to thorium-228, a member of the thorium decays series, which subsequently decays to produce several strong gamma-emitting radionuclides. In addition to being an internal dose hazard, U-232 and its gamma-emitting progeny represent a significant external radiation hazard. The purpose of the "thorium strike" operation was to remove Th-228 from U-233, thus reducing the gamma radiation levels.

5.4.1 Exposure Sources from U-233 Operations

Locations of U-233-related operations at RFP are summarized in Table 5-4. Note that the information on 1964 activities, although inconsistent with published reports from the same era (Investigation Summary, 1965), is included because it was based on logbook entries that appear to be factual in terms of early testing operations (Logbook, 1965-1967).

U-233 residues were received and initially processed in Building 771, Room 114. Room 114 is where the thorium strike process took place (Investigation Summary, 1965, pdf pp. 8-9, 17, 44; Incident Reports 2/64 – 5/65, pdf p. 30). Based on information from personnel interviews, the U-233 material at RFP may have gone through several thorium strikes before it was processed to produce U-233, as some material was not immediately processed (Personal Communication, 2013n). The extracted Th-228 was containerized for disposal and shipped to Idaho National Laboratory in Arco, Idaho (Investigation Summary, 1965, pdf p. 81). The uranium was converted to peroxide and then shipped to Building 881 where it was ultimately reduced to U-233 metal. Casting and machining of parts also took place in Building 881, while other fabrication steps were handled in Building 883. By the mid-1970s, work previously performed in Building 881 shifted to the R&D areas of Building 771. It is likely that machining steps also took place in Building 779A. Final component assembly took place in Building 777/777A. Uranium oxides and green salt residues were converted to uranyl nitrate in Building 771 and then shipped back to Oak Ridge or to Lawrence Livermore Laboratory. Wastes from casting and machining were burned in Building 881 and the waste oxides from this and other processes were then converted to a nitrate solution for shipping back to Oak Ridge. The liquid wastes were handled in Building 774 with all low-level wastes being drummed and sent to Idaho for burial (Investigation Summary, 1965; RFP, 1999).

The U-233 process included the following steps (Investigation Summary, 1965):

1. Material received as nitrate solution
2. Thorium strike (thorium fluoride precipitation > peroxide precipitation > UO_4 cake)
3. Conversion (UO_4 > UO_3 > UO_2 > UF_4)
4. Reduction to metal and casting into an ingot
5. Rolling ingot into a sheet and producing part blanks from the sheet
6. Machining
7. Sampling

Table 5-4: Location of Rocky Flats U-233 Activities								
Year	**RFP Building Number**							
	559	**771**	**774**	**777**	**777A**	**779A**	**881**	**883**
1964*		X					X	
1965		X	X	X	X		X	X
1966		X	X	X	X		X	X
1967		X	X	X	X		X	X
1968		X	X	X	X		X	X
1969		X					X	
1970	X	X					X	
1971	X	X					X	
1972	X	X					X	
1973	X	X	X				X	
1974		X	X					
1975		X						
1976	X	X	X					
1977	X	X	X	X	X	X		
1978	X	X	X	X	X	X		
1979	X	X	X	X	X	X		
1980	X	X	X	X	X	X		
1981	X	X	X	X	X	X		
1982	X	X	X	X	X	X		
1983		X	X					

* Information on 1964 based on logbook entries (Logbook, 1964-1967); all other data from RFP, 1999, Table 3.

559: Analytical Laboratories
771: Chemical processing, analytical laboratories, waste processing
774: Waste disposal
777: Non-destructive testing, inspection, manufacturing processing
777A: Assembly
779A: Machining
881: Chemical processing, casting, machining
883: Fabrication

Rocky Flats U-233 operations continued through 1982, with the majority of the remaining U-233 being shipped off site in 1983 (RFP, 1999). The U-233 remaining on site at the end of RFP operations was in the form of contaminated waste materials, which were expected to be disposed of as waste (ORNL, 1998).

Based on the available information, the quantities of U-233 processed at RFP are summarized in Table 5-5.

Table 5-5: Summary of RFP U-233 Quantity Estimated To Be Present at Any One Time		
Time Period	**Quantity (amount/year)***	**Basis and SRDB Ref ID**
1964	47 g	Documented in RFP, 1965b, pdf p. 9.
1965	20 kg	Data contained in Investigation Summary, 1965 indicate the button size to be approximately 2 kg (pdf p. 62), and that nine such buttons were produced (pdf pp. 57, 62), coupled with the presence of four 'boats' of leftover material, each weighing approximately 400-700 g (pdf pp. 7, 26, 72).
1966 – 1968	150 kg	RFP, 1999 states that kilogram quantities of U-233 were received, processed, and shipped between 1966 and 1968. The quantity is based on one-third of the estimated total quantity produced through 1968 in the entire AEC complex, assuming the equal distribution of U-233 between ORNL/RFP, SRS, and Hanford (Building 3019, pdf p. 24).
1969 – 1973	1 kg	RFP, 1999, pdf p. 10 and Dow, 1972 (for 1972) indicate quantities < 1 kg during this period.
1974 – 1977	10 kg	RFP, 1999 states that during 1974 – 1977, kg quantities of U-233 arrived and were processed at RFP. RFP, 1978a indicates that 530 g of $^{233}UF_4$ were used for each of 8 castings performed for a total of ~5 kg.
1978 – 1983	1 kg	RFP, 1999 indicates quantities < 1 kg during this period.

* The presented values are based upon review of readily available unclassified documents. The quantities presented, therefore, may not be bounding or reflect actual throughput. Exact quantities are not provided due to classification issues.

Material characteristics based on the available data are summarized in Table 5-6.

Table 5-6: Characteristics of U-233 Material Processed at RFP		
Applicability	**Summary**	**Basis and SRDB Ref ID**
1964	2.5 years old, 42 ppm U-232	Documented in RFP, 1965b.
1965	90 days old, 50 ppm U-232	RFP, 1999 states that U-233 processed in 1965 contained approximately 50 ppm U-232. Documentation from the period indicates that material would be processed for thorium recovery if not shipped in 90 days (Thorium U-233 Shipping, pdf pp. 10-11). During interviews with many former RFP workers, several of them indicated that thorium strikes were periodically performed to clean up material (Investigation Summary, 1965; Personal Communication, 2012m; Personal Communication, 2012n; Personal Communication, 2012o; Personal Communication, 2012s; Personal Communication, 2013n).
1966 – 1982	90 days old, 8 ppm U-232	RFP, 1999 states that U-233 operations subsequent to the 1965 operations contained only 7-8 ppm U-232. RFP, 1977a indicates that U-233 processed in a 1976 operation contained 8 ppm U-232. RFP, 1979 indicates that U-233 processed in a 1977 operation contained 7 ppm U-232 and had undergone a thorium strike two months prior to shipment.

5.4.2 U-233 Radiological Programs

RFP activities involving U-233 were of limited scope and, while being performed, accommodations were made to account for the high specific activity of the U-232 material in an attempt to preclude cross-contamination of Pu-239 and U-235 materials with U-233, which was also fissile. However, a cross-contamination event occurred in 1965 involving U-233 and U-235 (Investigation Summary, 1965). The quantities of U-233 that were available for use across the entire weapons complex were also limited. The total quantity of U-233 produced is not readily available for any one site due to classification issues, but overall quantities produced in the complex can be estimated based on the available documentation (Building 3019, 1994).

5.4.3 U-233 Incidents

NIOSH is unaware of any specific incidents or accidents involving U-233 at RFP that increased the potential for radiation exposure. A cross-contamination event occurred in 1965 when 447 grams of other uranium isotopes, including U-235, were mistakenly added to U-233 residues (Investigation Summary, 1965). An unspecified financial loss due to contamination by U-235 of otherwise-purified U-233 residues is mentioned in the above-referenced document; however, there are no suggestions that this event resulted in an increase in personnel exposure or increased the potential for exposure.

5.5 Np-237 Exposure Sources, Radiological Programs, and Incidents

Neptunium was processed at Rocky Flats as early as 1962 (Conner, 1981, pdf p. 6). The potential for radiological exposures from handling and processing neptunium existed in the Material Balance Areas (MBAs) where it was stored and processed. These MBAs were located in Buildings 371, 559, 707, 771, 776, 777, 779, 779A and 991 from 1963 forward (Vejvoda, 2005, pdf pp. 75-76).

Captured documents indicate that the potential for exposure to neptunium existed from 1962 to 1988, the period during which neptunium is known to have been present at RFP (Conner, 1981, pdf p. 6; Vejvoda, 2005, pdf pp. 75-79). The potential for exposure to neptunium present as residual contamination during plant decommissioning after 1988 is also assumed.

Source term data for neptunium available to NIOSH for Rocky Flats is limited to the reported quantities from Material Balance Area accounts (Vejvoda, 2005, pdf pp. 75-79; Inventory, 1966-1988). Only totals for the plant are available by year, and in some cases, by quarter. Individual Material Balance Areas having accountable quantities of neptunium are indicated for the annual totals, but not the amounts located in specific work areas.

NIOSH is unable to assess whether an energy employee, or class of employees, did or did not potentially enter specific areas of the Rocky Flats Plant having the potential for neptunium exposures during defined periods of time; therefore, NIOSH cannot define individual worker exposure scenarios based on specific Rocky Flats areas or work locations during the period from April 1, 1952 to December 31, 1983.

NIOSH is also unable to eliminate any specific worker from potential neptunium exposure scenarios based on job titles or job assignments.

5.5.1 Exposure Sources from Np-237 Operations

NIOSH has captured documents indicating that neptunium was processed at Rocky Flats as early as 1962 (Conner, 1981, pdf p. 6). Nuclear Material Control and Accountability (NMC&A) records show that neptunium inventories at Rocky Flats from 1963 to 1988 varied between 29 g and 1,318 g (Vejvoda, 2005, pdf pp. 75-76). Table 5-7 below shows reported fiscal-year-end inventories for this period. NIOSH believes at this time that activities associated with neptunium virtually ceased after 1983, even though neptunium inventories existed until the end of 1988. Whether neptunium was handled or processed from 1984-1988 at Rocky Flats is still being evaluated.

Table 5-7: RFP Neptunium-237 Fiscal-Year-End Inventories							
Fiscal Year	**Np-237 (g)**		**Fiscal Year**	**Np-237 (g)**		**Fiscal Year**	**Np-237 (g)**
1963	29		1972	788		1980	744
1964	601		1973	768		1981	486
1965	1,292		1974	470		1982	699
1966	740		1975	485		1983	869
1967	1,215		1976*	485		1984	1,040
1968	972		1976A*	468		1985	931
1969	1,190		1977	458		1986	985
1970	1,105		1978	567		1987	995
1971	1,318		1979	492		1988	970

Source: Conner, 1981, pdf p. 76

* The source document does not explain why they are two inventories for 1976. However, the values correspond to those for the June 30, 1976 and September 30, 1976 inventory values from the reference (Inventory, 1966-1988) from which Figure 5-1 was generated.

Quarterly inventory values from December 31, 1967 were also captured (Inventory, 1966-1988) and are presented graphically in Figure 5-1 below along with the year-end values listed for 1963 through1966 in Table 1 above.

Buildings having neptunium inventories included Buildings 371, 559, 707, 771, 776, 777, 779, 779A, and 991 (Vejvoda, 2005, pdf pp. 76-77). Refined neptunium for special projects undertaken at the request of other DOE laboratories was often recovered as metal or oxide from scrap and waste (Conner, 1981, pdf pp. 6-8; ChemRisk, 1992, pdf pp. 77, 100; Wittenberg, 1970, pdf p. 8). Typical special projects included the preparation of Np Pu alloys (Vejvoda, 2005, pdf p. 77) and specific configurations of neptunium, such as thin foils (Conner, 1969, pdf p. 10). Evidence points to a number of specific tasks performed at the request of other DOE laboratories from 1962 until around 1983, involving a few grams to a few hundred grams of neptunium. Information from reports in the SRDB, and from reviews of classified documents, do not suggest that any special orders or other projects at Rocky Flats involved more than about 300 g of neptunium (Conner, 1967).

Neptunium processing at Rocky Flats included preparation of pure neptunium oxide, metal and metal alloys, and the recovery of Np-237 from a variety of residues (Conner, 1981, pdf p. 6). Processes employed included dissolution, anion exchange, precipitation, filtration, calcination, conversion to fluoride, and reduction to metal. Fabrication steps such as casting and rolling were also sometimes performed for the production of high-purity metal shapes and foils. Neptunium was recovered from residual materials including sand, slag, crucibles, casting skulls, and alloys (Np-Sn, Np-U, and Np-Zr).

Some early neptunium work was conducted in open hoods, but most was performed in "alpha containment" glove boxes in general-purpose research facilities. The first hydrofluorination equipment used for neptunium consisted of a glove box used to load NpO_2 into reaction "boats," and several open hoods enclosing the front portion of the hydrofluorination furnaces. A second system used for this purpose was smaller and enclosed in a glove box, limiting batch sizes to 110 g of NpO_2. These first hydrofluorination systems (which were originally designed for applications other than neptunium processing) were subsequently replaced with a glove- box-enclosed system specifically designed for converting small batches (≤100 g) of NpO_2 to NpF_4 (Conner, 1981, pdf pp. 20-23).

A typical glove box for aqueous Np processing consisted of a "wet" section (for aqueous processes) and a "dry" section (for calcining precipitates and weighing powders) separated by an air lock. Each section had separate air inlet and exhaust filters. A door in the air lock was used to pass equipment and material between the wet and dry sections. A ⅛-inch-thick lead sheet was bonded to the stainless steel portion of the glove box and ¼-inch leaded glass was placed over the glove box windows as a shield against gamma radiation from the neptunium and its impurities (Conner, 1981, pdf pp. 7-8). Radiological impurities in neptunium included other actinides, primarily Pu isotopes. Occasionally, neptunium contaminated with thorium (typically 200 ppm – 2,000 ppm) was processed. One 343-g batch of NpO_2 with 3% thorium by weight was processed (Conner, 1981, pdf p. 18).

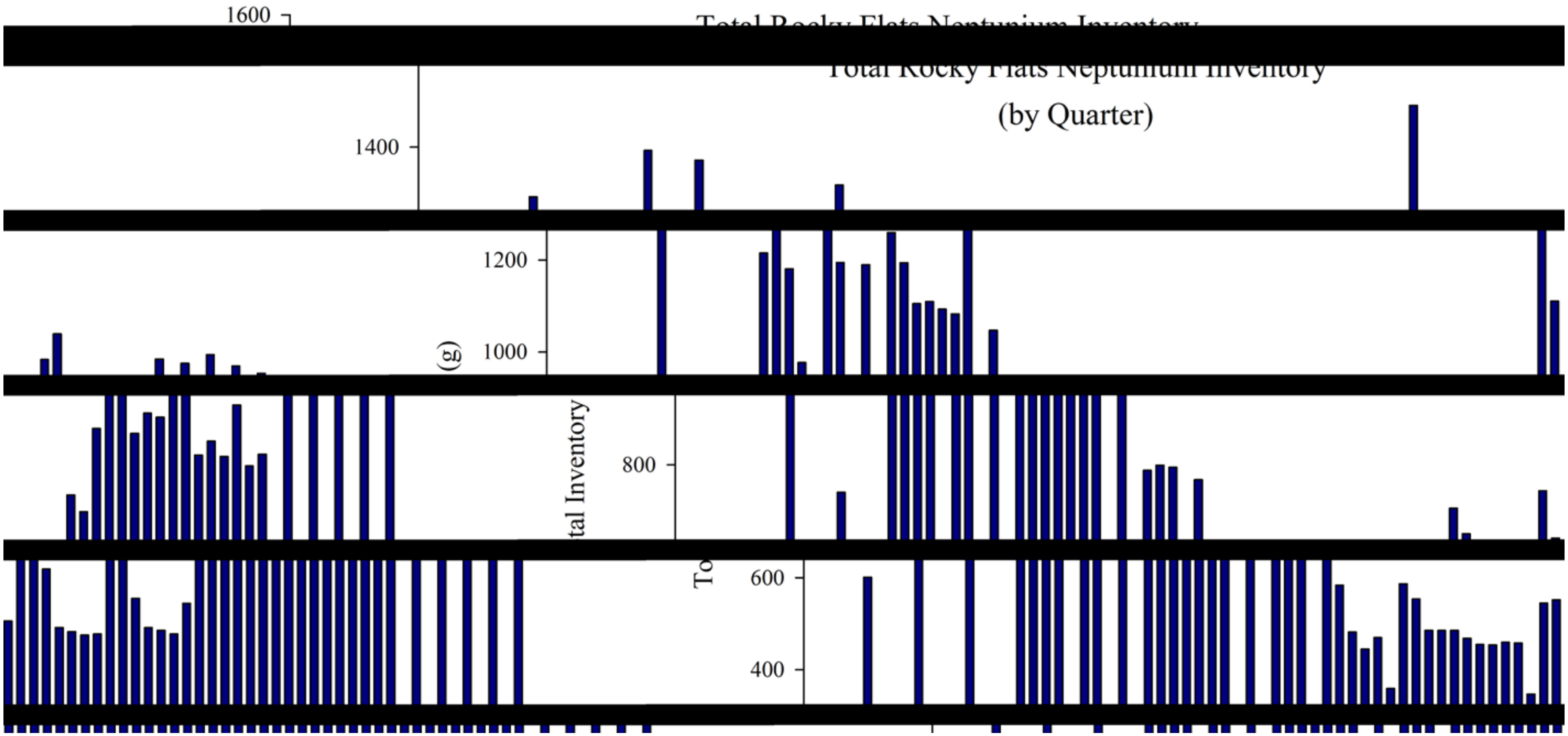
5.5.2 Np-237 Radiological Programs

NIOSH has found no workplace monitoring records (e.g., surface contamination samples, air samples) specific to neptunium.

5.5.3 Np-237 Incidents

No radiological incidents involving neptunium at Rocky Flats have been identified by NIOSH.

[redacted]



Source: Inventory, 1966-1988; Vejvoda, 2005, pdf p. 76

Figure 5-1: Total Rocky Flats Neptunium Inventory by Quarter

6.0 Summary of Available Monitoring Data for the Class Evaluated by NIOSH

The following subsections provide an overview of the state of the available internal and external monitoring data for the Rocky Flats Plant class under evaluation. The previous RFP evaluation (SEC-00030) that was assessed by the Board Working Group in multiple meetings and reviews assessed many facets of the RFP personnel monitoring program but it did not conclusively address issues with tritium. The extensive assessment identified no significant RFP internal monitoring program deficiencies or SEC-related issues that resulted in a recommendation for an SEC class at RFP (current SEC classes are based on external monitoring issues for neutrons). The result of the SEC-00030 assessment as it relates to internal monitoring complements the findings and recommendations in this SEC-00192 evaluation, which is exclusive to the tritium exposure issue at RFP. This section focuses solely on the available tritium data at RFP.

6.1 Available Rocky Flats Plant Internal Monitoring Data

The following subsections discuss the availability of Rocky Flats internal monitoring data for tritium, thorium, U-233 and associated progeny, and neptunium-237.

6.1.1 Available RFP Internal Monitoring Data for Tritium

As discussed in the operations portion of this report, because tritium was not handled as part of RFP operations, it was not considered to be a significant source of personnel exposure prior to the 1973 tritium chronic exposure incident. Other than the known sources on site relating to neutron generator targets, the site did not expect tritium-contaminated materials to be on site or a source of exposure, which has been corroborated by interviews performed by NIOSH as part of this evaluation. The site acknowledged the presence of sealed tritium sources, such as those associated with the neutron generators, but concluded that those sources presented very little potential for exposure. Consequently, monitoring for tritium exposure prior to 1973 was not performed on a routine basis or as a part of the routine radiological monitoring program. After the 1973 incident, the site assessed the tritium sources on site, and the potential for personnel exposures associated with those sources. Based on the potential personnel exposure and environmental release issues, the site implemented a routine tritium monitoring program in 1973 (Tritium Monitoring History, 1973; Release Investigation, 1973).

As a result of the 1973 incident, tritium monitoring was performed on 148 individuals who were judged to have had a potential for tritium exposure. The results of that monitoring are well documented (Case Studies, 1973; Personnel, 1973; Tritium Release, 1973; Urine Sampling, 1973). Of the personnel who were monitored, five were identified as having potentially-significant exposures. The bioassay data for these individuals are provided in the documents above. One of the individuals who had positive exposures is included in the NOCTS database; the tritium bioassay results were included in the dosimetry data provided by RFP. Dose histories that include tritium monitoring results are included in the SRDB for all five of these individuals.

The 1974 incident is discussed in the *Investigation of Tritium Releases, Building 777* (Building 777 Investigation, 1974). This was primarily a release to the environment with no significant exposure to personnel.

"Special Analysis Logbooks" (Special Analyses Logbook, 1965-1969) contain sample analysis data; there are results for tritium bioassays taken in 1966. This document includes names and associated results, all of which were "0". A notation indicates these samples were related to an "incident @ Box A-5". There is another set of samples processed in the January 1969 period.

Air sampling and smear sampling were performed routinely where the site deemed it appropriate. The document, *Tritium Contamination,* describes the precautions to be taken to determine the presence of tritium on parts being returned for retirement and describes some of the results (Tritium Contamination, 1981). Several documents provide air sampling results for this location in late 1977, with the conclusion that it was left over from the 1973 incident (Investigation, 1977; Tritium Reports, 1983). There are also listings of smear results for the period from 1979-1980 (Tritium Smears, 1979).

Because tritium was normally present in only trace quantities in the production lines and was considered to be an insignificant source of personnel exposures, routine bioassay for tritium was not implemented. Room air samples were typically less than the limit of detection to 0.02% of Radiation Control Guides (RCG) established by AEC (Tritium Status, 1975).

As previously mentioned, a "routine" bioassay program was implemented after the 1973 incident to evaluate the potential for tritium exposures by sampling for tritium in 10% of the urine intended for Pu analysis. In 1975, this routine monitoring program was discontinued because not a single positive tritium sample was found (Bioassay Procedure, 1979). This evaluation further supports the contention that the possibility of exposure to the workers from tritium was extremely low if not non-existent.

However, procedures were implemented that specified that personnel working a job involving more than 1 mCi of tritium would be sampled. This policy is supported by letters from the site that identify the personnel who should provide tritium samples (Routine Bioassay, 1992). One document contains letters covering 1980-1983 that identify the personnel who should be sampled for tritium (Special Tritium Samples, 1983). [Sentence redacted]. Tritium bioassay results were found for 13 of the 16 individuals in NIOSH's Site Research Database (Tritium Bioassay Results, 1979; Tritium Bioassay Results, 1980; Tritium Bioassay Results, 1982).

The post-1973 radiation protection program was aware of the presence of tritium and monitored for it in both the workplace and the workers. Based on the available RFP operational information as it relates to tritium, NIOSH believes that these available tritium data sufficiently represent the worst-case exposure scenario for any RFP operational period where tritium existed, or could have existed.

As part of its tritium assessment for this evaluation, NIOSH reviewed all available RFP health physics, industrial hygiene, and environmental monitoring reports which exist for all operational years at the site. For the years prior to the 1973 incident, there are limited results identified specifically for tritium (as expected, because the site did not handle or process tritium other than tritium targets for neutron generators). The available documentation discusses the use of tritium monitors such as tritium sniffers (used to periodically monitor incoming materials/shipments), area air monitoring systems capable of monitoring for tritium (triton portable and fixed air monitors), swipe and smear surveys (counted with instruments including, but not limited to, gas-flow proportional counters), and the use of vibrating reed and liquid scintillation monitoring/detection systems/instruments. These methods/surveys are periodically discussed in the pre-1973 documentation as it related to environmental soil, water, and air monitoring in the areas surrounding the site, as well as RFP work area radiological monitoring.

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

Table 6-1 provides the available RFP tritium data for 128 claims noted in Table 4-1 of this report that are currently in NOCTS (as of September 12, 2013).

Table 6-1: Available RFP Tritium Data from 128 NOCTS Claims

Year	Tritium Bioassays in NOCTS	No. of Tritium Bioassays in SRDB (source documents)	
1960	None	7	(Monthly Reports, 1960-1961; Special Analyses Logbook, 1960)
1965	None	6	(Monthly Reports, 1963-1965; Monthly Reports, 1965-1967; Logbook 1965)
1966	None	13	(Monthly Reports, 1965-1967; Logbook, 1966-1969)
1968	None	2	(Logbook, 1966-1969; Status Report, 1968)
1969	None	5	(Logbook, 1966-1969; Status Report, 1968; Monthly Reports, 1968-1971)
1973	156	180	(Urine Sampling, 1973)
1974	49	11	(Building 777 Investigation, 1974)
1975	48	None	
1976	6	None	
1977	13	None	
1978	10	None	
1979	11	23	(Tritium Bioassay Results, 1979)
1980	30	95	(Tritium Bioassay Results, 1980)
1981	19	87	(Tritium Bioassay Results, 1981)
1982	1	24	(Tritium Bioassay Results, 1982)
1983	No info	2	(Tritium Bioassay Results, 1993)
1991	2	None	
1993	7	None	
1995	2	None	
1996	2	None	

6.1.1.1 SEC-00192, Rev. 0 Tritium Data Follow-up

As part of the follow-up to the Board review of Rev. 0 of the SEC-00192 evaluation report, NIOSH performed additional focused data capture efforts and assessments/reviews of the data to determine the applicability of the bounding approach defined in the ER. The documentation and data reviewed as part of this research were specific to Board working group issues regarding tritium bubblers, contamination surveys on shipping containers, and Building 123 radiological surveys/operations; these documentation and data are presented in the following subsections. The additional documents and interviews obtained during the post-ER follow-up efforts provide additional evidence of the potential for tritium exposures. However, the information also supports the case that estimates of potential tritium exposure that could have occurred prior to 1973 are bounded by the exposure estimate for the 1973 event, and that more precise estimates are feasible.

Follow-up on Tritium Bubblers

Significant information on the bubbler monitors was discovered during the additional follow-up data capture efforts. There is some documentation in the SRDB that discusses the use of tritium bubblers. Based on the available data, including the most recent information (schematics and pictures of the tritium air sampling and monitoring equipment and processes [RFP, 1974a through RFP, 1978d]), there was a program that included the use of tritium bubblers to monitor enclosed and exhaust systems for tritium (Personal Communication, 2013j). As previously discussed, the exact start date for the use of bubblers has not been confirmed, but they did exist on site before the 1973 incident (Personal Communication, 2013o). Most individuals interviewed were not well-informed on bubbler use or operation.

The SRDB contains some tritium bubbler results (Tritium Bubbler Results, 1992; Tritium Bubbler Results, 1998) as well as detailed schematics and pictures of the units (Dow, 1973; RFP, 1977b; RFP, 1978f; RFP, 1978e; RFP, 1978b; RFP, 1978c; RFP, 1983). Based on these results, the information discovered during the follow-up research and in the interviews, there is nothing to support the occurrence of a release event more significant than the 1973 incident. Table 6-2 presents a summary of the Rocky Flats tritium bubbler information contained in the SRDB.

Table 6-2: Rocky Flats Tritium Bubbler Information in the SRDB (This table spans two pages)			
SRDB Ref ID	**Year**	**File Description**	**Comments**
Category: Tritium Monitoring Results, Procedures, and Occurrences			
17824 (RFP, 1990a)	1990-1991	Occurrence reports	Contains two occurrence reports involving inoperable bubblers, and one report of a Triton tritium air monitor that was shut off. None of the occurrences involved tritium releases.
24164 (Tritium Releases, 1976-1983)	1976-1983	Tritium inventories and effluents	Contains: an evaluation of tritium-release potential from a proposed neutron crate counter (1983); elevated tritium effluents from Bldg 776/777 (January 1981); estimated inventory of tritium as surface contamination in glove boxes, ducts, and exhaust plenums in Bldg 776/777 (1980); evaluation of ethylene glycol in place of water in tritium bubblers (1978); special study of tritium in ambient air (1976); a report, *Estimates of Maximum Tritium Releases to the Atmosphere from Operations at the Rocky Flats Plant* (1976); and a Call Report indicating that 0.058 µCi of tritium would probably be vented to the atmosphere for an experiment on May 20, 1974.
24307 (RFP, 1990b)	1986	Procedure for effluent and room air tritium sampling	Operating procedure
111095 (Tritium Bubbler Results, 1992)	1977-1981	Tritium bubbler sampling results	Log of analytical results for bubblers in operating areas, including room air and near downdraft tables. Most results are <100 pCi/m^3, but results exceed 1,000 pCi/m^3 on several occasions in Bldg. 559 – Rm. 102, and in Bldg. 881- Rm. 283. Highest result appears to be 89,230 pCi/m^3 in Bldg 771 for the period May 11-18, 1978.
122466 (Personal Communication, 2013j)	2013	Documented interview with [Name redacted]	Includes a discussion of the different laboratories at Rocky Flats for analyzing tritium and other radionuclides in samples.
122712 (Tritium Bubbler Results, 1998)	1998	Lab report - tritium activity in bubblers	Detailed analytical report from Thermo NUtech, including sample activity, counting uncertainty, detection limit, and total propagated uncertainty.
122907; 24167 (Personal Communication, 2013o; Tritium Release, 1973)	2013	Documented interview with [Name redacted]; 1973 incident report	Includes a discussion of the tritiated targets for laser fusion experiments and corroboration that bubblers were in use at several Rocky Flats locations prior to the 1973 tritium release incident.

Table 6-2: Rocky Flats Tritium Bubbler Information in the SRDB (This table spans two pages)			
SRDB Ref ID	**Year**	**File Description**	**Comments**
Category: Tritium Sampler Photos and Design Documents			
122691 (Dow, 1973)	1973	Photos – tritium operations at Dow	Relevance of photos to tritium monitoring or tritium operations is not apparent, except for one photo of a Triton tritium monitor.
122692 (RFP, 1977b)	1977	Photos - tritium monitoring	Good photos of sampling fixture for sealed cans and drums, Triton Model 955B tritium monitor, and bubblers mounted outside a glove box for sampling glove box air.
122693 (RFP, 1983)	1983	Photos – tritium air sampling station	Labeled tritium sampling assembly showing building number, air flow rates, and water volume.
122779 (RFP, 1974a)	1974	Drawing 1 of 8 - Tritium and iodine sampler assembly	Engineering drawing
122780 (RFP, 1974d)	1974	Drawing 2 of 8 - Tritium and iodine sampler assembly	Engineering drawing
122781 (RFP, 1974b)	1974	Drawing - Environmental tritium and radioiodine sampler details	Engineering drawing
122782 (RFP, 1975)	1974	Drawing - Environmental tritium and radioiodine sampler wiring diagram	Engineering drawing
122783 (RFP, 1974c)	1974	Drawing - Environmental tritium and radioiodine sampler mounting detail	Engineering drawing
122784 (RFP, 1974f)	1974	Drawing - Environmental tritium and radioiodine sampler onsite electrical hookup	Engineering drawing
122785 (RFP, 1974g)	1974	Drawing - Environmental tritium and radioiodine sampler offsite electrical hookup	Engineering drawing
122786 (RFP, 1974e)	1974	Drawing - Environmental tritium and radioiodine sampler onsite and offsite electrical hookup	Engineering drawing
122787 (RFP, 1978f)	1978	Drawing – Tritium detector assembly	Engineering drawing
122788 (RFP, 1978e)	1978	Drawing – Tritium detector details (1)	Engineering drawing
122789 (RFP, 1978b)	1978	Drawing – Tritium detector details (2)	Engineering drawing
122790 (RFP, 1978c)	1978	Drawing – Tritium detector details (3)	Engineering drawing
122791 (RFP, 1978d)	1978	Drawing - Tritium detector flow diagram	Engineering drawing

Follow-up on Shipping Containers

Additional research was performed regarding the issue of tritium contamination in shipping containers. This issue arose from one of the classified interviews (Personal Communication, 2012n). Tritium contamination in shipping containers was corroborated in an SRDB document (Dow, 1974); however, no actual contamination surveys have been found. The follow-up survey requirements and processes were corroborated in a follow-up interview in which the interviewee discussed implementing the shipping container tritium survey program in response to the 1973 incident (Personal Communication, 2013o). During that interview, the interviewee said that no tritium contamination was ever found. Other classified interviewees indicated that they had heard about shipping-container contamination, but they had no direct experience of it.

Follow-up on Building 123

Analytical capability existed in both the production areas and in Building 123 (Personal Communication, 2013d), which housed the laboratories supporting worker health and safety (Industrial Hygiene and Health Physics) as well as the environmental programs (Personal Communication, 2013a). Samples collected in the production areas may have been analyzed either in the production laboratories or in Building 123, depending on the anticipated level of analytes and the potential for contamination with plutonium or uranium, for which strong contamination-control practices were in place. Tritium samples from stack exhausts, which were filtered several times before sampling and release to the environment, were typically analyzed in Building 123. Samples collected in the work areas were analyzed in a production area laboratory to eliminate the possibility of introducing plutonium contamination into the Building 123 lab (Personal Communication, 2013a). Samples with a high likelihood of elevated tritium content might also be analyzed in a production lab to prevent tritium contamination in the low-level Building 123 laboratories (Personal Communication, 2013c).

Some effort was made prior to 1973 to use commercially-available tritium monitoring equipment (e.g., the vibrating reed spectrometer and tritium sniffers) (Neutron Generators, 1973; Personal Communication, 2013e; Personal Communication, 2013h; Personal Communication, 2013i) or to develop an in-house capability (through development of specialized ion chambers or tritium concentration techniques, such as silica gel traps [Logbook, 1969-1972; Status Report, 1968]). Liquid scintillation counting was reportedly used for quantitative analysis of a variety of radioactive materials in the production areas; it quickly became the technique of choice for tritium sample analysis after the 1973 environmental tritium release. Tritium sniffers continued to be used to indicate elevated tritium in the workplace, but they did not provide quantitative data of record.

No results for tritium samples analyzed in the production areas have been captured, and only limited data are available from the Building 123 laboratories. The information regarding the criteria for determining where tritium samples were analyzed comes solely from interviews with former Rocky Flats Plant employees.

6.1.2 Available RFP Internal Monitoring Data for Thorium

While no major thorium campaigns were performed as part of the RFP operations, there were operations that could have contributed to personnel exposures to thorium. In addition to issues associated with limited information and monitoring data for thorium at RFP, classification issues (as discussed in Section 5) compound the difficulties and issues relating to the development of a bounding dose reconstruction methodology for thorium. While there were limited thorium operations at RFP, and no established routine thorium monitoring program or documented protocol for personnel, there are some limited thorium-monitoring data available for operations in the 1960s.

NIOSH has access to monitoring data contained in RFP special monitoring logbooks. One logbook contains two monitoring points, for one individual, in mid-1966 (Logbook, 1966-1969, pdf p. 6). The second logbook contains data from 1960 and provides an indication of some personnel (urine samples) and area (swab/swipe samples). However, the results appear to be in terms of volumes or quantities of material, with no clear indication of an activity result in the documentation (Special Analyses Logbook, 1960, starting pdf p. 20). As previously discussed, NIOSH has collected some thorium-specific personnel and area monitoring data during its research for development of this revised evaluation report; these data are contained in the Site Research Database (Dosimetry History, date unknown, pdf p. 11; ChemRisk 3&4, 1992, pdf p. 136; Monthly Reports, 1956-1957, pdf p. 116-125; Monthly Progress Reports, 1958, pdf p. 50; Monthly Reports, 1960-196, pdf p. 8, 72, 96-112); Logbook, 1966-1969, pdf p. 6 [8/16/66, 9/1/66]; Special Analyses Logbook, 1960 [starting pdf p. 20 for 1960, including urine samples starting p. 25]).

6.1.3 Available RFP Internal Monitoring Data for U-233

The uranium internal dose monitoring program at RFP is described in the Site Profile, ORAUT-TKBS-0011-5. The uranium bioassay program was also discussed in SEC-00030. NIOSH is unaware of any internal monitoring at RFP that was specific to U-233, U-232, or the associated Th-228 for the period of U-233 operations at the site.

6.1.4 Available RFP Internal Monitoring Data for Np-237

NIOSH has found no workplace air or contamination measurements specific to neptunium. Air and contamination measurement results are typically expressed in units of activity per unit volume (e.g., dpm/m^3) or unit area (e.g., dpm/100 cm^2). No results were captured that specify neptunium as the contaminant, nor any that provide locations or dates of neptunium processing/handling that can be correlated with air results.

NIOSH has captured documents with only two reported bioassays for neptunium. A urinalysis result in July 1966 was “Below Significant Level” (Progress, Jun1966, pdf p. 74; Logbook, 1966-1969, pdf p. 3), and a urinalysis result of 0.9 dpm/24h was reported for a worker in August, 1966, followed by a body count that showed no detectable uptake (Progress, Jul1966, pdf p. 78; Logbook, 1966-1969, pdf p. 5).

Urinary excretion of “gross alpha” was used to monitor workers for exposure to plutonium/americium and uranium prior to its being discontinued in the early 1970s. Results were reported as dpm/24 h of enriched uranium (through 1963) or plutonium (after 1963). Results were non-specific, so that neptunium exposures might not have been identified as such for workers on routine bioassay sampling schedules and who might have worked with a variety of actinides, including neptunium, curium, plutonium, and uranium (ORAUT-TKBS-0011-5, pdf p. 27; Personal Communication, 2013s, pdf pp. 3-5).

NIOSH has been unable to capture early RFP bioassay procedures for either gross alpha or neptunium. Old procedures were not archived, but rather, were destroyed prior to the late 1980s (Personal Communication, 2013r). Ambiguity exists in NIOSH's understanding of the procedures used. According to one source, the entire urine sample prior to 1962 was 'ashed' (taken to dryness), which was time-consuming and resulted in significant self-attenuation of radiations due to the resulting solids containing the radioactive materials (Personal Communication, 2013s, pdf p. 4). According to this same source, a co-precipitation process involving chemical separation and extraction using TTA (thenoyltrifluoracetone) replaced the total sample ashing in 1962, and was supplemented by a TOPO (trioctylphosphine oxide) extraction process in 1964. These methods reduced both the volume of liquid to be ashed and the mass of salts (and self-attenuation) in the sample to be counted.

According to a second source, two methods were used to analyze urine samples for gross alpha counts from either plutonium or uranium. The ether extraction method was used from 1952 to December 12, 1962, and the TBP (tri-butyl-phosphate) extraction method was used from December 12, 1962 to 1964. The TBP method was replaced by the TOPO (tri-octyl-phosphine-oxide) method (ORAUT-TKBS-0011-5, pdf p. 64; MDA, 2003, pdf p. 10).

Total sample ashing without treatment retains all actinides in the residue, but counting the residue without spectroscopic analysis does not provide nuclide-specific information; thus, the presence or absence of neptunium could not be determined by this method alone. The effectiveness of bioassay procedures for neptunium using solvent separation cannot be determined without the detailed procedures themselves because chemical recoveries of specific elements in extractions using solvents such as TTA, TBP, and TOPO vary considerably with the conditions established by the particular procedure (Procedures Review, 1957, pdf p. 21; Internal Dosimetry, 2002, pdf p. 7; Enriched Uranium Urinalysis, 1959). Knowledgeable sources interviewed about bioassay procedures at Rocky Flats were uncertain whether neptunium would be recovered effectively using these methods (Personal Communication, 2013r, pdf p. 4; Personal Communication, 2013r, pdf p. 4).

Ion exchange, followed by electroplating and analysis by proportional counters, and later, PHA (pulse-height analysis), was specific for U and Pu and replaced chemical separation and extraction techniques. These newer techniques provided "cleaner" samples (i.e., with fewer interferences) that were almost 'massless' (greatly reducing or eliminating self-attenuation) (Personal Communication, 2013s, pdf p. 4); however, these techniques were not designed to detect neptunium.

In vivo counters of the 1960s and 1970s would have had difficulty distinguishing between the 59.6-keV gamma emission from Am-241 and the 86-keV photon from Np-237 (Personal Communication, 2013r, pdf p. 5).

6.2 Available Rocky Flats Plant External Monitoring Data

The claimant files and other documents available to NIOSH in the SRDB contain external radiological exposure data for all years under evaluation. The principal source of external doses for members of the evaluated class was evaluated in the SEC-00030 Rocky Flats Plant Evaluation Report. SEC-00030 concluded that all external dose, except neutrons, could be estimated with sufficient accuracy and nothing performed as part of this evaluation has been discovered to dispute that finding. Therefore, additional analysis or evaluation of external monitoring data for the purpose of bounding external dose at RFP will not be performed in this evaluation report.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determination for the class of employees under evaluation in this report is governed by both EEOICPA and 42 C.F.R. § 83.13(c)(1). Under that Act and rule, NIOSH must establish whether or not it has access to sufficient information either to 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 to 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, NIOSH would then determine that it would be feasible to conduct dose reconstructions.

In determining 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. If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that 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 as summarized in Section 7.6. This approach is discussed in DCAS's SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00192 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Rocky Flats Plant Data

This subsection answers questions that need to be asked before performing a feasibility evaluation. Data Pedigree addresses the background, history, and origin of the data. It requires looking at site methodologies that may have changed over time; primary versus secondary data sources and whether they match; and whether data are internally consistent. All these issues form the bedrock of the researcher's confidence and later conclusions about the data's quality, credibility, reliability, representativeness, and sufficiency for determining the feasibility of dose reconstruction. The feasibility evaluation presupposes that data pedigree issues have been settled.

7.1.1 Tritium Monitoring Data Pedigree Review

As discussed above in Section 6.1, RFP personnel were aware of the potential for tritium exposures from known sources of tritium, and methods existed to perform the corresponding personnel and area monitoring. Based on the site's 1973 assessment, the trace quantities of tritium that may have been present at any time in the production lines, and from other known sources, were small relative to the levels and corresponding exposure potential during routine operations with tritium-contaminated scrap and returns. Based on its review of the available information leading up to and following the 1973 tritium incident, NIOSH believes that there is sufficient information associated with site returns and scrap processing (most of which is classified) that (when coupled with the available air monitoring, radiological survey, and bioassay data) can be used to corroborate this position. Based on NIOSH's review of the available information in the SRDB and other sources, the monitoring results and data as well as other operational, source/source term, and radiological program information are available in original form and can be used to support the assessment performed for the RFP class under evaluation.

Although there were several incidents during RFP's history that involved significant quantities of tritium, only one in particular resulted in exposures to personnel. The personnel involved in this 1973 incident were carefully monitored as part of the investigation conducted after this incident. The results of the personnel and area monitoring were also included in the reports conducted for this incident. The results are numerous over a period of time after the incident. The monitoring results from this incident are available in both claimants' files and the SRDB. The information is also available in original form and can be used to support the assessment performed for the RFP evaluated class in this evaluation.

In summary, a program was in place at RFP to sample workers who had potential for exposure to tritium, especially as it applied to the site's follow-up to the 1973 tritium incident. The workers were identified and sampled. The bioassay results are available and have been provided to NIOSH as a part of the claims process. Based on its assessment of the documentation and data, NIOSH finds that RFP workers for whom tritium monitoring data was not provided had very little potential for exposure.

7.1.2 Thorium Monitoring Data Pedigree Review

In this evaluation, NIOSH has determined that it lacks sufficient monitoring data relating to worker internal doses from work performed at RFP during the operational period from April 1, 1952 through December 31, 1983, which includes the thorium processing/operating period from 1952-1966. As discussed in Sections 5 and 6, NIOSH has located limited routine air sampling or area monitoring data for thorium during RFP operations, although most of the data contains references to the source or original information or documentation. Lacking the original documentation or source information, a data sufficiency and pedigree evaluation is not possible for the thorium data type for this period at RFP.

7.1.3 U-233 Monitoring Data Pedigree Review

A data pedigree review is not possible for U-233 because there are no available internal monitoring data for U-233 (or U-232). Pedigree of the available internal dosimetry data for other radionuclides at RFP, including other isotopes of uranium, were evaluated and addressed in the SEC-00030 RFP Evaluation Report. That report reached the following conclusion:

> *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.*

7.1.4 Np-237 Monitoring Data Pedigree Review

Only two neptunium bioassay results have been identified by NIOSH. Both were recorded in 1966 Industrial Hygiene and Bioassay Monthly Progress Reports (Monthly Reports, 1965-1967, pdf pp. 74, 78) and in a Special Analysis Logbook (Logbook, 1966-1969, pdf pp. 3, 5). There is no corresponding record of reasons for the bioassays, the analytical procedure(s) used, where the analyses were performed, or by whom. Therefore, no conclusions can be drawn regarding the Np-237 data pedigree for this evaluation report.

7.2 Evaluation of Bounding Internal Radiation Doses at Rocky Flats

The following subsections evaluate the bounding of internal radiation doses for tritium, thorium, U-333 and associated progeny, and neptunium-237.

7.2.1 Evaluation of Bounding Process-Related Tritium Doses

As discussed in the previous sections of this evaluation, the principal source of internal tritium radiation doses for members of the class under evaluation was tritium-contaminated materials returned to RFP from other sites in the form of scrap and retired weapons returns. The following subsections address the ability to bound tritium doses, methods for bounding doses, and the feasibility of tritium dose reconstruction. The following subsections also summarize the extent and limitations of information available for reconstructing the process-related internal tritium doses of members of the class under evaluation.

Tritium Urinalysis Information and Available Data

There are limited tritium bioassay data for years other than 1973 at RFP. Table 6-1 indicates the number of RFP tritium bioassay samples currently available to NIOSH. The most significant RFP tritium exposures occurred in 1973, which is also the year with the highest number of bioassay sample analyses. Based on the available information, the incident occurred between April and September of 1973. Dow (the site contractor at the time) commenced a sampling protocol that included any employee who was thought to have had the best chance of being exposed to tritium. These data are available and support NIOSH's ability to develop a bounding approach to reconstructing RFP tritium exposures for the class under evaluation. Based on the information available to NIOSH, RFP identified the capability of monitoring personnel for tritium exposures over the majority of the operational period under evaluation. Very limited bioassay results are available prior to the 1973 incident. It is expected that these available data correspond to work assignments that constituted maximum-exposure scenarios or include workers with the highest tritium exposure potential (of known RFP tritium sources); no radiologically-significant personnel exposure results are indicated in the available pre-1973 monitoring data. NIOSH has discovered no evidence of an ongoing exposure potential outside of the 1973 incident discussed in this evaluation report. Based on its reviews and the analysis performed below, NIOSH concludes that the available bioassay data are sufficient to support bounding the tritium exposures at the site.

Tritium Airborne Survey Data

Environmental and operational air sample data are available for the majority of the years under evaluation in this report. There is limited information and documentation relating to tritium radiological surveys and air sampling prior to 1973. The most significant quantity of radiological survey data specific to tritium sampling are primarily available for the years after the 1973 incident. Although limited, the existence of these data over the RFP operational period, coupled with the information associated with the existence of tritium on site, does support the position that the site maintained the ability to assess tritium emissions and personnel exposures to determine if there were radiological issues or releases occurring as a result of known operations. In addition, the data corroborate the position presented in this evaluation regarding the ability to bound tritium dose based on the available bioassay data for the 1973 incident.

Evaluation of Bounding Ambient Environmental Internal Tritium Doses

The proposed bounding method for tritium defined in this evaluation accounts for, and includes the potential contribution of, doses associated with environmental tritium exposures at the site. Therefore, further assessment of the doses from environmental tritium exposure sources is not necessary for the RFP class under evaluation.

7.2.1.1 SEC-00192, Rev. 0 Tritium Dose Feasibility Follow-up

The potential for tritium exposure to Rocky Flats personnel was not considered significant by the site until an unexpected release occurred in April 1973. NIOSH conducted a follow-up effort to validate the tritium bounding method for Rev. 0 of the SEC-00192 RFP ER, which uses information from the 1973 tritium incident as the maximum exposure scenario. Additional document data captures and personnel interviews were conducted regarding the existence of tritium on site and associated personnel exposures as well as follow-up on tritium bubbler sampling, shipping container tritium surveys, and sampling analysis performed in Building 123.

In light of the additional information and data gathered during this follow-up effort, this revised SEC-00192 evaluation report presents a refined dose reconstruction approach. This approach provides specific analyses and recommended dose reconstruction methodologies for three periods at RFP: (1) pre-1973 [1959-1972]; (2) 1973; and (3) post-1973.

Follow-up on the Pre-1973 Tritium Exposure Period and Methods for Bounding Dose

Although tritium was used as a boost gas in weapons and as target material in neutron generators, it was not processed or handled in any significant quantities at Rocky Flats. Tritium was monitored in the environment around the site for a time, but that monitoring ceased and was left to the State of Colorado for a brief period preceding an environmental release that occurred in April 1973. No analytical records have been captured by NIOSH that might help establish the Rocky Flats workplace tritium environment prior to that time.

The management of Rocky Flats woke abruptly to the potential for tritium workplace and environmental contamination when a tritium release occurred in April 1973 associated with 500 Ci - 2,000 Ci of tritium-contaminated scrap. This release was primarily from Building 779A, and its eventual detection in waters draining into a reservoir serving as a municipal drinking water supply (Incident Summary, 1976; Release Investigation, 1973a; Release Investigation, 1973b). The release also resulted in tritium exposure to a small number of Rocky Flats personnel. Subsequent workplace monitoring and personnel bioassay was implemented, in part to establish the baseline tritium environment against which future incidents could be evaluated. A smaller and less-impactful tritium release occurred in September 1974 from Building 777; the subsequent investigation report (Building 777 Investigation, 1974) includes release details along with summaries of tritium workplace monitoring results prior to the incident for comparison. These data provide the basis for a model for bounding chronic tritium exposures to workers and of smaller, less-notable tritium releases that might have occurred prior to 1973.

Several factors single out the 1973 tritium release as bounding for the entire history of Rocky Flats operations. These factors include the large quantity of tritium involved, the chemical form of the released tritium, and the meteorological conditions at the time of the release. Other documented releases involved smaller quantities of elemental tritium, having a much smaller dose conversion factor than the tritium oxide released in 1973. Bounds for personnel tritium exposures after the 1973 release can be developed based on measurement results, since personnel bioassay, air sampling, and workplace contamination monitoring for tritium became more common after that release. There are only very limited tritium measurement results prior to 1973 because tritium was not perceived as a radionuclide of occupational or environmental interest at Rocky Flats. Bounding tritium exposures for the pre-1973 period are more difficult to develop as a result of this lack of measurement data. According to the ChemRisk report (ChemRisk 5, 1994), there was no environmental monitoring for tritium prior to 1970, and little in the way of workplace monitoring until after the 1973 tritium release; therefore, evidence of tritium releases prior to 1973 is primarily anecdotal. A 600-Ci release of elemental tritium (from a different source than the 1973 release) occurred in 1968.

The ChemRisk report said the following with regard to possible releases from tritiated Pu shipments (ChemRisk 5, 1994, pdf p. 285):

> *The 1973 findings associated with the tritiated plutonium initiated an investigation of other possible similar shipments and processing of tritiated plutonium. The investigation discovered three other shipments with maximum estimated tritium releases of 57 Ci (April 1969), 40 Ci (March 1971), and 29 Ci (November 1971).*

The reported investigation and the documented 1968 release of elemental tritium are the only sources of information about other possible releases. The 1968 release was elemental tritium with no significant environmental or personnel exposure. None of the three identified potential releases from tritiated Pu was near the magnitude of the 1973 release. There is no evidence of a tritium release comparable to the magnitude and impact of the 1973 release prior to that year.

Despite the lack of measurement data, it is possible to develop pre-1973 tritium exposure bounds based on measurement results provided in a Rocky Flats Area Office (RFAO) report issued subsequent to a tritium release in one of the Rocky Flats production buildings on August 30, 1974 (Building 777 Investigation, 1974). The information contained in this report includes measurement data (i.e., results from air samples, surface contamination surveys, and bioassay) from the production area where the release occurred as well as comparison data from other areas prior to, during, and after the release. Several factors support the use of these data as surrogates for bounding the tritium environment at Rocky Flats prior to 1973:

1. Background tritium levels immediately prior to the incident described in the RFAO report, although undoubtedly elevated since the more-significant 1973 release, were well below dosimetrically-significant values and can be considered fairly representative of typical background levels for this analysis. The background tritium levels monitored in the months prior to the 1974 incident are consistent with internal radiation doses from tritium of well under 1 mrem annually. They are dosimetrically insignificant in this sense.

2. The quantity of tritium released (1.5 Ci) was significantly less than that released in 1973, and is probably more typical of potential undocumented releases in work areas – particularly those resulting from opening contaminated shipping containers.

   The 1974 1.5-Ci tritium release is the only documented release from a shipping container in the Rocky Flats workplace. It is taken to be typical since there are no other such documented releases to use in forming the model. There is documented concern about tritium releases, as shown in the following quote from the ChemRisk report (ChemRisk 5, 1994, pdf p. 38):

   > *As early as 1962, Rocky Flats maintained instruments for detection of tritium gas in particular work areas of the plant because operations have sometimes resulted in the storage of tritium containers.*

   The instruments available to Rocky Flats at that time were only semi-quantitative for indicating the presence of tritium; NIOSH has captured no records of these results.

Because NIOSH has only identified six documented releases from 1968-1974 (an average of 1 per year), the application of a daily release would be a significant/bounding overestimate of the number of RFP tritium releases.

3. Tritium was released to the workplace environment, and not in a glovebox.

4. The release involved elemental tritium (HT, T_2), and not tritium oxide (HTO)[12].

5. The tritium was released from a contaminated shipping container which was procured by Rocky Flats in 1970 and can be taken as representative of shipping containers in use prior to 1973.

   As stated in the discussion of Item 2, the 1974 1.5-Ci tritium release is the only documented release from a shipping container in the Rocky Flats workplace. It is taken to be typical since there are no other such documented releases to use in forming the model. There is documented concern about such releases, as shown in the following quote from the ChemRisk report (SDRB 8017, pdf p. 38):

   > *As early as 1962, Rocky Flats maintained instruments for detection of tritium gas in particular work areas of the plant because operations have sometimes resulted in the storage of tritium containers.*

   The instruments available to Rocky Flats at that time were only semi-quantitative for indicating the presence of tritium; NIOSH has captured no records of these results.

   Because NIOSH has only identified six documented releases from 1968-1974 (an average of 1 per year), the application of a daily release would be a significant/bounding overestimate of the number of RFP tritium releases.

6. The incident occurred close enough in time to the 1973 tritium release that work practices and controls were likely more similar to those prior to 1973 than to those even a year or two later, as procedures and controls evolved with greater sensitivity to the potential for tritium contamination.

The RFAO report provides the best source of monitoring data for use in bounding both chronic and accidental tritium exposures to Rocky Flats personnel prior to the unique circumstances of the 1973 release.

The RFAO report states that elevated tritium concentrations were detected in air samples from Room 452 (Special Assembly Area) in Building 777 and from the Building 205 exhaust plenum servicing Building 776/777 over the period of August 29 – September 4, 1974 (Building 777

[12] The impact of the 1973 tritium release was largely due both to the quantity (500 Ci – 2,000 Ci) and the chemical form (HTO) of the material. The presence of tritium oxide in the 1973 release resulted from peculiarities of the plutonium recovery operation from which it was generated. There is no indication that any other tritium release at Rocky Flats involved the oxide. Tritium in its elemental form (HT, T_2) is far more likely to have been a contaminant at Rocky Flats because of the nature of its possible source terms – tritiated accelerator targets (neutron generators), plutonium hydride in recovery operations, and boost gas in returned reservoirs or pits.

Investigation, 1974, pdf p. 9). Subsequent sampling and investigation of the elevated sample results concluded that about 1.5 Ci of tritium was released from the exhaust system of Room 452, Building 777, when a shipping container (referred to as a "pressure cooker") received in July 1974 from Battelle Pacific Northwest Laboratory (BNW) was opened on a downdraft table in Room 452 on August 30 (Building 777 Investigation, 1974, pdf pp. 36-39). No elevated environmental tritium levels were detected as a result of the incident, but workplace tritium levels seven times the applicable Radiological Control Guide were detected in air samples collected on August 30 in Room 452 adjacent to the downdraft table, with average concentrations for the work week about 1.5 times the guidelines. Table 7-1 shows the reported values.

Table 7-1: Reported Tritium Air Concentrations (μCi/m^3) from the August 30, 1974 Release

Sampling Reference	Plenum 205, Bldg. 776/777[a]	Room 452, Bldg. 777
Normal Concentrations	$<1\times10^{-2}$	$<1\times10^{-2}$
August 29-30, 1974	0.148	37.7
September 3-4, 1974	2.51	1.1

Source: Building 777 Investigation, 1974, pdf pp. 93-96

[a]The Special Assembly Glovebox Line in Room 452, Building 777, was normally served by Plenum 206, but exhaust air from this area was vented through Plenum 205 from February 11 – August 7, 1974 while a new Plenum 206 was constructed. A tritium air sampler for Plenum 206 was installed on August 30, 1974, but showed no elevated results. However, both Plenums 205 and Plenum 206 showed elevated tritium removable contamination (Building 777 Investigation, 1974, pdf pp. 74-82).

An air sampler located near the downdraft table in Room 452 indicated a tritium air concentration of 4.9×10^{-3} μCi/m^3 on August 29 and 37.7 μCi/m^3 on August 30. The applicable Radioactive Concentration Guideline at the time was 5 μCi/m^3. Two "pressure cookers" were opened at the downdraft table, coincident with the elevated tritium-in-air measurements, and were smear-sampled for removable tritium contamination. One cooker showed smear levels of 1.16×10^{-2} μCi; the other showed 3.43×10^{2} μCi and was presumed to be the source of the gaseous tritium release.

Results from air samples collected daily in Room 452, Building 777, are available from June 3 to September 11, 1974. The air sampler was located near the downdraft table entry to the Special Assembly Line where the tritium contaminated "pressure cooker" was opened and was the only tritium air sampler in Building 777 at the time. Room air samples were collected in a water bubbler during the day shift (approximately 6 or 8 hours sampling time) at an air flow rate of 2 L/min. Individual results are shown in Table 7-2 (Building 777 Investigation, 1974, pdf pp. 87-89).

Table 7-2: Tritium Activity Concentrations in Room Air: Rm. 452 - Special Assembly - Bldg. 777							
Analysis Date (1974)	**H-3 (pCi/m^3)**		**Analysis Date (1974)**	**H-3 (pCi/m^3)**		**Analysis Date (1974)**	**H-3 (pCi/m^3)**
3-Jun	9,428		8-Jul	3,872		8-Aug	628
5-Jun	12,121		5-Jul	3,030		12-Aug	1,256
4-Jun	20,370		3-Jul	4,655		13-Aug	1,301
7-Jan	5,892		10-Jul	2,602		16-Aug	---
6-Jun	16,498		9-Jul	2,512		20-Aug	2,439
14-Jun	5,387		11-Jul	4,553		21-Aug	3,140
13-Jun	4,553		17-Jul	21,022		22-Aug	3,298
12-Jun	12,358		16-Jul	5,040		23-Aug	---
11-Jun	13,972		15-Jul	6,742		26-Aug	2,927
11-Jun	10,894		19-Jul	5,041		27-Aug	3,089
21-Jun	4,348		18-Jul	4,209		28-Aug	4,874
20-Jun	4,553		24-Jul	1,010		29-Aug	3,986
19-Jun	4,414		23-Jul	4,866		30-Aug	37,676,609
18-Jun	5,781		22-Jul	4,866		3-Sep	1,098,901
17-Jun	6,829		29-Jul	2,512		4-Sep	8,477
26-Jun	4,519		26-Jul	2,118		5-Sep	5,108
25-Jun	---		25-Jul	3,089		6-Sep	---
24-Jun	---		1-Aug	1,842		9-Sep	3,030
2-Jul	3,454		30-Jul	1,727		10-Sep	3,140
1-Jul	4,348		1-Aug	2,269		11-Sep	2,898
27-Jun	5,366		7-Aug	1,179		---	---
27-Jun	4,553		5-Aug	2,512		---	---

Source: Building 777 Investigation, 1974, pdf pp. 87-89

The average and standard deviation of daily air sample results prior to August 30, the day of the tritium release from the contaminated shipping container, are (5343 ± 4518) pCi/m^3. The result on August 30 is 37,676,609 pCi/m^3, and the sample taken on September 3 indicated a tritium concentration in the room air of 1,098,901 pCi/m^3. However, the September 3 result is suspect because the sample was collected in the same vessel that was used on August 30 and which had not been cleaned. Smear surveys of Room 452 on September 3 failed to show significant tritium contamination (Building 777 Investigation, 1974, pdf pp. 37-38). Tritium levels in Building 777 were known to be somewhat elevated over normal background because of residual contamination present since the 1973 tritium release.

The practice of pulling a sample of air from within shipping containers through a tritium air monitor to check for contamination was implemented after the 1973 tritium release. This practice was discontinued after urinary tritium results in the range of 0.75 µCi/L – 1.3 µCi/L were detected in May

1974 for the health physics technician who performed the monitoring. The technician's urinary tritium dropped to less than 0.1 µCi/L beginning in early July 1974 (Building 777 Investigation, 1974, pdf pp. 18-19).

All employees who worked in Room 452, Building 777, submitted urine samples after the August 30 tritium release, with a high result of 32,320 pCi/L. Table 7-3 shows individual results (Building 777 Investigation, 1974, pdf p. 90).

Table 7-3: Tritium Urinalysis Results - Exposed Workers and Others, August 30, 1974

Worker ID	Area	Urinary Tritium (pCi/L)	Uncertainty (pCi/L)
510	777	32320	± 6170
869	777	25610	± 6100
180	779	24000	---
548	777	22370	± 5800
12	777	21600	± 5800
112	707	17000	---
998	777	15740	± 6100
680	777	15730	± 5640
449	779	14000	---
801	707	13700	± 5370
004	123	630	± 580
Non-Occupational (Denver)		470	---

Source: Building 777 Investigation, 1974, pdf p. 90
Three hyphens (---) = Value not provided.

The report indicates that both a Denver resident and a Dow employee who did not work in radioactive material-handling areas were sampled with results < 0.01 µCi/L (<10,000 pCi/L). The Denver resident is identified in Table 3, and Worker ID 004 is believed, by implication, to be the Dow non-radiological worker.

Over 200 smear results for tritium are tabulated in the RFAO report (Building 777 Investigation, 1974, pdf pp. 74-82). Most appear to be surveys inside gloveboxes, but there are also workplace area results that can be used as indicators of likely sources of internal contamination of workers following an event such as the one in August 1974. The workplace smear results are shown in Table 7-4.

Table 7-4: Tritium Smear Surveys - Work Areas in Buildings 776-777 (This table spans two pages)			
Date	**Bldg/Room**	**Location**	**Maximum Smear (pCi)**
9/6/74	776-205	205 Plenum - cold side	< 100
9/6/74	776-206	206 Plenum - cold side	< 100
9/6/74	777-452	206-532 - top of box	< 100
9/6/74	777-430	E.S. Welder	353,000
9/6/74	777-437	Penthouse	< 100
9/6/74	777-437	A-1	110,000
9/6/74	777-437	A-2	4,800
9/6/74	777-437	A-3	9,400
9/6/74	777-463	A-5	1,200
9/6/74	777-463	Conveyor Line	7,900
9/6/74	777-463	A-7	7,700
9/9/74	776-205	205 Plenum (hot side)	211,000
9/9/74	776-206	206 Plenum (hot side)	1,230,000
9/10/74	776 - Size Reduction	Floor	< 500
9/10/74	776-201	Floor	1,100
9/11/74	777-452	Floor at J-24	460
9/11/74	777-452	Floor at K-24	470
9/11/74	777-452	Floor at L-24	640
9/11/74	777-452	Floor at M-24	780
9/11/74	777-452	Floor at K-25	560
9/11/74	777-452	Floor at J-25	950
9/11/74	776-250	Plenum Floor	< 100
9/11/74	776-250	Plenum Fan	< 100
9/11/74	776-252	Plenum Floor	465
9/11/74	776-252	Plenum Filter	1,636
9/11/74	776-S-8	Plenum Filter	< 100
9/11/74	776-S-8	Plenum Deep Beds	< 100
9/11/74	776-S-7	Plenum Filter	< 100
9/11/74	776-S-7	Plenum Floor	< 100
9/11/74	776-S-4	Plenum Filter	< 100
9/11/74	776-251	Plenum Floor	3,625
9/11/74	776-251	Plenum Filter	3,603
9/11/74	776-440	Floor	1,000
9/11/74	776-432	Floor K-20	500
9/11/74	776-432	Floor H-19	1,460
9/11/74	776-432	Floor H-20	710

Table 7-4: Tritium Smear Surveys - Work Areas in Buildings 776-777
(This table spans two pages)

Date	Bldg/Room	Location	Maximum Smear (pCi)
9/11/74	776-432	Floor K-19	520
9/11/74	776-201	#1 System Kathene	160,000
9/11/74	776-201	#4 System Kathene	400,000
9/11/74	776-201	#3/7 System Kathene	450,000
9/11/74	776-201	#8 System Kathene	140,000
9/11/74	776-201	GBDA System Kathene	400,000

Source: Building 777 Investigation, 1974, pdf pp. 74-82

The exhaust plenums and the Kathabar air driers (which use a lithium chloride solution called Kathene) appear to have collected the greatest amount of tritium after the release. Workers responsible for changing filters in the plenums or recharging the Kathabar systems would appear to be at greatest risk for tritium uptake after the initial release.

NIOSH assessed the 1.5-Ci tritium release from a contaminated shipping container that occurred on August 30, 1974. The RFAO report provides air survey, bioassay, and smear survey results (Building 777 Investigation, 1974). Specific urine sample collection dates were not included in the report but data were matched to two NOCTS claims, which reported a collection date of September 5, 1974. NIOSH performed a dose assessment using the Integrated Modules for Bioassay Analysis (IMBA) software. An intake date of August 30, 1974 was assumed, and the largest reported result collected after the incident of 36,320 pCi/L was used. There was a slight discrepancy (one digit) between the result included in the RFAO report and that in the NOCTS case file; the NOCTS value is assumed to be correct because it is the handwritten urinalysis record and is also the larger of the two values. The resulting dose from NIOSH's analysis is < 1 mrem (0.15 mrem). Assuming one incident per day at 0.15 mrem for 250 days results in a dose of 37.5 mrem/year for the pre-1973 time period.

Follow-up on the 1973 Tritium Exposure Period and Methods for Bounding Dose

Based on NIOSH's evaluation in this report, it has been determined that the 1973 data serve as the bounding exposure scenario for tritium exposures at RFP. Therefore, these data will be used to develop a bounding approach for the purpose of reconstructing dose for unmonitored workers who may have been exposed to tritium as a result of RFP plutonium-recycling operations with tritium-contaminated materials.

The report, *Investigation of the Tritium Release Occurrence at the Rocky Flats Plant* (Release Investigation, 1973c, pdf p. 16), describes a 1973 incident that prompted the site to sample a number of workers for tritium exposure (Dosimetry Records, name1; Dosimetry Records, name2; Dosimetry Records, name3; NOCTS, 2012; Release Investigation, 1973, pdf p. 16). A shipment of scrap plutonium from LLNL was discovered to have been contaminated with tritium. This material was processed at the Rocky Flats Plant from April 9 to 25, 1973 in Building 779A, Room 154. Because it was not immediately identified as being contaminated, monitoring of potentially-exposed individuals did not begin until late September 1973.

Two hundred fifty people were sampled following the discovery; this included all employees who worked in areas in which the contaminated scrap was processed. The waste stream from the processing of this material was also contaminated, providing opportunities for intake of H-3 at later dates; therefore, all employees involved in the processing of wastes from this scrap were also included in the urinalysis program. The collection of samples from a tritium-contaminated water bubbler on September 19 and September 25, 1973 were also identified as possible opportunities for intakes.

Due to the large sample load, raw urine samples were first analyzed in many of the cases. It was noted that the counting efficiency was only about 3% for these analyses, and that the corrections made for spectral shift could lead to abnormally-high readings. Nineteen employees were initially identified as having elevated tritium levels in their urine. These samples were distilled and re-analyzed. Upon this recheck, fourteen of these employees were found to be below the 10,000 pCi/L action level established by the site. The five most-exposed individuals were identified and details of their potential exposures, including bioassay results, are included in the investigation report. One of these five individuals is in NOCTS. The results of the five workers who exceeded the 10,000 pCi/L action level were reviewed by NIOSH.

Exhibit 14 of the referenced report contains a section on Personnel Exposure Data. The following is an excerpt (Release Investigation, 1973c, pdf p. 122):

> *SAMPLING PROTOCOL*
>
> *Dow began by sampling urines from all employees who were thought to have had the best chance of being exposed to tritium. As of October 15, 1973, about 250 employees have been tested. Dow is continuing to trace leads to other possible exposure and will sample them as they are found. Dow intends to sample many employees who have had only a remote chance of coming in contact with tritium. Dow also tests the urine of any employee who requests this whether or not they are candidates for exposure.*
>
> *ACTION LEVELS*
>
> *An "action level" of 10,000 pCi/l was tentatively chosen for resampling. This level was chosen for several reasons such as:*
>
> 1. *An article by Fitzsimmons indicated that people wearing tritiated watches could excrete levels of 10,000 pCi/l.*
>
> 2. *A calculation of worst possible circumstances indicate that an employee would have to exceed levels of 23,000 pCi/l before any permissible yearly levels of whole body radiation would be exceeded.*

3. *The sample load was such that Dow could handle resampling only a limited number of employees on a frequent basis. It turned out that a relatively small number were over 10,000 pCi/l but a large fraction were in the 5,000 and 10,000 pCi/l range.*

4. *Without predistilling the urine samples the counting efficiency drops to about 3% and the corrections made for spectral shift can lead to abnormally high reading.*

5. *With a large sample load, counting time devoted to each sample must be restricted so that 10,000 pCi/l might be considered lowest detection limit available under the present circumstances.*

All samples above 10,000 pCi/l are redone by counting the distillate of the original sample.

Rocky Flats identified five workers with tritium urinalysis results exceeding the action level of 10,000 pCi/L. Results from these five workers are reviewed here. Fourteen other workers initially exceeded 10,000 pCi/L but fell below this level upon recount (as noted above, the distillates of the original samples were counted, offering better counting statistics during recount).

The document contains information, including tritium bioassay results and brief work histories about the five workers with the largest tritium sample results. This information was used to assess the doses to the affected workers and is displayed in italics in the sections below. All five cases had initial samples that were not distilled, with one to five later samples that were distilled. In general, the non-distilled and distilled sample results tended to not match up, with the distilled samples yielding lower values. This is to be expected, given the site discussion above (see Item 4). The pre-distilled results were used in the development of this analysis because there were more results available and they yielded claimant-favorable doses. The following assumptions were employed in this assessment:

- Equal weight to all samples (measurement error the same for all samples)
- Only pre-distilled samples used for fits (these are shown as blue dots in the figures; distilled samples appear in red and are not used in the analysis)
- H-3 in the form of tritiated water (HTO)
- IMBA model for inorganic H-3, as described in *Guidance on Use of IMBA Software for DOE Safety Applications* (DOE, 2006)
- Injection intake (for modeling with IMBA)
- Intake dates based on worker information and examination of fit to urine sample results

The five workers identified as having the largest H-3 urinalysis results are assessed below. Text in italics indicates an excerpt from the incident report.

Case A

Case A worked in Room [location redacted] *from* [date range redacted].

He was involved in the hydrating [sic: likely hydriding] *and processing of the parts in question from* [date range redacted], *along with Cases* [case identifiers redacted]. *He was not involved in any of the following special projects:*

a. [date, special project name redacted]
b. [date, special project name redacted]
c. [date, special project name redacted]

He was involved in taking samples from a tritium-contaminated [device redacted] *on* [dates redacted]. *On* [date redacted], *this was done without a* [item redacted].

From this history, it would appear the most likely exposure occurred on [dates redacted]. *If an exposure had occurred between* [date range redacted], *it is likely that both Cases* [case identifiers redacted] *would have been exposed to the same source, and subsequently, excreted the same quantities of tritium.*

The RFP document also states:

In Case A, a history of his work assignment and his urine results for the first two weeks indicate that he sustained a recent exposure. At the present time he is excreting tritium with an elimination half life of less than 10 days. According to Sanders and Snyder, this is the pattern of elimination from an exposure up to 90-days post exposure.

The statement that Case A's intake appears to be recent agrees with current models for HTO intakes. If an intake on [date redacted] is assumed, a very poor fit to the data is achieved, as shown in Figure 7-1.

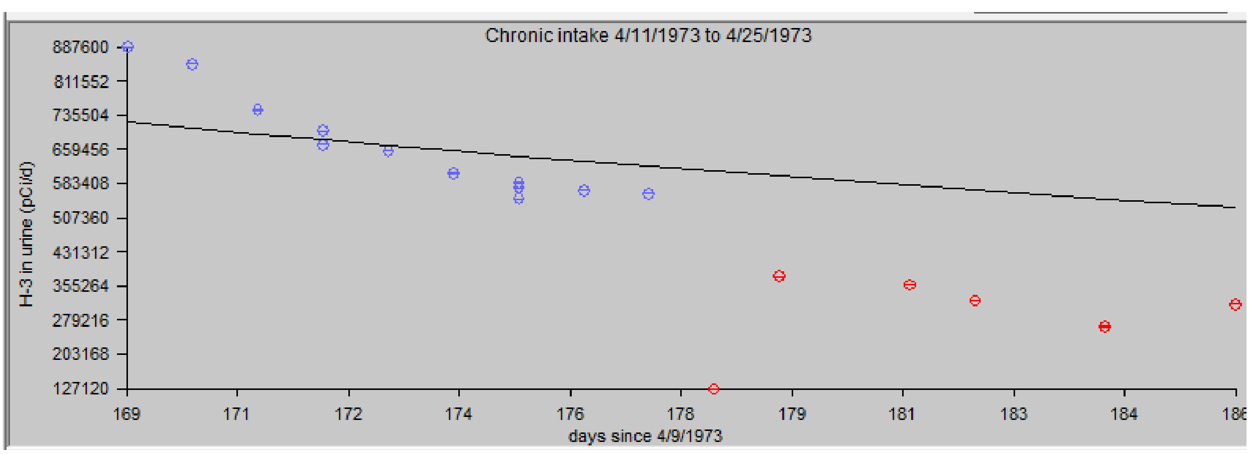


Figure 7-1: Case A Chronic Intake of HTO from April 11 through April 25, 1973

Based on the worker's history and the bioassay result pattern, an acute intake was assumed to have occurred on September 19, 1973. Using the results of samples collected from Sept. 25 to Oct. 4, and applying a uniform error to each of the samples, the intake is 38.7 µCi. The corresponding dose is 2.6 mrem. These samples are presumed to be pre-distilled because later samples from Oct. 5 to Oct. 12 are labeled as "distilled." This yields a very good fit to the pre-distilled results (see Figure 7-2).

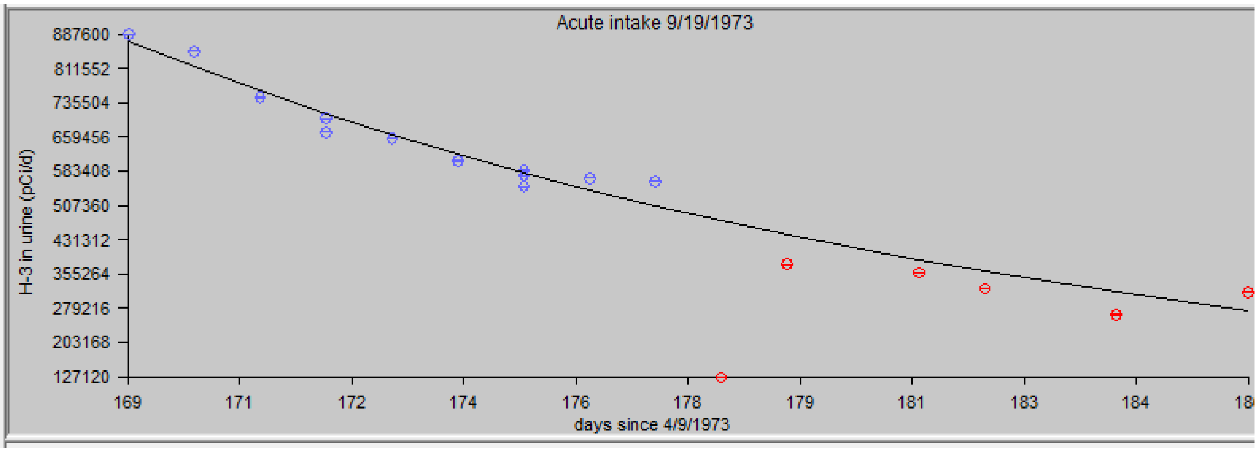


Figure 7-2: Case A Acute Intake of HTO on September 19, 1973

Case B

He has worked in [location redacted] *since* [date redacted]. *He was in the room when* [action redacted].

Assuming a chronic intake from July 1 through Sept. 25 (date of first urine sample) yields an intake rate of 0.33 µCi/d (for a total intake of 28.1 µCi) and provides a reasonable fit to the results (see Figure 7-3). The dose is 1.90 mrem.

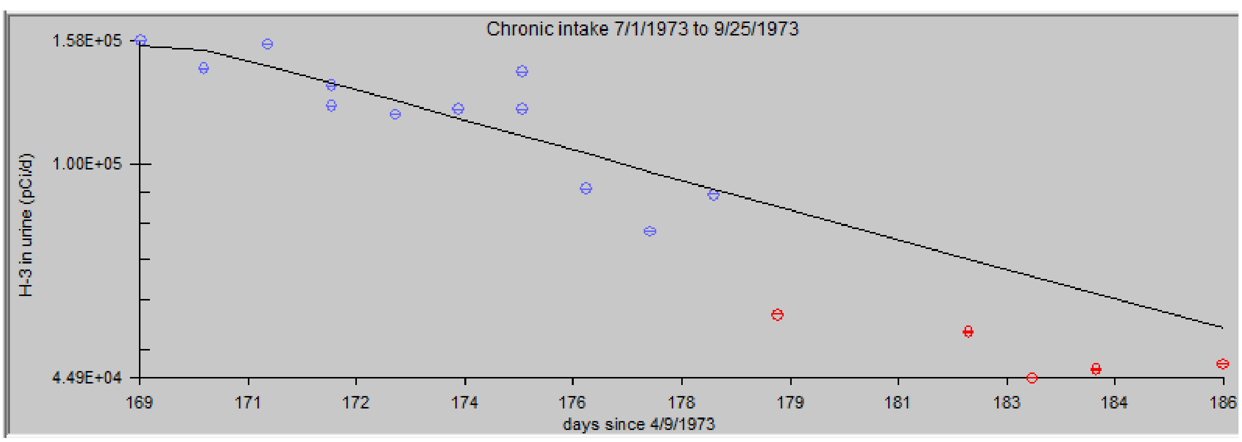


Figure 7-3: Case B Chronic Intake of HTO from July 1 through September 25, 1973

Assumption of an acute intake on Sept. 19 (date of the first bubbler sample) yields an intake of 7.28 µCi. This fit (see Figure 7-4) is almost identical to the first scenario.

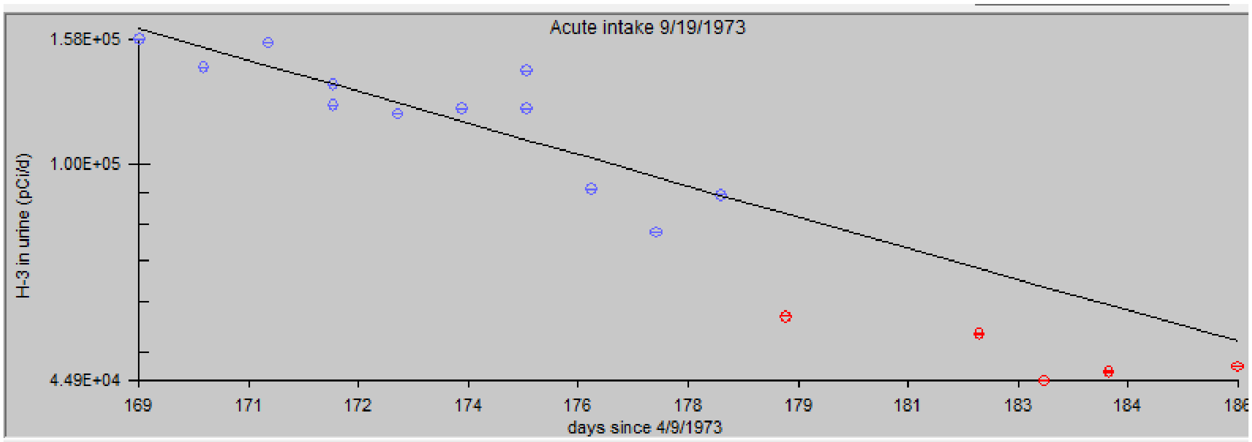


Figure 7-4: Case B Acute Intake of HTO on September 19, 1973

A single acute intake on his first day in the area (July 1) yields an intake of 720 µCi and a dose of 49 mrem (see Figure 7-5).

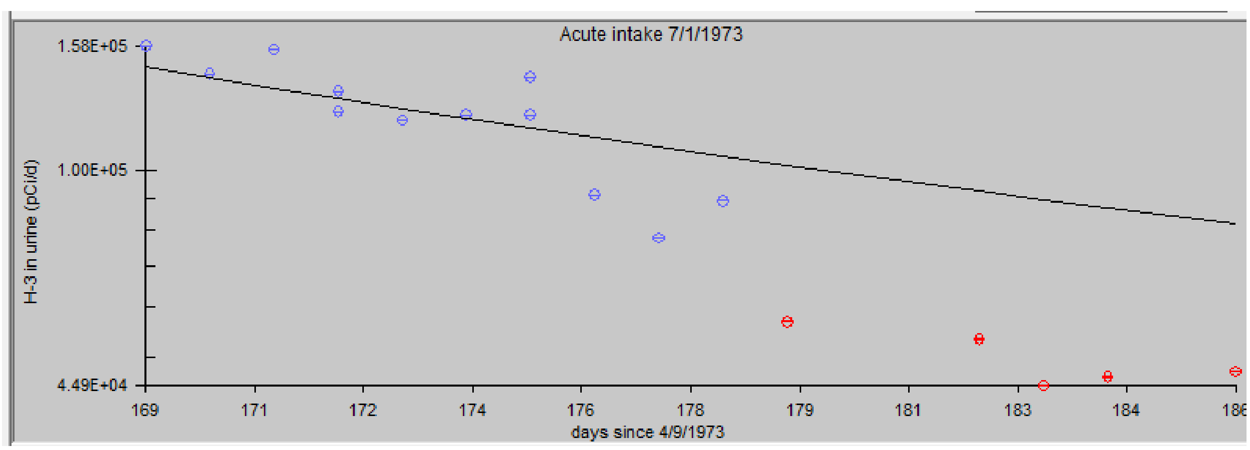


Figure 7-5: Case B Acute Intake of HTO on July 1, 1973

The single acute intake on July 1 does not provide a good fit to the later pre-distilled results. The first two scenarios (chronic intake from July 1 through Sept. 25, and acute intake on Sept. 19) provide similar fits that reasonably follow the pattern of the pre-distilled samples. The chronic intake yields a larger intake so it is used for the best estimate.

Case C

He worked in [location redacted] *since* [date redacted]. *He was not in the room when* [action redacted].

Given that the worker did not start in the area until August 27, an acute intake was assumed on this date (see Figure 7-6). Using only the pre-distilled sample results, his intake is 21.3 µCi with a dose of 1.4 mrem.

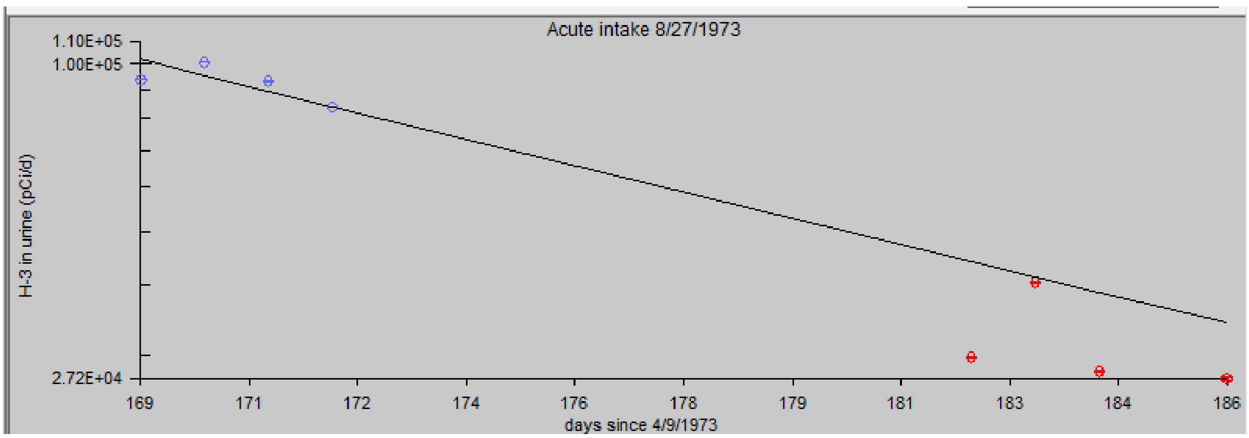


Figure 7-6: Case C Acute Intake of HTO on August 27, 1973

If a chronic intake is assumed to have started on his first day of potential exposure (August 27) and continued until the date of his first sample (Sept. 25), the resulting intake is 0.24 µCi/d for a total intake of 7.08 µCi. This fit is shown in Figure 7-7.

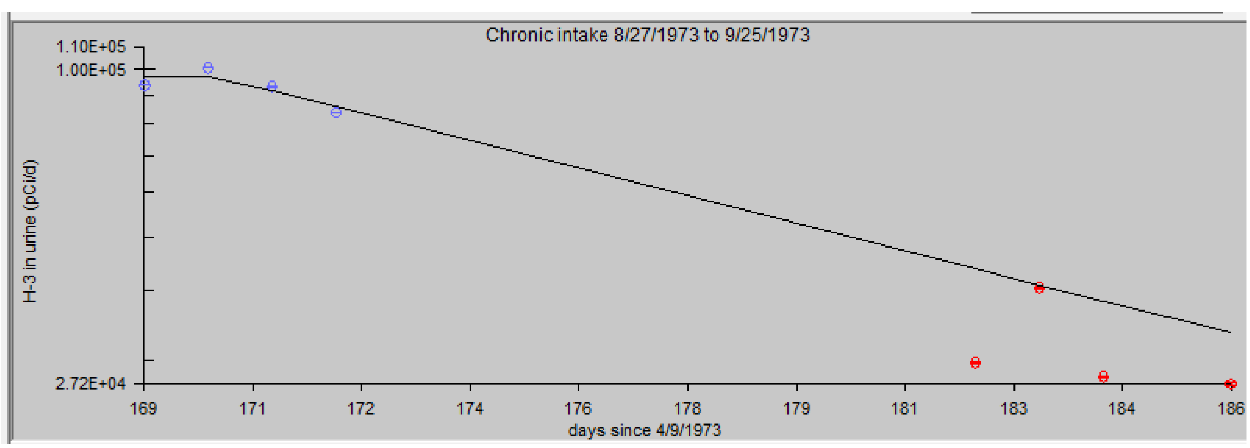


Figure 7-7: Case C Chronic Intake of HTO from August 27 through September 25, 1973

The two fits are very similar, so the acute intake is selected as the best fit as it results in a dose that is more favorable to the claimant.

Case D

He worked in [location redacted], *between* [date range redacted]. *He has not been exposed to tritium since* [date redacted].

Case D submitted samples on only three days, although there are two results on two of those days. In one instance, one of the samples was distilled; on the other day, there is a note stating “repeated with sample channel ratio.” On the latter day, the results differ by a factor of almost two; the larger of these results is assumed to be the pre-distilled analysis and is used for the intake assessment. An assumed chronic intake from April 10 through 25 (last date of incident) yields an intake of 71.2 µCi/d for a total intake of 1070 µCi (see Figure 7-8). The resulting dose is 72 mrem.

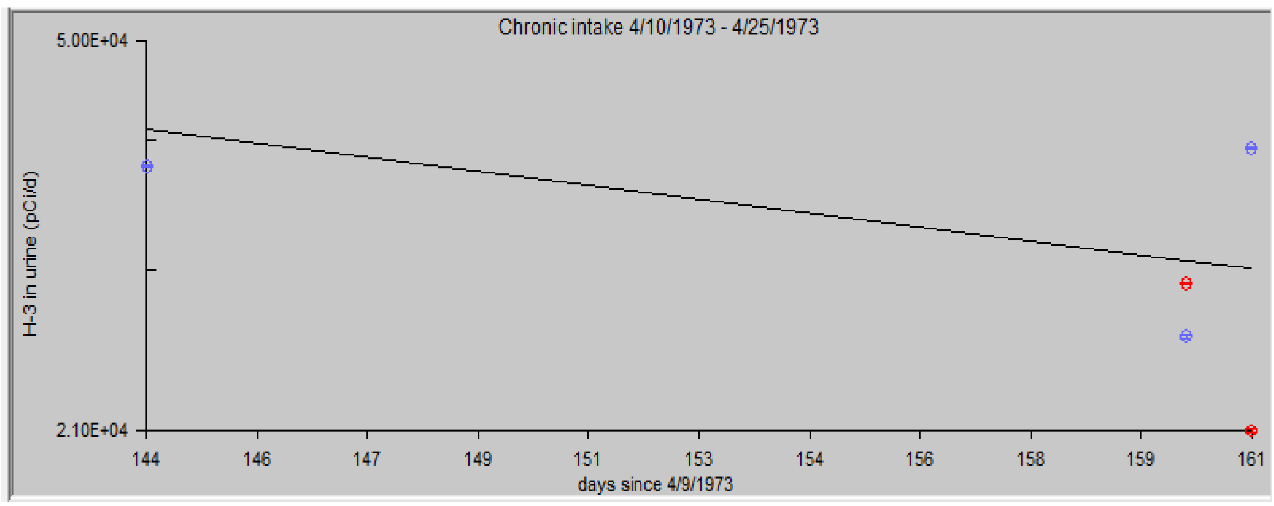


Figure 7-8: Case D Chronic Intake of HTO from April 10 through April 25, 1973

A chronic intake from April 10 to June 15 yields an intake rate of 8.84 µCi/d for a total intake of 581 µCi (39 mrem), as shown in Figure 7-9.

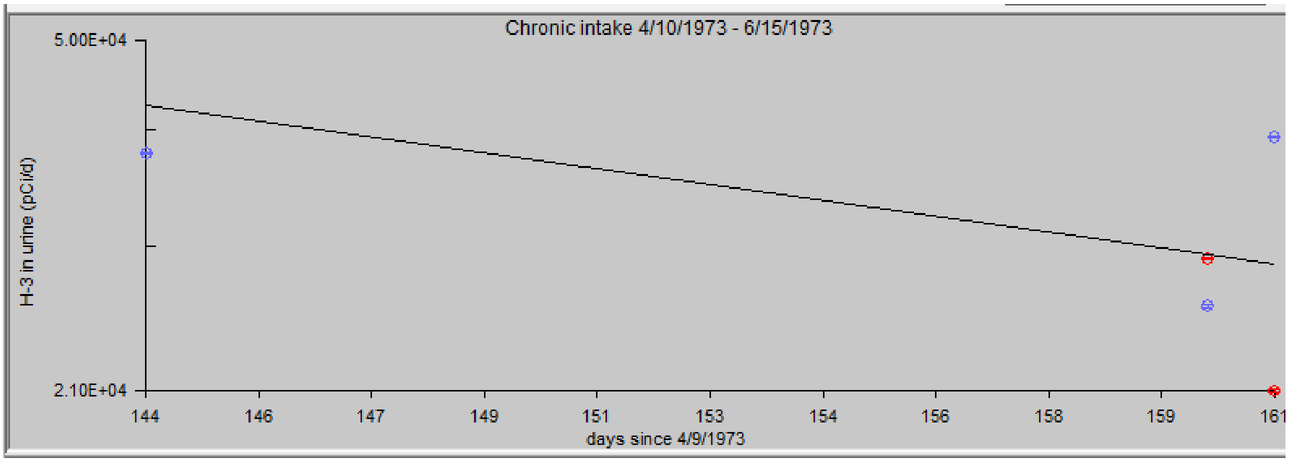


Figure 7-9: Case D Chronic Intake of HTO from April 10 through June 15, 1973

Because there are few samples and the results follow no specific pattern, there is little difference between the fits. Therefore, the acute intake is assigned because it yields the larger dose.

Case H

He came in contact with the possible source of tritium on [date redacted].

No other information is included in the report. The conclusion in the report is: *(It is expected that, as a result of a review of his work history and urinalysis data, a dose assignment of less than 3 rem will be made.)* However, no follow-up information is available.

Because the only available information indicates that an intake would have occurred on April 6, an acute intake was modeled (see Figure 7-10). The resulting intake is 1240 µCi with a dose of 84 mrem.

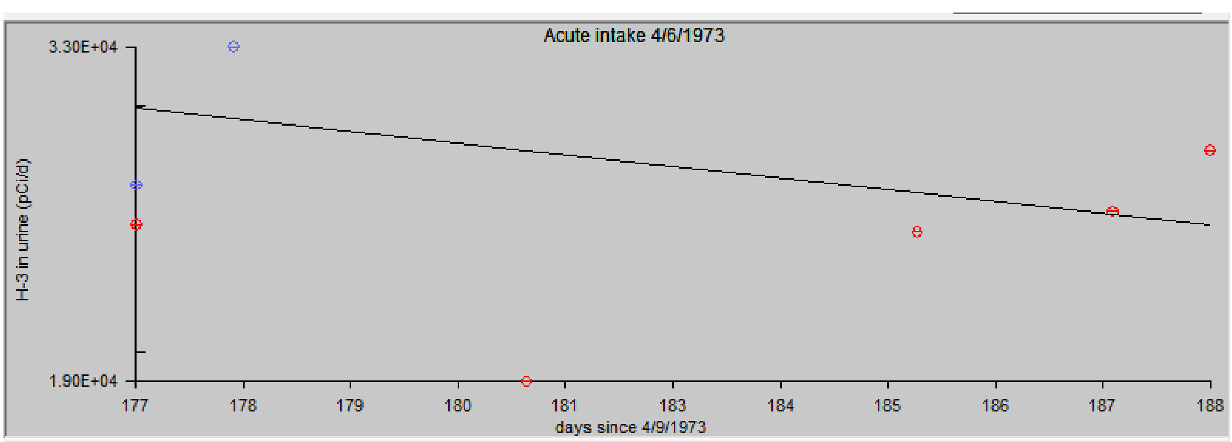


Figure 7-10: Case H Acute Intake of HTO on April 6, 1973

The best estimates for the five cases reviewed are summarized in Table 7-5 below. Tritium contamination was associated with plutonium scrap material; therefore, H-3 doses will be assigned to all individuals who were monitored for plutonium in 1973. Because monitoring began several months after the potential start of exposure, the largest assessed dose (84 mrem) will be assigned.

Table 7-5: Summary of Intake Assessments for the RFP 1973 Incident

Case	Intake Date	Intake (µCi)	Dose (mrem)
A	9/19/73	38.7	2.6
B	7/1 thru 9/25/73	28.1	1.9
C	8/27/73	21.3	1.4
D	4/10 thru 4/25/73	1070	72
H	4/6/73	1240	84

Follow-up on the Post-1973 Tritium Exposure Period and Methods for Bounding Dose

For the assessment of tritium exposures at RFP for the 1974-1975 period, a co-worker study was performed using data from NOCTS for 1974 and 1975. There are 38 individuals with tritium data in 1974 and 37 in 1975. ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling*, provides justification and guidance.

When assessing tritium intakes for most sites, it is assumed that intake potential exists only while tritium bioassay monitoring is being performed because monitoring is cheap, easy, and requires only spot samples, thus presenting less of a burden than other forms of bioassay on both the employer and the employee. Because tritium was not of primary concern at RFP and was present only as a potential contaminant on equipment, a given individual was not placed on a routine sampling program. Instead, a program was established whereby one-tenth of the urine samples collected for plutonium analysis were also analyzed for tritium content (Tritium Monitoring, 1974) as well as the collection of samples when there was a particular concern. Samples available in NOCTS for these two years indicate that analyses were performed throughout the year, with most individuals sampled only once.

For the purpose of the co-worker study, it was assumed that each worker had the potential to be exposed at a constant level throughout the year in which the urine sample was collected. The 95th percentile was used because one-tenth of the population was sampled. The co-worker study for 1974 - 1975 yielded doses of 0 mrem for everyone.

For the years after 1975, there are 11 or fewer individuals in NOCTS with tritium data; this is insufficient for performing a co-worker study. Results for these years are consistent with those from the previous years and show a general decreasing trend. The intake rate from the 1974-1975 co-worker study (i.e., 0 mrem - see above) will apply to these years; therefore, no additional dose due to tritium, as it relates to the assessment performed in this analysis, will be assigned after 1973.

7.2.1.2 Internal Tritium Dose Reconstruction Feasibility Conclusion

Based on the assessment presented in the preceding sections of this evaluation, NIOSH concludes that there are sufficient data and knowledge of processes and operations to support bounding the associated tritium dose using the methods and information presented in this evaluation. This assessment corroborates that the original tritium assessment presented in Rev. 0 of SEC-00192 did provide a bounding tritium assessment. The assessment provided in this Rev. 1 of the report provides a sufficiently accurate assessment of tritium dose at RFP for use in individual dose reconstruction. The pre-1973, 1973, and post-1973 dose values are summarized below.

- Pre-1973: Using the largest reported result collected after the August 30, 1974 incident, the resulting dose is < 1 mrem (0.15 mrem). Assuming one incident per day at 0.15 mrem for 250 days results in a dose of 37.5 mrem/year for the pre-1973 time period.

- 1973: Using the bioassay samples collected after tritium incident associated with contaminated scrap in mid- to late-April 1973 resulted in a maximizing dose of 84 mrem and is applied as a bounding estimate of all unmonitored workers. This dose is more precise than the estimate in Revision 0 of the SEC00192 evaluation report, but is still maximizing.

- Post-1973: A co-worker study using data from NOCTS for 1974 and 1975 resulted in an annual dose of less than 1 mrem; therefore, no dose will be assigned for unmonitored tritium after 1973.

7.2.2 Evaluation of Bounding Process-Related Thorium Doses

While the RFP SEC evaluation performed as part of the SEC-00030 petition review included an assessment of thorium operations at the site, additional issues were opened during the review and assessment of SEC-00192 that required a response to support closure of the issue. As part of the thorium follow-up, NIOSH reviewed the SEC-00030 working group discussion on this issue and located the final response from the SEC-00030 documentation (NIOSH, 2007). Because the Working Group and SC&A rejected the originally-proposed NUREG-1400 approach and the use of GA data from operations, NIOSH's final response proposed using data from a surrogate data source. This response preceded the final deliberations with the Board on the use of surrogate data published in IG-0004 in 2008. After further review of the air data included in the Albert document, it was found that the data were from a study published by the Albany Research Center in Albany, Oregon (Thorium, 2006). NIOSH determined that the report was a one-time operation conducted under experimental laboratory conditions, and therefore, does not meet the surrogate data criteria for use for RFP dose reconstruction. The additional information gained from the most recent data captures support the reopening of this issue, and the identification of a class for which dose cannot be reconstructed with sufficient accuracy.

The principal source of internal thorium radiation doses for members of the class under evaluation was associated with RFP thorium research and development operations. There is limited information and data available for reconstructing the process-related internal thorium doses of members of the class under evaluation. There are limited thorium monitoring data, including two *in vitro* bioassay (urinalysis) results for thorium in 1966 (listed in NOCTS and the SRDB). There are additional urine bioassay records and some area monitoring information for the 1950s and 1960s in the SRDB, but there are no clear monitoring results associated with the records. While NIOSH has identified source term information to support the existence of thorium on site starting with the beginning of RFP operations in 1952 through the late 1960s and early 1970s, these data are a snapshot of the quantity of thorium on site at a point in time and do not represent throughput of thorium at the site. In addition, classification issues limit NIOSH's ability to present additional detail on material amounts in this evaluation report.

7.2.2.1 Methods for Bounding Thorium Dose at Rocky Flats

NIOSH has found limited personnel and workplace monitoring records and data specific to thorium for the period under evaluation that can be used to bound the associated dose. Most of the available data are gross alpha concentrations. Limited radionuclide-specific air-sampling data for thorium have been identified. In addition, NIOSH lacks sufficient source term information that would allow it to present an estimate for potential thorium exposures to which the proposed class may have been exposed.

7.2.2.2 Internal Thorium Dose Reconstruction Feasibility Conclusion

NIOSH has evaluated the available personnel and workplace monitoring data and has determined that these data are insufficient for estimating internal thorium exposures. In the absence of adequate *in vitro* or *in vivo* bioassay, NIOSH would employ source term data. However, NIOSH lacks sufficient source term data that are inclusive of the throughput amounts of thorium (i.e., they only represent a snapshot in time in regards to quantities); these data do not support estimating potential internal exposures to thorium during the period of RFP thorium operations from April 1, 1952 through December 31, 1966.

NIOSH has determined that the significant thorium operations at RFP were secured prior to the end of the SEC class being proposed in this report. Therefore, NIOSH finds that the available internal monitoring data for RFP are adequate to support sufficiently accurate dose reconstruction beginning January 1, 1984. Furthermore, NIOSH believes that maturation of RFP work practices and programs as well as the nature of work performed after 1983 were such that dose from potential intakes of residual thorium can be bounded with sufficient accuracy.

Although NIOSH found that it is not possible to completely reconstruct internal thorium radiation doses for the period from April 1, 1952 through December 31, 1966, NIOSH intends to use any internal thorium monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at RFP during the period from April 1, 1952 through December 31, 1966, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.2.3 Evaluation of Bounding Process-Related U-233 Doses

Production of U-233 also results in the unavoidable production of uranium-232, a problematic contaminant with a half life of 72 years. U-232 decays via alpha emission to thorium-228, a member of the thorium decays series, which subsequently decays to produce several strong gamma-emitting radionuclides. In addition to being an internal dose hazard, U-232 and its gamma-emitting progeny represent a significant external radiation hazard. The purpose of the "thorium strike" operation was to remove Th-228 from U-233, thus reducing the gamma radiation levels.

7.2.3.1 U-233 Urinalysis Information and Available Data

Previous SEC reviews and evaluations did not dispute the adequacy of the RFP internal monitoring practices for uranium – workers with potential for uranium exposures were assigned to bioassay programs. The RFP Site Profile provides a method for assessing dose from uranium exposures for individual dose reconstructions that does not discriminate between uranium isotopes. However, the Site Profile does not specifically address potential intakes of U-233, or the associated U-232.

Operators involved with the U-233 process that were listed in the early U-233 operations logbook were used to support a review of participation in the RFP uranium bioassay program for the early years of the U-233 operation (Logbook, 1965-1967, pdf pp. 4-5). Of the 46 individuals involved in U-233 operations at that time, as listed in the logbook, 18 are NOCTS claimants. All of these 18 NOCTS claimants participated in the RFP bioassay program over their entire employment period (this includes uranium, plutonium, and gross-alpha bioassay results as well as some chest-count data in their dosimetry records). All but one claimant have uranium bioassay results in the period associated with the U-233 work represented in the logbook.

7.2.3.2 U-233 Airborne Survey Data

NIOSH has identified some limited air monitoring data for operations involving U-233. A source document states that "thorium purification" of U-233 solution was carried out in Building 771 from April 26 through May 1, 1965 (Investigation Summary, 1965, pdf pp. 8-9, 17, 44). Data presented in Table 7-6 appear to indicate relatively-low air concentration levels during this operation (RFP, 1965a).

Table 7-6: April 1965 Air Sample Results from Building 771, Room 114

Date	Maximum Percent of Radiation Control Guides (RCG)
4/26/65	32%
4/27/65	<25%
4/28/65	<25%
4/29/65	39%

Source: RFP, 1965a, pdf pp. 12, 19, 25-26

From these data, however, it is unclear what the relative concentrations of Th-228 may have been. As is often the case with air monitoring data, the representativeness of the sampling locations to actual worker breathing zones is also uncertain.

An RFP interviewee indicated that thorium strikes occurred in Building 81, Room 266 (Personal Communication, 2007). The air sampling data associated with that location and operations period (April 26-29, 1965) are below 50% RCG (Air Monitoring, 1965, starting at pdf p. 115). As with the data presented in Table 7-6, it is unclear from the Building 81 data what the Th-228 concentrations may have been and the representativeness of the sample locations is also questionable.

In a logbook that appears to be related to U-233 operations during the 1965-1967 time period, the author states (Logbook, 1964-1967):

> *Air samples were all way below MPL with the exception of those taken inside plastic house around the furnace in Rm. 142. During foundry operations air samples inside plastic house varied from 35% MPL to 13,054% MPL. Furnace operations have to be watched closely for airborne problems.*

The term "MPL" is assumed to be Maximum Permissible Level established by the AEC; NIOSH has no confirmed relationship between MPL and RCG.

7.2.3.3 Evaluation: Bounding Ambient Environmental Internal U-233 Doses

The predominant forms of uranium processed at RFP were depleted and enriched uranium, consisting of the naturally occurring isotopes, U-234, U-235, and U-238. For this reason, these uranium isotopes were likely to have been the predominant contributors to the ambient environmental dose from all uranium isotopes at RFP. Methodologies for evaluating environmental dose from enriched and depleted uranium are described in ORAUT-TKBS-0011-4. Because of the data issues and limitations presented in this report, no specific methods to bound environmental doses from U-233 and U-232 have been pursued or defined.

7.2.3.4 Methods for Bounding U-233 Dose at Rocky Flats

If uranium bioassay data are available for individual claimants who are known to have been potentially exposed to U-233 and U-232, it may be feasible to reconstruct their internal doses by making claimant-favorable assumptions with regard to the uranium isotopes present in their urinalyses. However, since U-233 has a much higher specific activity when compared to the other naturally-occurring uranium isotopes ("140 times that of enriched U-235 normally handled at Rocky Flats" [Investigation Summary, 1965]), NIOSH cannot assume that it was handled in a similar manner as other uranium isotopes. For this reason, co-worker models using internal dosimetry data for other uranium isotopes cannot be used to bound intakes of U-233 or U-232 for workers who were not specifically monitored for uranium.

In the absence of thorium bioassay records, NIOSH has not developed an acceptable method for reconstructing potential internal dose from Th-228 that would have been associated with U-233 processes.

7.2.3.5 Internal U-233 Dose Reconstruction Feasibility Conclusion

For claimants with available uranium bioassay records and who were known to have been potentially exposed to U-233 and U-232, it may be feasible to reconstruct internal doses to these isotopes by making claimant-favorable assumptions with regard to the uranium isotopes present in their urinalyses. However, in its review of available bioassay records for individuals identified as having worked in U-233 processing areas, NIOSH has determined that uranium bioassay data may not be available for all potentially affected individuals. Additionally, these same workers were also potentially exposed to Th-228. NIOSH lacks thorium bioassay data for Rocky Flats personnel.

NIOSH also recognizes that the available U-233 inventory numbers do not necessarily represent production throughput. Furthermore, NIOSH has determined that workplace air monitoring and contamination surveys for U-233 processes are insufficient for bounding dose reconstruction purposes. In the absence of adequate personnel or workplace monitoring data, NIOSH would employ source term data. However, NIOSH lacks sufficient source term data that are inclusive of the throughput amounts of U-233 or its progeny (i.e., they only represent a snapshot in time in regards to quantities); these data do not support estimating potential internal exposures to U-233 or its progeny during the period of RFP U-233 operations from 1964 through 1983. Without uranium and thorium bioassay results, NIOSH has concluded that it cannot estimate with sufficient accuracy the potential internal exposures to U-233, U-232, and Th-228 which the proposed class may have received.

Although NIOSH found that it is not possible to completely reconstruct internal U-233/U-232/Th-228 radiation doses for the period from 1964 through 1983, NIOSH intends to use any related internal monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at RFP during the period from 1964 through 1983, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.2.4 Evaluation of Bounding Process-Related Np-237 Doses

Insufficient information exists for evaluating bounding doses for neptunium exposures. Only two bioassay results obtained in 1966 have been captured (Monthly Reports, 1965-1967, pdf pp. 74, 78; Logbook, 1966-1969, pdf pp. 3, 5). NIOSH has not captured workplace air monitoring, surface contamination surveys, or process details sufficient to reconstruct the neptunium exposure environment for any year under evaluation.

7.2.4.1 Np-237 Urinalysis Information and Available Data

Two bioassay results obtained in 1966 have been captured (Monthly Reports, 1965-1967, pdf pp. 74, 78; Logbook, 1966-1969, pdf pp. 3, 5).

7.2.4.2 Np-237 Airborne Survey Data

Any ambient environmental exposures to monitored individuals will be accounted for in assigning the process-related dose based on individual monitoring data. Therefore, no additional dose from ambient environmental internal exposures would be assigned unless: (1) the ambient environmental dose is assigned separately to ensure claimant-favorability in the dose reconstruction; or (2) the ambient environmental dose is representative of the internal exposures for monitored individuals with little or no workplace exposure potential.

The primary internal exposure pathway (ambient or workplace) cannot be determined for unmonitored workers, since there is no evidence of a personnel monitoring program for neptunium.

7.2.4.3 Internal Np-237 Dose Reconstruction Feasibility Conclusion

Beginning in 1962, neptunium was processed at Rocky Flats by request from other DOE sites. NIOSH currently believes that activities associated with neptunium virtually ceased after 1983, even though neptunium inventories existed until the end of 1988. Whether neptunium was handled or processed from 1984-1988 at Rocky Flats is still being evaluated. Less than 1,500 g of neptunium was reported in inventory for any year, and processing capacity was limited to quantities of less than 500 g per batch. The number of Rocky Flats employees who worked with neptunium appears to have been quite limited, but no personnel records have been captured with information about these workers or their work assignments with neptunium exposure potential. Only two neptunium bioassay results have been captured by NIOSH. The bioassay results are not accompanied by additional information about the specific task performed, the conditions under which the exposure occurred, the degree to which neptunium work was part of the employee's regular job assignment, or whether other employees might also have been exposed. Neptunium-handling procedures appear to have been the same as those for plutonium, with separation provided between the neptunium and workers by hoods or glove boxes. The processing resulted in purified neptunium as oxide, fluoride, or metal that was then used in further processing or fabrication of specific items specified by the requesting DOE site.

Neptunium exposure potential for RFP workers existed at every processing step, including extraction and purification, hydrofluorination, reduction to metal, alloying with U and Pu, casting, and rolling. Urinalysis procedures for neptunium existed, given that two neptunium bioassay results from 1965 were captured; however, there is no information about the procedures, which may have been performed in the 771 Building rather than in the environmental and personnel monitoring labs (Personal Communication, 2013s, pdf p. 3).

NIOSH has evaluated the available personnel and workplace monitoring data and has determined that these data are insufficient for estimating internal neptunium exposures. In the absence of adequate *in vitro* or *in vivo* bioassay, NIOSH also lacks sufficient source term data to support estimating potential internal exposures to neptunium during the period of RFP neptunium operations from 1962 through December 31, 1983.

According to a report published in 1981, some early work with neptunium was accomplished at Rocky Flats in open hoods, which were later replaced by alpha containment gloveboxes (SRDB 127272, pdf p. 7). There is insufficient information to determine how much neptunium was processed in the open hoods or when the neptunium work was moved to gloveboxes. It is clear, though, that all neptunium processing was performed in gloveboxes by the time of the 1981 report. It is also apparent from interviews with knowledgeable individuals that *in vitro* bioassay techniques were improved by 1981 (with ion exchange separation, electroplating, and isotope-specific pulse-height analysis); these improved techniques provided the capability of isolating and quantifying neptunium in bioassay samples (Personal Communication, 2013s, pdf pp. 4-5; Personal Communication, 2013r, pdf pp. 3-5). In addition, *in vivo* techniques improved greatly beginning in 1976 with the use of high-purity germanium detectors in place of sodium iodide or phoswich detectors for resolving interfering photopeaks in whole-body and organ counts (ORAUT-TKBS-0011-5, Appendix B).

There is no information to determine conclusively when neptunium operations ceased at Rocky Flats, but nuclear material inventories, which fluctuated substantially during the period from 1962 through 1983, became relatively stable after 1983 (Inventory, 1966-1988). This inventory stability suggests that plant receipts and shipments of the material were much less dynamic from 1984 through 1988, indicating that there was little or no neptunium processing during this period. After 1988, there was no accountable neptunium on site. NIOSH believes that RFP neptunium operations ceased by the end of 1983. Therefore, in the absence of bioassay results (except for two in 1965) and of workplace air or contamination results for neptunium, and because of the uncertainty of Rocky Flats' ability to adequately measure neptunium in biological samples at the time of the two known neptunium bioassay results in 1965, NIOSH finds that the available internal and workplace monitoring data for neptunium are inadequate to support sufficiently accurate dose reconstruction during the period of neptunium operations before the end of 1983. Furthermore, NIOSH believes that maturation of RFP work practices (e.g., alpha containment gloveboxes, contamination control) and programs (e.g., documented laboratory techniques, improved radiological monitoring technology, improved record keeping) as well as the nature of work performed after 1983 were such that dose from potential intakes of residual neptunium after 1983 can be bounded with sufficient accuracy.

In the absence of adequate personnel or workplace monitoring data, NIOSH would employ source term data. However, NIOSH lacks sufficient source term data that are inclusive of the throughput amounts of neptunium (i.e., they only represent a snapshot in time in regards to quantities); these data do not support estimating potential internal exposures to neptunium during the period of RFP neptunium operations from 1962 through December 31, 1983.Without sufficient bioassay results, NIOSH has concluded that it cannot estimate with sufficient accuracy the potential internal exposures to neptunium which the proposed class may have received.

Although NIOSH found that it is not possible to completely reconstruct internal neptunium radiation doses for the period from 1962 through December 31, 1983, NIOSH intends to use any internal neptunium monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at RFP during the period from 1962 through December 31, 1983, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.3 Evaluation of Bounding External Radiation Doses at Rocky Flats

The principal source of external radiation doses for members of the evaluated class was as evaluated in the SEC-00030 Rocky Flats Plant Evaluation Report. SEC-00030 concluded that all external dose except neutrons could be estimated with sufficient accuracy. Because this revision of SEC Evaluation Report SEC-00192 was initiated based upon NIOSH's subsequent research and determination that internal radiation exposures to U-233, thorium, and Np-237 could not be reconstructed, NIOSH has determined that there is no need to assess external exposures and the ability to reconstruct dose at RFP beyond what has already been presented and assessed in SEC-00030. Therefore, NIOSH will not assess external or medical X-ray dose reconstruction methods further in this evaluation. NIOSH defers to the SEC-00030 RFP report for all external and medical X-ray decisions regarding bounding of dose at RFP as well as the definition of dose reconstruction methods.

7.4 Evaluation of Petition Basis for SEC-00192

The following subsections evaluate the assertions made on behalf of petition SEC-00192 for the Rocky Flats Plant site.

7.4.1 Incidents

SEC-00192: The petitioner asserted during the consultation telephone calls on this petition that there were one or more unmonitored, unrecorded, or inadequately monitored or recorded exposure incidents at the Rocky Flats Plant site, specifically claiming an Item E.5 basis.

NIOSH's initial interpretation was that the information provided by the petitioner in one affidavit seemed to indicate a description of a radiological incident, for which additional detail was requested from the petitioner. In subsequent phone conversations and emails (DSA Ref ID: 115629), the petitioner later clarified the intent and indicated that the situation was given as an example of a worker who should have been monitored but was not (applicable to Petition basis F.1). Based on its review, NIOSH concluded that there was no intent to include or support an Item E.5 basis.

7.4.2 Building 460 Plutonium

SEC-00192: *Originally, the DOL Site Exposure Matrix showed that plutonium was present in Building 460. NIOSH was advised of this in the attached email dated December 8, 2009. According to the statement submitted in that email, a former* [job title redacted] *related that waste drums from the 700 complex were stored in Building 460 in 1988 when the governor of Idaho refused to allow shipments of radioactive waste from Rocky Flats into the state. Building 460 was a "cold" building and workers were not monitored for exposure to radiation.* [This was specific to an Item F.1 basis.]

As stated in the Site Profile and the SEC-00030 Evaluation Report, the majority of workers at Rocky Flats were monitored for radiation exposure, and NIOSH has exposure records for most workers. Some workers may not have been monitored if it was determined that their exposure potential was below the threshold for dose monitoring to be required. Building 460 was considered a "cold" building, so dose monitoring may not have been required for workers assigned there. The affidavit regarding the stored drums describes the performance of radiological monitoring of those drums and states that there were radiological postings due to the exposure rates from the drums. This indicates to NIOSH that radiological controls were being exercised to prevent unmonitored workers outside the posted areas from receiving exposures above appropriate limits. NIOSH does not see indication that the movement and storage of these drums was controlled differently than the general waste storage activities on site. The doses associated with general waste-handling and storage activities are represented in the dose monitoring records of the RFP worker population. The adequacy of RFP worker population dose records for the development of co-worker distributions for the assignment of unmonitored internal and external does has already been evaluated by NIOSH and the ABRWH for SEC-00030.

In addition, records available to NIOSH indicate that the [job title redacted] had plutonium bioassay during the period of concern, although [redacted] stated normal work areas, including the 400 area (depleted U) and 800 area (enriched U), would likely require only uranium bioassay. The plutonium bioassay indicates to NIOSH that the site was aware of the added plutonium concern, and serves as an example that the site was monitoring individuals.

Relative to the requirements of 42 C.F.R § 83.9 (a)(5), NIOSH has determined that this information provides no substantially new information regarding unmonitored plutonium or uranium exposures beyond what NIOSH has previously addressed in its evaluation for SEC-00030.

7.4.3 Tritium Exposures

SEC-00192: Affidavit states - *I attest that there were occasions when I was not monitored. When I worked in the 700 complex, one of my duties was to work on site returns. I clearly remember one incident at a down draft table. I was given the incorrect measurements and when the machine tool reached the given measurement the shell was breached. I remember that I had a nasal smear taken after the breach. I have requested a copy of this nasal smear report numerous times but have not received it. I was later told that I was probably exposed to tritium gas. I have no bioassay for tritium exposure.* [This was specific to an Item F.1 basis.]

NIOSH has available personal or area monitoring data applicable to a tritium incident that occurred in 1973, which was evaluated as part of SEC-00030. The affiant states that he was employed from [date range redacted]. NIOSH does not have this individual's data readily available, and as of the time of the qualification review of the SEC-00192 petition, did not have a clear time period when the incident occurred. Since there was an apparent lack of personal monitoring for tritium prior to the 1973 incident and possibly during the affiant's employment period ([date range redacted]), NIOSH has determined there was evidence of possible tritium exposures warranting evaluation beyond that performed for SEC-00030. The additional evaluation is presented in this SEC-00192 evaluation report.

7.4.4 Previous Issues – RFP Site Profile

SEC-00192: *NIOSH has failed to reconcile outstanding site profile issues* [These issues were specific to an Item F.1 basis]:

a. *Accepted unsworn statement from the supervisor for the thorium strikes, which contradicts RFP-5331, which was reviewed by NIOSH and rejected.*

b. *Only 5 individuals interviewed about thorium at RFP.*

c. *ER's subsequent to RFP have been reversed after reviewing classified docs. RFP not afforded the same level of investigation.*

d. *Sworn affidavits dismissed because they weren't backed up by documentation. Yet, as noted above, NIOSH readily accepted an unsworn testimony over a document.*

e. *RFP SEC class definition is inconsistent with other SECs and difficult for DOL to administer. The class is building specific. But, it is not possible to determine all occupants.*

Issue a. was extensively discussed by the ABRWH under SEC-00030. The number of individuals interviewed in previous efforts, as presented in Issue b, does not provide evidence of lost, falsified, or destroyed records; or that there is no information regarding monitoring, source term, or processes. Relative to Issue c, classified documents were available to NIOSH, SC&A, and the Advisory Board and were reviewed as necessary under SEC-00030; SEC-00030 was afforded an extensive level of investigation. Relative to Issue d, NIOSH believes this statement is inaccurate. Affidavits were not dismissed. They were extensively investigated and compared to documentary evidence and discussed with the Rocky Flats Working Group associated with SEC-00030. The statement presented in Issue e is inaccurate in that the SEC-00030 class definition is based on potential neutron exposure. Work location is one issue that is considered, but there are others (such as neutron dosimetry). The class definition is an administrative issue associated with the previously-evaluated SEC-00030.

Relative to the requirements of 42 C.F.R § 83.9 (a)(5), NIOSH has determined that this information provides no substantially new information beyond what NIOSH has previously addressed in its evaluation for SEC-00030, nor does this information provide evidence of lost, falsified, or destroyed records; or that there is no information regarding monitoring, source term, or processes.

7.4.5 Information Not Provided in the Previous SEC Evaluation

SEC-00192: *Information the Board did not have when deciding the RFP SEC petition.* [These were specific to an Item F.1 basis]:

a. Presence of plutonium in Building 460 (waste drums stored in the building).

b. Contaminated equipment present in Buildings 440, 444, & 447 (a contaminated Empire lift-a-loft was shipped from Building 371 to these buildings, which were considered "cold").

The issue regarding drums stored in Building 460 was previously determined to be a non-issue during the assessment of the SEC-00030 evaluation report. The contaminated equipment report states the levels of contamination found on the equipment as well as the timeframe involved; therefore, NIOSH has area monitoring data. NIOSH has developed methods to estimate intakes to unmonitored workers at the Rocky Flats. The adequacy of the RFP monitoring programs, and ability to assess unmonitored dose, was the primary focus of the evaluation of SEC-00030.

Relative to the requirements of 42 C.F.R § 83.9 (a)(5), NIOSH has determined that this information provides no substantially new information regarding plutonium or other exposures beyond what NIOSH has previously addressed in its evaluation for SEC-00030.

7.4.6 Adequacy of Co-worker Models

SEC-00192: *Co-worker models are inaccurate for some buildings* [These were specific to an Item F.1 basis]:

a. *Site profile does not include the 1980 fire in Building 771's incinerator; in 1980 53% of badges had zero. If there was a release from the fire, then the coworker badge readings may not be accurate or reflect this incident.*
b. *The site profile does not include the plutonium recovery system in Building 440 post 1996.*

c. *The site profile does not consider high exposures at the stacker retriever. (Attached email states potential exposure rate of a "couple hundred" millirem per hour. Criticality engineers had to make sure spacing was maintained).*

d. *The highest number of zero readings occurred during the D&D period (2004).*

As presented in the NIOSH responses above, extensive personnel monitoring data are available to assess internal and external doses. NIOSH has stated that it will estimate incident-related dose based on individuals' personal data since most workers were routinely monitored. For unmonitored workers, NIOSH contends that exposures from incidents would be covered by the co-worker approach because incident doses are represented in the worker population dose. Specific to Issues a and d, the zero-dose issue was previously evaluated as a part of the SEC-00030 Evaluation.

Relative to the requirements of 42 C.F.R § 83.9 (a)(5), NIOSH has determined that this information provides no substantially new information beyond what NIOSH has previously addressed in its evaluation for SEC-00030.

7.4.7 Analysis Laboratories

SEC-00192: *Documents show evidence that the laboratories responsible for radiation readings were not in compliance with DOE criteria for radiation monitoring. It is likely they were also deficient when analyzing personnel dosimeters and breathing zone samples.* [This was specific to an Item F.3 basis]

The referenced compliance audits were performed specifically to evaluate the RFP environmental programs. Records do not indicate any correlations between the environmental and personnel dosimetry programs.

7.4.8 Analysis Laboratories

SEC-00192: *An Assessment of Criticality Safety at RFP document, dated June-Sept 1989, shows* [These were specific to an Item F.3 basis]:

a. Additional incidents from 1983 that are not reflected in the site profile.

b. Deficient or outdated safety practices.

c. Contamination in the ducts in Building 881 (Issue raised by plant mgrs out of concern for employee health.).

d. Building 881 issue indicated significant amounts of radioactive materials, including one instance of 288 grams of U-235 in an old laundry line.

As presented in the NIOSH responses above, extensive personnel monitoring data are available to assess internal and external doses. As part of the SEC-00030 evaluation, NIOSH has stated that it will estimate incident-related dose based on individuals' personal data since most workers were routinely monitored. For unmonitored workers, NIOSH contends that exposures from incidents would be covered by the co-worker approach because incident doses are represented in the worker population dose. This would also apply to the situations described. Issues c and d were discussed by the Board in a previous meeting in Westminster. In addition, the current SEC as implemented by DOL includes Building 881 workers. Therefore, further assessment of the Building 881 issues in regard to bounding dose is not productive from a SEC evaluation perspective.

7.4.9 Site and Process Information

SEC-00192: *RFP Site-wide Process Descriptions, Material Mass Balances, and Operational Emissions Support Document, dated Apr 12, 1994 not represented in the site profile, indicates that "radiography occurs in Buildings 122, 444, 460, 707, 777, and T371J". The site profile does not indicate that X-rays were present in Building 460. Workers in Building 460 were not monitored for radiation exposure.* [This was specific to an Item F.3 basis]

Where radiography is performed, regulations require specific protocols to prevent inadvertent exposure to unmonitored personnel, such as: radiological posting at area boundaries, constant radiation monitoring during the activities, and personnel monitoring for individuals performing the work. The Rocky Flats Plant had a standard operating procedure, *Radiation Safety for Field Radiography*, for performing radiographic testing, which states that "the personnel access boundary location shall not exceed 2 mR/hr". Therefore, the dose reconstruction methodologies for unmonitored workers described in the Site Profile would be adequate for this circumstance.

7.5 Other Potential SEC Issues Relevant to the Petition Identified During the Evaluation

During the feasibility evaluation for SEC-00192, NIOSH concluded that a review of the SEC-00030 issues and subsequent resolutions and closures should be documented in this evaluation. Only the primary issue title and associated resolution/response are provided here – specific details of the sub-tasks of the issue can be found in the Board Working Group's *Rocky Flats Site Profile Review: Matrix of Priority Issues Potentially Relevant to SEC Petition Review* (available on the NIOSH website at: http://www.cdc.gov/niosh/ocas/pdfs/dps/rockymatrix010807.pdf). The issues and their status are as follows:

- 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.

  RESPONSE: ORAUT-OTIB-0049 addresses Super-S and RFP fire particle size in Section 4.2. The concurrence that this issue was closed is presented in the March 7, 2007 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, page 193 of 269).

- 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.

  RESPONSE: See ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose*, Section 5.3, Bioassay Data; and Attachment B, Section 5.3.2, Lung Count Data, which states:

  > *In vivo lung counts have been performed at RFP since 1964 to determine the activity of plutonium in the lungs of workers who were exposed, or had the potential to be exposed, to airborne plutonium. The method of in vivo lung counts was to place one or more detectors over the chest of the subject and count the photons emitted from the plutonium mixture, if any, in the chest. Plutonium was not detected directly because of the low abundance of gamma photons and the severe attenuation of the more abundant L X-rays. Instead, the 59.5-keV gamma photon from 241Am was used to detect 241Am, which is present to some extent in all WG plutonium at RFP. The activity of plutonium was then calculated from the detected 241Am by measuring, calculating, or assuming the fraction of the 241Am in the plutonium mixture on the date of the lung count (see Section B.11 in Attachment B). At RFP, the fraction of the 241Am in the plutonium mixture has historically been characterized in terms of parts per million by weight. Direct in vivo measurement of plutonium in the lungs, although investigated, was never implemented at RFP.*

  ORAUT-TKBS-0011-5, Attachment B, Table B-11 summarizes the americium MDAs for RFP *in vivo* lung counts.

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

  RESPONSE: Neutron information and approaches were incorporated into ORAUT-TKBS-0011-6, *Rocky Flats Plant - Occupational External Dose*. In addition, it has been discussed in past working group meetings that the NDRP documentation indicates that workers who wore NTA film were part of the NDRP (NDRP, 2005, pdf p. 9). Possible sources of errors are addressed in the TBD. However, a result of the SEC-00030 evaluation was the recommendation of an SEC class based on neutron exposures for the period from April 1, 1952 through December 31, 1966.

- 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, and for workers involved with the Pu tetrafluoride and Pu-machining operations during the early period.

  RESPONSE: A default neutron-to-gamma ratio is provided in Tables 6-21 and 6-22 in Section 6.7.3.4 of ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*. However, a result of the SEC-00030 evaluation was the recommendation of an SEC class based on neutron exposures for the period from April 1, 1952 through December 31, 1966.

- ISSUE: The RFP Site Profile, while incorporating methodologies for assignment of missed dose, has not adequately bounded 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.

  RESPONSE: There were eight subtopics assessed as part of this issue. The results of those subtopic assessments were:

  1. Provide NDRP data (ORAUT-OTIB-0050): Completed and closed as indicated in the May 30, 2006 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/tr053006.pdf, page 73 of 276).

  2. Ruttenberg job exposure matrix: Not an SEC issue, as indicated in the March 28, 2006 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/tr032806.pdf, page 101 of 259).

  3. Completeness of external exposure monitoring data was explicitly discussed over several working group meetings.

  4. Co-worker model provided and agreed upon, as indicated in the April 30, 2007 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr043007.pdf, page 113 of 153); incorporated into the RFP TBD, ORAUT-TKBS-0011 in August 2007.

5. Zeros in badge readings were listed separately as two different issues (#12 and #28).

6. Correction factor from DNFSB report: Completed and closed, as indicated in the July 26, 2006 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr072606.pdf, page 168 of 381).

7. Criminal and security investigations: No supporting evidence of this based on NIOSH's reviews. Completed and closed, as indicated in the July 26, 2006 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr072606.pdf, page 173 of 381).

8. Demonstration of the reliability of the bioassay and external database was explicitly discussed over several working group meetings.

- <u>ISSUE</u>: 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.

  <u>RESPONSE</u>: Neutron information and approaches were incorporated into ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*. For pre-1971, the approach proposes the use of the method defined in the NDRP; for 1971-1976, the method incorporates a neutron-to-photon ratio approach. As a result of the SEC-00030 evaluation was the recommendation of an SEC class based on neutron exposures for the period from April 1, 1952 through December 31, 1966.

- <u>ISSUE</u>: Zero entries in dose record when badges were not returned. This issue is divided into two periods: 1) Pre-1964, when badges were not issued to all workers; 2) 1964 and after when badges were issued to all workers. The dose record may also contain blanks or "no data available." Methods to separate these kinds of entries or blanks from zeros that denote a value below the LoD are needed.

  <u>RESPONSE</u>: See False Entries response below. This issue was also addressed in ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*, Section 6.5, Table 6-2, Interpretation of Reported Data.

- <u>ISSUE</u>: Chips fell out of TLDs and readings were not included in worker records. Allegation in SEC petition.

  <u>RESPONSE</u>: See False Entries response below. This issue was also addressed in ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*, Section 6.6.5.2.1, Loose-Chip Thermoluminescent Dosimeters; and Section 6.8.5.2.1, Loose-Chip Thermoluminescent Dosimeter.

- <u>ISSUE</u>: Hair and body oils on TLD chips cause inaccurate readings (SEC-00030 Petition, Part a, p. 45)

  <u>RESPONSE</u>: See False Entries response below.

- ISSUE: Deliberately false entries were made into dose record: there is a charge of deliberate falsification of data. For instance, a worker alleges that his supervisor "would advise the dosimeter worker that the dose shown was too high to be possibly correct," and the worker was advised to change or delete the reading. (SEC-00030 Petition, Part a, p. 57.). Further, in Part b, p. 501, a worker alleges that zeros were entered into dose records when the TLD reader failed.

  RESPONSE: False entries, along with other issues such as zero dose entries, chips falling out of TLDs, and other data reliability issues constitute the "Rocky Flats Data Integrity Issues. The working group's discussion over several meetings culminated in a discussion that addressed and/or resolved the issue, as indicated in the March 7, 2007 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, page 154 of 269).

- ISSUE: Unauthorized work practices: the petition provides examples of unauthorized work practices (e.g., SEC-00030 Petition, Part a, p. 54)

  RESPONSE: The associated issues were addressed in the SEC-00030 evaluation report and were completed and closed, as indicated in the April 12, 2006 RFP working group meeting transcript (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wg041206.pdf , pages 233-239 of 347).

- ISSUE: Workers frequently did not wear badges in production areas and did not report non-use of badge (SEC-00030 Petition, Part a, p. 53). This raises a question of how missed dose is to be interpreted.
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  RESPONSE: This issue is addressed in ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*, Section 6.6.3, Missed Dose (photon); Section 6.7.3, Missed Dose (neutron); Section 6.8.3, Missed Dose (electron); and Appendix C.4, Adjustment for Missed Dose.

- ISSUE: Badge did not properly record organ dose due to organ being closer to the source than the badge or due to workers wearing the badge under their lead aprons. Petition provides examples where dose to head and other areas would be much greater than badge reading (SEC-00030 Petition, Part a, p. 53,). Some workers wore their badge under their lead aprons leading to under-recording of doses to some organs, such as the head, arms, and face. (SEC-00030 Petition, Part a, p. 53; Part b, p. 23). Note that these examples are also part of the suggestion that co-worker models for Rocky Flats worker external dose would not be valid.

  RESPONSE: This issue is addressed in ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*, Section 6.5.4, Exposure Geometry; and Section 6.5.5, Lead Aprons.

- ISSUE: Missing dose record in areas of high exposure: one worker has provided an affidavit saying that an entire year's dose record is missing from a time he worked in an area with radiation dose rates that ranged up to 8 R/hour. He was an [redacted] in the Stacker Receiver area of Building 371, and [redacted], he was not rotated out of the area since he was an [redacted] (SEC-00030 Petition, Part b, p. 32). A worker affidavit including this problem is provided on p. 539 of SEC-00030 Petition, Part b.

RESPONSE: See False Entries response above.

- ISSUE: Bioassays redone when they indicated high exposure. There are two examples cited that claim that bioassays were redone or individuals were recounted when the readings were high and subsequent results were declared as having no exposure or false positives (SEC-00030 Petition, Part a, p. 47; Part b, p. 32).

  RESPONSE: Missed dose is addressed in ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose*, Attachment D, Internal Coworker Dosimetry Data For Rocky Flats Plant.

- ISSUE: Most exposed workers were not monitored for neutrons. The petition cites [redacted] as saying that until July 1958, the most exposed workers were not monitored for neutrons (SEC-00030 Petition, Part a, p. 71), raising a question about how the neutron data in the NDRP study are to be used, even if the re-reading of the badges is accepted as sound.

  RESPONSE: These methods are now part of ORAUT-TKBS-0011-6, *Rocky Flats Plant – Occupational External Dose*. See Section 6.3.5.2, Neutron Dose Reconstruction Project File; Section 6.5, Common Issues; Section 6.7.3, Missed Doses; Section 6.7.3.3, Neutron Dose Reconstruction Project; and Section 6.7.3.4, Default Neutron-to-Gamma Ratio.

  The neutron-to-photon ratio for the period prior to 1970 is not included. In Section 6.1.2, the Scope states:

  > *Only a limited assessment of neutron doses can be performed prior to 1970. Unmonitored and notional neutron doses from 1952 through 1966 cannot be reconstructed under the Energy Employees Occupational Illness Compensation Program Act. Between 1967 and 1970, unmonitored and notional neutron doses should be replaced with external coworker doses. Reported NDRP and non-affected original neutron dose can be used during all years.*

  Section 6.7.3.3, Neutron Dose Reconstruction Project, Page 49:

  > *Only a limited portion of the NDRP neutron dose components can be used in dose reconstructions – 1952 through 1966: Only reported non-affected original neutron dose and NDRP neutron dose should be used in the reconstruction. Original and notional doses should not be used in the reconstruction of neutron doses. During periods where only original and notional doses are reported, the worker should be treated as an unmonitored worker. Unmonitored neutron dose cannot be reconstructed during this period.*

  However, a result of the SEC-00030 evaluation was the recommendation of an SEC class based on neutron exposures for the period from April 1, 1952 through December 31, 1966.

- ISSUE: Many incidents were not reported or recorded. The petition claims, "Throughout the history of the site it was common practice for incidents in the workplace to be handled at the floor or building level and not reported" (SEC-00030 Petition, Part a, p. 19). This goes to whether missed internal dose due to unreported and unrecorded incidents causes a problem in regard to adequacy of data for dose reconstruction. Tab E.5 has a detailed example of this and refers to others. Also, SEC-00030 Petition, Part a, p. 139 cites an unreported incident discovered during a routine bioassay. There are other examples of undocumented exposures in the pages that follow p. 179; Part a is an example of a worker who was in an explosion involving Pu but there is no film badge.

  RESPONSE: The information responding to this issue has been incorporated into ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose*, Attachment D, Internal Coworker Dosimetry Data For Rocky Flats Plant.

- ISSUE: Concern over potential exposures to other radionuclides. There were potentials for occupational exposure to tritium (gas, HTO and others), U-233, Am-241, Np-237, Cm-244, and Po-210. Purification of Am-241 began in 1962 and continued to 1979. U-233 processing at RFP was conducted from 1965-1982. Operations involving U-233 included metal processing, component manufacturing, material recovery, and waste handling. Curium, neptunium, and polonium were used as tracer for the purpose of testing components and were handled in small quantities.

  RESPONSE: The issues associated with this topic were addressed and closed, or otherwise determined to be other than a SEC issue, at the April, 12, 2006 working group meeting, January 26, 2007 working group meeting, and the March 3, 2007 working group meeting (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wg041206.pdf, starting at page 307 of 347; http://www.cdc.gov/niosh/ocas/pdfs/abrwh/tr012607.pdf, page 149-192 of 274; http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, pages 157-177 of 269).

- ISSUE: Safety Concern Reports indicate concerns with dosimetry results.

  RESPONSE: The issues were discussed at multiple working group meetings and NIOSH addressed the issues and closed, or otherwise determined them to be other than SEC issues, at the March 3, 2007 working group meeting. No further transcript discussions have been identified. (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, pages 177-192 of 269).

- ISSUE: Concerns were expressed over discrepancies between log books and personnel dosimetry records.

  RESPONSE: The issues were discussed at multiple working group meetings and NIOSH address the issues and closed, or otherwise determined to be other than a SEC issue, at the March 3, 2007 working group meeting – no further transcript discussions have been identified (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, pages 177-192 of 269).

- ISSUE: Concern that secondary dosimetry logs, contamination control logs, or foreman logs include exposure information (possibly individual specific data) which is inconsistent with individual personnel dosimetry records.

  RESPONSE: The issues were discussed at multiple working group meetings and NIOSH address the issues and closed, or otherwise determined to be other than a SEC issue, at the March 3, 2007 working group meeting – no further transcript discussions have been identified (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, pages 177-192 of 269).

- ISSUE: Concern was raised as to whether adequate information was available for reconstructing internal doses for D&D workers (including all subcontractors).

  RESPONSE: OCAS-TIB-014, *Rocky Flats Internal Dosimetry Coworker Extension*, extends ORAUT-OTIB-0038, *Internal Dosimetry Coworker Data for Rocky Flats Environmental Technology Site*. In order to extend the analysis beyond 1988, data were obtained from RFP's HIS-20 database. The purpose of OCAS-TIB-014 is to extend the previous ORAUT-OTIB-0038 using the same methodology.

- ISSUE: ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose*, indicates that urinalysis log books are available for purposes of assessing MDAs. These log books may be useful in assessing the reliability of the electronic data.

  RESPONSE: Log books were scanned and entered. The draft SC&A Logbook Analysis, Section 1.1.4, Field and Urinalysis Logbook Data Comparison, has a discussion of the analysis. The issues were discussed at multiple working group meetings and NIOSH addressed the issues and closed, or otherwise determined them to be other than SEC issues, at the March 3, 2007 working group meeting. No further transcript discussions have been identified (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, pages 177-192 of 269).

- ISSUE: Concerns raised about whether other radionuclides which were not specifically monitored for were an exposure concern. Radionuclides include: Th-232, U-233, Cm-244, Np-237, Am-241, Pu-238, and Po-210.

  RESPONSE: ORAUT-TKBS-0011-5, *Rocky Flats Plant – Occupational Internal Dose*, Section 5.2.5.2.4, Mold-Coating and Analytical Procedures, states:

  > *The uses of thorium in analytical procedures have been described as numerous but involving small (gram or less) quantities. Accounts of several small, laboratory procedures have been found in progress reports about research and development. Therefore, using the NUREG-1400 approach, with a release fraction R of 0.01, including a confinement factor C of 1, a dispersibility factor D of 10 and a quantity Q of <100 g (4×10^5 Bq), a quantity <100 g would result in potential intake of <0.04 Bq and is considered inconsequential.*

The issues associated with this topic were addressed and closed, or otherwise determined to be other than an SEC issue, at the April, 12, 2006 working group meeting, January 26, 2007 working group meeting, and the March 3, 2007 working group meeting (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wg041206.pdf, starting at page 307 of 347; http://www.cdc.gov/niosh/ocas/pdfs/abrwh/tr012607.pdf, page 149-192 of 274; http://www.cdc.gov/niosh/ocas/pdfs/abrwh/wgtr030707.pdf, pages 157-177 of 269). Documents captured by NIOSH in evaluating the feasibility of reconstructing tritium doses, however, led NIOSH to also re-examine the feasibility of estimating doses from other radionuclides that were present ancillary to the primary mission at the Rocky Flats plant or that were handled in small quantities. The feasibility of reconstructing doses for Rocky Flats Plant workers from exposures to uranium-233/thorium-232 and neptunium-237 during the period January 1, 1962 (the start of Np operations) through December 31, 1983 (the end of Np and U-233 operations) was also evaluated.

- ISSUE: An allegation was made that records related to occupational exposure were brought to the T-690 trailer and then removed and put in a landfill.

  RESPONSE: The issues associated with this topic were addressed in a document presented by NIOSH and closed, or otherwise determined to be other than an SEC issue, at the August 31, 2006 working group meeting. No further transcript discussions have been identified (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/tr083106.pdf, starting at page 317 of 367).

- ISSUE: Other Specific data integrity concerns (not detailed in above actions), including: [Redacted] case; neutron film blackening.

  RESPONSE: The issues associated with this topic were addressed in a document presented by NIOSH and closed, or otherwise determined to be other than an SEC issue, at the August 31, 2006 working group meeting. No further transcript discussions have been identified (http://www.cdc.gov/niosh/ocas/pdfs/abrwh/tr083106.pdf, starting at page 317 of 367).

7.5.1 Post-SEC-00192, Rev. 0 SEC Issues Follow-up

After the presentation of the SEC-00192, Rev. 0 evaluation report, the report was assigned to a Board working group. Working group reviews identified additional issues requiring additional response and follow-up; except as noted, these issues are addressed in this revised evaluation report.

- ISSUE: During subsequent Board working group reviews and meetings, the petitioner brought up issues regarding the 1989 FBI raid at RFP and the potential relationship between the environmental issues leading to the raid and the Occupational Radiological Monitoring program at the site.

  RESPONSE: Follow-up and response on this issue has been performed outside of the scope of this revised evaluation report. Therefore, the documented response will be submitted separately from this report.

- ISSUE: During subsequent Board working group meetings, the petitioner brought up issues regarding other potential thorium exposures at the RFP site.

  RESPONSE: Although an assessment of thorium exposures was performed as part of the SEC-00030 RFP evaluation, other thorium issues or unresolved thorium issues remain that require closure. The unresolved issues, other than Mg-Th alloys, have been assessed and included in this revised SEC evaluation report.

- ISSUE: As part of the working group follow-up reviews and interviews/site visits for RFP information, the working group identified the potential for more U-233 thorium strikes than were estimated in the SEC-00030 RFP evaluation report. As part of the follow-up to these additional thorium strikes, NIOSH identified issues with reconstructing U-233/U-232 dose and Th-228 dose relating to the U-233 and thorium-strike operations.

  RESPONSE: Although an assessment of U-233 operations and thorium exposures from thorium strikes was performed as part of the SEC-00030 RFP evaluation, additional issues or unresolved question remain that require closure. The unresolved U-233 operations and thorium strike issues have been assessed and included as part of this revised SEC evaluation report.

- ISSUE: As part of the working group follow-up reviews and interviews/site visits for RFP information, NIOSH and the working group identified issues relating to neptunium operations at RFP.

- RESPONSE: The unresolved neptunium operations and issues have been assessed and included as part of this revised SEC evaluation report.

7.6 Summary of Feasibility Findings for Petition SEC-00192

Table 7-7 summarizes the results of the feasibility findings at Rocky Flats Plant for each exposure source during the time period April 1, 1952 through December 31, 2005.

Table 7-7: Summary of Feasibility Findings for SEC-00192
April 1, 1952 through December 31, 2005

Source of Exposure	April 1, 1952 through December 31, 1983		January 1, 1984 through December 31, 2005	
	Reconstruction Feasible	**Reconstruction Not Feasible**	**Reconstruction Feasible**	**Reconstruction Not Feasible**
Internal[1]		**X**	**X**	
- Tritium	X		X	
- Thorium		X	X	
- U-233		X	NA	
- Np-237		X	X	
External[2]	**---**	**---**	**---**	**---**

[1] Internal includes an evaluation of bioassay data.
[2] Refer to the SEC-00030 evaluation report for a discussion of external exposure sources and dose reconstruction methods.

As of September 12, 2013, a total of 1963 claims have been submitted to NIOSH for individuals who worked at Rocky Flats during the period under evaluation in this report. Dose reconstructions have been completed, or otherwise addressed via the SEC process, for 1519 individuals (~77%).

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Rocky Flats during the period from April 1, 1952 through December 31, 1983, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

8.0 Evaluation of Health Endangerment for Petition SEC-00192

The health endangerment determination for the class of employees covered by this evaluation report is governed by both EEOICPA and 42 C.F.R. § 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. Section 83.13 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 those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

NIOSH has determined that there are insufficient data related to thorium, U-233 and Np-237. Based on the sum of information available from available resources, NIOSH's evaluation determined that it is not feasible to estimate radiation dose with sufficient accuracy for members of the NIOSH-evaluated class for the time period from April 1, 1952 through December 31, 1983. Therefore, the resulting NIOSH-proposed SEC class must include a minimum required employment period as a basis for specifying that health was endangered for this time period. NIOSH further determined that it is feasible to estimate radiation dose with sufficient accuracy for members of the NIOSH-evaluated class for the time period from January 1, 1984 through December 31, 2005. Therefore, a health endangerment determination is not required for this time period.

9.0 Class Conclusion for Petition SEC-00192

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes: All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Rocky Flats Plant in Golden, Colorado, from April 1, 1952 through December 31, 1983, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Based on its research, NIOSH has concluded that sufficient data are available to reconstruct internal dose for RFP workers from January 1, 1984 through December 31, 2005.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database (SRDB), for information relevant to SEC-00192. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining the feasibility or infeasibility of reconstructing dose for the class under evaluation.

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10.0 References

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Attachment 1: Data Capture Synopsis

Table A1-1: Data Capture Synopsis for Rocky Flats Plant

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded To SRDB
Primary Site/Company Name: Rocky Flats Plant; DOE 1951-2006 Alternate Site Names: Rocky Flats Environmental Technology Site Operating Contractor Names: Dow Chemical 1951-1975 Rockwell International 1975-1989 EG&G Rocky Flats, Inc. 1989-1995 Kaiser-Hill Company 1995-2006 Physical Size of the Site: 6,500 acres. Operations were conducted in the 300 acre Industrial Area, which contained over 800 structures, at the center of the site. The surrounding 6,200 acres were known as the Buffer Zone. Site Population: In 1973 the average site population was 3192. In 1993, at the time of the workforce reduction, there were approximately 6,800 employees on site.	Dosimetry databases, neutron dosimetry, site external dosimetry technical basis documents, dosimetry data, dosimetry software validations, radiological control procedures, training, tritium releases, tritium investigations, incident investigations, internal dosimetry manuals, radiological surveys, tritium monitor instruction manuals, air monitoring records, dosimetry audits and surveillances, corrective action plans, DOELAP testing results, TLD system descriptions, TLD response studies, plutonium bioassay studies, in vivo system studies, decommissioning closeout reports, log books, safety concerns, progress reports, epidemiologic reports, slide presentations, individual employee records, explanation of the HIS-20 database, Company/Union Safety Committee concerns, urinalysis records, and curium research.	03/22/2011	635
State Contacted: NA	The state was not contacted as its holdings either duplicate DOE holdings or concentrate on off-site contamination issues.	05/22/2012	0
Argonne National Laboratory - East (ANL-E)	Decontamination and disposal of plutonium gloveboxes and a 1961 weekly radiation safety summary.	03/26/2008	3
Brookhaven National Laboratory (BNL)	Ambient air monitoring at DOE sites and a draft preliminary hazard analysis.	10/24/2008	2
Cincinnati Public Library	Two histories of the Atomic Energy Commission.	02/10/2011	2

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Claimant Provided	Environmental monitoring data, links between occupational exposures and workforce illnesses, a New York State worker's compensation hearing, nuclear material codes, a claimant's job descriptions and dosimetry results, a safety concern regarding neutron dosimetry results, resuspension of environmental plutonium contamination, and the ORAU "Health Surveillance of Rocky Flats Radiation Workers".	08/15/2013	8
College Hill Library, Westminster, CO	Investigation of the 1969 fire in Building 776-777.	08/09/2006	4
Colorado State University Library	Am-241 in soils around the site and a report on characterizing environmental plutonium by nuclear track techniques.	01/05/2007	2
Curtiss-Wright, Cheswick, PA	Reference to the 1969 Rocky Flats fire and a trip report to Rocky Flats.	05/01/2009	2
Department of Labor / Paragon	A 1971 announcement of construction to take place at Rocky Flats, waste inventory, and treatment reports.	01/23/2012	3
DOE / SC&A	Tritium removable contamination limit at Rocky Flats.	02/22/2012	1
DOE Albuquerque Operations Office	The use of data from the 1969 fire to develop plutonium release factors and nonreactor hazard level classifications.	04/15/2010	2
DOE Environmental Information Center	A Paducah Gaseous Diffusion Plant metals recovery report including the recovery of silver from Rocky Flats film.	07/20/2011	1
DOE Environmental Management Consolidated Business Center (EMCBC) - Denver	Tritium release documentation, disassembly incident investigation, tritium effluent sampling, a documented communication, 1989 FBI raid search warrant, affidavit, and document lists, Rockwell president's notes on radiological program deficiencies, list of materials provided to the Grand Jury, types of records required by the Grand Jury, and responses to audits of Rocky Flats.	08/06/2013	27
DOE Environmental Measurements Laboratory	Beryllium reports.	02/10/2009	3
DOE Germantown	Beryllium reports, the 1965 weapons plant specific missions policy, records and claims search procedures, and the data tracking spreadsheet from the July 2012 data capture at DOE Germantown.	08/08/2012	6
DOELAP Office Idaho National Laboratory	1988 Albuquerque Operations Office applications for Department of Energy Laboratory Accreditation Program.	06/11/2009	1
DOE Legacy Management - Grand Junction Office	Progress reports, performance evaluations, long range planning, uranium scrap processing, plutonium in soil, accountability station symbols, waste disposal reports, sitewide mass balance and operational emissions support document, and a Neutron Dose Reconstruction Project spreadsheet.	01/24/2012	18

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
DOE Legacy Management - Morgantown	Fernald progress reports, material transfer reports, recycle uranium reports, all of which reference Rocky Flats, health and mortality studies of DOE employees, and Grand Junction Office employee exposure histories including Rocky Flats exposures.	09/19/2011	70
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Review of the environmental program, incineration of radioactive wastes, summaries of unusual occurrences, long range plans, bioassay and analytical chemistry meeting reports, plutonium internal depositions, material transfers from Fernald, a brief description of criticality dosimetry at Rocky Flats, and Mound incident reports referencing Rocky Flats.	04/22/2010	48
DOE Legacy Management - RFP Mountain View Office	Logbooks and logbook excerpts, internal dosimetry description and assessments, internal and external dosimetry reports, radiological surveys, dosimetry procedures, dosimetry progress and status reports, health physics progress and status reports, material transfers, terminated employee records, and thorium reports.	11/16/2006	127
DOE Legacy Management - Westminster Office	Tritium procedures, tritium monitoring, tritium analysis reports, thorium reports, the 1973 tritium release, processing of Los Alamos and Lawrence Livermore plutonium scrap, tritium surveys and air monitoring, tritium in water, effluent monitoring programs, environmental reports, urinalysis reports, tritium bioassay results and exposure data, Hot Man books, packaging of tritium wastes, individual dosimetry records, termination reports, tritium stack releases, neptunium analysis procedures, tritium process photographs, diagrams of tritium detection equipment, personnel strength reports, neutron/gamma surveys, incident reports, routine air sample reports, actinide analysis procedures, internal dosimetry audits, criticality safety non-compliance report, 1989 FBI raid search warrant and affidavit, and lists of documents seized during the FBI raid.	08/08/2013	428
DOE Nuclear Materials Management and Safeguards System (NMMSS)	Material transfer and inventory records.	07/10/2013	3
DOE Oak Ridge Operations Office	Former radiation worker medical surveillance files and radiation exposure history requests for workers starting at Rocky Flats, a visit to Mound, FOIA requests and responses, and the strategy for future use of U-233.	07/09/2012	31
DOE Oak Ridge Operations Records Holding Task Group	1953, 1954, and 1962 Production Division progress reports.	06/25/2013	3

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
DOE Office of Scientific and Technical Information (OSTI)	Technical papers from the 1968 Metallographic Group meeting, Pacific Northwest National Laboratory's description of source term data sources for contaminated buildings and sites, the method by which the Rocky Flats site was selected, waste shipments, transuranic shipments, research and development reports on U-233, investigation of the uranium 233-235 crossover incident, and the preparation of neptunium metal.	04/23/2013	13
DOE Rocky Flats Reading Room - Front Range Community College	Occurrence reports, 1994 Radiological Control Manual, health monitoring, beryllium surveillance, medical monitoring reports, neutron dose reconstruction project reports, contamination incident reports, high bioassay results, environmental surveillance reports, Colorado Department of Health meeting minutes, and remedial action closeout reports.	04/07/2006	256
[Name redacted]	The Pacific Northwest National Laboratory dosimetry system performance comparison for several DOE sites.	08/13/2003	1
Energy Technology Engineering Center	Rockwell International's annual reviews of the Energy Systems Group's radiological controls.	11/03/2005	4
Federal Records Center (FRC) - Chicago	A radioactive waste management working group meeting and a reference to Rocky Flats decontamination efforts as a learning tool for the termination of Mound's Special Metallurgical Building.	09/27/2006	2
Federal Records Center (FRC) - Denver	Dosimetry procedures, health physics procedures, health and mortality studies, chronological log of the Building 771 fire, and site problem areas.	02/01/2012	20
Federal Records Center (FRC) - Fort Worth	Exposure report for Pantex personnel while at Rocky Flats.	07/27/2006	1
Federal Records Center (FRC) - Kansas City / Bannister	ANL-E's consideration of Rocky Flats as a transuranic waste consolidation center.	08/15/2008	1
Federal Records Center (FRC) - San Bruno	Shielding design for a shipment of Na-24 to Rocky Flats, materials transfer notes, and reference to a Rocky Flats paper on plutonium monitoring.	08/02/2012	3
General Atomics	Material transfer reports.	11/02/2005	1
Hagley Museum and Library	Trip reports regarding transuranic waste incineration and exposures exceeding the DOE standard.	09/30/2010	5

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Hanford	Hanford monthly reports referencing Rocky Flats, material transfers, plutonium feed and fuel specifications, incident reports, plutonium contracts, distribution of updated site profiles, a 1991 assessment of Building 559, a 1967 material balance report, a 1952 report listing Rocky Flats visitors to Hanford, and a TRIM finding aid identifying Rocky Flats internal dosimetry documents.	01/02/2013	46
Hanford / SC&A	Volume III of the investigation of the 1969 Building 776-777 fire.	08/09/2006	1
Idaho National Laboratory (INL)	INL reports addressing issues with Rocky Flats fuel and waste and health physics logbooks.	06/07/2012	28
Interlibrary Loan	Proceedings of a criticality safety short course, survey of DOE mixed waste HEPA filters, proceedings of a conference on incinerating wastes, and environmental reports.	05/29/2012	14
Interlibrary Loan / SC&A	The December 1971 report of environmental levels of radioactivity at Rocky Flats.	01/21/2010	1
Internet - Defense Technical Information Center (DTIC)	Defense Nuclear Facility Safety Board reports, Los Alamos actinide research reports, plutonium machining and handling reports, plutonium stabilization and disposition reports, a report on mold and crucible coatings, and an indoor air modeling report.	09/28/2012	39
Internet - Defense Technical Information Center (DTIC) / SC&A	The 1995 Idaho National Laboratory environmental report which discusses Rocky Flats waste at INL.	01/09/2012	1
Internet - DOE	The review of solutions stabilization at Rocky Flats, a DOE guide of good radiological protection practices at plutonium facilities, and the data analysis from the DOE's handbook of airborne release fractions.	12/04/2008	3
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant documents identified.	05/22/2012	0
Internet - DOE Environmental Management	Chapter 3 of Linking Legacies.	10/28/2007	1
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	Hanford monthly reports referencing Rocky Flats, a reference to Rocky Flat's use of a shrouded probe stack sampler, button shipments to Rocky Flats, plutonium oxide reports, and trip reports.	06/06/2013	27
Internet - DOE Legacy Management Considered Sites	Legacy Management's site management guide, quality assurance plan, sampling and analysis plan, and an interim mixed waste inventory report.	08/01/2012	5
Internet - DOE National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant documents identified.	04/03/2012	0

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Internet - DOE OpenNet	A plutonium uptake incident description, U.S. Transuranium Registry summary reports, a summary history of the nuclear weapons program, Appendix B of Linking Legacies, openness press conference fact sheets, 1970 environmental branch activities, a 1964 AEC financial report, and a 1957 H-Division progress report.	12/14/2012	16
Internet - DOE OSTI Energy Citations	Proceedings of the ERDA D&D conference, an inventory of contaminated concrete in the DOE Complex, an assessment of Rocky Flats criticality safety, plutonium processing experimental reports, the decontamination and decommissioning waste estimate validation, DOE research and technology development annual summaries, contamination control reports, neptunium production and recovery, nuclear waste management reports, and the evaluation of an electro refining cell.	05/03/2013	61
Internet - DOE OSTI Information Bridge	Environmental reports, U.S. radioactive waste inventories, Hanford reports referencing Rocky Flats, material transfers, AEC and DOE radioisotope customers, Health and Safety Laboratory environmental reports, transuranic waste disposition, evaluations of beryllium exposures, assessment of airborne plutonium, waste stabilization reports, remediation of plutonium contaminated components, Savannah River Site reports referencing Rocky Flats plutonium waste, meteorological reports, transuranic waste characterization, storage, security reports, and production of neptunium.	07/31/2013	226

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Internet - Google	Environmental reports and plans, air monitoring program and reports, offsite dose assessment, DOE Complex histories and descriptions, DOE occupational radiation exposure reports, transuranic inventories, management, and disposition, DOE 5 year plans, building histories and descriptions, groundwater monitoring, EPA records of decision, an EPA report on radioactive emissions from DOE facilities, component closure plans, public hearings and meetings, radiological surveys, environmental remediation of transuranics, site remediation plan assessments, preparing and transporting radioactive waste, air emissions reports, the toxicology of uranium, radium disposition options, an ALARA analysis for hazardous waste disposal, improving tritium exposure reconstructions, the finding aid for the K.Z. Morgan papers at the University of Tennessee Hodges Library, decommissioning gloveboxes, DOE Legacy Management updates and plans, the appendices to the Rocky Flats historical release report, and the report of the Rocky Flats Grand Jury.	08/29/2013	536
Internet - Health Physics Journal	Establishing bounding internal dose estimates from thorium activities at Rocky Flats.	02/14/2013	1
Internet - Journal of Occupational and Environmental Hygiene	No relevant articles not already in the SRDB identified.	08/29/2013	0
Internet - National Academies Press (NAP)	An analysis of cancer risks in populations near nuclear facilities including Rocky Flats and health, safety, and environmental management in the nuclear weapons complex.	03/27/2012	2
Internet - National Institute for Occupational Safety and Health (NIOSH)	Reports on residual radioactive and beryllium contamination at atomic weapons employer and beryllium vendor facilities.	08/31/2011	3
Internet - NRC Agencywide Document Access and Management (ADAMS)	U.S. spent fuel and radioactive waste inventories, long-term surveillance and maintenance program reports, disposition of plutonium environmental impact statement, disposition of highly enriched uranium environmental impact statement, Hanford waste disposition environmental impact statements referencing Rocky Flats, an intervener petition referencing Rocky Flats, stockpile stewardship documents, seismic and fire hazards at DOE sites, storage of weapons-usable materials environmental impact statement documentation, the flammability and explosion potential of transuranic waste, and an article on DOE waste disposal practices.	09/16/2012	47

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Internet - Oak Ridge National Laboratory (ORNL)	ORNL operations and chemical technology reports referencing Rocky Flats, a 1956 report on metal recovery, and a 1957 report on the status of radioactive waste disposal.	11/08/2012	9
Internet - Oak Ridge National Laboratory (ORNL) Library	A 1969 ORNL radioisotope program report referencing Rocky Flats.	11/15/2012	1
Internet - Rocky Flats Environmental Technology Site (RFETS)	Air monitoring reports, radiological surveys, decommissioning closeout reports, project closeout reports, and site newsletters from closure period.	07/05/2006	70
Internet - US Army Corps of Engineers (USACE)	No relevant documents identified.	04/03/2012	0
Internet - US Environmental Protection Agency NEPIS	No relevant articles not already in the SRDB identified.	08/29/2013	0
Internet - US Transuranium and Uranium Registries	No relevant documents identified.	04/03/2012	0
Jim Langsted CD	A Defense Nuclear Facilities Safety Board (DNFSB) report, Rocky Flats responses to DNFSB reports, and employee medical and radiological records.	09/11/2012	6
Kansas City Plant	Mention of Rocky Flats closure during testimony on pits production, environmental reports referencing Rocky Flats, solid waste generated by Albuquerque Operations in 1979, and Rocky Flats' assistance in decontaminating the Kansas City Plant heavy machining area.	12/04/2012	6
Kansas City Plant / SC&A	A report on protective coatings for uranium-niobium alloys.	08/19/2013	1
Lawrence Livermore National Laboratory (LLNL)	Individual exposure files and a summary of LLNL employee internal doses at Rocky Flats.	06/10/2009	4
Los Alamos National Laboratory (LANL)	Trip reports, analysis of Rocky Flats environmental samples, support of FBI/EPA investigation at Rocky Flats, report of the 1969 fire, storage and disposition of plutonium, plutonium body burdens, documentation on nuclear worker autopsies, and cleaning procedures for components.	12/13/2007	27
Lovelace Respiratory Research Institute (LRRI)	LRRI annual reports referencing Rocky Flats and the analyses of cancer patterns around Rocky Flats.	05/22/2007	3
Mesa County Libraries, Grand Junction, CO	A newspaper article about Rocky Flats waste inventories.	01/06/2011	1
Mesa State College	The Health and Safety Laboratory quarterly fallout report from January 1972.	04/18/2011	1
Missouri Department of Natural Resources	The Plutonium Working Group reports on plutonium storage environmental, safety, and health vulnerabilities.	10/01/2008	2
Mound Laboratory	An analysis of dosimeter comparison studies.	11/18/2003	1

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Mound Museum	Material transfers, plutonium accountability and shipments, the Mound Laboratory index which mentions Rocky Flats, and newsletters mentioning Rocky Flats.	02/01/2012	26
National Archives and Records Administration (NARA) - Atlanta	A DOE indoor radon study, summaries of AEC accidents and high exposures, and directories of AEC consultants to contractors.	10/20/2005	7
National Archives and Records Administration (NARA) - College Park	A 1974 summary report from the U.S. Transuranium and Uranium Registry, environmental plutonium contamination, and a report of the 1973 tritium release.	04/16/2010	6
National Institute for Occupational Safety and Health (NIOSH)	Plutonium excretion study, the investigation of thorium handling at Rocky Flats, a logbook, interviews, affidavits from former workers, radiological surveys, worker outreach meeting minutes, SEC focus group meeting sign-in sheets, the protocol for the site epidemiological study, an amended NIOSH referral summary showing a visit to Rocky Flats, a claimant's public testimony to NIOSH, soil and leachate monitoring, a cost-saving plan for decontamination and demolition of tritium contaminated facilities, a NIOSH researcher's notes from document reviews at DOE Headquarters, responses to union requests for data, thorium inventory information, a redacted 1989 EPA interview, and a DOE initial agency decision regarding a whistleblower case.	05/01/2013	65
National Institute for Occupational Safety and Health (NIOSH) / SC&A	The Ohio Field Office Recycled Uranium Project report, highly enriched uranium working group reports, the former worker medical surveillance program, radiation protection program reviews, disposition of plutonium and U-233, a summary of Rocky Flats problems, and personnel protection requirements.	02/16/2006	25
Nevada Test Site (NTS)	The NTS Environmental Impact Statement and an area closure report detailing waste shipments from Rocky Flats.	04/14/2008	4
New York State Archives	A Tonawanda Area report showing that two radium sources were imported for Rocky Flats and a Lake Ontario Ordnance Works (LOOW) waste report where Rocky Flats was on distribution.	03/19/2012	2
Nuclear Information and Records Management Association (NIRMA)	The activities of the Rocky Flats Records Management Program during and after the 1989 FBI raid.	03/04/2013	1
Nuclear Regulatory Commission Public Document Room	References to Rocky Flats plutonium equipment and practices in Nuclear Materials and Equipment (NUMEC) special nuclear materials license documentation.	11/22/2006	5

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Oak Ridge Institute for Science and Education (ORISE)	Chelation DTPA data for DOE including Rocky Flats employees.	08/06/2009	115
Oak Ridge Library for Dose Reconstruction	Identification of radionuclides used at Rocky Flats, the Rocky Flats exposure pathway study, and Oak Ridge Gaseous Diffusion and National Laboratory reports referencing Rocky Flats.	05/23/2011	6
Oak Ridge National Laboratory (ORNL)	Records of shipments from ORNL to Rocky Flats, work at Rocky Flats for ORNL, and brief trip synopses.	01/17/2013	9
ORAU Library	A nuclear weapons databook showing shipments from Fernald to Rocky Flats.	10/12/2006	1
ORAU Team	ORAU Team technical basis documents and information bulletins, Rocky Flats' approaches to dose reconstruction, bioassay documentation, documented communications, analyses of cancer risks, annual DOE radiation exposure reports, external dosimeter characteristics, instrument descriptions and instructions, reviews of releases, Rocky Flats technical basis documents and procedures, reference to the 1985 completion of the Rocky Flats Custom Campaign at the INL Chemical Processing Plant Hot Chemistry Lab, and ORAU Team research notes from reviews of classified documents at the Office of Scientific and Technical Information and the Denver office of the DOE Environmental Management Consolidated Business Center.	07/18/2013	474
Paducah Gaseous Diffusion Plant	Paducah radiological reports referencing Rocky Flats.	09/18/2006	1
Pantex Plant	Confirmation that Rocky Flats was the back-up dosimetry processor for Pantex, the results of lead apron studies, and the development of diagnostic x-ray dose estimates.	11/01/2005	7
Pantex Plant / SC&A	Discussions of tritium contamination of returned components and the study of automated component handling in the staging area.	06/23/2011	3
Portsmouth Gaseous Diffusion Plant	A notation that Rocky Flats does not use extra shielding with its 14MeV neutron generator from Portsmouth.	05/10/2012	1
Sandia National Laboratories, California	A safe operating procedure naming Rocky Flats as a potential component disassembly location.	04/29/2013	1
Sandia National Laboratories, New Mexico	The Rocky Flats exposure histories for Sandia employees and material transfers handled by Ross Aviation.	02/17/2012	4
Savannah River Site (SRS)	Material transfers, FOIA responses, SRS progress reports referencing Rocky Flats, a discussion of plutonium in soil around Rocky Flats, the record of a californium shipment to Rocky Flats, and the flow of materials to and from Rocky Flats.	02/07/2012	46

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
S. Cohen & Associates (SC&A)	Confirmation that Rocky Flats personnel attended dosimetry training at Hanford, a Lawrence Livermore National Laboratory paper on dose reconstruction, discussions of neutron dosimetry, the analyses of Rocky Flats material returned to Y-12 and Mound, interactions between Sandia-Livermore and Rocky Flats, the vulnerabilities of plutonium storage, sample analyses, documents issued to SC&A by Y-12, a history of the INL Waste Management Complex including Rocky Flats waste, and documented communications.	04/07/2011	21
SC&A / Idaho National Laboratory (INL)	Discussions of Rocky Flats transuranic waste treated and stored at INL, reports of Rocky Flats waste incidents, and Rocky Flats waste data.	06/24/2010	35
SC&A / Nevada Test Site (NTS)	A 1950-1954 Santa Fe Operations report which summarizes Rocky Flats operations.	06/24/2010	1
SC&A / NIOSH	Highly enriched uranium working group report.	02/16/2006	1
SC&A / Pinellas	The 1993 annual DOE report on waste generation and minimization.	06/24/2010	1
SC&A / Stanford Linear Accelerator Center (SLAC)	A SLAC article detailing how SLAC technology was used to identify Rocky Flats soil contaminants.	06/13/2011	1
SC&A / Y-12	Inclusion of the Rocky Flats 1969 fire report in the investigation of the 1969 Y-12 thorium fire.	07/28/2010	1
Science Applications International Corp (SAIC)	Radiation exposure summaries.	09/02/2004	6
Southern Illinois University, Edwardsville, IL	Material transfers, a U.S. Transuranium and Uranium Registries report of a Rocky Flats whole body donation, Advisory Board on Radiation and Worker Health (ABRWH) meeting minutes, and a review of the Rocky Flats Special Exposure Cohort petition.	11/08/2008	9
University of Colorado Norlin Library	Air monitoring data, environmental reports, site cleanup activities, plutonium releases, release points, trends in plutonium environmental monitoring, draft tritium release investigation report, waste disposal reports, public doses from the 1969 fire, Rocky Flats 1998 internal dosimetry technical basis document, environmental surveys, thorium and U-233 handling reports, a 1992 subpoena, and historical radionuclide inventories.	11/16/2006	129
University of Tennessee Hodges Library	U.S. Transuranium and Uranium Registries reports, the distribution of transuranics in food chains, and a fact sheet on DTPA.	03/18/2010	5

Table A1-1: Data Capture Synopsis for Rocky Flats Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Unknown	Environmental reports, internal deposition of plutonium, site histories, a guide to Rocky Flats records series, air emissions annual reports, the angular dependence of NTA film, a dose control procedure, studies of plutonium particle size distribution, recycled uranium transfers, beryllium work, employee statements on exposure reporting and radiation controls, a history of Dayton Project and Mound dosimetry which mentions Rocky Flats dosimetry, mention of Rocky Flats as a weapons production site, DOE occupational exposure reports, and x-ray machine records.	04/26/2005	159
U.S. Transuranium and Uranium Registries	A review of two Rocky Flats whole body donor cases as part of a management proposal.	08/22/2005	1
Westinghouse Site (United Nuclear Corporation), Hematite, MO	A trip report to Rocky Flats.	03/13/2009	1
Y-12	A 1983 description of Y-12 extremity monitoring provided to Rocky Flats.	06/30/2006	1
Y-12 / SC&A	Y-12's transuranics sampling frequency for castings from Rocky Flats returns.	07/28/2010	1
TOTAL			**4109**

Table A1-2: Databases Searched for Rocky Flats Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**
NOTE: Database search terms employed for each of the databases listed below are available in the Excel file called “Rocky Flats plant Rev 02, (83 13) 09-20-13			
Defense Technical Information Center (DTIC) https://www.dtic.mil/ COMPLETED 09/28/2012	See Note above	1,319	62
DOE CEDR https://www.orau.gov/cedr COMPLETED 05/22/2012	See Note above	9	0
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 06/06/2013	See Note above	0	0
DOE Legacy Management Considered Sites http://www.lm.doe.gov/considered_Sites/ COMPLETED 08/01/2012	See Note above	38	0
DOE NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 04/03/2012	See Note above	0	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 12/14/2012	See Note above	160	0
DOE OSTI Energy Citations http://www.osti.gov/energycitations/ COMPLETED 05/03/2013	See Note above	7,811	5
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 07/31/2013	See Note above	5,038	19
Google http://www.google.com COMPLETED 08/01/2013	See Note above	4,141,787	399
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 02/14/2013	See Note above	158	1

Table A1-2: Databases Searched for Rocky Flats Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**
Journal of Occupational and Environmental Health http://www.ijoeh.com/index.php/ijoeh COMPLETED 08/29/2013	See Note above	82	0
National Academies Press http://www.nap.edu/ COMPLETED 03/27/2012	See Note above	12,974	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 09/16/2012	See Note above	90	0
USACE/FUSRAP http://www.lrb.usace.army.mil/fusrap/ COMPLETED 04/03/2012	See Note above	10	1
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 04/03/2012	See Note above	8	0

Table A1-3: DTIC Documents Requested for Rocky Flats Plant			
Document Number	**Document Title**	**Requested Date**	**Received Date**
ARCCD-CR-87011	Roll Forming Process For Cannon Caliber Depleted Uranium Penetrators	01/10/2012	
NA Ref ID: 120765	Indoor Air Modeling Dated January 1998, Author Kogan, Vladimir; Odasso, James	01/10/2012	05/21/2012
NA Ref ID: 107537	Swaging The Xm774 Depleted Uranium-0.75 Titanium Penetrator	01/10/2012	01/19/2012

Table A1-4: Interlibrary Loan Documents Requested for Rocky Flats Plant			
Document Number	**Document Title**	**Requested Date**	**Received Date**
NA Ref ID: 8779	Estimated Airborne Release of Plutonium During the 1969 Fire in Buildings 776-777	11/15/2012	11/29/2012
SA-93-010	Statistical Applications: Statistical Methodology for Determining Contaminants of Concern by Comparison of Background and Site Data with Applications to Operable Unit 2	06/02/2011	Could not locate

Table A1-5: OSTI Documents Requested for Rocky Flats Plant			
Document Number	**Document Title**	**Requested Date**	**Received Date**
RFP-1848 Ref ID: 122946	Casting of Multiple 233U Metal Target Disks dated May 1972	01/14/2013	03/18/2013
RFP-2680-A Ref ID: 122949	Chemistry Research and Development Semiannual Progress Report, January-June 1977 dated October 1977	01/14/2013	03/18/2013
RFP-4317; CONF-8905122-4 Ref ID: 106431	Pilot-Scale Production of Dicesium Hexachloroplutonate (Cs2/PuCl6) and Filtrate Recovery Dated 3/15/1989	01/11/2012	01/17/2012
RFP-4203 Ref ID: 106432	Preliminary Molten Salt Extraction Experiments with Dicesium Hexachloroplutonate (Cs2/PuCl6) Dated 1/30/1989	01/11/2012	01/17/2012
RFP-2134 Ref ID: 107471	An Evaluation of the Cryofit Tube Joining System in Selected Plutonium Chemical Processing Solutions	01/10/2012	01/13/2012
RFP-3780 Ref ID: 107472	Measurement Control For Plutonium Isotopic Measurements Using Gamma-ray Spectrometry	01/10/2012	01/13/2012