SEC Petition Evaluation Report
Petition SEC-00057-1

Report Rev # 05-15-07 Report Submittal Date 5/15/2007

Subject Expert(s):	James Berger
Site Expert(s):	N/A

Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition B Qualification Date	DOE/AWE Facility Name
SEC-00057-1	83.13	November 21, 2006	Hanford

Petitioner Class Definition

All employees in all facilities and areas of the Hanford Nuclear Reservation from January 1, 1942 through December 31, 1990.

Proposed Class Definition

All employees of the Department of Energy (DOE), its predecessor agencies, and DOE contractors and subcontractors, who were monitored, or should have been monitored, for internal radiological exposures while working at the Hanford Engineer Works in: the 300 Area fuel fabrication facilities from October 1, 1943 through August 31, 1946; the 200 Area plutonium separation facilities from November 1, 1944 through August 31, 1946; or the 100 B, D, and F reactor areas from September 1, 1944 through August 31, 1946; and 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 (excluding aggregate work day requirements).

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC-00050	83.13	Hanford	Merged with SEC-00057

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
SEC-00057-2, 2nd Part of this Evaluation Report	Hanford

ORAU Lead Technical Evaluator: Albert W. Wolff	**ORAU Review Completed By:** Dan Stempfley

Peer Review Completed By:	[Signature on file] *Sam Glover*	05/17/2007 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	5/18/2007 *Date*
SEC Evaluation Approved By:	[Signature on file] *Larry Elliott*	5/18/2007 *Date*

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Evaluation Report Summary: SEC-00057-1, Hanford

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

This petition reviews the requested class as follows:

- Petition SEC-00050, qualified on November 9, 2006, requested that NIOSH consider the following class: *All production workers in the 100 Area and 300 Area from January 1943 until September 1, 1946, and all 200 Area production workers and all guards and construction workers from December 1944 to September 1, 1946.*

- Petition SEC-00057, qualified on November 21, 2006, requested that NIOSH consider the following class: *All employees in all facilities and areas of the Hanford Reservation from January 1, 1942 to December 31, 1990.*

NIOSH-Proposed Class Definition

NIOSH merged the two petitions because the class requested in SEC-00050 is encompassed by the class requested in SEC-00057. For evaluation purposes, due to the complexity of Hanford operations over almost fifty years, the SEC-00057 class and associated evaluation report was divided into two separate time periods.

This report, SEC-00057-1, which defines a single class of employees for which NIOSH has determined it cannot estimate radiation doses with sufficient accuracy, covers the early years of the DuPont Company site operations from October 1, 1943 through August 31, 1946. The class for this report is defined as: All employees of the Department of Energy (DOE), its predecessor agencies, and DOE contractors and subcontractors, who were monitored, or should have been monitored, for internal radiological exposures while working at the Hanford Engineer Works in: the 300 Area fuel fabrication facilities from October 1, 1943 through August 31, 1946; the 200 Area plutonium separation facilities from November 1, 1944 through August 31, 1946; or the 100 B, D, and F reactor areas from September 1, 1944 through August 31, 1946; and 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 (excluding aggregate work day requirements).

The start dates for the class were chosen to coincide with the time periods when radioactive materials were used or created during DuPont-operated production in the specified areas. Uranium in the form of rods extruded off-site were first brought to Hanford in October 1943 and stored in the 300 Area (WHC-MR-0425). The first uranium machining operations began in December 1943. The first production reactor, 105-B, started operation in September 1944. Plutonium separation operations began with the first irradiated fuel being stored in the 200 North Area in November 1944. Prior to the start of operations in these various facilities, Hanford Engineer Works construction was underway (WHC-MR-0425).

A second evaluation report, SEC-00057-2, will evaluate the remaining SEC-00057 petitioner-requested years under various site operators (September 1, 1946 through December 31, 1990).

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has determined that it does not have access to sufficient information to: (1) estimate the maximum radiation dose incurred by any member of the class; or (2) estimate radiation doses more precisely than a maximum dose estimate. Information available from the site profile and additional resources is not sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period.

Health Endangerment Determination

Per EEOICPA and 42 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.

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SEC Petition Evaluation Report for SEC-00057-1

1.0 Purpose and Scope

ATTRIBUTION AND ANNOTATION: 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: Albert W. Wolff, Oak Ridge Associated Universities. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

This report evaluates the feasibility of reconstructing doses for all employees, contractors, and subcontractors of the DOE, and its predecessor agencies, who were monitored, or should have been monitored, for radiological exposures while working at the Hanford Engineer Works in: the 300 Area fuel fabrication facilities from October 1, 1943 through August 31, 1946; the 200 Area plutonium separation facilities from November 1, 1944 through August 31, 1946; or the 100 B, D, and F reactor areas from September 1, 1944 through August 31, 1946. 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 Office of Compensation Analysis and Support's (OCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.

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.[1]

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] 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, NIOSH must also then determine whether or not there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for 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 other SEC classes (excluding aggregate work day requirements).

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 to 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.[2]

3.0 Petitioner-Requested Class/Basis & NIOSH-Proposed Class/Basis

Two petitions associated with the Hanford Site requested that NIOSH consider classes for addition to the SEC:

- Petition SEC-00050, qualified on November 9, 2006, requested that NIOSH consider the following class: *All production workers in the 100 Area and 300 Area from January 1943 until September 1, 1946, and all 200 Area production workers and all guards and construction workers from December 1944 to September 1, 1946.*

- Petition SEC-00057, qualified on November 21, 2006, requested that NIOSH consider the following class: *All employees in all facilities and areas of the Hanford Reservation from January 1, 1942 to December 31, 1990.*

The petitioners provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Hanford workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00057-1 for evaluation:

[2] 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.

> The SEC-00057 petitioner claimed that personal monitoring data gaps existed for several of the individual workers listed in the petition. NIOSH found that the monitoring gap information provided by the petitioner did not support the submission basis for qualifying the petition. However, during the qualifying process, NIOSH identified some pre-1946 operational periods for which no internal exposure monitoring was performed. NIOSH qualified SEC-00057 on this basis.
>
> Petition SEC-00050 was qualified based on being completely encompassed by Petition SEC-00057.

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.

NIOSH merged the two petitions because the class requested in SEC-00050 is encompassed by the class requested in SEC-00057. For evaluation purposes, due to the complexity of Hanford operations over almost fifty years, the SEC-00057 class and associated evaluation report was divided into two separate time periods. This report (SEC-00057-1) defines a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy.

This report, SEC-00057-1, covers the early years of the DuPont Company site operations from October 1, 1943 through August 31, 1946. The class for this report is defined as: All employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for radiological exposures while working at the Hanford Engineer Works in: the 300 Area fuel fabrication facilities from October 1, 1943 through August 31, 1946; the 200 Area plutonium separation facilities from November 1, 1944 through August 31, 1946; or the 100 B, D, and F reactor areas from September 1, 1944 through August 31, 1946; and 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 (excluding aggregate work day requirements). The class was modified as a result of the feasibility evaluation documented in Section 7.0.

NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The start dates for the class coincide with the time periods when radioactive materials were present or used during DuPont-operated production in the specified areas. Uranium in the form of rods (extruded off-site) were first brought to Hanford in October 1943 and stored in the 300 Area. The first uranium machining operations began in December 1943. The first production reactor, 105-B, started operation in September 1944. Plutonium separation operations began with the first irradiated fuel being stored in the 200 Area in November 1944. Prior to the start of these radiological operations, Hanford Engineer Works personnel were engaged in non-radiological activities associated with site construction and project preparations (WHC-MR-0425).

A second evaluation report, SEC-00057-2, will cover the remaining SEC-00057 petitioner-requested years under various site operators (September 1, 1946 through December 31, 1990).

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed numerous data sources determine information relevant to determining the feasibility of dose reconstruction for the class of employees proposed for this petition. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following 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 Hanford operations or related topics/operations at other sites:

- *Technical Basis Document for the Hanford Site – Introduction*
  ORAUT-TKBS-0006-1; Rev. 02; August 30, 2006; SRDB Ref ID: 31193

- *Technical Basis Document for the Hanford Site – Site Description*
  ORAUT-TKBS-0006-2; Rev. 00 PC-1; December 29, 2004; SRDB Ref ID: 19489

- *Technical Basis Document for the Hanford Site – Occupational Medical Dose*
  ORAUT-TKBS-0006-3; Rev. 01; April 11, 2005; SRDB Ref ID: 19491

- *Technical Basis Document for the Hanford Site – Occupational Environmental Dose*
  ORAUT-TKBS-0006-4; Rev. 01; December 20, 2006; SRDB Ref ID: 31194

- *Technical Basis Document for the Hanford Site – Occupational Internal Dose*
  ORAUT-TKBS-0006-5; Rev. 01; November 24, 2004; SRDB Ref ID: 19494

- *Technical Basis Document for the Hanford Site – Occupational External Dose*
  ORAUT-TKBS-0006-6; Rev. 02; November 21, 2006; SRDB Ref ID: 29989

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. An ORAU 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 OTIBs and procedures as part of its evaluation:

- *OTIB: External Coworker Dosimetry Data for the Hanford Site*, ORAUT-OTIB-0030; Rev. 00 PC-1; November 7, 2006; SRDB Ref ID: 29961

- *OTIB: Internal Coworker Dosimetry Data for the Hanford Site*, ORAUT-OTIB-0039; Rev. 00 PC-2; January 31, 2007; SRDB Ref ID: 29969

- *OTIB: Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, ORAUT-OTIB-0054 (Draft - January 18, 2007); SRDB Ref ID: Under OCAS review

- PROC: *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*, ORAUT-PROC-0060, Rev. 01; June 28, 2006; SRDB Ref ID: 29986

- PROC: *Occupational X-Ray Dose Reconstruction for DOE Sites*, ORAUT-PROC-0061, Rev. 01; July 21, 2006; SRDB Ref ID: 29987

4.3 Facility Employees and Experts

To obtain additional information, NIOSH conducted telephone interviews with eleven former site employees specializing in radiation protection. None of these workers had been employed during the DuPont years; however, they provided insight into the availability of records, personal monitoring, the Health Instrument Group program, work practices, and other issues related to this evaluation. The interviewees were also asked if they were aware of any other Hanford radiation protection personnel workers employed during the DuPont years who were available for interviews; none were identified.

The following resources were reviewed for any pertinent information regarding the class of employees covered by this evaluation:

- SCA-TR-TASK1-0004, *Review of NIOSH Site Profile for the Hanford Site, Richland, Washington*; Site Expert Interviews, Att. 3, 4, and 5; S. Cohen & Associates; OCAS website: http://www.cdc.gov/niosh/ocas/hanford.html

- Worker Outreach Meeting with Central Washington Building and Construction Trades Council, AFL-CIO, January 13, 2004; OCAS website: http://www.cdc.gov/niosh/ocas/hanford.html

- Worker Outreach Meeting with Hanford Atomic Metal Trades Council, AFL-CIO (HAMTC), January 14, 2004; OCAS website: http://www.cdc.gov/niosh/ocas/hanford.html

- Worker Outreach Meeting with Paper, Allied-Industrial, Chemical and Energy Workers (PACE) Local #8-0369, April 22, 2004; OCAS website: http://www.cdc.gov/niosh/ocas/hanford.html

- Worker Outreach Meeting with DuPont Era Workers, March 28, 2007; Not yet on OCAS website: http://www.cdc.gov/niosh/ocas/hanford.html

- Notes from telephone interviews with eleven former Hanford Radiation Protection workers; SECIS ID: SEC00057, Non-submitter Communication ID: 135

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (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 for the period of January 1, 1942 through August 31, 1946. (NOCTS data available as of April 20, 2007)

Table 4-1: Number of Hanford Claims Submitted Under the Dose Reconstruction Rule
(January 1, 1942 through August 31, 1946)

Description	Totals
Total number of claims submitted for energy employees who meet the proposed class definition criteria	378
Number of dose reconstructions completed for energy employees who were employed during the years identified in the proposed class definition	328
Number of claims for which internal dosimetry records were obtained for the identified years in the proposed class definition (see explanation below)	49
Number of claims for which external dosimetry records were obtained for the identified years in the proposed class definition	244

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. As indicated in Table 4-1, NIOSH has been able to obtain external monitoring data for a majority of the claims that meet the proposed class definition. Of the total number of claims submitted, 244 (65%) have external monitoring data available.

Although there were 49 claims (13%) that had internal monitoring data, the internal dosimetry program was in its infancy during the time period of this class. The Hanford bioassay group was not founded until the early part of 1946 and early results were erratic with poor yields and poor process control. Even though there were approximately 500 assays done, many of the difficulties were not solved until August 1946, which is the final month of the class covered by this evaluation. (PNL-6125).

The dose reconstruction claimant interviews provided some information that is useful for dose reconstruction, such as work locations, hours worked, incidents, and hazards encountered. The interviews also identified conditions for which there would have been a potential for internal exposures.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database to locate documents supporting the evaluation of the proposed class. Six hundred seventy seven documents in this database were identified as pertaining to the Hanford site. A smaller number of documents (42) were written during the DuPont years. These documents were evaluated for their relevance to this petition. The documents include historical background on process descriptions, site history, Hanford Engineer Works monthly reports, Health Instrument Section monthly reports, incident documentation, and epidemiological studies.

4.6 Comprehensive Epidemiologic Data Resource (CEDR) Database

NIOSH searched the CEDR database for available internal and external monitoring data.

4.7 Hanford Radiological Exposure (REX) Database

NIOSH searched the REX database (maintained by the Hanford Site) for available internal and external monitoring data.

4.8 Other Technical Sources

Herbert M. Parker: Publications and Other Contributions to Radiological and Health Physics; Kathren, R., et al (editors); Columbus [Ohio]: Battelle Press, 1986; SRDB Ref ID: 27678

4.9 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the two Hanford petitions, NIOSH reviewed the following documents submitted by the petitioners:

Note: Some documents submitted by petitioners pertain to the later years of Hanford operations. Only documents pertaining to the class being evaluated by this report are included on this list.

Petition SEC-00050:

- *Technical Services Division Monthly Report,* HW-17410; March 1950; SECIS Ref ID: 9425
- *Report for the In Re Berg Litigation Reference-Hanford Releases,* K. G. McNeill and R.E. Jervis, University of Toronto; March 1, 1999; SECIS Ref ID: 9425
- *Errors in HEDR I-131 Release Estimates and Corrections to Dose Estimates to Account For These Errors,* Report to the Hanford Radiation Litigation, Tom H. Foulds and Richard Eymann, Attorneys; K. G. McNeill and R.E. Jervis, University of Toronto; March 2004; SECIS Ref ID: 9425
- *Source Term Task Responses (September 9, 1994) to EPRP Outstanding Issues Cited in June 17, 1994 FAX, Carter to Shipler,* Letter from A. G. Blasewitz to Dr. Melvin W. Carter, September 22, 1994, SECIS Ref ID: 9425
- *Stack Contamination - 200 Area,* Report from J. P. Martel to C. N. Gross, Page 8; August 6, 1948; SECIS Ref ID: 9425
- *Use of Natural Airborne Radioactivity to Evaluate Filters for Alpha Air Sampling,* C. L. Lindeken; Industrial Hygiene Journal; August 1961, SECIS Ref ID: 9425
- *Notes of Interview with Bernard Saueressig on 8/15/96,* Signed by Bernard Saueressig; October 7, 1996; SECIS Ref ID: 9425

- *Reconstructing Hanford Past Releases of Radioactive Materials: The History of the Technical Steering Panel 1988-1995*; November 1996; SECIS Ref ID: 9425

- *Atmospheric Diversion and Deposition of I-131 Released from the Hanford Site,* Ramsdell et al; Health Physics, Volume 71, Number 4; October 1996; SECIS Ref ID: 9425

- *Videotape Deposition of John Till, Ph.D.*, United States District Court, Eastern District of Washington, Master File, No. CY-91-3015-WFN; November 19, 2004; SECIS Ref ID: 9425

- *Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET)*, PNWD-2224 HEDR; Ramsdell, J. V., Jr., et al; February 1994; SECIS Ref ID: 9425

- *Hanford Cohort Study 1989*, and 1993, Further Description of the Hierarchical Organization of CEDR Structured Documentation, SECIS Ref ID: 9573

- *Affidavit of Cathie J. Boyer,* United States District Court, Western District of Washington, Master File, No. CY-91-3015-AAH; May 1994; SECIS Ref ID: 9573

- *Status of Document Search and Data Quality Objective Efforts,* PNWD-204; Gydesen, S. P.; Hanford Environmental Dose Reconstruction Project; October 1992; SECIS Ref ID: 9573

- *Estimation of the Pu-239 Releases to the Atmosphere from the Hanford Site,* Report to Tom H. Foulds, Hanford Litigation Office, Seattle; Klementiev, A. A.; December 21, 1995; SECIS Ref ID: 9573

- *Hanford Litigation-HEDR Vegetation Radiation Model Comparison,* Prepared for Tom H. Foulds and Associated Counsel for the Hanford Radiation Litigation, The, Jesse L, Ph.D.; P. Eng.; Lake Environmental Consultants, Inc.; February 26, 1999; SECIS Ref ID: 9573

- *A Re-Evaluation of the I-131 Atmospheric Releases from the Hanford Site*, Napier, B. A.; Health Physics, Vol 83, Number 2; August 2002; SECIS Ref ID: 9573

- *Hanford's Air Monitoring Program From 1945-1955 - A Compilation of Notes*, Letter to File, Mart, E.I.; February 10, 1988; SECIS Ref ID: 9573

- *Description of the Process Used to Create 1992 Hanford Mortality Study Database*, PNL-8449; Gilbert, E. S., et al; December 1992; SECIS Ref ID: 9601

- *A Guide to Environmental Monitoring Data, 1945-1972*, PNWD-2226 HEDR; Thiede, M. E., et al; Hanford Environmental Dose Reconstruction Project; March 1994; SECIS Ref ID: 9601

- *Environmental Radiological Monitoring of Air, Rain, and Snow on and near the Hanford Site, 1945-1957*; R. W. Hanf, M. E. Thiede; PNWD-2234 HEDR; March 1994; SECIS Ref ID: 9601

<u>Petition SEC-00057</u>:

- Collection of letters, memoranda, records of conversations, meeting notes, personal logbooks, court records, and depositions related to the SEC-00050 petitioners' allegations that the HEDR Study was biased; SECIS Ref ID: 9652

- *Potential Unrecorded Neutron Dose*, Letter to distribution; Jack J. Fix; August 27, 1997; SECIS Ref ID: 9959

- Eleven affidavits submitted by the SEC-00057 petitioner regarding missing dosimetry records, location of records, medical conditions of individual workers, incidents, and overexposures; SECIS Ref ID: 9959

- *Vern Haugen's Handwritten Diary*; June 6, 2006; SECIS Ref ID: 9959

5.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize both radiological operations at the Hanford Site from January 1943 to August 31, 1946, and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing both 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. Radiological operations are discussed in more detail in Section 5.2.

5.1 Hanford Site Process Descriptions

In 1943, the U.S. Army Corp of Engineers selected an area of approximately 600 square miles along the Columbia River in south-central Washington for the production of plutonium and other nuclear materials to support weapons production for World War II. This area, now known as the Hanford Site, was divided into three major operational areas, each located and designed specifically for its role in plutonium production. The 100 Areas handled production reactor operations; the 200 Areas handled fuel reprocessing, plutonium recovery, and waste management; and the 300 Area handled fuel fabrication and general research and development activities. To assure continuing capacity in case of maintenance downtime, emergencies, and sabotage, many major Hanford plutonium production operations were duplicated. They were also essentially self-sufficient, containing all necessary support services and facilities. Figure 5-1 shows the locations of these major operational areas.

There were other Hanford Areas, but they had little, if any, involvement with radioactive material operations. The 600 Area was the general category assigned to facilities that were located outside the security boundaries of major areas, and supported multiple operations. Such operations included road systems, fire stations, environmental and weather monitoring stations, and Nike Missile sites. Some 300 Area waste burial sites, which were located outside the 300 Area fence, were also included in the 600 Area designation. The 700 Area was located inside the community of Richland and consisted of administration, central supply, laundry, and repair/maintenance services. Richland Village was designated the 1100 Area, and the Richland Construction Camp was the 3000 Area.

Construction of facilities for plutonium production began almost immediately in 1943 and production operations were underway by the end of 1944. During 1944 and 1945, additional facilities were constructed to increase production. Research and development on reactor materials and technology and on biological and ecological effects of radiation were also started during this time. Table 5-1 summarizes Hanford Site development from 1943 through August 31, 1946. Section 5.2.7 provides a summary of key Hanford Site facilities. Additional information regarding the design and operation of the major facilities is presented in Sections 5.2.1 through 5.2.6.

Table 5-1: Hanford Site Development Chronology

Years	Areas	Comments	Plant Population
1943	All areas	Construction started in March	Construction 30,459
	300	Start-up of 305 test reactor and 313 fuel fabrication	
1944	All	Construction continues	Construction 43,019 Operating 5,289
	100	Start-up of B reactor and D reactor	
	200	Start-up of T Plant (221/224); construction of 64 storage tanks begins	
	300	Fuel canning started in 313; 314 fuels building start-up	
1945	All	Initial construction activities completed	Construction 343 Operating 6,099
	100	Start-up of F reactor	
	200	Start-up of B Plant (221/224); U Plant completed but only used for training and developing procedures and equipment for T and B Plants; plutonium finishing operations begin in 231-Z; construction of 64 storage tanks completed	
	300	3706 Radiochemistry Building and 321 cold semi-works start-up	
1946	All areas	Minimal construction or start-up of new facilities; emphasis on plutonium production operations and research on radiation effects	Construction 403 Operating 4,662

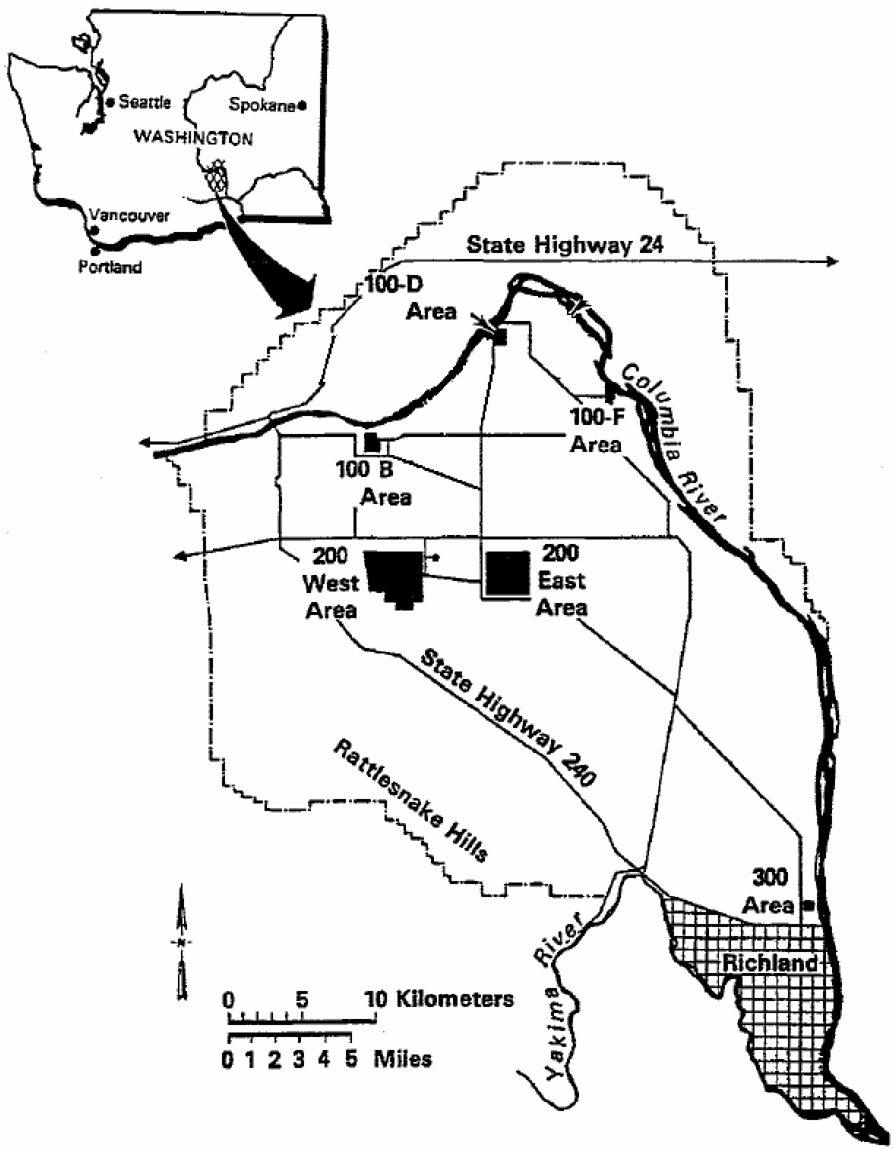

Figure 5-1: Hanford Site Operations Areas, 1943-1946

5.2 Hanford Functional Areas

Hanford operations during the period of 1943 through August 31, 1946 included the following major functional areas:

- Fuel Fabrication
- Reactor Operations
- Fuel Reprocessing
- Plutonium Finishing
- Research and Development
- Tank Farms and Waste Management

The primary mission of early Hanford operations was production of plutonium and other nuclear materials to support weapons production. Operations developed, changed, and expanded to satisfy changing U.S. defense needs and to further the development of nuclear knowledge and technology. Additional information regarding the functional areas of the Hanford Site can also be found in ORAUT-TKBS-0006.

5.2.1 Fuel Fabrication

Plutonium was produced by irradiation of uranium metal fuel in the Hanford Site reactors. The fuel for these reactors was fabricated in the 300 Area. Initially, natural uranium rods extruded to the required size were obtained from other sites and employed as feed material for machining and canning operations in the Metal Fuel Fabrication Building (313). Beginning in 1945, uranium was obtained in billets and extruded to size in the Metal Extrusion Building (314). Upon receipt, uranium rods and billets were stored in the 303 Buildings, where they were inventoried and inspected.

When beginning with uranium billets, the initial step in fuel fabrication consisted of preheating the billets in a furnace and extruding the uranium into rods. The rods were then heated in an argon atmosphere to drive off occluded gases. Rods were then straightened, if necessary. In the 313 Building, rods were cut to the desired length by turret lathe and then machine-finished into slugs. Slugs were inspected and degreased in a nitric acid solution. Slugs were then heated by immersion in molten baths and inserted into thin aluminum cans. This heating process was known as the triple-dip process. After the uranium slug was inserted into the aluminum can, an aluminum cap was welded in place. Bonds and welds were inspected and tested. The finished fuel elements, measuring 1.5 inches in diameter and 8 inches in length, were inspected and tested in 305 Building and then transferred and stored in the 100 Areas until undergoing irradiation in reactors.

Chips, turnings, and other solid scrap uranium were salvaged and pressed into briquettes. Liquids were settled and filtered to collect fines. Dusts and fines were burned to convert them to oxide form (DOE/RL-97-1047, page 2). These reclaimed uranium wastes were shipped offsite for recycling.

Reviewed documents did not mention the occurrence of fires during the fuel fabrication operations. Based on the history of other fuel fabrication operations (which entail machining of uranium metal), it is unlikely that such fires occurred.

5.2.2 Reactor Operation

Construction of three reactors (B, D, and F) to produce plutonium-239 by neutron irradiation of uranium-238 fuel elements started 1943. In September 1944, the first reactor (B) began operation. Start-up of D and F reactors occurred in December 1944 and February 1945. The selected design was a water-cooled, graphite-moderated pile with boron control rods. A typical reactor consisted of a large graphite block, approximately 36 feet by 36 feet by 28 feet, containing 2004 horizontal tubes for aluminum-clad natural uranium fuel elements. The block was surrounded by 8-10 inches of iron and 40-80 inches of reinforced concrete shielding. The assembly contained multiple lines for cooling water and gas systems.

These production reactors were located in the 100 Areas along the Columbia River. This location enabled access to large volumes of cooling water and achieved maximum distance from populated areas. Each reactor was located in its own complex, occupying approximately 1 square mile, and separated from other reactors by 1-3 miles to reduce the impact of possible malfunctions and sabotage. Reactors were located in buildings numbered105-B, 105-D, and 105-F, each measuring approximately 250 feet by 230 feet by 95 feet high. Also located in each 105 Building were the control room, spent fuel discharge area, fuel storage, and associated handling equipment. Each reactor complex included approximately 30 support buildings and facilities and essentially operated independently of the others.

With a reactor in the shutdown state, fresh fuel elements were loaded (“charged”) into fuel tubes at the face of the graphite block. As new elements were introduced, irradiated elements were pushed out of the back of the block, falling into a pool of water. Typically, about 25% of the fuel tubes were replaced at any one time. Irradiated fuel elements were allowed to cool in the pool to reduce radiation levels. Using remote handling tools, the elements were then loaded under 20 feet of water into large buckets (approximately 1000 pounds/bucket). After a further cooling period of 30 days, the buckets of spent fuel elements were transferred to the cooling basin where they awaited placement into shield casks and shipment to the 200 Areas for separation.

Each reactor complex included facilities for managing its own waste. Single-pass cooling water was pumped to retention basins. The liquids were released from the retention basins into the Columbia River or into soil columns. There were designated sites for burial of solid radioactive waste.

Reactors had associated high levels of direct gamma and neutron radiation during operations, and high gamma levels during shutdown conditions and spent fuel handling. There were potentials for worker exposures to surface and airborne contamination, in particular from fuel element failures. Monitoring of direct radiation was performed using fixed and portable systems, and workers wore personal monitoring devices. In potentially-contaminated areas, personnel protective clothing was worn, air monitoring was performed, and contamination monitors were provided. There were restrictions on eating and smoking in radiologically-contaminated areas.

5.2.3 Chemical Separations

Irradiated fuel elements were transported by rail in shielded casks from the 100 (reactor) Areas to the chemical separation plants in the 200 Areas. They were transported approximately half way to the separations facilities, where the elements were stored for up to 40 days in cooling basins in Buildings 212-N, 212-P, and 212-R to allow for decay of short-lived radionuclides. After cooling, the fuel elements were reloaded into the casks for the remainder of the journey.

The first of three separations plants, called the T Plant, began operation in December 1944. B Plant start-up occurred in April 1945. The U Plant was constructed during the time period of the proposed class, but was never used for plutonium separations; instead, it was used for training and decontamination and repair of equipment from the T and B Plants. Each plant included a separations building (221 Building) and a reduction building (224 Building). These plants were large rectangular reinforced concrete structures. They consisted of a gallery area containing piping, electrical, and operational facilities, and a process canyon, below which was chemical separations equipment. Dimensions were approximately 810 feet by 85 feet by 102 feet high (approximately 20 feet of the height was below grade. T-Plant had an extra section about 65 feet in length. As with other major production facilities at Hanford, each chemical separations area included all the buildings and support services required to function as a self-sufficient operation. There were nine buildings and 19 service facilities in 200 North Area, 60 buildings and 33 service facilities in 200 East Area, and 48 buildings and 29 service facilities in 200 West Area.

The plutonium chemical separations process used in the T and B Plants was known as the bismuth phosphate batch process. Three buckets of irradiated fuel elements were emptied into the dissolver tank in the Building 221 canyon, and the dissolver cell lid was replaced. A caustic solution was introduced into the tank and the aluminum cladding was dissolved from the fuel elements. After the decladded elements were rinsed, the fuel elements were dissolved in nitric acid. Bismuth phosphate was then added to precipitate plutonium as plutonium nitrate. Precipitation and centrifugation were repeated until the plutonium nitrate was thoroughly separated from the uranium, fission products, and impurities. At this stage, the plutonium nitrate was in a batch of approximately 330 gallons. This batch was next transferred to Building 224 (Bulk Reduction), where the 330 gallons was concentrated to approximately 8 gallons of plutonium nitrate paste, and further precipitations with hydrogen fluoride and lanthanum salts removed additional impurities. The plutonium nitrate paste was then transferred to the Building 231-Z for "finishing."

Chemical separations involved potentially-high radiation exposures. Of particular note was the sampling of process solutions on the canyon decks of T and B Plants. Direct gamma radiation levels were high and respirators were required. Service and maintenance of canyon cranes also involved potentially-high exposures.

5.2.4 Plutonium Finishing

Beginning in January 1945, plutonium nitrate solution from the 200 Area chemical separations facilities was transferred to the 231-Z Plutonium Isolation Building (also in the 200 Area). In this facility, the plutonium was separated from the nitrate solution by adding hydrogen peroxide. The plutonium was then dried and shipped to the Los Alamos site for conversion into metallic plutonium for weapons use. Operations in 231-Z were performed in large protective boxes equipped with rubber gloves and known as the Rubber Glove Line. The 231-Z Building also housed metallurgical and analytical laboratories that supported the finishing process.

Plutonium finishing facilities were plagued with recurring mechanical problems and process difficulties. Radiation-related concerns included direct neutron and gamma exposures, airborne activity, and surface contamination control. Use of respirators and periodic operation shutdowns were necessary.

5.2.5 Research and Development

Early research and development (R&D) was connected directly or indirectly with plutonium production. Simultaneously, due to the lack of knowledge regarding nuclear materials, their reactions, and their effects on biological and ecological systems, R&D in a wide variety of topical areas was initiated. Topics included radiation detection, human radiation experiments, meteorology and atmospherics, applied fish studies, radioactive field and reactor effluent studies, environmental and biological monitoring, radiobiology, and inhalation studies. R&D focus shifted with time to areas of basic research and product improvement.

Although R&D involved all areas of the Hanford Site, it was mainly associated with facilities in the 300 Area. The test reactor in the 305 Building began operation in 1943 and the 3706 Radiochemistry Building began operation in 1945. A pilot plant for developing separations processes was started in the "cold semi-works" Building 321 in 1945. Another noteworthy early R&D facility was the 100-F Area for biological studies.

5.2.6 Tank Farms and Waste Management

The Hanford Site mission was to bring facilities on line and operate them through WWII. Early waste management was based on limited technical understanding of nuclear physics and engineering. It was anticipated that problems in waste management would be addressed as technology developed. There are very limited records of waste disposal activities at Hanford during the Manhattan Project period. Many of the initial waste management practices were developed by trial and error; modifications were made as knowledge increased and undesirable and impractical practices were identified. Plutonium production operations produced large quantities of radioactive waste. The largest amounts and the most hazardous wastes were those from the separations operations in the 200 Areas.

The following categories of radioactive waste were generated by Hanford operations:

- <u>Low-level liquid wastes</u> were generally discharged to ponds, trenches, cribs, and injection wells. There were numerous such facilities located throughout the site. From these facilities, the liquids would percolate into the surrounding soil.

- <u>High-level liquid wastes</u> were collected in large storage tanks, from 6-11 feet below ground. These storage tanks were all located in the 200 Areas. Sixty four (64) single-shell tanks were constructed during 1944 and 1945, ranging in capacity from 55,000 to 1,000,000 gallons.

- <u>Solid wastes</u> were buried in facilities, ranging from shallow pits to large lined excavations. Most burials were at least 18 feet deep. There were multiple solid waste burial sites in the 100, 200, and 300/600 Areas. Burial distance above groundwater varied from approximately 5 feet in the 100, 300, and 600 Areas to 55 feet in the 200 Areas.

- <u>Airborne effluents</u> were discharged to the atmosphere through stacks. During initial production efforts, air discharges were not treated or filtered.

Each major functional area included its own waste management facilities and methods. Functional areas generated significantly different waste volumes and activities:

- Fuel fabrication wastes included low-level liquids, solids, and air effluents. These wastes contained predominantly uranium. Radiation from uranium associated with fuel fabrication was considered relatively minor compared to other site radionuclides and activities. However, some wastes from the 300 Area R&D activities contained much higher levels of fission products, such as cesium-137 and strontium-90, activated metal components, and transuranics. Liquid low-level wastes were collected in a process sewer which emptied into ponds located east of the 300 Area. Sludge from the ponds was periodically dredged to recover the uranium.

- Reactor wastes contained fission and activation products, transuranics, and uranium. Cooling water from the single-pass systems was discharged to the Columbia River. Low-level liquid wastes, including liquids from the 100-F Animal Farm experiments, were placed in trenches or cribs from which they entered soil columns. Although radionuclides were primarily short half-life, wastes included some with longer half lives, such as strontium-90, cesium-137, hydrogen-3, neptunium-237, plutonium-239, and uranium. There were no high-level liquid wastes from 100 Area operations. Solid wastes consisted primarily of protective clothing, reactor hardware and components, tools, and miscellaneous trash.

- Separations and plutonium finishing wastes in the 200 Areas contained fission products (primarily cesium-137 and strontium-90) and uranium. Low-level liquids were released to soil through ponds, trenches, French drains, cribs, and injection wells. High-level wastes were piped to underground storage tanks. As previously indicated, separations operations produced large quantities of liquid waste containing high levels of radioactive materials along with hazardous chemicals constituents. Solid wastes, disposed of in 200 Area burial grounds, consisted primarily of process hardware, construction debris, protective clothing, and soil contaminated by spills from storage tanks.

- Airborne effluents were released through 200-foot high stacks. During early production years, no treatment was provided to control airborne releases. The predominant radionuclide released in early operations was iodine-131. Other main contaminants included ruthenium-103, ruthenium-106, cerium-144, and strontium-90.

Numerous problems associated with waste management operations resulted in the spread of contamination and elevated radiation levels. Exposure rates up to 200 R/h were encountered during routine handling of solid waste. Waste fires occurred in solid waste burial sites in all major Areas. Containers of waste were ruptured during transport and from the weight of backfill soil. There were frequent leaks in underground storage tanks and waste transport lines. Cribs overflowed or otherwise malfunctioned, resulting in contamination of soil, groundwater, vegetation, and wildlife. In 1945, the 300 Area pond dike broke, releasing 14 million gallons of low-level liquid waste into the Columbia River. Reactor retention basins leaked, allowing low-level liquid waste to enter underlying soil. Prior to installation of filters in 1947, flakes contaminated with iodine-131, ruthenium-103, ruthenium-106, cerium-141, strontium-90, and other radionuclides were occasionally discharged from the separations stacks and contaminated the areas around the separations plants. Personnel in the vicinity of the plants were required to wear respiratory protection.

5.2.7 Summary of Key Hanford Site Facilities

Table 5-2 summarizes the key Hanford Site radiological facilities and operations.

Table 5-2: Key Hanford Site Facilities and Operations (1943 through August 1946)

Areas	Key Facilities	Operations
100	105-B, -D, and -F	Reactor buildings; each contained: graphite core reactor for irradiation of uranium fuel elements to produce plutonium; storage pool; handling facilities for irradiated fuel.
	103-B, -D, and -F	Storage of un-irradiated fuel elements awaiting insertion into the reactor.
	111-B	Facility for performing metallurgical tests on reactor materials.
	100-F Animal Farm	Area for conducting research on effects of radiation and radioactive materials on animals and fish.
	107-B, -D, and -F	Retention basins for reactor cooling water.
200	212-N, -P, and -R	Lag storage buildings located in 200 North for storage of irradiated fuel awaiting dissolution.
	213-J and -K	Magazine storage buildings located in 200 North for storage of plutonium nitrate paste from 231-Z.
	221-T and -B	Chemical separation buildings. T Plant was in 200 West; B Plant in 200 East. Used a bismuth phosphate process on irradiated fuel elements to separate plutonium from uranium and fission products.
	224-T and B	Bulk reduction buildings. Plutonium in solution from 221 Buildings was further purified and concentrated.
	221-U	Chemical separation building located in 200 West. Design similar to T and B Plants, but used for training, decontamination, and repair to support other separation operations.
	231-Z	Finishing building located in 200 West. Converted material from bulk reduction facilities to plutonium nitrate paste.
	216-E	Waste disposal trench located in 200 East. Used for burial of solid radioactive waste.
	241-B, -C, -T, and -U	Underground storage tanks for high-level liquid waste from separations operations. Each group contained 16 tanks. B and C tank farms were in 200 East; T and U farms in 200 West.
	222- B, -T, and -U	Sample preparation laboratories to support operations in the 221 and 224 Buildings.
	291- B, -T, and -U	Exhaust buildings and stacks. Provided exhaust ventilation for 221 and 224 Buildings.
	2723-W	Laundry for work shoe repair and cleaning clothing worn in 100 and 200 Areas. Only one facility - in 200 West.
300	303-A, -B, -C, -D, -E, -F, -G, J, and -K	Used for storage of uranium metal to be fabricated into fuel elements.
	305	Test reactor for development of fuel and reactor materials.
	313	Metal Fabrication building. Uranium slugs were prepared and canned for irradiation.
	314	Press building. Extrusion and straightening of uranium rods in preparation for cutting into slug lengths and canning.
	3706	Radiochemistry laboratory to support all Hanford Site operations.
	321	Separation building. Also known as “cold semi-works.” Pilot studies to support development of separations processes.
	316	Waste disposal trench used for burial of radioactive solid wastes.

5.3 Radiological Exposure Sources from Hanford Operations

During the period of October 1943 through August 1946, there was a potential for exposure radiation from a variety of internal and external sources. The primary mission of the Hanford Site was plutonium production; consequently, there were potential exposures to that material. In addition, other operations related to plutonium production also entailed potential exposures. For example, fuel fabrication from natural uranium gave rise to potential direct beta and photon exposures and to airborne exposure; reactors used to irradiate fuel elements generated direct beta, photon, and neutron radiation fields and the potential for surface and airborne contamination by uranium and a wide variety of fission and activation products; separations processes, research and development activities, and the collection and disposal of radioactive wastes also resulted in potential direct exposures to direct alpha, beta, photon, and neutron radiation fields and the potential for exposures to surface and airborne contamination by uranium and a wide variety of fission and activation products.

5.3.1 Alpha Particle Emissions

Primary alpha particle-emitting radioactive materials at the Hanford Site were uranium, plutonium, and other transuranic materials produced by the irradiation of uranium fuel. Table 5-3 lists the alpha-emitting radionuclides and their primary alpha energies.

Table 5-3: Principal Site Alpha-Emitting Radionuclides

Radionuclide	Energy (MeV)
Plutonium-238	5.46 (28%), 5.50 (72%)
Plutonium-239	5.11 (11%), 5.16 (88%)
Plutonium-240	5.12 (24%), 5.17 (76%)
Americium-241	5.44 (13%), 5.49 (85%)
Neptunium-237	4.78 (75%), 4.65 (12%)
Uranium-234	4.72 (28%), 4.77 (72%)
Uranium-235	4.37 (18%), 4.40 (57%), 4.58 (8%)
Uranium-238	4.15 (25%), 4.20 (75%)

5.3.2 Beta Radiation Fields

The primary sources of beta exposure were fission and activation products from reactor operations. The greatest potential for exposure to beta radiation from these materials was during the separations process and subsequent waste handling after the material was separated from the solid fuel and placed in a dispersible form. Beta radiation was also present from un-irradiated uranium fuel, but at significantly lower levels than encountered after the fuel was irradiated during reactor operations. Table 5-4 lists major beta-emitting radionuclides and the maximum beta energies and abundances of their primary beta energies.

Table 5-4: Hanford Site Beta-Emitting Radionuclides

Radionuclide	Maximum Energy (MeV)
Strontium-90/Yttrium-90	0.546 (100%) / 2.28 (100%)
Cesium-137	0.512 (95%)
Iodine-131	0.248 (2.1 %), 0.334 (2.2 %), 0.607 (90%)

Table 5-4: Hanford Site Beta-Emitting Radionuclides	
Radionuclide	**Maximum Energy (MeV)**
Cerium-144	0.318 (77%), 0.185 (20%)
Ruthenium-106/Rhodium-106	3.54 (79%), 2.41 (10%), 3.03 (8%)
Ruthenium-103/Rhodium-103	0.226 (91%)
Protactinium-234m (uranium decay chain)	2.29 (98%)
Thorium-234 (uranium decay chain)	0.103 (21%), 0.193 (79%)
Plutonium-241	0.021 (100%)

5.3.3 Neutron Exposures

Neutrons were produced by the reactor fission process. Thick biological shields surrounded reactor cores to moderate and absorb neutrons. During the separation and finishing processes, plutonium alpha particles interacted with low-atomic-number elements (e.g., fluorine and oxygen) in chemical reagents, plutonium compounds, and facility structural materials to produce neutrons. The Hanford TBD for Occupational External Dose (ORAUT-TKBS-0006-6) provides information regarding neutron sources, energy spectra, and neutron-to-photon ratios associated with various site operations.

5.3.4 Photon Exposures

Photons associated with plutonium are of low energy and would be shielded by construction materials in processing and handling facilities. However, the fission process releases high levels of photon radiation, and the fission and activation products resulting from fuel irradiation in reactors decay by photon emission. Biological shields around reactor cores reduced the levels of fission photons and photons from irradiated fuel within the core. After discharge from the reactor, irradiated fuel elements were stored under water and handled with remote tools to limit exposures. Photons from irradiated fuel were a concern throughout the latter stages in the plutonium production process, including transportation, chemical separation, waste management, and equipment maintenance. R&D activities utilized a wide variety of radionuclides with similar photon emissions as those generated in the fuel irradiation operations. The Hanford TBD for Occupational External Dose (ORAUT-TKBS-0006-6) provides information regarding photon sources and energy spectra associated with various site operations

5.3.5 Incidents and Fires

Reviewed documents contain general references to problems related to of radiation exposure control. Sections 5.2.2 through 5.2.6 briefly describe these problems. However, only a few specific incidents or releases were reported in these documents for the time period under evaluation:

- In 1945, the 300 Area pond dike failed, releasing 14 million gallons of low-level liquid waste into the Columbia River.

- Prior to installation of filters in 1947, flakes contaminated with iodine-131, ruthenium-103, ruthenium-106, cerium-141, strontium-90, and other radionuclides were occasionally discharged from the separations stacks and contaminated the areas around the separations plants. Personnel in the vicinity of the plants were required to wear respiratory protection.

6.0 Summary of Available Monitoring Data for the Proposed Class

The primary sources of monitoring data for this evaluation include the NIOSH Site Research Data Base (SRDB), the NIOSH OCAS Claims Tracking System (NOCTS), the Comprehensive Epidemiologic Data Resource (CEDR) database, and the Hanford Radiological Exposure (REX) system database. NIOSH investigated the REX database (maintained by the Hanford Site) and the CEDR database for available internal and external monitoring data. In addition, the NOCTS database was reviewed for claimant exposure data. Copies of many of the Hanford records are contained in the SRDB. Reviews of these sources identified personal monitoring data (e.g., film badge exposure results, TLD monitoring results, bioassay results) and area monitoring data.

Radiation protection was a major concern at Hanford from the beginning of operations. Throughout most of Hanford's history, considerable research was conducted toward improving survey instruments, effluent clean-up mechanisms, monitoring instrumentation, workplace air-sampling practices, and improved understanding of the biokinetics of radionuclide intakes (ORAUT-OTIB-0002). The science and practice of monitoring for intakes of plutonium, uranium, and mixed fission and activation products were in their infancy in the 1940s. Knowledge and skills associated with routine bioassay for plutonium and uranium were rapidly being developed and improved, and the scope of monitored workers was expanding.

6.1 Hanford Internal Monitoring Data

Based on the data resources listed in Section 6.0 and other source documents, NIOSH has determined that internal monitoring data for Hanford employees are not available for the 1943-1946 time period.

When plutonium production at Hanford commenced, a bioassay program to monitor employees for internal dose was still in the early stages of development. From 1943 to 1946, the site operated three production reactors, a fuel manufacturing facility with its associated test reactor, and four processing plants before a routine bioassay program was in place.

According to the history compiled by R. H. Wilson in 1987 (PNL-6125), a special studies group was formed in 1944. One of the priority tasks for this group was to determine a way to measure plutonium in the body. Limits on the amount of plutonium in the body were set as early as 1944, and, after experimentation with various methods, routine urine sampling and analysis for plutonium was initiated in September 1946. Urinalysis for uranium was piloted in 1946 also and was well established by 1948. Urinalysis for fission products started in this time frame as well, although the Wilson document indicates that separation from potassium-40 was not always successful prior to 1949 (ORAUT-TKBS-0006-5, p.8-9).

The intake radionuclides of concern at Hanford during the DuPont years have been plutonium, uranium, fission products, and activation products.

Although some records of uranium bioassay during the DuPont years are available, the Wilson history states that the uranium urinalysis program prior to 1948 was not reliable. The fluorometric method, which fused uranium from raw urine with sodium fluoride and measured the fluorescence when the compound was exposed to ultraviolet light, was implemented sometime during the first half of 1948 (PNL-6125; HW-10522).

Routine fission product urinalyses started in January 1947, but ferrous hydroxide precipitation was used on the supernatant from the plutonium lanthanum fluoride procedure, and the results were erratic with occasional breakthrough of K-40. So, data prior to 1948 are considered unreliable (ORAUT-TKBS-0006-5, p.27).

Considerable numbers of thyroid scans (hundreds per month) were being done for workers in the separation (canyon) buildings during the 1940s. There was a concern about potential I-131 uptake for workers who entered the canyons (e.g., crane operators). No information has been located in the records documenting what instruments were used, what MDAs were applicable, or what the actual results were. The tolerance level for iodine-131 in air was established in October 1945 as 1×10^{-7} $\mu Ci/cm^3$ (Cantril, 1945) based on a permissible equilibrium amount in the thyroid of 2 μCi. Based on other statements in the monthly reports, it is reasonable to assume that scans showing thyroid burdens over 2 μCi would have been considered significant (ORAUT-TKBS-0006-5, p.7).

In vivo counting equipment and techniques were not developed until the late 1950s and were not routinely used until 1960 (ORAUT-TKBS-0006-5, p.33).

Details regarding the various analyses used and the associated minimum detectable activities are presented in the Hanford TBD for Occupational Internal Dose (ORAU-TKBS-0006-5).

6.2 Hanford External Monitoring Data

The following discussion provides a general summary of the Hanford Site external dosimetry program, as well as the types, quantity, and quality of data that can be used for external dose reconstruction. Details regarding the external dosimetry equipment, methodologies, and techniques in use during the time period of the proposed class are described in *Manual of Standard Procedures: Personnel Meters* (Hart, 1946). Administrative practices are generally described in *Historical Review of Personnel Dosimetry Development and its Use in Radiation Protection Programs at Hanford*, (PNL-6125). A description of the historical recorded dose values is provided in *Historical Hanford Radiological Record Description* (Fix, 2001). Hanford monitoring practices were essentially the same as those used at other major MED facilities, such as University of Chicago and Clinton (Oak Ridge).

Based on available records, it appears that dosimeters were assigned to all workers who entered controlled radiation areas. Beginning with fuel fabrication operations in late 1943, pencil ionization chambers (PICs) were used to record doses to beta/gamma radiation. These PICs were prone to malfunction and/or accidental loss of charge, which typically results in high results. Therefore, dual PICs were issued to each worker to avoid assigning erroneously high radiation levels resulting from such performance problems. PICs were read and the readings recorded daily on an individual's dosimetry record card.

Starting in October 1944, two-element film dosimeters were issued and processed in-house. These two-element dosimeters presented difficulties in distinguishing between beta and low-energy photon radiations. Use of PICs continued as a contingency for damaged film dosimeters, but the film dosimeter was considered the official dose record. The weekly result was manually recorded on the individual's card and compared for compliance with radiation control limits. Early dosimetry records are often difficult to read and interpret (Fix, 2001).

Annual summaries of external dosimetry records, beginning in 1944, have been entered into the Hanford Radiological Exposure (REX) database, with the exception of records for those early DuPont workers who transferred with the DuPont organization to other work locations when General Electric Company took over as Hanford operating contractor.

Extremity film dosimeters were provided for monitoring the hands of fuel fabrication workers and for monitoring workers in other operations with potential for significant external radiation levels to the hands (e.g., personnel responsible for discharging irradiated fuel elements and transferring freshly-discharged fuel). These extremity film dosimeters were also read and recorded weekly.

Hanford implemented use of PICs with a liner enriched with boron-10 in 1944. These dosimeters did not permit distinguishing doses from different neutron energy groups; these PICs were, therefore, primarily useful for monitoring the presence of neutrons rather than neutron dose. NTA neutron dosimeters were not available at Hanford until 1950.

Table 6-1 contains annual dose summary statistics for Hanford years 1944 through 1946.

Table 6-1: Summary Statistics of Monitoring Data for Hanford (1944-1946)

Year	No. of Monitored Employees	Positive Photon Dose Results	Positive Neutron Dose Results	Positive Non-Penetrating Dose Results
1944	3495	1499	0	292
1945	5826	3573	0	1053
1946	4195	3466	0	1947

Source: PNL-8909, Tables A.5, A.6, and A.11

Details regarding the various analyses used and the associated minimum detectable activities are presented in the Hanford TBD for Occupational External Dose (ORAUT-TKBS-0006-6) and the *External Coworker Dosimetry Data for the Hanford Site* (ORAUT-OTIB-0030).

6.3 Hanford Air Sampling Data

Air monitoring at Hanford was based on gross alpha and gross beta measurements corrected for radon progeny. Limited air sampling results are available for this time period from the weekly and monthly reports of the Health Instrument Section of the Medical Department. These were brief summaries, mostly highlighting problems or indicating that air concentrations were below concern. Often no values were given, and locations relative to the workers location are unknown. In addition, air sample data from the reactors were almost never listed in these reports (ORAUT-TKBS-0006-5, p. 6). Table 6-2 summarizes located air sample data for the period:

Table 6-2: Hanford Air Sampling Data

Year	Facility	Maximum Concentration (µCi/cm³)	Most Sampler Concentrations (µCi/cm³)
1943	Building 305 Test Reactor		
1944	B Reactor		
	D Reactor		
	T Plant		
1945	T,U,B Canyon Bldgs	8E-12 Pu	<8E-13 Pu
	T,U,B Concentrator Bldgs (224T,U,B)	2E-11 Pu	<2E-12 Pu
	D Reactor		
	B Reactor		
	F Reactor		
	231-Z	One at 8E-11 Pu, very temporary and area immediately placed on mask; most highs were about 8E-12 Pu or less.	<8E-13 Pu
	300 Area Labs	6E-12 Pu	<8E-13 Pu
	Metal Fabrication Bldgs.	1E-9 Unat	<2E-10 Unat
1946[a]	T,U,B Canyon Bldgs.	4E-12 Pu[b]	
	T,U,B Concentrator Bldgs.		
	D Reactor		
	B Reactor		
	F Reactor		
	231-Z	4E-11 Pu	8E-13 Pu
	300 Area Metal Fabrication Bldgs.	2E-9 Unat	<1E-10 Unat
	3706 Bldg.	6E-12 Pu, 5E-10 Unat	<2E-12 Pu
	200 W Laundry	1E-11 Pu	4E-12 Pu

Source: Hanford Occupational Dose TBD, ORAUT-TKBS-0006-5 (Table 5.1-1)
Notes:
[a] **Based on monthly reports for July and September through December only.**
[b] **Excluding one incident in B Canyon involving only two workers, for which special urine samples were obtained.**

7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by 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 was 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 (discussed in Section 9.0 of this report). 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 OCAS'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-00057-1 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Hanford Data

This subsection answers questions that need to be asked before a feasibility evaluation is performed. The topic of 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 is 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.

Performing internal and external dose reconstructions requires worker monitoring data or source term and process information. Worker monitoring data includes data from members of the proposed class as well as data from workers outside the proposed class who were performing jobs with higher exposure potentials. Using such co-worker monitoring data provides a means for calculating claimant-favorable and maximum potential radiation doses for class members who were unmonitored or have gaps in their monitoring records.

7.1.1 Internal Data Review

NIOSH has found that the internal monitoring data and source term are insufficient for estimating most internal radiation doses with sufficient accuracy for members of the proposed class. A notable exception is the ability to estimate internal doses associated with uranium fuel fabrication activities utilizing available process descriptions and existing dose reconstruction techniques.

7.1.2 External Data Review

Hanford policies appear to have been in place for all significant external dosimetry parameters. A 1990 evaluation of the Hanford program identified no significant administrative practice that would jeopardize the integrity of the recorded external dose (PNL-7447). Two reviews of external dose records have been conducted. *A Study of Detailed Dosimetry Records for a Selected Group of Workers Included in the Hanford Mortality Study* (PNL-7439), found agreement between original paper records and the computerized Hanford Radiological Exposure (REX) Database. A study by the University of Pittsburgh, *Feasibility Study of the Correlation of Lifetime Health and Mortality Experience of AEC and AEC Contractor Employees with Occupational Radiation Exposure* (NYO-3394-5), concluded that good quality control was exercised over the film badge calibration and processing procedures at Hanford over the years covered by the proposed class.

7.2 Internal Radiation Doses at Hanford

The principal source of internal radiation doses to members of the proposed class would have been inhalation and ingestion of radiological contamination during the following operations:

1. Fabrication of uranium metal fuel elements
2. Irradiation of fuel elements in reactors to produce plutonium-239
3. Chemical separation of plutonium-239 from irradiated fuel elements
4. R&D support of production operations and biological and ecological systems
5. Waste management operations supporting all site radiological activities

The potential internal sources would have been dependent on the operational area and activities. For example: in fuel fabrication areas - natural to very slightly-enriched uranium; in reactor facilities – mixed fission and activation products; in separations and finishing facilities, fission/activation product (6% plutonium-239 mix). Potential internal sources from R&D, waste management, and other support operations would have been dependent on the particular activities.

7.2.1 Process-Related Internal Doses at Hanford

As indicated in Section 6.1, there are no bioassay or in-situ monitoring data from the onset of Hanford Site operations in 1943 through August 1946 that would allow direct reconstruction of an individual's internal dose. Weekly Health Instrument Section reports for the 100 Areas and the 300 Area provide limited air sampling data (HW-7-1635). However, these data are primarily for the fuel fabrication and separations facilities and provide practically no monitoring data for reactor and other Site operations. The contributions of the Health Instrument Section of the Medical Department to the Hanford Engineer Works Monthly Reports during 1945 summarize the weekly air data, but provide no further information or detail (HI Reports). Furthermore, NIOSH has not identified documentation describing air monitoring devices, sampling techniques, sample measurement and analytical methods, or information regarding air monitoring locations and their relationship to potentially-exposed individuals.

As a result of these limitations, NIOSH cannot establish maximum internal exposure scenarios that address all of the internal exposure potentials for the proposed class, and therefore, cannot estimate internal doses for members of this class with sufficient accuracy. NIOSH does however feel that it has sufficient process information to apply existing dose reconstruction (overestimating) techniques to bound internal doses associated with the uranium fuel fabrication work.

7.2.2 Ambient Environmental Internal Radiation Doses at Hanford

ORAUT-TBKS-0006-4, *Hanford Site-Occupational Environmental Dose*, describes the principal potential sources of dose received by individual while outside operational facilities on the Site. The principal potential source during the time period of the proposed class was inhalation of radionuclides, discharged from stacks of the T and B separations facilities and the 231-Z finishing plant. Levels during the early operations were high, because filtration was not yet available to restrict effluent discharges. Another potential source was discharges from the 100-B, -D, and -F reactor facilities. Estimated annual intakes of major radionuclides from these sources are provided in this reference and are summarized in Table 7-1 below.

Table 7-1: Annual Intakes of Particulate Radionuclides						
Radionuclide	**1944**		**1945**		**1946**	
	Bq	**GSD**	**Bq**	**GSD**	**Bq**	**GSD**
I-131	2.88E+02	3.78	1.04E+05	1.94	2.42E+04	1.90
Zr/Nb-95	1.91E-01	5.33	5.24E+01	2.60	7.29E+01	2.41
Ru/Rh-106	1.19E-02	2.87	4.09E+00	1.69	7.28E+00	1.63
Ru/Rh-103	1.83E-01	2.87	3.40E+01	1.68	4.28E+01	1.64
Sr/Y-90	4.84E-03	2.46	1.45E+00	1.59	2.67E+00	1.56
Ce/Pr-144	1.45E-01	2.46	3.79E+01	1.59	6.64E+01	1.56
Cs/Ba-137	4.18E-03	2.46	1.28E+00	1.59	2.35E+00	1.56
Pu-239	9.75E-06	12.00	6.84E-03	7.04	1.47E-02	6.43

Source: ORAUT-TKBS-0006-4.

7.2.3 Internal Dose Reconstruction

An approach for estimating internal exposures for unmonitored time periods (i.e., periods for which bioassay data are not available) is described in Section 6.0 of ORAUT-OTIB-0039, *Internal Dosimetry Coworker Data for the Hanford Site*. This approach is based on extrapolation back to the Hanford DuPont years from measured exposures during periods of comparable operations and production levels—conditions present at Hanford during the time period immediately following September 1, 1946. This approach also assumes an active and effective radiological protection program that provides quality air monitoring data and demonstrates compliance with established air concentration tolerance levels during an unmonitored time period. The intake rate during the monitored time period is estimated from bioassay data. This intake rate is then multiplied by a factor representing the ratio of the air concentration tolerance level during the unmonitored period to the tolerance level during the monitored period to provide an estimate of the intake rate for the unmonitored period.

Further adjustments to this intake rate estimate may be made to account for other differences between the monitored and unmonitored periods, such as changes in relative radionuclide ratios due to variations in cooling times and radiological ingrowth, and modifications to production levels. Use of this approach may be considered appropriate, provided the issue of air sampling data quality for the unmonitored time period can be favorably resolved. Another option particularly applicable to exposures associated with Hanford uranium fuel fabrication is to utilize process and source knowledge in conjunction with data available from other sites performing similar work. With this information, NIOSH can employ existing dose reconstruction techniques to calculate conservative (bounding) plausible exposures.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

Based on the absence of bioassay data for the period prior to September 1, 1946, the limited quantity of air monitoring data available for review (particularly for reactor and separations operations), and the lack of specificity regarding the location of air monitoring data relative to potential worker intake, NIOSH has concluded that internal dose reconstruction is not feasible, with the exception of those associated with uranium fuel fabrication.

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7.3 External Radiation Doses at Hanford

The principal sources of external radiation to the proposed class are those associated with nuclear fuel fabrication, nuclear reactor operations, and the radiochemical separation/refinement/finishing/storage of plutonium. The processes that generated the principal sources of external radiation dose are described in Section 5.0 of this document.

7.3.1 Process-Related External Radiation Doses at Hanford

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

7.3.1.1 Radiation Exposure Environment

The external dose received by workers at Hanford during the DuPont years was a function of the physical location of the workers on the site, the process taking place, the type and quantities of material present, and the time spent in each location. The radiation contributing to external dose was primarily beta and photon (including X-rays) and neutron.

Beta and Photon Characterization

The beta and photon radiations are well characterized in TBD ORAUT-TKBS-0006-6, Appendix A, Table A.2. A summary of the Table A.2 is provided in Table 7-2:

Table 7-2: Default Beta and Photon Energies/Percentages for Hanford DuPont Operations

Area	Starting Date	Radiation Type	<30 keV	30-250 keV	>250 keV
105-B, -D, and -F Reactors	September 1944	Photon [a]	0%	25%	75%
Plutonium Separation and Extraction, T, B Plants	December 1944	Photon [a]	0%	25%	75%
Plutonium Concentration and Storage, Z-Plant	January 1945	Photon	25	75%	0%
Waste Handling	January 1945	Photon [a]	0%	50%	50%

Source: ORAUT-TKBS-0006-6, Appendix A, Table A.2
Notes:
[a] **Beta energies in these areas are 100% >15keV.**

Neutron Field Characterization

During the DuPont years, Hanford work areas with the potential for neutron exposure included the 200 Area plutonium separation and concentration facilities, the 305 Test Reactor, and the 100 Area production reactors 105-B, -D, and -F.

At the 200 Area plutonium facilities, neutron radiation was generated from plutonium by either spontaneous fission, or importantly, by alpha particle interaction with light elements such as oxygen, fluorine, and beryllium. These interactions are commonly referred to as alpha-n reactions.

At the 100 Area nuclear reactor facilities and the 305 Test Reactor, neutrons were generated by fission of uranium and plutonium in the reactor core. Neutron exposures for workers in the reactors were accompanied by photon radiation that was readily measured with Hanford portable instruments, pocket ionization chambers (PICs), and personnel film dosimeters. These facilities generally had extensive shielding to reduce worker neutron and photon radiation exposure in most work areas. Neutron radiation was significant only while a reactor was in operation and only in those areas of a reactor that were typically closed to general worker access.

No neutron spectra measurements have been found for the DuPont years at Hanford.

7.3.1.2 History of Whole Body External Monitoring

Radiation dosimetry practices were initially based on experience gained during several decades of radium and X-ray medical diagnostic and therapy applications. These methods were generally well advanced at the start of the Manhattan Engineer District (MED). Hanford had an extensive radiation safety monitoring program to measure exposure in the workplace using portable radiation instruments, contamination surveys, zone controls, and personnel dosimeters. Doses from the dosimeters were recorded at the time of measurement and routinely reviewed by Hanford operations and radiation safety staff for compliance with radiation control limits (ORAUT-TKBS-0006-6).

External dose has been measured and recorded for Hanford personnel since the beginning of operations in 1944. During January 1944, before the Hanford film dosimetry system was operational, PICs were used for a few months to provide the dose of record (PNL-6125). PICs were issued to employees in duplicate (i.e., two to each worker) and exposures were recorded daily. PICs typically over-estimated the exposure from routine handling and environmental effects (HW-48751). Because of this “false-positive” dose from routine handling and environmental effects, the lower of the two daily readings was used to calculate the dose for comparison with then-current daily dose limits. Following use as the earliest dosimeters, PICs have been used throughout the history of Hanford operations to provide administrative control of worker dose until the personnel dosimeter was processed and the dose calculated. It has been routine practice since at least the early 1950s to compare the doses measured with PICs and dosimeters and, for significant differences, to document the reason(s) for the discrepancy (ORAUT-TKBS-0006-6).

The Two-Element Film Dosimeter was used from October 1944 to March 1957. This design was used at the Clinton Laboratory (now ORNL) and later by other MED/AEC/DOE laboratories. It was based on the dosimeter design developed at the Metallurgical Laboratory in Chicago, Illinois, by Pardue, Goldstein, and Wollan. The minimum detectable dose based on laboratory irradiations was 0.3 mSv

(30 millirem), and the routine dosimeter exchange period was weekly. During the years 1944-1947, Hanford assigned skin dose based on the dosimeter open window reading plus the silver-filtered dosimeter reading (ORAUT-TKBS-0006-6).

Routine Hanford practices appear to have required assigning dosimeters to all workers who entered a controlled radiation area. All dosimeters were processed and the measured results were recorded and used to estimate dose. There appears to be no use of recorded notional doses, although there are issues of "missed" recorded dose for low-dosed dosimeters as well as recorded doses for individual dosimeters at levels less than the statistical Minimum Detection Level (MDL) (ORAUT-TKBS-0006-6).

In 1944, Hanford implemented its individual worker neutron dosimetry methods using PICs (see Section 7.3.1.4).

7.3.1.3 History of Extremity Monitoring

Indications of an extremity dosimetry program exist as early as 1945 with finger-ring dosimeters being referred to in weekly Health Instrument Section reports (HW-7-1635). Records indicate that in 1945, 109 workers were monitored for extremity dose with a total of 349 mSv dose being recorded. In 1946, 285 workers were monitored for extremity dose with a total of 1754 mSv dose being recorded (PNL-6125, Table A.12).

The first dosimeter rings measured only beta. Later rings contained a silver shield to detect the gamma component, but these could be unsuitable for low-energy photons. Finger-ring dosimeters could be bulky and sometimes could not be used in tight areas. In such cases, a pliable film packet was used (HW-7-4211).

7.3.1.4 History of Neutron Monitoring

In 1944, Hanford implemented its individual worker neutron dosimetry methods using PICs. Enriched B-10 liners were used in the PICs to detect slow neutron exposure (PNL-6125). This method is generally acceptable to detect the presence of slow neutrons but not for dose measurement (ORAUT-TKBS-0006-6). Some attempts were made to measure fast neutrons using a fine-grain film to record tracks from recoil protons, but these attempts were unsuccessful (PNL-7447). There is no recorded neutron dose for any Hanford worker prior to 1950. In 1950, the NTA emulsion dosimeter capability was implemented (ORAUT-TKBS-0006-6). In addition, as reported in the Health and Instrument Section weekly and monthly reports, neutron surveys were performed with portable neutron survey instrumentation for the purpose of establishing safe workplace radiation levels, so as to limit neutron exposures to workers (HI Reports, HW-7-1635).

7.3.1.5 Dosimetry Records

Records of radiation doses to individual workers from personnel dosimeters worn by the worker and co-workers are available for Hanford operations beginning in 1944 (PNL-8909). As detailed in Section 6.2, data and documents covering external dosimetry, and related records covering the DuPont operational period, are readily available. An exception could possibly be DuPont corporate employees who left the Hanford Engineer Works when DuPont ceased site operation. Reports from interviewees and documents provided by the petitioner confirm that DuPont took the dosimetry records with them when they left the site. Workers who stayed on at Hanford retained their exposure records from their DuPont years. In addition, the DuPont records could be available in some form in the DOE record system at Hanford since these records were used to support the AEC's Health and Mortality Study performed by the University of Pittsburgh during the 1960s and 1970s (Kirklin; ORNL 67-3-10). The search for the DuPont records continues as this report is being written.

7.3.1.6 Application of Co-Worker Data for External Dose Reconstruction

For unmonitored workers, co-worker doses from photon radiation for Hanford are presented in ORAUT-OTIB-0030. Co-worker data may be used for cases not having complete monitoring data and may fall into one of several categories including:

- The worker was unmonitored and, even by today's standards, did not need to be monitored (e.g., a non-radiological worker).
- The worker was unmonitored, but by today's standards would have been monitored.
- The worker may have been monitored but the data are not available to the dose reconstructor.
- The worker may have partial information, but the available information is insufficient to permit a dose reconstruction.

The Hanford Co-worker study was developed using dosimetry data for monitored Hanford workers from the CEDR databases maintained by the DOE. The CEDR data evaluated represented primarily annual penetrating and non-penetrating dosimetry data provided by the Hanford site, which correspond to the shielded and "open-window minus shielded" dosimetry readings, respectively, and exclude neutron doses (ORAUT-OTIB-0030). Neutron doses are assigned based on a neutron-photon ratio as described later in Section 7.3.4.2 of this report.

A claimant-favorable approach was adopted in the development of co-worker dose summaries, and this approach should account for any underestimate of doses to Hanford radiological workers based on the considerations described above (ORAUT-OTIB-0030).

7.3.2 Ambient Environmental External Radiation Doses at Hanford

The TBD, *Hanford Site Occupational Environmental Dose*, ORAUT-TKBS-0006-4, and *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*, ORAUT-PROC-0060, provide the rationale, historical background, and data for the reconstruction of occupational environmental doses for unmonitored personnel at the Hanford Site. The occupational environmental dose is the dose received by individuals while outside operational facilities such as process buildings, chemical separations plants, reactors, or other structures. External dose from radioactive materials outside the body may be determined from immersion in a cloud of inert gases; deposition of particles on the skin; or adjacent operational facilities.

7.3.2.1 Ambient Radiation

Quarterly environmental monitoring reports published from 1945 to 1955 present gamma exposure levels at various locations throughout the Hanford site. The measured natural background radiation levels from 1946-1948 were 0.3 to 0.5 mrad per day. This natural background was not subtracted from the ambient readings. Table 4.8 of ORAUT-TKBS-0006-4 lists the external gamma measurements at Hanford from 1944 through 2001, including fallout and background. The values are averages in millirem per year for exposures of 2,000 hour/year and can be used to reconstruction dose from environmental radiation sources.

7.3.2.2 Releases of Noble Gases

Xenon-133 was released from the production reactors and its dose contribution can be estimated by comparing it with the iodine-131 release rate and dose conversion factors. At its peak in 1945, when Hanford used shorter fuel-element cooling times, the xenon-133 release rate was 42,000 Ci/mo. The I-131 release during the peak time was 89,000 Ci/mo. When comparing the dose conversion factors and release rates of iodine-131 and xenon-133, the iodine contribution to the dose was more than 10,000 times larger than that of xenon. Therefore, iodine is listed as a major contributor and Xe-133 is not (ORAUT-TKBS-0006-4).

Argon-41 was released from the Hanford reactors as a neutron activation product of stable argon in air and not from the chemical separations facilities. Effluent concentrations were measured for only brief periods over the years, and the reactors did not operate continuously. Table 4A-11 in ORAUT-TKBS-0006-4 provides submersion gamma dose and skin dose values that can be used to reconstruct dose.

7.3.2.3 Skin Deposition of Airborne Particulate Emissions

Starting in 1947, surveys of the ground in the T and B Plant areas revealed contamination in the form of discrete particles. The most likely source of these of particles was iron-oxide particulates coated with radioactive material from corroding ductwork in the T and B Plant ventilation systems. Analysis of the particles indicated that the radionuclides were deposited on the blowers and other iron surfaces and were released into the ventilation air stream as the iron parts corroded. Even though the particles were not discovered until 1947, there is no evidence that these releases were not on-going from the start of operations. These particles were emitted through April 1948 when sand filters were installed to stop the releases. The greatest activity measured on a T or B Plant particle was 3.2 μCi with the average being 1.1 μCi. ORAUT-TKBS-0006-4, Section 4.3.3, provides a method to estimate dose based on a conservative particle activity, the probability that a particle could land on a worker's skin, mean residence times, and dose coefficients for different radionuclides on the particles (ORAUT-TKBS-0006-4).

7.3.3 Hanford Occupational X-Ray Examinations

Pre-employment, termination, and periodic medical examinations were given to Hanford workers from the very beginning of the site. Cantril gives a count of 15 exams being given in December 1943, and states that the periodic exam program began in January 1944 (MDDC-602). These examinations included a chest X-ray.

In the site's early years, periodic X-ray examinations were relatively frequent. Groups of workers identified as being at-risk received medical exams, including X-rays, at more frequent intervals than other workers. For work with radiation hazards, interval exams in January 1944 were as close to every four weeks as possible. By July 1945, the exam intervals were lengthened from every four to every seven or eight weeks. Other employees not working with radiation or other special hazards were examined every three to six months. The frequency of medical radiographs was reduced to annually until 1959, and thereafter, on a schedule dependent on age but no more frequent than annually.

Review of the available documentation on the occupational medical program at Hanford from 1943 to the present revealed that only three diagnostic medical radiographic procedures were administered in connection with pre-employment or regular post-employment medical examinations:

1. Posterior-anterior (PA) 14" by 17" chest film
2. Lateral (LAT) 14" by 17" chest film
3. Photofluorographic 4" by 5" chest film

The 14" by 17" PA chest radiography was the most widely used diagnostic procedure. In some cases, stereo views were taken; these required two 14" by 17" films.

Beginning in March 1945, when Hanford received fluoroscopic equipment, photofluorographic chest films were taken. This method resulted in much greater worker doses than a standard radiographic procedure. Photofluorography used a smaller film (typically 4" by 5"), a smaller source-to-skin distance, and typically resulted in a several-fold greater radiation exposure. Exposure was regulated by photometers, which used exposure to the film to determine the time of exposure (MDDC-602; ORAUT-TKBS-0006-3).

7.3.4 External Dose Reconstruction

Through April 14, 2007, 378 EEOICPA claims from the Hanford workers—for the period of January 1, 1942 through August 31, 1946— had been submitted to NIOSH. Of those 378 claims, dose reconstructions have been completed for 328 claims. These claims cover the entire range of operation at Hanford and include claims with external monitoring data.

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

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

7.3.4.1 Photon and Electron Dose

External dose has been measured and recorded for Hanford personnel since the beginning of site operations. As previously shown in Table 4-1, the majority of completed dose reconstructions have had external dose records provided by DOE. Hanford worker-recorded dose measurements are considered reasonably accurate from 1944 through the present with one exception: the low-energy photon dose component measured in the plutonium facilities with the original two-element film dosimeter used prior to 1958 may be too low. Stated Hanford practice, for plutonium facilities only, was to add to the penetrating dose 20% of the measured non-penetrating dose. However, it has not been possible so far to clearly confirm that this practice was done for all years. Therefore, if the early photon dose is significant to the dose reconstruction, the penetrating dose may be adjusted by using 20% of the non-penetrating or shallow recorded dose to ensure a claimant-favorable assigned photon dose (ORAUT-TKBS-0006-6).

Missed dose, which occurs when the dose of record is zero because the dosimeter response was less than the MDL, or there is no dose of record for an assigned badge for a monitoring period, is accounted for by assigning a missed photon dose based on the MDL/2 method and the number of dosimeter exchange periods for the dosimetry system (ORAUT-TKBS-0006-6).

Hanford began using extremity dosimetry as early as 1945. A standard monitoring practice in operational health physics is to establish a factor between whole-body and extremity exposures to determine when extremity dosimeters should be assigned. Conservatively, it would not be necessary to monitor the extremity dose unless it was greater than three times the whole-body dose. To assign extremity dose for workers who have extremity cancer but no extremity dose data, the measured whole-body dose should be increased by a factor of three as a claimant-favorable assumption (ORAUT-TKBS-0006-6).

An adjustment for glovebox workers is used to adjust the measured photon dose for Hanford workers in plutonium facilities, based on the guidance in *Best Estimate External Dose Reconstruction for Glovebox Workers* (OCAS-TIB-0010).

To account for the uncertainty in beta/photon dosimeter measurements, a standard error of +30% is recommended for use in reconstructing dose. This is based on the estimated standard error of ±30% in recorded film badge doses from photons of any energy (ORAUT-TKBS-0006-6).

Based on the information available to NIOSH, the external photon and electron dose for the class under evaluation can be reconstructed with sufficient accuracy.

7.3.4.2 Neutron Dose

Neutron dose was monitored during this period using PICs containing enriched B-10 liners to detect slow neutron exposure. As stated in Section 7.3.1.4, this method is generally acceptable for detecting the presence of slow neutrons but not for dose measurement. Therefore, all neutron dose should be treated as missed dose because no neutron dose was recorded before the site started using neutron NTA film in 1950.

ORAUT-TKBS-0006-6 provides neutron-to-photon ratios for assigning neutron dose to employees. These ratios are based on work location and measured penetrating photon dose. A neutron dose should be calculated for all Hanford facilities with any potential for neutron dose using the specified ratio and ICRP energy correction factor (ICRP 60). The photon dose should be adjusted for any missed dose before applying the neutron-to-photon ratio to estimate neutron dose.

7.3.4.3 Unmonitored Individuals Working in Production Areas

Although all significantly-exposed Hanford workers should have been monitored with a recorded dose, unmonitored Hanford workers can be assigned unmeasured photon dose by using the Hanford co-worker doses presented in ORAUT-OTIB-0030, *External Coworker Dosimetry Data for the Hanford Site*.

Based on the information available to NIOSH, the dose to unmonitored workers in the class under evaluation can be reconstructed with sufficient accuracy.

7.3.4.4 Medical X-ray

Medical X-rays were performed on Hanford workers from the very beginning as part of their pre-employment, termination, and periodic medical examinations. Records of X-rays performed on a worker are typically included in the dose records provided by DOE. When records are not available, Table 3-3 of ORAUT-TKBS-0006-3, *Hanford Site Occupational Medical Dose*, provides a guideline to determine the number of X-rays. To summarize this table: Up to July 1, 1945, all employees are assumed to have had an entrance, exit, and every 3-6 months a 14"x17" PA chest X-ray. Radiation or special hazard workers are assumed to have had an X-ray every 4 weeks. After July 1, 1945, the radiation and special hazard workers' periodic interval was increased to 4-8 weeks (ORAUT-TKBS-0006-3). Organ doses are provided in ORAUT-TKBS-0006-3, Table 3-5, and are based on 1940s X-ray practices and dose factors given in ICRP 34 (ICRP 34; ORAUT-TKBS-0006-3; ORAUT-PROC-0061).

Beginning in March 1945, fluoroscopic equipment was received at Hanford and photofluorography chest films were taken at the site. These exams typically have a higher exposure than the 14"x17" PA chest X-rays. If uncertain as to the type of X-ray a worker received, the higher exposures due to photofluorography can be assumed. Organ dose estimations are provided in Section 3.3.3 of ORAUT-TKBS-0006-3.

ORAUT-TKBS-0006-3 provides a combined statistical uncertainty factor of +30% that can be assumed based on uncertainties such as measurement error, time of exposure, distance, and variations of tube current.

Based on the information available to NIOSH, the medical X-ray dose for the class under evaluation can be reconstructed with sufficient accuracy.

7.3.5 External Dose Reconstruction Feasibility Conclusion

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

7.4 Evaluation of Petition Basis for SEC-00057-1

The following subsections evaluate the assertions made on behalf of petition SEC-00057-1 for Hanford.

7.4.1 Evaluation of Major Topics Detailed in Petition SEC-00057-1

The following are the major topics applicable to the DuPont Hanford years that were detailed in the petitions that were merged to form SEC-00057-1. Italicized statements are from the petition; the comments that follow are from NIOSH.

7.4.1.1 Missing Hanford DuPont Area Dosimetry Records

SEC-00057-1: *There are no individual Hanford DuPont worker records in existence because they have all been destroyed.*

A review of claims in NOCTS show that records for DuPont-era workers who stayed on at Hanford after DuPont left were retained in the Hanford dosimetry files. This is consistent with responses from former Health Instrument Section radiation protection personnel interviews. DuPont did remove and retain the records for workers who left with DuPont and who had no further employment at Hanford. NIOSH reviewed claims in NOCTS for workers who left with DuPont. Some workers were employed at the Savannah River Site (SRS) when DuPont was the operator there and their records were transferred to SRS. Other workers who left with DuPont appeared to have job descriptions that were administrative or managerial in nature; they were unlikely to have been exposed to radiation or radioactive material and unlikely to have been monitored. DuPont Hanford exposure data were used in the *AEC Health and Mortality Study* and may be still available if a search is performed on those records (Kirklin; Fix, 2007).

7.4.1.2 Method Used to Estimate Releases Not Claimant Favorable

SEC-00057-1: *The computer program RATCHET has a tendency to underestimate. RATCHET is unsuitable to model Hanford emissions.*

The bulk of Hanford releases are episodic in that they resulted from batch processes and they are well-modeled using annual averages. To arrive at values for respirable particles, the transport and dispersion of the gases, mists, fumes, and small particles was estimated using the RATCHET computer code. RATCHET was developed to account for the episodic nature of the iodine (and other radionuclide) releases from the Hanford reprocessing plants in response to intense public interest and the inability to state a priori that longer-term averaging was adequate. However, subsequent analyses have shown that, when the additional uncertainty is appropriately accounted for, averaging over periods of months to years provides results that compare very favorably with the values generated using hourly release data. Radionuclides other than I-131 were released concurrently with the iodine. I-131 concentrations in the atmosphere calculated using the RATCHET model are, in fact, very close to those actually measured near Hanford. The other released radionuclides would likewise be adequately represented since they were released at essentially the same time as the iodine. (ORAU-SC&A, 2007 [draft])

7.4.1.3 Under-recording of Neutron Dose

SEC-00057-1: *Neutron dose was under-recorded for plutonium workers during the period of 1950-1971 when the Hanford Nuclear Track Emulsion, Type A, (NTA) film was used.*

Although the petitioner is commenting on a time period subsequent to the class under evaluation, the concern is relevant because the method for monitoring workers during the DuPont era also under-recorded neutron dose.

To assign neutron dose, a neutron-to-photon dose ratio is applied for each year of employment with a potential for neutron exposure.

Even though there are several sources of photon exposure that do not include an associated neutron dose (i.e., reactor maintenance while the reactor is not operating, reactor fuel fabrication, chemical processing), applying a neutron-to-photon dose ratio results in assigned neutron dose for these "photon only" exposures as well. Overall, the NIOSH expectation is that the reconstructed neutron dose will be over-estimated.

7.6 Summary of Feasibility Findings for Petition SEC-00057-1

This report evaluates the feasibility for completing dose reconstructions for employees at the Hanford Site from October 1, 1943 through August 31, 1946. NIOSH found that the available monitoring records, process descriptions, and source term data available are not sufficient to complete dose reconstructions for the proposed class of employees.

Table 7-3 summarizes the results of the feasibility findings at Hanford for each exposure source during the time period October 31, 1943 through August 31, 1946.

Table 7-3: Summary of Feasibility Findings for SEC-00057-1
(October 1, 1943 through August 31, 1946)

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal		
- U	X	
- Pu		X
- Fission Products		X
- Ambient Environmental[1]	X	
External		
- Gamma	X	
- Beta	X	
- Neutron	X	
- Ambient Environmental[2]	X	
- Occupational Medical x-ray	X	

Notes:

[1] **Internal ambient environmental dose reconstruction is considered feasible starting in 1944 per ORAUT-TKBS-0006-4**

[2] **External ambient environmental dose reconstruction is considered feasible starting in 1944 per ORAUT-TKBS-0006-4 and ORAUT-PROC-0060**

As of April 20, 2007, a total of 378 claims have been submitted to NIOSH for individuals who worked at Hanford for the period of January 1, 1942 through August 31, 1946. Dose reconstructions have been completed for 328 individuals (~87%).

8.0 Evaluation of Health Endangerment for Petition SEC-00057-1

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.

Although NIOSH has determined that, based on available data, estimating radiation dose for external radiation is feasible, the lack of routine bioassay for internal exposure as well as limited air sampling data make the estimation of internal doses—not associated with uranium fuel fabrication—unfeasible. Our evaluation determined that, except for doses from uranium, it is not feasible to estimate internal radiation dose for members of the proposed class with sufficient accuracy based on the sum of information available from available resources. A modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is required.

9.0 NIOSH-Proposed Class for Petition SEC-00057-1

This evaluation defines a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. This class includes: All employees of the DOE or DOE contractors or subcontractors who were monitored, or should have been monitored, for internal radiological exposures while working at the Hanford Engineer Works in: the 300 Area fuel fabrication facilities from October 1, 1943 through August 31, 1946; the 200 Area plutonium separation facilities from November 1, 1944 through August 31, 1946; or the 100 B, D, and F reactor areas from September 1, 1944 through August 31, 1946; and 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 (excluding aggregate work day requirements). The class was modified from the petitioner-submitted class to coincide with the time periods when radioactive materials were used or created during DuPont-operated production in the specified areas.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded to them herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Data Base (SRDB), for information relevant to SEC-00057-1. 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 that it would not be feasible to reconstruct the dose for the class proposed in this petition.

10.0 References

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