SEC Petition Evaluation Report
Petition SEC-00028

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

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Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Qualification Date	DOE/AWE Facility Name
SEC-00028	83.13	April 29, 2005	Y-12 Plant

Feasible to Estimate Doses with Sufficient Accuracy?

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

Petitioner Class Definition

All Steamfitters, Pipefitters, and Plumbers who worked at Y-12 from October 1944 through December 1957.

Proposed Class Definition

Employees of the DOE or DOE contractors or subcontractors who were monitored or should have been monitored for thorium exposures while working in Building 9202, 9204-1, 9204-3, 9206, or 9212 at Y-12 for a number of work days aggregating at least 250 work days during the period from January 1948 through December 1957 or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC-00026	83.13	Y-12 Plant	Designation Completed
SEC-00018	83.13	Y-12 Plant	Designation Completed

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
SEC Petition Evaluation Report SEC-00018	Y-12 Plant

Lead Technical Evaluator (Document Owner):	Signature on file *Al Wolff*	April 7, 2006 *Date*
Peer Review Completed By:	Signature on file *Lavon Rutherford*	April 7, 2006 *Date*
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SEC Petition Evaluation Approved By:	Signature on file *Larry Elliott*	April 7, 2006 *Date*

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Evaluation Report Summary: SEC-00028, Y-12 Plant

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

Petitioner Requested Class Definition

Petition SEC-0028, qualified on April 29, 2005, requested NIOSH to consider the following class: *All steamfitters, pipefitters, and plumbers who worked at Y-12 from October 1944 through December 1957.*

NIOSH Proposed Class Definition

Based on its research, NIOSH reduced the requested class because the feasibility of performing dose reconstruction for all workers employed from March 1943 through December 1947 has been addressed in a separate evaluation report: SEC-00018. Further, based on a detailed review of facility records and available information, the NIOSH proposed class covered in this evaluation includes: *Employees of the DOE or DOE contractors or subcontractors who were monitored or should have been monitored for thorium exposures while working in Building 9202, 9204-1, 9204-3, 9206, or 9212 at Y-12 for a number of work days aggregating at least 250 work days during the period from January 1948 through December 1957 or in combination with work days within the parameters established for one or more other classes of employees in the SEC.*

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83 and the guidance contained in NIOSH's Internal Procedures for SEC Evaluations, OCAS-PR-004. It provides information and analyses germane to considering a petition for adding a class of employees to the SEC. It does not provide any determinations concerning the feasibility of dose reconstruction that necessarily apply in the particular case of any individual energy employee who might require a dose reconstruction from NIOSH.

Feasibility of Dose Reconstruction

The feasibility determination for the class of employees covered by this evaluation report is governed by the requirements of the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 USC § 7384-7385 (EEOICPA) and 42 C.F.R. pt. 83. This section of the rule states that "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."

NIOSH has established in this evaluation that it does not have access to sufficient information to estimate either the maximum radiation dose incurred by any member of the proposed class or to estimate such radiation doses more precisely than a maximum dose estimate. The sum of information from the available resources is not sufficient to document or estimate the potential maximum internal thorium exposure to members of the proposed class, under plausible circumstances during the period of radiological operations at the Y-12 Site evaluated in this report.

Health Endangerment

The health endangerment determination for the class of employees covered by this evaluation report is governed by EEOICPA and 42 C.F.R. pt.83. Under these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also make a determination whether or not there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents.

If the occurrence of such an exceptionally high level exposure has not been established, then NIOSH is required to specify that health was endangered for 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 (excluding aggregate work day requirements).

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

NIOSH did not identify any evidence from the petitioners or from other resources that would establish that any members of the proposed class were exposed to radiation during any discrete incidents likely to have involved exceptionally high levels of exposure. However, there is evidence that some workers in the proposed class may have accumulated substantial chronic exposures through episodic intakes of thorium. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under the employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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SEC Petition Evaluation Report for SEC-00028

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for employees who worked at specified facilities during a specified time. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created Special Exposure Cohort (SEC).

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

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

2.0 Introduction

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

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

Under 42 CFR § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must also make a determination whether or not there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days either solely under the

[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 www.cdc.gov/niosh/ocas.

employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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

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

Petition SEC-00028, qualified on April 29, 2005, requested that NIOSH consider the following class: *All Steamfitters, Pipefitters, and Plumbers who worked at Y-12 from October 1944 through December 1957.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible. NIOSH considered the following information and affidavit statements sufficient to qualify SEC-00028 for evaluation.

> The petitioner asserted by affidavit that the energy employees listed on the petition did not receive or witness monitoring of radiation exposures or radiation doses for steamfitters, pipefitters, and plumbers.
>
> Steamfitters, Pipefitters, and Plumbers worked mostly in maintenance and new construction. New construction would have limited their exposure potential. However, maintenance activities were conducted all over the site. Worker interviews indicate that maintenance personnel had the potential to be exposed to all sources of exposure on site, because the maintenance group supported the entire site. Therefore, the maintenance personnel had the potential for exposure to:

- Uranium isotopes during uranium enrichment and recycling operations (neptunium)
- Thorium when two test batches were processed through the Building 9204-3 calutrons (for enrichment), during Research and Development activities in Buildings 9202, 9204-1, 9204-3, 9206, and 9212, and when used as a co-precipitation media to increase the uranium recovery percentage from decontamination solutions.
- Plutonium during the 1950s when plutonium was enriched with the calutrons
- Polonium 208 when polonium was produced with the cyclotron
- Other short lived radioactive isotopes produced by the cyclotron

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

The information provided by the petitioner supported the qualification of the petition for further consideration by NIOSH, the Board, and HHS.

NIOSH has already completed an evaluation of the feasibility of performing dose reconstruction for all workers at Y-12 employed from March 1943 through December 1947. The evaluation, summarized in report: SEC-00018, found that it was not feasible to estimate the radiation doses of this class of employees. SEC-00018 was considered by the Advisory Board on Radiation and Worker Health (the Board) on July 5-7, 2005 and the Board recommended the addition of the class to the SEC. The Secretary of HHS approved the addition of the class to the SEC on August 25, 2005. The designation of this class to the SEC became effective on September 24, 2005.

The NIOSH-proposed class evaluated in this report includes employees of the DOE or DOE contractors or subcontractors who were monitored or should have been monitored for thorium exposures while working in Building 9202, 9204-1, 9204-3, 9206, or 9212 at Y-12 for a number of work days aggregating at least 250 work days during the period from January 1948 through December 1957 or in combination with work days within the parameters established for one or more other classes of employees in the SEC. This report completes the evaluation of Petition SEC-00028.

4.0 Data Sources Reviewed by NIOSH

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

4.1 Site Profile Technical Basis Documents (TBDs)

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

- *TBD for the Y-12 Plant – Introduction*, ORAUT-TKBS-0014-1; October 11, 2005
- *TBD for the Y-12 Plant – Site Description*, ORAUT-TKBS-0014-2; October 11, 2005
- *TBD for the Y-12 Plant – Occupational Medical Dose*, ORAUT-0014-3; October 11, 2005
- *TBD for the Y-12 Plant – Occupational Environmental Dose*, ORAUT-0014-4; October 11, 2005
- *TBD for the Y-12 Plant – Occupational Internal Dose*, ORAUT-0014-5; February 14, 2006
- *TBD for the Y-12 Plant – Occupational External Dose*, ORAUT-0014-6; February 14, 2006

4.2 ORAU Technical Information Bulletins (OTIBs) and Technical Reports

ORAU Technical Information Bulletins (OTIB) and Technical Reports are general working documents that provide guidance concerning the preparation of dose reconstructions and particular sites or categories of sites. NIOSH reviewed the following OTIBs and Technical Reports which described the individual dose adjustment procedure and internal dosimetry coworker data at the Y-12 Plant:

- *Technical Information Bulletin: Individual Dose Adjustment Procedure for Y-12 Dose Reconstruction*, ORAUT-OTIB-0013; September 9, 2004
- *Technical Information Bulletin: Bayesian Methods for Estimation of Unmonitored Y-12 External Penetrating Doses with a Time-Dependent Lognormal Model,* ORAUT-OTIB-0015; September 9, 2004
- *Technical Information Bulletin: Internal Dosimetry Coworker Data for Y-12*, ORAUT-OTIB-0029; April 5, 2005
- *Analysis of Electronic Personnel Exposure Data from Y-12,* ORUAT-RPRT-0022; June 24, 2005
- *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1—Gamma Radiation,* ORAUT-RPRT-0032; March 21, 2005
- *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 2—Neutron Radiation,* ORAUT-RPRT-0032; March 21, 2005
- *Technical Information Bulletin: External Radiation Monitoring at Y-12 During 1948-1949 Period, Rev. 01*, ORAUT-OTIB-0047; September 20, 2005

4.3 Facility Employees and Experts

Additional information was obtained by interviewing nine Y-12 workers employed for at least some time during the 1948 to 1957 operational period. Selection was based on document references and distribution lists, recommendations from those being interviewed, and personal knowledge from within the Center for Epidemiological Research (CER). Efforts were made to interview people who held differing job types. The employee interviews ultimately included employees who worked on production lines, held supervisory positions, were members of the proposed class, and were health physicists.

Information obtained during the employee interviews contributed to the general knowledge base for Y-12 activities, thus, aiding in the dose reconstruction feasibility determination. The information gained from the employee interviews included (but was not limited to) processing details and timelines, supervisory roles and responsibilities, exposure potential, contamination minimization efforts, weapons assembly/disassembly activities, and information about monitoring practices.

4.4 Previous Dose Reconstructions

NIOSH reviewed its dose reconstruction database, NIOSH OCAS Claims Tracking System (NOCTS), to identify dose reconstruction cases under EEOICPA that might provide information relevant to the petition evaluation. Table 4-1 provides a results summary of this review for the January 1948 through December 1957 timeframe (Data available as of: March 8, 2006).

Table 4-1: Y-12 Claims Submitted Under Dose Reconstruction Rule[1]	
Description	**Totals**
Total number of cases submitted for energy employees who meet the class definition criteria	96
Number of dose reconstructions completed for energy employees who were employed during the years identified in the class definition	49
Number of cases for which internal dosimetry records were obtained for the identified years in the class definition	10
Number of cases for which external dosimetry records were obtained for the identified years in the class definition	0

Note:
[1]Results summary for the time period of January 1948 through December 1957.

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for each employee.

NIOSH has been able to obtain personal monitoring records and area monitoring data applicable to the evaluation of the proposed class in this report. When looking at previous dose reconstructions, NIOSH also reviewed the interviews conducted with claimants for these cases to determine whether they had provided relevant information for dose reconstruction. The interviews provided some information that would be useful for future dose reconstructions (i.e., work locations, hours worked, and hazards encountered).

4.5 NIOSH Site Research Database

The NIOSH Site Research Database (SRDB) was reviewed for documents to support the evaluation of the proposed class. Currently, there are 496 documents contained within this database pertaining to Y-12; these documents are largely in the form of reports, manuals, and memos. These documents include information for Y-12 regarding dust sampling, dose rate surveys, urinalysis data, the radiological control program, the film badge dosimetry program, medical monitoring, process materials, as well as process description information for the Y-12 Site.

4.6 ORAU Center for Epidemiologic Research Database

From 1978 through the 1980s the Y-12 Site delivered electronic files of worker data to the Center for Epidemiologic Research as a resource for the Health and Mortality Studies conducted for the Department of Energy (DOE) and its predecessor agencies. Files containing records for more than 17,000 Y-12 workers were received on magnetic tapes and included beta, gamma, and neutron radiation measurements, penetrating dose and skin dose, urinalyses results, and additional relevant information. CER transferred all the data from tape to disk and later constructed a carefully linked relational database with a standardized file format. Since 2002, the data have resided in a Microsoft © SQL Server database. Records contain all data elements received from the original Y-12 files unaltered, including first, middle, and last name, plant badge number, social security number, year of record, quarter of record, quarterly summations of dose readings for the monitoring period (weekly, monthly, or quarterly), and other work history, processing, and demographic data. This database includes 834,399 external monitoring records dating from 1950 through 1998; 694,221 urinalysis (bioassay) records spanning from 1950 through 1998; and 100,652 whole body counting records dating from 1961 through 1991. Details of the availability and quality of data relevant to the subject class is presented and discussed in Section 7.0 of this evaluation and Appendix 1.

4.7 Y-12 Health Physics Progress Reports

In addition to the numerous memos and other documents that NIOSH has available regarding Y-12, NIOSH has discovered that Y-12 Health Physics activities were documented in a series of reports that have been kept on file within the Y-12 Plant. These reports were produced with varying frequency over time (monthly, quarterly, and semi-annually) and have been retrieved from as early as September 1947.

Data typically contained within the Health Physics Progress reports includes external exposure rate, contamination level ranges (minimum, mean, and maximum results), alpha hand counting data, sampling locations, and sampling frequencies. Air contamination concentrations are most frequently presented as average uranium air concentrations in d/min/m^3. Sampling locations are detailed as are sample type (e.g. swipe, scan, breathing zone, general air, etc.) and specific jobs are assessed. Overall sampling frequencies reflect an effort to assess contamination levels in all plant areas with some regularity but maintain a focus on the known highest exposure locations associated with production. Contamination and exposure potentials associated with new and/or short duration research and developmental type activities were also assessed and documented. Longer lasting, non-uranium production activities such as the cyclotron work were given regular attention within the monitoring program and progress reports.

4.8 Y-12 Delta View Imaging System

Maintained by Y-12, the Delta View image system is comprised of scanned images of hard copy reports and monitoring data print-outs associated with Y-12 personnel. Not a typical database, Delta View stores copied images of documents that are searchable to the extent that key words have been associated with the individual images when initially loaded. The images in Delta View are therefore accessible by individual name and/or ID numbers, analysis, and sample type among other parameters. Delta View's focus has been primarily to maintain worker records that are generally not associated with the "routine" uranium urinalysis and external monitoring program. Examples of data in Delta View include information describing special studies, non-uranium urinalyses, medical evaluations, and corrections to memos.

4.9 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following document submitted by the petitioners and received March 28, 2005:

1. *Affidavit by petitioner*, March 24, 2004; SECIS document id: 8544

5.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize the radiological operations at the Y-12 Plant from January 1948 to December 1957 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, information describing the process through which the radiation exposures of concern may have occurred, and information regarding the physical environment in which radiation exposures may have occurred.

Claimant interviews indicate that the work performed by the class defined by the petitioner varied considerably. Some workers were assigned to an individual task within a single area for an extended period and other workers were assigned to multiple areas over their employment period. However, the wide-spread application of the worker class duties warrants summarizing the broad scope of radiological operations that occurred during the 1948 through 1957 timeframe. Predominantly functioning in new construction, maintenance, or repair capacities, it is expected that members of this proposed class generally had only intermittent affiliation with many of the activities and exposure sources described within this section, Section 5.0. Potential exposures received by members of this class from a given production activity for example, would in general be expected to be lower than doses received by daily operators for that production activity. A comparison of available monitoring results for the petitioner proposed class to other worker monitoring results is provided in Appendix 1.

5.1 Y-12 Plant and Process Descriptions

Located at the eastern section of the Oak Ridge Reservation in Oak Ridge, Tennessee, the Y-12 Plant occupies approximately 811 acres (0.67 mile wide and 3.2 miles long). The plant was initially constructed in the fall of 1942 under the direction of the U.S. Army Corps of Engineers of the Manhattan Engineer District (MED). Stone and Webster Construction Co. of Boston, Massachusetts served as the general engineering contractor for the Y-12 Facility, which eventually cost over $400 million.

Using an electromagnetic separation process within a calutron, the original mission of Y-12 was to separate fissionable isotopes of uranium (uranium-235) from uranium feedstock for use in the Hiroshima Atomic Bomb. Radiological operations, processes, and dose reconstruction information relevant to this specific uranium enrichment work is covered in a separate evaluation report: SEC Petition Evaluation Report SEC-00018.

While the SEC-00018 report evaluates the years1943 through1947, the SEC-00028 evaluation focuses on a time period that falls within what is generally described as the “second era” of Y-12 operational history. The electromagnetic separation process for uranium-235 enrichment (calutrons) was discontinued in 1947 in favor of the more efficient gaseous diffusion process. Extending from 1947 through1992, the primary mission of the second era was the production of key components of nuclear weapons and test devices. During this time, the vast majority of the work at Y-12 involved uranium processing, although other radioactive materials such as thorium, tritium, polonium, and transuranics were also present in very small quantities during the SEC period. During the 1948 through 1957 time period, the Y-12 operating contractors were Carbide and Carbon Chemicals and Union Carbide Nuclear Company, both divisions of Union Carbide Corporation predecessor companies.

5.2 Y-12 Functional Areas

Y-12 Plant operations included the following functional areas:

- Key Uranium Processes
- Lithium Isotope Separation Process
- Thorium Studies
- Waste Disposal in the S-3 and New Hope Ponds
- ORNL and Non-Uranium Activities at Y-12

5.2.1 Y-12 Key Uranium Processes

The following table, Table 5-1, summarizes the key uranium processes as well as the buildings and dates of operation involved.

Table 5-1: Y-12 Key Uranium Operations

Key Uranium Operations	Buildings Involved	Dates of Operation
Uranium Recovery and Recycle: Y-12 stopped enriching uranium after WWII and operations centered on uranium recovery and recycling of residual uranium found on equipment and scrap material. Operations included mechanical scraping and brushing, nitric acid washing, and distillation and recovery of solid uranium compounds adhered to surfaces. Uranium contaminated materials included condensates, scrubber solutions, raffinates, destructive distillates, oils, and miscellaneous residues. These Y-12 Facilities handled mostly normal uranium and depleted uranium.	**9202, 9203, 9206, 9212** ▪ 9202, 9203 received depleted uranium, slightly enriched uranium, and normal uranium. ▪ 9206 was the main uranium recovery and recycle facility and housed sanding, grinding, chemistry and incinerator operations. ▪ 9212 housed the largest chemical operations for enriched uranium purification, recovery and chemical conversion, as well as normal and depleted uranium machining operations	1945–1951 1950s–1990s
Uranium Salvage: Salvage operations involved recovery of uranium from materials not considered production equipment, such as liquid and solid waste materials from maintenance/cleanup activities such as mop water, laundry washes, and floor drain residues. In an effort to recover uranium, combustible materials such as wood, rags, sponges, filter paper, and carbon solids were burned in muffle furnaces and incinerators. Other salvage operations included mechanical scraping and brushing, nitric acid washing, and distillations.	**9206, 9207, 9211** ▪ 9206 housed salvage operations and process operations were similar to 9207 and 9211. ▪ 9207 and 9211 processed incinerated solid waste and recovered normal and slightly enriched uranium.	1945–1951

Table 5-1: Y-12 Key Uranium Operations		
Key Uranium Operations	**Buildings Involved**	**Dates of Operation**
Uranium Preparation/Recycle for Weapon Component Operations: Y-12 began a continuous growth of uranium weapons component manufacturing operations and handled a variety of uranium compounds and enrichment. Enriched uranium prepared for reduction to metal involved conversion of uranium hexafluoride to uranium fluoride purification of uranyl nitrate solutions, precipitation for uranium recovery, and then reduction to uranium metal.	**9212** ▪ 9212 housed the largest chemical operations for enriched uranium purification, recovery and chemical conversion, as well as normal and depleted uranium machining operations	1952–1995
Uranium Forming/Machining for Weapon Component Operations: Y-12 had operations capable of casting, rolling, and machining uranium metal. These operations handled enriched uranium, depleted uranium, and normal uranium. Uranium was pressed, rolled, shaped, and machined into finished weapon components.	**9201-5, 9204-4, 9215, 9998** ▪ 9201-5, 9204-4 housed depleted uranium ▪ 9215 housed enriched uranium ▪ 9998 contained H-1 foundry operations that included depleted uranium recycle and parts manufacturing.	1952–1995
Uranium Component Assembly: Machined components were sent through finishing operations that included drilling, welding, brazing, polishing, and final specification checks. Assembly operations generally were not associated with significant releases of uranium compounds. Any measurable amounts of uranium were recovered and recycled back into the production stream. Uranium was routinely recovered from articles such as rags, paper towels, oils, and liquid waste products. Process exhaust stacks were equipped with high efficiency particulate air (HEPA) filtrations and periodically inspected for buildup of uranium.	**9202, 9204-2, 9204-2E** ▪ 9204-2, 9204-2E housed uranium assembly operations. ▪ 9202 was primarily used for early pilot scale operations that involved design and implementation of fabrications and assembly processes and final inspection procedures.	1952–1995

5.2.2 Y-12 Lithium Isotope Separation Process

Following the Soviet test of a Hydrogen Bomb in 1953 in which lithium was detected in the fallout, a "crash" program implemented for the purpose of developing a large scale lithium separation plant. Thus, when the decision was made to pursue the development of the hydrogen bomb, Y-12 was chosen as the site for the separation of lithium-6 from the more abundant lithium-7.

NOTE: Although not a source term for dose reconstruction, the Lithium Isotope Separation process provides additional detail of the activities conducted during the class period..

The process concentrated lithium-6 and combined the lithium with deuterium, a heavy isotope of hydrogen, to form lithium deuteride. Lithium deuteride is the major source of fuel for the hydrogen fusion which takes place in a hydrogen bomb explosion.

Not unlike the earlier Manhattan Project, a massive mobilization of personnel and material resulted in operational plants in less than fifteen months. Lithium production cascades were housed in large buildings formerly used for uranium separation. Production for various separation processes started between 1953 and 1955. The chronology of lithium operations and facilities is described below in Table 5-2:

Table 5-2: Chronology of Lithium Production Operations	
Time Period	**Operations**
1950, 1951	Operated building 9733-2 - Development facility for elex (Electrical Exchange) process
1951, 1952	Operated building 9733-1 - Development facility for Orex (Organic Exchange) process
September 1951 - 1955	Operated building 9201-2 - Pilot plants for elex and colex processes
April 1953 - May 1955	Operated building 9201-2 - Pilot plant for Orex process
1953 - Spring 1956	Operated building 9204-4 - Elex Production Plant
January 1955 - February 1959	Operated building 9201-5 - Colex Production Plant

Production activities stopped after 1959. In 1962 partial operations resumed thru May of 1963. Lithium production at Y-12 was terminated in 1963 as the stockpile grew, and the material could be recycled from retired warheads.

5.2.3 Y-12 Thorium Studies

During the 1948 through 1958 time period, quantities of thorium at Y-12 ranged from tens of kilograms in 1948 to hundreds of kilograms in 1952 to thousands of kilograms in 1955. Work with thorium at Y-12 during this time period was mainly of a research and development nature with the exception of one activity. During the class period there were a number of activities conducted that involved quantities of thorium. These activities are presented in chronological order below:

1. Decontamination and decommissioning of the calutrons (primarily the 9201 Buildings) occurred when the uranium enrichment operations using the alpha-track calutrons were terminated in 1946. This work involved cleaning out the uranium from the calutron vacuum chambers and the product "pockets." The uranium was removed by scraping and acid dissolution. A note in a Y-12 Health Physics Progress report indicates that thorium was used as a co-precipitation media to increase the uranium recovery percentage from decontamination solutions. Although, uranium enrichment with the calutrons stopped in 1947, it's not clear whether Y-12 continued to use Thorium as a co-precipitating agent for later calutron operations.
2. In 1952, the Isotopic Separation program, which utilized the beta calutrons in Building 9204-3, used small quantities of thorium for specific isotopic separation and purification (Y-12 Plant; Y-12 Plant, 1991).
3. In 1956, thorium-oxide blending and slurry work associated with Research and Development activities in Building 9204-1(Y-12 Plant, 1956).
4. Thorium was used (kilogram quantities) in the Research and Development laboratories to develop and define the processes that would be incorporated in major thorium processing that occurred after the time period evaluated in this report. As reported in a 1957 Health Physics Progress Report, *thorium work is confined to one area in Building 9202, where the Development Department does some work with thorium* (Y-12 Health Physics Department, 1957).
5. Thorium was used in kilogram quantities to support ORNL Research and Development activities in Buildings 9206 and 9212 at Y-12.

Based on the Y-12 thorium activity research performed for this evaluation report, another activity was performed with potential thorium exposure. However, the timeframe for this activity falls outside of the SEC period evaluated in this report. The information is provided as supporting information for the class definition time period. This thorium work began as a pilot program in 1958. Following the pilot program was a 17-year period, beginning in 1960, where metric tons of thorium were processed (ORAUT-TKBS-0014-2 Rev. 00). This also corresponds to the period of available personnel monitoring and the incorporation of *in vivo* monitoring in the Y-12 Health Physics program. One hundred and three thorium fecal sample results were included in Delta View for the 1958 through 1960 time period; a small number of samples were also identified for the years of 1961 and 1962. Based on a review of the monitoring data, lung counting was the primary bioassay method used for thorium internal monitoring during the full scale operational period.

5.2.4 Y-12 Waste Disposal in the S-3 and New Hope Ponds

Between 1951 and 1984, four seepage pits known as the S-3 ponds were used to dispose of over 2,700,000 gallons of a variety of liquid wastes, including concentrated acids, caustic solutions, mop waters, and by-products such as uranium and other heavy materials, from the uranium recovery processes. These unlined seepage pits, referred to at one time as a "witch's cauldron," were designed to allow liquid either to evaporate or percolate into the ground. Various metal impurities and radionuclides stripped from highly enriched uranium during the solvent extraction steps in Buildings 9212 and 9206 (approximately 10% to 30% of recycled uranium, plutonium, neptunium, and technetium) were discharged with the dilute nitric acid and other process-derived acid wastewater in to the S-3 ponds prior to the mid 1980s (ORAUT-TKBS-0014-2 Rev. 00).

New Hope Pond was constructed and placed in operation in the 1950s to provide a retention basin at the East end of Y-12. The pond facilitated mixing of water and offered a sampling point for rainwater runoff, once-through cooling water, steam plant boiler blow-down, and secondary production process wastewaters. The pond also functioned to remove any suspended contamination from rainwater, miscellaneous releases from various tank farms and storage yards, and inadvertent releases from process buildings.

5.2.5 ORNL and Non-Uranium Activities at Y-12

Space at Y-12 was utilized by the Oak Ridge National Laboratory (ORNL) Research and Development divisions for several projects. Four of the projects included the beta calutrons, the 86-inch cyclotron, the Criticality Experiments Facility, and the 5-MeV Van de Graff Accelerator, all of which are briefly summarized below. Several of these projects involved the production and/or separation and purification of both stable and radioactive isotopes. A listing of these isotopes is presented in Appendix 2. The radioactive isotopes were produced generally in small quantities and/or had short half lives.

Work performed at these facilities presented external and internal radiation exposure potential. At times, Y-12 workers supported efforts at the facilities and in some cases Y-12 employees were administratively transferred to ORNL.

<u>Beta Calutrons</u>

During the 1950s, the calutrons at Y-12 were used for the production, enrichment, and purification of an extensive list of stable and radioactive isotopes for medical research worldwide (see Appendix 2). A plutonium isotopic separation program using the calutrons was also in the planning and design stages during the period evaluated in this report (Wilcox, 1999).

Based on a series of progress reports (approximately 30) that were produced by the Electromagnetic Research Division and subsequent organizations, it is evident that plutonium isotopic enrichment work was occurring in 1952 and 1957. Also documented, plutonium urinalyses were performed during the years 1952 through at least 1965, air monitoring was performed, and personnel protection was provided for by clothing and respiratory protection. Calutron facilities provided for double containment of the calutron(s) and glove box handling of collection pockets.

86-Inch Cyclotron

The 86-inch cyclotron began operation in November 1950 and was used to perform radiation damage studies for the Nuclear Aircraft Project. As the world's largest fixed-frequency proton cyclotron, it produced a proton beam four times more intense than any other cyclotron. One of the original uses of the Oak Ridge 86-inch cyclotron was the production of polonium-208 (ORNL-1392; Butler 1963; Johnson, 1994). Polonium was produced in the 86-inch cyclotron as early as 1951. In 1952, internal revisions of the position and mounting of the ion source resulted in proton energy of 23 MeV. At the higher energy, the polonium-208 yield was more than doubled and a total of approximately 9 Ci of polonium-208 were produced before the project was terminated in August of 1953 (ORNL-1392).

During the next few years, the groundwork was laid for the production of neutron-deficient radioisotopes (Butler, 1963). However, from 1952 to 1961, the 86-inch cyclotron was used primarily for nuclear physics research by the ORNL Electronuclear Research Division (Howard 1954; Livingston, 1958). Isotope production time was made available only when it did not interfere with the primary program (Butler, 1963).

Appendix 2 contains information regarding the stable and radioactive isotopes produced and/or separated and purified at Y-12.

Critical Experiments Facility

Prior to the construction of the Critical Experiments Facility in 1950, several critical experiment programs had been carried out at ORNL and the K-25 Oak Ridge Gaseous Diffusion Plant (ORNL/TM-349 Rev. 1). However, in 1949, due to the expected demands for further experimentation in (1) the safety of metallurgical and chemical processes and (2) the support of new reactor designs, the inadequacy of the previous facilities was recognized. This inadequacy was further emphasized by a program in Oak Ridge on the development of nuclear propulsion for aircraft (Johnson, 1994). As a result, it was decided that a laboratory adequate for a wide variety of critical experimentation be established, and that the various programs of critical experiments in Oak Ridge be combined and the work administered by ORNL (ORNL/TM-349 Rev. 1). Thus, near-critical and criticality experiments were started at the Critical Experiments Facility in late August and early September 1950.

The Critical Experiments Facility was at a remote site in the Southwest portion of the Y-12 complex in a pocket formed by surrounding hills as much as 200 feet higher than the Critical Experiments

Facility building itself (ORNL/TM-349, ORNL/TM-349 Rev. 1). During its operational years, access to the Critical Experiments Facility was restricted by means of a chain link fence (ORNL/TM-349, ORNL/TM-349 Rev. 1).

5-MeV Van de Graff Accelerator

A 5-MeV Van de Graff accelerator was also operated in the East end of Building 9202-2 in the early 1950s for a period of about one year while a permanent structure was being built for the accelerator at the X-10 site. The 5-MeV Van de Graff Accelerator was an X-10 project and the health physicists and all other workers at the 5-MeV Van de Graff were X-10 employees.

5.2.6 Weapons Assembly and Disassembly

Information regarding weapons assembly and disassembly work at Y-12 was obtained through document reviews and through a series of interviews with employees with first-hand knowledge of Y-12 weapons activities during the evaluated class time frame. Six Y-12 employees were interviewed who had the following job titles while employed at Y-12:

- Assembly Division Head
- Assembly Dept Head
- Assembly Foreman
- Disassembly Foreman
- Chemical Operator
- Health Physicist

From these sources it was learned that weapons assembly/disassembly work began as early as 1952-1953. Typically, weapons components were assembled at Y-12 and then sent to other site(s) for further assembly. Much more assembly work was done than disassembly work. Prior to 1960, work was done in glove boxes or in open areas which were by necessity, very clean environments. The exposure potential was from external radiation only, since the parts for assembly were essentially clad or otherwise sealed. Badges were worn on normal plant clothing.

During the weapons assembly and disassembly operations, a small crew (a maximum of three plus one foreman) was used. These crews never included maintenance or crafts people. The workers interviewed agreed that presence of pipefitters, plumbers, and steamfitters in the assembly areas was infrequent and only after the assemblies were either covered and/or removed, thus, making radiation exposure potential essentially nonexistent. In addition, when maintenance personnel were needed in the area, they were always required to wear personal dosimeters.

5.3 Radiological Exposure Sources from Y-12 Operations

Over the 1948 through 1957 time period, many individual research and development projects occurred at Y-12 involving various radiological exposure sources. Besides the thorium associated with two test batches processed through Building 9204-3 calutrons (for enrichment), Research and Development activities in Buildings 9202, 9204-1, 9206, and 9212 and when used as a co-precipitation media the principal source term at the plant was (and continues to be) uranium process materials. The uranium materials existed in any of the standard ICRP-68 clearance classes or in any combination thereof.

Additionally, because Y-12 served primarily as a nuclear weapons fabrication and production facility during this time, the uranium that was present included natural uranium, depleted uranium (uranium-238), and enriched uranium (uranium-235).

5.3.1 Alpha Particle Emissions

Both uranium-235 and uranium-238 are primarily alpha-particle emitters. As such, gamma radiation exposure potential was very low for most members of this class. The majority of the radiological exposure potential at Y-12 has been internal and chronic in nature, resulting from inhalation or ingestion of particles comprised of various forms of uranium during nuclear material fabrication and processing work. Uranium-bearing chemicals present at the facility during the 1948 through 1957 time period included (but are not limited to):

- Uranium oxide (U_3O_8)
- Uranium dioxide (UO_2)
- Uranium trioxide (UO_3)
- Uranium hexafluoride (UF_6)
- Ammonium diuranate [$(NH_4)_2U_2O_7$]
- Uranyl nitrate [$UO_2(NO_3)_2$]
- Uranium peroxide ($UO_4 \cdot 2H_2O$)
- Uranium tetrachloride (UCl_4)
- Uranium pentachloride (UCl_5)
- Uranium tetrafluoride (UF_4)

Research and Development activities, as previously discussed, involving thorium (including thorium-230 and thorium-232 in limited quantities) were also performed during the evaluation period. However, concerns associated with thorium alpha emissions/exposures were limited to Building 9202, 9204-1, and 9204-3.

5.3.2 Beta/Photon Radiation Fields

Though less of a threat than internal exposure, significant external exposure potential existed at times in specific locations/activities. The external workplace radiation fields of most concern were due to processes involving either enriched uranium or depleted uranium. Additional radiation fields of concern (summarized in Table 5-3 below) involved industrial radiation generating equipment (X-rays and electron accelerators) and isotopic gamma-ray and neutron sources for testing purposes (e.g., cobalt-60, californium-252, and radium-beryllium or polonium-beryllium neutron sources).

As noted previously in Section 5.3.1, the uranium-235 and uranium-238 contained in Y-12 uranium materials are primarily alpha emitters. However, uranium-235 does emit a 185-KeV photon in 54% of its decays and short lived uranium-238 decay products (thorium-234, protactinium-234m, and protactinium-234) are beta and photon emitters. From an external dose standpoint, the most significant radiations emitted by these decay products of uranium-238 are: (1) the 2.29-MeV beta particle from protactinium-234m, and (2) the photons emitted by protactinium-234 with energies as large as 1.962 MeV.

Table 5-3 summarizes beta and photon energies as associated with various Y-12 processes (ORAUT-TKBS-0014-6 Rev. 00).

Table 5-3: Beta and Photon Energies

Y-12 Site Processes	Building	Operations		Radiation type	Energy Selection	Percent
		Begin	End			
Enriched uranium product recovery and salvage operations	9203	1947	1951	Beta Photon	> 15 KeV 30-250 KeV	100% 100%
	9206[a]	1947	1959			
	9211	1947	1959			
	9201-1	1952	1963			
Uranium chemical operations and weapon production operations	9202	1947	1995	Beta Photon	> 15 KeV 30-250 KeV	100% 100%
	9206[a]	1947	1995			
	9212[b]	1949	Ongoing			
Special nuclear material receiving and storage	9720-5	1949	Ongoing	Photon	30-250 KeV	100%
Uranium forming and machining for weapon component operations	9201-5	1949	Ongoing	Beta Photon	> 15 KeV 30-250 KeV	100% 100%
	9204-4	1949	Ongoing			
	9215	1950	Ongoing			
Depleted uranium process operations	9201-5	1949	Ongoing	Beta Photon	> 15 KeV 30-250 KeV > 250 KeV	100% 50% 50%
	9204-4	1949	Ongoing			
	9766	1949	1995			
	9998	1949	Ongoing			
Final weapon component assembly operations	9204-2	1952	Ongoing	Beta Photon	> 15 KeV 30-250 KeV	100% 100%
	9204-2E	1952	Ongoing			
ORNL 86-inch cyclotron	9201-2	1950	Ongoing	Photon	30-250 KeV >250 KeV	50% 50%
Chemical assay and mass spectrometry laboratories	9203	1947	Ongoing	Photon	Specific to radiation source. Photon default values: 30-250 KeV >250 KeV	50% 50%
Radiographic laboratory	9201-1	1947	Ongoing	Photon		
Calibration laboratory	9983	1949	Ongoing	Photon		
Weapon component assay laboratory	9995	1952	Ongoing	Photon		

Notes:
[a]Building 9206 Complex includes Buildings 9768, 9720-17, 9409-17, 9510-2, 9767-2, and the east and west tank farm pits.
[b]Building 9212 Complex includes Buildings 9809, 9812, 9818, 9815, and 9980.

5.3.3 Neutron Sources

Radionuclide sources that produced neutrons by alpha particle reactions in boron or beryllium provided a convenient source of neutrons for a number of applications (Rees, 1967). Their use at the Y-12 Plant has been summarized in the following table.

Table 5-4: Neutron Sources used at the Y-12 Plant

Location	Y-12 Building	Neutron Source
Assay Laboratory[a] Critical experiments Facility[b]	9203 (Room 8), 9205 9213	Radium-Beryllium, Polonium-Beryllium Polonium-Beryllium, Plutonium-Beryllium Fission Neutrons
Electromagnetic Research[c]	9201-2, 9204-3	Polonium-Beryllium

		86-Inch Cyclotron
Health Physics[d] Instrument Department[e] Chemical Operations[f]	9983 (Calibration Laboratory) 9737 9202, 9206, 9212	Polonium-Beryllium, Americium-Beryllium Polonium-Beryllium Highly Enriched Uranium Fluoride and Oxide Compounds

Sources:
[a]Struxness, 1949; Stuxness, November-December 1950
[b]Stuxness, November-December 1950; Struxness, January-June 1953; ORNL/TM-349, ORNL/TM-349 Rev. 1
[c]Struxness, January-June 1951; Struxness, November-December 1950; ORNL 1173; ORNL 1196, ORNL 1392, Struxness, July-December 1951; Struxness, January-July 1952; Livingston (1958)
[d]Struxness, January-June 1951; Struxness, January-July 1952; Y-12 Plant, 1963
[e]Struxness, January-June 1951
[f]ORAUT-TKBS-0014-2 Rev. 00, DOE (2000)

Neutron sources were used in basic research (Buildings 9201-2 and 9204-3), critical assembly and reactor research (Building 9213), calibration of radiation dosimeters and radiation detection instruments (Buildings 9737 and 9983), and material assay (Buildings 9203 and 9205). Shielding was used to protect workers from unnecessary exposures to the radionuclide sources. Nevertheless, some dose was received even in shielded areas and some dose was also received from the bare sources. The largest exposure would occur while sources were withdrawn from their shields during the calibration of radiation instruments or during periodic tests for leakage of radioactive materials from the sealed containers about the sources.

Two other neutron sources not listed in the table above are a Cockcroft-Walton linear accelerator capable of producing a maximum of 1×10^{10} fast neutrons per second (Struxness, January-June, 1953) and a 5-MeV Van de Graff accelerator capable of producing a fast neutron flux as high as 560 fast neutrons per cm2 second near the target (Struxness, January-June 1951; Struxness, July-December 1951). The Cockcroft-Walton was installed in the Oak Ridge National Laboratory Biology Division (Building 9207) in early 1953, and the 5-MeV Van de Graff was installed in the East end of the building housing the Oak Ridge 86-inch cyclotron (Building 9201-2) in late 1951. The 5-MeV Van de Graff was operated at Y-12 during part of 1951 and part of 1952 while a permanent structure was being built for the accelerator at the ORNL Site (Johnson, 1994).

5.3.4 X-ray and Electron Generating Equipment

The X-ray or electron generating equipment used at Y-12 included linear electron beams, electron beam welders, scanning electron microscopes, X-ray photoelectron spectrometers, secondary ion mass spectrometers, enclosed beam diffraction equipment, and medical diagnostic X-ray equipment. The emitted energy range is from 15 KeV to 9 MeV.

5.3.5 Recycled Uranium and Other Radionuclides of Concern

From 1953 until 1999 recycled uranium activities introduced radionuclides intoY-12 plant systems unlike those typically associated with the Y-12 weapons processes. These contaminants were a result of fission and activation processes of a variety of uranium enrichment isotope mixtures which were irradiated in production and test reactors. As a result, the recycled uranium contained transuranic material, fission products and reactor-generated uranium products. After completing their useful life in the reactors, the unused uranium in the spent fuel elements or targets was recovered in chemical extraction plants and returned to the inventories in the DOE system along with trace quantities of the contaminants.

The primary recycled uranium contaminants of concern at Y-12 began in 1953 with shipments of very highly enriched uranium from the Idaho Chemical Processing Plant with the Savannah River Plant sending large quantities of highly enriched uranium/very highly enriched uranium recycled uranium materials a few years later. The primary contaminants were plutoinium-238 (plutonium-239 in lesser quantities), neptunium-237, and technetium-99. All of the highly enriched uranium/very highly enriched uranium was processed through chemical extraction, which had been designed to remove other contaminants such as trace metals. However, some removal of recycled uranium radioisotopic contaminants occurred (in parts per billion quantities) and was generally disposed of with the raffinates.

Shortly after recycled uranium was introduced at Y-12, AEC directed that an effort be made to remove neptunium-237 from process streams for use as targets in the production of plutoinium-238 in the production reactors. X-10 designed the ion exchange system for liquid processes, which contained neptumiun-237 and Y-12 installed this system on the liquid feed to the chemical processing plant. The spent columns were removed and sent off-site for further processing. No significant handling of these sources of neptunium occurred at Y-12.

6.0 Summary of Available Monitoring Data for the Proposed Class

The following descriptions of available monitoring data contain information on the subject class under evaluation and on the Y-12 Plant worker population and monitoring programs as a whole. The more general information and data are included because the feasibility of performing dose reconstruction for the proposed class relies in part on the utilization of data from workers in higher exposure potential jobs to calculate maximum plausible exposures for the proposed class members.
The majority of the data evaluated are results obtained from employee monitoring during the proposed class time period (1948 through 1957). However, monitoring results from years immediately following the proposed class timeframe were also reviewed as the plant activities were generally similar (see Section 5). As such, the availability of data through 1960 is discussed.

Historically, the main purpose of the radiation monitoring programs at the Y-12 Plant have been to assure that worker exposures to radiation be kept below the annual prescribed occupational exposure limit in effect at that time. This is evidenced by text found in essentially all of the acquired Health Physics Progress reports, many memos and reports (available in the NIOSH Site Research Database), and as explained by several workers that were interviewed. Personal radiation dosimetry data in the early years (prior to 1961) was seldom collected for workers who were considered to have low potential for exposure. Monitored workers were usually those believed by health physics staff to have potential for external radiation exposures greater than 10% of the radiation protection guidelines in effect during that period of time. Determination of monitoring needs was based on the results of health physics assessments which included air sampling (area and breathing zone), surface swipes, and radiation surveys. As early as 1947, results of the health physics department's activities were documented in progress reports; these progress reports are available to NIOSH. External penetrating and shallow exposures to particulate and photon radiation were monitored using radiation sensitive materials housed in personnel badges worn by workers. Detailed historical evaluations of the Y-12 gamma, neutron, and beta monitoring programs including applicable radiation protection guidelines can be found in parts one and two of reports titled *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee* (ORAU Technical Report 2004-0888; ORAU Technical Report 2004-1406). Internal exposures to radionuclides were monitored by counting radioactive emissions in workers' excreta (urine) and via air sampling. Routine *in vivo* chest counting at Y-12 was not initiated until 1961. However, limited data is available for the thorium related activities associated with two test batches processed through Building 9204-3 calutrons (for enrichment), Research and Development activities in Buildings 9202, 9204-1, and 9204-3, and when used as a co-precipitation media that preceded the 17-year period where metric tons of thorium were processed which started in 1960.

6.1 Y-12 Internal Monitoring Data

The earliest urine sample results available are from 1950 when samples were collected monthly. Weekly collection began in 1951. As was the case for external monitoring, collection of routine urine samples was based on exposure potential. However, available Y-12 records show that the number of employees receiving internal monitoring was generally greater than the number of employees who received external monitoring (see following CER Data summary in Section 6.4). Fluorometric analyses were performed on samples submitted from workers in natural and depleted uranium work areas and electrodeposition of uranium followed by gross alpha counting for samples submitted by workers in enriched uranium areas.

In addition to the uranium urinalyses, non-uranium/special urinalyses were performed. These data are maintained in a separate Y-12 database known as Delta View (see Section 4.8). Delta View is comprised of approximately 470,000 scanned images of hard copy reports and monitoring data print outs associated primarily with Y-12 personnel. Information on these images is varied and can include general information in addition to bioassay data. Examples include selected dose calculation reports, data from both Y-12 and X-10 analytical labs, and lab reports of bioassay urine and fecal analysis results.

The following table, Table 6-1, is a summary compilation of non-uranium bioassay results extracted from approximately 6,000 images stored in the Delta View Database. These 6,000 images were extracted from the system using pre-defined keywords located in comments fields that were thought to represent Y-12 bioassay data on non-uranium isotopes for the period of interest.

Table 6-1: Non-Uranium Bioassay Results from Delta View

Isotope	1952	1953	1954	1955	1956	1957	1958	1959	1960
Alpha emitters in urine	2	0	0	0	0	0	0	0	0
Hydrogen-3	0	0	0	0	605	0	0	0	0
Polonium	0	18	0	0	0	0	0	0	0
Plutonium	275	100	277	52	36	0	45	30	71
Thorium	0	0	0	0	0	0	44	37	12

As indicated in Table 6-1, some fecal analysis data, starting in 1958, is available for the thorium related activities associated with Research and Development performed in Building 9202, 9204-1, and 9204-3. A total of 103 thorium fecal sample results were identified in the Delta View database for the 1958 through 1962 time period. Additional details regarding the various analyses used and the associated minimum detectable activities are presented in the *Y-12 Occupational Internal Dose Technical Basis Document* ORAUT-TKBS-0014-5, Rev. 01-A.

Whole-body counting was not routinely practiced a Y-12. The primary *in vivo* detection method was chest counting. The Y-*12 in vivo* chest-counting facility was developed in the late 1950s but was not put into routine use until 1961. Chest counting was done for uranium and thorium isotopes, neptunium, and other radionuclides.

No *in vitro* or *in vivo* bioassay data specific to thorium monitoring related to the period evaluated in this report, was identified in any of the documentation reviewed by NIOSH for this evaluation.

6.2 Y-12 External Monitoring Data

Prior to 1950, external monitoring was performed on a small scale to monitor the external exposures of individuals working in the Assay Laboratories, Radiographic Shop, Spectrographic Shop, and Machine Shops where uranium metals were being handled (Murray, January 1948; Murray, February 1948; Struxness, May 1948; Struxness, December 1948). External monitoring was accomplished by wearing pocket ionization chambers (PICs), also called pocket meters or pocket chambers typically changed on a weekly basis. A limited set of external monitoring data exists for 1948 and 1949 (West, 1980).). NIOSH has also obtained an electronic file with 11,492 records covering the period evaluated in this report. Data elements in the electronic file include film badge ID, date of weekly readings, PIC readings, three photographic film dosimeter readings, and descriptive comments. NIOSH is attempting to link the film badge ID in the Y-12 pre-1950 external monitoring file with Y-12 worker names in the ORAU DOE facility database, but has not yet verified the accuracy of this linkage. The data are, however, currently useful in a variety of ways for dose reconstruction. Details regarding this monitoring period and associated data set have been documented in External Radiation Monitoring at the Y-12 Facility During the 1948-1949 Period (ORAUT-OTIB-0047 Rev.00-A).

An expanded personnel monitoring program for external radiation exposure was initiated at Y-12 in 1950 (McLendon, 1960). All Y-12 personnel working with (1) depleted uranium, (2) discrete gamma, beta, or neutron sources, (3) X-rays, and (4) materials contaminated with fission products were required to wear a film badge dosimeter. The film badges were also augmented with film rings to assess the radiation exposure to the hands of uranium metal workers. Dosimetry practice was to record weekly dose to skin from beta particles (and low energy X-rays) or the penetrating doses from gamma rays as zero if they were less than 30 mrem (West, 1993). Film badges containing a nuclear track emulsions type-A film (so-called NTA film) were used to monitor neutron exposures. These NTA equipped badges were assigned only to those workers who had a substantial potential for neutron exposure and were exchanged on a biweekly schedule (Kerr, 2005). The minimum detection limit (MDL) of the neutron film is uncertain, but it is believed to be about 50 mrem for all years of usage at Y-12 (ORAUT-TKBS-0014-6 Rev. 00).

Dosimetry policy from 1952 through mid-1956 was to assign the MDL dose for weeks with monitoring results less than the MDL for either beta or gamma radiation. The MDL was 50 mrem for 1952 (weeks 1-38 approximately), all of 1953, and 1954 (weeks 1-30, approximately). In 1952 the MDL was 43 mrem for weeks 39-52. For the remainder of 1954 and all of 1955 and 1956, the MDL was 30 mrem. In practice, however, weekly doses less than the MDL were often left blank.

The Oak Ridge Associated Universities Center for Epidemiologic Research received a copy of the Y-12 monitoring records from Y-12. These files contained records for more than 17,000 Y-12 workers. From the Y-12 records, available external data relevant to the subject class are presented by year in Section 6.4.

6.3 Y-12 Air Sampling Data

In addition to personal monitoring for internal and external doses, thousands of air samples were collected during the 1948 through 1957 time period. Most air samples were obtained from general air samplers placed in areas where some possibility of airborne contamination existed. Breathing zone samples were also collected. Samples were predominantly analyzed for uranium and, to a lesser extent, thorium. The results were generally reported as disintegrations per minute (dpm)/m^3 uranium in air. Thorium air sampling for the 1948 through 1957 time frame was limited. To date, NIOSH has obtained a limited number of these thorium air sampling results. No thorium production level work occurred in the period evaluated in this report. Full production did not get underway until 1960 with the highest thorium production activity occurring between the years 1962 through 1965 and 1970 through 1975. Over 80,000 thorium air sampling records are available covering the production years extending from 1960 through 1976.

6.4 Summary of CER Data

The following table, Table 6-2, summarizes the general types and numbers of monitoring data records electronically available to NIOSH to support dose reconstructions relevant to the proposed class. Originally obtained from Y-12, the data summarized within the table are from databases maintained by the ORAU Center for Epidemiologic Research.

Table 6-2: Summary of Available Monitoring Data for Y-12 Workers (1948-1960)

		Urinalysis (uranium)		Air Monitoring	External Monitoring[a]	
Year	**Total Number of Employees**	**# of Records**	**# of Employees Monitored**	**# of Uranium Records**	**# of Records**	**# of Employees Monitored**
1948	2,511	-	-	-	3,599	162
1949	2,248	-	-	-	7,893	49
1950	2,552	1,110	166	-	268	148
1951	4,036	4,124	367	15,655	406	184
1952	4,169	13,317	393	-	1,157	498
1953	4,866	14,222	490	8,010	793	387

Table 6-2: Summary of Available Monitoring Data for Y-12 Workers (1948-1960)						
		Urinalysis (uranium)		Air Monitoring	External Monitoring[a]	
Year	Total Number of Employees	# of Records	# of Employees Monitored	# of Uranium Records	# of Records	# of Employees Monitored
1954	5,817	23,430	1,316	20,217	1,240	682
1955	5,768	28,806	1,225	26,976	1,920	624
1956	5,443	29,914	1,119	36,280	2,181	730
1957	5,169	33,443	1,443	41,354	2,510	796
1958	5,164	38,783	1,791	77,373	2,879	996
1959	5,460	47,339	2,277	66,150	3,664	1,266
1960	5,593	46,381	2,193	44,433	4,296	1,336

Notes:

- Indicates No Data Available

[a] External monitoring records include all currently known available gamma, beta, and neutron data.

6.5 Y-12 Health Physics Progress Reports

In addition to the monitoring data listed in Table 6-2, other aspects of the Y-12 Health Physics Program are documented in Y-12 Health Physics Progress reports kept within Y-12 plant records. Reports from as early as the fall of 1947 have been retrieved. Written by Y-12 Health Physics staff, the reports' contents reflect a health physics program focused on determining maximum exposure areas within the plant, and documenting compliance with applicable standards. The reports present general period activities and incidents with the potential personnel exposure potential, regular radiological and chemical sampling result summaries, and detail measurements made. Additionally they document sampling protocols, procedures followed, training given, and recommendations made to increase worker safety (e.g. increased ventilation, personal protective equipment use, or new shielding requirements).

Data typically contained with the Y-12 Health Physics Progress reports include exposure rate and contamination level ranges (minimum, mean, and maximum results) including alpha hand counting data, dating as far back as 1947. However, the report contents vary somewhat between different reporting periods and by measurement types. Air contamination concentrations are most frequently presented as average uranium air concentrations in d/min/m^3. Sampling locations are detailed as are sample type (e.g. swipe, scan, breathing zone, general air, etc.) and specific jobs are assessed. Overall sampling frequencies reflect an effort to assess contamination levels in all plant area and are highest in the exposure locations associated with production. Contamination and exposure potentials associated with new and/or short duration research and developmental type activities are also documented.

Longer lasting, non-uranium production activities, such as the cyclotron work, were regularly addressed in the monitoring program and progress reports.

Below is an example of the content from a Y-12 Health Physics Progress Report for the time period of January 1, 1952 through July 1, 1952. This table of contents is provided to demonstrate the scope of work performed and discussed within these reports.

Topics Included in the Y-12 Health Physics Progress Report for January 1, 1952 through July 1, 1952

INTRODUCTION	PERSONNEL MONITORING	ACCELERATORS	ANALYTICAL REASEACH
New Facilities	Film Badges, Pocket Chambers, and Rings	86-Cyclotron	Fluorophotometric Analysis of Urine for Uranium
Visitors	Urinalysis Processing and Results	Isotope Production Program	
Orientation and Training		Neutron Shielding	SPECIAL STUDIES
	AREA MONITORING	Medical Examinations	Internal Uranium Exposures
INDUSTRIAL HYGIENE	Air Sampling	External Exposures	Neutron Monitoring
Air Sampling	Surface Surveys	Air-borne Contamination	Aerosol Generator
Hood Design	Shipments and Intraplant Transfers	Target Handling Facilities	Particle Size Studies
Stack Sampling	Building Surveys	Decontamination Facilities	
Mercury Analysis in Urine		Alignment Dry Box	
Hexone Analysis		Cyclotron Change House	
		Air Ventilation	
		Plastic Covers	
		Other Accelerators	

7.0 Feasibility of Dose Reconstruction for the Proposed Class

The feasibility determination for the proposed class of employees covered by this evaluation report is governed by EEOICPA and 42 CFR § 83.13(c)(1). Under this Act and Rule, NIOSH must establish whether or not it has access to sufficient information to either, 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, then it would be determined that it was feasible to conduct dose reconstructions.

In making determinations of feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the proposed class. If not, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure NIOSH can estimate either the maximum doses members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class. This approach is specified in the SEC Petition Evaluation Internal Procedures (OCAS-PR-004 Rev. 0) and implements the SEC Rule requirements and is available at www.cdc.gov/niosh/ocas.

Common to performing a majority of the internal and external dose reconstructions for this class is the utilization of coworker data for estimating exposures to radionulcides, other than thorium. The monitoring data used include data from members of the proposed class and data from workers outside the proposed class that were performing jobs entailing higher exposure potentials than members of the proposed class. This approach provides a means of estimating claimant-favorable radiation doses for class members that were unmonitored or had gaps in their monitoring records.

Utilizing available personal and process monitoring data to calculate claimant favorable radiation doses for unmonitored employees is appropriate and possible only if the data are of sufficient quality. In addition to determining appropriate sampling, measurement, and analytical techniques, data quality sufficiency is dependant upon confidence that the selection of monitoring locations and personnel were appropriate and included the highest exposure locations and activities within the plant throughout the evaluated time frame. Similarly, it is important to determine that exposure potential associated with activities that were not production oriented, new, and/or short-lived (e.g., research and development) were also evaluated.

Monitoring devices, sampling techniques, and analytical methods were well documented for exposures to radionuclides other than thorium in many collected historical documents reviewed by NIOSH for the period evaluated in this report. Additional information supporting sampling device and method adequacy is presented in the Y-12 Site Profile (ORAUT-TKBS-0014-1 Rev. 00) and in *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1 and 2* (ORAU Technical Report 2004-0888; ORAU Technical Report 2004-1406). Also contained within these documents is information indicating that activities and personnel associated with the highest exposure potentials were regularly monitored. This evaluation has included additional data sources and analyses as part of the verification of the sufficiency of coworker data to calculate maximum exposure potentials. These include: 1) the retrieval and review of Health Physics Progress reports and additional monitoring related documents, 2) conducting focused interviews with plant workers employed during the subject time frame, and 3) a statistical analysis of available personal monitoring data.

The evaluation that follows examines separately the availability of information necessary for reconstructing internal and external radiation doses of members of the proposed class, as well as data sufficiency and reliability, and the petition basis and other issues relevant to the evaluation of this petition. A summary of the feasibility findings, based on the examinations performed in the process of evaluating this petition, is also included.

7.1 Analysis of Data Sufficiency and Reliability

Performing internal and external dose reconstructions requires worker monitoring data. 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 worker monitoring data provides a means of calculating claimant-favorable and maximum potential radiation doses for class members who were unmonitored or have gaps in their monitoring records.

Utilizing available personal and process monitoring data to calculate claimant favorable radiation doses for unmonitored employees is appropriate and possible only if the data are of sufficient quality. In addition to determining appropriate sampling, measurement, and analytical techniques, data quality sufficiency is dependant upon confidence that the selection of monitoring locations and personnel were appropriate and included the highest exposure locations and activities within the plant throughout the evaluated timeframe. Similarly, it is important to determine that exposure potential associated with activities that were not production oriented, new, and/or short-lived (e.g., research and development) were also evaluated.

In addition to the sampling, analytical, and record keeping information, NIOSH also evaluated other documentation related to Y-12. Historical Y-12 documents include detailed information about monitoring devices, sampling techniques, and analytical methods. In addition to historical document resources, further information supporting the adequacy of monitoring devices, sampling techniques, and analytical methods is presented in the Y-12 Site Profile (ORAUT-TKBS-0014-2 Rev. 00; ORAUT-TKBS-0014-6; ORAUT-TKBS-0014-6, Rev.00; ORAUT-TKBS-0014-1, Rev. 00; ORAUT-TKBS-0014-3, Rev.00; ORAUT-TKBS-0014-5, Rev. 01-A) and in *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee:* Part 1 and 2 (ORAU Technical Report 2004-0888; ORAU Technical Report 2004-1406). Also contained within the Y-12 Site Profile and in *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1 and 2* is information supporting the proposition that activities and personnel associated with the highest exposure potentials were regularly monitored.

Documentation supports NIOSH findings that activities and personnel associated with the highest exposure potential were regularly monitored. However, given the importance of verifying coworker data sufficiency, additional activities focused on historical monitoring selection and data credibility have been included in this evaluation and are presented in Appendix 1. The additional activities included:

- Statistical analysis of available personal monitoring data
- Examination of the monitoring data set to determine data consistency
- Interviews with plant workers employed during the subject time frame
- Retrieval and review of Health Physics Progress reports and additional monitoring related documents

7.2 Internal Radiation Doses at Y-12

The principal source of internal radiation doses for members of the proposed class was airborne uranium particulate material. This dust could be inhaled by individuals and then be deposited in the respiratory tract. The dust would also settle onto surfaces and be available for re-suspension back into the air where it could be inhaled or ingested in the body by transfer from contaminated surfaces via hand to mouth. Exposures over the history of operations were considered to be chronic in nature.

Although there are no bioassay results from before 1950, the first intake period was assumed to begin on January 1, 1947. Primary operations from 1947 through 1951 consisted of salvage, recovery, and recycle operations (from previous uranium enrichment work), with uranium preparation and machining beginning in 1949. The information in the Y-12 documentation reviewed by NIOSH for this evaluation, supports the assumption that exposure conditions beginning in 1947 were similar to those in the early 1950s.

In addition to uranium, which is the primary radionuclide contributing to internal dose at Y-12, exposure to various other radionuclides would have occurred from uranium salvage work and from two other Oak Ridge National Laboratory programs; one of which involved a proton-accelerating cyclotron and the second program which used the same cyclotron to create neutron-deficient radionuclides. The other radionuclides of concern included fission/activation products, thorium, and transuranics.

The subsections below summarize the extent and limitations of information available for reconstructing the internal doses of members of the class. Most of the information summarized below is provided in greater detail in the individual TBDs and other document sources as described in Section 4.0. Methods for utilizing coworker data to perform internal dose reconstruction for this class of workers are detailed in the Technical Information Bulletin *Internal Dosimetry Coworker Data for Y-12* (ORAU-OTIB-0029).

7.2.1 Process-related Internal Doses at Y-12

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

7.2.1.1 Urinalysis Information and Available Data

Y-12 began *in vitro* urinalysis using flourometry in1948. The primary purpose of this initial program, in conjunction with medical examinations, was to monitor for nephrotoxicity from uranium. However, beginning in 1950, workers in uranium production areas were placed on the urinalysis program for estimating internal dose. The program expanded to include certain maintenance workers in 1954. A monthly monitoring frequency was initially established with some employees monitored on a weekly basis. Beginning in 1957, specific workers with the potential for exposure to plutonium or tritium were monitored for intakes by urinalysis accordingly. Also, records were identified where urinalysis for polonium was performed as a result of an unusual exposure that occurred from a ruptured polonium-beryllium source. No thorium *in vitro* bioassay results were identified during NIOSH's reviews, for the time period evaluated in this report.

NIOSH has access to thousands of urinalysis results representing approximately 7% to 40% of the Y-12 worker population at different times during the period covered by this report. Approximately 12 percent of members of the proposed class received urinalysis monitoring during the 1950 through 1957 timeframe. This lower monitoring frequency reflects the program focus on the highest exposure potential activities and the personnel performing those activities. The urinalysis program was implemented primarily for employees working in uranium production and recovery areas, and the program was further differentiated for most of the period on the basis of the type uranium managed in each area, i.e. natural, depleted, or enriched. Records indicate that non-routine urinalyses were also performed for plutonium and tritium in work areas where these exposures occurred. Specific methods for dose reconstruction using bioassay data have been developed and include provisions for missed doses, including the period from 1948 to 1950 when no urinalysis records are available. Conservative intake values for radionuclides associated with the recycled uranium work are also accounted for; the associated methods are provided in Y-12 Occupational Internal Dose TBD (ORAUT-OTIB-0047 Rev. 00-A) and the Technical Information Bulletin *Internal Dosimetry Coworker Data for Y-12* (ORAU-OTIB-0029).

Because the uranium isotopes present at Y-12 have very long half-lives and the material is retained in the body for long periods, excretion results are not independent. For example, an intake in the early 1950s could contribute to urinary excretion in the 1980s and later. To avoid potential underestimation of intakes for people who worked at Y-12 for relatively short periods, each intake was fit independently, using only the bioassay results from the single intake period. This will likely result in an overestimate of intakes, particularly for assumed Type-S exposures, extending through multiple assumed intake periods (ORAUT-OTIB-0047 Rev. 00-A; ORAU-OTIB-0029)

Uranium compounds—in enriched, depleted, and natural isotopic abundances— exhibiting all solubility classes would have been present in various operations at the Y-12 Plant during the site's history (ORAUT-TKBS-0014-1, Rev. 00). Chemically soluble forms in solution, moderately soluble compounds, and relatively insoluble compounds could have been encountered by site workers. Section 5.1.1 of the ORAU Technical Report 2004-0888 notes, "while the exceptional cases with unusually protracted lung clearance are important, it is more important to note that, for the vast majority of individuals, lung clearance took place in approximate accordance with the ICRP Publication 2 "Insoluble" model, which fits within the current "Type-M framework." Because there have been cases of very insoluble material noted on the site, both types M and S were evaluated.

7.2.1.2 Analysis of Coworker Bioassay Data

Analysis of Coworker Bioassay Data for Internal Dose Assignment describes the general process used for analyzing bioassay data for assigning doses to individuals based on coworker results (ORAUT-OTIB-0019). Bioassay results were obtained from the Oak Ridge Institute for Science and Education (ORISE) Center for Epidemiologic Research Dosimetry Database, which contains uranium urinalysis records from the Y-12 site for 1950 to 1988.

As described in *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, uranium urine results were fit using a Type-M material (ORAUT-OTIB-0019). Results of the individual fits are not shown here but they fit reasonably well. Table 7-1 summarizes the intake periods and corresponding intake rates for the 50th and 84th percentiles. At the time of this evaluation, internal exposure co-worker data sets, specific to radionuclides other than uranium, have not been established for Y-12. However, methods to relate those exposures to the uranium exposure do exist in some cases.

Table 7-1: Type-M Uranium Intake Periods and Rates

Start Date	Stop Date	Uranium Intake Rate (dpm/day)		GSD
		50th percentile	**84th percentile**	
01-01-1947	02-28-1978	169.34	598.93	3.54
01-01-1947	04-30-1952	354.59	1,154.9	3.26
08-01-1953	11-30-1953	547.22	1,963.1	3.59
01-01-1956	02-28-1959	226.90	825.31	3.64

Table 7-1: Type-M Uranium Intake Periods and Rates				
		Uranium Intake Rate (dpm/day)		
Start Date	Stop Date	50th percentile	84th percentile	GSD
06-01-1961	12/31/1962	248.68	866.81	3.49
10-01-1968	12/31/1972	160.67	601.60	3.74
03-01-1978	09-30-1984	80.03	355.93	4.45
10-01-1984	12-31-1988	44.203	223.85	5.06

The intake periods used in the Type-M fits were also applied to the Type-S material fits. Table 7-2 summarizes the intake rates for the 50th and 84th percentiles. The geometric standard deviations (GSDs) were determined by dividing the 84th percentile intake rates by the 50th percentile intake rates.

Table 7-2: Type-S Uranium Intake Periods and Rates				
		Uranium Intake Rate (dpm/day)		
Start Date	Stop Date	50th percentile	84th percentile	GSD
01-01-1947	02-28-1978	1,844.4	6,544.2	3.55
01-01-1947	04-30-1952	5,210.4	16,970	3.26
08-01-1953	11-30-1953	17,983	64,559	3.59
01-01-1956	02-28-1959	5,694.6	20,560	3.61
06-01-1961	12-31-1962	6,849.4	23,632	3.45
10-01-1968	12-31-1972	3,290.3	12,415	3.77
03-01-1978	09-30-1984	1,280.3	5,802.9	4.53
10-01-1984	12-31-1988	884.85	4,340.6	4.91

Several intake periods overlapped, so they were combined to make 12 distinct intake periods, with a single intake rate and associated geometric standard deviations (GSD) for each. For 1947 through February 1978, all GSDs were within 10% of each other, so the largest GSD for the period was assigned to all intake rates for simplicity. Table 7-3 summarizes the 12 intake periods. Note that these are equivalent to the eight intake periods specified in Table 7-2, but provide a chronological layout of the changing intake rates over time.

Table 7-3: Combined Uranium Intake Periods and Rates

Start Date	Stop Date	Type-M Intake Rate (dpm/day)			Type-S Intake Rate (dpm/day)		
		50th Percentile	84th Percentile	GSD	50th Percentile	84th Percentile	GSD
01-01-1947	04-30-1952	523.93	1,753.83	3.74	7,054.4	23,514.2	3.77
05-01-1952	07-31-1953	169.34	598.93	3.74	1,844.4	6,544.2	3.77
08-01-1953	11-30-1953	716.56	2,562.03	3.74	19,827	71,103.2	3.77
12-01-1953	10-31-1956	169.34	598.93	3.74	1,844.4	6,544.2	3.77
11-01-1956	02-28-1959	396.24	1,424.23	3.74	7,539	27,104.2	3.77
03-01-1959	05-31-1961	169.34	598.93	3.74	1,844.4	6,544.2	3.77
06-01-1961	12-31-1962	418.02	1,465.73	3.74	8,693.4	30,176.2	3.77
01-01-1963	09-30-1968	169.34	598.93	3.74	1,844.4	6,544.2	3.77
10-01-1968	12-31-1972	330.01	1,200.53	3.74	5,134.4	18,959.2	3.77
01-01-1973	02-28-1978	169.34	598.93	3.74	1,844.4	6,544.2	3.77
03-01-1978	09-30-1984	80.03	355.93	4.45	1,280.3	5,802.9	4.53
10-01-1984	12-31-1988	44.20	223.85	5.06	884.85	4,340.6	4.91

7.2.1.3 Other Types of Bioassay/Workplace Indicators

Other *in vitro* or *in vivo* techniques for evaluating occupational uptakes were not implemented at Y-12 until after the period covered by this report. These other techniques were fecal sampling begun in the 1960 to investigate uranium clearance and chest counting by gamma spectroscopy. This was accomplished by using NaI (sodium iodine) scintillation detectors put into routine use in 1961 (ORAU-OTIB-0029). Although these procedures began after the time period covered by this report, the data combined with clearance models can be used to supplement determination of internal uptakes and resultant internal doses for the class covered in this evaluation.

7.2.1.4 Airborne Levels

A review was made of the available site information that described process activities conducted during the time period of the proposed class. An air monitoring program was in place during this time period that emphasized sample collection in those process areas with higher potential for airborne contamination. In addition to general area airborne concentration levels, there are data available from job-specific breathing zone air sampling events. Using the thousands of air sample results available for the period covered by the proposed class, NIOSH can establish a maximum exposure scenario based on an assumed isotopic uranium (enriched uranium, natural uranium, and depleted uranium) source term, process data, and the available air sampling and bioassay results. However, sufficient air monitoring data does not exist to establish a maximum thorium exposure scenario.

7.2.1.5 Other Radionuclides

Uranium has always been the dominant contributor to collective internal dose at Y-12. Monitoring for other radionuclides has been performed on a limited basis. Both the relatively small concentrations and the difficulty of analyses have contributed to the lack of data. One of the primary sources of significant contaminants (including the production of other than the normal uranium isotopes) that were introduced into the Y-12 plant systems were those associated with recycled uranium from 1953 until 1999. These contaminants were a result of fission and activation processes of a variety of uranium enrichment isotope mixtures, which were irradiated in production and test reactors.

The predominant recycled uranium and associated contaminants (plutonium, neptunium, technetium, and thorium) were in highly enriched uranium and very highly enriched uranium materials. However, all of the uranium at Y-12 came from other DOE facilities, which had also either generated and/or received recycled uranium materials. Therefore, nearly all of the uranium in the DOE facilities contained recycled uranium contaminants to varying degrees through being processed in the same equipment, blending with other materials to adjust the degree of enrichment, etc. For example, most of the depleted uranium received and processed at Y-12 was seldom chemically processed but was received in forms from which parts were produced by mechanical processing. However, even these materials were received from other plants, such as Fernald, which also had a recycled uranium contaminant inventory. Therefore, the depleted uranium contaminant levels at Y-12 were inferred from both the Fernald and the Idaho Specific Manufacturing Capability projects' recycle reports (ORAU Technical Report 2004-0888; DOE 2000).

The fundamental conclusion from a variety of reports is that for dose reconstruction purposes, a default level of recycled uranium contaminants can be derived and applied as a percentage increase to the derived uranium intake for each of the four major contaminants. Analytical information derived from a variety of sources allows the calculation or interpolation of the levels of the predominant recycled uranium contaminants in the uranium materials received, processed, and handled at Y-12. Details regarding these calculations are presented within the *Technical Basis Document for the Y-12 National Security Complex – Occupational Internal Dose* (ORAUT-TKBS-0014-5).

In addition to recycled uranium, vigorous programs were initiated and conducted at Y-12 during the time period evaluated in this report providing transition of operations from the electromagnetic enrichment of uranium to the separation/processing/enrichment of an extensive list of other stable and radioactive isotopes (See Appendix 2). The 72 beta calutrons (preserved for the purpose stable/radioactive separation and processing) and cyclotrons were used in the creation of a wide range of isotopes for research, biomedical, and weapons needs. These varied programs transitioned to X-10 management and control in 1951 and are described in both Production reports and Health Physics Progress reports for all time periods. These reports provided information regarding operations of these facilities and the associated equipment including general information about, surface, and effluent monitoring results, as well as health and safety measures and related incidents (i.e.: target ruptures and other off-normal conditions) associated with the operations. All associated incidents or events that had the potential to, or did result in Y-12 personnel exposures were investigated by the Y-12 HP staff and documented in the these Production and Health Physics reports and (in the case where further of exposure evaluations were performed) in incident reports that are included in the applicable personnel files. The correlation, between incidents in the Production/HP reports and the existence of incident reports in individual files, was confirmed by NIOSH in the review of two cases where two individual claimants were involved in incidents that resulted in exposure assessments (involved in a 1958 and 1961 (associated with cyclotron) incidents, respectively).

NIOSH has access to the applicable Production/HP reports in the Site Research Database and through access to the Y-12 and Delta View Databases, which includes directly related X-10 monitoring data for X-10 operations performed at Y-12 (individual monitoring data for scientists and individuals directly involved in cyclotron work at Y-12). The complete set of Production/HP and incident reports are also maintained by the Y-12 Site records management group. This data will be used to supplement and support the information that exists in a claimant's dosimetry records (including any incident reports) provided by the DOE. The internal dose reconstruction methods and requirements that are incorporated in the current EEOICPA dose reconstruction program will be applied and evaluated to determine the internal dose. In the case of an individual exposure or potential exposure is from a non-typical radioactive isotope (not calculable using the dose reconstruction tools available to NIOSH) the dose will be evaluated through the manual/hand application of the program requirements for dose reconstruction.

NIOSH also has access to individual plutonium bioassay data, for the limited number of workers who had the potential for plutonium exposures and were therefore monitored accordingly, from the Delta View database for the 1951-1952 period. This data is also provided with the DOE individual dosimetry data when that data is requested from the DOE by NIOSH as part of the EEOICPA radiological dose reconstruction program. These data and sample information will be used to bound plutonium intakes during the years where the exposure potential existed.

7.2.2 Ambient Environmental Internal Radiation Doses at Y-12

Further evaluation regarding the ambient environmental internal radiation doses is not necessary because these doses are accounted for in the process related internal dose evaluation.

7.3 External Radiation Doses at Y-12

Potential external radiation exposures at Y-12 during 1948 to 1960 time period would have occurred as a result of uranium operations that included analysis, recovery and recycling, purification and conversion, forming, machining, and component assembly. Occupational external exposures could have included beta, gamma, and neutron radiations as well as X-ray exposures from required periodic medical examinations.

The most prevalent potential source of external exposure to the majority of workers would have resulted from the gamma emissions from uranium-235 in the enriched uranium process areas of the plant and the beta and gamma emissions from the uranium-238 progeny (protactinium-234, thorium-234, and protactinium-234m) in the depleted uranium plant areas. The depleted uranium process areas have historically had the largest workplace exposures. Additional external gamma exposure sources include activated materials in 86-inch cyclotron vault and activation/fission contaminants found in the recycled, highly enriched uranium.

Exposure to neutron radiation also was possible at Y-12. Neutron exposures would have occurred primarily from reactions with the alpha particles emitted from highly enriched uranium interacting with low-Z material (e.g., fluorides and oxides of uranium), stray neutron fields while the 86-inch cyclotron was operating, and also from other neutron sources that were present at the site. These sources included both neutron emitting instrument calibration sources (e.g. polonium-beryllium, plutonium-beryllium, and radium-beryllium), and neutrons emitted from fissile material testing that took place onsite.

Occupational medical exposures to X-rays, when such screening X-rays are a condition of employment, are also included in EEOICPA dose reconstructions. During this time period, individuals at the Y-12 Site were required to have pre-employment, annual, and termination chest X-ray examinations. The Y-12 Occupational Medical Dose TBD (ORAUT-PROC-0042) documents the method and feasibility of reconstructing these medical exposures.

The subsections below summarize the extent and limitations of information available for reconstructing external doses of members of the worker classes addressed by this report. More detailed information is provided in the Y-12 Site Profile (ORAUT-TKBS-0014-1 Rev. 00) and in *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee, Part 1 – Gamma Radiation* (ORAU Technical Report 2004-0888).

7.3.1 Film Badge Monitoring at Y-12

External exposure monitoring of a limited number of workers began at the Y-12 site in 1948. The initial method used pocket ionization chambers (PICs) that were changed out on a weekly basis as well as hand film pads for uranium metal workers. Some film badges were also used at the onset of the program and replaced use of the PICs by 1950. Extremity monitoring of metal workers transitioned in 1951 from the hand film pads to film rings.

The film badge used was a two element badge designed with a portion of the badge having an "open window" to measure significant beta radiation and a separate portion covered by cadmium filter for evaluating gamma exposure. Badges were exchanged on a weekly basis from 1948 to 1958 and on a monthly basis for the final two years covered by this evaluation. The routine monitoring practice during the timeframe covered by this evaluation was to require dosimetry badges for those employees who might receive a dose in excess of 10% or the Radiation Protection Guidelines in effect at that time. Upwards of 25% of the total employees required dosimetry at any given time during the period.

Furthermore, the dosimeters also held a nuclear track Type-A emulsion (NTA) film used to measure neutron doses. However because neutron areas were limited to only a few departments, the NTA film was read only for those cases where a worker entered a neutron area.

7.3.1.1 Gamma/X-ray, Beta, and Non-Specific Beta-Gamma Exposures

The majority of the external radiation dose at the Y-12 site resulted from a variety of uranium work activities. NIOSH has access to the results of the film badge monitoring program for reconstructing both deep and shallow external dose components from the monitored population. Because those individuals monitored were selected based on having the highest exposure potential—i.e. greater than 10% of the Radiation Protection Guidelines —external doses for missed doses or co-located, unmonitored workers could be conservatively calculated. Deficiencies in the monitoring program, such as non-conservative placement of the film badge on the worker relative to the source location, energy dependence of the film badge, and recording of doses as zero when results were less than the minimum detectable level have been addressed and methods developed for correcting the reported or missed doses in a dose reconstruction procedure (ORAUT-PROC-0042 Rev. 1; Kerr, 2005).

7.3.1.2 Neutron Exposures

There were only a few areas at the Y-12 facility were workers were exposed to neutrons on a routine basis, and in these areas, personnel monitoring was provided by film badges containing a neutron sensitive film (Emlet, 1956). Neutron exposures to Y-12 workers occurred primarily in the stray radiation fields about the 86-inch cyclotron (Building 9201-2), areas used for storage of highly enriched uranium compounds of UF_4 and UO_3 (Building 9212 Complex), and the Criticality Experiments Facility (Building 9213). The stray neutron fields from these sources have been well characterized for use in dose reconstruction for Y-12 workers (ORAU Technical Report 2004-1406).

Most of the neutron sources at Y-12 were small and produced neutrons by alpha particle reactions in beryllium. These small polonium-beryllium, plutonium-beryllium, and Americium-beryllium sources were used mainly in basic research (Buildings 9201-2 and 9204-3), critical assembly research (Building 9213), calibration of radiation detection instruments and dosimeters (Buildings 9737 and 9983). The small neutron sources were shielded when not in use and neutron exposures to these sources during usage were rigidly controlled. The neutron fields around these small shielded sources have also been well characterized for use in dose reconstruction (ORAU Technical Report 2004-1406; ORAUT-OTIB-0055).

A historical report has been prepared on neutron film badge usage at the Y-12 Plant (ORAU Technical Report 2004-1406). This reports states that NTA films for neutron dosimetry were added to the film badges in 1949. No personal neutron exposures appear to have been made prior to this time (Souleyrette, 2003). Occupational neutron exposure potential to Y-12 workers was primarily confined to the years from 1952 through 1962. During this period, there were 375 positive quarterly neutron doses among 143 workers at the Y-12 facility (ORAU Technical Report 2004-1406).

The use of the available NTA film monitoring data in dose reconstruction for Y-12 workers is discussed in the document titled *Effect of Threshold Energy and Angular Response of NTA Film on Missed Neutron Dose at the Oak Ridge Y-12 Facility* (ORAUT-OTIB-0055). This technical information bulletin discusses and provides correction factors for missed dose due to the energy detection threshold and angular response of the NTA film. These factors are also applied to missed neutron dose to a worker that resulted from the routine practice of recording a zero when the quarterly neutron dose to the worker was less than the minimum detectable limit (MDL) of 50 mrem for the NTA film (ORAU Technical Report 2004-1406). The assignment of missed dose to Y-12 workers is also discussed in *Effect of Threshold Energy and Angular Response of NTA Film on Missed Neutron Dose at the Oak Ridge Y-12 Facility* (ORAUT-OTIB-0055).

7.3.2 Ambient Environmental External Radiation Doses at Y-12

An evaluation of ambient environmental external radiation doses is not necessary because this dose is accounted for in the process related external dose evaluation.

7.4 Evaluation of Petition Basis for SEC-00028

The following subsections evaluate the assertions made on behalf of petition SEC-00028 for the Y-12 Plant.

7.4.1 Evaluation of General Concerns Raised in Petition SEC-00028

The following addresses general concerns raised in the discussion of petition SEC-00028.

7.4.1.1 Inadequate Monitoring

The petitioner asserted by affidavit that the energy employees listed on the petition did not receive or witness monitoring of radiation exposures or radiation doses for steamfitters, pipefitters, and plumbers.

Documentation in NIOSH/ORAU databases for the applicable time period for this proposed class have been reviewed and evaluated and it was determined that the databases do not contain monitoring data for Steamfitters, Pipefitters, and Plumbers employed during the earliest years of the proposed class time frame (1944-1947). However, with the exception of thorium exposure, monitoring data applicable for the later years of the proposed class time frame are available (post-1947), as discussed in the Y-12 Site Profile and Co-Worker Data OTIB.

7.4.1.2 Exposure Potential

Steamfitters, Pipefitters, and Plumbers worked mostly in maintenance and new construction. New construction activities on or at new facilities (that have not gone through startup), by the nature of that work, does not entail a significant exposure potential. New construction work in operational facilities are addressed under the same conditions as those expected for facility maintenance work which were potentially conducted in many areas at the Y-12 site. Worker interviews indicate that because the maintenance group supported the entire site, the maintenance personnel had the potential to be exposed to all sources of exposure on site. Therefore, the maintenance personnel had the potential for exposure to:

- Uranium isotopes during uranium enrichment and recycling operations (neptunium)
- Thorium when two test batches were processed through the Building 9204-3 calutrons (for enrichment), during Research and Development activities in Buildings 9202, 9204-1, and 9204-3, and when used as a co-precipitation media to increase the uranium recovery percentage from decontamination solutions.
- Plutonium during the 1950s when plutonium was enriched with the calutrons
- Polonium 208 when polonium was produced with the cyclotron
- Other short lived radioactive isotopes produced by the cyclotron

As a result of this evaluation, NIOSH has determined that it can estimate radiation doses with sufficient accuracy for the subject class and time frame to all identified potential exposures except those associated with thorium exposures while working in Building 9202, 9204-1, or 9204-3.

7.5 Summary of Feasibility Findings for Petition SEC-00028

This report evaluated the feasibility for completing dose reconstructions for employees at the Y-12 Plant from January 1948 through December 1957. NIOSH found that the monitoring records, process descriptions and source term data available for determining thorium exposures are not sufficient to complete dose reconstructions for the proposed class of employees.

Table 7-4 summarizes the results of the feasibility findings at the Y-12 Plant for each exposure source for the time period of 1948 through 1957.

Table 7-4: Summary of Feasibility Findings for SEC-00028		
Source of Exposure	**Maximum Exposure can be Determined**	**Maximum Exposure cannot be Determined**
Internal		X
- Uranium	X	
- Thorium		X
- Other Radionuclides	X	
External	X	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical x-ray	X	

8.0 Evaluation of Health Endangerment for Petition SEC-00028

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

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

NIOSH did not identify any evidence from the petitioners or from other resources that would establish that any members of the proposed class were exposed to radiation during any discrete incidents likely to have involved exceptionally high levels of exposure. However, there is evidence that some workers in the proposed class may have accumulated substantial chronic exposures through episodic intakes of thorium. Consequently, NIOSH has determined that health was endangered for those workers covered by this evaluation who were employed for at least 250 aggregated work days either solely under the employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

9.0 NIOSH Proposed Class for Petition SEC-00028

This evaluation defines a single class of employees for which NIOSH can estimate radiation doses with sufficient accuracy. This class includes employees of the DOE or DOE contractors or subcontractors who were monitored or should have been monitored for thorium exposures while working in Building 9202, 9204-1, 9204-3, 9206, or 9212 at Y-12 for a number of work days aggregating at least 250 work days during the period from January 1948 through December 1957 or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

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