SEC Petition Evaluation Report
Petition SEC-00186

Report Rev #: 0 Report Submittal Date: July 18, 2011

Subject Expert(s):	Jason Davis
Site Expert(s):	N/A

Petitioner Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition A Receipt Date	DOE/AWE Facility Name
SEC-00186	83.14	April 22, 2011	Y-12 Plant

NIOSH-Proposed Class Definition

All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Y-12 facility in Oak Ridge, Tennessee, during the period from January 1, 1948 through December 31, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC-00018	83.13	Y-12 Plant	Class added to the SEC: Mar 1943 through Dec 1947
SEC-00026	83.13	Y-12 Plant	Merged with SEC-00018
SEC-00028	83.13	Y-12 Plant	Class added to the SEC: Jan 1948 through Dec 1957 (for workers in specified areas of the Y-12 site)
SEC-00098	83.14	Y-12 Plant	Class added to the SEC: Mar 1, 1943 through Dec 31, 1947

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
SEC Petition Evaluation Report for Petition SEC-00018 (merged with SEC-00026)	Y-12 Plant
SEC Petition Evaluation Report (and Supplement) for Petition SEC-00028	Y-12 Plant
SEC Petition Evaluation Report for Petition SEC-00098	Y-12 Plant

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Peer Review Completed By:	[Signature on file] *Lara Hughes*	7/18/2011 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	7/19/2011 *Date*
SEC Evaluation Approved By:	[Signature on file] *Stuart L. Hinnefeld*	7/19/2011 *Date*

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Evaluation Report Summary: SEC-00186, 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 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

NIOSH-Proposed Class Definition

All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at Y-12 Plant in Oak Ridge, Tennessee, from January 1, 1948 through December 31, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

The intent of this evaluation is to address consistency and implementation issues associated with previous Y-12 Special Exposure Cohort evaluations, specifically SEC-00028. Many of the class definitions in the earlier SEC evaluations were based on petitioner-requested wording, which caused an obvious variance in class definitions. A recent review of existing SEC class definitions evaluated criteria such as consistency, applicability and whether any class definitions needed to be corrected by NIOSH (NIOSH 2010). In this review NIOSH determined that the class definition as set forth in SEC-00028 needed revising, because problems existed with the implementation of the previous class. In addition, through the course of ongoing dose reconstruction and research, NIOSH has determined that, due to undocumented worker movements across the site, limited claimant-specific information pertaining to work locations, and a determination by the Department of Labor (DOL) that employment records do not indicate work locations, NIOSH is unable to eliminate any specific worker from potential exposure scenarios based on assigned work location. NIOSH has found that a determination cannot always be made as to the specific area an employee worked in, or whether an employee should have been monitored for radiological exposures. Accordingly, NIOSH has determined that it is necessary to remove the area-specific and monitoring criteria from the class description associated with SEC-00028 thorium and cyclotron exposures for the period from January 1, 1948 through December 31, 1957. As such, NIOSH has determined that is also necessary to expand the SEC class definition to include all areas of the Y-12 Plant, and all employees of DOE, its predecessor agencies, and their contractors and subcontractors who worked at the Y-12 Plant during the period from January 1, 1948 through December 31, 1957. The SEC-00186 evaluation recommends a class that is consistent with current DCAS methods for defining a recommended SEC class.

Feasibility of Dose Reconstruction Findings

NIOSH lacks sufficient information, which includes biological monitoring data, sufficient air monitoring data, or sufficient process and radiological source term information, to allow it to estimate with sufficient accuracy the potential internal exposures to radionuclides associated with cyclotron operations, or to thorium and its progeny, to which the proposed class may have been subjected.

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

- Principal sources of internal and external radiation for members of the proposed class included exposures to uranium and thorium and their decay progeny as well as various radionuclides produced as a result of cyclotron operations.

- NIOSH previously determined in its evaluation of petition SEC-00028 that it did not locate sufficient data, including bioassay results, ambient air concentrations, or process information to estimate with sufficient accuracy internal exposures to thorium for workers in several of the Y-12 buildings (Buildings 9201-3, 9202, 9204-1, 9204-3, 9206, and 9212). In addition, NIOSH did not locate sufficient data, including bioassay results, ambient air concentrations, or process information to estimate with sufficient accuracy internal exposures to radionuclides for workers in the cyclotron area of the Y-12 Plant (Building 9201-2). In 2006, DHHS designated the following class for inclusion in the SEC:

  Department of Energy (DOE) employees or DOE contractor or subcontractor employees who were monitored or should have been monitored for: thorium exposures while working in Building 9201-3, 9202, 9204-1, 9204-3, 9206, or 9212 at Y-12 for a number of work days aggregating at least 250 work days from January 1948 through December 1957, or in combination with work days within the parameters established for one or more classes of employees in the SEC; or radionuclide exposures associated with cyclotron operations in Building 9201-2 at Y -12 for a number of work days aggregating at least 250 work days from January 1948 through December 1957, or in combination with work days within the parameters established for one or more classes of employees in the SEC (HHS, 2006).

- NIOSH found that internal exposure could be reconstructed for all employees between January 1948 and December 31, 1957, with the exception of internal exposure to thorium and cyclotron radionuclides, as determined in the evaluation of SEC-00028.

- NIOSH found that external exposure, including occupational medical doses, could be reconstructed for all employees between January 1948 and December 31, 1957, as determined in the evaluation of SEC-00028.

- Pursuant to 42 C.F.R. § 83.13(c)(1), NIOSH determined that there is insufficient information to either: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the radiation doses of members of the class more precisely than a maximum dose estimate.

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Y-12 Plant during the period from January 1, 1948 through December 31, 1957, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

Health Endangerment Determination

The NIOSH evaluation did not identify any evidence supplied by the petitioners or from other resources that would establish that the class was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures, such as nuclear criticality incidents or other events involving similarly high levels of exposures. However, the evidence reviewed in this evaluation indicates that some workers in the class may have accumulated chronic radiation exposures through intakes of uranium and thorium and their decay progeny as well as various radionuclides produced as a result of cyclotron operations. Therefore, 42 C.F.R. § 83.13(c)(3)(ii) requires NIOSH to specify that health may have been endangered for those workers covered by this evaluation who were employed for a number of work days aggregating at least 250 work days within the parameters established for this class 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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SEC Petition Evaluation Report for SEC-00186

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluator: Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for employees who worked at the Y-12 Plant during a specified time. It provides information and analysis germane to considering a petition for adding a class of employees to the Congressionally-created SEC.

This report does not make any determinations concerning the feasibility of dose reconstruction that necessarily apply to any individual energy employee who might require a dose reconstruction from NIOSH, with the exception of the employee whose dose reconstruction could not be completed, and whose claim consequently led to this petition evaluation. The finding in this report is not the final determination as to whether or not the proposed class will be added to the SEC. This report will be considered by the Advisory Board on Radiation and Worker Health (the Board) and by the Secretary of Health and Human Services (HHS). The Secretary of HHS will make final decisions concerning whether or not to add one or more classes to the SEC in response to the petition addressed by this report.

This evaluation, in which NIOSH provides its findings both on the feasibility of estimating radiation doses of members of this class with sufficient accuracy and on health endangerment, was conducted in accordance with the requirements of EEOICPA and 42 C.F.R. § 83.14.

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate, with sufficient accuracy, the radiation doses of the proposed class of employees through NIOSH dose reconstructions.[1]

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioners and the Advisory Board on Radiation and Worker Health. The Board will consider the NIOSH evaluation report, together with the petition, comments of the petitioner(s) and such other information as 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 a decision on behalf of HHS. The Secretary

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

of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this final decision process, the petitioner(s) may seek a review of certain types of final decisions issued by the Secretary of HHS.[2]

3.0 NIOSH-Proposed Class Definition and Petition Basis

The NIOSH-proposed class includes all employees of the Department of Energy, its predecessor agencies, and DOE contractors or subcontractors who worked at the Y-12 facility in Oak Ridge, Tennessee during the period from January 1, 1948 through December 31, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort. During this period, employees at this facility were involved primarily in the processing of uranium for the production of nuclear weapons components and test devices.

The evaluation responds to Petition SEC-00186 which was submitted by an EEOICPA claimant whose dose reconstruction could not be completed by NIOSH due to a lack of sufficient dosimetry-related information. NIOSH's determination that it is unable to complete a dose reconstruction for an EEOICPA claimant is a qualified basis for submitting an SEC petition pursuant to 42 C.F.R. § 83.9(b).

There is currently one class of Y-12 workers associated with the previous NIOSH evaluation of SEC petition SEC-00028 (NIOSH, 2006a; NIOSH 2006b), for which the Secretary of Health and Human Services (HHS) has designated for inclusion in the Special Exposure Cohort:

> Class added to the SEC effective September 7, 2006 (HHS, 2006): Department of Energy (DOE) employees or DOE contractor or subcontractor employees who were monitored or should have been monitored for thorium exposures while working in Building 9201-3, 9202, 9204-1, 9204-3, 9206, or 9212 at Y-12 for a number of work days aggregating at least 250 work days from January 1948 through December 1957, or in combination with work days within the parameters (excluding aggregate work day requirements) established for one or more classes of employees in the SEC; or radionuclide exposures associated with cyclotron operations in Building 9201-2 at Y -12 for a number of work days aggregating at least 250 work days from January 1948 through December 1957, or in combination with work days within the parameters (excluding aggregate work day requirements) established for one or more classes of employees in the SEC.

A recent review of existing SEC class definitions evaluated criteria such as consistency, applicability and whether any class definitions needed to be corrected by NIOSH (NIOSH 2010). In this review NIOSH determined that the class definition as defined in SEC-0028 needed revising, because problems existed with the implementation of the previous class. In addition, through the course of ongoing dose reconstruction and research, NIOSH has determined that, due to undocumented worker movements across the site, limited claimant-specific information pertaining to work locations, and a determination by the Department of Labor (DOL) that employment records do not indicate work

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

locations, NIOSH is unable to eliminate any specific worker from potential exposure scenarios based on assigned work location. NIOSH has found that a determination cannot always be made as to the specific area an employee worked in, or whether an employee should have been monitored for radiological exposures. Accordingly, NIOSH has determined that it is necessary to remove the area-specific and monitoring criteria from the class description associated with SEC-00028 thorium and cyclotron exposures for the period from January 1, 1948 through December 31, 1957. As such, NIOSH has determined that is also necessary to expand the SEC class definition to include all areas of the Y-12 Plant, and all employees of DOE, its predecessor agencies, and their contractors and subcontractors who worked at the Y-12 Plant during the period from January 1, 1948 through December 31, 1957. The SEC-00186 evaluation recommends a class that is consistent with current DCAS methods for defining a recommended SEC class.

4.0 Radiological Operations Relevant to the Proposed Class

The following subsections summarize the radiological operations at the Y-12 Plant from January 1, 1948 through December 31, 1957 and the information available to NIOSH to characterize particular processes and radioactive source materials. Using available sources, NIOSH has attempted to gather process and source descriptions, information regarding the identity and quantities of radionuclides of concern, and information describing processes through which the radiation exposures of concern may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is meant only to be a summary of the available information.

4.1 Operations Description

The Y-12 Plant is located in Oak Ridge, Tennessee on an 811-acre (0.67 miles wide and 3.2 miles long) site. For the period under evaluation by NIOSH, the Y-12 Plant workforce ranged from 2,511 employees in 1948 to 5,169 workers in 1957 with a peak employment of 5,817 workers in 1954 (NIOSH, 2006a, Table 6-2).

Using an electromagnetic separation process within a calutron, the original mission of Y-12 was to separate fissionable isotopes of uranium (U-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 report: SEC Petition Evaluation Report SEC-00018 (NIOSH, 2005).

While the SEC-00018 and SEC-00098 reports evaluate the years 1943 through 1947 (NIOSH 2005; NIOSH 2008), the previous SEC-00028 evaluation (NIOSH, 2006a; NIOSH, 2006b), and this current SEC-00186 evaluation focus 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 U-235 enrichment (calutrons) was discontinued in 1947 in favor of the more-efficient gaseous diffusion process. Extending from 1947 through 1992, the second era's primary mission was the production of key components of nuclear weapons and test devices. During this era, the vast majority of the work at Y-l2 involved uranium processing, although other radioactive materials such as thorium, tritium, polonium, and transuranics were also present in very small quantities during the period under evaluation. During the 1948 through 1957 period, the Y -12 operating contractors were Carbide and

Carbon Chemicals and Union Carbide Nuclear Company, both divisions of Union Carbide Corporation predecessor companies (Oak Ridge, 1993, pdf p. 174).

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
- Oak Ridge National Laboratory (ORNL) and Non-Uranium Activities

4.1.1 Y-12 Key Uranium Processes

Table 4-1 summarizes the key uranium processes, buildings, and dates of operation (Oak Ridge, 1999, pdf p. 171).

Table 4-1: Key Uranium Operations
(This table spans two pages)

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/clean-up 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 distillation.	9206, 9207, 9211: • 9206 housed salvage operations and process operations similar to those in 9207 and 9211. • 9207 and 9211 processed incinerated solid waste and recovered normal and lightly enriched uranium.	1945-1951

Table 4-1: Key Uranium Operations
(This table spans two pages)

Key Uranium Operations	Buildings Involved	Dates of Operation
Uranium Preparation/Recycle for Weapons 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.	9206, 9207, 9211: • 9206 housed salvage operations and process operations similar to those in 9207 and 9211. • 9207 and 9211 processed incinerated solid waste and recovered normal and lightly enriched uranium.	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) filters and periodically inspected for build-up of uranium.	9202, 9204-2, 9204-2E: • 9202 was primarily used for early pilot-scale operations that involved design and implementation of fabrication and assembly processes and final inspection procedures. • 9204-2, 9204-2E housed uranium assembly operations.	1952-1995

4.1.2 Y-12 Lithium Isotope Separation Process

NOTE: Although not a radionuclide of concern for dose reconstruction, the Lithium Isotope Separation process provides additional detail regarding the activities conducted during the period under evaluation.

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

The process concentrated Li-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 (Wilcox, 2001).

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 shown in Table 4-2.

Table 4-2: 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 (Column Exchange) 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 through May 1963. Lithium production at Y-12 was terminated in 1963 as the stockpile grew and the material could be recycled from retired warheads (Wilcox, 2001).

4.1.3 Y-12 Thorium Studies

During the January 1, 1948 through December 31, 1957 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. Thorium work at Y-12 during this period was mainly of a research and development nature. Activities involving thorium are presented in chronological order below (Owings, 1995):

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 medium to increase the uranium recovery percentage from decontamination solutions. Although uranium enrichment with the calutrons stopped in 1947, it is not clear whether Y -12 continued to use thorium as a co-precipitating agent for later calutron operations (NIOSH, 2006a).

2. In 1952, the Isotopic Separation Program, which employed the beta calutrons in Building 9204-3, used small quantities of thorium for specific isotopic separation and purification (Air Monitoring, 1943-1959).

3. In 1956, thorium-oxide blending and slurry work associated with Research and Development activities were performed in Building 9204-1(Semiannual Report, 1956).

4. Kilogram quantities of thorium were used in the Research and Development laboratories to develop and define the processes that would be incorporated in major thorium processing that took place after the time period under evaluation. A 1957 description of the Health Physics Program states: *Thorium work is confined to one area in Building 9202, where the Development Department does some work with thorium* (Health Physics Program, 1957, pdf p. 52).

5. Kilogram quantities of thorium were used to support ORNL Research and Development activities in Buildings 9206 and 9212 (Owings, 1995).

Based on the Y-12 thorium activity research performed for NIOSH's evaluation of SEC-00028, another activity involved potential thorium exposure; however, the timeframe for this activity falls outside of the period under evaluation. Information on this activity is provided in support of the 1957 end date for the class period. This thorium work began as a pilot program in 1958. Following the pilot program was a 17-year period (beginning in 1960) during which metric tons of thorium were processed (Assessment, 2001). 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.

4.1.4 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 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 into the S-3 Ponds prior to the mid-1980s (Recycled Uranium, 2000).

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 served to remove any suspended contamination from rainwater, miscellaneous releases from various tank farms and storage yards, and inadvertent releases from process buildings (Recycled Uranium, 2000).

4.1.5 ORNL and Non-Uranium Activities at Y-12

Space at Y-12 was used 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 Attachment 2. Generally, the radioactive isotopes were produced 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.

Beta Calutrons

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

Based on a series of about 30 progress reports produced by the Electromagnetic Research Division and subsequent organizations, it is evident that plutonium isotopic enrichment work was occurring in 1952 and 1957. Documents also show that plutonium urinalyses were performed from 1952 through at least 1965, air monitoring was performed, and personnel protection was addressed through clothing and respiratory protection. Calutron facilities provided for double containment of the calutron(s) and glove-box handling of collection pockets (Progress Report, 1962; Progress Report, 1958).

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 (Polonium-208, 1952; Progress Report, 1963; ORNL, 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 Po-208 yield was more than doubled and a total of approximately 9 Ci of Po-208 were produced before the project was terminated in August 1953 (Polonium-208, 1952).

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

Attachment 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 (Safety Analysis, 1967). 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 (ORNL, 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 (Safety Analysis, 1967). 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 (Safety Review, 1962; Safety Analysis, 1967). During its operational years, access to the Critical Experiments Facility was restricted by means of a chain link fence (Safety Review, 1962; Safety Analysis, 1967).

5-MeV Van de Graff Accelerator

In the early 1950s, a 5-MeV Van de Graff accelerator operated for about one year in the east end of Building 9202-2 while a permanent structure was being built for the accelerator at the X-10 site. The 5-Me V Van de Graff Accelerator was an X-10 project and the health physicists and all other workers involved with the Van de Graff were X-10 employees (Oak Ridge, 1993; Struxness, January-June 1951; Struxness, July-December 1951).

4.1.6 Weapons Assembly and Disassembly

Information regarding weapons assembly and disassembly work at Y-12 was obtained through document reviews and a series of interviews with employees with first-hand knowledge of Y-12 weapons activities during the period under evaluation. The interviews were conducted as part of the evaluation effort for petition SEC-00028 (NIOSH, 2006a; NIOSH, 2006b). No additional interviews were necessary for this current evaluation because SEC-00186 specifies the same class period as SEC-00028.

From the document reviews and interviews, 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 another 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 interviewed workers agreed that the 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.

4.2 Radiation Exposure Potential from Operations

The following subsections provide an overview of the internal and external exposure potential for the Y-12 Plant class under evaluation.

Over the 1948 through 1957 time period, many individual research and development projects occurred at Y-12 involving various radiological exposure sources. The use of thorium at Y-12 is 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 use as a co-precipitation medium. In addition, there exist a number of radionuclides produced as a result of 86-inch cyclotron operations. However, 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.

In addition, because Y-12 served primarily as a nuclear weapons fabrication and production facility during this period, the uranium that was present included natural uranium, depleted uranium, and enriched uranium.

4.2.1 Alpha Particle Emissions

Both U-235 and U-238 are primarily alpha-particle emitters. As such, gamma radiation exposure potential was very low for most members of the class under evaluation. 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 (Oak Ridge, 1993, pdf p. 222; Oak Ridge, 1999, pdf pp 172-185; Technical Basis, 2003, pdf p. 11):

- Uranium oxide (D_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)

As previously discussed, Research and Development activities involving thorium (including Th-230 and Th-232 in limited quantities) were also performed during the evaluation period. Th-232 decays primarily by alpha emission, yielding a 4.081 MeV alpha particle in the process. Although Th-232 has a long (1.405 x 10^{10} years) half-life, many of its short-lived decay products, such as Ra-224 and Rn-220, also decay by alpha emissions. Similarly, Th-230 also decays primarily by alpha emission, yielding a 4.770 MeV alpha particle with a half-life of 7.538 x 10^4 years. Like Th-232, Th-230 also gives rise to several daughter radionuclides that decay by alpha emission with short half-lives, as shown in Table 4-3. However, concerns associated with thorium alpha emissions/exposures were limited by operational location and design to Buildings 9202, 9204-1, and 9204-3.

Table 4-3: Thorium Decay Chain Alpha Emissions

Isotope	Half-life	Energy Released (MeV)
Th-230	7.5380 x 10^4 y	4.770
Ra-226	1.602 x 10^3 y	4.871
Rn-222	3.8235 d	5.590
Po-218	3.10 min	6.115
At-218	1.5 s	6.874
Rn-218	35 ms	7.263
Bi-214	19.9 min	1.024
Bi-210	5.013 d	5.982
Po-210	138.376 d	5.407
Th-232	1.405 x 10^{10} y	4.081
Th-228	1.9116 y	5.520
Ra-224	3.6319 d	5.789
Rn-220	55.6 s	6.404
Po-216	0.145 s	6.906
Bi-212	60.55 min	6.208
Po-212	299 ns	8.955

4.2.2 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 4-3) involved industrial radiation-generating equipment (X-rays and electron accelerators) and isotopic gamma-ray and neutron sources for testing purposes (e.g., Co-60, Cf-252, and radium-beryllium or polonium-beryllium neutron sources).

As noted in Section 4.2.1, the U-235 and U-238 contained in Y-12 materials are primarily alpha-emitters. However, U-235 does emit a 185-Ke V photon in 54% of its decays and short-lived U-238 decay products (Th-234, Pa-234m, and Pa-234) are beta and photon emitters. From an external dose standpoint, the most significant radiations emitted by these U-238 decay products are: (1) the 2.29-MeV beta particle from Pa-234m; and (2) the photons emitted by Pa-234 with energies as large as 1.962 MeV. In addition, the various nuclides produced as a result of cyclotron operations (listed in Appendix 2) would produce an external exposure potential that is proportional to the emitted energy of the nuclide as well as the quantity produced.

Table 4-4 summarizes beta and photon energies as associated with various Y-12 processes (ORAUT-TKBS-0014-6).

Table 4-4: Beta and Photon Energies

Y-12 Site Processes	Building	Operations		Radiation type	Energy Selection[a]	Percent[b]
		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[c]	1947	1995			
	9212[d]	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	Ongoing			
	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] Source: *NIOSH Interactive RadioEpidemiological Program (NIOSH-IREP) Technical Documentation* (NIOSH-IREP, 2002)
[b] Source: *Handbook of Health Physics and Radiological Health* (Rad Handbook, 1998)
[c] Building 926 Complex includes Buildings 9768, 9720-17, 9409-17, 9510-2, 9767-2, and the east and west tank farm pits.
[d] Building 9212 Complex includes Buildings 9809, 9212, 9818, 9815, and 9980.

4.2.3 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 Y-12 is summarized in Table 4-5.

Table 4-5: 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, Polonium 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; Struxness, November-December 1950
[b] Struxness, November-December 1950; Struxness, January-June 1953; Safety Review, 1962; Safety Analysis, 1967
[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; DOE, 2000

Neutron sources were used in the 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 housing the sources.

Although the neutron spectrum produced as a result of the α,n reaction can be complex, Table 4-6 lists the average neutron energies and the neutron yield per curie of the alpha-emitting isotope.

Table 4-6: Neutron Data for Commonly-used Neutron Sources

Source	Average Neutron Energy (MeV)	Yield per Ci (neutrons per s)
Polonium-Beryllium	4.2	2.5×10^6
Radium-Beryllium	4.0	1.3×10^7
Americium-Beryllium	4.5	2.2×10^6

Source: Rad Handbook, 1998

Two other neutron sources not listed in Table 4-4 are a Cockcroft-Walton linear accelerator capable of producing a maximum of 1E10 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 square-centimeter-second near the target (Struxness, January-June 1951; Struxness, July-December 1951). The Cockcroft-Walton was installed in late 1951 in the ORNL Biology Division building housing the Oak Ridge 86-inch cyclotron (Building 9201-2). 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 (ORNL, 1994).

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 (Technical Basis, 2001).

4.2.5 Recycled Uranium and Other Radionuclides of Concern

From 1953 until 1999, recycled uranium activities introduced radionuclides into Y-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 that 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 its 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 arrived in 1953 with shipments of very-highly-enriched uranium from the Idaho Chemical Processing Plant. A few years later, the Savannah River Plant started sending large quantities of highly-enriched uranium/very-highly-enriched uranium and recycled uranium materials. The primary contaminants were Pu-238 (Pu-239 in lesser quantities), Np-237, and Tc-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 these were generally disposed of with the raffinates (Technical Basis, 2001).

Shortly after recycled uranium was introduced at Y-12, the AEC directed that an effort be made to remove Np-237 from process streams for use as targets in the production of Pu-238 in the production reactors. X-10 designed the ion exchange system for liquid processes, which contained Np-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 (NIOSH, 2006a).

4.3 Time Period Associated with Radiological Operations

Per the DOE Office of Health, Safety and Security, the time period associated with DOE operations at the Y-12 Plant is from 1942 to the present. As presented in Section 3.0, HHS has already designated (for SEC-00028) that monitored workers who worked in Buildings 9201-3, 9202, 9204-1, 9204-3, 9206, or 9212, or with cyclotron operations in Building 9201-2, during the period from January 1948 through December 1957 be included in the SEC. The period of radiological operations associated with this current evaluation remains the same as that associated with the previously-designated class for SEC-00028. However, the time period for this evaluation report on Y-12 exposures specifies the logical start date of January 1, 1948 and the logical end date of December 31, 1957.

4.4 Site Locations Associated with Radiological Operations

The Y-12 facility is comprised of many buildings where many different (often experimental) activities occurred. As presented in Section 3.0, HHS has already designated (for SEC-00028) that monitored workers working in Buildings 9201-3, 9202, 9204-1, 9204-3, 9206, or 9212, or with cyclotron operations in Building 9201-2, during the period from January 1948 through December 1957 be included in the SEC. Through the course of ongoing dose reconstruction and research associated with the SEC-00028 class period, NIOSH has determined that, due to undocumented worker movements across the site, limited claimant-specific information pertaining to work locations, and a determination by the Department of Labor that employment records do not indicate work locations, NIOSH is unable to eliminate any specific worker from potential exposure scenarios based on assigned work location.

4.5 Job Descriptions Affected by Radiological Operations

Y-12 workers were potentially exposed to radiation in areas where radiological operations took place. NIOSH has determined that the site-specific and claimant-specific data available for the Y-12 Plant for the time period under evaluation are insufficient to allow NIOSH to determine that any specific work group was not potentially exposed to thorium or cyclotron-related radionuclides during the period under evaluation.

NIOSH has insufficient information associating job titles and/or job assignments with specific thorium or cyclotron radiological operations or conditions. Without such information, NIOSH is unable to define potential radiation exposure conditions based on worker job descriptions.

5.0 Summary of Available Monitoring Data for the Proposed Class

The primary data used for determining internal exposures are derived from personal monitoring data, such as urinalyses, fecal samples, and whole-body counting results. If these are unavailable, the air monitoring data from breathing zone and general area monitoring are used to estimate the potential internal exposure. If personal monitoring and breathing zone area monitoring are unavailable, internal exposures can sometimes be estimated using more general area monitoring, process information, and information characterizing and quantifying the source term.

This same hierarchy is used for determining the external exposures to the cancer site. Personal monitoring data from film badges or thermoluminescent dosimeters (TLDs) are the primary data used to determine such external exposures. If there are no personal monitoring data, exposure rate surveys, process knowledge, and source term modeling can sometimes be used to reconstruct the potential exposure.

A more detailed discussion of the information required for dose reconstruction can be found in OCAS-IG-001, *External Dose Reconstruction Implementation Guideline*, and OCAS-IG-002, *Internal Dose Reconstruction Implementation Guideline*. These documents are available at: http://www.cdc.gov/niosh/ocas/ocasdose.html.

5.1 Data Capture Efforts and Sources Reviewed

As a standard practice, NIOSH completed an extensive database and Internet search for information regarding Y-12 Plant. The database search included the DOE Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, the Atomic Energy Technical Report database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet search included OSTI OpenNet Advanced searches, OSTI Information Bridge Fielded searches, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) web searches, the DOE Office of Human Radiation Experiments website, and the DOE-National Nuclear Security Administration-Nevada Site Office-search. Attachment One contains an updated summary of Y-12 Plant documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

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

Detailed information regarding NIOSH’s data capture efforts for the Y-12 Plant can be found in the related NIOSH evaluation reports for SEC-00018, SEC-00028, and SEC-00098 (NIOSH, 2005; NIOSH, 2006a; NIOSH, 2006b; NIOSH, 2008).

5.2 Worker Interviews

To obtain additional information in support of its 2006 evaluation of Petition SEC-00028, NIOSH interviewed nine former Y-12 Plant employees. Details regarding these interviews can be found in the SEC Petition Evaluation Report for Petition SEC-00028, Y-12 Plant (NIOSH, 2006a). Additional interviews for the specific purpose of supporting these evaluations were not deemed necessary, and therefore were not performed.

5.3 Internal Personnel 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 the Y-12 internal and external data summary in Section 5.4). Fluorometric analyses were performed on samples submitted from workers in natural and depleted uranium work areas and electro-deposition of uranium followed by gross alpha counting for samples submitted by workers in enriched uranium areas. (NIOSH, 2006a, NIOSH, 2006b)

Table 5-1 provides a summary of the uranium urinalysis records available through the ORAU Center for Epidemiologic Research.

Table 5-1: Summary of Available Y-12 Uranium Urinalysis Data (1948-1960)

Year	Total Number of Employees	Urinalysis (Uranium)	
		No. of Records	No. of Employees Monitored
1948	2,511	-	-
1949	2,248	-	-
1950	2,552	1,110	166
1951	4,036	4,124	367
1952	4,169	13,317	393
1953	4,866	14,222	490
1954	5,817	23,430	1,316
1955	5,768	28,806	1,225
1956	5,443	29,914	1,119
1957	5,169	33,443	1,443
1958	5,164	38,783	1,791
1959	5,460	47,339	2,277
1960	5,593	46,381	2,193

Notes:
A table cell with a hyphen (-) indicates No Data Available.
[a] External monitoring records include all currently known available gamma, beta, and neutron data.

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 printouts 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-l0 analytical labs, and lab reports of bioassay urine and fecal analysis results. (NIOSH, 2006a; NIOSH, 2006b)

Table 5-2 provides 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 under evaluation.

Table 5-2: 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
Tritium	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

Table 5-2 lists the quantities of available fecal analysis data, starting in 1958, for the thorium-related activities associated with Research and Development performed in Buildings 9202, 9204-1, and 9204-3. A total of 93 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.

Whole-body counting was not routinely practiced at 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 or cyclotron-produced radionuclide monitoring during the period under evaluation were identified in any of the documentation reviewed by NIOSH for this report or for the previous NIOSH evaluation of SEC-00028.

5.4 External Personnel 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, that were typically changed weekly. 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 under evaluation. 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).

An expanded personnel monitoring program for external radiation exposure was initiated at Y-I2 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 augmented with film rings to assess the radiation exposure to uranium metal workers' hands. 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. The minimum detection limit (MDL) of the neutron film is uncertain, but it is believed to be about 50 mrem for all years of use at Y-12 (ORAUT-TKBS-0014-6).

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 (NIOSH, 2006a).

The Oak Ridge Associated Universities Center for Epidemiologic Research received a copy of the Y-12 monitoring records. These files contained records for more than 17,000 Y-12 workers. From these Y-12 records, available external data relevant to the subject class are presented by year in Table 5-3.

Table 5-3: Summary of Available Monitoring Data for Y-12 Workers (1948-1960)			
Year	**Total No. of Employees**	**No. of Records**	**No. of Employees Monitored**
1948	2,511	3,599	162
1949	2,248	7,893	49
1950	2,552	268	148
1951	4,036	406	184
1952	4,169	1,157	498
1953	4,866	793	387
1954	5,817	1,240	682
1955	5,768	1,920	624
1956	5,443	2,181	730
1957	5,169	2,510	796
1958	5,164	2,879	996
1959	5,460	3,644	1,266
1960	5,593	4,296	1,336

Notes:
Source: NIOSH, 2006a
A table cell with a hyphen (-) indicates No Data Available.
[a] External monitoring records include all currently known available gamma, beta, and neutron data.

5.5 Workplace Monitoring Data

In addition to personal monitoring for internal and external doses, thousands of air samples were collected during the January 1, 1948 through December 31, 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 data for uranium air sampling are summarized in Table 5-4. The results were generally reported as disintegrations per minute (dpm)/m^3 uranium in air. Thorium air sampling for the 1948 through 1957 timeframe was limited. To date, NIOSH has obtained a limited number of these thorium air sampling results. As presented in NIOSH's previous evaluation of SEC-00028 (NIOSH, 2006a; NIOSH 2006b), no thorium production level work occurred in the period under evaluation in this report. Full production did not get underway until 1960 with the highest thorium production activity occurring between 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 (NIOSH, 2006a).

Table 5-4: Summary of Available Uranium Air Monitoring Data for Y-12 Workers (1948-1960)		
Year	**Total No. of Employees**	**No. of Uranium Records**
1948	2,511	-
1949	2,248	-
1950	2,552	-
1951	4,036	15,655
1952	4,169	-
1953	4,866	8,010
1954	5,817	20,217
1955	5,768	26,976
1956	5,443	36,280
1957	5,169	41,354
1958	5,164	77,373
1959	5,460	66,150
1960	5,593	44,433

Notes:
A table cell with a hyphen (-) indicates No Data Available.
[a] External monitoring records include all currently known available gamma, beta, and neutron data.

5.6 Radiological Source Term Data

During the period from January 1, 1948 through December 31, 1957, workers may have been exposed to uranium, thorium, and their decay progeny. During the operation of the cyclotron, workers may have been exposed to various radionuclides arising from cyclotron operations. Table A2-1 in Appendix 2 lists the quantities of the various radionuclides produced and/or processed at Y-12.

Additional information regarding the Y-12 Plant source term data available to NIOSH can be found in the related Y-12 Plant Evaluation Report for SEC-00028 (NIOSH, 2006a; NIOSH, 2006b).

6.0 Feasibility of Dose Reconstruction for the Proposed Class

42 C.F.R. § 83.14(b) states that HHS will consider a NIOSH determination that there was insufficient information to complete a dose reconstruction, as indicated in this present case, to be sufficient, without further consideration, to conclude that it is not feasible to estimate the levels of radiation doses of individual members of the class with sufficient accuracy.

In the case of a petition submitted to NIOSH under 42 C.F.R. § 83.9(b), NIOSH has already determined that a dose reconstruction cannot be completed for an employee at the DOE or AWE facility. This determination by NIOSH provides the basis for the petition by the affected claimant. Per § 83.14(a), the NIOSH-proposed class defines those employees who, based on completed research, are similarly affected and for whom, as a class, dose reconstruction is similarly not feasible.

In accordance with § 83.14(a), NIOSH may establish a second class of coworkers at the facility for whom NIOSH believes that dose reconstruction is similarly infeasible, but for whom additional research and analysis is required. If so identified, NIOSH would address this second class in a separate SEC evaluation rather than delay consideration of the claim currently under evaluation (see Section 10). This would allow NIOSH, the Board, and HHS to complete, without delay, their consideration of the class that includes a claimant for whom NIOSH has already determined a dose reconstruction cannot be completed, and whose only possible remedy under EEOICPA is the addition of a class of employees to the SEC.

This section of the report summarizes research findings by which NIOSH determined that it lacked sufficient information to complete the relevant dose reconstruction and on which basis it has defined the class of employees for which dose reconstruction is not feasible. NIOSH's determination relies on the same statutory and regulatory criteria that govern consideration of all SEC petitions.

6.1 Feasibility of Estimating Internal Exposures

NIOSH has evaluated the available personnel and workplace monitoring data and source term information and has determined that there are insufficient data for estimating internal exposures, as described below.

As presented in Section 3.0 of this report, HHS has designated an SEC class for Y-12 workers for the period from January 1948 through December 1957 (HHS, 2006). In the class designation letter, HHS states:

> *There are insufficient bioassay or air sampling data to reconstruct internal thorium dose for employees who worked from January 1948 through December 1957 in buildings where thorium operations took place: buildings 9201-3, 9202, 9204-1, 9204-3, 9206, and 9212.*
>
> *There are insufficient bioassay or air sampling data to reconstruct internal dose for cyclotron workers (employees who worked in Building 9201-2) from January 1948 through December 1957. These workers may have accumulated substantial chronic exposures through episodic intakes of a variety of radionuclides that were produced during the cyclotron operation period.*

The associated SEC class designated by HHS included only those employees who worked "in Building 9201-3, 9202, 9204-1, 9204-3, 9206, or 9212" or "in Building 9201-2" (HHS, 2006). This class description was based on the NIOSH determination that exposure potential was limited to workers in these buildings, that all workers with the potential for radiation exposures during the proposed SEC class time period were included in the external dose monitoring program, and that unmonitored workers had no potential for radiation exposures.

A recent review of existing SEC class definitions evaluated criteria such as consistency, applicability and whether any class definitions needed to be corrected by NIOSH (NIOSH 2010). In this review NIOSH determined that the class definition as defined in SEC-00028 needed revising, because problems existed with the implementation of the previous class. In addition, through the course of ongoing dose reconstruction and research, NIOSH has determined that, due to undocumented worker movements across the site, limited claimant-specific information pertaining to work locations, and a determination by the Department of Labor (DOL) that employment records do not indicate work locations, NIOSH is unable to eliminate any specific worker from potential exposure scenarios based on assigned work location. NIOSH has found that a determination cannot always be made as to the specific area an employee worked in, or whether an employee should have been monitored for radiological exposures. Accordingly, NIOSH has determined that it is necessary to remove the area-specific and monitoring criteria from the class description associated with SEC-00028 thorium and cyclotron exposures for the period from January 1, 1948 through December 31, 1957. As such, NIOSH has determined that it is also necessary to expand the SEC class definition to include all areas of the Y-12 Plant, and all employees of DOE, its predecessor agencies, and their contractors and subcontractors who worked at the Y-12 Plant during the period from January 1, 1948 through December 31, 1957. The SEC-00186 evaluation recommends a class that is consistent with current DCAS methods for defining a recommended SEC class.

A method for estimating uranium exposures for the years between 1948 and 1957 in Buildings 9202, 9204-1, 9204-3, 9206, and 9212 was included in the Evaluation Report for SEC-00028. This could be applied for workers who could be shown to have worked within those buildings. Dose reconstructions for individuals employed at Y-12 during the evaluated time period, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

NIOSH does not have access to sufficient personnel monitoring, workplace monitoring, or source term data to estimate potential internal exposures to thorium or radionuclides produced as a result of cyclotron operations during the period from January 1, 1948 through December 31, 1957. Consequently, NIOSH finds that it is not feasible to estimate, with sufficient accuracy, internal exposures to thorium or radionuclides produced as a result of cyclotron operations and resulting doses for the class of employees covered by this evaluation.

Although NIOSH found that it is not possible to completely reconstruct internal radiation doses for the period from January 1, 1948 through December 31, 1957, NIOSH intends to use any internal monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at the Y-12 Plant during the period from January 1, 1948 through December 31, 1957, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

6.2 Feasibility of Estimating External Exposures

This evaluation responds to a petition based on NIOSH determining that internal radiation exposures to thorium could not be reconstructed for a dose reconstruction referred to NIOSH by the Department of Labor (DOL). As noted above, HHS will consider this determination to be sufficient without further consideration to determine that it is not feasible to estimate the levels of radiation doses of individual members of the class with sufficient accuracy. Consequently, it is not necessary for NIOSH to fully evaluate the feasibility of reconstructing external radiation exposures for the class of workers covered by this report.

In its previous evaluation of petition SEC-00028, NIOSH concluded that for the period from January 1948 through December 1957, it has access to sufficient information to either: (1) estimate the maximum external radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the external radiation doses to members of the class more precisely than a maximum dose estimate. This current evaluation has found no evidence to the contrary.

Adequate reconstruction of medical dose is likely to be feasible by using bounding assumptions in the technical information bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT-OTIB-0006), and Y-12 Plant technical basis documents, collectively referred to as ORAUT-TKBS-0014.

6.3 Class Parameters Associated with Infeasibility

HHS has designated an SEC class associated with SEC-00028 for Y-12 Plant workers for the period from January 1948 through December 1957 (HHS, 2006). The time period covered by this current report is unchanged from that previously designated by HHS in 2006. NIOSH therefore recommends that the class include the time period from January 1, 1948 through December 31, 1957.

7.0 Summary of Feasibility Findings for Petition SEC-00186

This report evaluates the feasibility for completing dose reconstructions for employees at the Y-12 Plant from January 1, 1948 through December 31, 1957. NIOSH determined that members of this class may have received radiation exposures from uranium, thorium, their associated decay progeny, and various radionuclides arising as a result of cyclotron operations. NIOSH lacks sufficient information, which includes thorium and cyclotron-related bioassay data, source term data, and workplace monitoring data that would allow it to estimate the potential thorium and cyclotron-related exposures to which the proposed class may have been exposed.

A recent review of existing SEC class definitions evaluated criteria such as consistency, applicability and whether any class definitions needed to be corrected by NIOSH (NIOSH 2010). In this review NIOSH determined that the class definition as defined in SEC-00028 needed revising, because problems existed with the implementation of the previous class. In addition, through the course of ongoing dose reconstruction and research, NIOSH has determined that, due to undocumented worker movements across the site, limited claimant-specific information pertaining to work locations, and a determination by the Department of Labor (DOL) that employment records do not indicate work locations, NIOSH is unable to eliminate any specific worker from potential exposure scenarios based on assigned work location. NIOSH has found that a determination cannot always be made as to the specific area an employee worked in, or whether an employee should have been monitored for radiological exposures. Accordingly, NIOSH has determined that it is necessary to remove the area-specific and monitoring criteria from the class description associated with SEC-00028 thorium and cyclotron exposures for the period from January 1, 1948 through December 31, 1957. As such, NIOSH has determined that it is also necessary to expand the SEC class definition to include all areas of the Y-12 Plant, and all employees of DOE, its predecessor agencies, and their contractors and subcontractors who worked at the Y-12 Plant during the period from January 1, 1948 through December 31, 1957. The SEC-00186 evaluation recommends a class that is consistent with current DCAS methods for defining a recommended SEC class.

NIOSH has documented herein that it cannot complete the dose reconstructions related to this petition. The basis of this finding demonstrates that NIOSH does not have access to sufficient information to estimate either the maximum radiation dose incurred by any member of the class or to estimate such radiation doses more precisely than a maximum dose estimate.

Consistent with its findings associated with SEC-00028 (NIOSH, 2006a; NIOSH, 2006b), NIOSH finds that it is not feasible to estimate, with sufficient accuracy, the internal radiation doses received by members of the proposed class of employees from January 1, 1948 through December 31, 1957.

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Y-12 during the period from January 1948 through December 1947, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

8.0 Evaluation of Health Endangerment for Petition SEC-00186

The health endangerment determination for the class of employees covered by this evaluation report is governed by EEOICPA and 42 C.F.R. § 83.14(b) and § 83.13(c)(3). Pursuant to these requirements, if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class. The regulations require NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

NIOSH has determined that members of the class were not exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. However, the evidence reviewed in this evaluation indicates that some workers in the class may have accumulated chronic radiation exposures through intakes of radionuclides and from direct exposure to radioactive materials. Consequently, NIOSH is specifying that health was endangered for those workers covered by this evaluation who were employed for a number of work days aggregating at least 250 work days within the parameters established for this class or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

9.0 NIOSH-Proposed Class for Petition SEC-00186

The evaluation defines a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. This class includes all employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Y-12 facility in Oak Ridge, Tennessee from January 1, 1948 through December 31, 1957, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees in the Special Exposure Cohort.

10.0 Evaluation of Second Similar Class

In accordance with § 83.14(a), NIOSH may establish a second class of coworkers at the facility, similar to the class defined in Section 9.0, for whom NIOSH believes that dose reconstruction may not be feasible, and for whom additional research and analyses are required. If a second class is identified, it would require additional research and analyses. Such a class would be addressed in a separate SEC evaluation rather than delay consideration of the current claim. At this time, NIOSH has not identified a second similar class of employees at the Y-12 Plant for whom dose reconstruction may not be feasible.

11.0 References

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42 C.F.R. pt. 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule; May 2, 2002; SRDB Ref ID: 19392

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Attachment 1: Data Capture Synopsis

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
Primary Site/Company Name: Y-12 Plant 1942-present, DOE Other Site Names: NA Physical Size of the Site: 811 acres holding over 350 buildings. Personnel Data: In 1945, more than 22,000 workers at the site. During the Cold War 8,000 people worked around the clock. Noted 6,866 employees in June 1963 and 6,000 in 2011.	Bioassay data, 86-inch cyclotron program and radiation protection, buildings and years where thorium was present, external exposure information, foundry health physics, handling and working with Np, in-vivo monitoring program and results, list of names and badge numbers, neutron field measurement, uranium air limits and their impact on Y-12, personnel notebooks, plant procedures, plutonium air problem, progress reports, radiation generating devices, radiation safety manual, radiological incidents, radiological surveys (airborne, contamination, etc.), record book of materials, run sheets from 86-inch cyclotron, separation of isotopes, neutron film results, sunflower foundry employees, thorium program lung count results, transuranic hazard assessment, uranium in effluent, urinalysis and fecal sample program related information, various technical basis documents, applying thorium surface contamination limits, internal dosimetry program, background subtraction and critical level for ET1 dosimeters, calibration factors, estimating the shallow dose equivalent using HBG element four readings, and dosimetry quality control program information.	07/18/2011	403
State Contacted: See description	State was not contacted due to Y-12 being an active Department of Energy site.	NA	NA
Claimant Provided	Work products from inter-agency working groups - links between exposure to occupational hazards and illnesses in the DOE contractor workforce and a hearing before the workers' compensation board state of New York.	04/18/2005	2
College Park NARA	Meteorological conditions, machining of uranium metal, and monthly status and progress reports.	08/17/2010	7
Colorado State University Library	A cost/benefit study of a formal safety program.	04/10/2006	1
Curtiss-Wright	Shipping information and orders.	04/24/2009	1
Department of Labor/Paragon	Background report and evaluation of resurvey requirements for the former atomic energy commission portion of the Lake Ontario Ordinance Works, request for scrap evaluation, shipment of Schenectady wastes to Oak Ridge, and a visit from Cotter Corporation personnel.	12/30/2008	5

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
DOE Argonne National Laboratory (ANL-E)	Organization of National Nucleonics Program and plutonium scrap processing information.	04/02/2008	4
DOE Brookhaven National Laboratory	Ambient air monitoring parameters at DOE facilities.	03/01/2006	1
DOE Germantown	Beryllium history, monthly accountability, thorium information, site history, and Manhattan District history.	03/07/2011	6
DOE Hanford	Annual and monthly progress reports, environmental monitoring and protection committee information, smelting uranium-contaminated ferrous metal scrap, production of tritium, and accountability survey data.	07/21/2010	20
DOE Lawrence Berkeley National Laboratory (LBNL)	Laboratory contacts.	02/06/2007	1
DOE Legacy Management - Grand Junction Office	Accomplishments of the National Lead Company of Ohio, Electro Metallurgical weekly production report, requests for material transfers, storage/disposal requests, electromagnetic separation of isotopes at Oak Ridge, results of mobile gamma scanning activities, results of soil sample analysis, return of thorium from Savannah River programs, return of thorium from Davison Chemical, LOOW production report describing materials shipped to Y-12, an accidental radiation excursion at Y-12, and history of Hanford.	03/14/2010	32
DOE Legacy Management - Morgantown	Health and mortality studies of federal nuclear workers, uranium in urine samples, appraisal of occupational medical program, bioassay department highlights report, comparison of FMPC's uranium in urine sample results with Y-12's results, comprehensive epidemiologic data resource, DOE studies finding excess cancer mortality at several DOE nuclear facilities, disposal of thorium residues, Extrusion Plant (RMI) receipts and shipments, progress and production reports and orders, material balance report by facility, plutonium content of NLO feed materials, production order enriched uranium to Y-12, results of uranium urines, thorium shipments, trip reports, and uranium urine exchange program information.	02/03/2011	111

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Air emissions annual report, annual report of the Health and Safety Division, Colonie site receipts of depleted uranium, DOE health and mortality study, environmental reports, Grand Junction processing of feed material scraps, incineration of radioactive solid wastes, major thorium campaigns and accountability documents, radioactive waste shipments, radiological incidents, shipping and receipt documents for enriched uranium and thorium, thorium bioassay investigations, thorium derby metal for Y-12, thorium nitrate specifications, trip reports, and Y-12 Plant thorium powder or pellet procurement specifications.	01/17/2011	58
DOE Los Alamos National Laboratory (LANL)	Excursion at the Oak Ridge criticality experiments facility, nonnuclear consolidation environmental assessment, polonium contamination at Pajarito, low-level mixed waste streams for the DOE complex, radiation excursions at the ORNL critical experiments laboratory, and radioactive waste disposal and related issues.	12/12/2007	7
DOE Oak Ridge Gaseous Diffusion Plant (K-25)	Procedure manual for production plants, compilation of data relating to personnel historical radiation exposures in the Y-12 Plant, and a uranium salvage procedure.	06/09/2005	4
DOE Oak Ridge National Laboratory (X-10)	Radiological incidents, history of the Analytical Chemistry Division of Oak Ridge National Laboratory, Aircraft Nuclear Propulsion Project progress report, cyclotron operations, electromagnetic isotope separations, evaluation of neutron dosimetry, exposures received from typical diagnostic x-ray examinations at ORNL, health physics instrument manual, neutron dosimetry with the ORNL badge, Oak Ridge 86-inch cyclotron, X-ray facility reviews, production of radioisotopes in the ORNL 86-inch cyclotron, quarterly progress report, radiation safety manual, stable isotope separation in calutrons, technical basis for nuclear accident dosimetry, inventory of electromagnetically enriched isotopes, X-10 medical X-ray compliance survey, and Y-12 film monitoring program.	03/30/2011	86

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
DOE Oak Ridge Operations Records Holdings Task Group Vault	Building index, contamination control, discontinuation of Dupont film, employee work history records, external exposure reports, film badge program, foundry beta radiation control, health physics records, internal exposures at Y-12 , personnel participating in decontamination work, monthly health physics report, collection and recovery of airborne tuballoy, radiological incidents, radiological surveys, reduction of radiation exposures, technical basis for beta skin dose calculations at the Y-12 plant, uranium dust concentrations, urinalysis and whole body count information, African Metals invoices, materials in 0101 area - Clinton Engineer Works, and the storage of U-235 from Los Alamos at Clinton Engineer Works.	12/15/2010	98
DOE Office of Scientific and Technical Information (OSTI)	Closed-cycle beta process, alpha II calutron development, uranium recovery by spray cleaning, and thorium receipts.	01/26/2010	6
DOE Paducah Gaseous Diffusion Plant	Alpha hazards from neptunium, computer program for whole body count, disposal of stored "tru" waste, environmental assessments and reports, estimates of transuranium alpha fed to Paducah cascade, exposure assessments, health protection information on uranium metal, in vivo monitoring results, inventory of radioactivity released to environments, land burial of radioactive waste at the Paducah Plant, licensing of byproduct material, neptunium and plutonium plant material balance, dust studies, radiation protection program, radioactive contaminants in Paducah scrap, radioactive effluent release, monitoring and control, radioactive waste management, radiological incidents, study of plutonium and fission products, Paducah information, technical basis for the Centralized External Dosimetry System, trip reports, waste disposal criteria, and Y-12 TLD results that include Paducah area dosimeters.	10/06/2006	15
DOE Portsmouth Gaseous Diffusion Plant	Eighth Analytical Services Forum Paducah Gaseous Diffusion Plant.	09/07/2009	1
DOE Rocky Flats Plant	MED/AEC/DOE External Dosimetry Technology.	10/03/2003	1
DOE Sandia National Laboratories/NM	Technical basis for workplace air monitoring of airborne radioactive material at Y-12 and Ross Aviation shipment surveys and documents.	10/20/2010	3
DOE Savannah River Site	Dosimetry visitors cards.	08/26/2008	1
DOE Weldon Spring	Analysis of long term data on uranium in air.	11/29/2004	1
Dr. Denise DeGarmo Personal Files	Biological research program at Clinton National Laboratories.	11/24/2009	2

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
Environmental Measurements Laboratory (EML) Library	Air sampling for the control of internal exposure from enriched uranium at Y-12 and in vivo counting as a device for evaluating uranium exposure.	01/21/2011	3
Federal Records Center - Atlanta	Uranium tolerances, finger film, and tritium information.	04/29/2004	3
Federal Records Center - Dayton	Radiation dose determinations from indium foils in multi-plant security badges, limits for material from K-25 and Y-12 potentially contaminated with tritium, and dose estimates for a Y-12 incident.	03/03/2006	3
Federal Records Center - Denver	Mortality among radiation workers at a plutonium weapons facility.	06/14/2010	2
Federal Records Center - San Bruno	Beta run reports, personnel medical records handling, personnel assignment logs, schedule for track B, and fuels and materials development programs.	11/12/2010	9
General Atomics	Criticality incident at Oak Ridge.	08/16/2005	1
Hagley Museum & Library	General history of Clinton Engineer Works, Race for the Bomb, the Hanford Story, and uranium experimental program on heat treatment.	09/29/2010	8
Interlibrary Loan	Environmental levels of radioactivity at Atomic Energy Commission Installations and work history reports for oxide conversion facility.	04/06//2010	15
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	Health physics hygiene progress report and the impact of downsizing and reorganization on employee health and well-being at the DOE Y-12 Plant.	01/23/2010	3
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	Fourth Atomic Energy Commission Air Cleaning Conference.	11/30/2007	1
Internet - DOE Legacy Management Considered Sites	Monthly progress report and a preliminary site survey report for the former Elza Gate Warehouse area, Oak Ridge.	12/20/2007	2
Internet - DOE OpenNet	Criticality accident at the Y-12 Plant, declassification of the quantity of enriched lithium produced at Y-12, Manhattan District history, monthly status and progress reports, semiannual reports of the Atomic Energy Commission, operational accidents and radiation exposure experience, release of radioactivity to the environs request by AEC, and uranium dust exposure and lung cancer risk in four uranium processing operations.	10/01/2010	15

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
Internet - DOE OSTI Energy Citations	Clean atmosphere approach to radiological decontamination of concrete surfaces, model for uranium lung clearance at the Y-12 plant, Y-12 discharge of enriched uranium to the sanitary sewer, study of TLD beta calibration factor for exposure to depleted uranium, coaxial germanium detectors in the Y-12 in vivo monitor, disposal of United Nuclear Company materials at the Y-12, environmental survey report, modeling of Elza Gate contaminated material, and a Pinellas Plant feasibility study.	10/27/2010	15
Internet - DOE OSTI Information Bridge	DOE Complex buried waste characterization assessment, Conversion and Blending Facility highly enriched uranium to low enriched uranium as uranium hexafluoride, disposition of highly enriched uranium obtained from the Republic of Kazakhstan environmental assessment, electromagnetically enriched isotopes inventory, environmental evaluation and reports, export license issued for DOE Oak Ridge for shipment of uranium-235, human radiation experiments, in vitro data and comments, list of ERDA radioisotope customers, occupational dose reduction, post construction report for the United Nuclear Corporation disposal site, radiological risk assessment of a radioactively contaminated site, remedial investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, sampling approach for characterization of the Scarboro community, testing of the Y-12 Plant criticality accident alarm system detectors at the Sandia Pulsed Reactor Facility, metal fabrication program for the Clinton Engineering Works and the Hanford Engineering Works including the dummy slug program, waste vitrification projects, Y-12 salvage yard scrap metal characterization study, and Y-12 Plant solid waste management system.	11/15/2010	57
Internet - Environmental Management	Linking Legacies - Wastes.	10/28/2007	1

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
Internet - Google	Accountability and control of sealed radioactive sources, annual site environmental reports, Clinton Engineer Works photos, Clinton Laboratory expands to Y-12 buildings, depleted uranium operations at Y-12, division progress reports, Eastman at Oak Ridge during World War II, environment monitoring assessment and reports, epidemiological studies, evaluation of iodine-131 releases, historical evaluation of the film badge dosimetry program at Y-12, liquid waste disposal at Oak Ridge National Laboratory, major relocation of highly enriched uranium completed at Y-12, Manhattan Engineer District history, neutron and gamma dosimeter intercomparison study, Oak Ridge, Tennessee, warehouses site fact sheet, operating Oak Ridge's "calutrons", radiological incidents, Site X, Oak Ridge, Tennessee (map), status of highly enriched uranium processing capability at Y-12 building 9212, study of metal hydrides, Oak Ridge 86-inch cyclotron, urine bioassay program, personal air sampling (PAS) data in the internal dosimetry program, and Y-12 history and fact sheet.	01/10/2010	245
Internet - National Nuclear Security Administration (NNSA) - Nevada Site Office	Babcock & Wilcox Technical Services cited for violation.	01/23/2010	1
Internet - NRC Agencywide Document Access and Management (ADAMS)	DOE inventory report, evaluation of the potential for recycling of scrap metals from nuclear facilities, feasibility study for the United Nuclear Corporation disposal site at the Oak Ridge Y-12, integrated data base: U.S. spent fuel and radioactive waste inventories, projections, and characteristics, and a soil management plan for the Oak Ridge Y-12.	10/27/2010	9
Iron Mountain Storage Facility	Survey of Control Over Source and Special Nuclear Materials National Distillers and Chemicals Corporation.	09/11/2006	1
Kansas City Plant	Statement of Dr. Victor H. Reis, before the subcommittee on Military Procurement Committee on National Security, US House of Representatives.	10/01/2004	1
Mesa State College, CO	Recovery of uranium from carnotite ores and progress report of carnotite studies.	11/19/2010	6
Metals & Controls Corp	Analysis of Possible Nuclear Material Losses and Possible Liabilities Associated with Present Fuel Manufacturing.	08/24/2004	1
Mound Museum	Disposition of depleted salvage material, exposure to polonium from a neutron source, and fabrication of weapon components.	07/10/2008	5

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
NARA - Atlanta	AEC handbook on Oak Ridge operations, annual health protection review, bioassay results and procedures, calutron beam study, control of radiation hazards by Carbide and Carbon Chemicals Division, environmental data, equipment numbering system, film badge program description, hazards of piles at Y-12, monthly accountability reports, organization charts, personnel exposure data, progress reports, radiological and criticality incidents, radiological surveys, report of annual health protection review - New Brunswick Lab, reports of destruction of classified material, shipments from Metal Hydrides to AEC facilities, shipping receipts, work done at Iowa State college, and handling fissionable material.	12/10/2010	112
NARA - Kansas City	Historical Information from Property Insurance Association on Niagara Falls Storage Site / African Metals Leased Areas.	06/24/2005	1
National Technical Information Service (NTIS)	Feasibility study of the correlation of lifetime health and mortality experience of AEC and AEC contractor employees.	08/21/2006	2
New York State Department of Environmental Conservation	Recovery of Uranium from Sylvania Scrap, contract no. AT(40-1).	07/31/2008	2
NIOSH	Audit report confirmatory bioassay testing at selected sites, highly enriched uranium safety and health vulnerabilities associated with storage of highly enriched uranium, Los Alamos Scientific Laboratory information, nondestructive testing of uranium, radioactive waste shipment, recycled uranium mass balance project, history of the Oak Ridge National Laboratory's first 25 years, strikes at Y-12, trip reports, and worker outreach meeting minutes.	10/19/2010	16
NIOSH/SC&A	BWXT-ORAU correspondence 2003-2005, recycled uranium project report, highly enriched uranium working group report, NP237-U238 alloy radiation safety requirements, remarks on personnel monitoring at Y-12, technical basis document for the Internal Dosimetry Program at the Y-12, uranium urinalysis program, and Y-12 complex description.	02/05/2009	15
Oak Ridge Library for Dose Reconstruction	Status report on Clinch River study, high-flux isotope reactor description, and engineering development of hydraulic fracturing as a method for permanent disposal of radioactive wastes.	03/03/2011	3

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
Oak Ridge Associated Universities (ORAU)	Brief history of the Y-12 external monitoring program, correction factors for film badge data, data collection, validation, and description for mortality studies, dosimetry records and radiation hazards questionnaire, film badge data, names of persons having dosimetry information, radiation dosimetry for epidemiologic lung cancer study, history of buildings at Y-12, and information on the calutron program for uranium enrichment.	12/17/2010	14
ORAU Team	Accounting for incomplete personal monitoring data on penetrating gamma doses, exposure matrix for the Mallinckrodt Chemical Company, effect of threshold energy and angular response of NTA film on missed neutron dose at Y-12, annual report radiation exposures for DOE and contractor employees, radiological incidents, external radiation monitoring at Y-12, health and mortality among contractor employees at DOE facilities, evaluation of the film badge dosimetry program at Y-12, historical evaluation of the film badge dosimetry program at Y-12, potential missed dose to nuclear weapons assemblers, specific tables of isotopic production, Tiger Team assessment of the Pantex Plant, Y-12 exposure database, and analysis of electronic personnel exposure data from Y-12.	05/02/2011	75
Sanford Cohen & Associates (SC&A)	Assessment for acceptance of enriched uranium at Y-12, radiation worker health at Y-12, Oak Ridge reservation annual site environmental report, photographic film as a pocket radiation dosimeter, and recycled uranium mass balance project information.	12/11/2008	8
SC&A - Atlanta NARA	Glove decontamination and thorium metal processes.	09/26/2003	2
SC&A - Idaho National Engineering Laboratory	Environmental report and airborne radionuclide waste management information.	06/24/2010	3
Science Applications International Corporation (SAIC)	Annual summary of whole body radiation exposures to external penetrating radiation.	09/02/2004	8
Southern Illinois University	Nuclear fuel fabrication, Oak Ridge site description, observations on uranium exposures, and visit requests.	10/29/2008	7
University of Rochester	Return of Uranium Peroxide to Oak Ridge.	08/20/2008	1
University of Tennessee Library	Creation of Clinton Engineer Works and a health physics report.	11/16/2010	4

Table A1-1: Data Capture Synopsis for the Y-12 Plant			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded To SRDB**
Unknown	Annual radiation dose reports, annual environmental reports, designation of race tracks by number - Y12 and extension, dosimeter response characterization, estimation of radiation doses to the lungs of early uranium workers, excretion of uranium from mixed exposures under industrial conditions, fifth semiannual report of the atomic energy commission, flow of materials through the nuclear weapons complex, glossary of Y-12 coded terminology, health physics survey instruments used at Clinton, in vivo method to determine uranium lung burden, Mallinckrodt Plant inspections, miscellaneous Fernald documents, monthly status and progress reports, neutron dose equivalent and energy spectra measurements at ORNL and Y-12, overview of the history of Y-12, protective equipment evaluation, radiation safety manual, radiological incidents, radiological surveys, relationship between in vivo and urinalysis data collected, Rocky Flats site history, Simonds Saw & Steel material balance report, Westinghouse Nuclear Fuels Division and Westinghouse Atomic Power Development information, and X-ray radiation measurements in calutron cubicles.	02/10/2011	227
Westinghouse Site (MO)	Accidental radiation excursion at Y-12, estimated lung exposure, in vivo count results, and procedures and assignments for restricted personnel.	04/09/2009	7
TOTAL			**1,791**

Table A1-2: Internet Database Searches for the Y-12 Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded To SRDB**
NOTE: The normally-prescribed set of publicly-accessible Internet database searches was not performed for this evaluation because sufficient information already had been obtained through searches conducted for the previous three Y-12 evaluation reports.			

Table A1-3: OSTI Documents Requested for the Y-12 Plant			
Document Number	**Document Title**	**Requested Date**	**Received Date**
TID-5210 REF ID: 40189	Vacuum Problems and Techniques dated 1/1/1950	10/19/2007	11/26/2007
Y-681 REF ID: 40302	Electromagnetically Enriched Isotopes: Inventory, October 31, 1950 dated 10/31/1950	10/19/2007	11/26/2007
Y-727 REF ID: 40305	Electromagnetically Enriched Isotopes: Inventory, February 28, 1951 dated 2/28/1951	10/19/2007	11/26/2007
Y-772 REF ID: 40299	Electromagnetically Enriched Isotopes: Inventory, May 31, 1951 dated 5/31/1951	10/19/2007	11/26/2007
Y-783 REF ID: 40303	Electromagnetically Enriched Isotopes dated 6/30/1951	10/19/2007	11/26/2007
Y-790 REF ID: 40304	Electromagnetically Enriched Isotopes: Inventory, July 31, 1951 dated 7/1/1951	10/19/2007	11/26/2007
Y-819 REF ID: 40298	Electromagnetically Enriched Isotopes: Inventory, September 30, 1951 dated 9/30/1951	10/19/2007	11/26/2007
ORNL-1284 REF ID: 44484	Electromagnetically Enriched Isotopes: Inventory, April 30, 1952 dated 4/30/1952	10/19/2007	05/07/2008
ORNL-1355 REF ID: 44486	Electromagnetically Enriched Isotopes: Inventory, July 31, 1952 dated 7/31/1952	10/19/2007	05/07/2008
ORNL-1489 REF ID: 44490	Electromagnetically Enriched Isotopes: Inventory, January 31, 1953 dated 3/17/1953	10/19/2007	05/07/2008
ORNL-1568 REF ID: 44492	Electromagnetically Enriched Isotopes: Inventory, May 31, 1953 dated 1/1/1953	10/19/2007	05/07/2008
ORNL-1640 REF ID: 44502	The Inventory of Electromagnetically Enriched Isotopes dated 10/31/1953	10/19/2007	05/07/2008
ORNL-1691 REF ID: 44506	The Inventory of Electromagnetically Enriched Isotopes dated 3/5/1954	10/19/2007	05/07/2008
ORNL-1428 REF ID: 44487	Electromagnetically Enriched Isotopes: Inventory, October 31, 1952 dated 10/31/1952	10/19/2007	05/09/2008
AECD-4084 REF ID: 49009	Gaseous Flow dated 8/27/1946	10/19/2007	09/04/2008
CF-60-1-17 REF ID: 49012	Supplementary Report No. 1 on Vacuum Systems dated 1/6/1960	10/19/2007	09/04/2008
Y/DQ-40 REF ID: 59682	Technical Basis for the Internal Dosimetry Program at the Y-12 Plant dated March 2, 1992	01/05/2009	02/24/2009

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Attachment 2: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Aluminum-26m													b				
Aluminum-28																	
Antimony-121										305 mg	112 mg						
Antimony-122										961 mCi	4,735 mCi						
Antimony-123											20 mg						
Antimony-124										21 mCi	207 mCi						
Antimony-125										52,100 mCi	4 mCi						
Antimony-Be									278 mCi								
Argon-37									5 mCi	6 mCi	36 mCi						
Argon-38									11 mCi	9 mCi	6 cc						
Arsenic-74													3 Ci				
Arsenic-76											73 mCi						
Arsenic-77										28 mCi	32 mCi						
Barium-130										20 mg	81 mg						
Barium-131										19 mCi	3 mCi						
Barium-132										10 mg	55 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a “b” indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Barium-133										5 mCi	23 mCi						
Barium-134											540 mg						
Barium-135										20 mg	50 mg						
Barium-136											50 mg						
Barium-137											50 mg						
Barium-138										50 mg	300 mg						
Barium-140									9 mCi	13 mCi	688 mCi						
Beryllium-7									933 mCi				b				
Bismuth-209													b				
Bismuth-210									7 mCi	982 mCi	92 mCi						
Boron-10										10,260,721 mg	12,589,425 mg						
Boron-11										132,194 mg	313,338 mg						
Boron-13																	
Bromine-79										1 mg	20 mg						
Bromine-82									16 mCi	2 mCi	1,889 mCi						
Cadmium-106											10 mg						
Cadmium-108											59 mg						
Cadmium-109													b				

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Cadmium-111										367 mg							
Cadmium-112										40 mg	136 mg						
Cadmium-113										40 mg	41 mg						
Cadmium-114										100 mg	330 mg						
Cadmium-115									147 mCi	233 mCi	9 mCi						
Cadmium-115m									21 mCi	20 mCi	33 mCi						
Cadmium-116										25 mg	100 mg						
Calcium-40										225 mg	1,200 mg						
Calcium-42											235 mg						
Calcium-43										3 mg	63 mg						
Calcium-44							b			65 mg	21 mg						
Calcium-45									8 mCi	38 mCi	2,852 mCi						
Calcium-46										40 mg	3 mg						
Calcium-48										259 mg	20 mg						
Carbon-12										10 mg	10 mg						
Carbon-13											1 mg						
Carbon-14										1,983 mCi							

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a “b” indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Cerium-136											20 mg						
Cerium-138																	
Cerium-140										25 mg	230 mg						
Cerium-141									5,782 mCi	9,313 mCi	88 mCi						
Cerium-142										20 mg	507 mg						
Cerium-144									235 mCi	99 mCi	1686 mCi						
Cesium-132													b				
Cesium-134									1,001 mCi	2,344 mCi	1,562 mCi						
Cesium-136																	
Cesium-137										1,789 mCi			b				
Cesium-138										5 mg							
Chlorine-35										2,650 mg	2,017 mg						
Chlorine-36									2,366 mCi		10 mCi						
Chlorine-37										75 mg	100 mg						
Chromium-49												b					
Chromium-50										4303 mg	527 mg						
Chromium-51									4 mCi	8,475 mCi	7,384 mCi						
Chromium-52										28,062 mg	110 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a "b" indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Chromium-53										120 mg	40 mg						
Chromium-54										2,929 mg	10 mg						
Cobalt-55																	b
Cobalt-56													b				b
Cobalt-57									7,635 mCi	4,031 mCi	4 mCi		4 Ci				b
Cobalt-58									23 mCi	4 mCi	158 mCi						b
Cobalt-60										55 mCi							
Cobalt-61													b				
Copper-63										1,360 mg	30,110 mg						
Copper-64									2 mCi		16,642 mCi						
Copper-65										185 mg	30,476 mg						
Deuterium-Zr										3,834 mCi	2 mCi						
Dysprosium-156											2 mg						
Dysprosium-157																	
Dysprosium-160										20 mg	167 mg						
Dysprosium-161										2,002 mg	682 mg						
Dysprosium-162										2,000 mg	687 mg						
Dysprosium-163										1,786 mg	762 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a “b” indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Dysprosium-164											2,264 mg						
Erbium-150													b				
Europium							b										
Europium-145																b	
Europium-149													b		b		
Europium-151										3,540 mg	3,790 mg						
Europium-152/154									7 cc	6.5 cc	33 mCi						
Europium-153										3,415 mg	3,787 mg						
Europium-155										76 mCi	0 mCi						
Fissions Products									22 mCi	11 mCi	999 mCi						
Fluorine-18																	
Gadolinium-149													b				
Gadolinium-152										78 mg	59 mg						
Gadolinium-153													b				
Gadolinium-154										35 mg	510 mg						
Gadolinium-155										896 mg	1,050 mg						
Gadolinium-156										48 mg	1,000 mg						
Gadolinium-157										1,373 mg	1,051 mg						
Gadolinium-158										128 mg	1,155 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a "b" indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Gadolinium-160										264 mg	1,440 mg						
Gallium-64																	
Gallium-67						75 Ci											
Gallium-69										140 mg	1,203mg						
Gallium-71										280 mg							
Gallium-72										890 mCi	14 mCi						
Germanium-68													b				
Germanium-70										10,251 mg	360 mg						
Germanium-72										15,487 mg							
Germanium-73										3,224 mg							
Germanium-74										34,586 mg	1,830 mg						
Germanium-76										5,049 mg							
Gold-195													b				
Gold-198										10 mCi	175,654 mCi						
Gold-199									305 mCi	36,091 mCi	60 mCi						
Hafnium-174										17 mg	29 mg						
Hafnium-176										15 mg	60 mg						
Hafnium-177										858 mg							

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a "b" indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Hafnium-178										20 mg	35 mg						
Hafnium-179										889 mg	76 mg						
Hafnium-180										150 mg	102 mg						
Hafnium-181										29 mCi	268 mCi						
Helium-3										97 mCi							
Holmium							b										
Hydrogen-3									5,195 cc								
Indium-113										742 mg							
Indium-114											101 mCi						
Iodine-124													b				
Iodine-125									65 mCi				b				
Iodine-127																b	
Iodine-129									13.5 mCi	90 mCi						b	
Iodine-130									4 mg				b				
Iodine-131									50.8 mCi	10.4 mg						b	
Iridium-190														b			
Iridium-191										12 mg	5 mg						
Iridium-193										10 mg	250 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a "b" indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Iron-52												b					
Iron-54										2,873 mg	525 mg						
Iron-55									60 mCi	33 mCi	111 mCi		b				
Iron-55/59											79 mCi						
Iron-56										3,859 mg	3,026 mg						
Iron-57										25 mg	2,953 mg						
Iron-58										329 mg	675 mg						
Iron-59									589 mCi	146 mCi	820 mCi						
Lanthanum-139																b	
Lanthanum-140											131 mCi						
Lead-204										5 mg	135 mg						
Lead-206										406 mg	50 mg						
Lead-207										330 mg	905 mg						
Lead-208										1,350 mg	236 mg						
Lead-209						1.45 Ci											
Lithium-6									6,300 mg	1,292,922 mg	4,768,458 mg						
Lithium-7										58,118 mg	4,585,329 mg						
Lutetium-174													b				

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a "b" indicates that the isotope was used in Atomic Cross Sectional Studies.
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Magnesium-24										746 mg	250 mg			b			
Magnesium-25									50 mg	1,103 mg	381 mg						
Magnesium-26										495 mg							
Magnesium-27																	
Manganese-51												b					
Manganese-52												b	b				
Manganese-52m												b					
Manganese-54										411 mCi							
Manganese-57																	
Mercury-197										6 mCi	20 mCi						
Mercury-198											35 mg						
Mercury-199										2 mg	10 mg						
Mercury-200											45 mg						
Mercury-201										7 mg	15 mg						
Mercury-202										58 mg	94 mg						
Mercury-203									22 mCi		878 mCi						
Mercury-204										27 mg	40 mg						
Molybdenum-92										20 mg	260 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
A yellow or light-shaded data value cell with no entry indicates the presence of the radioisotope.
A yellow or light-shaded data value cell with a “b” indicates that the isotope was used in Atomic Cross Sectional Studies.
A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12																	
Isotope	**1947**	**1948**	**1949**	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1961**	**1963**	**1965**	**1967**	**1968**
Molybdenum-94										14 mg	40 mg						
Molybdenum-95										30 mg	2,920 mg						
Molybdenum-96										20 mg	5 mg						
Molybdenum-97										10 mg	10 mg						
Molybdenum-98										35 mg	50 mg						
Molybdenum-100										210 mg							
Neodymium-142											5,300 mg						
Neodymium-143										3,859 mg	3,260 mg						
Neodymium-144										200 mg	5,200 mg						
Neodymium-145										1,354 mg	2,810 mg						
Neodymium-146										290 mg	5,075 mg						
Neodymium-147										248 mCi	8 mCi						
Neodymium-148										40 mg	53 mg						
Neodymium-150										60 mg	117 mg						
Nickel-58										4,550 mg	1,255 g						
Nickel-60										8,117 mg	190 mg						
Nickel-61										72 mg	20 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12																	
Isotope	**1947**	**1948**	**1949**	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1961**	**1963**	**1965**	**1967**	**1968**
Nickel-62										2,575 mg	100 mg						
Nickel-63									3 mCi	7 mCi	90 mCi						
Nickel-64										210 mg	60 mg						
Niobium-92														b			
Niobium-93																b	
Niobium-94																b	
Niobium-95									76 mCi	77 mCi	56 mCi						
Nitrogen-13																	
Nitrogen-15											13,843 mg						
Osmium-190														b			
Osmium-191									47 mCi	55 mCi	43 mCi						
Palladium-102											10 mg						
Palladium-103													b				
Palladium-104										30 mg							
Palladium-105										30 mg							
Palladium-106										30 mg							
Palladium-108										15 mg	10 mg						
Palladium-109										2 mCi	190 mCi						
Palladium-110										20 mg	75 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Phosphorus-32										120 mCi							
Platinum-185													b				
Platinum-190											11 mg						
Platinum-192										3 mg	12 mg						
Platinum-194										6,016 mg	40 mg						
Platinum-195										25 mg							
Platinum-196										60 mg	155 mg						
Platinum-198										10 mg	5 mg						
Plutonium (feed)											110 g						
Plutonium-240									1,110 mCi		4.4 g						
Plutonium-241											0.9 g						
Plutonium-242											0.107 g						
Polonium-207																	
Polonium-208					2.6 g												
Polonium-209													b				
Polonium-211																	b
Potassium-38m												b					
Potassium-39										4,120 mg	1,787 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Potassium-40										2 mg	19 mg						
Potassium-41									30 mg	1,720 mg	201 mg	b					
Potassium-42											8,333 mCi						
Potassium-44								0.5 g									
Praseodymium-142									302 mCi	2,757 mCi							
Praseodymium-143										12 mCi	10 mCi						
Promethium-147									1 mCi	8 mCi							
Promethium-148													b				
Radium-219																	b
Rhenium-185										55 mg	1,220 mg						
Rhenium-186											61 mCi						
Rhenium-187										40 mg	75 mg						
Rubidium-74													b				
Rubidium-85										5,708 mg	200 mg						
Rubidium-86											1,978 mCi						
Rubidium-87										3,864 mg	265 mg						
Ruthenium-96											36 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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A blue or dark-shaded data value cell indicates stable isotopes.

Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Ruthenium-98										3 mg	12 mg						
Ruthenium-99									75 mg	9 mg	126 mg						
Ruthenium-100										9 mg	81 mg						
Ruthenium-101									150 mg	9 mg	116 mg						
Ruthenium-102									5 mg	215 mg	30 mg						
Ruthenium-103									628 mCi	2,190 mCi	44 mCi						
Ruthenium-104									75 mg	54 mg	41 mg						
Ruthenium-106									209 mCi	74 mCi	420 mCi						
Samarium-144										150 mg	585 mg						
Samarium-145															b		
Samarium-147										285 mg	1,180 mg						
Samarium-148											1,180 mg						
Samarium-149										1,495 mg	1,060 mg				b		
Samarium-150										285 mg	1,000 mg						
Samarium-152										550 mg	1,150 mg						
Samarium-153									717 mCi	330 mCi	136 mCi						
Samarium-154										294 mg	2,407 mg						
Scandium-40																	

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Scandium-43												b					
Scandium-44												b					
Scandium-44m												b	b				
Scandium-46										114 mCi	80,350 mCi						
Selenium-74										110 mg	14 mg						
Selenium-75									167 mCi		333 mCi						
Selenium-76											56 mg						
Selenium-77										60 mg	110 mg						
Selenium-78											100 mg						
Selenium-80										55 mg	200 mg						
Selenium-82										80 mg	310 mg						
Silicon-28										5,310 mg	40 mg			b			
Silicon-29										30 mg	559 mg						
Silicon-30									50 mg		30 mg						
Silver-107										830 mg	100 mg						
Silver-109										1,050 mg	2,200 mg						
Silver-110									420 mCi	421 mCi	273 mCi						
Silver-111									672 mCi	368 mCi	100 mCi						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12																	
Isotope	**1947**	**1948**	**1949**	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1961**	**1963**	**1965**	**1967**	**1968**
Sodium-22													b				
Sodium-24									59 mCi	31 mCi	2,602 mCi						
Strontium-84										12 mg	151 mg						
Strontium-85									1,676 mCi				b				
Strontium-86										2,826 mg	765 mg						
Strontium-87										1,790 mg	1,000 mg						
Strontium-88										4,016 mg	210 mg						
Strontium-89									12 mCi	1,474 mCi	1,439 mCi						
Sulfur-32										220 mg	50 mg						
Sulfur-33										45 mg	8 mg						
Sulfur-34										6 mg	135 mg						
Sulfur-35									1,924 mCi	1,250 mCi							
Technicium-99									75 mCi	161 mCi	82 mCi						
Tellurium-120											1 mg						
Tellurium-122										4 mg	100 mg						
Tellurium-123											100 mg						
Tellurium-123m											115 mg						
Tellurium-124											300 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Tellurium-125										3,200 mg	430 mg						
Tellurium-126										50 mg	430 mg						
Tellurium-128											115 mg						
Tellurium-130										1,050 mg	300 mg						
Thallium-203											1,007 mg						
Thallium-204									1 mCi	0.37 mCi	0 mCi						
Thallium-205											1,014 mg						
Thorium-223																	b
Thorium-230						150 g					259 mCi						
Thorium-nat											0.1966 g						
Thulium-168							b						b				
Tin-112										3 mg							
Tin-113									1,712 mCi	251 mCi	3,000 g						
Tin-114											5 mg						
Tin-115										508 mg	5 mg						
Tin-116										1,714 mg	165 mg						
Tin-117										1,080 mg	165 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12																	
Isotope	**1947**	**1948**	**1949**	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1961**	**1963**	**1965**	**1967**	**1968**
Tin-118										1,790 mg	120 mg						
Tin-119											170 mg						
Tin-120										837 mg	234 mg						
Tin-122										150 mg	20 mg						
Tin-124										150 mg	25 mg						
Titanium-44													b				
Titanium-45												b					
Titanium-46										4,763 mg	90 mg						
Titanium-47										5,576 mg	25 mg						
Titanium-48										53,655 mg	1,050 mg						
Titanium-49										4,178 mg	2,912 mg						
Titanium-50										4,086 mg	20 mg						
Tungsten-180										18 mg	13 mg						
Tungsten-181													b				
Tungsten-182										8,500 mg	499 mg						
Tungsten-183										3,546 mg	2,079 mg						
Tungsten-184										186 mg	530 mg						
Tungsten-185									118 mCi	26 mCi	29 mCi						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Tungsten-186										7,185 mg	650 mg						
Tungsten-187									0 mCi	95 mCi	79 mCi						
Turbium							b										
Uranium (feed)					4.265 Ci												
Uranium-227																	b
Uranium-234			18 g per run	100 g per run	13,600 g	4.945 Ci					5 mCi						
Uranium-235					10 mg						2.308 g						
Uranium-236					10.7 mg	50 mg					129.5143 g						
Uranium-238					1.8 g	352 mg					0.4798 g						
Vanadium-47												b					
Vanadium-48												b	b				
Vanadium-50										100 mg	2 mg						
Vanadium-51										100 mg							
Yttrium-87													b				
Yttrium-88													b				
Yttrium-90									126 mCi	35 mCi	2,288.294 g						
Yttrium-91									0 mCi	40 mCi	279 mCi						
Zinc-63						2 g											
Zinc-64										351 mg	328 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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Table A2-1: Stable and Radioactive Isotopes Produced and/or Separated and Purified at Y-12

Isotope	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1961	1963	1965	1967	1968
Zinc-65									250 mCi	940 mCi	1,068 mCi						
Zinc-66										4,993 mg	31 mg						
Zinc-67										135 mg							
Zinc-68										2,917 mg	151 mg						
Zinc-70										103 mg	25 mg						
Zinc-72													b				
Zirconium-89														b			
Zirconium-90										10,046 mg	4,783 mg				b		
Zirconium-91										3,040 mg	150 mg						
Zirconium-92										4,722 mg							
Zirconium-94										4,313 mg							
Zirconium-95											1,455 mCi						
Zirconium-96										122 mg	22 mg						

Source: NIOSH, 2006a; NIOSH, 2006b
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