SEC Petition Evaluation Report
Petition SEC-00174

Report Rev #: 0 Report Submittal Date: December 17, 2010

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Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00174	83.13	June 9, 2010	August 16, 2010	Wah Chang

Petitioner Class Definition

All employees who worked in all buildings at the Wah Chang facility from January 1, 1971 through January 11, 1979.

Class Evaluated by NIOSH

All employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, and the residual radioactivity period from January 1, 1973 through October 31, 2009.

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

All employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
N/A			

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
N/A	

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Evaluation Report Summary: SEC-00174, Wah Chang

This evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addresses a class of employees proposed for addition to the Special Exposure Cohort (SEC) per the *Energy Employees Occupational Illness Compensation Program Act of 2000*, as amended, 42 U.S.C. § 7384 *et seq.* (EEOICPA) and 42 C.F.R. pt. 83, *Procedures for Designating Classes of Employees as Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act of 2000*.

Petitioner-Requested Class Definition

Petition SEC-00174 was received on June 9, 2010, and qualified on August 16, 2010. The petitioner requested that NIOSH consider the following class: *All employees who worked in all buildings at the Wah Chang facility from January 1, 1971 through January 11, 1979.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified the petitioner-requested class. NIOSH evaluated the following class: All employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, and the residual radioactivity period from January 1, 1973 through October 31, 2009.

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

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, 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 class under evaluation was modified (see Section 3.0 below) because NIOSH does not have access to exposure data during the covered period and does not believe that bounding exposure limits can be established. NIOSH can establish bounding limits for the residual period, January 1, 1973 through December 31, 2009.

Feasibility of Dose Reconstruction

NIOSH finds it is not feasible to estimate internal or external exposures with sufficient accuracy for all workers at the site from January 1, 1971 through December 31, 1972. While it is apparent that Wah Chang did have a monitoring program in place at the time of the depleted uranium operations, NIOSH does not have access to the records. With the exception of this class, per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances; or (2) estimate radiation doses more precisely than an estimate of maximum dose. Information available from the site profile and additional resources is sufficient to document or estimate the maximum internal and external

potential exposure to members of the proposed class under plausible circumstances during the specified period January 1, 1973 through December 31, 2009.

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

- NIOSH finds that it is likely feasible to reconstruct occupational medical dose for Wah Chang workers with sufficient accuracy for the operational period

- Principal sources of internal radiation for members of the proposed class included exposures to inhalation and ingestion of depleted uranium dusts and fumes associated with the electron beam furnace uranium-melting operations and ingestion of dust or fumes from uranium and thorium wastes.

- A source term or dose reconstruction method can be established for uranium materials. However, the quantities of thorium from other processes could not be determined. NIOSH has determined that the available data are inadequate to reconstruct internal exposures to all thorium by-products resulting from zirconium extraction activities performed during the Wah Chang operational period January 1, 1971 through December 31, 1972.

- NIOSH has determined that reconstruction of internal doses is feasible for the residual period from January 1, 1973 through October 31, 2009.

- Principal sources of external radiation for members of the proposed class included exposures to gamma and beta radiation associated with handling and working in proximity to uranium and uranium compounds as well as trace quantities of naturally-occurring radioactive materials in the U-238 and Th-232 decay series present in zirconium sands.

- Although there are methods available to support bounding external uranium dose for the Wah Chang operational period, NIOSH has not identified sufficient information or data to support bounding the thorium exposures for the operational period. For that period, NIOSH was unable to determine a worker's actual work locations or whether a worker was restricted to one location. Workers may have been able to move about freely; therefore, all workers' exposures will be treated similarly. Consequently, NIOSH has determined that reconstruction of external doses for Wah Chang workers is not feasible for the operational period from January 1, 1971 through December 31, 1972.

- NIOSH has determined that reconstruction of external doses is feasible for the residual period from January 1, 1973 through October 31, 2009.

- Pursuant to 42 C.F.R. § 83.13(c)(1), NIOSH determined that there is insufficient information for the 1971-1972 operational period 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 Wah Chang during the period from January 1, 1971 through December 31, 1972, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is required because NIOSH has determined that it does not have sufficient information to estimate dose for the members of the proposed class from January 1, 1971 through December 31, 1972.

For the period January 1, 1973 through December 31, 2009, a health endangerment determination is not required because NIOSH has determined that it has sufficient information to estimate dose for the members of the proposed class.

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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: Ray Clark, Oak Ridge Associated Universities. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, and the residual radioactivity period from January 1, 1973 through October 31, 2009. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

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

This evaluation was conducted in accordance with the requirements of EEOICPA, 42 C.F.R. pt. 83, and the guidance contained in the Division of Compensation Analysis and Support's (DCAS) *Internal Procedures for the Evaluation of Special Exposure Cohort Petitions*, OCAS-PR-004.[1]

2.0 Introduction

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

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

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

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioner(s) and to the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[3]

3.0 SEC-00174 Wah Chang Class Definitions

The following subsections address the evolution of the class definition for SEC-00174, Wah Chang. When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00174 was received on June 9, 2010, and qualified on August 16, 2010. The petitioner requested that NIOSH consider the following class: All employees who worked in all buildings at the Wah Chang facility from January 1, 1971 through January 11, 1979.

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Wah Chang workers in question. NIOSH

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

deemed the following information and affidavit statements sufficient to qualify SEC-00174 for evaluation:

> My father, *[name redacted]*, worked at Wah Chang from March, 1951 to January 11, 1979, without being monitored and without proper protection.
>
> To the best of my knowledge, no documents exist showing internal or external exposure.

Based on its Wah Chang research and data capture efforts, NIOSH determined that almost no internal or external data are available for Wah Chang workers during the time period under evaluation. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that internal and external radiation exposures and radiation doses were not adequately monitored at Wah Chang, either through personal monitoring or area monitoring. The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified and expanded the petitioner-requested class. The Department of Energy has designated an operational period and a residual radioactivity period for the site. The operational period corresponds to the Wah Change contract for processing depleted uranium for the Y-12 site. Therefore, NIOSH defined the following class for further evaluation: All employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, and the residual radioactivity period from January 1, 1973 through October 31, 2009.

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

Based on its research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As a standard practice, NIOSH completed an extensive database and Internet search for information regarding Wah Chang. 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 1 contains a summary of Wah Chang documents. The summary provides data capture details and general descriptions of the documents retrieved.

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

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement, or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. The Site Profile for a small site may consist of a single document. There is no TBD for the Wah Chang site. However, as part of NIOSH's evaluation detailed herein, it examined the following TBD for insights into Wah Chang operations or related topics/operations at other sites:

- *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals*, Battelle-TBD-6000, PNWD-3738, Rev 0; Battelle; December 13, 2006; SRDB Ref ID: 30671

4.2 Technical Information Bulletins and Procedures

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

- *Estimation of Ingestion Intakes*, OCAS-TIB-009, Rev. 00; Office of Compensation Analysis and Support; April 13, 2004; SRDB Ref ID: 22397

- *Estimating the Maximum Plausible Dose to Workers at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0004, Rev. 03 PC-2; Oak Ridge Associated Universities; December 6, 2006; SRDB Ref ID: 29949

- *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 03 PC-1; Oak Ridge Associated Universities; December 21, 2005; SRDB Ref ID: 20220

- *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0070, Rev. 00; Oak Ridge Associated Universities; March 10, 2008; SRDB Ref ID: 41603

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed four former Wah Chang employees and two former State of Oregon employees. The interviews were conducted by telephone.

- Personal Communication, 2010a, *Personal Communication with Technical Administrator/Radiation Protection Officer (RPO)*; Telephone Interview by ORAU Team; September 13, 2010; SRDB Ref ID: 90796

- Personal Communication, 2010b, *Personal Communication with Metallographer*; Telephone Interview by ORAU Team; September 13, 2010; SRDB Ref ID: 90802

- Personal Communication, 2010c, *Personal Communication with Manager of Aerospace Projects*; Telephone Interview by ORAU Team; October 6, 2010; SRDB Ref ID: 90799

- Personal Communication, 2010d, *Personal Communication with Scrap Recovery Technician*; Telephone Interview by ORAU Team and NIOSH representative; October 7, 2010; SRDB Ref ID: 90800

- Personal Communication, 2010e, *Personal Communication with Oregon State Radiation Control Agency*; Telephone Interview by ORAU Team; October 12, 2010; SRDB Ref ID: 90795

- Personal Communication, 2010f, *Personal Communication with Oregon State Radiation Control/Protection Program*; Telephone Interview by ORAU Team; October 12, 2010; SRDB Ref ID: 90801

- Personal Communication, 2010g, *Personal Communication with General Laborer/Furnace Operator;* Telephone Interview by ORAU Team; October 21, 2010; SRDB Ref ID: 90665

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of August 17, 2010)

Table 4-1: No. of Wah Chang Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	4
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1971 through December 31, 1972 [operations]; and January 1, 1973 through October 31, 2009 [residual]).	4
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	4
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	0

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. None of the existing claims have monitoring data.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. Two hundred nine (209) documents in this database were identified as pertaining to Wah Chang. These documents were evaluated for their relevance to this petition. The documents include historical background on company history, inspection reports, dust sampling, air monitoring, monitoring data, the radiological control program, process materials, and process descriptions.

4.6 Documentation and/or Affidavits Provided by Petitioners

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

- *Affidavit from [Authorized Representative]*; June 3, 2010; OSA Ref ID: 112010 (Affidavit, 2010)

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the Wah Chang site from January 1, 1971 through October 31, 2009 and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 Wah Chang Plant and Process Descriptions

Plant History and Description

Beginning in 1947, the U.S. Bureau of Mines (BOM) experimentally produced zirconium and other metals for defense and nuclear technology research in their Albany Research Center in Albany, Oregon. In 1950, BOM constructed a plant to accommodate large-scale production and modification of the process (State of Oregon, 1981). In the early 1950s, the Naval Nuclear Power program required zirconium and BOM was scrambling to assure an adequate supply. In early 1956, the Atomic Energy Commission (AEC) contracted with the Wah Chang company to run BOM's zirconium plant and develop high-purity zirconium for the Navy.

In 1956, Wah Chang purchased land and built a second plant on the 45-acre site in Albany. This is the site represented in the SEC-00174 petition and evaluated for this report. The site began producing zirconium in 1957, using chemical and high-heat processes to separate zircon and silica in zircon silicate sand; reactor- and commercial-grade zirconium sponge and hafnium as were produced as side-products.

Beginning in 1959, Wah Chang partnered with Boeing to develop niobium/columbium alloys for rocket engines and satellites. In the early 1960s, the AEC's aircraft nuclear propulsion project fueled demand for niobium/columbium products and Wah Chang installed additional production facilities for these materials at its Albany plant (Wah Chang Profile, 2007).

In 1962, Wah Chang had 350-400 persons employed at Albany and the facility consisted of 36 buildings (Compliance Report, 1962). NIOSH believes the only buildings involved in the AWE work were the Electron Beam Melting Furnace building (S-6) (discussed below) and the storage facility located at East Front and Fulton Street, Albany (SRDB 82189, pdf p. 3) (License, 1970, pdf pp. 54-57; License, 1971a, pdf pp. 14-18; License, 1978). The S-6 project manager recalled that there were only 7 to 10 people involved in the depleted uranium melting project in S-6 (discussed below) (Personal Communication, 2010c). However, NIOSH was unable to determine actual work locations for Wah Chang workers or whether workers were restricted to one location.

In 1967, Teledyne, Inc., purchased the Wah Chang facilities. During the following decade, Teledyne Wah Chang Albany (TWCA) expanded niobium/columbium production to meet the needs for rocket nozzle skirt extensions, satellite orbit thrusters, MRI equipment, and particle accelerators.

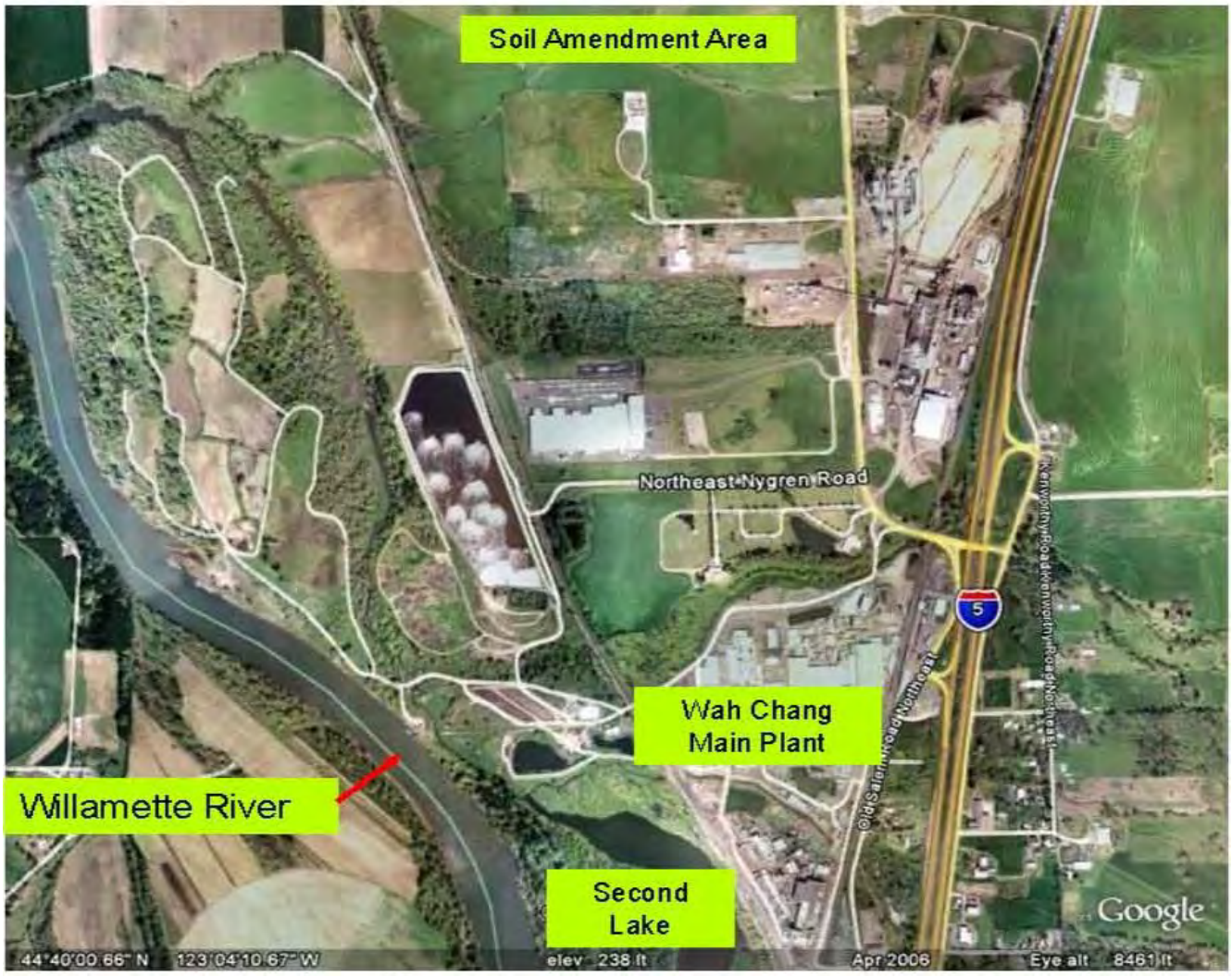
Commercial nuclear application of zirconium and hafnium also grew as Wah Chang supplied material for nuclear power plants. During the early 1970s, TWCA grew to become the world's largest production facility for zirconium and hafnium metals, niobium/columbium and tantalum alloys, and a leading research center for refractory metals (Assessment, 2009; Wah Chang Profile, 2007). These are rare earth materials that are not naturally radioactive. However, they are often found in ore that contains naturally-occurring radioactive materials such as uranium, thorium, and radium. There is no indication that these waste products were ever sold to the U.S. government for use in the atomic weapons program (ERDA, 1977).

TWCA is an active plant used to produce nonferrous metals and products. The site consists of a 10-acre plant site (which contains the plant's former sludge ponds) and a 115-acre farm site (which contains four active wastewater sludge ponds). Portions of the TWCA site are within the Willamette River's 100- and 500-year floodplain. The three-acre Lower River Solids Pond (LRSP) received sludge from TWCA's on-site wastewater treatment plant from 1967 to 1979 and held approximately 75,000 cubic yards of sludge in 1989. Schmidt Lake (0.6 acre) accepted sludge from 1974 to 1979 and held approximately 10,000 cubic yards of sludge in 1989. The sludge in both the LRSP and Schmidt Lake contained heavy metals, organic compounds, and trace levels of radionuclides. Because the ponds contained radioactive materials and a potential source of ground water contamination, TWCA decided to clean up the ponds without waiting for a full site remedial investigation to be completed (EPA, 1989).

S-6 Electron Beam Furnace Process Description

Wah Chang began operating electron beam furnaces for the production of reactive and refractory ingots in 1957. According to a post-1993 document, Wah Chang was operating four electron beam furnaces at the Albany facility in the early 1990s. These furnaces were used to purify and consolidate ingots of niobium/columbium, zirconium, hafnium, vanadium, titanium, tantalum and their alloys. Ingots up to seventeen inches in diameter by 125 inches long were routinely produced by vertical drip melting. The furnaces were commissioned in 1969, 1979, 1986, and 1991 (Electron Beam Furnace, post-1993).

In 1971 and 1972, Wah Chang was subcontracted to Union Carbide Corporation to melt uranium-bearing materials for the Oak Ridge Y-12 plant. In contrast to past AEC contracts with Wah Chang, this was the only contract that involved processing radioactive materials. Operations under this contract were performed subject to a source material license granted by the State of Oregon, an AEC/NRC agreement state (ERDA, 1977). Amendment 10 to Wah Chang’s radioactive material license ORE-0001-1 (issued April 8, 1970) added the task of melting up to 50,000 pounds of thorium and forming the finished product into ingots (License Application, 1970). This license was further amended on March 11, 1971 (Amendment 16) to add depleted uranium (DU) in the amount of up to 50,000 pounds (License, 1971b). The DU melting did occur (discussed below). The license amendment for thorium was written in anticipation of a thorium contract that was never awarded; as a result, the thorium work did not take place (Elimination Recommendation, 1987; Personal Communication, 2010a; Personal Communication, 2010c).



Source: Wah Chang Assessment, 2010

Figure 5-1: Aerial Photo of Wah Chang Site

Under the uranium-related amendment, Wah Chang was to refine DU using an electron beam furnace and a process known as S-6. The actual S-6 furnace was located across the street from the main plant because the Wah Chang management was concerned about the possibility of contamination of the zirconium refining processes (Personal Communication, 2010a). S-6 was located across Old Salem Road. Therefore, the likely location was in the lower right corner of Figure 5-1 to the east of Old Salem Road and Interstate 5.

There were 7 to 10 people involved in the DU project (Personal Communication, 2010c). S-6 was a 300kW furnace which used a transverse direct emission gun and was primarily used for small orders and experimental work (Electron Beam Furnace, post-1993). In the process, a large ingot of metal to be purified was lowered into the furnace. An electron beam melted the metal which then dripped into a copper crucible. Impurities and small amounts of source material were deposited on the furnace

walls. The furnace was periodically cleaned and the deposits were disposed of through Chem Nuclear, Inc. (Inspection Report, 1972). As of March 1, 1977, the only remnant of this contract was approximately five pounds of DU contamination in the decontaminated furnace in the S-6 Building (ERDA, 1977; NORM, 1977). The issue of remaining DU was explored in an interview with a former Wah Chang manager, who stated: "There was no leftover DU stored. We cleaned the furnace and decontaminated it completely. It was made so we could disassemble it completely and we did within two months after the DU operations were over. I was the designer and designed it that way. It was decontaminated down to doing wipes and scans and all contaminated materials were disposed of - I believe at Hanford" (Personal Communication, 2010c).

Zirconium Process Description

Wah Chang began producing zirconium at the Albany plant in 1957. A 2003 planning document states: "Wah Chang has processed about 200 million kilograms of zircon sand during the past thirty years. This sand has contained approximately 0.03% uranium and 0.02% thorium or the equivalent of about 60 thousand kilograms of natural uranium and about 40 thousand kilograms of natural thorium. Wah Chang has made attempts to recover the uranium for use in the nuclear fuel industry, but none have been successful due to various technological and economic obstacles. Wah Chang expects to continue to process zircon at the same rate into the future." (Site D&D, 2003)

The radiological aspects of the zirconium extraction process derive from the fact that zircon sand contains trace quantities of naturally-occurring radioactive materials in the U-238 and Th-232 decay series. The radionuclides of concern in the uranium decay series, because of their toxicities or other characteristics, are Ra-226, radon-222, Po-210, and Th-230. The radionuclides of concern for the thorium decay series are Ra-224 and radon-220 (Wah Chang Operations, 1977).

Zircon sand is a durable crystal in which uranium, thorium, and their decay progeny are tightly bound within the crystal. The durability and tightness of the zircon crystal effectively impedes the release of the radioisotopes, including radon gas, even under severe conditions such as intense heat, submersion in acidic water, and elevated or depleted pressure (Site D&D, 2003).

To produce metal products, Wah Chang dissolves a mixture of zircon and carbon with chlorine under high heat. The resulting chlorides of zirconium, hafnium, and silicon are recovered through condensation. The uranium, thorium, and their progeny are less reactive than the zirconium, hafnium, and silicon atoms under these conditions; consequently, they accumulate in the reaction vessel. In subsequent processing, the zirconium and hafnium chlorides are processed into useful metal products. Silicon tetrachloride is also purified and distributed as a useful product. The uranium, thorium, and their radioactive progeny are extracted from the reaction vessel in a carbonaceous residual waste product known at Wah Chang as "chlorination residue." (Site D&D, 2003)

A portion of the uranium contained in the zircon sand is volatilized in the chlorination process, and is later rejected in the zirconium/hafnium liquid-liquid countercurrent separation process. The aqueous side of the separation process contains most of the uranium. In subsequent processing of this aqueous stream to recover ammonia, the addition of lime (CaO) causes the uranium and other dissolved solids to precipitate from solution and flow to the Wah Chang central wastewater treatment system (Site D&D, 2003).

Other Processes Involving Radioactive Materials

Wah Chang possessed several AEC licenses for thorium in the 1950s and 1960s. However, these licenses all indicate the thorium was in the form of thorium dioxide, and it was used as insulation in Wah Chang's furnaces. Around 1959, these furnaces were dismantled or removed from service; the thorium dioxide was stored on site until a suitable disposal site was found. Final disposition of 5000 pounds of thorium oxide occurred February 19, 1968, when the material was shipped off site (Thorium Disposition, 1969).

Wah Chang also had other radioactive sources. They were primarily used in the metallurgical processes to accomplish various measurements such as material level and density detection. These sources included thorium and thorium compounds, powders, and crystals; uranium and enriched uranium contained in analytical standards (0.13 grams U-234 maximum); trace quantities of U-235 in Zircaloy, zirconium, and hafnium; and Cs-137 contained in several gauges used in the Chlorination and Fabrication Departments. Safety rules were in place for the operation, handling, and storage of these sources (License Application, 1969; Operating Instructions, 1968).

5.2 Radiological Exposure Sources from Wah Chang Operations

The primary source of internal exposure was inhalation and ingestion of contaminated air resulting from re-suspension of surface contamination during operations. The primary sources of external exposure were direct radiation from handling and processing depleted uranium, natural uranium, natural thorium and their daughters, as well as submersion in the air contaminated with these metals.

The following subsections provide an overview of the internal and external exposure sources for the Wah Chang class under evaluation.

5.2.1 Internal Radiological Exposure Sources from Wah Chang Operations

Inhalation and ingestion of airborne and surface contamination during the various operational processes were the primary sources of internal exposure.

5.2.1.1 Uranium, Depleted Uranium, and Alloys

The principal sources of internal exposure during the DU Project were from the inhalation and ingestion of dust or fumes generated during various processes, including butt removal, and handling during storing and shipping. Most of these operations were conducted in the same building. During each of these processes there was the possibility of airborne dust or fumes that potentially contained uranium metal. The EB furnace operated under a very high vacuum and was not a source of airborne contamination (Electron Beam Furnace, 1970)

The principal sources of internal exposure during the zirconium processes were from the inhalation and ingestion of dust or fumes generated during various processes as well as handling during storing and shipping. Most of these operations were conducted in the other buildings at the Wah Chang site. During each of these processes there was the possibility of airborne dust or fumes that potentially contained uranium and thorium from the waste products.

5.2.1.2 Thorium and Thorium Alloys/Oxides

Thorium was used as an insulator in the furnaces during the non-AEC zirconium-refining processes; exposure was primarily during the installation of thorium oxide in the furnaces. The workers' internal exposure to thorium was significantly less than their exposure to uranium. However, the possibility of direct exposure to radiation from thorium as well as inhalation and ingestion of thorium dust and fumes did exist.

5.2.1.3 Residual Exposures

In a March 1977 survey, the Energy Research and Development Administration (ERDA) conducted a review of AEC contract work performed at Wah Chang. ERDA stated that only the 1971-72 contract with Union Carbide (Y-12 Plant) for melting uranium-bearing material involved radioactivity. ERDA also stated that Wah Chang had plans to decontaminate the furnace facility at a future date and that "Residual contamination is very limited and remains primarily inside the furnace" (ERDA, 1977). Later in 1977, an inventory of Normally Occurring Radioactive Material stated that five pounds of depleted uranium remained in the Decontaminated Electron Beam Furnace in the S-6 Building (NORM, 1977; License Amendment, 2006).

5.2.2 External Radiological Exposure Sources from Wah Chang Operations

The principal source of external exposure during the operational period (other than medical X-rays) was the direct exposure to depleted uranium during the melting process, submersion in air potentially-contaminated with uranium during the cutting of ingots, and exposure to contaminated surfaces. There was some exposure to non-AEC thorium in working around the furnace during regular operations.

The principal source of external exposure during the zirconium processes was dust generated during various processes as well as handling during storing and shipping. Most of these operations were conducted in the other buildings at the Wah Chang site. During each of these processes there was the possibility of airborne dust that potentially contained uranium and thorium from the waste products.

Tables 5-1 and 5-2 list the radionuclides of concern for external radiation from uranium and thorium during the operational period.

Table 5-1: Principal Radiation Emissions from Natural Uranium and Its Short-lived Decay Products			
Radionuclide	**Half-life**	**Beta Energy (MeV Max**	**Photon (x or γ) Energy (MeV)**
U-238	4.468 x 10^9 years	None	x: 0.013 (8.8%)
Th-234	24.1 days	0.096 (25%)	x: 0.013 (9.6%)
		0.189 (73%)	γ: 0.063 (3.8%)
			γ: 0.093 (5.4%)
Pa-234m	1.17 minutes	2.28 (98.6%)	γ: 0.765 (0.2%)
		~1.4 (1.4%)	γ: 01.001 (0.6%)
U-235	7.038 x 10^9 years	None	x: 0.013 (31%)
			x: 0.090-0.105 (9.3%)
			γ: 0.144 (10.5%)
			γ: 0.163 (4.7%)
			γ: 0.186 (54%)
			γ: 0.205 (4.7%)
Th-231	25.5 hours	0.206 (15%)	x: 0.013 (71%)
		0.288 (49%)	γ: 0.026 (14.7%)
		0.305 (35%)	γ: 0.084 (6.4%)
U-234	244,500 years	None	x: 0.013 (10.5%)
			γ: 0.053 (0.2%)

Source: Battelle-TBD-6000, pdf p. 20. The table shows the principal radiation emissions from natural uranium and its short-lived decay products that are of concern for external radiation (not including bremsstrahlung).

Table 5-2: Principal Radiation Emissions from Th-232 and its Short-Lived Decay Products			
Radionuclide	**Half-life**	**Beta Energy (MeV Max)**	**Photon (x or γ) Energy (MeV)**
Th-232	1.405 x 10^{10} years	None	0.059 (0.19%)
			0.126 (0.04%)
Ra-228	5.71 years	0.389 (100%)	0.0067 (6 x 10^{-5}%)
Ac-228	6.25 hours	0.983 (7%)	0.338 (11.4%)
		1.014 (6.6%)	0.911 (27.7%)
		1.115 (3.4%)	0.969 (16.6%)
		1.17 (32%)	1.588 (3.5%)
		1.74 (12%)	---
		2.08 (8%)	---
		(+33 more βs)	---
Th-228	1.9116 years	None	0.084 (1.19%)
			0.132 (0.11%)
			0.166 0.08%)
			0.216 (0.27%)
Bi-212	60.55 minutes	1.59 (8%)	0.040 (1%)
		2.246 (48.4%)	0.727 (11.8$)
		---	1.620 (2.75%)
Tl-208	3.1 minutes	1.28 (25%)	0.277 (6%)
		1.52 (21%)	0.5108 (21.6%)
		1.80(50%)	0.583 (85.8%)
		---	0.860 (12%)
		---	2.614 (100%)

Source: *Handbook of Health Physics and Radiological Health* (Rad Handbook, 1998). Intensities refer to the percentage of disintegrations of the nuclide itself, not to original parent of series. Gamma percents are given in terms of observable emissions, not transitions.

5.2.2.1 Photon

The majority of the photons from natural uranium metals are in the 30-250 keV energy range. Solid uranium objects provide considerable shielding of the lower-energy photons and harden the spectrum, causing the majority of the photons emitted from a solid uranium object (such as an ingot) to have energies greater than 250 keV. While it is recognized that solid uranium sources will have a hardened photon spectrum, exposure to a thin layer of uranium on a surface will result in a larger fraction of exposure to lower-energy photons (Battelle-TBD-6000).

Table 5-1 shows the primary isotopes and photon energies associated with uranium metal. Exposure to these photons was possible during all phases of the refining process from direct radiation during submersion in air potentially-contaminated with uranium during the cutting of ingots, and exposure to contaminated surfaces. The EB furnace operated under a very high vacuum and was not a source of airborne contamination (Electron Beam Furnace, 1970).

Thorium has a significant number of higher-energy photons in the Th-232 decay chain. Based on the half lives of the progeny, only a partial equilibrium is possible; therefore, it is conservative to state

that equilibrium would be reached in this decay chain. It has been assumed that Ra-228 and Th-228 progeny were in equilibrium with Th-232. Therefore, air concentrations were assumed equal for all progeny. Under this assumption, the progeny are the major source of both penetrating and non-penetrating external exposure. Table 5-2 shows the primary isotopes and photon energies associated with thorium and its progeny. Photons from thorium must be considered for the operational period only but not during the residual period.

5.2.2.2 Beta

Tables 5-1 and 5-2 show the principal beta emitters and their energies for the uranium undergoing the refining process as well as thorium. As indicated in these tables, there are a significant number of high-energy beta radiations that represent a shallow dose exposure concern to site workers. Workers who handled the uranium metal would have received shallow dose exposures. The primary exposure areas would have been the hands and forearms, the neck and face, and other areas of the body that might not have been covered. Beta exposures must be considered for the operational period only but not for the residual period (due to the isolation of the point source material during the residual period).

5.2.2.3 Neutron

Neutrons were not measured at Wah Chang and were not expected to be a source of exposure for the class under evaluation. However, neutrons could arise from the α-n reaction with light elements, interactions with the oxides, and through spontaneous fission. According to Battelle-TBD-6000, uranium oxides would be the most common generators of (α,n) reactions. Spontaneous fission yields and (α,n) yields in oxides are provided in Table 3.5 of Battelle-TBD-6000. Based on its analysis, NIOSH concludes that none of these sources would be sufficient to result in a significant neutron exposure.

5.2.2.4 Residual Exposures

In a March 1977 survey, the Energy Research and Development Administration (ERDA) conducted a review of AEC contract work performed at Wah Chang. ERDA stated that only the 1971-72 contract with Union Carbide (Y-12 Plant) for melting uranium-bearing material involved radioactivity. ERDA also stated that Wah Chang had plans to decontaminate the furnace facility at a future date and that "Residual contamination is very limited and remains primarily inside the furnace" (ERDA, 1977). Later in 1977, an inventory of Normally Occurring Radioactive Material stated that five pounds of depleted uranium remained in the Decontaminated Electron Beam Furnace in the S-6 Building (NORM, 1977; License Amendment, 2006).

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

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to determine whether internal and/or external personal monitoring records have been obtained for EEOICPA claimants; no internal or external monitoring data have been found or discovered for any Wah Chang claimants. The following subsections provide an overview of the state of the available internal and external monitoring data for the Wah Chang class under evaluation.

6.1 Available Wah Chang Internal Monitoring Data

Medical Records

No medical records were found. No references mentioned medical examinations of any kind for Wah Chang workers.

Bioassay Data

NIOSH has found two sets of bioassay results (Inspection Report, 1972), which consist of handwritten pages containing names and urinalysis results for the listed individual. One data set has 10 names in a list labeled "before"; the other data set has 9 of these same 10 names in a list labeled "after melting campaign." None of the EEOICPA claimant records includes bioassay results. Furthermore, NIOSH did not locate any bioassay records of exposures to by-products resulting from zirconium production or other non-AWE work.

Air Sample Data

A limited number of air samples were located for the operational period, as shown in Table 6-1. These samples were taken in the tantalum-columbium feed make-up processing areas; they list the Maximum Permissible Concentrations (MPC) for alpha counts for the area. Also listed is the MPC for uranium ore and uranium dust (Inspection Report, 1972, pdf p. 11).

Table 6-1: Available Uranium Air Sample Results for the Wah Chang Operational Period

Sample Date	Sample Location	MPC	Result (dpm/ft^3)
April 5, 1971 (day shift)	Feed Make-up Area	1 x 10^{-10} µc/ml or 6.3 dpm/ft^3	1.0
April 5, 1971(swing shift) to noon April 7, 1971	Feed Make-up Area	1 x 10^{-10} µc/ml or 6.3 dpm/ft^3	1.2
September 28, 1971	S-6 Bldg.	Not stated	0.01[a]
September 29, 1971	S-6 Bldg.	Not stated	0.01[a]
September 30, 1971	S-6 Bldg.	Not stated	0.01[a]

[a] 0.01 dpm/ft^3 = 2 x 10^{-13} µCi/ml
Source: Inspection Report, 1972

A memo from the Wah Chang Radiation Protection Officer attached to the inspection report states: "The radiation levels have been found to be between 16% and 19% of the limits set by the State Board of Health" (Inspection Report, 1972, pdf p. 15). The memo further states: "Continuous air sampling will be performed until all of the ore lot is consumed to ensure that the limits are not exceeded.

Residual Survey Data

In a survey conducted in March 1977, the Energy Research and Development Administration (ERDA) conducted a review of AEC contract work performed at Wah Chang. It stated that only the 1971-72 contract with Union Carbide (Y-12 Plant) for melting uranium-bearing material involved radioactivity. The report stated that the license for the work was with the State of Oregon and the license was still in effect. It also stated that Wah Chang had plans to decontaminate the furnace facility at a future date and "Residual contamination is very limited and remains primarily inside the furnace" (ERDA, 1977). Later in 1977, an inventory of Normally Occurring Radioactive Material stated that five pounds of depleted uranium remained in the Decontaminated Electron Beam Furnace in S-6 building (NORM, 1977; License Amendment, 2006). A May 1978 survey stated that the furnace was stored in a locked room at the licensee's "Chem R&D Building at East Front and Fulton Street, Albany" (Inspection Report, 1978). An interview with an individual present at the time of the uranium operation indicated that the facility was prepared using strippable paint and covered with paper prior to operations and that this material was removed after the cessation of operations to facilitate decontamination of the area in which radiological operations occurred (Personal Communication, 2010a). The issue of remaining DU was explored in an interview with a former Wah Chang manager, who stated: "There was no leftover DU stored. We cleaned the furnace and decontaminated it completely. It was made so we could disassemble it completely and we did within two months after the DU operations were over. I was the designer and designed it that way. It was decontaminated down to doing wipes and scans and all contaminated materials were disposed of – I believe at Hanford" (Personal Communication, 2010c).

6.2 Available Wah Chang External Monitoring Data

Operations Period

NIOSH has found no external personnel monitoring results (including medical X-ray records) documenting exposures to depleted uranium or to by-products of any non-AWE work for the Wah Chang operations period from 1971 through 1972.

Operational Survey Data

One area survey was located for April 5, 1971; it was performed "during the dumping of radioactive euxenite ore." The area included the storage area and the dump area. In the storage area, readings on drums varied from 1 to 50 mr/hr gamma with an average reading of <2 mr/hr gamma at six feet. In the dumping area, beta/gamma readings were taken from opened barrels, with the "hottest barrel" reading 25 mr/hr with the detector window closed and 35 mr/hr with the detector window open. A memo attached to the inspection report states that the dose received by the operators actually handling the ore will not exceed 30% of the maximum radiation exposure allowed by the State Board of Health for long-term occupational exposure (Inspection Report, 1972, pdf pp. 14-15).

Residual Period

NIOSH has found little survey data for Wah Chang during the residual period from 1973 through 2009. In a survey conducted in March 1977, ERDA stated in an inventory of Normally Occurring Radioactive Material that five pounds of depleted uranium remained in the Decontaminated Electron Beam Furnace in S-6 building (NORM, 1977; License Amendment, 2006). A May 1978 survey stated that the furnace was stored in a locked room at the licensee's "Chem R&D Building at East Front and Fulton Street, Albany" (Inspection Report, 1978). The disposition of the remaining DU was addressed in an interview with a former Wah Chang manager: "There was no leftover DU stored. We cleaned the furnace and decontaminated it completely. It was made so we could disassemble it completely and we did within two months after the DU operations were over. I was the designer and designed it that way. It was decontaminated down to doing wipes and scans and all contaminated materials were disposed of - I believe at Hanford." (Personal Communication, 2010c).

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

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

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.6. This approach is discussed in DCAS's SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00174 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Wah Chang Data

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

7.1.1 Internal Monitoring Data Pedigree Review

NIOSH has located two sets of bioassay monitoring samples from workers involved in the DU operations for the operational period under evaluation (January 1, 1971 through December 31, 1972). The urine samples were taken "before" and "after" a uranium "melting campaign" in the S-6 furnace, and therefore, likely represent the maximally-exposed workers for AEC-related work. The data consist of two handwritten pages with names and corresponding urinalysis values for before and after the melting of uranium ingots (Inspection Report, 1972). None of the 10 named individuals are listed as EEOIPCA claimants; however, two of the listed individuals were confirmed by interviews to have been directly involved in the administration of the S-6 program. These individuals describe a robust radiological controls program in which bioassay sampling and whole-body counting were regularly performed. In addition, bioassay samples were analyzed by an off-site laboratory (Personal Communication, 2010a; Personal Communication, 2010c).

NIOSH did not locate any internal monitoring data from non-AEC sources for the operational period under evaluation (January 1, 1971 through December 31, 1972). Therefore, a data sufficiency and pedigree evaluation is not possible for this data type for this period.

The air sampling and survey data from the period are contained in original reports and are primary data sources. Therefore, no additional pedigree review was performed for those data. Air samples were taken on five occasions during the period under evaluation; only three of those samples were taken in the DU operational area. Due to the lack of operational logs and records, NIOSH could not establish what operations were occurring during the sampling; therefore, no conclusion could be drawn about the representativeness of the samples for the purpose of estimating personnel intakes.

7.1.2 External Monitoring Data Pedigree Review

NIOSH did not locate any external monitoring data for the operational period under evaluation (January 1, 1971 through December 31, 1972). Therefore, a data sufficiency and pedigree evaluation is not possible for this data type for this period.

NIOSH has identified limited external data for the residual period (January 1, 1973 through December 31, 2009). These data are in original reports (Dosimetry Report, 1973; Inspection Report, 1975). Two individuals directly involved in the administration of the S-6 program were interviewed. They described a robust radiological controls program in which external monitoring, bioassay sampling, and whole-body counting were regularly performed. In addition, external monitoring data were analyzed by an off-site laboratory (Personal Communication, 2010a; Personal Communication, 2010c).

7.2 Evaluation of Bounding Internal Radiation Doses at Wah Chang

The principal source of internal radiation doses for members of the class under evaluation was inhalation and ingestion of uranium and uranium progeny contained in dusts and fumes associated with the electron beam furnace uranium-melting operations. Additional exposures potentially occurred from radioactive by-products (e.g., uranium, thorium, and radium) resulting from zirconium extraction from zircon sands.

The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

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

7.2.1.1 Urinalysis Information and Available Data

Urinalysis data consist of two handwritten pages with names and corresponding urinalysis values before (10 names) and after (9 of 10 names) melting uranium ingots. All results, except for three individuals, showed lower values after melting, with six out of nine reported at < 1 ug/L, as shown in Table 7-1 (Inspection Report, 1972). NIOSH does not have access to bioassay data for exposures to non-AEC sources.

Table 7-1: Uranium Melting Urinalysis Data			
Before Melting		**After Melting**	
Worker	**Result (µg/L)**	**Worker**	**Result (µg/L)**
A	5.1	A	<1
B	0.8	B	4.5
C	*	C	2.4
D	2.5	D	3.4
E	2.0	E	<1
F	3.7	F	<1
G	3.4	G	<1
H	3.0	H	*
I	2.0	I	<1
J	1.4	J	<1

* No result reported

7.2.1.2 Airborne Levels

Air samples were taken on five occasions during the period under evaluation, three of which were in the depleted uranium operational area. However, due to lack of operational logs and records, NIOSH cannot determine the operations for which the sampling was performed, and therefore, cannot establish the relevance or representativeness of those samples to the evaluated class. See Table 6-1 for sample details.

7.2.1.3 Alternative Data Sources for Bounding Internal Dose

Wah Chang maintains a license through the state of Oregon for the use and handling of radioactive materials. According to the licenses for the uranium operational period (1971-1972), Wah Chang was limited to possession of a maximum of 50,000 pounds of uranium at any one time (SRDB 82159, pdf p. 27). A source term can be established for DU using these data.

7.2.2 Evaluation of Bounding Residual Period Internal Doses

NIOSH has not identified any internal monitoring records applicable to the residual radioactive material remaining from the limited operations involving EEOICPA-covered activities with radioactive materials. Interviews with both the Radiation Protection Officer and an employee who was directly involved with the S-6 Electron Beam furnace operation indicate that the furnace was decontaminated after the uranium operations were completed (Personal Communication, 2010a; Personal Communication, 2010g), including grinding of the internal furnace walls to remove deposited uranium metal (Personal Communication, 2010a). The project engineer responsible for the S-6 Electron Beam furnace stated that, at the cessation of uranium operations, the furnace was disassembled and completely decontaminated (Personal Communication, 2010c). The project engineer further indicated that the presence of residual uranium metal would have interfered with

future use of the furnace in which non-radioactive, reactor-grade metals were processed (Personal Communication, 2010c). These interviews all provide a consistent account of the status of the furnace at the end of the uranium operations and would seem to indicate that uranium contamination inside the furnace during the residual period was unlikely. However, later reports assign an inventory value of five pounds of depleted uranium to the S-6 furnace and indicate that this inventory was assigned to internal contamination which could not be reduced by further decontamination (NORM, 1977). Considering all this information, NIOSH can reasonably conclude that there was no potential for internal exposure from the residual depleted uranium assigned to the S-6 furnace because this material was not readily accessible due to its location (i.e., inside the furnace).

Although interviews with the S-6 furnace project engineer indicate that strippable coatings were used in the furnace work area after the cessation of the uranium work to limit the presence of residual contamination, a bounding estimate of the surface contamination level may be calculated using the air monitoring data in Table 6-1 of this report and the methodology presented in ORAUT-OTIB-0070. This estimated surface activity may then be used to arrive at a bounding estimate of the potential airborne activity, also using the ORAUT-OTIB-0070 methodology.

7.2.3 Methods for Bounding Internal Dose at Wah Chang

7.2.3.1 Methods for Bounding Operational Period Internal Dose

NIOSH has determined that the available data are inadequate to reconstruct worker exposures to by-product radionuclides resulting from zirconium extraction activities performed during the Wah Chang operational period under evaluation.

NIOSH has determined that uranium internal exposures during the operational period can be bounded using dose reconstruction methods described in Battelle-TBD-6000 and applying the intakes for the process and job category from Table 7.8 (for inhalation) and Table 7.9 (for ingestion) that result in the greatest dose.

7.2.3.2 Methods for Bounding Residual Period Internal Dose

Based on the analysis presented in Section 7.2.2, NIOSH has determined that there is no potential for internal dose during the residual period from exposure to residual radioactive material present inside the S-6 furnace. The stated amount of five pounds residual material is an estimate of the uranium residues that may have been present in inaccessible areas inside the furnace (ERDA, 1977; NORM, 1977).

Although there is anecdotal evidence that the residual contamination was limited to the inside of the furnace, the potential for internal exposure from a bounding estimate of surface contamination can be made using the air monitoring data in Table 6-1 of this report. Employing the methodology contained in Section 2.4 of ORAUT-OTIB-0070, based on a measured air concentration of 0.01 dpm/ft^3 and assuming that this level of air activity was present for the entire two-year duration of covered operations, the surface contamination level can be estimated to be 1700 dpm/100 cm^2. Based on a re-suspension factor of 1 E-6 and a breathing rate of 1.2 m^3/hr, this level of surface contamination could result in an inhalation intake of 1.6 dpm/workday. Based on the methodology in OCAS-TIB-009, this could also result in an ingestion intake of 3.3×10^{-2} dpm/workday. Normalizing these intake

quantities to calendar days results in bounding estimates for inhalation and ingestion intakes of 1.1 and 2.3 x 10^{-2} dpm/day, respectively.

The daily intake described above is based on source term data from operations and is likely to be significantly higher than intakes encountered at the start of the residual period. In order to account for the continued depletion of the operational source term during the residual period, a source term depletion of 1% of the surface activity per day is assumed to occur during the first year (1973); the resulting adjustment of 0.03 is applied for the second year (1974). Likewise, a source term depletion of 1% of the surface activity per day is assumed to occur during the second year, and the resulting adjustment of 0.0007 is applied to the third year (1975). For the remainder of the residual period, the source term is assumed to remain constant (ORAUT-OTIB-0070, Table 3-1). Table 7-2 shows the adjustments used in this method to account for the depletion of the source term during the residual period and the resulting intake rates.

Table 7-2: Source Term Depletion Adjustments for Wah Chang Residual Period (1% Per Day)

Year	Depletion Adjustment	U-234 Inhalation (dpm/d)	U-234 Ingestion (dpm/d)
1973	1	1.1E+00	2.3E-02
1974	0.03	3.3E-02	6.9E-04
1975 – present	0.0007	7.7E-04	1.6E-05

Based on the potential presence of recycled uranium contaminants within the material used, exposure to recycled uranium constituents can be scaled to the uranium intake using activity fractions for recycled uranium components contained in *Estimating the Maximum Plausible Dose to Workers at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0004), shown below in Table 7-3.

Table 7-3: Activity Fractions of Recycled Uranium Contaminants

Pu-239	Np-237	Tc-99	Th-232	Th-228
0.00246	0.00182	0.379	2.73E-06	2.73E-06

Source: ORAUT-OTIB-004, Table 3-1

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

Although there are methods available to NIOSH in Battelle-TBD-6000 to support bounding internal uranium dose for the Wah Chang operational period, NIOSH has not identified sufficient information or data to support bounding internal exposures to all zirconium extraction by-product radionuclides for the operational period. Consequently, NIOSH has determined that reconstruction of internal doses for Wah Chang workers is not feasible for the operational period from January 1, 1971 through December 31, 1972.

NIOSH has determined that reconstruction of internal doses is feasible for the residual period from January 1, 1973 through October 31, 2009 using the assumptions and approaches presented within Section 7.2.2 of this report.

Although NIOSH found that it is not possible to completely reconstruct internal radiation doses for the period from January 1, 1971 through December 31, 1972, 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 Wah Chang during the period from January 1, 1971 through December 31, 1972, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.3 Evaluation of Bounding External Radiation Doses at Wah Chang

The principal source of external radiation doses for members of the evaluated class was exposure to gamma and beta radiation associated with handling and working in proximity to uranium and uranium compounds (ERDA, 1977) as well as trace quantities of naturally-occurring radioactive materials in the U-238 and Th-232 decay series present in zirconium sands.

The following subsections address the ability to bound external doses, methods for bounding doses, and the feasibility of external dose reconstruction.

7.3.1 Evaluation of Bounding Process-Related External Doses

NIOSH has not identified any external monitoring records or personal dosimetry data associated with the uranium processing and thorium use that occurred during the period under evaluation. NIOSH has not been able to identify any radiological surveys or area monitoring data from during this time period.

NIOSH has identified methods in Battelle-TBD-6000 to support bounding external uranium dose for the type of metal work performed during the operational period at Wah Chang. However, NIOSH has not identified sufficient information or data to support bounding the external exposures associated with thorium wastes from the non-AEC-related zirconium processes during the operational period.

In light of the above information, NIOSH has concluded that sufficient data are available for bounding external uranium dose during the operational period; however, sufficient data are not available to estimate a bounding external dose from thorium wastes resulting from non-AEC zirconium processes occurring during the operational period January 1971 through December 1972.

7.3.2 Evaluation of Bounding Residual Period External Doses

NIOSH has not identified any external monitoring records applicable to the residual radioactive material that remained from the limited operations involving EEOICPA-covered activities with radioactive materials. However, sufficient information is available to bound the quantity (less than five pounds), type (depleted uranium), and location (inside the S-6 furnace) to allow external exposure rates to be calculated. (ERDA, 1977; NORM, 1977; Inspection Report, 1972; Inspection Report, 1978). This may be done by modeling the external dose based on the source term present.

In addition, the surface contamination level estimated in Section 7.2.3.2 can be used to determine the external dose by using conversion factors in Battelle-TBD-6000.

7.3.3 Wah Chang Occupational X-Ray Examinations

Although no specific information regarding occupational medical dose has been identified for Wah Chang, the dose associated with medical X-ray exams, if required as a condition of employment, can be bounded by using the assumptions in the complex-wide Technical Information Bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT-OTIB-0006). NIOSH believes this methodology supports its ability to bound the occupational medical X-ray doses for the Wah Chang class under evaluation.

7.3.4 Methods for Bounding External Dose at Wah Chang

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

- Photon Dose
- Beta Dose
- Neutron Dose
- Medical X-ray Dose

NIOSH has identified methods in Battelle-TBD-6000 to support bounding external uranium dose for the type of metal work performed during the operational period at Wah Chang. However, NIOSH has not identified sufficient information or data to support bounding the external exposures associated with thorium wastes from the non-AEC related zirconium processes during the operational period.

In light of the above information, NIOSH has concluded that sufficient data are available for bounding external uranium dose during the operational period, but that sufficient data are not available to estimate a bounding external dose due to thorium wastes resulting from non-AEC zirconium processes that occurred during the operational period from January 1971 through December 1972. NIOSH has determined that external dose can be bounded during the evaluated residual period (January 1, 1973 through October 31, 2009).

7.3.4.1 Methods for Bounding Operational Period External Dose

NIOSH has not identified any external monitoring records or personal dosimetry data associated with the uranium processing conducted during the period under evaluation. However, external uranium doses may be bounded using the methods detailed in Battelle-TBD-6000. NIOSH has not identified sufficient information or data to support bounding the external exposures associated with thorium wastes from the non-AEC related zirconium processes that occurred during the operational period. Therefore, NIOSH has concluded that external doses for the Wah Chang operational period of January 1, 1971 through December 31, 1972 cannot be bounded.

Medical X-ray Dose

Although NIOSH has not located specific parameters associated with occupational medical X-rays (i.e., specific information on the X-ray devices), default values of entrance KERMA developed for the three most commonly-used occupational medical diagnostic procedures are available in ORAUT-OTIB-0006. The ORAUT-OTIB-0006 values can be used to support bounding the medical X-ray dose for the time period under evaluation. These default values are upper limit values developed from review of patient doses as reported in the literature, machine characteristics, and knowledge of X-ray procedures used during different time periods. These default values can be used in lieu of actual measurement data or entrance KERMA derived from technique factors to bound the occupational X-ray exposures for the Wah Chang site. NIOSH believes this methodology supports its ability to bound occupational medical X-ray doses (reconstruct the medical X-ray dose with sufficient accuracy) for the operational period for the class under evaluation.

7.3.4.2 Methods for Bounding Residual Period External Doses

External dose during the residual contamination period can be bounded using the available source term data and knowledge of the radioactive material present. As previously indicated, the total inventory of depleted uranium present at any one time during the residual period was five pounds. The external dose rate determined in Section 7.3.2 for this quantity of radioactive material can be used to bound external exposure to penetrating radiation.

A bounding estimate of external dose was calculated assuming that the five pounds of depleted uranium constituted an unshielded point source using gamma ray constants for U-235, U-238, and associated short-lived progeny obtained from the *Rad Toolbox* software package. Based on a composition of 0.2 % U-235 and 99.8% U-238, the external dose rate at a distance of one meter was calculated to be 0.06 mrad/hr. Assuming an exposure duration of 2000 hours/year, the total annual external exposure would be 120 mrad.

The surface contamination estimate from Section 7.2.3.2 (1700 dpm/100 cm^2) may be used to estimate the external dose to individuals by using surface-activity-to-dose conversion factors contained in Battelle-TBD-6000. Based on the values in Table 3-10 of that document (4.49E-9 mR/d per dpm/m^2), the dose rate associated with the surface contamination level of 1700 dpm/100 cm^2 is less than 1mR/yr, which is nominal in comparison to the value calculated from direct exposure to the material held up in the furnace (120 mrad/yr).

7.3.5 External Dose Reconstruction Feasibility Conclusion

Although there are methods available to NIOSH in Battelle-TBD-6000 to support bounding external uranium dose for the Wah Chang operational period, and methods available in ORAUT-OTIB-0006 for bounding medical X-ray dose for the operational period, NIOSH has not identified sufficient information or data to support bounding the thorium exposures for the operational period. Furthermore, although only 7 to 10 workers were involved in the DU work, NIOSH was unable to determine workers' actual work locations or whether workers were restricted to one location during that period. Workers may have been able to move about freely; therefore, all workers' exposures will be treated similarly. Consequently, NIOSH has determined that reconstruction of external doses for Wah Chang workers is not feasible for the operational period from January 1, 1971 through December 31, 1972.

NIOSH has determined that reconstruction of external doses is feasible for the residual period from January 1, 1973 through October 31, 2009 using the assumptions and approaches presented within the preceding section of this report.

Although NIOSH found that it is not possible to completely reconstruct external radiation doses for the period from January 1, 1971 through December 31, 1972, NIOSH intends to use any external 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 Wah Chang during the period from January 1, 1971 through December 31, 1972, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.4 Evaluation of Petition Basis for SEC-00174

The following subsections evaluate the assertions made on behalf of petition SEC-00174 for the Wah Chang site.

7.4.1 Lack of Monitoring and Proper Protection

SEC-00174*:* The petitioner stated that, to the best of his knowledge, his father, [Name Redacted], worked at Wah Chang from March 1951 to January 11, 1979, without being monitored and without proper protection (Affidavit, 2010).

The petitioner's statement was the basis for qualifying this petition.

7.4.2 Lack of Exposure Documentation

SEC-00174: The petitioner stated that, to the best of his knowledge, documents showing internal or external exposure do not exist (Affidavit, 2010).

Information available to NIOSH indicates that internal and external exposures were monitored and information at Teledyne Wah Chang was recorded. Available documents confirm that internal and external monitoring protocols were established and data were gathered during the petitioner-requested class period.

Based on the available information, a source term or dose reconstruction method can be established for uranium materials for the Wah Chang operational period. However, NIOSH has determined that the available data are inadequate to bound internal and external exposures to all thorium by-products resulting from zirconium extraction activities during the operational period. For that period, NIOSH was unable to determine workers' actual work locations or whether workers were restricted to one location. Workers may have been able to move about freely; therefore, all workers' exposures will be treated similarly. Consequently, NIOSH has determined that complete reconstruction of internal and external doses for Wah Chang workers is not feasible for the operational period from January 1, 1971 through December 31, 1972. NIOSH has determined that reconstruction of internal and external doses is feasible for the residual period from January 1, 1973 through October 31, 2009.

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

During the feasibility evaluation for SEC-00174, a number of issues were identified that needed further analysis and resolution. The issues and their current status are:

- ISSUE: Thorium may have been processed during the operational period under evaluation.

  RESPONSE: Based on a review of Wah Chang documents in the SRDB, Teledyne Wah Chang submitted a bid for thorium work but did not receive the awarded contract (Thorium Memo, 1971). Although no thorium was processed during the operational period, exposures to thorium were possible due to the thorium content of the zirconium wastes.

- ISSUE: Identify non-AEC (commercial) sources of exposure present at the Wah Chang site during the 1971-1972 timeframe.

  RESPONSE: Non-AEC (commercial) exposures during the operational period could have been from uranium, thorium, and their decay progeny (Site D&D, 2003). These sources include natural uranium and thorium waste products from the zirconium-refining processes. These are addressed within this evaluation report in Sections 5.1, 5.2, 7.2, and 7.3.

7.6 Summary of Feasibility Findings for Petition SEC-00174

This report evaluates the feasibility for completing dose reconstructions for employees at the Wah Chang site during the operational period from January 1, 1971 through December 31, 1972, and the residual radioactivity period from January 1, 1973 through October 31, 2009. NIOSH found that the available monitoring records, process descriptions and source term data available are not sufficient to complete dose reconstructions during the operational period of the evaluated class, but are sufficient to complete dose reconstructions for the residual radioactivity period.

Table 7-4 summarizes the results of the feasibility findings at Wah Chang for each exposure source during the time period January 1, 1971 through October 31, 2009.

Table 7-4: Summary of Feasibility Findings for SEC-00174
January 1, 1971 through October 31, 2009

Source of Exposure	Operational Period (January 1, 1971-December 31, 1972)		Residual Period (January 1, 1973-October 31, 2009)	
	Reconstruction Feasible	**Reconstruction Not Feasible**	**Reconstruction Feasible**	**Reconstruction Not Feasible**
Internal		**X**	**X**	
- Uranium	X		X	
- Thorium		X	N/A	N/A
External		**X**	**X**	
- Uranium beta-gamma	X		X	
- Thorium beta-gamma		X	N/A	N/A
- Neutron	N/A	N/A	N/A	N/A
- Occupational Medical X-ray	X		N/A	N/A

As of August 31, 2010, a total of four claims have been submitted to NIOSH for individuals who worked at Wah Chang and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for four individuals (100%).

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 Wah Chang during the period from January 1, 1971 through December 31, 1972, 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-00174

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

Due to a lack of internal and external monitoring data, NIOSH's evaluation determined that it is not feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy for the operations period (January 1, 1971 through December 31, 1972). Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is required. For the residual period (January 1, 1971 through October 31, 2009), a health endangerment determination is not required because NIOSH has determined that it has an established methodology for estimating dose.

9.0 Class Conclusion for Petition SEC-00174

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all employees who worked in any building at the Wah Chang facility in Albany, Oregon, for the operational period from January 1, 1971 through December 31, 1972, 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 class under evaluation was modified and expanded because the Department of Energy has designated an operational period and a residual radioactivity period for the site. The designated operational period corresponds to the Wah Chang contract for processing depleted uranium for the Y-12 site.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database (SRDB), for information relevant to SEC-00174. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

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

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10.0 References

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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*; Final Rule; May 28, 2004; SRDB Ref ID: 22001

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Attachment 1: Data Capture Synopsis

Table A1-1: Summary of Holdings in the SRDB for Wah Chang			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Primary Site/Company Name: Wah Chang AWE 1971-1972; Res. Rad. 1973 - October 2009 Other Site Names: Teledyne Wah Chang ATI Wah Chang	The ORAU Team contacted the Wah Chang Point of Contact (POC) on 12/02/2009, 12/07/2009, 01/06/2010, and 03/23/2010 requesting authorization to perform a data capture at the Wah Chang facility. The POC did not authorize a site visit. The Wah Chang Radiation Safety Officer did review and release the records held by the State of Oregon for the data capture conducted at the state Radiation Protection Services 05/24/2010-05/28/2010.	05/28/2010	0
State Contacted: [Name Redacted], Manager, Radiation Protection Services	Fact sheet, production documentation, environmental reports, 1996-2004, 2008, 2009 occupational exposure records, general licensing documentation, radiation protection programmatic documents, laboratory protocols, license inspection reports, Oregon radioactive materials licenses, site surveys, site plot plans, licensing documentation for the uranium melting project including start-up, decontamination, and description of the form and location of the residue following decontamination.	05/28/2010	79
DOE Hanford	A search request was made to Hanford. The results of the search are undergoing a sensitivity review.	OPEN	0
DOE Legacy Management - Grand Junction Office	Fact sheet for the Albany, OR site and a 1977 draft ERDA letter removing Wah Chang from the resurvey program.	01/08/2010	2
DOE Legacy Management - Morgantown	No relevant data identified.	10/19/2010	0
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Documents regarding the 1961 shipment of alloyed scrap from Fernald to Wah Chang.	05/21/2008	3
Department of Labor/Paragon	Documents regarding the vitrification of zirconia/lime sludge.	12/30/2008	4
Internet	A description of two electron beam incidents and corrective actions from the 1990s.	08/17/2010	1
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant data identified.	08/11/2010	0
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	No relevant data identified.	08/11/2010	0
Internet - DOE Legacy Management Considered Sites	No relevant data identified.	08/11/2010	0
Internet - DOE OpenNet	No relevant data identified.	08/11/2010	0
Internet - DOE OSTI Energy Citations	The Superfund Record of Decision.	08/11/2010	1
Internet - DOE OSTI Information Bridge	Lists of DOE customers with summaries of radioisotope shipments, FY 1978 and FY 1983.	08/11/2010	2

Table A1-1: Summary of Holdings in the SRDB for Wah Chang			
Data Capture Information	**Data Capture Description**	**Completed**	**Uploaded into SRDB**
Internet - Google	Site description and company histories, health assessments, superfund documents, Albany Research Center histories, site geological profile, cleanup reports, Oregon mineral industry publications mentioning Wah Chang, and an industry publication report documenting the start of electron beam melting of rare earth metals in 1959.	01/05/2010	110
Internet - HP Journal	No relevant data identified.	10/18/2010	0
Internet - Journal of Occupational and Environmental Health	No relevant data identified.	10/18/2010	0
Internet - National Academies Press (NAP)	The 1994 report on Bureau of Mines research programs.	08/11/2010	1
Internet - National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant data identified.	08/11/2010	0
Internet - NRC Agencywide Document Access and Management (ADAMS)	A 2001 FUSRAP sites review, the response to FOIA 2000-0142 with AEC/NRC licensing documents, and Wah Chang's comments on an NRC proposed rule for transfers of source materials.	08/11/2010	4
Internet - US Army Corps of Engineers	No relevant data identified.	08/11/2010	0
Internet - Washington State University (U.S. Transuranium and Uranium Registries)	No relevant data identified.	08/11/2010	0
National Archives and Records Administration (NARA) Kansas City	Letters from 1959 regarding a thorium ore shipment and a proposal to establish a thorium/rare earth mill.	11/10/2004	1
ORAU Team	Project spreadsheet.	Unknown	1
Unknown	1961 NYOO samples taken at Wah Chang (page 217), facility information, FUSRAP elimination recommendation, removal of Wah Chang from the ERDA resurvey program, and discussion of zirconium work.	Unknown	2
Total			**211**

Table A1-2: Database Searches for Wah Chang			
Database/Source	**Keywords/Phrases**	**Hits**	**Uploaded into SRDB**
NOTE: Database search terms employed for each of the databases listed below are available in the Excel file called "Data Capture Synopsis for Wah Chang, Albany, OR."			
DOE CEDR http://cedr.lbl.gov/ COMPLETED 08/11/2010	See Note above	0	0
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 08/11/2010	See Note above	14	0
DOE Legacy Management Considered Sites http://csd.lm.doe.gov/ COMPLETED 08/11/2010	See Note above	0	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 08/11/2010	See Note above	494	0
DOE OSTI Energy Citations http://www.osti.gov/energycitations/ COMPLETED 08/11/2010	See Note above	12,019	1
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 08/11/2010	See Note above	7,307	2
Google http://www.google.com COMPLETED 01/05/2010	See Note above	1,641,249	110
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 10/18/2010	See Note above	0	0
Journal of Occupational and Environmental Health http://www.ijoeh.com/index.php/ijoeh COMPLETED 10/18/2010	See Note above	0	0

Table A1-2: Database Searches for Wah Chang			
Database/Source	**Keywords/Phrases**	**Hits**	**Uploaded into SRDB**
National Academies Press http://www.nap.edu/ COMPLETED 08/11/2010	See Note above	1,818	1
NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 08/11/2010	See Note above	3	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 08/11/2010	See Note above	2,528	4
USACE/FUSRAP http://www.lrb.usace.army.mil/fusrap/ COMPLETED 08/11/2010	See Note above	0	0
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 08/11/2010	See Note above	1	0