SEC Petition Evaluation Report
Petition SEC-00094

Report Rev # 0 Report Submittal Date: 3/12/2008

Subject Expert(s):	Joe Guido, Bob Coblentz
Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition B Qualification Date	DOE/AWE Facility Name
SEC-00094	83.13	October 11, 2007	Horizons, Inc.

Petitioner Class Definition

All employees who worked in all locations at Horizons, Inc., from January 1, 1944 – December 31, 1956 and from January 1, 1957 – July 31, 2006 (residual period).

Class Evaluated by NIOSH

All Atomic Weapons Employer employees who worked at Horizons, Inc., from January 1, 1944 through December 31, 1956 and from January 1, 1957 through July 31, 2006 (residual period).

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

All Atomic Weapons Employer employees who worked at Horizons, Inc., for a number of work days aggregating at least 250 work days from January 1, 1952 through December 31, 1956, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
None			

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
None	

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Evaluation Report Summary: SEC-00094, Horizons, Inc.

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-00094, qualified on October 11, 2007, requested that NIOSH consider the following class: *All employees who worked in all locations at Horizons, Inc. from January 1, 1944 – December 31, 1956 and from January 1, 1957 – July 31, 2006 (residual period).*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. NIOSH evaluated the following class: All AWE employees who worked at Horizons, Inc. from January 1, 1944 through December 31, 1956 and from January 1, 1957 through July 31, 2006 (residual period).

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

Based on its research, NIOSH evaluated the class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all AWE employees who worked at Horizons, Inc., for a number of work days aggregating at least 250 work days from January 1, 1952 through December 31, 1956, or in combination with work days within the parameters established for one or more other classes of employees in the SEC.

NIOSH modified the petitioner-proposed class because NIOSH has access to the necessary information to support its conclusion that the site was not licensed to operate at the covered location prior to September 4, 1947, and NIOSH has found no evidence that radiological material was on site prior to 1952; therefore, NIOSH finds that there would be no health endangerment associated with radiological activities at this site location prior to this time (as discussed below). NIOSH does has evidence that site activities involving radioactive material were performed after 1951, and that it lacks sufficient information to support the ability to perform bounding dose reconstructions with sufficient accuracy for pre-1957 workers; however, NIOSH does have access to sufficient monitoring information for the residual radioactivity period to support performing bounding dose reconstructions with sufficient accuracy for post-1956 workers.

Feasibility of Dose Reconstruction

NIOSH finds it is not feasible to estimate internal exposures with sufficient accuracy for all workers at the site from January 1, 1952 through December 31, 1956 (NIOSH has identified no evidence of operations involving radioactive material at the site prior to1952). During this period there was no internal monitoring program and there is insufficient other data to support sufficiently accurate estimates of these doses. Because of the nature of operations at Horizons, these potential internal exposures are not limited to discrete workgroups or operational areas at Horizons; therefore, it is not feasible to completely reconstruct the radiation doses of any AWE employees at the facility. With the exception of this class, per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class; or (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. Information available from 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 (the residual period from January 1, 1957 through July 31, 2006).

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 is not feasible to estimate with sufficient accuracy doses associated with internal exposures for the members of the proposed class from January 1, 1952 through December 31, 1956. For the post-1956 period, 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.

NIOSH has confirmed that it has the necessary information to conclude that the site was not licensed to operate at the covered location prior to September 4, 1947, and NIOSH has no evidence of radioactive material on site prior to 1952. Consequently, NIOSH finds there would be no radiological source of exposure, and thus, no health endangerment associated with radiological activities at this location prior to January 1, 1952. Therefore, the determination for the period from January 1, 1944 through December 31, 1951 is that there was no health endangerment.

NIOSH did not identify any evidence supplied by the petitioners or from other resources that would establish that the proposed class who worked at Horizons, Inc., from January 1, 1952 through December 31, 1956 was exposed to radiation during a discrete incident likely to have involved exceptionally high-level exposures. However, evidence indicates that some workers in this proposed class may have accumulated substantial chronic internal exposures through episodic intakes of radionuclides, combined with external exposures to gamma and beta radiation. Consequently, NIOSH has determined that health was endangered for those workers covered by the NIOSH-proposed SEC class defined in this evaluation who were employed for at least 250 aggregated work days either solely under their employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

Table of Contents

Tables

SEC Petition Evaluation Report for SEC-00094

ATTRIBUTION AND ANNOTATION: This is a single-author document. All conclusions drawn from the data presented in this evaluation were made by the Oak Ridge Associated Universities Team Lead Technical Evaluator: Raymond Weaver, MJW Corp. 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 at Horizons, Inc., from January 1, 1944 through December 31, 1956 and from January 1, 1957 through July 31, 2006 (residual period). It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

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

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

2.0 Introduction

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

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

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

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, 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.[2]

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

Petition SEC-00094, qualified on October 11, 2007, requested that NIOSH consider the following class for addition to the SEC: *All employees who worked in all locations at Horizons, Inc., from January 1, 1944 – December 31, 1956 and from January 1, 1957 – July 31, 2006 (residual period).* The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Horizons workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00094 for evaluation:

> The petitioner provided an affidavit claiming that he/she has no knowledge of any monitoring data at Horizons, Inc.

Based on its Horizons research and data capture efforts, NIOSH determined that it has access to external monitoring data and records for Horizons workers during the time period under evaluation. However, NIOSH also determined that internal monitoring records are not complete for all time periods or for all radionuclides. NIOSH concluded that there is sufficient documentation to support the petition basis that internal radiation exposures and radiation doses were not adequately monitored at Horizons, either through personal monitoring or area monitoring for the period from January 1,

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

1952 through December 31, 1956. The information and statements provided by the petitioner, and the lack of internal monitoring data, qualified petition SEC-00094 to be evaluated for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

Based on its research, NIOSH modified the petitioner-requested class as to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employer (AWE) employees who worked at Horizons, Inc., for a number of work days aggregating at least 250 work days from January 1, 1952 through December 31, 1956, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. The class was modified as a result of the review of site operations documented in Section 5.0 and the feasibility evaluation documented in Section 7.0.

4.0 Data Sources Reviewed by NIOSH

NIOSH identified and reviewed numerous data sources to evaluate the feasibility of dose reconstruction for the class of employees proposed for this petition. This included determining the availability of information on personal monitoring, area monitoring, industrial processes, and radiation source materials. The following subsections summarize the data sources identified and reviewed by NIOSH.

4.1 Site Profile Technical Basis Documents (TBDs)

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

No site profile has been developed for Horizons, Inc. However, as part of this evaluation, NIOSH examined the following TBDs for insights into Horizons operations or related topics/operations at other sites:

- TBD: *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium*, Battelle-TBD-6000, Rev. F0; December 13, 2006; SRDB Ref ID: 30671

- TBD: *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium*, Battelle-TBD-6001, Rev. F0; December 13, 2006; SRDB Ref ID: 30673

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

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

- OTIB: *Dose Reconstruction From Occupationally Related X-Ray Procedures*, ORAUT-OTIB-0006, Rev 03 PC-1; December 21, 2005; SRDB Ref ID: 20220

- OTIB: *Lung Dose Conversion Factor For Thoron WLM,* OCAS-TIB-0011, Rev 2; January 13, 2006; SRDB Ref ID: 22409
- PROC: *Occupational X-Ray Dose Reconstruction for DOE Sites,* ORAUT-PROC-0061, Rev 00; July 21, 2006; SRDB Ref ID: 29987

- TIB: *Default Assumptions and Methods for Atomic Weapons Employer Dose Reconstructions*, Battelle-TIB-5000, Rev. 00; April 7, 2007; SRBD Ref ID: 32016

4.3 Facility Employees and Experts

To obtain additional information, NIOSH researched its NOCTS database, located one former Horizons employee who is still alive, and interviewed this individual. As of the time of this report, all other claims in NOCTS are for Horizons employees who are deceased.

- Personal Communication, 2007, *Personal Communication with Metallurgical Engineer*; Telephone Interview by ORAU Team; November 26, 2007; OSA Ref ID: 38320

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. A review of the employment history for the four claims in NOCTS indicates that none of the four had employment prior to January 1, 1952. This supports the NIOSH determination that AEC radiological work was not performed at the Horizons facility prior to January 1, 1952. Table 4-1 summarizes the results of this review for the evaluated class period of January 1, 1944 through December 31, 1956, and from January 1, 1957 through July 31, 2006 (residual period). (NOCTS data available as of March 14, 2008).

Table 4-1: No. of Horizons 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 proposed class definition criteria with employment from January 1, 1944 through December 31, 1956 and from January 1, 1957 through July 31, 2006 (residual period)	4
Number of dose reconstructions completed for energy employees who meet the proposed class definition criteria	0
Number of claims for which internal dosimetry records were obtained for the identified years in the proposed class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the proposed class definition	3

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. NIOSH located external monitoring data for the period evaluated in this report, but no internal monitoring data.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database to locate documents supporting the evaluation of the proposed class. Seventy-eight documents in this database were identified as pertaining to Horizons, Inc. These documents were evaluated for their relevance to this petition. The documents include historical background on monitoring, some program descriptions, process material information, process descriptions, air monitoring data, as well as later Formerly Utilized Sites Remedial Action Program (FUSRAP) and site D&D/remediation information.

4.6 Other Technical Sources

Information on AEC-related work performed by Horizons was also identified and gathered from the State of Ohio Department of Health, and from the United States Department of Energy, Office of Scientific and Technical Information (OSTI).

4.7 Documentation and/or Affidavits Provided by Petitioners

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

- *Affidavit from* [Survivor Name redacted]; November 26, 2007; OSA Ref ID: 38320

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the Horizons, Inc., facility from January 1, 1944 through December 31, 1956 and from January 1, 1957 through July 31, 2006 (residual period), and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing both processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is only a summary of the available information.

5.1 Horizons Plant and Process Descriptions

There are no records of any operations at the Cleveland, Ohio facility prior to September 1947. Available documentation indicates that Horizons, Inc., was not performing business in Ohio prior to this time; Horizons was licensed to do business in the state of Ohio on September 4, 1947 (License, 1993). The MED/AEC-related work under evaluation was performed at the facility owned and operated by Horizons, Inc., and located at 2909 East 79th St. in Cleveland, Ohio. Two of the three original buildings (B and C) at this location were initially used to perform research and development of electrochemical processes, and then during the 1950s, production processes for the Atomic Energy Commission (AEC) and other government agencies (Wagoner, 1990). A third original building also existed at the facility. No specific information is available regarding activities or operations that may have been performed in that building; however, available site remediation documentation does appear to indicate that no radioactive material operations were performed in this third building. However, due to the widespread contamination from the Horizons processes, and the inability to identify or designate specific work locations for any workers, no specific work locations or buildings will be called out in the evaluation of the proposed Horizons worker class. The conclusions and recommendations presented in this report include all Horizons work locations.

Horizons was working in the field of high-temperature fused salt electrochemistry as early as 1948. Most of the research was with titanium and zirconium. In early 1949, Horizons was contracted by the AEC to determine the feasibility of producing ductile zirconium in coherent form via electrolysis. From April 1952 through June 1956, Horizons was contracted by the AEC to determine the most economical method for the production of thorium metal. During the same time period, another contract covered research and development of high-purity niobium metal via electrolysis (FUSRAP, 1985). In addition to the thorium contract work, Horizons also had other radiological contracts, licenses, research, and work associated with uranium (Musser, 1954; USAEC, 1956) and radioactive silver (USAEC, 1958; USNRC, 1993; Maybaum, 1958).

In December 1954, a radiological survey was conducted by the AEC's Health and Safety Laboratory (HASL) (HASL, 1955). This survey discovered poor housekeeping, inadequate ventilation, nonexistent controls for certain operations, and improper work habits in violation of accepted housekeeping procedures.

In February 1977, Oak Ridge National Laboratory (ORNL) conducted a radiological survey as part of the FUSRAP program. The survey results identified thorium contamination in excess of free-release limits (ORNL, 1977).

In 1997 and 1998, another radiological survey was conducted by B. Koh & Associates which confirmed that thorium was present in excess of free-release limits (Koh, 1998). As a result of these findings, B. Koh & Associates developed and submitted a Site Remediation Plan in March 1998 (Koh, 1998).

Table 5-1 summarizes the Horizons, Inc., known facility operations over the period under evaluation.

Table 5-1: Horizons Operating Facilities

Building	Purpose
B	Wet Plant (24,500 ft^2): Feed material received, weighed into batches, placed into a dissolving tank, blended, and transferred as a salt to Dry Plant.
C	Dry Plant (5,185 ft^2): Metal was produced via an electrolytic process; metal was chipped from a cathode, crushed, dried, and packaged for final shipment.

Note: The source for the above information is the NRC inspection summary report for the former Horizons, Inc., site (USNRC, 1993). NIOSH research discovered no radiological information regarding a third original building at the Horizons, Inc., Cleveland location.

One report (FUSRAP, 1985) indicates that the buildings used for radiological work (B and C) may have more recently been consolidated into one large facility. Horizons sold the Cleveland facility during the 1966-67 timeframe. The facility changed hands several times in the years following the Horizons sale. The companies that owned and operated the former Horizons facilities constructed additions to the existing buildings and used the buildings for non-radioactive activities (USNRC, 1993).

5.2 Horizons Functional Areas

Horizons operations included the following functional areas:

- Thorium operations
- Uranium operations
- Silver operations

5.2.1 Horizons Thorium Operations

The thorium processes and activities, which were the largest radiological activities performed on the site, were performed in both Buildings B and C. Building C was originally used for receiving and processing radioactive materials, and Building B was used for bulk storage and final processing of the radioactive materials. The feed material was brought into the Wet Plant (Building C), weighed into batches, and placed in a dissolving tank. The thorium nitrate was converted to ammonium thorium chloride, blended with sodium chloride, and then transferred as a calcined salt to the Dry Plant (Building B), where thorium metal was produced by a high-temperature electrolytic process. The resulting metal was chipped from the cathode, crushed, washed, dried, and packaged in Building B for final shipment off site (USNRC, 1993).

From April 1952 to April 1954, Horizons focused on evaluation of all possible systems or methods for production and extrusion of thorium metal. Electrolytic operations were conducted in small, research-sized laboratory cells originally designed for titanium and zirconium metal research and production (FUSRAP, 1985).

In May 1954, by direction of the AEC, Horizons activities increased from small developmental quantities of thorium metal to scale pilot-plant operations for the production of hundreds of pounds of thorium. According to Horizons own “final report” (Fisher, 1956), this scale-up was initiated with little regard for suitability of the process for preparation of thorium nitrate tetrahydrate and availability of suitable equipment. This scale-up to production levels of thorium metal was to be accomplished within a six-month period. By the end of July 1954, 2000 pounds of thorium nitrate tetrahydrate had been delivered to the Horizons facility to be used as feed material for the electrochemical process.

During summer 1955, up to 10,000 pounds of thorium nitrate had been delivered to Horizons, yet by June 1956 all production related to thorium metal recovery had stopped (Fisher, 1956).

5.2.2 Horizons Uranium Operations

Horizons conducted research and development work with uranium metal. A 1953 Horizons semi-annual report to the AEC concerning research issuance material indicates the receipt of eight bars of uranium metal (total: 8290.8 grams) (Semi-annual Report, 1953). Another AEC memo in May 1954 indicates that Horizons received 39.8 pounds of uranium bars and blocks in support of uranium research (Uranium Bars, 1954). Although limited information exists on the actual operations, it appears that the research performed with this material included roll-cladding experimentation (cladding of uranium with zirconium). In July 1955, Horizons submitted a proposal for the research into electrolytic production of uranium; however, the AEC rejected the proposal (Bloch, 1955; FUSRAP, 1985).

5.2.3 Horizons Silver Operations

A July 1954 letter discusses the desired research to be performed at Horizons (Mataich, 1954). Planned research included the use of radioactive silver in fundamental studies to determine the surface diffusion rate of silver on gold or other materials. The process and controls are generally described in the letter, including the requirement to perform the work in a hood, for personnel to wear film badges, and for radiological surveys of the areas where work is to be performed. In 1955, Horizons requested a license from the AEC for 20 mCi of Ag-110 for research purposes. This material was received, used, and shipped back to the AEC (i.e., Oak Ridge National Laboratory) by September 23, 1958 (Maybaum, 1958). NIOSH concluded that the material being used was actually Ag-110m. Ag-110 has a 24.6-second half-life; therefore, Ag-110 would have decayed prior to receipt (Ag-110m has a 250-day half-life).

It appears that radioactive silver (Ag-110m) may have been on site during the residual radioactivity period. However, any potential internal dose associated with Ag-100m will not be included or accounted for in this report because silver operations were not part of the AEC-related work, and therefore, are not covered under the EEOICPA radiological dose reconstruction program for the residual radioactivity period. Therefore, further discussion of this radionuclide is not included or evaluated for the residual radioactivity period.

5.2.4 Summary of Key Horizons Operations

NIOSH reviewed the available information and determined that each of the thorium, uranium, and silver operations occurred within the time period under evaluation in this report. There is no information regarding AEC-related thorium operations for the period prior to 1952, nor information that indicates these thorium operations occurred prior to 1952 The information associated with the uranium operations is limited, but documentation states that uranium was on site in 1953 (DOE, 1985). Research using radioactive silver is not discussed in the available documentation prior to 1954 (Maybaum, 1958). The earliest available radioactive silver license request would support that radioactive silver was not on site until 1955 (DOE, 1985). All AEC-related activities associated with these radionuclides ended at Horizons in 1956, although some of the radioactive silver may have remained on site for other non-AEC related work after AEC-related operations were terminated (possibly remaining on site up to 1958) (Maybaum, 1958; FUSRAP, 1985).

As previously discussed, NIOSH has information that Horizons was working in the field of high-temperature fused-salt electrochemistry (mostly with titanium and zirconium) as early as 1948. In early 1949, Horizons was contracted for non-radioactive work by the AEC to determine the feasibility of producing ductile zirconium in coherent form via electrolysis. NIOSH has discovered no information for any operations or activities at the Horizons site in Cleveland prior to September 4, 1947.

Documentation demonstrates that AEC-related radioactive operations stopped at the Horizons facility after December 31, 1956. After January 1, 1957, the Horizons facility was used by other companies to perform non-radiological commercial work (Plan, 1993). Clean-up of the former Horizons facility was performed in the late 1990s. On February 26, 2001, an inspection of the clean-up work was performed by the NRC who deemed the facility acceptable for “free release” (Remediation Report, 2001).

Table 5-2 summarizes the Horizons, Inc., key processes and dates of operation known to NIOSH.

Table 5-2: Horizons Key Operations and Dates of Operation

Operation	Associated Activity	Dates
Thorium	Thorium electrolytic processing and associated operations	1952-1956
Uranium	Uranium roll-cladding experimentation and review of electrolytic processing	1953-1956
Silver	Research into the diffusion rate of silver in other materials	1954-1956

Based on the above information, NIOSH has concluded there was no potential for any AEC-related operations at the Horizons site prior to January 1, 1952. Therefore, further evaluation of the pre-January 1, 1952 period will not be performed or included in this report.

Documentation and information supports that Horizons performed AEC-related activities after September 4, 1947. However, NIOSH has no evidence of radioactive material on site prior to 1952. Based on the available information, all AEC-related work at Horizons stopped in 1956. On February 26, 2001, the site was deemed remediated and acceptable for "free release"; however, NIOSH has maintained the end date for the residual period as July 31, 2006 to be consistent with the DOE Office of Worker Advocacy, and in light of NIOSH's dose reconstruction feasibility conclusions for the residual radioactivity period (see Section 7.0). Therefore, NIOSH concludes that the operational period to be evaluated in this report extends from January 1, 1952 through December 31, 1956, and the residual radioactivity period to be evaluated in this report extends from January 1, 1957 through July 31, 2006.

5.3 Radiological Exposure Sources from Horizons Operations

The thorium and uranium electrolytic processing operations at Horizons resulted in alpha, beta, and gamma radiation exposures to workers. Because of the comparative sizes of the associated operations (thorium activities were much larger in scale than the uranium operations), the greatest source of contamination and internal radiological exposures in the buildings resulted from surface, airborne, and re-suspended dust particles contaminated with thorium and its progeny (e.g., thoron). During the production operations, thorium surface contamination and airborne dust resulted from high-temperature electrolytic processing, manual operations, and hand contact (e.g., chipping, crushing, sweeping) with thorium and uranium materials. In addition, radioactive silver (posing a beta radiation exposure hazard) was used on site for diffusion studies and research.

After the AEC-related operations were terminated at Horizons, residual thorium, thorium progeny and uranium radioactivity remained at levels that can be bounded by the operational exposure data. Work during the residual era also included alpha and gamma radiation exposures to workers. The residual exposures would have resulted from workers being in close proximity to contamination as well as the re-suspension of contaminated particles remaining from the Horizons operational period. The specific sources of exposure are listed in the following sections.

5.3.1 Alpha

Alpha particle emissions from the radioactive materials handled at Horizons present the greatest potential for exposure through internal deposition via inhalation and ingestion (alpha particles do not present an external exposure hazard). The principal alpha-emitting radioactive materials associated with Horizons, Inc. operations were uranium and thorium (and associated progeny). Processed natural uranium consists of approximately equal activities of U-238 (4.20 MeV and 4.15 MeV alpha particles) and U-234 (4.77 MeV and 4.72 MeV alpha particles) (Radiological Health, 1970). There are smaller amounts of U-235 (approximately 1/20 of the activity levels of U-238 or U-234) with alpha particles of 4.40 MeV and 4.36 MeV.

Th-232 emits alpha particles of 4.01 MeV and 3.95 MeV, and the natural thorium decay series includes six daughter products that also emit alpha particles, with energies ranging from 5.34 MeV to 8.78 MeV. The abundance of these daughter product emissions depends on the state of equilibrium with the Th-232 parent. Th-232 decays into Ra-228, emitting two primary alpha particles of 3.95 MeV (24%) and 4.01 MeV (76%). The decay series contains several other progeny, most of which decay by alpha particle emission, but each has a half-life of less than 12 hours. Other isotopes of thorium were likely to have existed at Horizons, including Th-228 (5.52 MeV) and Th-230 (4.62 MeV and 4.69 MeV), and are considered contributors to the thorium dose at the site.

5.3.2 Beta

As with the alpha emitters, the majority of the beta exposures at Horizons could have resulted from exposure to natural thorium and its progeny, or uranium and its decay products. For processed natural uranium, the dominant beta radiation was likely from U-238 decay products. The most energetic of these beta particles is 2.29 MeV from Pa-234m.

Thorium processes also involved unshielded contact with sources of beta radiation. While Th-232 itself does not emit beta particles, five of the daughter radionuclides in the natural thorium decay series do have beta emissions, ranging in energy up to a maximum of 2.26 MeV (Radiological Health, 1970). The abundance of these daughter product emissions depends on the state of equilibrium with the Th-232 parent.

Beta exposures were also possible from radioactive silver research and activities at Horizons, with energies ranging from 21.83 keV to 1.20 MeV.

5.3.3 Neutron

Based on the radioactive materials present on the Horizons site, no source of neutron exposures would result from the operations performed. Therefore, further discussion or evaluation of neutron exposures will not be included in this evaluation.

5.3.4 Photon

Photons from uranium are primarily from the Th-234 daughter of U-238 and are in the energy range of 30 - 250 KeV. There are higher-energy photons, up to 1.00 MeV, from another U-238 daughter, Pa-234m, but the abundance of these photons is less than 1%. Th-232 itself has no photons; however, many of the daughter radionuclides in the natural thorium decay series do emit photons. These photons have an energy range up to a maximum of 2.61 MeV (Radiological Health, 1970). The photon energies associated with radioactive silver range from 116 keV to 657 keV.

5.3.5 Incidents

Although there is information on a minor incident included in the documentation available to NIOSH for the Horizons site, no incidents of significant dose consequence (i.e., no discrete incidents) requiring evaluation were identified. Because personnel external dosimetry information is available for the proposed class, and because source term information associated with the potential non-discrete incident radionuclide exposures exists, further discussion or evaluation of incident exposures will not be included in this evaluation.

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

The following represents an overview of the state of the available internal and external monitoring data for the Horizons, Inc., class under evaluation.

6.1 Horizons Internal Monitoring Data

No urine sampling or whole-body counting was found during any time period evaluated in this report. The only available internal monitoring data are from periodic air monitoring conducted in the facility. Air samples and wipe samples were taken and analyzed for (alpha) thorium and reported in December 1954, and again for September 1955. Limited uranium air samples were also taken and reported for July 1953. In addition, source term information and associated process and operations information are available for the proposed worker class time period. Air monitoring is discussed further in Section 6.3.

6.2 Horizons External Monitoring Data

External monitoring data were located during the NIOSH data capture efforts. These monitoring data include dosimeter results from May 1954 to December 1955 (USAEC, 1954; USAEC, 1955). These data provide weekly dosimeter results from May 1954 through June 1955; monthly reports are provided for October 1955 through December 1955. Cycle data are also available for the 1954 Horizons workers (USAEC, 1954; Horizons, 1954; USAEC, 1955). A memo regarding a trip report to Horizons in July 1953 states that Horizons management instituted the wearing of film badges provided by Tracerlab; however, no film badge data have been located prior to May 1954 (Visit, 1953). There also appears to be a data gap between mid-May 1955 and October 1955. External dose measurements were recorded for beta and gamma exposures. Other than the data identified above, no other personnel external monitoring data were identified for the January 1, 1956 through December 31, 1956 part of the operational period, or for the entire residual radioactivity period. There are data from area monitoring performed as a part of the FUSRAP and remediation surveys; these data can be used with the available personnel monitoring data to bound doses for the residual radioactivity period, as discussed in the dose reconstruction feasibility evaluation in Section 7.0.

6.3 Horizons Air Sampling Data

Air sampling was conducted periodically at Horizons. Air samples and wipe samples were taken and analyzed for (alpha) thorium and reported in December 1954, and again for September 1955. Limited uranium air samples were also taken and reported for July 1953. There is no indication why the samples were taken or the method used to count the samples; therefore, these data will not be employed in this evaluation. Sampling (general air, breathing zone air, direct, and wipe) was also conducted at Horizons by the Health and Safety Laboratory (HASL) in February 1955 with the intent of: (1) estimating the daily weighted average exposures of personnel working on the AEC project; (2) determining the degree and extent of radioactive contamination of building and equipment; and (3) providing a basis for control recommendations where necessary. The methods used to collect and count the samples are clearly described in the HASL report and provide the data used to bound occupational exposures during the residual period. The HASL results indicated exposures exceeding the maximum permissible concentration to thorium relative to the limits prevailing at that time period (HASL, 1955).

During the post-AEC residual period at the former Horizons site, several inspections/evaluations and remediation surveys were performed. In 1977, the Oak Ridge National Laboratory (ORNL) performed a survey of the former Horizons site at the request of the Energy Research and Development Administration (ERDA). The survey included surface contamination and radiation surveys as well as thoron (radon-220) progeny airborne concentrations in the former production buildings (ORNL, Aug77; ORNL, Feb77; FUSRAP, 1979). The United States Nuclear Regulatory Commission (USNRC) also conducted a 1993 inspection of the former Horizons site that included radiological surveys of the former production facilities (USNRC, 1993). There were also two pre-remediation surveys of the site that included surface contamination evaluations and airborne radioactivity surveys (Fluor Daniel, 1994; Koh, 1998).

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

The feasibility determinations for the class of employees under evaluation in this report are 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 5.3. This approach is discussed in OCAS's SEC Petition Evaluation Internal Procedures, which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00094 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Horizons 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 Review

NIOSH did not locate any bioassay monitoring data for any period under evaluation. Therefore, an internal data sufficiency and pedigree evaluation is not possible for this data type.

NIOSH has access to some source term information for the thorium, uranium, and silver process activities during the operational period (January 1, 1952 through December 31, 1956). The 1985 FUSRAP report (DOE, 1985) and the 1954 HASL review of operations (HASL, 1955) document the operational conditions at the site, the scale-up in electrolytic operations prior to 1954, and the radiological conditions that existed prior to the implementation of the HASL corrective actions. The HASL report includes an air sample and surface contamination evaluation of the potential internal exposure conditions. NIOSH has drawn the following conclusions from its review of the source term data in these reports:

- The available thorium and thorium progeny data are not sufficient to support dose reconstruction during the operational period.

- The available data are sufficient to support bounding the internal dose for the residual radioactivity period.

The 1985 FUSRAP report supports NIOSH's view that the available radiological data represent the bounding exposure scenarios for the residual period (1957-2006). Not only is it illogical for the potential exposures from the residual period to exceed the operational period, but Horizons conducted clean-up activities and safety/exposure improvements after the HASL Survey (R&D, 1955). In support of this view, NIOSH compared data from the 1977 FUSRAP survey, the 1985 FUSRAP report, and the 1993-1995 remediation surveys. The results showed that the 1977 FUSRAP data would represent the highest potential radiological exposures during the residual radioactivity period. Based on this comparison, NIOSH used the 1977 FUSRAP survey data as a lower-bounding condition, and the 1954 HASL Survey operational data (HASL, 1955) as an upper-bounding condition for the internal exposure feasibility evaluation of the residual radioactivity period.

The internal dose reconstruction feasibility evaluations for all periods under evaluation are presented in Section 7.2.

7.1.2 External Monitoring Data Review

NIOSH has access to the original external dosimetry information and documentation for the period from 1954 through 1955 (some gaps in data do exist); this would be during the period of pilot-scale operations when thorium activities were performed on a constant basis in contrast to earlier, small-scale research and development (DOE, 1985; Service, 1954; Visit, 1953; Final Report 1954; Fused Salt, 1955; Report, 1954; 1Q Progress Report, 1952; 5Q Progress Report, 1953; 6Q Progress Report, 1953). In addition, NIOSH has source term information for the thorium, uranium, and silver process activities. The original external dosimetry data provide actual doses recorded by individuals for a specific time period (exchange frequencies were weekly or monthly depending on the time period). Only positive results were reported; all others are "X-ed" out. It is assumed that the "X" represents an actual datum that is below the limits of detection for the film.

Information included in the 1985 FUSRAP report (DOE, 1985) and the 1954 HASL review of operations (HASL, 1955) documents the conditions at Horizons during the operational period. These documents discuss the scale-up in electrolytic operations over the early years and the radiological conditions that existed prior to the implementation of the HASL corrective actions. The 1954 HASL Report names individuals who, based upon the report, would have a potential for external radiation exposure (i.e., furnace operator, metal chipping, and washing). NIOSH has identified recorded external doses for all but one of the individuals named in the report. In addition, many other individuals not named in the report also have recorded external doses.

In light of the conclusions reached regarding internal dose reconstruction feasibility for the operational period (see Sections 7.1.1 and 7.2.3), NIOSH did not perform an extensive external data sufficiency and pedigree evaluation for the external data associated with Horizons operations. Although no specific conclusions were drawn about the external data during the operational period and the associated dose reconstruction feasibility, NIOSH has drawn following general conclusions:

- The external data and source term information will be used for partial dose reconstructions for the operational period.

- The external data are sufficient to support bounding the external dose for the residual radioactivity period.

Using the data from the 1955 HASL survey (HASL, 1955) and the 1977 FUSRAP survey (ORNL, Aug77), it will be possible to interpolate the potential external exposure between the time of the two surveys. As discussed in Section 7.1.1, the 1977 FUSRAP survey data represent the highest potential radiological exposures during the residual radioactivity period when compared to the 1985 FUSRAP and 1993-1995 remediation survey data). Therefore, the 1977 FUSRAP survey data serve as a lower-bounding condition, and the 1954 HASL survey data (HASL, 1955) serve as the upper-bounding condition for the external exposure feasibility evaluation for the residual radioactivity period.

The external dose reconstruction feasibility evaluations for all periods under evaluation are presented in Section 7.3.

7.2 Internal Radiation Doses at Horizons

The principal source of internal radiation doses for members of the proposed class was exposures to thorium (as well as thorium daughter products and thoron), uranium, and radioactive silver (FUSRAP, 1985; Mataich, 1954). A discussion of the feasibility of internal dose reconstruction for the proposed class is provided below.

7.2.1 Sources of Internal Radiation Dose and Related Monitoring Data

The following subsections summarize the extent and limitations of information available for reconstructing the internal doses of members of the proposed class. As previously discussed, no *in vivo* or *in vitro* bioassay data are available for the Horizons proposed worker class. Therefore, the internal dose feasibility evaluation is based solely on air monitoring, source term, and process information.

7.2.1.1 Operations-Related Internal Dose

Internal exposures during the Horizons operational period (January 1, 1952 through December 31, 1956) included exposures related to the high-temperature electrolytic operations, laboratory analysis and testing, and related activities. Exposures were possible in the direct vicinity of the operations/activities, and also from ambient environmental exposures (in the immediately surrounding work areas). The analyses of potential personnel exposures for this time period are described below.

Airborne Levels

The 1954 HASL report includes an airborne monitoring and surface contamination evaluation conducted during the stage of Horizons operations at which radiological controls were insufficient for maintaining personnel occupational internal exposures below maximum permissible exposure levels in effect at that time (HASL, 1955). Descriptions of the operations evaluated during the period of the HASL review discussed activities that were likely to produce significant personnel internal exposures (i.e., open area radioactive material chipping and crushing, sweeping of contaminated surfaces, and hand-scooping of materials). The air sampling data (alpha radiation counts of general area and personnel breathing zone) are representative of elevated exposure scenarios for such operations in both buildings associated with the high-temperature electrolytic processes during that time. However, there is not enough evidence to support that these data provide bounding values for the operational period. Therefore, these data cannot be used to perform dose reconstructions for internal exposures at Horizons. NIOSH concludes that the HASL data are not appropriate for dose reconstruction during the operational period for the following reasons:

1. Although the HASL study was performed during Horizons pilot-scale operations when more radioactive material was present at (as opposed to R&D activities), NIOSH has little information about the initial process, process changes, and process controls implemented during the R&D period that would allow NIOSH to conclude that exposure levels were likely lower during the R&D period.

2. Based on its review and analysis of the electrolytic process, NIOSH has concluded that the high temperature associated with the thorium electrolytic operations would have likely resulted in the release of radium (Ra-228 and Ra-224), thoron (Rn-220), and associated radon progeny (Bi-212 and Pb-212). This would have resulted in significant localized internal exposure conditions in the electrolytic process equipment. The delay period between the collection and counting of the HASL air sample data (24 to 34 days), and the associated half-lives of the radium and thoron and associated progeny, directly impact NIOSH's ability to bound the radium internal exposures or to reconstruct with sufficient accuracy the internal exposures from these radionuclides.

Information associated with Horizons silver operations discusses the controls that were in place for the research and plating work performed with the radioactive silver (Mataich, 1954; DOE, 1985). The silver operations were performed after the HASL site evaluation and were performed with radiological controls (i.e., within ventilation hoods) to prevent personnel exposures (Mataich, 1954). Because NIOSH had already determined that the internal dose cannot be reconstructed during the operational period, NIOSH did not make a feasibility determination with respect to silver exposures. NIOSH currently has no personnel monitoring data for silver exposures. If monitoring data become available, NIOSH will evaluate the use of these data for partial dose reconstructions.

7.2.1.2 Residual Radioactivity-Related Internal Dose

Ambient environmental dose is the primary source of internal dose for the residual radioactivity period under evaluation in this report (January 1, 1957 through July 31, 2006). The internal dose for this period can be estimated (as described below) based on the data available from the 1955 HASL survey and the 1977 post-operation remediation survey; each dataset provides values that represent the maximum exposure points at the time of the survey (HASL, 1955; Survey, 1955).

After AEC-related operations ceased at Horizons in 1956, the contracts and associated radioactive material licenses were terminated (FUSRAP, 1985; DOE, 1985). No AEC-related thorium or uranium high-temperature operations occurred during the residual radioactivity period, thus eliminating any localized source of internal exposures from uranium or thorium (or its progeny). Cessation of AEC-related high-temperature operations also eliminated the Ra-224 and thoron exposures produced these processes. The short half-lives of radium, thoron, and its associated progeny contributed to this elimination. Ra-228 exposures can be bounded using FUSRAP report data and Ra-228 decay information.

Considering the above information, NIOSH assumes that the 1955 HASL data are appropriate for bounding internal dose reconstruction during the residual period for the following reasons: (1) the HASL study was performed toward the end of operations when more radioactive material was present at Horizons; (2) the study was specifically performed as an assessment of workers' exposure; (3) conditions improved after the study because operations were suspended while decontamination efforts were performed (R&D, 1955); and (4) of the limited data available during the operational period, the HASL study data provide the highest level of confidence that the samples were collected and analyzed appropriately. Therefore, the radiological conditions at any point during the residual period could not have been any worse than described in that study.

Compared to the 1993, 1994, or 1998 survey data, the 1977 FUSRAP data represent the highest potential intakes associated with the residual radioactivity (post-operational) period. This outcome supports the application of the 1977 FUSRAP data as the lower bound in the evaluation of internal dose for the residual radioactivity period.

7.2.2 Internal Dose Reconstruction

The following subsections present the general dose reconstruction methodology for determining whether doses can be bounded or reconstructed with sufficient accuracy for the proposed class of Horizons workers.

7.2.2.1 Operational Period

The Horizons operational period will not be discussed because NIOSH has already determined that dose reconstruction for the operational period is infeasible.

7.2.2.2 Residual Period

Based on the available Horizons process information, source term information, air sample data for the operational period, and pre-remediation survey data over multiple periods, NIOSH has the necessary data to support bounding internal exposures for uranium, thorium, and thorium progeny during the residual period. Because radioactive operations were terminated at the end of the operational period, the residual period doses can be bounded through the application of the operational data, although this would result in over-estimates for residual period exposures and doses. The methods described in this section provide a sufficiently accurate estimation of the residual radioactivity period doses at Horizons (January 1, 1957 through July 31, 2006).

Based on the elimination of the exposure source after operations ceased, and the half-life and decay of any residual contamination, no exposure evaluation of the radioactive silver was required or performed for the residual period.

Thorium and Radium Internal Dose Reconstruction during the Residual Period

Thorium and radium intakes during the residual period can be bounded using data from the 1955 HASL survey to represent the upper bound air activity at the start of the residual period (January 1, 1957), and data from the 1977 FUSRAP report (Survey, 1955) to represent the air activity in 1977. The information provided by HASL, and from the Quarterly Report to the AEC immediately after the HASL report was issued (R&D, 1955)indicating that work had been temporarily suspended for clean-up and implementation of the HASL recommendations, demonstrates that the data provided by HASL are bounding. Since contamination levels documented in the 1993 pre-remediation survey were similar to those documented in 1977, and lower than those identified by the HASL report, the 1977 air activity is assumed to be representative of air concentrations during the 1978-1993 period as well. With cessation of operational activities (and any associated acute localized releases of radioactivity), air concentrations would be driven by re-suspension of previously- deposited materials. Re-suspension of contamination within the facility is assumed to decrease according to an exponential model (Healy, 1971; Sehmel, 1980; Till, 1983), as described below.

- 1957 Air Concentration: HASL conducted a thorough airborne radioactivity survey during the end of the operational period. This survey included both breathing zone and general area air samples. A bounding estimate of airborne radioactivity during the start of the residual period was calculated using the 95th percentile of the general area air samples collected in the HASL study (64 samples total). Samples that were labeled as breathing zone, or were clearly associated with operational activities, were excluded from this dataset. The general area room air concentrations included one location that was 16 times higher than all the others and therefore excluded because it was clearly impacted by operational activities. The resultant air concentration was 12 pCi/m^3 resulting in an intake of 77 pCi/d (averaged over one year). Since the HASL air sample data were total alpha, this intake quantity represents both Th-232 and Th-228 (i.e., Th-232 + Th-228).

- 1977 Air Concentration: Total gross alpha surface contamination (fixed + removable) and removable alpha surface contamination measurements are documented in the 1977 FUSRAP survey. The 1977 air concentration was calculated by applying a re-suspension factor of 1E-6 to the 95th percentile of the total alpha surface contamination values collected in building B (200 measurements) and a re-suspension factor of 1E-4 to the maximum removable activity in the

overhead areas of Building B. These two components were summed. The resultant intake quantity was 1.6 pCi/m^3 resulting in an intake of 10 pCi/d (averaged over one year). This value greatly exceeds the airborne alpha concentrations reported in the 1977 FUSRAP report based on a limited survey (0.0011 pCi/m^3).

Building B values were used because they were higher than Building C and because it was likely impossible to estimate the time spent within each building. An evaluation of the suitability of the 1E-6 re-suspension factor was performed using the RESRAD Build code (RESRAD, 2003). Probabilistic distributions for sensitive parameters (deposition velocity, re-suspension rate, air exchange rate, air release fraction, removable fraction and source lifetime) were selected (USNRC 2000). The resultant re-suspension factor at the 95th percentile was 3E-7.

- Exponential Model: The 1957 and 1977 daily intake rates were used to estimate the annual intake from the following equation:

$$I_t = I_0 * e^{-\lambda * t}$$

where:

I_t = daily intake rate at time t
t = time (days) since January 1, 1957
I_0 = daily intake on January 1, 1957
λ = exponential constant

The constant was determined to be 0.00028 day^{-1}.

- Radium 228 Intake: Because of the potential for elevated levels of Ra-228 due to high-temperature operations, intakes were adjusted to account for the potential disequilibrium conditions. Since Th-232 and Ra-228 were shown to be in equilibrium in 1977 (FUSRAP, 1979), the maximum Ra-228 concentration in 1957 can be determined based on the radiological half-life of Ra-228 (6.9 yr) and setting the Ra-228 intake quantity equal to the thorium value in 1977.

Table 7-1 shows the resulting intake quantities for the period 1957 through 1977. No further reduction in intake quantity is assumed after 1977 based on the 1993 facility survey that showed contamination levels in 1993 that were similar but lower to those in 1977. Using the 1977 intake quantities provides a conservative approach to dose reconstruction post-1977. Corresponding ingestion intakes (OCAS-TIB-009) are shown in Table 7-2.

Table 7-1: Thorium and Ra-228 Inhalation
(pCi/d) (Table 7-1 spans two pages)

Year	Th-232 + Th-228	Ra-228
1957	77	288
1958	70	236
1959	63	193
1960	57	158
1961	52	129

Table 7-1: Thorium and Ra-228 Inhalation (pCi/d) (Table 7-1 spans two pages)		
Year	**Th-232 + Th-228**	**Ra-228**
1962	47	105
1963	42	86
1964	38	70
1965	34	58
1966	31	47
1967	28	39
1968	25	31
1969	23	26
1970	21	21
1971	19	17
1972	17	14
1973	15	12
1974	14	9
1975	13	8
1976	11	6
1977	10	5
> 1977	10	5

Table 7-2: Thorium and Ra-228 Ingestion (pCi/d)		
Year	**Th-232 + Th-228**	**Ra-228**
1957	2.4	8.8
1958	2.1	7.2
1959	1.9	5.9
1960	1.7	4.8
1961	1.6	3.9
1962	1.4	3.2
1963	1.3	2.6
1964	1.2	2.1
1965	1.0	1.8
1966	0.9	1.4
1967	0.9	1.2
1968	0.8	1.0
1969	0.7	0.8
1970	0.6	0.6
1971	0.6	0.5
1972	0.5	0.4
1973	0.5	0.3
1974	0.4	0.3
1975	0.4	0.2
1976	0.3	0.2
1977	0.3	0.2
> 1977	0.3	0.2

Thorium Progeny Internal Dose Reconstruction

During the 1977 FUSRAP survey, evidence of thoron emanation into the facility was identified (elevated alpha levels at floor drains and near cracks where floors and walls intersect). A series of measurements indicated Pb-212 levels ranging from 0.005 pCi/l to 0.49 pCi/l. Measured concentrations of Bi-212 ranged from non-detectable to 0.19 pCi/l. A bounding estimate of the Pb-212 concentrations in 1977 was made using the 95th percentile (0.38 pCi/l). The Rn-220 (thoron) concentration was assumed to be equal to the Pb-212 concentration. Since the thoron concentration would be expected to track with the total thorium inventory, the 1957 through 1976 concentrations were normalized to the thorium concentration in each respective year. Resultant values in units of working level month (Rn-220) are shown in Table 7-3.

Table 7-3: Thoron (Rn-220)

Year	Rn-220 (WLM)
1957	6.2E+00
1958	5.5E+00
1959	4.9E+00
1960	4.4E+00
1961	3.9E+00
1962	3.5E+00
1963	3.1E+00
1964	2.7E+00
1965	2.4E+00
1966	2.2E+00
1967	1.9E+00
1968	1.7E+00
1969	1.5E+00
1970	1.3E+00
1971	1.2E+00
1972	1.1E+00
1973	9.4E-01
1974	8.4E-01
1975	7.5E-01
1976	6.6E-01
1977	6.0E-01
>1977	6.0E-01

7.2.3 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has established that it cannot estimate with sufficient accuracy the internal exposures during the operational period (January 1, 1952 through December 31, 1956). However, NIOSH can bound the residual uranium, thorium, and thorium progeny exposures and associated doses for the residual radioactivity period (January 1, 1957 through July 31, 2006).

7.3 External Radiation Doses at Horizons

The principal source of external radiation doses for members of the proposed class was exposures to thorium, uranium, and radioactive silver (FUSRAP, 1985; Mataich, 1954). A discussion of the feasibility of the external dose reconstruction for the proposed class is provided below.

7.3.1 Sources of External Radiation Dose and Related Monitoring Data

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

7.3.1.1 Operations-Related External Dose

External exposures during the Horizons operational period (January 1, 1952 through December 31, 1956) included exposures from thorium and uranium as well as Ag-110m during high-temperature electrolytic operations, laboratory analysis and testing, and related activities. Exposures were possible in the direct vicinity of the operations/activities, and also from ambient environmental exposures (in the immediately surrounding work areas). The analyses of the potential personnel exposures for this period are described below.

Dosimeter Results for Horizons

In addition to having the original personnel external dosimetry information and documentation for the period 1954-55 (some data gaps do exist), NIOSH has source term information for the thorium, uranium, and silver process activities. Beta and photon external exposures from these radioactive materials did occur as a result of the work at Horizons.

7.3.1.2 Residual Radioactivity Period-Related External Dose

Ambient environmental dose is the primary source of external dose for the residual radioactivity period under evaluation in this report (January 1, 1957 through July 31, 2006). The external dose for this period can be estimated (as described below) based on the data available from the 1955 HASL survey and the 1977 post-operation remediation survey; each dataset provides values that represent the maximum exposure points at the time of the survey (HASL, 1955; Survey, 1955).

7.3.2 Horizons Occupational X-Ray Examinations

No information is available on occupational medical X-ray examinations for Horizons workers during any covered timeframe. Information obtained from a former employee indicated that pre-employment physicals were required to work at Horizons, but there was no recollection if a chest X-ray was part of the exam. For the purpose of partial dose reconstructions, a single PA radiographic chest X-ray will be assumed to have been required during each pre-employment, annual, and termination physical at Horizons. The assignment of X-ray dose is in accordance with ORAUT-OTIB-0006.

7.3.3 External Dose Reconstruction

By December 21, 2007, four EEOICPA claims meeting the proposed class definition being evaluated in this report had been submitted to NIOSH. Of those four claims, NIOSH has completed dose reconstructions for none of these claims.

There is an established protocol for assessing external exposure when performing dose reconstructions. These protocol steps are discussed in the following subsections for both the operational and residual radioactivity periods.

- Photon/Electron Dose (Monitored and Unmonitored)
- Medical X-ray

7.3.3.1 Photon/Electron Dose during the Operational Period

The external dose for the operational period will be evaluated based on the available personnel dosimetry data for the period. The available external dosimetry data represent the maximally-exposed worker and exposure scenarios for the period. These data have been used to support NIOSH's evaluation of the ability to bound external doses, as described in the following subsections.

Monitored Individuals

NIOSH will use the actual, original dosimetry documentation to reconstruct dose for those members of the proposed class for whom NIOSH has these data. This is the preferred data type and dose reconstruction method specified by the dose reconstruction program. When an individual is unmonitored (or data are unavailable, missing, or otherwise unavailable), the unmonitored approach can be used as a bounding approach for external dose reconstruction.

Unmonitored Individuals

Results of film badges worn from May 31, 1954 through December 1955 (Horizons, 1954; USAEC, 1955) are summarized in Tables 7-4 and 7-5 and can be used either to fill in gaps between periods where monitoring data are available, or for unmonitored workers. Results from weekly badge cycles (May 1954 – June 13, 1955) and monthly cycles (September 1955 – December 1955) were analyzed separately. Positive badge results were fit to a lognormal distribution. Missed dose was based on a lognormal distribution with a geometric mean equal to the dosimeter LLD/2 and 95^{th} percentile of the LLD (resulting GSD of 1.52). The annual dose quantities were determined by weighing measured and missed dose distribution by the fraction of cycles with measured and missed dose, respectively. A dosimeter LLD of 40 mR was used based on the typical response for film dosimetry (NRC, 1989).

Table 7-4: Horizons Film Badge Gamma Radiation Results
(mR/hr or mrad/hr, as applicable)

Period	D_D		D_M		Total Dd+Dm	
	GM	GSD	GM	GSD	GM	GSD
5/31/1954 - 6/13/1955 (weekly data)	189	1.71	961	1.52	1149	1.71
September 1955 - December 1955 (monthly data)	863	1.54	116	1.52	979	1.54

D_D and D_M are dosimeter dose and missed dose, respectively, as defined in OCAS-IG-001.

Table 7-5: Horizons Film Badge Beta Radiation Results
(mR/hr or mrad/hr, as applicable)

Period	D_D		D_M		Total Dd+Dm	
	GM	GSD	GM	GSD	GM	GSD
5/31/1954 - 6/13/1955 (weekly data)	29	1.96	1240	1.52	1270	1.96
September 1955 - December 1955 (monthly data)	Analysis not performed, reported values were gamma only					

D_D and D_M are dosimeter dose and missed dose, respectively, as defined in OCAS-IG-001.

7.3.3.2 Photon/Electron Dose during the Residual Period

Dose rate measurements were performed in 1955 (HASL, 1955) during the HASL survey, and in 1977 (Survey, 1955) during the FUSRAP survey. These results were fit to a lognormal distribution shown in Table 7-6. Note that for the 1955 data, only general area dose rate values (i.e., not associated with process equipment or material) were used in the analysis. Annualized values (based on a 2000-hr work year) are shown in Table 7-7 and may be used to bound external exposure during the residual period. Note that the 1955 values are assumed to remain constant until 1977, at which time the use of 1977 values are recommended.

Table 7-6: Summary of Available Data
(mR/hr or mrad/hr, as applicable)

Type	1955 HASL Report		1977 Fusrap Report	
	GM	GSD	GM	GSD
Gamma	0.194	2.60	0.013	1.75
Beta	0.053	2.01	0.045	2.13

Table 7-7: Recommended Dose Values (R/yr)				
Type	**1957 - 1976**		**1977 onward**	
	GM	**GSD**	**GM**	**GSD**
Gamma	0.388	2.60	0.025	1.75
Beta	0.106	2.01	0.091	2.13

7.3.3.3 Medical X-ray

A single PA radiographic chest X-ray is assumed to have been required during each pre-employment, annual, and termination physical at Horizons. Although no records are identified indicating that occupational medical X-rays were required of Horizons employees, for the purpose of partial dose reconstructions during the operational period (before January 1, 1957), X-ray exams will be assumed to have been required. This assumption provides a level of conservatism to the dose reconstruction. Organ doses from PA chest X-ray for all time periods are available in ORAUT-OTIB-0006. NIOSH believes that by using this methodology, occupational medical X-ray doses can be reconstructed.

7.3.4 External Dose Reconstruction Feasibility Conclusion

Using actual data or co-worker data and the methodologies described, NIOSH has established that it can estimate the external exposures associated with radioactive operations during the operational period and bound external exposures for the residual period. NIOSH believes that the data identified during the operational period (pilot-scale) are conservative relative to the earlier R&D period and the later post-operations period. Beginning in 1957, Horizons documentation discusses the clean-up effort undertaken in response to the HASL survey; this clean-up would be expected to result in lower exposure potential (USAEC, 1954; Horizons, 1954; USAEC, 1955; Film, 1955; Monthly, 1955).

7.4 Evaluation of Petition Basis for SEC-00094

The petition basis provided in SEC-00094 stated that members of the proposed class incurred unmonitored radiation exposures at Horizons (through lack of personal or area monitoring) and doses during the operations period (January 1, 1944 through December 31, 1956) and residual period (January 1, 1957 through July 31, 2006). The following topic was detailed in petition SEC-00094. Italicized statements are from the petition; the comments that follow are from NIOSH.

SEC-00094: *I have no knowledge of any monitoring data for Horizons, Inc*

Personal monitoring, area monitoring, or co-worker monitoring are not always required in order to develop an exposure model for a given facility. However, if these monitoring data are not available, NIOSH must have access to source term information and detailed process information in order to develop a sufficiently accurate exposure model. NIOSH has determined that it does not have adequate internal monitoring data for members of the proposed class, nor does it have enough source term or process information applicable to the class to develop a sufficiently accurate model for dose reconstruction for these exposures during the associated time period. However, as discussed in Section 5.0, NIOSH has discovered no information regarding any operations or activities at the

Horizons site in Cleveland prior to licensing on September 4, 1947. Furthermore, NIOSH has found no evidence that radiological material was on site prior to 1952; therefore, the operations period is considered to be January 1, 1952 through December 31, 1956.

7.5 Summary of Feasibility Findings for Petition SEC-00094

This report evaluates the feasibility for completing dose reconstructions for employees at Horizons, Inc., from January 1, 1944 through December 31, 1956, and for the residual period from January 1, 1957 through July 31, 2006. As discussed in Section 5.0, NIOSH has discovered no information for any radiological operations or activities at the Horizons site in Cleveland prior to January 1, 1952; therefore, the operations period is considered to be January 1, 1952 through December 31, 1956. NIOSH found that the available monitoring records, process descriptions, and source term data are not sufficient to complete dose reconstructions for the class of employees who worked during the operational period under evaluation.

Table 7-8 summarizes the results of the feasibility findings at Horizons for each exposure source during the time periods from January 1, 1952 through December 31, 1956 and from January 1, 1957 through July 31, 2006.

Table 7-8: Summary of Feasibility Findings for SEC-00094

Operations Period from January 1, 1952 through December 31, 1956
and Residual Period from January 1, 1957 through July 31, 2006

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal (Operational Period: January 1, 1952 through Dec 31, 1956)[1]		X
Internal (Residual Period: Jan 1, 1957 through Jul 31, 2006)[1, 3]	X	---
External (Operational and Residual Periods)		
- Gamma	X	---
- Beta	X	---
- Occupational Medical X-ray	X	---

[1] Internal includes an evaluation of airborne dust and source term data.
[2] Includes radium (Ra-228 and Ra-224), thoron (Rn-220), and associated radon progeny (Bi-212 and Pb-212).
[3] Ag-110m is not considered during the residual period.

As of December 21, 2007, a total of four claims have been submitted to NIOSH for individuals who worked at Horizons, Inc. and are covered by the proposed class definition evaluated in this report. Dose reconstructions have been completed for none of these individuals.

8.0 Evaluation of Health Endangerment for Petition SEC-00094

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.

Based on available data, knowledge of source terms and activities, and surveys conducted during both the operational and residual periods, NIOSH's evaluation determined that it is not feasible to estimate internal radiation dose for members of the proposed class with sufficient accuracy during the operational period. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is required.

9.0 NIOSH-Proposed Class for Petition SEC-00094

Based on its research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all AWE employees who worked at Horizons, Inc., for a number of work days aggregating at least 250 work days from January 1, 1952 through December 31, 1956, or in combination with work days within the parameters established for one or more other classes of employees in the SEC. The class was modified because collected data are not sufficient to support reconstruction of internal radiation doses with sufficient accuracy during the operational period; however, collected data are sufficient to support reconstruction of doses with sufficient accuracy for the residual period.

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-00094. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

These actions are based on existing, approved NIOSH processes used in dose reconstruction for claims under EEOICPA. NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not

available, or is very limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining that it would not be feasible to reconstruct the dose for the class proposed in this petition during the operational period, but that it would be feasible to reconstruct dose for the residual period.

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