SEC Petition Evaluation Report
Petition SEC-00116

Report Rev #: 0 Report Submittal Date: August 17, 2009

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Site Expert(s):	N/A

Petition Administrative Summary			
Petition Under Evaluation			
Petition #	Petition Type	Petition Qualification Date	DOE/AWE Facility Name
SEC-00116	83.13	November 4, 2008	United Nuclear Corporation

Petitioner Class Definition
All site employees that worked in any area of the United Nuclear Corporation – Hematite, MO, site from January 1, 1958 through December 31, 1969 and January 1, 1970 through June 30, 2011 due to residual contamination.

Class Evaluated by NIOSH
All site employees that worked in any area of the United Nuclear Corporation – Hematite, MO, site from January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006.

NIOSH-Proposed Class(es) to be Added to the SEC
None

Related Petition Summary Information			
SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
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Related Evaluation Report Information	
Report Title	DOE/AWE Facility Name
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Evaluation Report Summary: SEC-00116, United Nuclear Corporation

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-00116, qualified on November 4, 2008, requested that NIOSH consider the following class: *All site employees that worked in any area of the United Nuclear Corporation – Hematite, MO, site from January 1, 1958 through December 31, 1969 and January 1, 1970 through June 30, 2011 due to residual contamination.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH modified the petitioner-proposed class because, although the petitioner requested an end date of June 2011, the employment period end date is limited to the covered period defined by the DOE Office of Health, Safety and Security, which is July 2006. The covered operational period was also adjusted to account for the Department of Labor (DOL) change in the operational period which was extended through 1973. NIOSH evaluated the following class: *All site employees that worked in any area of the United Nuclear Corporation – Hematite, MO, site from January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006.*

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

Based on its full research of the class under evaluation, including personnel interviews, NIOSH has obtained urinalysis, general area and fixed location air samples, personnel whole body dosimetry, and radiation survey records for the United Nuclear Corporation, Hematite, MO facility. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

Feasibility of Dose Reconstruction

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 the site profile and additional resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the evaluated class under plausible circumstances during the specified period.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is not required because NIOSH has determined that it has sufficient information to estimate dose for the members of the evaluated class.

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SEC Petition Evaluation Report for SEC-00116

ATTRIBUTION AND ANNOTATION: All conclusions drawn from the data presented in this evaluation were made by the ORAU Team Lead Technical Evaluators: Ray Clark and Alex Boerner, Oak Ridge Associated Universities (ORAU). 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 site employees that worked in any area of the United Nuclear Corporation site at Hematite, Missouri, from January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006. 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.*

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

[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.

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 SEC-00116 United Nuclear Corporation Class Definitions

The following subsections address the evolution of the class definition for SEC-00116, United Nuclear Corporation at Hematite, Missouri (UNC-Hematite). 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-proposed class. If some portion of the petitioner-proposed 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-00116, qualified on November 4, 2008, requested that NIOSH consider the following class for addition to the SEC: *All site employees that worked in any area of the United Nuclear Corporation, Hematite, MO, site from January 1, 1958 through December 31, 1969 and January 1, 1970 through June 30, 2011 due to residual contamination.*

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

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the UNC-Hematite workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00116 for evaluation:

> No Hematite personnel radiation dose records have been provided to NIOSH and possibly do not exist; therefore, it is quite conceivable that a fair and accurate dose reconstruction cannot be obtained with sufficient accuracy because data are lacking for this site (Affidavits, 2008, pdf pp. 28-29).
>
> I was never monitored for radium or thorium (Affidavits, 2008, pdf p. 36).

At the time NIOSH qualified this petition, NIOSH's UNC-Hematite research and data capture efforts (including interviews with former site employees) led to the conclusion that a significant number of site records exist for the petitioner-proposed class. However, NIOSH had been provided only limited internal and external dose information for UNC-Hematite workers during the time period under evaluation. While results were unavailable at that time, NIOSH believed that general area air sampling (continuous air monitoring) and fixed location (breathing zone) sampling were also conducted. In addition, NIOSH believed that external monitoring (i.e., personnel whole body [film badge] dosimetry and routine radiation surveys) were primary components of the external dosimetry program. Nevertheless, NIOSH determined that dosimetry monitoring data records were not currently available for all time periods or for all radionuclides. NIOSH concluded that there was sufficient documentation to support, for at least part of the proposed time period, the petition basis that internal and external radiation exposures and radiation doses were not adequately monitored at UNC-Hematite, 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 the petitioner-proposed class because, although the petitioner requested an end date of June 2011, the employment period end date is limited to the covered period defined by the DOE Office of Health, Safety and Security, which is July 2006. The covered operational period was also adjusted to account for the Department of Labor (DOL) change in the operational period which was extended through 1973 (DOL, 2009). Therefore, NIOSH defined the following class for further evaluation: All site employees that worked in any area of the United Nuclear Corporation, Hematite, MO, site from January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006.

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

Based on its research and multiple on-site data capture efforts, NIOSH has obtained urinalysis, general area and fixed location air samples, personnel whole body dosimetry, and radiation survey records for UNC-Hematite. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot bound the radiation doses (estimate radiation doses with sufficient accuracy).

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

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

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement, or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. The Site Profile for a small site may consist of a single document. As part of NIOSH's evaluation detailed herein, it examined the following TBDs for insights into UNC-Hematite operations or related topics/operations at other sites:

- Battelle-TBD-6000, *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals*, PNWD-3738 Rev 0, Rev. F0; Battelle; December 13, 2006; SRDB Ref ID: 30671

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

- Battelle-TBD-6001, Appendix D, *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium—Appendix D United Nuclear Corp.*, Rev. 0; Battelle; March 14, 2008; SRDB Ref ID: 41835

4.2 Technical Information Bulletins (TIBs)

A Technical Information Bulletin (TIB) 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 TIBs as part of its evaluation:

- Battelle-TIB-5000, *Default Assumptions and Methods for Atomic Weapons Employer Dose Reconstructions*, PNWD-3741, Rev. 00; Battelle; April 2, 2007; SRDB Ref ID: 32016

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

- ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*, Rev. 00; Oak Ridge Associated Universities; April 7, 2005; SRDB Ref ID: 19445

- ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities,* 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 UNC-Hematite employees. Three of the interviews were established through an initial telephone call followed by email correspondence that provided a preliminary list of anticipated interview questions, call-in information, and ORAUT contact information. The final interview was established and conducted on site during an ORAUT data capture trip in March 2009. NIOSH identified three production workers for possible interviews; however, attempts to make contact were unsuccessful. NIOSH was fortunate in locating three former managers and one former clerical employee. NIOSH was unable to locate any surviving Health Physics or Radiation Technicians. Following each interview, notes were prepared by team members and submitted to the DOE for classification review.

- Personal Communication, 2009a, *Personal Communication with Leader/Director (various titles)*; Telephone Interview by ORAU Team and NIOSH on February 4, 2009; SRDB Ref ID: 61673

- Personal Communication, 2009b, *Personal Communication with Office Worker*; Telephone Interview by ORAU Team on February 5, 2009; SRDB Ref ID: 61669

- Personal Communication, 2009c, *Personal Communication with Engineer/Manager (various titles)*; Telephone Interview by ORAU Team and NIOSH on February 12, 2009; SRDB Ref ID: 61676

- Personal Communication, 2009d, *Personal Communication with Supervisor/Superintendant (various titles)*; On-site Interview by ORAU Team on March 12, 2009; SRDB Ref ID: 69965

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 June 8, 2009)

Table 4-1: No. of UNC-Hematite Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	51
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006).	51[1]
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).	33
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	23[1]
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	23[1]

[1] Of the 51 submitted claims:

- Three were pulled by DOL and are no longer active; therefore, additional data linking has not occurred.
- Eight were pulled by DOL because the claims are covered by an existing SEC class. These claims are no longer active; therefore, additional data linking has not occurred.
- Four have employment only during the residual period; therefore, the data that may be available would not be representative of the site's AEC operations.
- Eight have missing data but have completed, compensable individual dose reconstructions. These claims are no longer active; therefore, additional data linking has not occurred.
- Five have claimed UNC employment that is still being researched by the site (current status: no indication of UNC-Hematite employment for these individuals).

As a result of the above actions and circumstances, NIOSH's review of claims to evaluate available internal and external dosimetry data was performed only for the remaining 23 claims; all 23 have internal and external data for their UNC-Hematite employment during the covered operational period.

NIOSH reviewed each claim as well as transcripts from the computer-assisted telephone interviews (CATI) to determine whether internal and/or external personal monitoring records could be obtained for the employee. Dose reconstructions performed to date were completed prior to the availability of personnel monitoring records. External doses estimates were based on a NIOSH assessment of the external dose information reported in a 1960 AEC inspection report for UNC-Hematite license renewal that was available when the TBD for UNC-Hematite was developed (Battelle-TBD-6001,

Appendix D). Internal doses estimates were based on a NIOSH assessment of the airborne radioactivity data (1959-1960 air samples) and personnel bioassay data (1962-1964 urinalysis data) that were available when the TBD for UNC-Hematite was developed (Battelle-TBD-6001, Appendix D). Dose reconstructions also employed the methodologies in ORAUT-OTIB-0004. During the data capture efforts conducted in support of the UNC-Hematite SEC petition evaluation, NIOSH identified internal and external monitoring records for individual UNC-Hematite workers that cover the entire Atomic Weapons Employer (AWE) operations period at the site. These data have been collected by NIOSH and are available for individual dose reconstructions, as applicable.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the evaluation of the proposed class. As of June 15, 2009, 1136 documents in this database were identified as pertaining to UNC-Hematite. These documents were evaluated for their relevance to this petition. The documents include historical background on the evolution of the site, licensing documentation and correspondence, process descriptions and procedures, logbook entries, radiological monitoring summaries and data (urinalysis, general area and fixed location air samples, personnel whole body dosimetry, and radiation survey records), radiological and contamination control program information and reporting, criticality controls, and incident documentation

4.6 Other Technical Sources

ORAUT-TKBS-0014-2, *Technical Basis Document for the Y-12 National Security Complex - Site Profile*, Rev. 02; Oak Ridge Associated Universities; November 8, 2007; SRDB Ref ID: 36045

4.7 Documentation and/or Affidavits Provided by Petitioners

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

- *Affidavits, Authorization Forms, and Associated Attachments from Name1, Name2, Name 3, and Name4*; June 13, 2008; OSA Ref ID: 106292, pdf pp. 1-39 (Affidavits, 2008)

- *NIOSH Dose Reconstruction Report for Name2*, April 8, 2008; OSA Ref ID: 106292, pdf pp. 40-47 (NIOSH, 2008)

- *NIOSH Dose Reconstruction Activity Report for Name2*, correspondence; January 25, 2006; OSA Ref ID: 106292, pdf pp. 48-50 (NIOSH, 2006)

- *Engineering Evaluation and Cost Analysis Regarding Local Aquifer in the Vicinity of the Westinghouse Former Fuel Cycle Facility*, select pages from a groundwater report; January 2003; OSA Ref ID: 106292, pdf pp. 51-53 (Cabrera Services, 2003)

- *Letter and Q&A Regarding the Combustion Engineering Plant at Hematite, Missouri Inspection Program*, correspondence and select attachments; November 24, 1978; OSA Ref ID: 106292, pdf pp. 54-56 (Keppler, 1978)

- *Investigation to Determine the Source of Technetium-99 in Groundwater Monitoring Wells 17 and 17B*, select pages of report; September 1996; OSA Ref ID: 106292, pdf pp. 57-61 (Gateway, 1996)

- *Cancel Permit Application*, correspondence to EPA; December 27, 1973; OSA Ref ID: 106292, pdf p. 62 (Loysen, 1973)

- *Executed Application for Renewal of Operating Permit for Septic System*, correspondence to Missouri Clean Water Commission; February 6, 1974; OSA Ref ID: 106292, pdf p. 63 (Darr, 1974)

- *Hematite Revisited*, news story; OSA Ref ID: 106292, pdf pp. 64-70 (MCW News, unknown date)

- *Remedial Investigation Report for the Westinghouse Hematite Site*, select pages from report; January 2007; OSA Ref ID: 106292, pdf pp. 71-92 (SAIC, 2007)

- *Federal Register Notices*, Volume 66, No. 11; January 17, 2001; OSA Ref ID: 106292, pdf pp. 93-96 (Federal Register, 2001)

- *Consult Call Response Letter;* October 3, 2008; OSA Ref ID: 107083, pdf p. 1 (Consult Call, 2008)

- *Clarification Responses to NIOSH on the Submitted Petition SEC 00116*; document detailing SEC-00116 changes; October 3, 2008; OSA Ref ID: 107083, pdf pp. 2-7 (Clarification , 2008)

- *Letter and Associated Attachments Discussing Incorrect and/or Assumed Statements*; Name2; April 15, 2008; OSA Ref ID: 107083, pdf pp. 8-14 (Letter, 2008)

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at UNC-Hematite from January 1, 1958 through December 31, 1973 and the information available to NIOSH to characterize particular processes and radioactive materials for the covered period at the site. 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 the processes through which radiation exposures to workers 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 UNC-Hematite Plant and Process Descriptions

The UNC-Hematite site was centrally located on approximately 228 acres of land roughly 40 miles south of St. Louis, Missouri near the town of Hematite, just west of Festus, Missouri. The northern boundary of the site is Missouri State Highway 21-A (also known as State Road P). Joachim Creek forms the southern boundary. Private property bounds the site on the east and west. The Mallinckrodt Corporation acquired 150 acres of farm property in 1955; construction of the original production facilities began in March 1956. The plant first became operational in September 1956, producing uranium for use in the navy nuclear fuel program. Other non-navy production work involving radioactive materials subject to Atomic Energy Commission (AEC) licensing began in 1958. Additional purchases of surrounding land were negotiated in later years by the plant's various owners, the last such purchase taking place in 1991 by Westinghouse Electric.

There have been six owners of the UNC-Hematite facility:

- U.S. Government contracting phase of operations: Mallinckrodt (1956-1961); United Nuclear Corporation (1961-1969); Gulf United Nuclear Fuels Corporation (1970-1973).

- Commercial phase of operations: Combustion Engineering (1974-1989); Asea Brown Boveri Combustion Engineering (1989-2000); and Westinghouse Electric Company (2000-present).

Site operations involved about seven acres near the geographic center of the property. The production facilities consisted of two main buildings, each with several thousand square feet of floor space. An incoming storage and blending building and an outgoing storage building were located between the two main buildings (AEC, 1960).

Throughout its history, the UNC-Hematite plant's primary function was to manufacture uranium metal and uranium compounds from natural and enriched uranium feed stocks for use as fuel in nuclear reactors, including the U.S. Navy's submarine reactors. From its inception in 1956 through the end of the government contracting phase, the facility was used primarily in support of U.S. Government contracts that required production of enriched uranium products. Starting in 1959, the facility processed un-irradiated uranium scrap for the recovery of enriched uranium for use in the AEC's nuclear weapons complex (DOE, 1997; Facility List, 2001; FUSRAP, 1987; FUSRAP, 2000; Major Activities, 1962; Un-irradiated Scrap, 1958). Recovering uranium, especially enriched uranium, from scrap, process effluents, and other waste was a high priority in the nuclear weapons complex due to scarcity and cost of these materials (DOE, 1997). This activity continued until 1973 (AEC, 1962; DOE, 1997; FUSRAP, 2000; Site Assessment, 2005).

Radioactive material licenses issued to both Mallinckrodt Chemical Works (MCW) and UNC-Hematite authorized the site to possess thorium. Information from the Bureau of Mines Yearbook indicates that MCW and UNC-Hematite had the capability to process thorium in the early 1960s (Bureau of Mines, 1932-1993; Thorium License, 1958). Documentation from 1963 indicates that the UNC-Hematite site placed a bid on an AEC-related thorium contract (Thorium Bid, 1963). Other information supports that this thorium work was related to the production of Th-U fuel assemblies for use in breeder reactors like the Elk River reactor (Personal Communication 2009a; UNC Health Physics, 1964). This may have been a common or collaborative effort between UNC-Hematite, MCW, and Weldon Spring (Project Proposal, 1966; Thorium Conversion, 1965; Thorium Meeting, 1965; Thorium Operations, 1965). In 1964, the UNC-Hematite facility also produced approximately nine tons of thorium dioxide fuel pellets as a demonstration of its ability to produce Th-U fuels (Pellet Plant, 1964; Personal Communication 2009a; UNC Health Physics, 1963; UNC Health Physics, 1964). Over the period 1964-1968, UNC-Hematite (and several other sites) provided examples of their product for AEC approval; W.R. Grace/Nuclear Fuel Services was ultimately selected as the primary Th-U fuel element contractor (Nuclear Fuel Services, 1967; Procurement, 1968; Thorium Fuel Cycle, 2005; Thorium Shipments, 1969, pdf pp. 150, 167; W. R. Grace, 1963;).

UNC-Hematite shipped the remainder of the unused fuel to Maxey Flats disposal facility (Thorium Shipments, 1969, pdf p. 71). The information available on UNC-Hematite's thorium operation provides no corroboration that this effort was AEC-related weapons work. Based on this information, the issue of thorium exposure during the residual radioactivity period is not considered covered under EEOICPA rules, and therefore, is not evaluated in this report.

The operations at UNC-Hematite also included converting uranium hexafluoride to uranium dioxide powder using steam and dissociated ammonia. The UO_2 was then pressed into pellets and furnace-fired into a ceramic form suitable for loading into fuel assemblies. Chemical conversions of UF_6 to uranium carbide and uranium metal also took place. In addition, various research and development projects were conducted at the plant, as were uranium scrap recovery processes performed for the AEC nuclear weapons programs.

According to an AEC License inspection conducted on August 18-19, 1958 (Inspection, 1958) most operations at the UNC-Hematite plant at that time were being conducted under one of two AEC licenses issued to the Mallinckrodt Chemical Works Corporation: Source Material License No. C-2734, originally issued on September 23, 1955 (License C-2734, 1958), and License No. SNM-33, issued for special nuclear material (SNM-33, 1958). SNM-33 was amended and modified many times over the covered operational years at Hematite to authorize changes in operations and quantities of materials.

Per an AEC license re-inspection conducted January 12-14, 1960, authorizations derived from two additional licenses had been activated: C-4495 and SNM-230 (AEC, 1960). By 1960, all licenses previously issued to the Mallinckrodt Chemical Works had been reissued to a new, wholly-owned subsidiary, Mallinckrodt Nuclear Corporation, with the exception of C-2734, which had been allowed to expire on November 30, 1959.

This Evaluation Report emphasizes operations involving the use of radioactive materials occurring during the DOE defined time period of January 1, 1958 through December 31, 1973. This includes operations emphasizing uranium production activities for use in commercial and navy reactors. Thorium processing operations, isolated to a single project in 1964, are also included. The residual period, which commences on January 1, 1974, is considered separately in this and other sections of the report.

5.2 Radiological Exposure Sources from UNC-Hematite Operations

Based on information and documentation available to NIOSH, the potential for internal and external radiation doses from (primarily) uranium and uranium decay products existed at the UNC-Hematite site. To a much more limited extent, thorium compounds were also received, processed, and monitored at the plant. The following subsections provide an overview of the internal and external exposure sources for the UNC-Hematite class under evaluation.

5.2.1 Internal Radiological Exposure Sources from UNC-Hematite Operations

Data capture efforts and subsequent review of the information available to NIOSH identified the potential for internal radiation exposures to workers. The primary source of this exposure was deposition of alpha-emitting materials via inhalation and ingestion of airborne uranium and thorium (and progeny). Alpha particles do not present an external exposure hazard.

5.2.1.1 Uranium

Uranium was present at UNC-Hematite in both natural (also referred to as "normal") and enriched forms - as a solid metal and in various compounds, including uranium hexafluoride, uranium tetrafluoride, and uranium dioxide powder. Exposure to uranium posed a potential internal exposure hazard. Natural uranium refers to uranium consisting of approximately 0.7% U-235, 99.3% U-238, and a very small residual amount of U-234, by weight. In terms of radioactivity, natural uranium contains approximately equal percentages of U-238 (48.6%) and U-234 (49.2%). These radionuclides emit alpha particles with primary emission energies of 4.20 MeV and 4.15 MeV (U-238), and 4.77 MeV and 4.72 MeV (U-234) (Radiological Health Handbook, 1970). The radioactivity contribution from U-235 is much smaller (approximately 2.2%) relative to U-238 or U-234. U-235 emits alpha particles with energies of 4.40 MeV and 4.37 MeV.

Enriched uranium refers to uranium with a higher percentage of U-235 by weight. Through the gaseous diffusion process, the specific activity of uranium increases with enrichment primarily because of the increase in the amount of U-234 present, rather than the increase in U-235. The determination of the enriched uranium specific activity (typically performed for uranium alpha emitters) can be calculated and accounted for using standard methods if enrichment levels are known for the associated work areas (DOE-STD-1136-2000; Rich, 1988).

Compliance Inspection Reports for License No. SNM-33, dated January 1960 and March 1961, describe two process areas designed for "Manufacture of cermet type fuel elements and metal from uranium enriched in U-235 to 20% and higher" and "production of low enriched materials up to 6% U-235" (AEC, 1960; Enriched Materials, 1959). A review of allocation requests from 1959 through 1966 (the only such documents located to date) indicates that approximately 7,576 kilograms of uranium were requested for government-related projects, and 1,887 kilograms of uranium were requested for commercial projects (United Nuclear HSA, 2003; Westinghouse, 2003).

In general, an increase in enrichment was associated with operations occurring in the Green Room (~2 to 5 % enrichment), Blue Room (~5 to 20% enrichment), and Red Room (greater than 20% enrichment) (Personal communications, 2009a). Operations in the Green Room and Blue Room were designed for "low" and "intermediate" enrichment activities, respectively; the Blender Room was used for both low and intermediate enrichment operations (General Survey, 1959). Operations occurring in the Item Plant, which was often designated for classified operations, likely involved highly-enriched uranium.

UNC-Hematite also contracted directly with the Oak Ridge AEC office and other government contractors for the recovery of uranium from scrap materials. Scrap recovery projects at UNC-Hematite included the recovery of uranium from scrap generated by a variety of Navy projects and CUNO [company name] filter scrap generated by the Aircraft Nuclear Propulsion program (United

Nuclear HSA, 2003; Westinghouse, 2003). Interviews with former energy employees (EE) indicate that only un-irradiated scrap was processed (Personal Communications, 2009a and 2009c). A FUSRAP Stewardship Report for Site "MO.O-03 - United Nuclear Corporation" documents that UNC-Hematite processed un-irradiated scrap for the AEC in the 1960s (FUSRAP, 2000).

5.2.1.2 Thorium

Thorium-232 is the parent radionuclide in the thorium series. Thorium-232 decays by alpha emission into Ra-228, emitting two primary alpha particles of 3.95 MeV (24% abundance) and 4.01 MeV (76% abundance). The natural thorium decay series includes six progeny that emit alpha particles, with energies ranging from 5.34 MeV to 8.78 MeV.

Approximately nine tons of natural thorium was on site during the covered period for a single, specific project conducted in 1964 in the Pellet Plant. Thorium dioxide powder was blended with uranium dioxide powder to produce Th-U fuel pellets to be used in fuel assemblies for breeder reactors like the Elk River Reactor in Minnesota (Pellet Plant, 1964; Personal Communication 2009a and 2009c; Thorium Bid, 1963; UNC Health Physics, 1963; UNC Health Physics, 1964). Each pellet consisted of a mixture of 97 % ThO2 - 3 % UO2, compressed and sintered (heated) in a furnace. The uranium (un-irradiated) was "fully-enriched" with a nominal U-235 enrichment of 93% (Elk River, 1961, pdf p. 15). The fuel pellets were produced to demonstrate UNC-Hematite's fuel fabrication capabilities in an attempt to obtain breeder-reactor-fuel contracts. Based on the operational and monitoring data, thorium exposures from the 1964 fuel pellet operations posed a potential internal hazard to plant production workers. Information accompanying some of the air sample data associated with the thorium operation indicates that clean-up of residual thorium dioxide was conducted (Pellet Plant, 1964).

5.2.2 External Radiological Exposure Sources from UNC-Hematite Operations

Operations at the UNC-Hematite facility potentially would have resulted in exposures primarily to uranium and uranium decay products. Uranium operations included high-enriched uranium (HEU), low-enriched uranium (LEU), and the recovery of uranium in scrap materials. In addition, documented thorium operations would have been a potential source of external personnel exposures. Dose rates and resultant doses would have varied depending on the source term.

5.2.2.1 Photon

Personnel photon exposures at UNC-Hematite were directly related to uranium enrichment processes, primarily from operations in the Red Room, Blue Room, Green Room, and Item Plant. These processes are known to have been a routine component of plant operations during the entire covered period from 1958-1973 based on NIOSH review of plant radiation safety manuals and procedures (HP Standards, 1968; ThO_2-UO_2, 1964), plant correspondence and operations logs (Activities Log, 1969), film badge results (External Exposure Reports, 1963; External Exposure Reports, 1964; External Exposure Reports, 1965; Film Badge Summary, 1961; Film Badge Summary, 1962; Tabulation Sheet, 1966; Tabulation Sheet, 1967; Tabulation Sheet, 1969; Tabulation Sheet, 1970; Tabulation Sheet, 1971; Tabulation Sheet, 1972; Tabulation Sheet, 1973), and site interviews (Personal communications, 2009a and 2009c). Uranium in various forms and compounds was used (see Section 5.1). Accordingly, external exposures to photon radiation would have resulted from radionuclides in the uranium decay chain. The uranium progeny that result in the most significant photon exposures include Th-234 and protactinium-234m (Radiological Health Handbook, 1970).

Secondary sources included exposures from thorium operations in the Pellet Plant. Thorium processing was limited to 1964 when thorium dioxide powder was mixed with uranium dioxide powder to produce fuel pellets. Radionuclides of interest included Th-232 and decay progeny (e.g., Ac-228, Th-228, and Ra-224).

5.2.2.2 Beta

Exposure to beta sources at UNC-Hematite would have resulted principally from uranium decay products. In the uranium-series decay scheme, beginning with U-238, the short-lived isotope Pa-234m emits the most energetic beta particle (2.28 MeV). It is this beta particle that accounts for the shallow-dose hazard associated with handling uranium. This radionuclide was likely encountered during routine scrap recovery operations and other production activities at the site.

Beta exposures from thorium processing activities were also likely, though limited in both time and quantity relative to uranium. Decay progeny, including the beta emitters Ra-228 and Ac-228, can be (and likely were) liberated through heating processes (ThO_2-UO_2, 1964).

5.2.2.3 Neutron

There was a potential for personnel neutron exposures from the uranium-enrichment operations at UNC-Hematite. As described in Section 5.2.1.1, the site received and processed uranium compounds containing fluorine and oxygen. These low-atomic-number elements emit neutrons when struck by alpha particles, referred to as alpha-neutron ("α-n") reactions. These reactions result in a radiation field that varies for fluorine compounds from 0.2 mrem/h to 4 mrem/h depending on a variety of factors, including enrichment levels (DOE-STD-1136-2000, pdf p. 157; ORAUT-OTIB-0024, pdf. p. 12). The site was authorized by the AEC to receive enriched uranium hexafluoride ($^{235}UF_6$) and typically requested quantities of 50 to 100 kilograms (kg) on a quarterly basis with enrichments ranging from approximately 20 to 93% (Compliance, 1960, pdf pp. 4-5). Dose rates would therefore conceivably range up to the maximum value. By comparison, neutron yields for oxide compounds are lower by approximately 100 times, resulting in correspondingly lower exposure rates (DOE-STD-1136-2000, pdf p. 159; ORAUT-OTIB-0024, pdf. p. 10).

5.2.3 Incidents

NIOSH did not identify any documented accidents at UNC-Hematite that resulted in exceptionally high personnel exposure levels (such as a criticality event). Interviews conducted with former site employees did not reveal any specific radiological or contamination events (Personal Communications, 2009a and 2009c). However, documentation was reviewed that cited several radiological incidents resulting in external or internal exposures during the covered operational period. In each instance, investigations were conducted, area and personnel samples collected for analysis, individuals identified by name and/or health number, and results provided. The plant reported these events to the AEC as warranted based on their evaluation of the circumstances. These incidents included: external radiological overexposures per film badge results in 1963 in the Pellet Plant (Overexposures, 1963); UF_6 releases in the Red Room in 1966 (UF-6 Release, 1966) and 1967 (UF-6

Release, 1967); an HEU release in the Red Room in 1967 (Personnel Exposure, 1967); a UO_2 release in the "Recycle" Room in 1968 (UO_2 Release, 1968a); a Pellet Plant Press Hopper Release in 1968 (UO_2 Release, 1968b); a UO_2 release in the Red Room Milling Hood in 1969 (UO_2 Exposure, 1969); an HF_6 release in the Oxide Building in 1969 (HF Leak, 1969); and various spills and releases in 1970 (Special Bioassay, 1970).

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

NIOSH researched, collected and reviewed site data made available to the agency through several means, including two on-site data capture efforts initiated and completed during one-week periods in March and April, 2009. The current owner of the former UNC facility (Westinghouse Electric) authorized NIOSH subcontractor staff to review and scan documents housed in several on-site locations. The following subsections provide an overview of the available monitoring data.

UNC-Hematite was originally owned and operated by the Mallinckrodt Chemical Works (MCW) Company. Mallinckrodt initiated a film badge program at its original MCW location in 1942 to measure exposure to beta and gamma radiation. They also took periodic breath samples from those personnel whose duties involved exposure to radon. Initially, Mallinckrodt forwarded the film badges and breath samples to the AEC Medical Laboratories at Rochester, New York, for examination and checking, but later conducted complete handling of the film badges in-house (Fleishman-Hillard, 1967). The monitoring program at UNC-Hematite was a natural extension of the program instituted early on in Mallinckrodt's government work with uranium. The new operations drew on the history and experience of the previous health and safety programs.

An August 1958, MCW Plant Inspection states personnel monitoring was conducted by routine use of film badges, bioassay, and physical examination (AEC, 1958). Film badges were obtained from the St. John X-Ray Laboratory in New Jersey and distributed on a frequency determined by individual job assignment. Permanent operating personnel were monitored on a weekly basis and rotating personnel were monitored monthly. The sections that follow discuss more specifically the available internal and external monitoring data for UNC-Hematite.

6.1 Available UNC-Hematite Internal Monitoring Data

Internal monitoring data available for the operational period primarily consist of urinalysis, dust sampling, and air monitoring results. "Dust" sampling was a commonly-used term during the covered period and refers to sampling for airborne radioactive dust particulates. Dust and air samples were collected in the same manner (i.e., using a pump to draw a known volume of air through a Whatman paper filter to collect particulates). Resulting airborne radioactivity concentrations were reported by the plant in μc/ml (representing the measurement units in "microcuries per milliliter" or "μCi/ml" as used today). This Evaluation Report will cite the airborne concentration measurement units used by the plant. Results were compared to the applicable site administrative levels (maximum acceptable concentrations) and federal airborne radioactivity limits. With one exception discussed below, data were collected covering the entire operational period. Tables 6-1 and 6-2 summarize available internal monitoring data for the operational period.

All UNC-Hematite employees were assigned a "Health Number" that was used in part to track worker doses. The methodology for reconstructing internal dose in the UNC-Hematite TBD (Battelle-TBD-6001, Appendix D) assessed the limited personnel and area monitoring data available at the time the TBD was developed to establish maximum internal exposure scenarios. The evaluation in this report will include (as appropriate) recently-collected personnel internal monitoring data not available to NIOSH when the TBD was developed.

Urinalysis Data

Beginning in 1957, MCW Hematite plant operating personnel submitted urinalysis samples on a three- to six-month basis dependent on specific work assignments. Results recorded from 1957 until 1960 included a maximum uranium alpha reading of 329.9 d/m/l (representing the measurement units in "disintegrations per minute per liter"), with an average value of 3-5 d/m/l (Compliance, 1960).

NIOSH identified original, reliable data citing urinalysis results by year and employee as reported by three analysis vendors, Nuclear Science and Engineering Corporation, Controls for Radiation Inc., and Isotopes, Inc. (UNC urinalysis, 1962-1964; Bioassay Results, 1964; Bioassay Results, 1965; Bioassay Results, 1966; Bioassay Results, 1967; Bioassay Results, 1968; Bioassay Results, 1969; Special Bioassay, 1970). UNC-Hematite adopted various action levels for uranium in urine. In 1960, for example, the plant established a "desirable maximum" of 45 d/m/l (Urinalysis Results, 1960). In 1966, the threshold for a follow-up investigation was 50 d/m/l (Bioassay Results, 1966). Data results occasionally included a breakdown by job categories that included operators, technicians, engineers, foremen, and guards. Sample analysis incorporated gross activity counting methods to determine uranium activity levels (Urinalysis Results, 1965-68). Expansion of the routine bioassay program to include additional radionuclides did not occur within the AWE operational period ending December 31, 1973.

The urinalysis sampling program was discontinued as of January 1, 1961. Plant management cited two primary factors: The program, in their view, had been in place for a sufficient period of time to furnish "reliable data for an overall evaluation of concentrations that may be routinely found in urinalysis samples from personnel working in the licensee's Hematite plant." Secondly, the program's cost was compared to its value "as a real and practical device for routinely measuring radiation exposure." The plant determined that bioassay services would be provided "where desirable or necessary" as required by 10 C.F.R. 20 (Compliance, 1961, pdf p. 14).

The program was re-instituted in December 1962 following operational events where several plant operators in the Red Room had higher intakes to airborne radioactive materials than expected and a higher probability of reportable overexposures during the first six months of the program. These intakes exceeded 10 C.F.R. 20 limits and were reported to AEC officials (Various authors, 1963, pdf p. 47). In August 1963, several individuals were selected for follow-up whole-body counting radiation measurements at the DOE Y-12 nuclear weapons plant (Estimated Exposures, 1963; *In Vivo*, 1964; Oak Ridge Trip, 1963; Various authors, 1963). A more complete discussion is provided in the next section.

Although the urinalysis program continued uninterrupted from 1962 through the remainder of the operational period (1973), the site contracted with a new sample analysis vendor in 1971. In the 1980s, this vendor was determined to have protocol discrepancies in the urinalysis work it performed for other government sites. For all EEOICPA-related work, NIOSH has adopted the conservative position that analytical results provided by this vendor are suspect and thus are deemed unreliable. For this SEC evaluation report, this administrative decision impacts UNC-Hematite urinalysis data only for the period 1971 through 1973. There is no impact from this vendor on other applicable monitoring for this site for the period under evaluation.

Table 6-1 summarizes by year the number of Energy Employees and the minimum number of bioassay samples collected during the operational period. The bioassay program emphasized production workers (operators) in the processing areas (e.g., Item Plant, Red Room) as these locations represented the workers receiving the highest internal exposures. Bioassay information for “non-operators” was limited and is reported for one year (1968). UNC-Hematite evaluated bioassays by different analytical protocols, including enriched and fluorometric uranium techniques.

Table 6-1: Summary of Urinalysis Samples Collected During the Operational Period

Year	No. of Energy Employees	Minimum No. of Urinalysis Samples	SRDB Ref IDs
1958	19	7	62301
1959	41	138	17606
1960	37	106	17606
1961*	0	0	N/A
1962*	74	196	11713, 11714, 11724
1963	110	1730	11713, 11714, 11724
1964	45	1537	62390
1965	57	1238	62386
1966	87	1351	62383
1967	64	1320	62381
1968	116 (operators)	1626	62379
1968	74 (non-operators)	228	62379
1969	131 (operators)	1980	62377
1970	45	158**	62373
1971	***	***	***
1972	***	***	***
1973	***	***	***

* From January 1, 1961 through December 1962, the routine bioassay program was discontinued. During this period, site management agreed to collect bioassay samples on a limited basis as warranted by operational situations (Compliance, 1961, pdf p. 13). In 1962, elevated air sampling results were obtained in process areas and bioassay samples were collected from selected workers. The routine bioassay program was re-instituted in December 1962 (UNC *In Vivo*, 1963-1965; Various authors, 1963, pdf pp. 57-63).

** Includes sample data from review of petition claims record.

*** For the years 1971-73, routine urine sampling continued and the urinalysis data are available; however, the analytical results from the vendor are considered unreliable. The number of employees sampled under the site bioassay program and the number samples forwarded to the vendor are consistent with workforce levels for preceding years (1971: 789 samples for 106 employees; 1972: 326 for 42 employees; 1973: 423 samples for 88 employees).

Whole Body Counting Data

Direct (*in vivo*) bioassay data, as a component of a routine whole-body counting (WBC) program, were identified for the years 1968-1973 (*In Vivo* and Bioassay, 1960s; *In Vivo* Counts, 1967-73; Whole Body, 1969; Whole Body Counts, 1968-73; Whole Body Issues, 1968-69). These years represented the period when this methodology was becoming more widespread within the nuclear industry. UNC-Hematite contracted Helgeson Nuclear Services, Inc., to conduct WBC for evidence of U-235 intakes.

WBC was also conducted during the years 1963, 1964, and 1965 for several workers, using "total body" counters available at the Y-12 plant in Tennessee (Estimated Exposures, 1963; *In Vivo*, 1964; Oak Ridge Trip, 1963; Various authors, 1963). Emphasis was placed primarily on several workers who had received elevated internal exposures in the Red Room (exceeding 10 C.F.R. 20 limits). The analysis was performed to assay the amount (micrograms) of U-235 in the workers' lungs. Probable causes of the exposures, according to plant correspondence, were the lack of appropriate containment associated with the milling of uranium oxides and surface (hand) contamination. The workers were tracked for three years to confirm that U-235 levels in the body had decreased.

Other employees were also assayed for uranium at Y-12 during these years but not on a consistent basis. There was one specific internal assessment for thorium evaluated at Y-12 in 1965 with a subsequent "0" result (UNC *In Vivo*, 1963-1965). A specific explanation for the additional worker selection and thorium evaluation has not been determined either through available documentation or interviews conducted with site employees (Personal communications, 2009a and 2009c). The monitoring results for these workers are available to NIOSH (UNC *In Vivo*, 1963-1965; Various authors, 1963).

Air Monitoring Data

Considerable air monitoring data were also located. These data include periodic uranium airborne studies (General Survey, 1959; Uranium Dust, 1962) and air samples collected at specific plant locations over a week's period and assigned to individual workers (AEC Visit, 1963; Dust Exposure, 1962). Air samples were also routinely collected during the covered period in operational areas such as (but not limited to) the Red Room, Blue Room, Green Room, Item Plant, Pellet Plant, Oxide Plant, and the Blending Room (a summary of the available air monitoring data is provided in Table 6-2). Results were provided in units of μc/ml per the reporting convention in place during this time, and as was the case for bioassays by urinalysis, again emphasized exposure to uranium. As noted previously, this Evaluation Report will cite results using the measurement units employed during the operational period.

Former site employees interviewed for this report emphasized that during the covered period, alpha-emitting radionuclides were the primary source of exposure rather than beta contributors. Consequently, potential alpha internal exposures received significant attention by UNC-Hematite radiological personnel (Personal communications, 2009a and 2009c).

Air samples, specifying "ThO_2" as the compound of interest, were also identified and evaluated. These samples were collected in the Pellet Plant in 1964 (Pellet Plant, 1964; Smear Surveys, 1966) and were related to processing thorium dioxide pellets and mixing them with uranium dioxide pellets in the test production of thorium-uranium breeder reactor fuel elements. Over two hundred thorium-designated samples were collected; airborne concentrations were routinely less than $2x10^{-11}$ μc/ml, the MAC established by UNC-Hematite for thorium work. Approximately 10% of the concentrations were greater than $1x10^{-10}$ μc/ml (the uranium MAC for that time period) and were associated with unusual events. The maximum result for the data representing UNC-Hematite's Th-U fuel effort, 1.6 x 10^{-8} μc/ml, was associated with a spill. Based on NIOSH's review, the range and limits of this set of air sample data is comparable to the uranium airborne concentrations associated with the uranium work performed at the Pellet Plant and other plant areas. Based on the information in the air sample data sheets, the samples represent a combination of general area/high volume, process, breathing zone/lapel, stack, and hood air sample data (Pellet Plant, 1964; Smear Surveys, 1966). Several breathing zone air samples were identified in these data sets. Although the thorium air samples have notations indicating that they are thorium-related air samples, NIOSH was unable to confirm that specific analyses for thorium isotopes (e.g., Th-232) were conducted.

Uranium area air samples were also collected in "clear" (clean) areas—such as the warehouse, lunch room, guard station, offices and bathrooms (Non-process Air Samples, 1961-63; Non-process Air Samples, 1964) - and at fence-line and off-site locations (Air Sample Summaries, 1963). These data can be compared to data collected from occupational areas.

Smear Data

Smear data, used as a measure of removable or transferable contamination, and therefore, as a potential supplemental means to assess inhalation and ingestion doses, were identified for the years 1961-64, 1966, and 1971-72. This information was limited to partial years, collected on equipment, floor, and other surfaces, and for both "clear" (clean) and potentially- contaminated areas (Floor Swipes, 1962-64; Non-process Air Samples, 1961-63; Plant-wide, 1963; Smear Report, 1964; Smear Survey, 1964; Smear Surveys, 1966; Smear Survey, 1971; Smear Survey, 1972). Additional smear data, other than the data previously described, were not identified by NIOSH. However, NIOSH believes that additional data exist based on the plant's health physics procedures that required the conduct of contamination surveys at a specified frequency (HP Manual, 1963, pdf p. 45).

6.2 Available UNC-Hematite External Monitoring Data

External monitoring data available to NIOSH consist of film badge results covering the entire operational period under evaluation. All UNC-Hematite employees were assigned a "Health Number" that was used in part to track worker doses. These results were identified during two on-site data capture trips to the UNC-Hematite facility in March and April 2009. Table 6-2 summarizes available external monitoring data for the operational period.

An August 1958 AEC compliance inspection of MCW's Hematite facility states personnel monitoring was conducted by routine use of film badges, bioassay, and physical examination (AEC, 1958). Film badges were obtained from the St. John X-Ray Laboratory in New Jersey and distributed on a frequency determined by individual job assignment. Permanent operating personnel were monitored on a weekly basis and rotating personnel were monitored monthly.

In January 1960, an AEC license compliance inspection reiterated that operations personnel working at the Hematite plant at that time were routinely monitored as part of a film badge program. Film processing was performed at the Mallinckrodt Chemical Works plant in St. Louis using a procedure patterned after the protocols established at the AEC Weldon Springs Plant (also operated by Mallinckrodt at that time). The film badges included an indium foil that could have been used to segregate personnel exposed in the event of a criticality event (Compliance, 1960; Personal Communications, 2009a and 2009c). According to the 1962 UNC-Hematite Health Physics Manual, all personnel assigned to the plant were issued a film badge upon entry to the facility (HP Manual, 1963, pdf p. 15). Interviews with former site employees corroborated the use of film badges and the criticality foil (Personal Communications, 2009a and 2009c).

Beta-Gamma

During the operational period, the following AEC regulatory radiation exposure limits were in effect:

- Whole body (including lens of eye): 3 rem per quarter (beta plus gamma)
- Skin of whole body: 6 rem per quarter (beta plus gamma)

The unit "rem" was cited specifically in the AEC regulations—a convention that continues today under the NRC's 10 C.F.R. 20 radiation protection regulations. However, compliance inspections described in this section and other references in this Evaluation Report, cite other radiation units. These include the "rad" and the "rep," or the units "millirad" (mrad) and "millirep" (mrep), representing a dose one thousand times smaller. In this Evaluation Report, the units specifically cited in reference documentation will be used. As a simplification, however, for results pertaining to beta and gamma radiations, a rad (millirad) or rep (millirep) can be considered equivalent to a rem (millirem).

As stated in the 1958 AEC compliance inspection, "The average exposure of Hematite plant personnel during the past year, as indicated by the records, was 80 mrad due to beta radiation and 36 mrad due to gamma radiation. The maximum single six months accumulative exposure recorded as due to beta was 2,525 mrad while the maximum due to gamma was 380 mrad." The report, however, did not identify the number of plant workers specifically monitored (AEC, 1958).

The January 1960 AEC inspection report for site license renewal (applicable to the 1959 reporting period) stated plant exposures somewhat differently than the 1958 inspection in terms of the reporting period (monthly) and reporting units. The occupational external dose monthly average badge results for beta radiation were 80-90 millirep (mrep); the maximum monthly result was 240 mrep (Compliance, 1960). The "rep"—an abbreviation for "roentgen equivalent physical"—was a radiation unit still in use at that time. One rep was generally defined as the amount of ionizing radiation of any type (e.g., alpha, beta, gamma radiation) resulting in the absorption of energy at the point in question in soft tissue equivalent to 93 ergs per gram. One rep was equivalent to 1000 mrep. As previously stated, for the purpose of this report, it is considered equivalent to a dose in millirad or millirem (mrem).

The 1960 compliance inspection report also states "Gamma readings to 15 mrem for the monthly program are also recorded." This was reported as applicable to workers in the production areas. The report also indicated that readings were lower for all other monitored workers (i.e., pilot plant, laboratory, and maintenance personnel). When extrapolated to an annual dose, the resulting 180 mrem value (15 mrem per month times twelve months) would be representative of certain UNC-Hematite workers during the entire operational period. At the same time, however, the maximum ("to 15 mrem") monthly gamma radiation exposure results for 1959—also included in the UNC-Hematite TBD (Battelle-TBD-6001, Appendix D)—are significantly lower relative to many workers monitored during all other years of the operational period. The explanation resides in the methodology for reconstructing external dose in the UNC-Hematite TBD. The methodology for reconstructing external dose in the TBD assessed the limited personnel dose information available at the time the TBD was developed to establish a maximum external exposure scenario. The evaluation in this report will include (as appropriate) recently-collected personnel external monitoring data not available to NIOSH when the TBD was developed in conjunction with the TBD methodology.

During March 20-23, 1961, another AEC compliance inspection was conducted. Regarding the 1960 external monitoring period, the report stated that no exposures were identified exceeding 10 C.F.R. Part 20 limits in effect prior to January 1, 1961 with "some few readings up to 100 mrem/wk but the majority of the readings were near the threshold of the film or no greater than 50 mrem/wk." (Compliance, 1961)

For the remaining years 1961-1973, annual film badge reports typically cited external beta and gamma exposures to personnel emitted from uranium isotopes and associated decay products (External Exposure Reports, 1963; External Exposure Reports, 1964; External Exposure Reports, 1965; Film Badge Summary, 1961; Film Badge Summary, 1962; Tabulation Sheet, 1966; Tabulation Sheet, 1967; Tabulation Sheet, 1969; Tabulation Sheet, 1970; Tabulation Sheet, 1971; Tabulation Sheet, 1972; Tabulation Sheet, 1973). Results were provided in these reports either as separate columns for beta and gamma dose, as collective "beta-gamma" results, or simply as a total "Exposure."

In contrast to the 1960 AEC inspection report, a broader range of maximum beta and gamma doses (in rem) were recorded in summary monitoring reports for 1961-1973. For the years 1961-1964, results were provided by calendar month and then compared to the "Maximum Permissible Dosages for a Calendar Quarter" or "Cumulative Quarterly Total" (e.g., as noted in the 1962 film badge summary report [Film Badge Summary, 1962]). A review of several end-of-quarter summary reports (ending in March, June, September, and December) for 1961-1964 revealed that the majority of the workers (70 to 98%) received less than 0.25 rem on a calendar quarter basis (combined beta plus gamma). A much smaller percentage (up to 4%) would occasionally receive a quarterly dose of between one and two rem. No documentation was identified indicating that any site worker exceeded the quarterly limits.

For the years 1965 through 1973, a different reporting format was used by UNC-Hematite by which annual dose totals (rem) were provided. Maximum employee exposures during these years (in chronological sequence) were 2.11, 6.35, 1.61, 5.98, 3.12, 4.91, 0.67, 2.57, and 6.64 rem (Tabulation Sheet, 1965; Tabulation Sheet, 1966; Tabulation Sheet, 1967; Tabulation Sheet, 1968; Tabulation Sheet, 1969; Tabulation Sheet, 1970; Tabulation Sheet, 1971; Tabulation Sheet, 1972; Tabulation Sheet, 1973). The lowest and highest values occurred in 1971 and 1973, respectively. The overall higher maximum values for 1965-1973 should not be interpreted as a consequence of the change from the 1961-1964 reporting format. A worker under the prior quarterly reporting system could conceivably meet or exceed these values when projected over an entire year. However, NIOSH was not able to determine the specific reason for the elevated maximum annual doses for 1965-1973 relative to prior years.

NIOSH's review of badging records also identified employees who were issued film badges that did not have job assignments in uranium-processing areas. Examples included employees assigned to office areas (Terminated, various years). This serves to confirm the "universal" aspect of the badging program (HP Manual, 1963, pdf p. 15).

In addition to documentation containing dose summary information and reports for the years 1958 through 1973, NIOSH received external monitoring records for former workers in the claim pool for the years 1961 through 1993 (monthly exchange) and 1994 through 2003 (annual exchange).

Documentation was also identified pertaining to the conduct of routine site radiation and contamination surveys in clear and contaminated areas of the plant (AEC, 1960; Compliance, 1961; Beta-Gamma Survey, 1965; Hand Monitor, 1963; Plant-wide, 1963; Smear Survey, 1964). Surveys were required per the plant's health physics manual and licensing requirements (AEC, 1960; HP Manual, 1963).

Neutrons

NIOSH reviewed available UNC-Hematite documentation to identify records related to neutron exposures. Records reviews included Health Physics procedural manuals, AEC regulations and licensing inspections, dosimetry records, and site radiation survey records. While UNC-Hematite received and processed uranium in various forms (including uranium hexafluoride), neutron exposures were not identified as a radiological concern by plant personnel either as a component of routine plant operations or the external dose monitoring program (Health Program, 1962; HP Manual, 1963; HP Standards, 1968). The AEC's 10 C.F.R. 20 1961 regulations, Sections 20.201 (*Surveys*) and 20.202 (*Personnel Monitoring*), only generally referred to the need to conduct surveys and provide monitoring devices. No specific requirement existed to conduct neutron surveys and track neutron personnel exposures (10 C.F.R. 20, pdf p.13). AEC licensing inspection reports did not cite the lack of routine neutron monitoring as a concern or recommend any action in this regard. No radiological monitoring records specifying exposure to neutron radiation were identified and UNC-Hematite did not list portable neutron instrumentation in its inventory (AEC, 1958; AEC, 1960; Compliance, 1961).

A technical basis exists to justify the lack of routine neutron monitoring. A NIOSH hazard evaluation report for the Portsmouth Gaseous Diffusion Plant, cited and discussed in the Portsmouth External Dose TBD, assessed neutron dose rates on contact and at one meter from high-enriched uranium (ORAUT-TKBS-0015-6; Cardarelli, 1996). The report explored several radiation exposure scenarios, including different enrichments and worker stay times and concluded that, as a percentage of the applicable regulatory dose limits, neutron monitoring was unnecessary. In the case of UNC-Hematite, the site operator may also have concluded, based on operational history and/or regulatory compliance thresholds, that neutron monitoring was not warranted. In an interview with an individual who worked during the operational period, the person could not recall any specific discussions or correspondence during his tenure concerning a technical basis justification for or against a routine neutron survey and personnel monitoring program (Personal communications, 2009c).

Because NIOSH did not identify radiological survey records addressing neutron personnel exposures, the neutron dose at UNC-Hematite will be estimated using other methods. Further discussion is provided in Section 7.

Although neutron exposure was not a site concern under normal operations, the potential for a non-routine (accident) criticality event in the plant received significant attention following the Y-12 criticality accident in 1958. UNC-Hematite purchased a radiation detection and alarm system (AEC, 1958). In addition, the plant conducted frequent plant inspections, including routine instrumentation and alarm-operability checks, implemented corrective actions to avoid the potential for a criticality, and incorporated an indium foil in film badges to detect the presence of neutrons in the unlikely event of an accident.

6.3 Summary of UNC-Hematite Available Monitoring Data

Table 6-2 summarizes internal and external monitoring data available to NIOSH for the covered period. Values in the table for each data type represent either the minimum number of samples or measurements taken (for urinalysis, air samples, and smears) or the number of energy employees monitored (for whole body counting and film badge data). Summary data include samples collected from process and non-process (clean) areas. In some instances, information was either unavailable or present in limited quantities due to the manner in which the information was reported by the site during that period, or because NIOSH was unable to locate that information during data capture efforts.

Table 6-2: Summary of UNC-Hematite Available Internal and External Monitoring Data

Year	Internal					External
	Bioassay (Urinalysis)	Bioassay (WBC-Routine)	Bioassay (WBC-Non-Routine)[1] (SRDB ID)	Dust/Air Sampling (SRDB ID)	Smears (SRDB ID)	Film Badges (SRDB ID)
1958	7	---	---	21 (3944)	---	X[2] (3822)
1959	138	---	---	305 (62357) 65 (3944) 1620 (17606)	---	X[2] (3944) X[2] (7145)
1960	106	---	---	1429 (17606)	---	X[2] (56196)
1961[3]	0	---	---	29 (62285) 3 (62282) 38 (62283) 112 (62276) 29[4] (62171)	24[4] (62171)	150 (62278)
1962	196	---	---	58 (62172) 5 (62285) 4 (62282) 21 (62276) 35 (62306) 4 (62345) 6[4] (62171)	10 (62352) 53 (62345) 16[4] (62345)	153 (62277)

Table 6-2: Summary of UNC-Hematite Available Internal and External Monitoring Data						
Year	Internal					External
	Bioassay (Urinalysis)	Bioassay (WBC-Routine)	Bioassay (WBC-Non-Routine)[1] (SRDB ID)	Dust/Air Sampling (SRDB ID)	Smears (SRDB ID)	Film Badges (SRDB ID)
1963	1730	---	5 (62318)	17 (62285) 30 (62428) 199 (62432) 122 (62340) 4 (62282) 38 (62279) 9 (62283) 13 (62356) 14 (62341) 7 (62343) 563[5] (62276) 16 (62170) 17 (62178) 8[4] (62171) 35[6] (62355)	27[4] (62352) 44 (62426) 61 (62276)	102 (62274)
1964	1537	---	4 (62314)	2927 (62168) 445 (62279) 578 (62356) 860[7] (62343) 125 (62348) 246 (62341) 302[4] (62361) 850[6] (62355)	797 (62320 and 62352) 28 (62356) 2508[4] (62320, 62352, 62358)	130 (62272)
1965	1238	---	5 (11724)	X[2]	---	137 (62271)
1966	1351	---	---	12 (62298)	665 (62384) 467[4] (62384)	139 (62180)
1967	1320	---	---	2 (62428)	---	127 (62267)
1968	1854	11[8] (62412)	---	5390 (62300)	---	169 (62187)
1969	1980	103[9] (62334, 62412)	---	X[2]	---	182 (62266)
1970	158[10]	67 (62020, 62175, 62419)	---	1169 (62207) 6540[4] (62184) 608[4] (62186) 335[5] (62200)	---	213 (62231)
1971	---[11]	71 (62020, 62175, 62419)	---	36 (62142) 5485[4] (62186) 296[5] (62212)	478 (62442) 479[4] (62442)	64 (62229)
1972	---[11]	48 (62020, 62175, 62419)	---	97 (62144) 17 (62146) 30[4] (62149) 31[4] (62152) 497[4] (62154) 703[4] (62139) 31[4] (62140) 5294[4] (62155)	101 (62436) 548[4] (62436)	93 (62227)

Table 6-2: Summary of UNC-Hematite Available Internal and External Monitoring Data						
Year	Internal					External
	Bioassay (Urinalysis)	Bioassay (WBC-Routine)	Bioassay (WBC-Non-Routine)[1] (SRDB ID)	Dust/Air Sampling (SRDB ID)	Smears (SRDB ID)	Film Badges (SRDB ID)
1973	---[11]	90 (62020, 62175, 62419)	---	66 (62137) 44 (62146) 15[4] (62145) 27[4] (62152) 256[5] (62139) 27[4] (62140) 1080[4] (62154) 4894[4] (62155)	---	64 (62225)

1 Whole body counting for a maximum of five site employees was conducted annually from 1963-1965 at the DOE Y-12 plant, Oak Ridge, Tennessee. Note: A subset of workers receiving exposures at UNC-Hematite were evaluated for because of potential elevated uranium/thorium exposures.

2 "X" indicates that data exist, but the specific number of samples collected or individuals monitored was not available.

3 From January 1, 1961 through December 1962, the routine bioassay program was discontinued. During this period, site management agreed to collect bioassay samples on a limited basis as warranted by operational situations (Compliance, 1961, pdf p. 13). However, air sampling (including BZ and GA samples) continued in the work areas over this time period (Air Sample Data, 1961; Assorted Results, 1963; Overexposure Report, 1976; Green Room, 1961-63; Air Sample Data, 1961-63; Pellet Plant, 1961-62; Uranium Dust, 1962; Blue Room, 1960-63; Blue Room, 1962-63). In 1962, elevated air sampling results were obtained in process areas; consequently, bioassay samples were collected from selected workers. As a result of these elevated exposures, the routine bioassay program was re-instituted in December 1962 (UNC *In Vivo*, 1963-1965; Various authors, 1963, pdf pp. 57-63).

4 Collected in non-process areas (e.g., warehouse, lunch room, offices) other than fenceline (see Footnote 6).

5 Includes CUNO filter stack and additional stack samples.

6 Non-process fenceline samples.

7 Includes over 200 thorium samples.

8 Data available for one month in 1968.

9 Data only available for March, June, and December 1969.

10 Includes both routine and suspected overexposure samples.

11 For the years 1971-73, urinalysis data are available, but the analytical results from the vendor are considered unreliable (see Table 6-1 footnote).

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 7.1. 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-00116 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of UNC-Hematite 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

Two one-week data capture visits were conducted at the former UNC-Hematite site in March and April 2009. NIOSH now has reliable routine urinalysis for most years of the operational period (1958-1973) with the following exceptions: (1) January 1961 through early December 1962, during which time the program was discontinued [Compliance, 1961, pdf p. 13]; and (2) 1971-73 for which the vendor's analytical vendor's results are considered unreliable. Although bioassay samples were collected on a limited basis during the 1961-62 period (as warranted by operational occurrences), a routine bioassay program was not re-instituted until December 1962 (UNC *In Vivo*, 1963-1965; Various authors, 1963, pdf pp. 57-63). NIOSH also has routine air sampling data for the entire operations period. Whole body counting as an assay methodology for U-235 was used by UNC-Hematite beginning in the latter 1960s. This corresponds with the time when the use of whole body counting became more widespread within the nuclear industry. Contamination smear results for a portion of the covered period are also available.

All these data are contained in primary sources (i.e., handwritten or typed documents). The data are legible (with some exceptions involving hand-written documentation). Appropriate reporting units were used. NIOSH reviewed the urinalysis reports received by UNC-Hematite from the main analysis vendor, Nuclear Science and Engineering Corporation [NSEC] (UNC urinalysis, 1962-1964; Bioassay Results, 1964; Bioassay Results, 1965; Bioassay Results, 1966; Bioassay Results, 1967; Bioassay Results, 1968; Bioassay Results, 1969; Special Bioassay, 1970) and two additional vendors, Controls for Radiation Inc., and Isotopes, Inc., that provided urinalysis results beginning in mid-1967 (Bioassay Vendor Results, 1967). The evaluation methods employed by the UNC-Hematite analytical vendors during the covered period focused on exposure to U-235 and alpha radioactivity. As discussed, NIOSH has access to personnel bioassay data for the entire operational period with the exception of 1961-62 and 1971-73. Nevertheless, during those periods, the site maintained a routine air sampling program, including breathing zone (BZ) and general area (GA) air samples (discussed below). These data, coupled with the other sources of information and data discussed below, are of sufficient quantity and quality to support the ability to bound internal dose for the UNC-Hematite class under evaluation.

Several original, handwritten dust monitoring results (General Survey, 1959; Uranium Dust, 1962) as well as air sampling results (Air Sample Data, 1963; Air Sample Log, 1964; Assorted Results, 1963; Blending Room, 1961-63; Blue Room, 1962-63; Green Room, 1964; Item Plant, 1964; Uranium Dust, 1962) and employee termination summaries (Terminated, various years) were identified. These data are legible with some exceptions (especially for years early in the operational period). Appropriate reporting units were used. Based on its review of the available data, NIOSH has access to air sample data that can be used to supplement the bioassay data. These data include breathing zone (BZ) and general area (GA) air samples for the UNC Hematite work areas from 1961-1962 during the period when UNC-Hematite discontinued its personnel bioassay program.

Air sampling emphasized uranium alpha monitoring and evaluation. An exception was the short-term workplace air monitoring for thorium conducted in the Pellet Plant for work performed in 1964 associated with the thorium-uranium fuel pellet work. A former site employee stated that it was highly unlikely that “dedicated” workers were assigned to the Pellet Plant for this project alone (Personal Communications, 2009a).

The thorium-uranium fuel pellet activities involved work with thorium dioxide powder and the concern was alpha radioactivity. Air samples, designated specifically as “ThO_2” (thorium dioxide) were collected in the Pellet Plant during 1964 (Pellet Plant, 1964; Smear Surveys, 1966). NIOSH identified the collection of over two hundred “ThO_2” samples. The highest airborne concentration reported, associated with a spill, was 1.6 $\times 10^{-8}$ μc/ml (Pellet Plant, 1964, pdf p. 60) though the vast majority of results were less than 1×10^{-10} μc/ml. These air sampling results are handwritten documents and are legible. NIOSH’s analysis of these results, which represent a combination of general area/high volume, process, breathing zone/lapel, stack, and hood air sample data, indicate that the results are representative of all operations performed during the Th-U fuel pellet work (Pellet Plant, 1964; Smear Surveys, 1966). These results are similar to the range of available uranium air sample values. In addition, there is documentation discussing the application of Maximum Allowable Concentrations (MAC) values for the thorium work, including discussion of administrative limits and adjusted MAC values for mixtures of radionuclides (Pellet Plant, 1964; Smear Surveys, 1966; ThO_2-UO_2, 1964). Based on this information, NIOSH concludes that the data are of sufficient pedigree to support the evaluation of the thorium dose for UNC-Hematite’s Th-U fuel pellet work performed during 1964.

NIOSH identified routine whole-body counting results for 1968 through 1973 (*In Vivo* and Bioassay, 1960s; *In Vivo* Counts, 1967-73; Whole Body, 1969; Whole Body Counts, 1968-73; Whole Body Issues, 1968-69). The site contracted with Helgeson Nuclear Services, Inc. for this service. The analysis emphasized the detection and quantification of gamma rays emitted from U-235. These data are in original form (either hand-written or typed documents) and are legible. Results for 1968 and 1969 are limited relative to other years; data for only one month in 1968 and three months in 1969 were identified. The contractor’s operations and processes for personnel counting are provided or available for the personnel counts. As the personnel urine bioassay are available for the time period that *in vivo*/whole body counts were performed, the *in vivo* data can be used to supplement the available urine bioassay data for bounding the dose for the UNC-Hematite class under evaluation.

NIOSH also has several investigation reports, correspondence and analyses on elevated internal exposures pertaining to unanticipated operational events in 1962 for which a group of individuals were sent to Oak Ridge during three consecutive years (1963-1965) for *in vivo* monitoring for U-235 at the Y-12 plant (Estimated Exposures, 1963; *In Vivo*, 1964; Oak Ridge Trip, 1963; Various authors, 1963). A more complete discussion is provided in Section 6.1. These data are in original form (either hand-written or typed documents) and are legible. These data can be used, as applicable, to supplement the evaluation of internal dose for the specific time frame of the site’s review, for the UNC-Hematite class under evaluation.

Smears for evidence of removable contamination are available for 1961-1964, 1966, and 1971-1972 (Plant-wide, 1963; Smear Report, 1964; Smear Survey, 1964; Smear Surveys, 1966; Smear Survey, 1971; Smear Survey, 1972). Original smear data were reviewed from restricted and clean (non-process) areas of the plant. Smears were also collected on respirators for evidence of radioactive contamination. Because the data provided to NIOSH was handwritten, legibility in certain circumstances was a factor. Additional data presumably exist because the plant's health physics procedures required the conduct of contamination surveys at a specified frequency (HP Manual, 1963, pdf p. 45). However, because internal dose estimates employ bioassay results (supplemented with air sample and *in vivo* data) as the primary means of dose assessment, and these bioassay (and air sample) data are available, the acquisition and pedigree analysis of additional smear data was not performed for this evaluation.

Based on the information available to NIOSH, UNC-Hematite management and supervisory staff tracked and reported worker exposures as required by 10 C.F.R. 20 and implemented corrective actions when necessary. This included job rotations to reduce exposures (Assignments, 1969; Urinalysis Results, 1960; Whole Body Issues, 1968-69, pdf p. 14) and additional urinalyses and whole body counting (see the discussion above regarding Y-12's assistance with evaluating elevated worker exposures). The total number of site workers during the covered period is not clear; however, a universal badging policy was applied (HP Manual, 1963, pdf p. 15). A review of urinalysis data indicates that an average of 76 workers was monitored annually for internal exposures (External Exposure Reports, 1963; External Exposure Reports, 1964; External Exposure Reports, 1965; Film Badge Summary, 1961; Film Badge Summary, 1962; Tabulation Sheet, 1966; Tabulation Sheet, 1967; Tabulation Sheet, 1969). An annual summary of exposures for 1961 indicated that 150 employees were monitored for external exposures and 132 via air monitoring. Results of that monitoring relative to the federal radiation regulatory limits were documented. This included those operational and supervisory workers involved in uranium enrichment activities in the Green, Blue, and Red Rooms, and the Item Plant.

In summary, bioassay and air sampling data are available in sufficient quantity and quality to adequately represent internal dose for the UNC-Hematite class under evaluation over the entire operational period. These data, applied as defined in the UNC-Hematite TBD (Battelle-TBD-6001, Appendix D), can also be used to support the evaluation of the UNC-Hematite internal dose over the site's residual radioactivity period. Multiple site documents were located containing bioassay and air sampling results for the covered period. Reliable routine urinalysis data are available for the entire operational period with the exception of 1961-62 and 1971-73. Daily and weekly air samples were collected in operational and clean areas of the facility per procedure (HP Manual, 1963, pdf p.11). The available air sample data, including BZ and GA data, are available and can be used to supplement the bioassay data, or as the primary source of internal monitoring data for the period from 1961-1962. In addition, NIOSH has access to other radiological monitoring data and investigation reports that support bounding internal dose for the UNC-Hematite class under evaluation.

7.1.2 External Monitoring Data Pedigree Review

The external monitoring data, based on film badge dosimetry results, are available in sufficient quantity and quality to adequately represent the class under evaluation. Between 100 and 200 employees were monitored on any given year during the operational period (External Exposure Reports, 1963; External Exposure Reports, 1964; External Exposure Reports, 1965; Film Badge Summary, 1961; Film Badge Summary, 1962; Tabulation Sheet, 1966; Tabulation Sheet, 1967; Tabulation Sheet, 1969; Tabulation Sheet, 1970; Tabulation Sheet, 1971; Tabulation Sheet, 1972; Tabulation Sheet, 1973). With limited exceptions (some reported badge contaminations), no problems were reported by the analysis vendor in evaluating the film badges (External Exposure Reports, 1964; External Exposure Reports, 1965).

The available external dosimetry data are primary source documents that contain the personnel monitoring (film badge) results for individual workers across the site. The data are legible and appropriate reporting units were used. There are documented reports of the practice of universal external monitoring using film badges (Compliance, 1960; HP Manual, 1963, pdf p. 15) as well as accounts from former UNC-Hematite workers confirming that universal badging was employed (Personal Communications, 2009a and 2009c). The monitoring results were provided in summary reports to the AEC. NIOSH also identified supporting source-term information contained in licensing documentation, and several summary work history external dose reports.

In summary, the available external dosimetry monitoring data are available in sufficient quantity and quality to adequately represent external dose for the UNC-Hematite class under evaluation over the entire operational period. The dosimetry data are the primary data source that will be used to bound external dose for the UNC-Hematite class under evaluation. These data, applied as defined in the UNC-Hematite TBD, can also be used to support the evaluation of the UNC-Hematite external dose over the site's residual radioactivity period.

NIOSH did not identify any neutron dosimetry data; therefore, a pedigree review of neutron external dosimetry data was not possible. Based on its review of the available information, the potential neutron dose was evaluated using guidance contained in ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds* (see Section 7.3 of this report).

7.2 Evaluation of Bounding Internal Radiation Doses at UNC-Hematite

The principal source of internal radiation doses for members of the class under evaluation was uranium metal and uranium oxides in the form of radioactive particulates (Mallinckrodt, 1960). Thorium dioxide processing did not represent routine plant operations as it was a special project limited to a single time period in 1964. However, air samples to evaluate the presence of thorium were collected during this operation (Pellet Plant, 1964; Smear Surveys, 1966). 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.

The primary contributor to internal radiation dose during the time period under evaluation was inhalation of uranium isotopes. To a much more limited extent, thorium exposure (thorium dioxide) was also a contributor (Pellet Plant, 1964; Smear Surveys, 1966). With the exception of 1961-62, internal monitoring data were collected annually (at a minimum) during the covered period via indirect bioassay (urinalysis) in order to evaluate alpha activity from uranium isotopes. There is a substantial quantity of bioassay data for uranium; however, urinalysis vendor results for 1971-73 are considered unreliable. Beginning in the latter 1960s, direct bioassay methods in the form of whole-body counting became more available. Data from such measurements are restricted to 1968-1973 with limited results for 1968 and 1969 available for UNC-Hematite workers. Non-routine WBC was conducted during 1963-1965 at the Y-12 plant in Oak Ridge, Tennessee to address several elevated worker intakes in UNC-Hematite process areas (Estimated Exposures, 1963; *In Vivo*, 1963; *In Vivo*, 1964; Oak Ridge Trip, 1963).

In support of this evaluation, NIOSH obtained documentation through various means, including a finding aid provided by the current owner for use with several hundred boxes of site records. This information was reviewed and used in support of two data capture efforts at the Hematite facility near Festus, Missouri (March and April 2009). It is clear from these efforts that a credible radiation safety program was in effect at UNC-Hematite during 1958-1973 in conjunction with significant regulatory oversight by the Atomic Energy Commission. Based upon an initial review of site records, 712 boxes and 12 file cabinets were identified as containing site information and health physics related records for the time period under evaluation. A more focused review determined that 113 boxes and 29 files from the file cabinets were potentially valuable to the evaluation. NIOSH performed a labor-intensive on-site review of over 85 percent of these boxes in addition to the records identified from the file cabinets.

Identified records include: correspondence on plant management and operating issues, radiological and contamination surveys, licensing documentation, general and special operating procedures, site inspections, audits, equipment and facilities descriptions, exposure reports, urinalysis reports, air sampling and monitoring results, radiation incident reports, radiation work permits, radioactive material handling, stack air monitoring, nasal smears, whole body counting, and As Low As Reasonably Achievable (ALARA) reports.

These site-specific and health physics records indicate that uranium (and thorium) isotopes in various forms were handled, processed, and monitored. For example, glove-boxes were employed as engineering controls, airborne concentrations were monitored, personal protective equipment (PPE) (e.g., respirators) was used, surface contamination surveys were conducted, and radiation protection oversight was provided.

NIOSH investigated the test production of Th-U fuel pellets performed at UNC-Hematite. Procedures for the use of thorium, license modifications to allow thorium work, and several references to thorium in the Historical Site Assessment documents were obtained; however, no purchases and/or shipments of thorium powder to or from the UNC-Hematite facility have been identified (United Nuclear HSA, 2003; Westinghouse, 2003). Nevertheless, interviews with former site employees confirmed that in 1964 thorium dioxide was used in concert with uranium to produce mixed-oxide fuel pellets for use in breeder reactors like the Elk River Reactor Project (Personal Communications, 2009a and 2009c).

Reviewed correspondence provided insights into UNC-Hematite management's commitment to evaluate each individual's internal exposures. Emphasis was placed on identifying *a priori* those individuals with significant potential for elevated radiation exposures, or *a posteriori* employing corrective measures to prevent re-occurrence. This included reassignments and job rotations employed as "ALARA-equivalent" measures to reduce unnecessary exposures (Assignments, 1969; Overexposures, 1963; Whole Body Issues, 1968-69).

Various incidents that occurred during the covered period as a result of operational activities were documented. Examples include: external radiological overexposures per film badge results in 1963 in the Pellet Plant (Overexposures, 1963); UF_6 releases in the Red Room in 1966 (UF-6 Release, 1966) and 1967 (UF-6 Release, 1967); an HEU release in the Red Room in 1967 (Personnel Exposure, 1967); a UO_2 release in the "Recycle" Room in 1968 (UO_2 Release, 1968a); a Pellet Plant Press Hopper Release in 1968 (UO_2 Release, 1968b); a UO_2 release in the Red Room Milling Hood in 1969 (UO_2 Exposure, 1969); an HF_6 release in the Oxide Building in 1969 (HF Leak, 1969); and various spills and releases in 1970 (Special Bioassay, 1970).

7.2.1.1 Urinalysis Information and Available Data

Uranium

The largest intakes at UNC-Hematite involved isotopes of uranium. Internal exposure data from uranium isotopes for the entire covered period are readily available. The majority of the results are for *in vitro* (bioassay) sampling. UNC-Hematite implemented a bioassay (urinalysis) program, initially conducted on a routine basis, from the latter 1950s through 1960. This bioassay program was discontinued in 1961 and re-instituted in late 1962. The program incorporated gross counting methods to determine exposure to uranium.

The routine bioassay program was not designed to monitor all UNC-Hematite workers. Rather, it was based on job assignment and those with exposure potential. Workers were divided into specific groups, provided with a urine sample schedule (Air Sample Summaries, 1963, pdf 19-20), and informed of their responsibilities to provide urine samples. Responsibilities typically entailed receiving a collection device prior to the weekend and returning the sample the following Monday (Personal Communication, 2009c). One of these groups was comprised of the plant operators who worked in all process areas containing low- to high-enriched uranium. Due to the nature of their job assignments, these workers had the greatest probability of exposure to uranium compounds. NIOSH confirmed through record reviews that each group, including operators, was routinely evaluated for uranium intakes. UNC-Hematite employed off-site vendors to determine the urinalysis results (typically reported in units of d/m/l) on a specified frequency and by employee. The availability of bioassay data for most of the covered period, coupled with the air sampling data and whole body/*in vivo* count data (discussed below), provides sufficient data to bound internal uranium doses for all operational years at UNC-Hematite. Based on this information, NIOSH can identify the maximally-exposed work group/scenario at the site. This information supports NIOSH's ability to bound the internal uranium dose for the UNC-Hematite class under evaluation.

Thorium

No specific personnel thorium bioassay data, other than one whole-body count, were located by NIOSH for the thorium work. The site did perform thorium air sampling (see Section 7.2.1.3).

7.2.1.2 Lung Counting Information and Available Data

Whole-body and lung counting was not commonplace in the 1960s and was limited to a few locations in the United States. As noted in Section 7.2.1.1, urinalysis was the primary bioassay method in place at UNC-Hematite during this period. However, beginning in 1968 and continuing until 1973 (the end of the covered period), there was increased use of direct bioassay as a routine monitoring method.

The only other whole body/lung count information available for UNC-Hematite is for individuals who were identified for follow-up *in vivo* bioassay based on their urine bioassay results (identified as personnel with potential exposures to elevated airborne radioactivity levels in their work area). The exposures were the result of enriched uranium deposited in the lungs of the involved individuals. One source was the exposure to airborne concentrations in excess of the limits specified in 10 C.F.R. 20. Hand contamination was found to be another contributor. Individuals found to have exceeded allowable internal exposure limits were sent to the DOE Oak Ridge Y-12 plant in 1963 for lung counts. Follow-up annual urinalysis and lung count measurements for U-235 were taken in 1964 and again in August 1965 (Estimated Exposures, 1963; *In Vivo*, 1963; *In Vivo*, 1964; Oak Ridge Trip, 1963). While uranium was the primary element of interest, there was one evaluation for exposure to thorium. These data are available to NIOSH (Various Authors, 1963), but are not considered the primary data source for the purpose of evaluating the ability to bound UNC-Hematite personnel internal dose. The available data can be used to supplement the urine bioassay data but the lack of *in vivo*/whole body count data does not preclude NIOSH's ability to bound dose for the proposed worker class evaluated in this report.

7.2.1.3 Airborne Levels

Uranium

Substantial airborne dust and air monitoring data, involving thousands of samples, were identified for the entire covered period. From 1961-1973, air samples were collected routinely in a variety of process and clean ("clear") areas. In addition to urinalysis results (Section 7.2.1.1), these samples can be used as a means for reconstructing and supporting bounding estimates of UNC-Hematite internal doses during the operational period under evaluation.

Thorium

As discussed in this report, NIOSH has analyzed the thorium air samples associated with the Th-U pellet work at UNC-Hematite. These air samples represent a combination of general area/high volume, process, breathing zone/lapel, stack, and hood air sample data and are representative of all operations performed during the performance of the Th-U fuel pellet work (Pellet Plant, 1964; Smear Surveys, 1966). Of the two hundred plus available air samples taken during UNC-Hematite's thorium work, more than 75% of the results were less than 2×10^{-11} μc/ml, which was the thorium administrative MAC established by UNC-Hematite for thorium work (Pellet Plant, 1964; Smear

Surveys, 1966; ThO_2-UO_2, 1964). Most of the results greater than $1x10^{-10}$ μc/ml (the uranium MAC for that time period) were associated with unusual events or include descriptions related to unusual events (e.g., material spills). The maximum result for the data representing UNC-Hematite's Th-U fuel work was associated with a spill; the value was 1.6 x 10^{-8} μc/ml (Pellet Plant, 1964; Smear Surveys, 1966; ThO_2-UO_2, 1964). These results are similar to the range of available uranium air sample values. Because the uranium work continued at the site during the same time and the same building as the thorium work, there are potential contributions from uranium airborne contaminants on the air samples. Because there is no indication that air samples were specifically analyzed for thorium isotopes, a bounding estimate of the thorium dose contribution could be accomplished by assuming that 100 percent of the particulates collected on the filters designated as thorium samples were due to thorium deposition. Based on this information, NIOSH concludes that the data are sufficient for use in evaluating its ability to bound thorium dose for the Th-U fuel pellet work performed at UNC-Hematite during 1964.

Evaluation of the Impact of Changing Site Operators

During a review of SRDB documents, nothing was located that implied or otherwise stated that Hematite site operations were affected in any material way with the change from UNC to Gulf United Nuclear Fuels Corporation (GUNFC) in the spring of 1970. Observed experience at other government-funded operational sites undergoing similar corporate mergers and business alterations would indicate that there were only minimal effects to the on-going day-to-day operations (e.g., Y-12, sequence of operators: Eastman, 1943-47; Union Carbide, 1947-84; Martin Marietta, 1984-94; Lockheed-Martin Energy Systems, 1994-98; BWXT Y-12, 1998 – present [ORAUT-TKBS-0014-2]).

Beginning in 1957, MCW Hematite plant operating personnel submitted urinalysis samples based on specific work assignments (Compliance, 1960). An August 1958 MCW Plant Inspection stated that personnel monitoring was conducted by routine use of film badges, bioassay, and physical examination (AEC, 1958). Permanent operating personnel were monitored on a weekly basis and rotating personnel were monitored monthly. The urinalysis sampling program was discontinued as of January 1, 1961 but was re-instituted in December 1962, and continued for the duration of the operational period (Compliance, 1961).

Internal monitoring data available for the operational period primarily consist of urinalysis, dust sampling, and air monitoring results. Results were compared to the applicable site administrative levels (maximum acceptable concentrations) and federal (10 C.F.R. 20) airborne radioactivity limits. Airborne exposure limits were established in 1959 with 5.0 x 10^{-ll} μc/ml/40 hr. week the permissible level for uranium (AEC, 1960; Mallinckrodt, 1960). Additionally, health physics procedures were established to control exposures to personnel; they remained in effect throughout the operational period (HP Manual, 1963).

NIOSH found no documentation to suggest there were changes in the level of operations from UNC to GUNFC. Operations under GUNFC continued under licenses C-2734 and SNM-33, which were in effect at the time of changeover (License Review, 1979). As shown in Table 7-1, continuous air monitoring records for the period of 1963-1973 do not show increases other than occasional "spikes" recorded in single-day measurements. Notations in the "comments" section of the data sheets indicate that these spikes accompany maintenance actions (filter changes, etc.) Neither the number of records nor the levels recorded indicated any increasing trends. This information, coupled with the comparison of operations controls and methods, provides sufficient support for using the values in Battelle-TBD-6001, Appendix D to bound the potential exposures for the period. The 1963-1973 timeframe has equivalent, or lower, potential exposures based on the data comparison.

Table 7-1: Comparison of Air Sample Totals and Results for UNC and GUNFC Operations

Year	No. Dust/Air Samples (SRDB ID)	High Sample (10^{-10} uCi/ml)	Low Sample (10^{-10} uCi/ml)	Sample Total for Year
1963	17 (62285) 30 (62428) 199 (62432) 122 (62340) 4 (62282) 38 (62279) 9 (62283) 13 (62356) 14 (62341) 7 (62343) 563 (62276) 16 (62170) 17 (62178) 8 (62171) 35 (62355)	0.48 18.50 27.00 270.00 1.20 52.60 0.38 1022.5 6.40 0.45 473.30 4.90 170.0 1.30 0.05	.0013 .008 0.00017 0.0011 0.019 0.001 0.013 0.014 0.06 0.02 0.00 0.005 0.14 0.00 0.000	1016
1964	2927 (62168) 445 (62279) 578 (62356) 860 (62343) 125 (62348) 246 (62341) 302 (62361) 850 (62355)	26.79 52.60 188.30 204.384 26.79 5.30 1.172 0.086	0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	6333
1965	X	---	---	X
1966	12 (62298)	687.085	0.438	12
1967	2 (62428)	1.373	0.033	2
1968	5390 (62300)	39.175	0.000	5390
1969	X	---	---	X
1970	1169 (62207) 6540* (62184) 608* (62186) 335 (62200)	101.955 4.611 2.027 18.612	0.000 0.000 0.000 0.000	8652
1971	36 (62142) 5485* (62186) 296* (62212)	12.473 2.808 10.562	0.000 0.001 0.000	5817
1972	97 (62144) 17 (62146) 30* (62149) 31* (62152) 497* (62154) 703* (62139) 31* (62140) 5294* (62155)	29.425 1.461 2.774 .233 7.864 .030 .233 3.66	0.0 .004 .004 0.0 0.0 0.0 .002 0.0	6700

Table 7-1: Comparison of Air Sample Totals and Results for UNC and GUNFC Operations				
Year	**No. Dust/Air Samples (SRDB ID)**	**High Sample (10^{-10} uCi/ml)**	**Low Sample (10^{-10} uCi/ml)**	**Sample Total for Year**
1973	66 (62137) 44 (62146) 15* (62145) 27* (62152) 256* (62139) 27* (62140) 1080*(62154) 4894* (62155)	9.009 2.774 .169 .233 .18 .205 .012 1.147	.006 .002 0.0 0.0 0.0 0.0 0.0 0.0	6409

"X" indicates that data exist, but the specific number of samples collected was not available.
* Includes CUNO filter stack and additional stack samples.

7.2.2 Evaluation of Bounding Residual Period Internal Doses

Although non-AEC-related radioactive materials work continued at UNC-Hematite after 1973, NIOSH is required to evaluate the potential internal exposures from the residual radioactivity that remained as a result of weapons-related work during the operational years at the site (1958-1973); under EEOICPA rules, this would not include the site's Th-U pellet work. The weapons-related work performed during the covered operational years involved uranium only. For the purpose of bounding the internal uranium dose associated with the weapons-related residual radioactivity that remained on site after the end AEC-related operations, NIOSH can use the method defined in the UNC-Hematite TBD (Battelle-TBD-6001, Appendix D, Section D.6). For reconstructing internal dose, the method involves determining a maximum air concentration which is assumed to settle and accumulate over a predetermined amount of time at the end of the operations period. NIOSH can back-calculate the airborne concentration for use in this method based on the bounding/maximum intakes rates for the UNC-Hematite operational period, as discussed in Battelle-TBD-6001. The available air monitoring data for the site can be used to supplement the calculations and corroborate that this method provides a bounding internal dose reconstruction approach for the residual radioactivity period.

7.2.3 Methods for Bounding Internal Dose at UNC-Hematite

7.2.3.1 Methods for Bounding Operational Period Internal Dose

Intakes to monitored UNC-Hematite workers may be estimated using readily-available *in vitro* (urinalysis) and/or *in vivo* (whole body counting) data for uranium isotopes. Of the two evaluation methods, significantly more urine bioassay data exist for the covered period under consideration. The description of the radiological program as it relates to internal monitoring and dose assessment supports that: (1) the primary radionuclide of concern was uranium (other than the case of the thorium blended for thorium-uranium fuel pellets in 1964); (2) those with the potential for exposure to uranium were monitored for internal exposures; (3) there are breathing zone and general area air sampling data available for the work performed over the operational years at UNC-Hematite, and (4) NIOSH has access to the applicable monitoring data. NIOSH intends to use the personnel monitoring data and existing internal dose reconstruction processes and procedures set forth in Battelle 6001, Appendix D, to reconstruct uranium dose for the class under evaluation. NIOSH may also use the available uranium air monitoring data, source term information, and process descriptions to supplement the reconstruction of the uranium dose and support bounding the associated dose. These resources support the ability to reconstruct uranium dose using methods that are more precise than a bounding dose estimate.

NIOSH also has access to extensive air monitoring data for the natural thorium work associated with the thorium-uranium fuel pellet work performed at the site. NIOSH intends to use this air monitoring data, coupled with the available source term information, process descriptions, and existing internal dose reconstruction processes and procedures set forth in Battelle 6001, Appendix D, to support bounding the thorium dose for the class under evaluation. Based on the assessment in Section 7.2.1.3, and the evaluation of the thorium air sample data, NIOSH intends to apply the uranium MAC of 1×10^{-10} μc/ml (applied as 100% Th-232) as the bounding airborne concentration for routine Th-U pellet operations performed at UNC-Hematite during 1964. For identified incidents (e.g. spills) that may have occurred during the period, NIOSH intends to evaluate the range of values greater than 1×10^{-10} μc/ml to establish a bounding thorium airborne concentration applicable to the specific situation. These airborne concentrations can be converted to personnel intake rates by applying a standard breathing rate and exposure time. NIOSH can consider the application of the MAC for mixtures (U and Th: 8.7×10^{-11} μc/ml); the thorium MAC for the time period (3×10^{-11} μc/ml); the UNC-Hematite Administrative MAC (2×10^{-11} μc/ml); or a percentage of the selected MAC in order to evaluate an internal dose estimate that is more precise than a bounding estimate for members of the class under evaluation. Such an approach would be applicable for evaluating internal exposures over a wide range of job titles/duties.

7.2.3.2 Methods for Bounding Residual Period Internal Dose

Although non-AEC-related radioactive materials work continued at UNC-Hematite after 1973, NIOSH is required to evaluate the potential internal exposures from the residual radioactivity that remained as a result of weapons-related work during the operational years at the site (January 1, 1958 through December 31, 1973). The weapons-related work performed during the covered operational years at UNC-Hematite involved uranium only. Residual contamination from weapons-related work may have been present in various outdoor and indoor locations at UNC-Hematite (Battelle-TBD-6001, Appendix D). The UNC-Hematite Historical Site Assessment also mentioned this likelihood (Westinghouse, 2003). This results in the potential for internal exposure from inhalation and ingestion of residual radioactive materials/contamination as a result of re-suspension. Battelle-TBD-6001, Section D.6, provides a method to bound internal doses associated with residual radioactivity exposures at UNC-Hematite. The method involves determining a maximum operational period air concentration (from bounding/maximum intake rates associated with the operations period) which is assumed to settle and accumulate over a predetermined amount of time at the end of the operations period. NIOSH may also choose to evaluate the residual contamination/radiation based on the maximum air sample results over the operational period versus the calculated value based on intake rates. Standard re-suspension factors can be applied to the calculated surface contamination values to support calculating a post-1973 airborne concentration as a result of the residual radioactivity. The airborne concentration can be used to determine a corresponding intake of those radioactive materials (applying standard breathing rate and work period). Since the development of the UNC-Hematite TBD, NIOSH has collected personnel and area monitoring data for the operational and post-AEC operations period. These data, coupled with the approaches defined in Battelle-TBD-6001, support NIOSH's ability to bound internal dose for the residual radioactivity period.

As presented and discussed in ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, more precise intake estimates can be evaluated considering the depletion of the AEC related source term/material, and the decline of the re-suspension factor, over the residual period at UNC-Hematite.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

This evaluation concludes that NIOSH can bound internal dose (reconstruct dose with sufficient accuracy) for members of the class under evaluation. NIOSH located sufficient personnel monitoring data to support bounding internal uranium and thorium exposures at UNC-Hematite for the operational period of January 1, 1958 through December 31, 1973, and to support bounding AEC-related residual radioactivity exposures during the residual radioactivity period from January 1, 1974 through July 31, 2006. This feasibility conclusion is based on the collective availability of bioassay (urinalysis) and air sampling data in sufficient quantity and quality for the entire covered period to adequately represent the class under evaluation. Supporting information, while limited, exists related to workplace activities, area monitoring, and associated source terms. Whole-body counting, thorium air sampling, and smear data represent additional, partial data sources and can be used to supplement and corroborate the bounding exposure assessments for the class.

7.3 Evaluation of Bounding External Radiation Doses at UNC-Hematite

The principal source of external radiation exposure for members of the class under evaluation was photon and beta (electron) radiation associated with AEC operational activities, including handling of radioactive materials in production or research activities; or radioactive waste-handling operations. Uranium metal and uranium compounds from natural and enriched uranium constituted the principal external radiation dose-producing material sources for members of the class. Per a Westinghouse Decommissioning Plan, these materials included uranium hexafluoride (UF_6), uranium dioxide (UO_2), uranium carbide, uranium dioxide pellets, and uranium metal (Personal Communications, 2009a and 2009c; Westinghouse, 2006; Westinghouse Plan, 2006).

As of the date of this evaluation, NIOSH has located individual external monitoring records for UNC-Hematite employees associated with uranium material processing during the operational period under evaluation. As expected, the highest doses were received by operations workers in the plant's processing areas. Documentation retrieved from the site verifies that a robust personnel external monitoring program existed for photon and beta radiation exposures, as reflected in the individual external monitoring records. Neutron personnel exposures were not tracked as a component of the routine external dosimetry program. Possible reasons for this decision are discussed in Section 6.2. A suggested approach to bound neutron dose in lieu of monitoring data is provided in Section 7.3.4.1.

The available documentation and information for the operational period also supports NIOSH's ability to bound the post-1973 residual period external dose from exposures to residual radioactivity/contamination remaining on site as a result of AEC weapons-related operations.

Employment at UNC-Hematite involved routine medical X-ray examinations required as a condition of employment; therefore, occupational X-rays are also a source of external radiation dose.

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

7.3.1 Evaluation of Bounding Process-Related External Doses

As discussed in the prior sections of the evaluation, UNC-Hematite historical documentation specifies potential workplace external radiation hazards, applicable radiation exposure guidelines, and methods to limit worker exposure.

NIOSH has located external monitoring records for beta and gamma radiation for UNC-Hematite employees associated with uranium processing during the class period under evaluation. Individual dosimetry data for the operational period is the preferred data source for evaluating the external radiation doses for members of the UNC-Hematite class. However, no dosimetry data was identified related to potential personnel exposures to neutrons; therefore, an approach for bounding neutron doses is provided in Section 7.3.4.1.

NIOSH has the methodology and external uranium dose reconstruction assumptions and approaches described in Battelle-TBD-6001 at its disposal. NIOSH will use individual dosimetry data in conjunction with this methodology and to validate or adjust any assumptions, as appropriate. The monitoring data and methodologies available to NIOSH support its ability to bound external dose associated with UNC-Hematite uranium operations.

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

7.3.1.1 Personnel Dosimetry Data

NIOSH has located records documenting the implementation of an external monitoring program for beta and photon exposure at UNC-Hematite. A routine external monitoring program for neutron exposure did not exist at the site. In addition to the documentation described below, NIOSH conducted interviews with two former workers who stated that they routinely wore a film badge (Personal Communications, 2009a and 2009c). An interview with a third person confirmed that badging occurred at the site, but the type of badging (film, etc.) could not be recalled (Personal Communication, 2009b). A review of the CATI interview reports for information on the routine use of radiation dosimeters supports a routine badging program at UNC-Hematite.

Photon

The available personnel external monitoring data, in the form of film badges, provide external photon/gamma dose information for the personnel working during the operational period at UNC-Hematite. These data can be used to reconstruct dose for members of the worker class under evaluation. In addition, Battelle-TBD-6001, Appendix D, describes how to develop the estimate of photon exposure for the former UNC-Hematite workers when site information is not available. As discussed in this evaluation, the available personnel monitoring data include data that represent the maximally-exposed work group and work scenario over the UNC-Hematite operational period. Therefore, NIOSH has concluded that the available personnel monitoring data and information for UNC-Hematite support its ability to bound the photon dose for the class under evaluation.

Beta

The available personnel external monitoring data, in the form of film badges assigned to workers over the operational time period, were used to evaluate not only whole-body photon doses, but also workplace beta doses. Information regarding external exposures to beta radiation is also described in Battelle-TBD-6001, Appendix D, Section D.4, which references a 1960 AEC inspection report (Clarification, 2008) describing monthly badge results for workers in operations areas. Information for beta dose, as described in Battelle-TBD-6001, Appendix D, shows how to develop the estimate of beta exposure for the former UNC-Hematite workers when site information is not available. As discussed in this evaluation, the available personnel monitoring data include data that represents the maximally-exposed work group and work scenario over the UNC-Hematite operational period. Therefore, NIOSH has concluded that the available personnel monitoring data and the UNC-Hematite TBD support NIOSH's ability to bound the beta dose for the class under evaluation.

Neutron

A routine external monitoring program for neutron exposure did not exist at UNC-Hematite. Rather, the site emphasized administrative and engineering controls to prevent a criticality accident. An indium foil (for indication of a neutron exposure from such an accident) was included with worker film badges.

Because a routine monitoring program for neutrons did not exist, NIOSH evaluated several possible methods to bound neutron doses. A suggested approach that employs ORAUT-OTIB-0024 is provided in Section 7.3.4.1.

7.3.1.2 Area Monitoring Data

A Compliance Inspection Report (AEC, 1960) states that routine radiation surveys were made of the Hematite plant area with portable radiation survey instruments, that results of the surveys were recorded on floor plans, and that these surveys were usually made weekly by the health physics technician but the frequency varied depending on the work load of the technician. Records of the surveys show almost all readings to be < 2.5 mr/hr gamma with an occasional beta plus gamma reading recorded as 20 * [* = illegible symbol]. (Note: "mr/hr" represented the unit used during this period representing an exposure rate in milliroentgens per hour; today, it would be cited as "mR/hr.") "Mr. *[name redacted]; Supervisor, Industrial Hygiene Department]* stated that instruments with 20 mr/hr maximum range have been used for the surveys and that the readings recorded as greater than 20 mr/hr would not be expected to exceed 20 mr/hr to a significant extent. Mr. *[name redacted]* stated that no readings in excess of 2 mr/hr have been observed outside the Hematite restricted area." (AEC, 1960, pdf p. 51)

NIOSH identified records addressing the conduct of routine site radiation and contamination surveys in clear and contaminated areas of the plant (AEC, 1960; Beta-Gamma Survey, 1965; Hand Monitor, 1963; Plant-wide, 1963; Smear Survey, 1964). Surveys were required per the plant's health physics manual and licensing requirements (AEC, 1960; HP Manual, 1963). NIOSH does not intend to use this as the primary source of information for the purpose of bounding external dose. However, this data can be used to supplement the personnel external dosimetry data and to corroborate the defined bounding approaches for the class under evaluation.

7.3.2 Evaluation of Bounding Residual Period External Doses

As previously discussed, non-AEC-related work continued at UNC-Hematite after 1973. NIOSH is required to evaluate the potential external exposures from the residual radioactivity that remained as a result of weapons-related work during the operational years at the site (1958-73). The weapons-related work performed during the covered operational years at UNC-Hematite involved uranium only. For the purpose of bounding the external dose associated with the weapons-related residual radioactivity that remained on site after the end AEC-related operations, NIOSH can use the method defined in the UNC-Hematite TBD (Battelle-TBD-6001, Appendix D, Section D.6). For reconstructing external dose, the method involves determining a maximum air concentration which is assumed to settle and accumulate over a predetermined amount of time at the end of the operations period. NIOSH can use the method of calculating external exposure rates based on the bounding/maximum accumulated radioactive material at UNC-Hematite, as discussed in Battelle-TBD-6001. The available air monitoring data for the site can be used to supplement the calculations and corroborate that this method provides a bounding external dose reconstruction approach for the residual radioactivity period.

7.3.3 UNC-Hematite Occupational X-Ray Examinations

Per interviews with former UNC-Hematite plant management and records reviews, employees were required to complete medical examinations, including chest X-rays (posterior-anterior and lateral X-rays) prior to beginning work, annually, and upon termination (Health Program, 1962, pdf p. 12; HP Manual, 1963, pdf p. 15; Personal Communications, 2009a and 2009c; Medical Program, 1962).

Although NIOSH has not located specific parameters associated with these 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, *Dose Reconstruction from Occupationally Related X-Ray Procedures*. These values can be used to support bounding the medical X-ray dose for the time period under evaluation. These default values are maxima or 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 UNC-Hematite. 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 class under evaluation.

7.3.4 Methods for Bounding External Dose at UNC-Hematite

Dose reconstructions performed prior to the date of this evaluation were completed using estimates of external dose based on source term data and worker stay times derived from interview data and site operations (Battelle-TBD-6000). External monitoring records are now available for beta and photon radiation exposures; these primary data sources will be used in conjunction with Battelle-TBD-6000 methodologies for the purpose of bounding the external dose. External dosimetry data associated with neutron exposures were not identified.
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

7.3.4.1 Methods for Bounding Operational Period External Dose

NIOSH has obtained sufficient personal dosimetry records for individual workers exposed to beta and photon radiation during the AWE operations period. A routine neutron dosimetry program did not exist at UNC-Hematite; therefore, an alternative bounding approach is provided below.

Photon Dose

Photon doses can be reconstructed using available film badge summary reports for all years associated with the covered period. Badging extended to all site employees whether in process or non-process areas.

Beta Dose

Exposures to beta radiation were routinely recorded during the covered period as a component of the external dosimetry (i.e., film badging) program. General area beta doses (rem), as measured by personnel dosimeters, were provided in annual dose summaries either as stand-alone “beta” results or as “beta-gamma.” NIOSH located no indication of beta dose monitoring of extremities by the radiation protection program; however, NIOSH confirmed that the site did attempt to determine hand exposures to alpha particles by survey (HP Standards, 1968). Using process-specific electron dose rates provided in Table 7.3 of Battelle-TBD-6001, NIOSH has determined that it is possible to evaluate a reasonable upper-bound estimate of shallow beta dose to extremities. Estimation of extremity dose would be necessary only if warranted by the specific parameters of an individual case. Sufficient dosimetry information exists to estimate external doses from this radiation type.

Neutron Dose

Because a routine monitoring program for neutrons did not exist, NIOSH evaluated several possible methods to bound these potential doses. These methods included consideration of spontaneous fission, uranium compound source terms and quantities used at the site, enrichment levels, neutron yields from alpha-neutron and spontaneous fission reactions, worker stay times under different exposure scenarios, and neutron-to-photon ratios. Due to its low production rate, spontaneous fission can be eliminated as a viable dose contributor (Battelle-TBD-6000). Based on the remaining considerations, NIOSH has determined that it can bound neutron doses using information contained in ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*.

Medical X-ray Dose

UNC-Hematite employees were required to have chest X-rays prior to beginning work, annually, and upon termination. Although NIOSH has not located specific parameters associated with these occupational medical X-rays, default values of entrance kerma, developed for the three most commonly-used occupational medical diagnostic procedures are available in ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally Related X-Ray Procedures*. These values can be used to support bounding the medical X-ray dose for the time period under evaluation.

7.3.4.2 Methods for Bounding Residual Period External Doses

Although non-AEC-related radioactive materials work continued at UNC-Hematite after 1973, NIOSH is required to evaluate the potential external exposures from the residual radioactivity that remained as a result of weapons-related work during the operational years (from January 1, 1958 through December 31, 1973). Battelle-TBD-6001, Section D.6, provides a method to bound external doses associated with residual radioactivity exposures at UNC-Hematite. The method involves determining a maximum operational period air concentration (from bounding/maximum intake rates associated with the operations period) which is assumed to settle and accumulate over a predetermined amount of time at the end of the operations period. NIOSH may also choose to evaluate the residual contamination/radiation based on the maximum air sample results over the operational period versus the calculated value based on intake rates. NIOSH could evaluate the bounding personnel external exposure based on the calculated dose rates associated with the accumulated radioactive materials. Since the development of the UNC-Hematite TBD, NIOSH has collected personnel and area monitoring data for the operational and post-AEC operations period. These data, coupled with the approaches defined in Battelle-TBD-6001, support NIOSH's ability to bound external dose for the residual radioactivity period.

More precise external dose estimates can be evaluated by accounting for the depletion of the AEC-related source term/material over the UNC-Hematite residual period. This can be evaluated as presented and discussed in ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*.

7.3.5 External Dose Reconstruction Feasibility Conclusion

This evaluation concludes that NIOSH can bound external dose (reconstruct dose with sufficient accuracy) for members of the class under evaluation. NIOSH located sufficient personnel beta and photon monitoring data to estimate external exposures at UNC-Hematite for the operational period of January 1, 1958 through December 31, 1973, and to support bounding AEC-related residual radioactivity exposures during the residual radioactivity period from January 1, 1974 through July 31, 2006. This feasibility conclusion is based on the availability of film badge data in sufficient quantity and quality for the entire covered operational period to adequately represent the class under evaluation. While more limited, there is supporting information related to workplace activities, area monitoring, and associated source terms. Due to the absence of neutron monitoring data, an alternative approach for bounding neutron doses employs the methods provided in ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*.

7.4 Evaluation of Petition Basis for SEC-00116

The following subsections evaluate the assertions made on behalf of petition SEC-00116 for the United Nuclear Corporation.

7.4.1 Personnel Records Lost, Falsified, or Destroyed

SEC-00116: *It is our position that personnel records are being lost, falsified, or destroyed.*

Based on its review and assessment of the available data in the SRDB and in NOCTS, NIOSH has not found evidence that would corroborate the petitioner's claim of falsified or destroyed personnel monitoring records. NIOSH verified during data capture visits to the Hematite site in March and April 2009, that hundreds of records boxes and other data files were present in multiple on-site locations and maintained under appropriate document control procedures, including key access and Westinghouse administrator control.

7.4.2 Dose Reconstruction Infeasible

SEC-00116: *It is our position that a Dose Reconstruction cannot be completed with sufficient accuracy given the lack of data, absence of a site profile, and extensive on-off site contamination.*

As confirmed during NIOSH's review, substantial internal and external data exist. The process and source term information, coupled with the NIOSH approaches for reconstructing uranium dose, are sufficient to support bounding the uranium internal and external dose for members of the class under evaluation.

7.4.3 Lack of Site Profile

SEC-00116: *No site profile of the Hematite facility has been performed.*

Battelle-TBD-6001, Appendix D, provides a site profile for UNC-Hematite. A site profile is not a prerequisite for the performance of dose reconstruction.

7.4.4 Lack of Internal Monitoring

SEC-00116: *The employees did not receive routine internal monitoring such as bioassays, blood samples, and breath (sic) tests.*

During the AWE operational period for UNC-Hematite (1958 through 1973), workers were monitored by bioassay and required to submit urinalysis samples on a specified frequency (ranging from monthly to every three-to-six months, depending on job assignment and year). While the bioassay program was discontinued in 1961, air sampling continued in both process and non-process areas and the data were evaluated by the site for potential internal doses. A routine bioassay program was re-instituted in December 1962 (UNC *In Vivo*, 1963-1965). Examples of existing internal data are in the following reference documents: Bioassay Results, 1964; Bioassay Results, 1965; Bioassay Results, 1966; Bioassay Results, 1967; Bioassay Results, 1968; Bioassay Results, 1969; HP Standards, 1968; *In Vivo* and Bioassay, 1960s; *In Vivo* Counts, 1967-73; UNC urinalysis, 1962-1964; UNC urinalysis, 1963-1964; Various Authors, 1963; Whole Body, 1969; Whole Body Counts, 1968-73; Whole Body Issues, 1968-69; Special Bioassay, 1970.

7.4.5 Monitoring Thoroughness

SEC-00116: *The former Atomic Energy Commission, the Department of Energy, the Nuclear regulatory* [sic] *Commission nor NIOSH has* [sic] *thorough personnel or environmental monitoring.*

See the NIOSH response in Section 7.4.4 above.

7.4.6 Lack of Personnel Radiation Dose Records

SEC-00116: *As far as we know, no Hematite personnel radiation dose records have been provided to NIOSH and possibly do not exist.*

NIOSH has obtained bioassay, air sampling, and external dosimetry data in sufficient quantity and quality to adequately represent internal and external dose for the UNC-Hematite class under evaluation over the entire operational period (see Sections 6.1, 6.2, and 6.3). These data can also be used to support the evaluation of the UNC-Hematite external dose over the site's residual radioactivity period.

7.4.7 Residual Contamination

SEC-00116: *The Hematite site remained active as a commercial manufacturer until 2000 without a proper decommissioning. Residual contamination is evidently present and just as radioactive today.*

NIOSH recently collected personnel and area monitoring that support bounding the internal dose for the UNC-Hematite operational period. In addition, NIOSH has access to personnel and area monitoring data collected at UNC-Hematite during non-AEC operations that continued into the residual radioactivity period (after AEC operations ended in 1973), as well as site remediation surveys. In addition to individual external monitoring records, status surveys and confirmatory surveys performed during the residual period would be used along with available personnel records to establish the upper bound of potential exposure from residual radiation. Knowledge of the AEC process operations performed during the operational period, and the available data for the associated timeframes, support NIOSH's ability to reconstruct dose during the residual radioactivity period at the site. For the UNC-Hematite residual period, only the personnel exposures to AEC-related residual radioactivity are assessed. This topic is discussed further in Sections 7.2.2 and 7.3.2.

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

During the feasibility evaluation for SEC-00116, issues were identified by NIOSH that needed further analysis and resolution. The issue and its current status are:

- ISSUE: Was thorium present at the site?

  RESPONSE: Interviews with former UNC-Hematite energy employees confirm the presence of thorium powder in site operations. The thorium operations occurred in 1964 and included the production of UO_2-ThO_2 pellets for reactor fuel rods. NIOSH maintains that by bounding the doses for uranium oxides, the lesser radionuclides, including thorium, are also bounded.

  Through a review of air sampling logs, NIOSH identified the collection of air samples in the Pellet Plant during 1964 specifically for the presence of thorium dioxide. Air sampling results fell within the range of uranium air sampling results. Therefore, NIOSH maintains that uranium results can be used to bound thorium results.

- ISSUE: Why was neutron personnel monitoring non-existent as a component of a routine external dosimetry program?

  RESPONSE: NIOSH interviewed a former UNC-Hematite plant manager who could not recall any technical discussions concerning the need for a routine neutron survey and personnel monitoring program. NIOSH reviewed available UNC-Hematite documentation to identify records related to neutron exposures. Records reviews included Health Physics procedural manuals, AEC regulations and licensing inspections, dosimetry records, and site radiation survey records. While UNC-Hematite received and processed uranium in various forms (including uranium hexafluoride), neutron exposures were not identified as a radiological concern by plant personnel either as a component of routine plant operations or the external dose monitoring program. AEC regulations in 10 C.F.R. 20 (1961) only generally referred to the need to conduct surveys and provide monitoring devices. No specific requirement existed in the regulations to conduct neutron surveys and track neutron personnel exposures. AEC licensing inspection reports did not cite the lack of routine neutron monitoring as a concern or recommend any action in this regard. No radiological monitoring records specifying exposure to neutron radiation were identified and UNC-Hematite did not list portable neutron instrumentation in its inventory. Because neutron records were not identified, NIOSH provided an alternative approach to bound the neutron dose at UNC-Hematite using a combination of operational site information and ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*.

7.6 Summary of Feasibility Findings for Petition SEC-00116

This report evaluates the feasibility for completing dose reconstructions for employees at UNC-Hematite from January 1, 1958 through December 31, 1973, and for the residual period from January 1, 1974 through July 31, 2006. NIOSH found that the available monitoring records, process descriptions and source term data available are sufficient to complete dose reconstructions for the evaluated class of employees.

Table 7-2 summarizes the results of the feasibility findings at UNC-Hematite for each exposure source during the time periods from January 1, 1958 through December 31, 1973, and for the residual period from January 1, 1974 through July 31, 2006.

Table 7-2: Summary of Feasibility Findings for SEC-00116

January 1, 1958 through December 31, 1973; residual period from January 1, 1974 through July 31, 2006

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal[1]	**X**	
- U	X	
- Th	X	
External	**X**	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

[1] Internal includes an evaluation of urinalysis (*in vitro*), airborne dust, and limited lung (*in vivo*) data

As of June 8, 2009, a total of 51 claims have been submitted to NIOSH for individuals who worked at UNC-Hematite and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for 33 individuals (~65%).

8.0 Evaluation of Health Endangerment for Petition SEC-00116

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 feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is not required.

9.0 Class Conclusion for Petition SEC-00116

Based on its full research of the class under evaluation, NIOSH found no part of said class for which it cannot estimate radiation doses with sufficient accuracy. This class includes all site employees that worked in any area of the United Nuclear Corporation, Hematite, MO, site from January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006.

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-00116. 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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ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally Related X-Ray Procedures*, Rev. 03 PC-1; Oak Ridge Associated Universities (ORAU); December 21, 2005; SRDB Ref ID: 20220

ORAUT-OTIB-0024, *Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*, Rev. 00; Oak Ridge Associated Universities; April 7, 2005; SRDB Ref ID: 19445

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

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Attachment 1: Data Capture Synopsis

Table A1-1: Data Capture Synopsis For United Nuclear Corp., Hematite, Mo

Data Capture Information	Data Captured Description	Date Completed	Uploaded
Primary Site/Company Name: United Nuclear Corp AWE 1958-1969; Residual Radiation 1970-July 2006 Other company names: 1956-1961 Mallinckrodt Chemical Works 1961-1970 United Nuclear Corporation 1970-1973 Gulf United Nuclear Fuels Corporation, a joint venture of Gulf Nuclear Corporation and United Nuclear Corporation 1973 United Nuclear closed the plant and began decommissioning 1974-1989 Combustion Engineering, plant restarted to produce commercial nuclear fuel rods 1989-2000 Asea Brown Boveri/Combustion Engineering 2000-Present Westinghouse Electric Company	Negotiating with Michele Gutman, Westinghouse Electric Company Assistant General Counsel, to gain access to a collection of 600 Hematite site boxes.	Last contact was 01/11/2009	0
State Contacted: Missouri Department of Natural Resources	Process knowledge interview, interim groundwater monitoring plan, site description, human health risk assessment, ecological risk assessment, and site chronology.	01/01/2009	6
Comprehensive Epidemiologic Data Resource (CEDR)	No relevant data identified.	12/03/2008	0
DOE Hanford Declassified Document Retrieval System (DDRS)	Inventory of Pu scrap.	09/18/2008	1
DOE Legacy Management Considered Sites	Superseded by DOE LM GJO DVD files.	N/A	N/A
DOE Legacy Management Grand Junction Office DVD Files	Airborne radioactivity reports, environmental monitoring, material accountability reports, AEC licenses including correspondence and amendments, material transfers and purchases, compliance inspection reports, procedures, waste disposal, nuclear safety calculations, stakeholder complaints, shipping procedures, shipping container design, and AEC contracts.	11/19/2008	318
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	EU and DU shipment documentation, long range plans, and comments on Clean Air Acy effluent limitations.	04/02/2008	4
DOE OpenNet	No relevant data identified.	11/30/2008	0
DOE OSTI Energy Citations	No relevant data identified.	11/30/2008	0
DOE OSTI Information Bridge	Carbide fuel development, groundwater monitoring, uranium alloy metallurgy, and FY-1973 radioisotope shipments.	12/28/2008	4

Table A1-1: Data Capture Synopsis For United Nuclear Corp., Hematite, Mo			
Data Capture Information	**Data Captured Description**	**Date Completed**	**Uploaded**
General Atomics	SNAP-8ER reports and GAMAS trailer exposures.	01/10/2006	3
Google	Discussion of nuclear workers' health risks and proposals for Congressional action.	03/09/2008	1
NARA - Atlanta	Bioassay program and results, processing 3.9% EU, UF6 to UF4 processing, and in-vivo monitoring data.	03/30/2007	10
National Academies Press (NAP)	No relevant data identified.	12/03/2008	0
National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant data identified.	12/03/2008	0
NRC Agencywide Document Access and Management (ADAMS)	AEC licenses including correspondence and amendments, site radiological characterization, decommissioning status reports, FOIA responses, aerial survey, environmental impact information, compliance inspections, corrective action plans, decommissioning plans, and a burial site survey.	01/01/2009	184
NRC FOIA Files	License SNM-33, U and Pu scrap recovery, FUSRAP reports, and license inspections.	Unknown	1
NRC Public Reading Room	Proposed NRC fine and decommissioning update.	12/28/2008	2
NRC Records	Annual exposure summaries, license SNM-33 correspondence, and airborne uranium dust exposures 1959-1960.	07/13/2005	11
ORAU Team	Process knowledge interviews, employee lists, evaluations of medical and work history records, site profiles for AWE's that processed U and Th, and Appendix D United Nuclear Corporation.	03/17/2008	2
Organization for Economic Cooperation and Development	Report on stakeholder involvement in decommissioning.	01/01/2009	1
SAIC	Annual summary of exposures for 1962.	09/02/2004	1
Southern Illinois University	Radiological contingency plans, requests for information, request for environmental monitoring, and news articles.	10/27/2008	20
United Kingdom Patent Office	Patents for measuring the carbon content of molten metal and the production of uranyl fluoride.	01/12/2009	2
United States Patent Office	Patents for chemical processes, the production of uranium tetrafluoride, and a carrier for uranium oxide pellets.	01/12/2009	3
U.S. Army Corps of Engineers	Uranium residues historical synopsis.	03/18/2008	1
Washington State University (U.S. Transuranium and Uranium Registries)	No relevant data identified.	12/03/2008	0
Unknown	Responses to exposure information requests, site descriptions and inspections, correspondence regarding and inspections of license SNM-33, material transfer requests, and recycled uranium program.	07/06/2005	13
TOTAL			**588**

Table A1-2: Database Searches for United Nuclear Corp., Hematite, Mo			
Database/Source	**Keywords**	**Hits**	**Uploaded**
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 11/30/2008	"United Nuclear" + Hematite + 01/01/1957 - 11/25/2008	5	**0**
DOE OSTI Energy Citations http://www.osti.gov/energycitations/ COMPLETED 11/30/2008	"United Nuclear" + 01/01/1957 - 11/26/2008 "United Nuclear" + Hematite + 01/01/1957 - 11/26/2008	1239	**0**
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 12/28/2008	"United Nuclear " + 01/01/1957 - 11/25/2008 "United Nuclear" + Hematite + 01/01/1957 - 11/26/2008	464	**4**
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 01/01/2009	"United Nuclear" AND Hematite	256	**184**
DOE CEDR http://cedr.lbl.gov/ COMPLETED 12/03/2008	"United Nuclear"	7	**0**
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 09/18/2008	"United Nuclear" + 01/01/1957 - 11/25/2008	1	**1**
National Academies Press http://www.nap.edu/ COMPLETED 12/03/2008	"United Nuclear" + Hematite	0	**0**
NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 12/03/2008	"United Nuclear"	0	**0**
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 12/03/2008	"United Nuclear"	0	**0**
Google http://www.google.com COMPLETED 03/09/2008	americium OR Am241 OR Am-241 OR "AM 241" OR 241Am OR 241-Am OR "241 Am"+"United Nuclear" + Hematite ionium OR Th230 OR Th-230 OR "Th 230" OR 230Th OR 230-Th OR "230 Th"+"United Nuclear" + Hematite neptunium OR Np237 OR Np-237 OR "Np 237" OR 237Np OR 237-Np OR "237 Np"+"United Nuclear" + Hematite	1,919	**1**

Table A1-2: Database Searches for United Nuclear Corp., Hematite, Mo			
Database/Source	**Keywords**	**Hits**	**Uploaded**
	polonium OR Po210 OR Po-210 OR "Po 210" OR 210Po OR 210-Po OR "210 Po" +"United Nuclear" + Hematite thorium OR Th232 OR Th-232 OR "Th 232" OR 232Th OR 232-Th+"United Nuclear" + Hematite "232 Th" OR "Z metal" OR myrnalloy OR "chemical 10-66" OR "chemical 10-12"+"United Nuclear" + Hematite ionium OR UX1 OR UX2 OR Th-230 OR Th230 OR "Th 230" OR 230-Th OR "230 Th"+"United Nuclear" + Hematite 230Th OR Th-234 OR Th234 OR "Th 234" OR 234-Th OR 234Th OR "234 Th"+"United Nuclear" + Hematite tritium OR H3 OR H-3 OR mint OR HTO+"United Nuclear" + Hematite uranium OR U233 OR U-233 OR "U 233" OR 233U OR 233-U OR "233 U" +"United Nuclear" + Hematite U234 OR "U 234" OR U-234 OR 234U OR 234-U OR "234 U"+"United Nuclear" + Hematite U235 OR "U 235" OR U-235 OR 235-U OR 235U OR "235 U" OR U238 +"United Nuclear" + Hematite "U 238" OR U-238 OR 238-U OR 238U OR "238 U"+"United Nuclear" + Hematite U308 OR "U 308" OR U-308 OR 308-U OR 308U OR "308 U" OR "uranium extraction" OR "black oxide" OR "brown oxide"+"United Nuclear" + Hematite "green salt" OR "orange oxide" OR "yellow cake" OR UO2 OR UO3+"United Nuclear" + Hematite		

Table A1-2: Database Searches for United Nuclear Corp., Hematite, Mo			
Database/Source	Keywords	Hits	Uploaded
	UF4 OR UF6 OR C-216 OR C-616 OR C-65 OR C-211 OR U3O8+"United Nuclear" + Hematite plutonium OR Pu-238 OR Pu238 OR "Pu 238" OR 238Pu OR 238-Pu OR "238 Pu" +"United Nuclear" + Hematite Pu-239 OR Pu239 OR "Pu 239" OR 239Pu OR 239-Pu OR "239 Pu"+"United Nuclear" + Hematite Pu-240 OR Pu240 OR "Pu 240" OR 240Pu OR 240-Pu OR "240 Pu"+"United Nuclear" + Hematite Pu-241 OR Pu241 OR "Pu 241" OR 241Pu OR 241-Pu OR "241 Pu"+"United Nuclear" + Hematite radium OR Ra-226 OR Ra226 OR "Ra 226" OR 226-Ra OR 226Ra OR 226-Ra +"United Nuclear" + Hematite Ra-228 OR Ra228 OR "Ra 228" OR 228Ra OR 228-Ra OR "228 Ra"+"United Nuclear" + Hematite radon OR Rn-222 OR Rn222 OR "Rn 222" OR 222Rn OR 222-Rn OR "222 Rn"+"United Nuclear" + Hematite thoron OR Rn-220 OR Rn220 OR "Rn 220" OR 220Rn OR 220-Rn OR "220 Rn"+"United Nuclear" + Hematite protactinium OR Pa-234m OR Pa234m OR "Pa 234m" OR 234mPa OR 234m-Pa OR "234m Pa"+"United Nuclear" + Hematite strontium OR Sr-90 OR Sr90 OR "Sr 90" OR 90-Sr OR 90Sr OR "90 Sr"+"United Nuclear" + Hematite oralloy OR postum OR tuballoy OR "uranyl nitrate hexahydrate" OR UNH OR K-65 OR "sump cake"+"United Nuclear" + Hematite		

Table A1-2: Database Searches for United Nuclear Corp., Hematite, Mo			
Database/Source	**Keywords**	**Hits**	**Uploaded**
	"uranium dioxide" OR "uranium tetrafluoride" OR "uranium trioxide"+"United Nuclear" + Hematite "uranium hexafluoride" OR "air count"+"United Nuclear" + Hematite accident+"United Nuclear" + Hematite "air dust" OR "air filter" OR "airborne test"+"United Nuclear" + Hematite "alpha particle" OR "belgian congo ore" OR bioassay OR bio-assay+"United Nuclear" + Hematite breath OR "breathing zone" OR BZ OR calibration OR "chest count" OR collimation OR columnation+"United Nuclear" + Hematite contamination OR curie OR denitration OR "denitration pot"+"United Nuclear" + Hematite derby OR regulus OR dose OR dosimeter+"United Nuclear" + Hematite dosimetric OR dosimetry OR electron OR environment+"United Nuclear" + Hematite "Ether-Water Project" OR exposure OR "exposure investigation" OR "radiation exposure"+"United Nuclear" + Hematite external OR "F machine" OR fecal OR "feed material" OR femptocurie OR film OR fission OR fluoroscopy+"United Nuclear" + Hematite "Formerly Utilized Sites Remedial Action Program" OR FUSRAP OR gamma-ray OR "gas proportional" OR "gaseous diffusion"+"United Nuclear" + Hematite		

Table A1-2: Database Searches for United Nuclear Corp., Hematite, Mo			
Database/Source	**Keywords**	**Hits**	**Uploaded**
	health OR "health instrument" OR "health physics" OR "H.I." OR HI OR HP OR "highly enriched uranium" OR HEU+"United Nuclear" + Hematite hydrofluorination OR "in vitro" OR "in vivo" OR incident OR ingestion OR inhalation OR internal+"United Nuclear" + Hematite investigation OR isotope OR isotopic OR "isotopic enrichment" OR "JS Project" OR Landauer OR "liquid scintillation"+"United Nuclear" + Hematite log OR "log sheet" OR "log book" OR "low enriched uranium" OR LEU+"United Nuclear" + Hematite "maximum permissible concentration" OR MPC OR metallurgy OR microcurie OR millicurie+"United Nuclear" + Hematite "mixed fission product" OR MFP OR monitor OR "air monitoring" OR nanocurie OR "nasal wipe" OR neutron OR "nose wipe"+"United Nuclear" + Hematite nuclear OR Chicago-Nuclear OR "nuclear fuels" OR "nuclear track emulsion" OR "type A" +"United Nuclear" + Hematite NTA OR "occupational radiation exposure" OR occurrence OR "ore concentrate" OR "PC Project"+"United Nuclear" + Hematite permit OR "radiation work permit" OR "safe work permit" OR "special work permit" OR RWP OR SWP+"United Nuclear" + Hematite "phosphate research" OR photofluorography OR photon OR picocurie OR pitchblende OR "pocket ion chamber" OR PIC OR problem OR procedure+"United Nuclear" + Hematite radeco OR radiation OR radioactive OR radioactivity OR radiograph OR radiological+"United Nuclear" + Hematite		

Table A1-2: Database Searches for United Nuclear Corp., Hematite, Mo			
Database/Source	**Keywords**	**Hits**	**Uploaded**
	"Radiological Survey Data Sheet" OR RSDS OR radionuclide OR raffinate OR reactor+"United Nuclear" + Hematite respiratory OR "retention schedules" OR roentgen+"United Nuclear" + Hematite sample OR "air sample" OR "dust sample" OR "general area air sample"+"United Nuclear" + Hematite "solvent extraction" OR source OR "sealed source" OR spectra OR spectrograph OR spectroscopy +"United Nuclear" + Hematite spectrum OR standard OR "operating standard" OR "processing standard"+"United Nuclear" + Hematite survey OR "building survey" OR "routine survey" OR "special survey" OR "technical basis"+"United Nuclear" + Hematite "thermal diffusion" OR "thermoluminescent dosimeter" OR TLD OR "Tiger Team"+"United Nuclear" + Hematite "tolerance dose" OR urinalysis OR urine OR "whole body count" OR WBC +"United Nuclear" + Hematite "working level" OR WL OR X-ray OR "X ray" OR Xray OR "x-ray screening"+"United Nuclear" + Hematite		

Table A1-3: OSTI Documents Ordered for United Nuclear Corp., Hematite, Mo			
Document Number	**Document Title**	**Requested**	**Received**
UNC-5134;(Vol.1) OSTI ID: 4550383 SRDB: 53617	CARBIDE FUEL DEVELOPMENT. Final Report, May 15, 1959-October 15, 1965	10/20/2008	11/06/2008
US 3632095 OSTI ID: 4688644 SRDB: 57574	CARRIER FOR URANIUM OXIDE PELLETS dated 12/31/1972 (patent)	01/12/2009	01/12/2009
US 3413099 OSTI ID: 4794811 SRDB: 57573	PRODUCTION OF URANIUM TETRAFLUORIDE dated 1/1/1968 (patent)	01/12/2009	01/12/2009
US 3019139 OSTI ID: 4822590 SRDB: 57572	CHEMICAL PROCESS AND PRODUCT FORMED dated 1/30/1962 (patent)	01/12/2009	01/12/2009
GB 1073198 OSTI ID: 4342486 SRDB: 57569	DEVICE FOR MEASURING THE CARBON CONTENT OF MOLTEN METAL dated 7/1/1967 (patent)	01/12/2009	01/12/2009
GB 1260562 OSTI ID: 4690162 SRDB: 57571	PRODUCTION OF URANYL FLUORIDE dated 1/1/1972 (patent)	01/12/2009	01/12/2009
N/A OSTI ID: 4531422 SRDB: 53617	CARBIDE FUEL DEVELOPMENT. Final Report, May 15, 1959-October 15, 1965	01/12/2009	01/12/2009
UNC-5144 OSTI ID: 4537877	STUDY OF URANIUM-PLUTONIUM MONOXIDES. FinaL Summary Report dated 1/31/1966	01/13/2009	N/A
UNC-RD-3061 CONF-650616-32 OSTI ID: 4450054	SOME PROBLEMS AND ADVANCES IN THE STATE-OF-THE-ART IN THE ANALYSIS OF THE WOOD RIVER JUNCTION, RHODE ISLAND ACCIDENTAL CRITICALITY EXCURSION dated 1/1/1965	01/13/2009	N/A
UNC-5118 OSTI ID: 4591969	SHIELD SMALL SOURCE EXPERIMENTS. Report No. 2 dated 5/6/1965	01/13/2009	N/A
UNC-5138 OSTI ID: 4607769	STUDY OF URANIUM-PLUTONIUM MONOXIDES. Quarterly Progress Report, July 1- September 30, 1965	01/13/2009	N/A
UNC-1001 OSTI ID: 4828518	CHARACTERIZATION OF UO2 POWDERS. Quarterly Report No. 5, October 10, 1961 to January 10, 1962	01/13/2009	N/A
UNC-1000 OSTI ID: 4832177	CHARACTERIZATION OF UO2 POWDERS. Fourth Quarterly Report, July 10, 1961- October 10, 1961	01/13/2009	N/A

Table A1-3: OSTI Documents Ordered for United Nuclear Corp., Hematite, Mo			
Document Number	**Document Title**	**Requested**	**Received**
ORO-468 OSTI ID: 4837429	CHARACTERIZATION OF UO2 POWDERS. Progress Report No. 8, May and June 1961	01/13/2009	N/A
CONF-127-1 OSTI ID: 4679109	RECENT ADVANCES IN THE POWDER METALLURGY OF URANIUM CARBIDE dated 10/31/1962	01/13/2009	N/A
CONF-39-51 OSTI ID: 4504180	FUEL ELEMENTS FOR THE ARGONNE ADVANCED RESEARCH REACTOR dated 1/1/1962 from American Nuclear Society Meeting June 1963 pg 18?	01/13/2009	N/A
UNC-5046 OSTI ID: 4731602	SPONGE FUEL EVALUATION. Phase II Report, August 23, 1961 to January 31, 1963	01/13/2009	N/A
UNC-5094 OSTI ID: 4618068	CARBIDE FUEL DEVELOPMENT. Progress Report, October 1, 1963 to June 30, 1964	01/13/2009	N/A
UNC-5081 OSTI ID: 4618481	CARBIDE FUEL DEVELOPMENT. Phase V Report, October 1, 1962-September 30, 1963	01/13/2009	N/A
UNC-3001 OSTI ID: 4787377	NUCLEAR FUEL RESEARCH FUEL CYCLE DEVELOPMENT PROGRAM QUARTERLY PROGRESS REPORT, OCTOBER 1-DECEMBER 31, 1961	01/13/2009	N/A
UNC-5263 OSTI ID: 4097063	FAST REACTOR MIXED-CARBIDE FUEL ELEMENT DEVELOPMENT PROGRAM. Twelfth Quarterly Progress Report, April--June 1970	01/13/2009	N/A
UNC-5003 OSTI ID: 4816515	CARBIDE FUEL DEVELOPMENT. Progress Report, September 15, 1961 to December 31, 1961	01/13/2009	N/A
NDA-2162-3 OSTI ID: 4045372	CARBIDE FUEL DEVELOPMENT. Progress Report Period, February 1, 1961 to April 30, 1961	01/13/2009	N/A
UNC-5055 OSTI ID: 4685476	CARBIDE FUEL DEVELOPMENT. Phase IV Report, September 15, 1961-September 30, 1962	01/13/2009	N/A
UNC-5030 OSTI ID: 4785553	CARBIDE FUEL DEVELOPMENT. Progress Report, April 1, 1962 to June 30, 1962	01/13/2009	N/A
UNC-5013 OSTI ID: 4800249	CARBIDE FUEL DEVELOPMENT. Progress Report, January 1, 1962 to March 31, 1962	01/13/2009	N/A
UNC-5072 OSTI ID: 4081098	SHIELD SMALL SOURCE EXPERIMENTS. Summary Report dated 11/8/1963	01/13/2009	N/A
UNC-5264 or BHO-66-1 OSTI ID: 4083688	PLUTONIUM PASSIVE ASSAY FACILITY PLANT INSTRUMENTATION PROGRAM. First Quarterly Progress Report, April--June 1970	01/13/2009	N/A
UNC-5266 or BHO-65-1 OSTI ID: 4084733	ENRICHED URANIUM ACTIVE ASSAY PROGRAM. First Quarterly Progress Report, April--June 1970	01/13/2009	N/A

Table A1-3: OSTI Documents Ordered for United Nuclear Corp., Hematite, Mo

Document Number	Document Title	Requested	Received
UNC-5015 OSTI ID: 4772538	FUEL CYCLE DEVELOPMENT PROGRAM. Quarterly Progress Report, January 1 to March 31, 1962	01/13/2009	N/A
UNC-5065 OSTI ID: 4159280	OUT-OF-PILE PROPERTIES OF MIXED URANIUM-PLUTONIUM CARBIDES. Progress Report, February 6, 1962-October 31, 1962	01/13/2009	N/A
UNC-5198 OSTI ID: 4511540	POST-IRRADIATION EXAMINATION OF HIGH-DENSITY (UPu)C PELLET-FUELED EBR-II RODS IRRADIATED TO 30,000 Mwd/T dated 1/1/1968	01/13/2009	N/A
UNC-5056 OSTI ID: 4685447	CARBIDE FUEL DEVELOPMENT. Progress Report, October 1, 1962-March 31, 1963	01/13/2009	N/A
UNC-5217 OSTI ID: 4476426	FAST REACTOR MIXED-CARBIDE FUEL ELEMENT DEVELOPMENT PROGRAM. Third Quarterly Progress Report, January--March 1968	01/13/2009	N/A
UNC-5238 OSTI ID: 4176921	FAST REACTOR MIXED-CARBIDE FUEL ELEMENT DEVELOPMENT PROGRAM. Quarterly Progress Report No. 6, October--December 1968	01/13/2009	N/A
UNC-5048 OSTI ID: 4721743	THE DEVELOPMENT OF URANIUM CARBIDE AS A NUCLEAR FUEL. Third Annual Report, September 1, 1961 to October 31, 1962	01/13/2009	N/A
UNC-5074 OSTI ID: 4111496	OUT-OF-PILE PROPERTIES OF MIXED URANIUM-PLUTONIUM CARBIDES. Final Report dated 12/6/1963	01/13/2009	N/A
PB-90-111311/XAB OSTI ID: 5274400	Health assessment for United Nuclear Corporation Churchrock NPL (National Priorities List) Site, McKinley County, New Mexico, Region 6. CERCLIS No. NMD030443303. Final report	01/13/2009	N/A
Y/ER/Sub-90 VK168/4-D2 ER-16-D2 OSTI ID: 5534924	Proposed plan for the United Nuclear Corporation Disposal Site at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee dated 3/1/1991	01/13/2009	N/A
NDA-2165-5 OSTI ID: 4803712	CARBIDE FUEL DEVELOPMENT. Phase III Report, September 15, 1960-September 15, 1961	01/13/2009	N/A
NUREG-0532 OSTI ID: 6426034	Final environmental statement related to the United Nuclear Corporation, Morton Ranch, Wyoming Uranium Mill (Converse County, Wyoming)	01/13/2009	N/A
PB-89-206171/XAB; EPA/ROD/RO-6-88/044 OSTI ID: 5624608	Superfund Record of Decision (EPA Region 6): United Nuclear Corporation, Mckinley County, New Mexico, ground-water operable unit (first remedial action) September 1988	01/13/2009	N/A

Table A1-3: OSTI Documents Ordered for United Nuclear Corp., Hematite, Mo			
Document Number	**Document Title**	**Requested**	**Received**
N/A OSTI ID: 6946920	Uranium cartel`s fallout: billion-dollar lawsuits are popping up everywhere dated 11/21/1977 from Time? Pp 96-98	01/13/2009	N/A
Y/TS-827 OSTI ID: 6677900	Disposal of United Nuclear Company materials at the Y-12 Plant dated 12/19/1983	01/13/2009	N/A
EGG-1183-1756-Rev. 1 OSTI ID: 6316102	Aerial radiological survey of the area surrounding the UNC Recovery Systems Facility, Wood River Junction, Rhode Island dated 5/1/1981	01/13/2009	N/A
CONF-710617-1 OSTI ID: 4715735	NUCLEAR MATERIALS CONTROL SYSTEM IN A MULTI-ENRICHMENT PROCESSING PLANT. Dated 6/29/1971 from the 12th Annual Meeting of the Nuclear Materials Management	01/13/2009	N/A

Table A1-4: Cincinnati Public Library Documents Ordered For United Nuclear Corp., Hematite, Mo			
Document Number	**Document Title**	**Requested**	**Received**
N/A OSTI ID: 4762207	UNITED NUCLEAR CORPORATION PLUTONIUM FACILITY dated 11/1/1962 from the Transactions of the American Nuclear Society Vol. 5 pp 328-329	01/13/2009	01/13/2009
N/A OSTI ID: 4705788	FUEL ELEMENTS FOR THE ARGONNE ADVANCED RESEARCH REACTOR dated 6/1/1963 from Transactions of the American Nuclear Society Vol. 6 pg 161	01/13/2009	01/13/2009
N/A OSTI ID: 4511791	DEVELOPMENT AND TESTING OF HIGH-LOADED UO2--Cb CERMET FUEL dated 1/1/1967 from Transactions of the American Nuclear Society Vol. 10 pp 483-484	01/13/2009	01/13/2009
N/A OSTI ID: 4767976	UNITED NUCLEAR CORPORATION PLUTONIUM FACILITY dated 1/1/1962 from the Proceedings of the Hot Lab Equipment Conference, 10th pp 313-320	01/13/2009	N/A
N/A OSTI ID: 4740539	ARC SKULL MELTING AND CASTING OF URANIUM CARBIDE dated 3/1/1963 from American Society Metals, Trans. Quart Vol 56 pp 176-193	01/13/2009	N/A
N/A OSTI ID: 4828168	SELECTION OF A URANIUM DILUENT ENRICHMENT FOR RECYCLED PLUTONIUM dated 11/1968 from the Transactions of the American Nuclear Society Vol. 11 pp 440-441	01/14/2009	01/14/2009

Table A1-4: Cincinnati Public Library Documents Ordered For United Nuclear Corp., Hematite, Mo			
Document Number	**Document Title**	**Requested**	**Received**
N/A OSTI ID: 4733964	FABRICATION OF URANIUM--PLUTONIUM CARBIDES dated 1/1/1969 from the Transactions of the American Nuclear Society Vol. 12 pp 578-579	01/14/2009	01/14/2009
N/A OSTI ID: 4813768	FUNDAMENTAL STUDY OF THE COMPATIBILITY OF STAINLESS STEEL AND MIXED CARBIDE FUEL dated 1/1/1968 from the Transactions of the American Nuclear Society vol. 11 pg 511	01/14/2009	01/14/2009
N/A OSTI ID: 4258537	Recovery and restoration phases of a criticality accident dated 1/1/1974 from the Transactions of the American Nuclear Society Vol. 19 pp 193-194	01/15/2009	01/15/2009
N/A OSTI ID: 4204735	Uranium recovery as a by-product of phosphoric acid production dated 6/1/1975 from the Transactions of the American Nuclear Society Vol. 21 pg 245	01/15/2009	01/15/2009
N/A OSTI ID: 4100019	REQUIREMENTS FOR RADIATION PROTECTION DURING HANDLING OF PLUTONIUM RECYCLE FUEL RODS AND ASSEMBLIES dated 11/1970 from the Transactions of the American Nuclear Society Vol. 13 pp 883-884	01/15/2009	01/15/2009
N/A OSTI ID: 4346387	MONOXIDE-TYPE COMPOUNDS OF URANIUM AND PLUTONIUM: I. OXYCARBIDES dated 6/21/1967 from the Journal of American Ceram Soc Vol. 50 pp 321-325	01/16/2009	N/A
N/A OSTI ID: 4671348	EFFECTS OF FABRICATION AND COMPOSITION ON THE IRRADIATION STABILITY OF URANIUM CARBIDE dated 1/1/1964 from Met Soc, Am Inst Mining, Met Petrol Engrs, Inst Metals Div, Spec Rept, Vol. 13 pp 765-784	N/A	N/A