SEC Petition Evaluation Report
Petition SEC-00195

Report Rev #:0 Report Submittal Date: August 30, 2012

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Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00195	83.13	October 20, 2011	January 17, 2012	Nuclear Metals, Inc.

Petitioner-Requested Class Definition

All employees who worked in Buildings A, B, C, D, E, the Butler Building, external storage containers, and outside areas immediate to plant grounds at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1970 through December 31, 1983.

Class Evaluated by NIOSH

All employees who worked at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1958 through December 31, 1983.

NIOSH-Proposed Class to be Added to the SEC

All Atomic Weapons Employees who worked at the facility owned by Nuclear Metals Inc. (or a subsequent owner) in West Concord, Massachusetts during the period from October 29, 1958 through December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Related Petition Summary Information

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

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
N/A	N/A

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Evaluation Report Summary: SEC-00195, Nuclear Metals, Inc.

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

Petitioner-Requested Class Definition

Petition SEC-00195 was received on October 20, 2011, and qualified on January 17, 2012. The petitioner requested that NIOSH consider the following class: *All employees who worked in Buildings A, B, C, D, E, the Butler Building, external storage containers, and outside areas immediate to plant grounds at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1970 through December 31, 1983.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH expanded the petitioner-requested class. The start date of the evaluated class was changed from the date petitioned to be consistent with the Nuclear Metals, Inc. movement of operations from the Hood Building in Cambridge, Massachusetts, to their new facility at 2229 Main Street in Concord, Massachusetts in 1958. NIOSH evaluated the following class: All employees who worked at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1958 through December 31, 1983. NIOSH has determined that the information gained during recent data capture efforts warrant further analysis for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Because the continuing analysis affects only post-1979, NIOSH has determined that it is appropriate to proceed with the pre-1980 feasibility evaluation while continuing to analyze the impact that the data have on post-1979 dose reconstruction. NIOSH is therefore reserving its feasibility determination for the period from January 1, 1980 through December 31, 1983 pending full assessment of the available post-1979 data. NIOSH is continuing to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983.

NIOSH-Proposed Class to be Added to the SEC

Based on its full research, to date, of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employees who worked at the facility owned by Nuclear Metals Inc. (or a subsequent owner) in West Concord, Massachusetts during the period from October 29, 1958 through December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort. The class under evaluation was accepted (see Section 3.0 below) because radiation doses potentially incurred by members of the proposed class may not have been adequately monitored through personal monitoring or through area monitoring. The NIOSH-proposed class does not comprise the entire evaluated class because: (1) the Department of Labor has recently determined the start of Atomics Weapons Employer operations at the Nuclear Metals, Inc. Concord, Massachusetts site to be October 29, 1958; and (2) NIOSH is still evaluating information gained during recent data capture efforts for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Consequently, NIOSH is continuing to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it does not have 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 not sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period.

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

- Principal sources of internal radiation for members of the proposed class included exposures to natural, depleted, and enriched uranium, thorium oxides and metals existing either separately or as alloys, and uranium and thorium progeny. The primary modes of exposure were likely inhalation and ingestion, with entry through wounds also being possible during the processing of these metals.

- Early operations at the Concord facility consisted primarily of research and development in fundamental metallurgy, physical metallurgy, chemical metallurgy, fuel element development and manufacture, and high temperature materials. In the mid-1970s, the focus of Concord site radiological operations shifted to large-scale production including the manufacture of depleted uranium shields, counter weights, and armor penetrators; the manufacture of metal powders including thorium; and continued reactor fuel development.

- Internal exposure monitoring data available to NIOSH include:
  - urine bioassay results for most years in the evaluation period except 1968, 1972, and 1975 (with the number of urinalysis results increasing dramatically from 1978 through 1983);
  - approximately 500 lung counting results beginning in 1982;
  - summary air data for the pre-1975 period giving only maximum, minimum, and average air concentrations; and
  - 28,000 breathing zone and work area air sample results during the period 1980 through 1983.

- NIOSH has been unable to obtain sufficient internal monitoring data specific to enriched uranium, thorium, uranium progeny, or thorium progeny for the period through December 1979 and is continuing to evaluate available data for the period 1980 through 1983. Consequently NIOSH has determined that it does not have access to sufficient personnel monitoring, workplace monitoring, or source term data to estimate with sufficient accuracy internal exposures to enriched uranium, thorium, uranium progeny, and thorium progeny, for Nuclear Metals, Inc. workers during the period from October 29, 1958 through December 31, 1979. NIOSH found that it may be feasible to reconstruct internal doses from natural and depleted uranium for employees during the recommended SEC period from October 29, 1958 through December 31, 1979, using available claimant and site monitoring data, and information in established procedures such as *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals*, Battelle-TBD-6000.

- Principal sources of external radiation for members of the proposed class included exposures to gamma and beta radiation associated with handling and working in proximity to natural, depleted, and enriched uranium and thorium oxides and metals existing either separately or as alloys. The modes of exposure were direct radiation, submersion in potentially-contaminated air, and exposure to contaminated surfaces.

- External monitoring data available to NIOSH consist of film badge and thermoluminescent dosimeter results covering the entire operational period under evaluation. NIOSH has determined that reconstruction of external doses, including occupational medical doses, is likely feasible for the period from October 29, 1958 through December 31, 1983.

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

- Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at Nuclear Metals, Inc. during the period from October 29, 1958 through December 31, 1979, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

Health Endangerment Determination

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

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

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SEC Petition Evaluation Report for SEC-00195

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

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1958 through December 31, 1983. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC. The Department of Labor (DOL) has recently determined the start of Atomic Weapons Employer (AWE) operations at the Nuclear Metals, Inc. Concord, Massachusetts site to be October 29, 1958 (DOL, 2012). For completeness, this report does include information on Nuclear Metals, Inc. operations prior to October 29, 1958, even though such operations are not included in any SEC recommendations for the facility in Concord, Massachusetts.

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

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

2.0 Introduction

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

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

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

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 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 one or more other SEC classes.

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 the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[3]

3.0 SEC-00195, Nuclear Metals, Inc. Class Definitions

The following subsections address the evolution of the class definition for SEC-00195, Nuclear Metals, Inc. When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of the 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-00195 was received on October 20, 2011, and qualified on January 17, 2012. The petitioner requested that NIOSH consider the following class: *All employees who worked in Buildings*

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

A, B, C, D, E, the Butler Building, external storage containers, and outside areas immediate to plant grounds at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1970 through December 31, 1983.

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Nuclear Metals, Inc. workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00195 for evaluation:

> The petitioners indicated there were many unmonitored uranium airborne and external exposures. They provided many examples including a video that showed an explosion that occurred when workers were passivating the furnace lid during the process of reducing UF_4 (green salt) to a uranium metal derby. The petitioners also offered evidence of many violations of regulations that showed Nuclear Metals, Inc. failed to perform the surveys necessary to assure that employees exposed to airborne uranium-238 and associated alpha, beta, and gamma emitting daughters were not exposed to concentrations exceeding those specified in 10 C.F.R. Section 20.103 (Supporting Doc, 1974-2006). In addition, the petitioners indicated how hazardous the process was for receiving green salt. The green salt was supplied in 55-gallon drums weighing approximately 2,000 lbs. Some of the drums leaked, spilling green salt over the shop floor and equipment. The drums were emptied, one at a time, in a conical blender and mixed with magnesium granules. The mixture was transferred to the "bomb", capped with graphite, and contained in a one-inch thick steel cap bolted to the vessel. The petitioners stated that this was a hazardous operation that constantly exposed workers to significant airborne contamination (Affidavits, 2011).

Based on its Nuclear Metals, Inc. research and data capture efforts, NIOSH determined that it has access to internal and external dosimetry data for Nuclear Metals, Inc. workers during the time period under evaluation. However, NIOSH also determined that internal dosimetry records are not complete for all time periods or for all radionuclides. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that internal radiation exposures and radiation doses may not have been adequately monitored at Nuclear Metals, Inc., 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 expanded the petitioner-requested class because NIOSH determined that work from a DOE site, the Hood Building in Cambridge, Massachusetts, was likely transferred to the Nuclear Metals, Inc. site in Concord in 1958, and such work warranted a NIOSH evaluation beginning in 1958. NIOSH designated the time period of the class to be evaluated to be consistent with the move of operations from the Hood Building to the Nuclear Metals, Inc. new facility at 2229 Main Street Concord, Massachusetts in 1958. Therefore, NIOSH defined the following class for evaluation: All employees who worked at the Nuclear Metals, Inc. facility in West Concord, Massachusetts, during the period from January 1, 1958 through December 31, 1983. The January 1, 1958 start date corresponded with the AWE period start date listed in the DOE Office of Health, Safety and Security facility database.

3.3 NIOSH-Proposed Class to be Added to the SEC

Based on its research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all Atomic Weapons Employees who worked at the facility owned by Nuclear Metals Inc. (or a subsequent owner) in West Concord, Massachusetts during the period from October 29, 1958 through December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

Notes: The DOL has determined that the period from January 1, 1958 through October 28, 1958 is not included in the covered AWE designation for the Nuclear Metals, Inc., Concord, Massachusetts facility (DOL, 2012).

As explained further in Section 7 of this report, NIOSH has determined that the information gained during recent data capture efforts warrant further analysis for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Because the continuing analysis affects only post-1979, NIOSH has determined that it is appropriate to proceed with the pre-1980 feasibility evaluation while continuing to analyze the impact that the data have on post-1979 dose reconstruction. NIOSH is therefore reserving its full assessment of the available post-1979 data and will continue to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As is standard practice, NIOSH completed an extensive database and Internet search for information regarding Nuclear Metals, Inc. 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, 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 Nuclear Metal, Inc. 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. Although there is not a specific Site Profile for Nuclear Metals, Inc., as part of NIOSH's evaluation detailed herein, it examined the following TBD for insights into Nuclear Metals, Inc. operations or related topics/operations at other sites:

- *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals,* Battelle-TBD-6000; Rev. 1; June 17, 2011; SRDB Ref ID: 101251

4.2 ORAU Technical Information Bulletins (OTIBs)

An ORAU Technical Information Bulletin (OTIB) is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following OTIBs as part of its evaluation:

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

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

- *OTIB: Guidance on Assigning Occupational X-ray Dose Under EEOICPA for X-rays Administered Off Site*, ORAUT-OTIB-0079, Rev. 00; January 1, 2011; SRDB Ref ID: 89563

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed eight former Nuclear Metals, Inc. employees. Interviewee selection was based on individual availability and the potential knowledge of Nuclear Metals, Inc. working conditions during the period under evaluation. Information obtained during the interviews contributed to the general knowledge of Nuclear Metals, Inc. conditions and monitoring practices.

- Personal Communication, 2012a, *Documented Communication with a Plant Engineer*; Telephone Interview by ORAU Team; March 5, 2012, 10:00 AM EST; SRDB Ref ID: 111249

- Personal Communication, 2012b, *Documented Communication with a Plant Engineer*; Telephone Interview by ORAU Team; March 8, 2012, 3:30 PM EST; SRDB Ref ID: 111248

- Personal Communication, 2012c, *Documented Communication with a Plant Manager*; Telephone Interview by ORAU Team; March 8, 2012, 10:00 AM EST; SRDB Ref ID: 111247

- Personal Communication, 2012d, *Documented Communication with a Machine Operator*; Telephone Interview by ORAU/NIOSH Team; March 7, 2012, 2:00 PM EST; SRDB Ref ID: 111246

- Personal Communication, 2012e, *Documented Communication with a REP Machine Operator*; Telephone Interview by ORAU Team; March 27, 2012, 12:00 PM EST; SRDB Ref ID: 114279

- Personal Communication, 2012f, *Documented Communication with a Senior Health Physicist*; Telephone Interview by ORAU Team; April 17, 2012, 2:00 PM EST; SRDB Ref ID: 114280

- Personal Communication, 2012g, *Documented Communication with a Health Physics Technician*; Telephone Interview by ORAU Team; March 27, 2012, 9:00 AM; SRDB Ref ID: 114281

- Personal Communication, 2012h, *Documented Communication with a Foundry Worker*; Telephone Interview by ORAU Team; March 26, 2012, 11:00 AM; SRDB Ref ID: 114282

In addition to the eight interviews conducted, three worker outreach meetings were held in Concord, Massachusetts on March 14 and March 15, 2012. The meetings consisted of a presentation and discussion-type format. Approximately 50 former workers and owners of the company attended these meetings. Significant insight into the operations and potential problems were identified and discussed.

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (referred to as NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. Table 4-1 summarizes the results of this review. (NOCTS data available as of August 7, 2012)

Table 4-1: No. of Nuclear Metals, Inc. Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	23
Total number of claims submitted for energy employees who worked during the period under evaluation (January 1, 1958 through December 31, 1983)	19
Number of dose reconstructions completed for energy employees who worked during the period under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	16
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	15
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	18

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. One thousand six hundred twenty documents in this database were identified as pertaining to Nuclear Metals, Inc. These documents were evaluated for their relevance to this petition. The documents include historical background on locations, licenses, process descriptions, radiological training, hazards associated with uranium, external dosimetry monitoring data, air sample data, urinalysis data, lung counts, medical program, and the radiological control program.

4.6 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed affidavits as well as multiple supporting documents submitted by the petitioners. Brief descriptions and summaries are provided below:

- *Ten Affidavits from Former Nuclear Metals, Inc. Workers*; various dates and multiple versions with extensive support documentation (e.g., reports, statements, photographs, movie clip, contract numbers, newsletters); DSA Ref IDs: 115097, 115105, 115107, 115119, 115557, 115558, 115640, 115703, 116321, 116322, 116553, 116554, 116561, 116574, 116737, 116930, 116931, 117078, 117079

- *Various Atomic Energy Commission, Nuclear Regulatory Commission, and Nuclear Metals, Inc. Documents Describing Site Health and Safety Inspection Violations, Necessary Corrective Actions, On- and Off-Site Contamination Problems, and Archival Documents*; multiple authors; multiple dates; DSA Ref ID: 115098

- *South Carolina Administrative Law Proceedings in 2002*; filed on June 27, 2002; DSA Ref ID: 115115

- *Dumping on History: A Radioactive Nightmare in Concord, Massachusetts*, article that details the burial of 3,800 drums of radioactive waste; Ed Ericson, Jr.; Jan-Feb 2004; DSA Ref ID: 115113, pdf pp. 9-10

- *Uranium Movement at the Nuclear Metals, Inc./Starmet Site Concord, Massachusetts*, 2000 report of the isotopic content of the holding basin at Nuclear Metals, Inc.; Radioactive Waste Management Associates; September; DSA Ref ID: 115113, pdf pp. 13-25

- *Nuclear Metals, Inc. Claim Statistics*, reconstructed from employee and claimant interviews; DSA Ref ID: 115099

- *A List of Prior Nuclear Metal, Inc. Employees,* contact information was obtained from September 13, 2000 Starmet (Nuclear Metals, Inc.) employee list; DSA Ref ID: 115111

- *Limited List of Contracts Awarded to Nuclear Metals, Inc.*; DSA Ref ID: 115110

- *Nuclear Metals, Inc. Unmonitored Exposure Matrix Summary,* summary includes dates ranging from 1967 through 1983; DSA Ref IDs: 115703, pdf pp. 30-35 and 116303

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize both radiological operations at the Nuclear Metals, Inc. site from January 1, 1958 through December 31, 1983, and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 Nuclear Metals, Inc. Plant and Process Descriptions

Nuclear Metals, Inc. was located at 2229 Main Street, Concord, Massachusetts, on 30 acres of land during the evaluated time period, but later expanded to 46.4 acres of land in 1990 when Nuclear Metals purchased adjacent properties from the Memorial Drive Trust (MDT) (MACTEC, 2004). For the period evaluated by NIOSH, the Nuclear Metals, Inc. workforce, based on various contracts held during different times, varied from approximately 60 to over 650 workers. The number of employees decreased during the period from 1960 through the mid-1970s. The number of employees (obtained from various inspection reports) increased rapidly starting in the latter half of the 1970s, peaking around 1982 through 1983 to over 650. Table 5-1 shows the Nuclear Metals, Inc. workforce population from 1959 through 1972. In the years not represented in the table below, NIOSH has found no indication regarding the number of employees per year. However, an inspection report for August 1983 states “The NMI workforce has doubled in recent years to a present strength of 654 employees.”

Table 5-1: Nuclear Metals, Inc. 1959-1972 and 1983 Workforce Population

Month and Year	No. of Employees	SRDB Ref ID
October 1959	275	25090, pdf p. 48
October 1960	350	25090, pdf p. 70
July 1961	250	25090, pdf p. 74
January 1962	165	25090, pdf p. 80
September 1962	167	25090, pdf p. 88
October 1963	156	25090, pdf p. 96
February 1964	154	25090, pdf p. 98
August 1964	167	25090, pdf p. 101
October 1964	163	25090, pdf p. 104
May 1965	143	25090, pdf p. 106
November 1965	135	25090, pdf p. 114
May 1966	128	25090, pdf p. 119
July 1970	100	109544, pdf p. 6
July 1971	80	105866, pdf p. 6
July 1972	50	105867, pdf p. 4
August 1983*	654	112167, pdf p. 5

Note:
* The number of employees between 1972 and 1983 has not been identified.

Nuclear Metals, Inc work evolved from the Massachusetts Institute of Technology (MIT) Metallurgical Laboratory, which began experimental work on producing uranium metal in the spring of 1942 using a process involving melting and casting. This work continued from 1942 through 1946, at which time the work performed under Manhattan Engineer District (MED) contracts was relocated to the Hood Building in Cambridge, Massachusetts. The MED, and subsequently the Atomic Energy Commission (AEC), owned the Hood Building which was located adjacent to the MIT campus. In 1954, Nuclear Metals Inc. was established and assumed the work that MIT had been performing in the Hood Building. Operations at the Hood Building continued until October 29, 1958, when the work was again relocated to Concord, Massachusetts. The Hood Building was acquired by the General Services Administration (GSA) for disposition when it was declared surplus to government needs. The GSA turned the building over to the Department of Health, Education, and Welfare, which, in turn, deeded the property to MIT with the proviso that the property be used for educational purposes and MIT pay for the demolition (MIT, 1963). The Hood building was subsequently demolished after which it was released by the AEC on July 11, 1963 (DOE, 2010).

On August 29, 1957, Nuclear Metals purchased approximately 30 acres of undeveloped property and constructed and occupied the original Concord facility buildings by March 1958 (MACTEC, 2004, pdf p. 21). The information available to NIOSH associated with the March 1958 occupancy date is limited to a Health and Safety Plan document produced by a SUPERFUND contractor (MACTECH, 2004). NIOSH has no further information specifying whether or not radioactive materials could have arrived on the Concord site from the Hood Building facility prior to March 1958. Although Nuclear Metals, Inc. occupied the Concord Facility buildings in March 1958, there are indications that operations did not begin until October 1958 (Monitoring, 1955-1966, pdf p. 39). The start date for AWE operations at the Concord facility is determined by DOL to be October 29, 1958 (DOL, 2012). In a letter to NIOSH, DOL states "*… Nuclear Metals was legally a DOE contractor between July 1, 1954 and October 28, 1958 due to the AEC's ownership of the Hood Building. Nuclear Metals only became an AWE when it left the Hood Building for Concord, MA, on October 29, 1958*."

The original facility consisted of three principal buildings, designated as Buildings A, B, and C. Building A contained office space and research laboratories. Building B contained services (e.g., cafeteria, laboratories, etc.). Building C was initially configured for use as the main production facility and included foundry equipment for melting metals, extrusion presses, metal working equipment, pickling and etching tanks, and electroplating equipment (MACTEC, 2004, pdf p. 21). Later, additional buildings were added. Table 5-2 lists the main buildings at Nuclear Metals, Inc., as well as each building's year of construction, physical dimensions, type of structure, and a brief description of the building's function.

Table 5-2: Nuclear Metals, Inc. Building Details

Building	Year Constructed	Dimensions (ft)	Area (ft^2)	Structure Type	Building Function
A	1958	216 x 80 x 26	34,000	2 story	Building A was used for office space, laboratory work, and quality control.
B	1958	97 x 60 x 26	11,130	2 story	Initially Building B contained the boiler room, which serviced the entire complex, electrical switch room, telephone entrance room, toilets and locker rooms, and the company clinic.
C	1958	200 x 130 x 26	26,000	1 story with a mezzanine	Building C housed the foundry, which was the heart of all the processes that were involved in the production of depleted uranium (DU) penetrators and most of the other work.
D	1978	280 x 160 x 26	44,800	High Bay, 1 story	Building D was built to expand the production capability and housed the copper removal/pickling operation, long rod straightening, outgas/solution heat treatment, aging, re-machining, quality control, and finish machining.
E	1983 Occupied in 1984	200 x 223 x 20	39,300	High Bay, 1 story	Building E included closed-loop pickling, resource recovery area, waste treatment and recovery, acid splitting, coolant recovery, quality control, and waste processing.
Butler 1	1958	64 x 32	1,800	Pre-engineered	Butler Building 1 was unrestricted and used for non-DU related purposes. However Butler 1 had previously been used for packing and storing DU components.
Butler 2	1960	64 x 32	1,800	Pre-engineered	Butler Building 2 was unrestricted and used for non-DU related purposes.
Butler 3	1976	60 x 40	2,400	Pre-engineered	Butler Building 3 was used for storing DU components.
Butler 4	1977	80 x 60	4,800	Pre-engineered	Butler Building 4 was unrestricted and used for non-DU related purposes.
Tank House	1958	Not stated	1,200	2-level slab on grade	The Tank House was used for receipt of process-contact water which was received and then gravity fed into two 3,700 gallon, diked, wooden-cypress tanks. This process-contact water was ultimately pumped into the resource recovery unit in Building E.

Source: ACI, 1994, pdf p. 20

Figure 5-1 shows a diagram of the Nuclear Metals, Inc. facility.

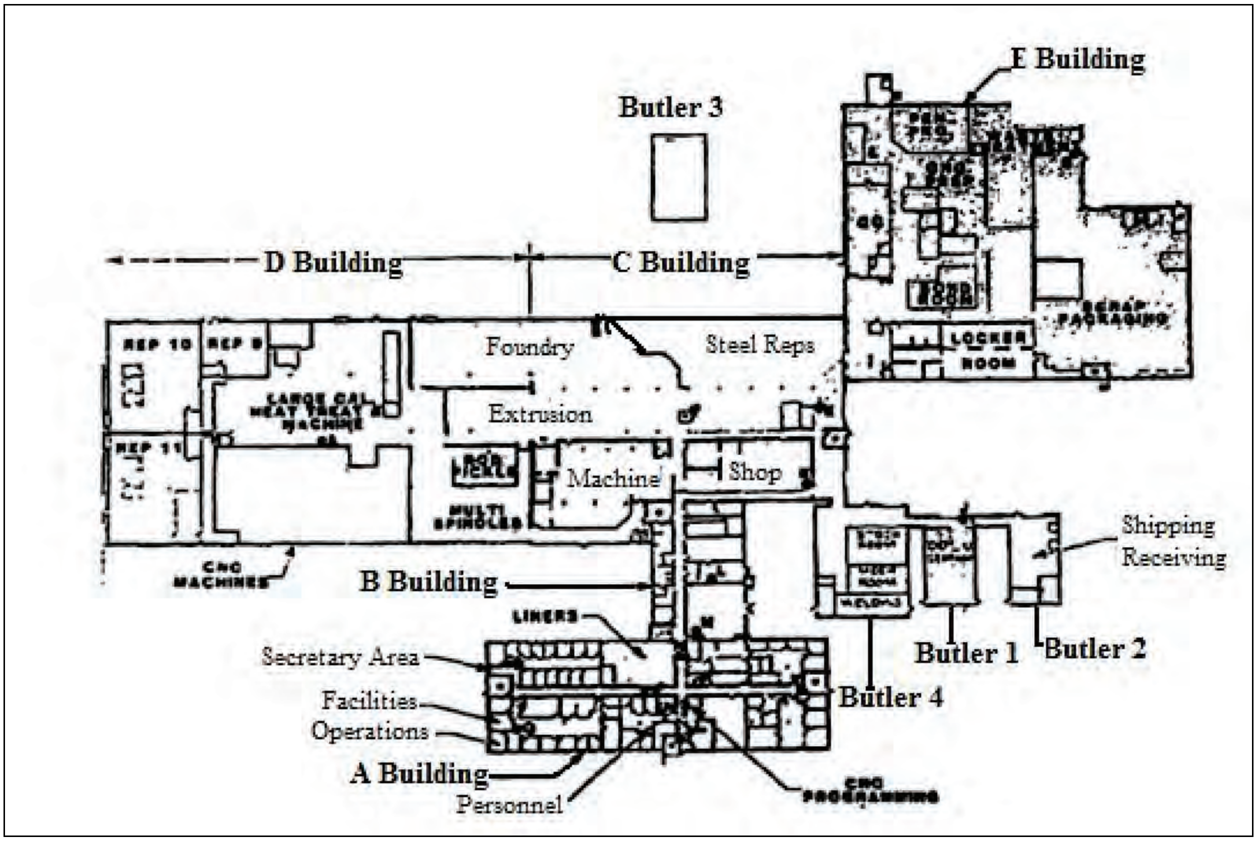

Figure 5-1: Diagram of Nuclear Metals, Inc.
Source: ACI, 1994, pdf p. 26, with enhanced text

The Concord, Massachusetts site was originally a specialty metal research and development facility that was licensed to possess low-level radioactive substances. After 1972, Nuclear Metals, Inc. developed a manufacturing orientation. Building D was constructed in 1978 to expand the production capabilities of the facility. Building E was constructed in 1983 and occupied in January 1984 and was used to house the radioactive waste-processing operations (MACTEC, 2004, pdf p. 22).

In 1990, Nuclear Metals, Inc. acquired adjacent properties designated as Parcels A and B from the Memorial Drive Trust (MDT), which owned land to the west and south of the Nuclear Metals, Inc. property. At the same time, MDT acquired Lots C and D from Nuclear Metals, Inc. The Nuclear Metals, Inc. property then consisted of approximately 46 acres (MACTEC, 2004, pdf p. 22). On October 1, 1997, Nuclear Metals, Inc. changed its name to Starmet Corporation (Quinn, 2001, pdf p. 13).

5.1.1 Operations (1958-1972)

In the beginning of operations, after the transfer to Concord, operations consisted primarily of research and development in fundamental metallurgy, physical metallurgy, chemical metallurgy, engineering and product development, fuel element development and manufacture, and high temperature materials (MACTEC, 2004, pdf p. 29). Many, if not all of these operations were carried over from the work at the Hood Building. Most of the operations at the Concord site were for the United States Atomic Energy Commission (AEC) and the Department of Defense (DOD). Additional activities were completed for private industry in the investigation and development of materials for missiles, airframes, and other components. Examples of the operations performed at the Hood Building and transferred to the Concord site are presented below; non-radiological operations are included here for completeness only (MACTEC, 2004, pdf p. 29).

- Conducting studies of the causes of brittleness in beryllium.
- Determining the original phase diagrams for alloys of uranium-beryllium, zirconium, hafnium, tungsten and other special metals.
- Alloying uranium for specific properties, including corrosion resistance and high stress-rupture characteristics. Similar studies were conducted to achieve higher strength in beryllium.
- Using unique techniques for testing and evaluating fuel elements and fuel-element materials.
- Developing high-strength zirconium alloys for use as cladding on fuel elements.
- Conducting electroplating studies.
- Conducting basic studies of corrosion in zirconium and uranium alloys, and the oxidation mechanism for zirconium.
- Learning the effects of liquid-metal environments on zirconium and uranium alloys.
- Developing cermets, including beryllium-beryllium oxide and stainless steel-uranium oxide.
- Developing original methods of chemical analysis for various constituents in beryllium, uranium, and zirconium alloys.
- Conducting oxidation studies of graphite, platinum, and refractory metals.
- Developing and fabricating inter-metallic compounds of uranium.
- Developing melting and casting techniques for beryllium and uranium alloys.
- Developing machining methods for uranium, thorium, beryllium, yttrium, and other metals.
- Performing technical and economic evaluation of proposed reactor-fuel types and fabrication procedures.
- Submarine reactor fuel elements.
- Producing fuel elements for several different reactors at National Laboratories.
- Developing methods of extrusion and drawing seamless molybdenum tubing and molybdenum tubing clad inside and out with other metals such as stainless steel.
- Developing extrusion methods for niobium and tantalum.
- Investigating materials and design problems in nose-cone reentry studies, with particular emphasis on the use of materials in combination.

5.1.2 Operations (1972-1979)

In the mid-1970s, the focus of Concord site operations shifted from research and development to large-scale production. Large-scale production included the manufacture of depleted uranium (DU) shields, counter weights, and armor penetrators; the manufacture of metal powders, beryllium and beryllium alloy-parts production; and the manufacture of specialty titanium parts. Reactor fuel development, which began at the MIT facilities in the 1940s, also continued during this period. The following is a summary of some of the processes conducted at Nuclear Metals, Inc. and are included because they are all potential sources of exposure.

Process Descriptions by Building

Below is a general description of the processes within the individual buildings of Nuclear Metals, Inc. at the Concord site.

Building A

Building A was used for office space, laboratory work, and quality control. About 60 percent of the building was built as laboratory space for analytical chemistry, chemical metallurgy, physical metallurgy, metallography, applied physics, and a glass shop. The laboratories included vacuum furnaces, induction heating, machine shop, X-Ray equipment, electromagnets, and traditional laboratory equipment. Building A is connected to Building B (MACTEC, 2004, pdf p. 33).

Building B

Originally, Building B was completely unrestricted with no activities related to DU (ACI, 1994, pdf p. 11). Building B contained the boiler room, which serviced the entire complex, electrical switch room, telephone entrance room, toilets and locker rooms, and the company clinic. Portions of Building B were converted for other uses during facility operations. Building B is connected to Building A and Building C (MACTEC, 2004, pdf p. 33).

Building C

Building C housed the foundry, which was the heart of all the processes that were involved in the production of DU penetrators and most of the other work performed by Nuclear Metals, Inc. at the Concord site.

Foundry Operations-Melting and Casting

A DU melt typically consisted of one DU derby weighing approximately 600 kg, approximately 200 kg DU recycle and titanium metal sponge. As an option, a melt charge could consist of 100% approved DU recycle. The charge was melted under vacuum in a zirconia-coated graphite crucible. The coating prevented reaction between the molten uranium and graphite. Following a hold at 1400^{o} C to uniformly distribute the titanium in the alloy, the melt was poured into yttria-coated molds. One melt produced nine ingots. Upon removal from the molds, ingots were inspected for surface quality and length. Major equipment used in this process included induction furnaces, cleaning stations, and various sawing equipment (ACI, 1994, pdf p. 12).

Billet Assembly

Ingots were assembled into airtight copper cans and evacuated prior to extrusion. Each ingot was checked for surface condition, ingot-to-can fit, and melt-lot identification. The ingots were then slipped into lengths of copper tube blocked at one end. A copper endplate equipped with an evacuation tube was welded onto the open end. The evacuation tube was then connected to a vacuum system and each billet assembly was evacuated. The evacuation tube was then crimp-sealed to form a leak-tight assembly (ACI, 1994, pdf p. 12).

Extrusion Operations

Extrusions were accomplished in a 1,400 ton Loewy extrusion press. Billets were loaded into ovens and maintained at 600^{o} C for one hour minimum prior to extrusion. Dies and liner assemblies were preheated to 370^{o} C. The die was lubricated and the billets were pushed through the die at a constant ram speed. Immediately upon exiting the extrusion press, each rod was automatically transferred to a forced/air/water mist cooling bed. Major equipment used in this process included a 1,400 ton press, billet and cooling furnaces, and a bar handling system (ACI, 1994, pdf pp. 12-13).

Building D

Building D was built to expand the production capability and housed the copper removal/pickling operation, long rod straightening, outgas/solution heat treatment, aging, re-machining, quality control, and finish machining.

Copper Removal/Pickling Operation

The copper sheath on the extruded bars was removed by acid digestion in a sulfuric acid-hydrogen peroxide solution. The acid solution was pumped into Building E where it was regenerated by electorwinning the copper and precipitation of UO_4. The closed-loop pickling system was the only major component used in this operation.

Long Rod Straightening

After removal of the copper sheath, extruded rods were straightened using a Sutton Rotary Straightener (two-roll) to facilitate subsequent cutting operations. The "straightener" guides and rolls were set such that the work piece would transit along the "pass line" and proper deflection was provided to achieve the desired straightened end product. The rod stock was cut into blanks of appropriate length by sawing. After an initial crop to remove front extrusion imperfections, a front chemistry sample was cut and identified. Blanks were cut and identified in sequence until finally no material remained of sufficient length to yield a blank. A rear chemistry sample was then cut and identified. The major piece of equipment used in this process was the Sutton Rotary Straightener (ACI, 1994, pdf p. 14).

Outgas/Solution Heat Treatment

Solution heat treatment of DU blanks was carried out in a multi-step operation involving:

- Outgas
- Rotary Straighten
- Solution/Quench
- Rotary Straighten

Blanks up to 32 inches in length could be vacuum outgassed in an AVS vacuum solution heat-treat furnace which had been modified for this purpose. The blanks were heated to 850^{o} C under vacuum and held for sufficient time to ensure a hydrogen content of less than one part per million. The blanks were then cooled under vacuum into the alpha temperature range (500-700^{o} C) and then rapidly cooled to ambient temperature (ACI, 1994, pdf p. 15).

Some distortion occurs during outgassing. In order to facilitate the next induction heat-treat step, each blank was rotary straightened under minimal stress conditions. Induction solution heat treatment was accomplished in a vertical induction unit. Blanks were fed at a controlled rate through an induction coil where they were heated to a surface temperature in air of 950-1000^{o} C. The blanks were then progressively quenched in agitated water. Additionally an automated induction furnace was in place that would ensure a continuous flow of parts as production quantities increased. Having been quenched into water, some distortion of the blanks would have occurred. All blanks were again straightened using predetermined parameters. Major equipment used in this process included outgassing furnaces, a rotary straightener, degreaser, and a horizontal induction unit (ACI, 1994, pdf p. 15).

Aging

All DU blanks were aged in recirculating inert-gas furnaces. Time-temperature parameters were selected to achieve the mechanical properties required. Two recirculating inert-gas furnaces were used in this operation (ACI, 1994, pdf p. 15).

Pre-Machining

Finish machining required a precision pre-machined blank with a uniform diameter and flat ends perpendicular to the bar axis. These requirements were met by centerless grinding to the desired finished diameter. The ends were faced flat and perpendicular to the bar axis (ACI, 1994, pdf p. 16).

Finish Machining

DU penetrator blanks were turned into their final configuration on Computer Numerical Control (CNC) lathes. All feeds, speeds, and depths of cut were commensurate with production requirements (ACI, 1994, pdf p. 16).

Quality Control

Quality Control Inspectors supported large-caliber DU penetrator programs in Building D through a number of processes including: selection of mechanical test bars after aging runs, laser marking of DU bars and finished penetrators, in-process inspection and measurements and inspection of DU bars, and final inspection of finished penetrators. Equipment utilized during Quality Control operations included a laser marker, various comparators, gauges, run-out fixtures, and ancillary support equipment (ACI, 1994, pdf p. 16).

Building E

Closed-Loop Pickling, Resource Recovery Area

In Building D copper clad was removed from extruded-uranium rod stock by etching a 5% (by volume) sulfuric acid solution using hydrogen peroxide as the oxidant. After the copper was removed from the rod stock, the solution was transferred to electrowinning in Building E for electrolytic recovery of copper and concurrent regeneration of sulfuric-acid value. The acid solution was then recycled back for additional copper removal after the addition of hydrogen peroxide to remove residual uranium. The slurry, containing gypsum and precipitated uranyl peroxide, was separated by filtration and then disposed of in an approved land burial site. The filtrate, containing the copper, was transferred to electrowinning for copper recovery and recycle (ACI, 1994, pdf p. 17).

Waste Treatment and Recovery

Waste liquors, which consisted of floor-wash waters, steam-cleaning water, closed-loop pickling rinse water, and other waste-process waters, were collected in two tanks for storage. The waste waters were then transferred to the Waste Water Treatment areas where lime and acid were added to agglomerate residual oils and adjusted the pH of the solution to 5. The resultant slurry was allowed to thicken and was then filtered to remove the solids. The liquid solution was then oxidized with hydrogen peroxide and neutralized to a pH above 7 (between 9.7 and 7.5). The neutralized liquor was then evaporated in the pulse combustion dryer, where the steam produced was exhausted into the atmosphere after the solids separation and HEPA filtration. The solids (including the filter cake) were collected and packaged for disposal in an approved burial site (ACI, 1994, pdf p. 18).

Acid Splitting

Oil-bearing aqueous liquors, such as machine coolant and steam-cleaning water, were treated by adding sulfuric acid and aluminum sulfate. The liquor was then allowed to settle and the oil fraction, which floats to the surface, was removed. The liquor was neutralized to a pH of 8.5 to allow the aluminum to react to form aluminum hydroxide, which agglomerated any residual oil remaining in the liquor. After settling, the aqueous phase was removed and the agglomerated solids were removed. The oils and agglomerated solids were then transferred to waste processing for solidification and subsequent disposal (NSWC, 1997, pdf p. 18).

Coolant Recovery

Machine coolant was treated to remove tramp oil and solids by allowing it to settle and then separating the oil from the fine solids by centrifuge. The oil was transferred for acid splitting and the solids transferred to waste processing for disposal. The treated coolant was monitored to ensure high quality and additional coolant concentrated pH adjusters and other additives were added as required. The coolant was then recycled back to machining.

Quality Control

The Quality Control Laboratory, Calibration Laboratory, Bond Room holding area, final inspection, and offices were located in Building E. The first floor of the Quality Control Laboratory contained inspection equipment, including equipment for powder analyses, hardness testing, tensile testing, radiography, helium-leak testing, and all forms of final inspection. Outside of the main Quality Control Laboratory was equipment for performing ultrasonic inspection and hardness testing of DU bars. The Quality Control Calibration Laboratory was contained in an environmentally controlled enclosure. Adjacent to the Calibration Laboratory was a fenced-in area for the Quality Control Bond Room where non-conforming material was temporarily stored. This area was also used for refurbishing DU aircraft counterweights (ACI, 1994, pdf p. 19).

Waste Processing

Decontamination systems and waste-processing systems were located in Building E. Decontamination systems included a water-blasting booth, composed of a skid-mounted 20,000 psig, 100 HP unit, with walk-in-booth 16’(L) x 12’(W) x 8’(H). It was used for concrete surface cleaning and cutting, surface coating removal, and with abrasive slurry, the ability for cutting up a 2” thick metal plate. Other systems included a detergent cleaning tank, 4’(L) x 4’(W) x 3’(H), ½ HP, centrifugal pump with spray bars, locally fabricated, for less aggressive cleaning of small parts, an acid etching tank, 120 gallon capacity, used with H_2SO_4 and H_2O_2 solution, locally fabricated, for aggressive cleaning of metal objects and inaccessible surfaces (e.g., threaded holes, etc.), a steam cleaner (for light cleaning, grease removal, etc.), and a portable scarifyer (for light cleaning of concretes slabs and asphalt). Other waste-processing equipment included a cutting and grinding booth, 8’(L) x 8’(W) x 9’(H), fully ventilated into a HEPA filtration system, locally fabricated. A band saw and acetylene cutting torch were also utilized for initial preparation and scrap material sizing. The dry, active waste was processed utilizing a dual-drive shredder and various compactors. Machine coolant and oils were processed using a solidification pan-type mixer with ventilation at the reaction chamber and a five-gallon capacity. The processing of pyrophorics via encapsulation was accomplished by using a ring mill pulverizer (with spray bars, reservoir, and pumping), a cement mixer (with 40 ft^3 capacity), a skip hoist, and a dust control unit. The encapsulation line also utilized an unbagging station for opening sand and cement bags and cement molds (a cylindrical split-form type designed by Nuclear Metals, Inc.) as well as a cement vibrator and a cement mixer. In addition to the standard waste-packaging techniques this area also housed a bulk bag-filling station with dust control venting (ACI, 1994, pdf p. 19).

Butler Buildings

Butler Building 3 was used for storing DU components. Butler Buildings 1, 2, and 4 were unrestricted and were used for non-DU related purposes, although Butler Building 1 had previously been used for packing and storing DU components (ACI, 1994, pdf p. 20).

Tank House

The Tank House was used for receipt of process-contact water, which was received and then gravity fed to two 3,700 gallon, diked wooden cypress tanks. This process-contact water was ultimately pumped into the resource recovery unit in Building E (ACI, 1994, pdf p. 20).

Powder Manufacturing

Metals were converted to powder by the Rotating Electrode Process (REP) equipment. A bar of metal was rotated in a helium-filled chamber where it was melted by an electric arc. As the metal was liquefied, it spun off and solidified into a powder. Metals used included aluminum, steel, titanium, and nickel-based super alloys. These powders were used in the photocopier industry, electronic component cleaning mediums, and for surgical implants. Thorium rods were also used in this process.

Fuel Manufacturing

Work with enriched uranium (EU) for fuel was conducted at Nuclear Metals, Inc. from 1958 until August 1973, although fuel work continued with natural uranium after 1973. Work producing DU penetrators started in the early 1960s; however, full production work started in the mid-1970s and continued throughout the period evaluated for this class. There were also several hundred to thousands of applications for DU, such as counterweights for aircraft, sheet metal for protection of tanks from armor-piercing bullets, sinkers and shaped charges for the oil industry, etc.

5.1.3 Health Physics Program Practices and Inspections

As indicated above, Nuclear Metals, Inc. was involved in research in many aspects of metallurgy, materials development, and new product development. In many instances it was necessary to develop new methods and procedures to accomplish their mission. In performing those functions they were often unaware of the radiological hazards they might encounter or the effort that would be required to work in a radiological environment. As a result, it took many years for their radiological safety program to evolve. The program deficiencies are documented in the various inspection reports by the regulatory agencies (e.g., Inspection Report, Dec1973-Jan 1974, pdf pp 5-7) (Inspection Report, March 1973, pdf pp 6-7).

The quality of the contamination monitoring and control programs appears to have degraded after the mid-1960s. There were problems with spills and contaminations. The inspection report from February 10, 1964, noted that a significant uranium spill was found on the floor (Monitoring, 1955-1966, pdf p. 98). The workers were aware of the spill but did not report it to the Safety Department.

The AEC inspection report dated May 1, 1973, noted that lack of trained HP personnel and lack of a routine program for surveys for personnel and contamination was a shortcoming (Inspection Report, Dec1973-Jan1974). A February 15, 1974, inspection report noted that a significant amount of undetected beta-gamma contamination existed in the work area (Inspection Report, Dec1973-Jan1974). Management was unable to guarantee that employees always changed clothes before leaving the plant. Inspectors revisited the plant and visited employees' homes and found contamination (Inspection Report, Dec1973-Jan1974, pdf p. 24).

As an example of a practice that resulted in the spread of contamination, the petitioners stated that during the period from 1973 through 1975 there were no restrictions for entering the process area. The volume of DU increased after 1974, but the Health & Safety practices did not change. The 30-mm Ammunition Factory was set up on the 2nd floor of the H-shaped Building B; and the DU chips were collected on carts, wheeled down the hallway and down the elevator. No effort was made to decontaminate the cart. Chip dust was embedded in the floor.

The Nuclear Metals, Inc. radiological program developed slowly, and in 1981 the inspection report from the Massachusetts Department of Labor and Industries (Inspection Report, Dec1981) stated "The Radiation Safety Program has been strengthened in keeping with the Company's continued growth. The Health Physics staff has been augmented. A full time Training Specialist has been employed and is used to provide orientation training to new employees, particularly in the area of Radiation Safety. Health Physics personnel devote an increased percentage of their time in the work areas reviewing procedures and surveilling work habits of employees."

The report continued "The number of stationary air monitoring systems has been increased in the foundry and reduction areas. Evaluation of the air samples and area wipes are now performed in-house, thereby eliminating or reducing the delay attending previous off-site processing and reporting."

Nuclear Metals, Inc. continued to improve their program as documented in the January 4-5, 1983 inspection report (Inspection Report, Jan1983, pdf pp. 2-3). Nuclear Metals, Inc. augmented their HP staff by six technicians in order to achieve HP coverage during all operating shifts. They hired an industrial hygienist and a health physicist. The Employee Training program was expanded in 1982 in terms of the coverage relative to the radiation protection procedures and practices. In addition to the orientation training for new employees, refresher training was given to all radiation workers at four month intervals. Nuclear Metals, Inc. fabricated charge trays for storing derbies between various production activities; the shielded trays were provided with 1/4 in. aluminum covers to reduce bremstrahlung and served to reduce beta exposures to charge preparation workers in the foundry. Nuclear Metals, Inc. required more frequent washing of floors and surveillance to ensure employees exiting radiation areas properly surveyed their clothing and shoes. It is expected that these improvements in the Health Physics program, which began modestly around 1978-1979 along with the increased bioassay, as shown in Table 6.1 and Figure 6.1, are indicative of their improving ability to appropriately monitor the personnel and the workplace and to provide sufficient information and data adequate to support NIOSH dose reconstructions.

5.2 Radiological Exposure Sources from Nuclear Metals, Inc. Operations

The following subsections provide an overview of the internal and external exposure sources for the Nuclear Metals, Inc. class under evaluation.

5.2.1 Internal Radiological Exposure Sources from Nuclear Metals, Inc. Operations

Inhalation of airborne contamination during the various processes, inhalation of resuspended contamination, and associated ingestion were the primary sources of internal exposure to Nuclear Metals, Inc. workers. Various processes mentioned in Section 5.1 were capable of producing airborne contamination, thereby subjecting the workers to an internal exposure hazard. In addition, there were many fires that were unmonitored and explosions during the pacification of the furnace lid (Furnace Explosion, unspecified date).

5.2.1.1 Uranium

The amount of uranium in the Nuclear Metals Inc. facility at any one time is not known to NIOSH; however, according to the Nuclear Metals Inc. 1981 NRC license, they were authorized to have 2,500,000 kg of DU, 25,000 kg of natural uranium (NMI, 1981), and a maximum of 714 kg EU (ORNL, 1996) for fuel production in a license issued in November 1964.

NIOSH has identified information pertaining to the manufacture of highly enriched uranium fuel elements; however, these processes are classified and are not discussed in this document. Highly enriched uranium (93% enriched U-235) was used in the development of fuel for Argonne National Laboratory (Quinn, 2001).

DU was used for manufacturing counterweights to balance control surface movements on commercial and military aircraft, balance weights on nose cones and rockets, sinker bars used by well loggers to overcome the oil well head pressure when lowering instruments into the hole, and armor penetrators for the military.

At the time of the move from Cambridge to Concord in 1958, there was approximately 10 tons of uranium (natural and enriched) and one ton of thorium in storage at the Hood Building (Monitoring, 1955-1966, pdf p. 36).

5.2.1.2 Thorium

Nuclear Metals, Inc. did work with thorium at MIT and the Hood Building before moving to the Concord facility. The work continued at Concord during the period of this evaluation and beyond. As indicated previously, one ton of thorium was transferred to Concord from the Hood building in 1958. Other work that was performed with thorium included the following:

- In the 1960s Nuclear Metals, Inc. extruded thorium into rods for British and French companies (Thorium, 2012).
- Thorium rods were converted into powder (Thorium, 2012).
- Nuclear Metals, Inc. extruded thorium powder (Thorium, 2012).

- Nuclear Metals, Inc. cast thorium into billet size followed by machining, jacketing, extrusion, pickling, and machining to REP-2[4] size (1-inch) (Thorium, 2012). Section 5.1.2 provides a brief description of the REP process.
- Nuclear Metals, Inc. received thorium billets from Tennessee Nuclear Specialties and returned the material in powder form or rod stock (Personal Communication, 2012c).
- Nuclear Metals, Inc. manufactured tungsten electrodes for use in REP-2 (Personal Communication, 2012c).

NIOSH has not identified the quantity of thorium used in the processes listed above during the period of evaluation.

5.2.1.3 Radon/Thoron

As indicated above, thorium work continued after the move from the Hood Building to the Concord site. There are indications that radon/thoron may have been a concern; however, NIOSH has not identified any monitoring data for radon/thoron during the evaluated period.

5.2.1.4 Recycled Uranium

Fission products may have been present in small quantities due to the use of recycled uranium that was part of the uranium used in the production at Nuclear Metals, Inc. There is no evidence that monitoring for fission products was performed. However, fission products were not identified in the whole-body/chest counts reviewed by NIOSH. NIOSH has established procedures and ratios to determine possible exposures to recycled contaminants (Battelle-TBD-6000).

5.2.2 External Radiological Exposure Sources from Nuclear Metals, Inc. Operations

Based on information and documentation available to NIOSH, the potential for external radiation doses from thorium, uranium, and uranium decay products existed at the Nuclear Metals, Inc. site. Although Nuclear Metals, Inc. is best known for the production of DU penetrator rounds, the facility was also used to produce reactor fuel elements for the Fermi Test Reactor (CP-5) from the mid-1960s until 1974 (Quinn, 2001). Nuclear Metals, Inc. was also licensed to handle thorium and thorium oxides.

Both U-235 and U-238 are primarily alpha-particle emitters. However, U-235 does emit a 185-keV photon in 54% of its decays. Most of the external dose from U-238 comes from its short-lived Th-234, Pa-234m, and Pa-234 decay products. From an external dose standpoint, the most significant radiations from these decay products of U-238 are (1) the 2.29-MeV beta particles from Pa-234m, and (2) the photons emitted by Pa-234m with energies as large as 1.926 MeV.

During casting operations, the decay products of U-238 float to the top surface of the molten metal and remain as surface residues (Progress Report, Jul-Dec1952, pdf p. 105). These surface residues result in an increased exposure potential because of the high beta and photon energies that are

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[4] REP-2 is the rotating-electrode process whereby rods of thorium or other metals were turned into powder form. REP-2 is just one of the versions of the REP process.

associated with the Pa-234m and Pa-234 nuclides. The Pa-234 nuclide emits a number of high-energy photons and has a specific activity that is approximately 2×10^{15} times larger than the specific activity of its U-238 parent (Henderson, 1991). For Pa-234, the percentages of photons with energies of 30 to 250 keV and 250 keV or more are about 7% and 93%, respectively. For U-238 in equilibrium with its short-lived Th-234, Pa-234m, and Pa-234 decay products, the percentages of photons with energies of 30 to 250 keV and 250 keV or more are about 82% and 18%, respectively.

In addition to the process materials on hand, Nuclear Metals, Inc. possessed two industrial X-ray units and was licensed for up to 40 mCi of unencapsulated Ir-192 for tracer studies and 45 Ci of Ir-192 in the form of a film coating a copper thimble. At the time Nuclear Metals, Inc. was transferring operations to the West Concord facility, the company possessed only 5 µCi of unsealed Ir-192 and 10 Ci of Ir-192 film (Monitoring, 1955-1966, pdf p. 42). In January 1960, Nuclear Metals, Inc. acquired a 100 kV medical X-ray machine (Monitoring, 1955-1966, pdf p. 52). By July 31, 1960, Nuclear Metals, Inc. was using a total of five industrial X-ray production devices. In the X-ray Laboratory there were three diffraction X-ray machines: (1) a North American Phillips was operated at 35 kV and 20 mA; (2) a Norelco machine was operated at 45 kV and 20 mA; and (3) a Picker machine was operated at 35 kV and 10 mA. In the Analytical Chemistry Laboratory, a Norelco Spectrometer was operated at 50 kV and 40 mA. In the production area, a Norelco Searchray was run at 150 kV and 5 mA (Monitoring, 1955-1966, pdf p. 60).

5.2.2.1 Photon

Nuclear Metals, Inc. workers handled depleted and enriched uranium metals. External exposures to photon radiation would have resulted from the immediate daughter radionuclides in the uranium decay chain. The uranium progeny that result in the most significant photon exposures include Th-234 and Pa-234m (Rad Handbook, 1970). Note that these isotopes have relatively short half-lives and can be assumed to be in equilibrium with the parent U-238. Because of their short half-lives, the exposure potential from these isotopes would travel with the parent and will not be considered separately.

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

Table 5-3 shows the primary isotopes and photon energies associated with uranium.

Table 5-3: Principal Radiation Emissions from Natural Uranium and Short-lived Decay Products

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

Notes:
Source: Rad Handbook, 1998
Intensities refer to the percentage of disintegrations of the nuclide itself, not to original parent of series.
Gamma percentages are given in terms of observable emissions, not transitions.

Thorium has a significant number of higher-energy photons in the Th-232 decay chain. Based on the half-lives of the progeny, only a partial equilibrium is possible; therefore, it is conservative to state that equilibrium would be reached in this decay chain. It has been assumed that Ra-228 and Th-228 progeny were in equilibrium with Th-232. Under this assumption, the progeny are the major source of both penetrating and non-penetrating external exposure.

Table 5-4 shows the primary isotopes and photon energies associated with thorium and its progeny.

Table 5-4: Principal Radiation Emissions from Th-232 and its Short-Lived Decay Products			
Radionuclide	**Half-life**	**Beta Energy (MeV Max)**	**Photon (x or γ) Energy (MeV)**
Th-232	1.405 x 10^{10} years	None	0.059 (0.19%)
			0.126 (0.04%)
Ra-228	5.71 years	0.389 (100%)	0.0067 (6 x 10^{-5}%)
Ac-228	6.25 hours	0.983 (7%)	0.338 (11.4%)
		1.014 (6.6%)	0.911 (27.7%)
		1.115 (3.4%)	0.969 (16.6%)
		1.17 (32%)	1.588 (3.5%)
		1.74 (12%)	---
		2.08 (8%)	---
		(+33 more βs)	---
Th-228	1.9116 years	None	0.084 (1.19%)
			0.132 (0.11%)
			0.166 0.08%)
			0.216 (0.27%)
Bi-212	60.55 minutes	1.59 (8%)	0.040 (1%)
		2.246 (48.4%)	0.727 (11.8$)
		---	1.620 (2.75%)
Tl-208	3.1 minutes	1.28 (25%)	0.277 (6%)
		1.52 (21%)	0.5108 (21.6%)
		1.80(50%)	0.583 (85.8%)
		---	0.860 (12%)
		---	2.614 (100%)

Notes:
Source: Rad Handbook, 1998
Intensities refer to the percentage of disintegrations of the nuclide itself, not to original parent of series.
Gamma percentages are given in terms of observable emissions, not transitions.

5.2.2.2 Beta

Radiation fields from uranium are frequently dominated by contributions from daughter-product radionuclides. For example, nearly the entire beta radiation field from DU comes from the daughter radionuclide Pa-234m, and to a lesser extent from Th-234. During melting and casting operations these daughter elements may concentrate on the surface of the castings and equipment, producing beta radiation fields of up to 20 rad per hour.

Table 5-3 shows the principal beta emitters and their energies for the uranium present at Nuclear Metals, Inc. As indicated, there are a significant number of high-energy beta radiations that represent a shallow dose exposure concern for site workers. Workers who handled the uranium would have received shallow dose exposures. The primary exposure areas would have been the hands and forearms, the neck and face, and other areas of the body that might not have been covered.

5.2.2.3 Neutron

Neutrons were not measured at Nuclear Metals, Inc. and were not expected to be a source of exposure for the class under evaluation. However, neutrons could arise from the α-n reaction with light elements (e.g., beryllium and fluorine), interactions with the oxides, and through spontaneous fission. According to Battelle-TBD-6000, uranium oxides would be the most common generators of (α,n) reactions. The intensity of the radiation field from these reactions increases as a function of the enrichment. However, quenching and brushing off the rods would minimize this source of neutrons. Spontaneous fission yields and (α,n) yields in oxides are provided in Table 3.5 of Battelle-TBD-6000. The significance of each of these sources of neutrons may be evaluated using the methods described 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).

5.2.3 Incidents

NIOSH did not identify any documented accidents at the Nuclear Metals, Inc. site that resulted in exceptionally high personnel exposure levels (i.e., such as a criticality event). However, small fires, material spills, and loss of contamination control occurred throughout the plant. There are petitioner references to many unmonitored fires and airborne exposures (Affidavit, 1970-1983). The employees were not monitored by personal air monitors and workers were not wearing personal protective clothing. An incident report dated September 17, 1981, states that a green salt spill occurred in the Reduction Area. Personal air monitors and respirators were issued (Incident, 1981-1984, pdf pp. 6-7).

There were problems with spills and contaminations. The inspection report from February 10, 1964, noted that a significant uranium spill was found on the floor (Monitoring, 1955-1966, pdf p. 98). The workers were aware of the spill but did not report it to the Safety Department. The AEC inspection report dated May 1, 1973, noted that lack of trained HP personnel and lack of a routine program for surveys for personnel and contamination was a shortcoming (Inspection Report, Dec1973-Jan1974). A February 15, 1974, inspection report noted that a significant amount of undetected beta-gamma contamination existed in the work area (Inspection Report, Dec1973-Jan1974). Management was unable to guarantee that employees always changed clothes before leaving the plant. Inspectors revisited the plant and visited employees' homes and found contamination (Inspection Report, Dec1973-Jan1974, pdf p. 24).

In April 1981, a probable overexposure of an individual to airborne concentration of DU took place (Incident, 1981, pdf p. 3). The problem was first recognized by high urinary concentration of DU (935 µg/L) in a urine sample taken on April 6, 1981. The NRC document states that the worker was a recent hire who had been grinding and polishing DU and that the ventilation on the grinding machine had not been working properly for some period of time prior to the April 6th sample. A whole-body count on the individual was performed in October 1981. In the internal NRC letter from the Materials Radiological Protection Section to the Materials Safety Section, dated December 8, 1981, a request was made to evaluate the health significance of concentration of uranium in worker urine exceeding the licensee's guide of 120 micrograms per liter (Monitoring, 1981b). On December 30, 1981, NRC contracted a consultant to evaluate the health significance of this intake (Incident, 1981, pdf p. 2).

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

The following subsections provide an overview of the state of the available internal and external monitoring data for the Nuclear Metals, Inc. class under evaluation.

6.1 Available Nuclear Metals, Inc. Internal Monitoring Data

Discussed below are the available bioassay, air monitoring, lung count, and surface contamination data that are available to NIOSH. It is uncertain whether NIOSH has captured all existing urinalysis data. Information on sample preparation, if any, has not been located. Most of the urinalysis sample datasheets indicate that the samples were analyzed for total uranium by fluorometric methods. Some samples were analyzed for EU using alpha proportional counters. NIOSH has not identified any information related to sample preparation prior to counting.

6.1.1 Urine Bioassay Data

This section attempts to present in chronological order the number of urine bioassay samples and, where possible, the results or range of results for enriched uranium, uranium, depleted uranium, and thorium during the period of evaluation. There is some overlap in the various sections to maintain the continuity of the presentation provided in the source documents.

The bioassay monitoring program was carried over to the Concord facility from the Cambridge facility. Urinalysis results for 1968, 1972, and 1975 have not been located. The number of urinalyses jumped dramatically from 1978 through 1983 following a DU ammunition contract and a recommendation by a Health Physics consultant for monthly sampling starting in the first quarter of 1978; biweekly sampling starting later that same year.

The inspection report from October 1960 stated that natural uranium was being melted intermittently and very little thorium melt work was being performed (Monitoring, 1955-1966, pdf p. 71). Some EU work may also have been in progress. Inspectors found that only select groups of workers were subjected to periodic urinalysis and some workers were found to be smoking in the work area. After the inspection, Nuclear Metals, Inc. added most of the workers to the urinalysis program and banned smoking in any radioactive material area.

The workload was low in April 1961 (Monitoring, 1955-1966, pdf p. 65). Urinalysis was performed every six months on production workers and all results were well below allowable concentrations. Air sample results were negligible. Workers working closely at the extrusion process with aluminum-clad natural uranium were provided with respirators. The October 1961 inspection report (Monitoring, 1955-1966, pdf p. 77) stated that urinalysis had not been done for a long time. Nuclear Metals, Inc. reduced the urinalysis frequency because of low air activity, but expected to start the program in the winter months for personnel records. A wipe test in the production area showed activity less than 5 dpm/100 cm^2 and a fixed alpha air contamination result showed no activity.

Early urine samples were analyzed by the AEC New York Operations Office Health and Safety Laboratory. Many samples analyzed by the AEC sometimes took several months for the results to be returned. One example indicates the samples were received on May 9, 1958, with the results reported on October 15, 1959 (Monitoring 1955-1959, pdf p. 37). A July 1961 inspection report (Monitoring, 1955-1966, pdf p. 74) stated that urinalysis in the future will be performed by the AEC and partly by a private consultant. Later sample results are written on the Nuclear Metals Health and Safety Department Medical Sample forms. Examination of datasheets starting September 1974 reveals that the urine samples were analyzed by a consulting radiochemist, located in Cambridge, Massachusetts (Monitoring, 1974-1977, pdf p. 20). In October 1982, the consultant was replaced by Bolton & Galanek, Inc. (Monitoring, 1982, pdf p. 34).

Table 6-1 and Figure 6-1 indicate the number of urinalysis results by years that were available to NIOSH. There are datasheets for 101 urinalysis results, apparently from the mid-1960s, which do not include the year that the sampling was performed (Monitoring, 1960-1969, pdf pp. 17-27). There are medical sample datasheets for 69 additional urine samples from 1964 (Monitoring, 1960-1969, pdf pp. 47-51) and datasheets for 67 additional urine samples from 1976 and 1977 (Monitoring, 1973-1977, pdf pp. 6-12), but the results have not been found.

Table 6-1: Number of Urinalysis Results by Year (1958-1983)

Year	Uranium	Depleted Uranium	Enriched Uranium	Total	SRDB Ref ID
1958	15	-	-	15	24978, 10512
1959	96	-	24	120	24978, 26863
1960	82	-	38	120	29172
1961	52	-	-	52	29172
1962	278	-	4	282	10512, 29172
1963	14	-	-	14	10512, 29172
1964	310	-	-	310	10512, 29172
1965	144	-	-	144	29172
1966	19	-	-	19	29172
1967	103	-	-	103	29172
1968	-	-	-	-	-
1969	10	-	-	10	29172
1970	12	-	11	23	28439
1971	11	-	-	11	28439
1972	-	-	-	-	-
1973	24	-	-	24	25057
1974	25	-	-	25	25057, 28440
1975	-	-	-	-	-
1976	46	-	-	46	25057, 28440
1977	136	-	-	136	25057, 28440
1978	368	-	-	368	29195
1979	837	-	-	837	25049, 28442
1980	1,987	-	-	1,987	29174
1981	4,020	-	-	4,020	29175
1982	6,080	-	-	6,080	28443
1983	-	435	-	435	25074

Note:
Cells with a dash (-) indicate that there was no data available for the year specified.

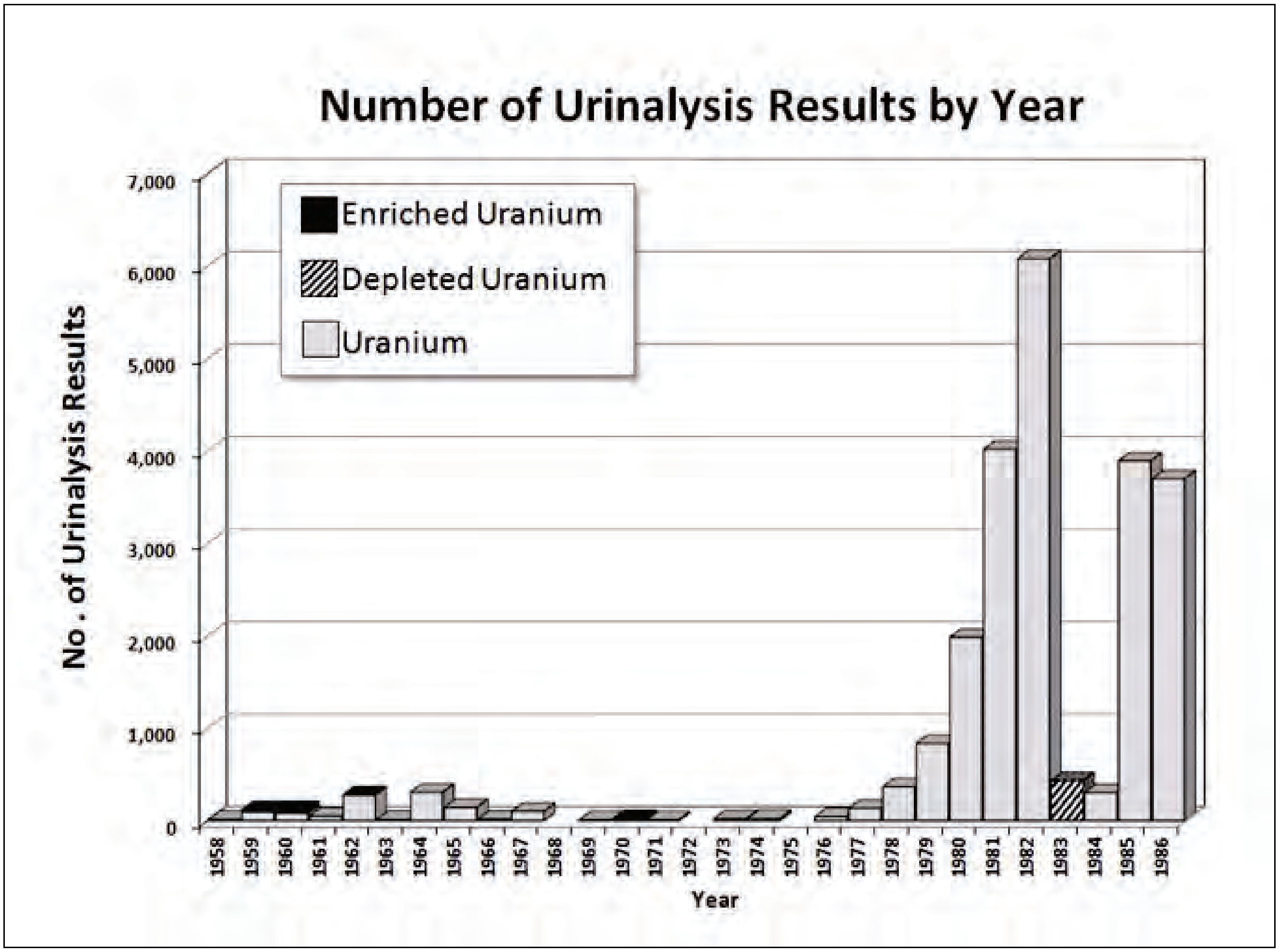

Figure 6-1: Number of Urinalysis Results by Year at Nuclear Metals, Inc.

Most of the urinalysis samples were analyzed for total uranium by fluorometric methods. Some samples were analyzed for EU using alpha-proportional counters.

Enriched Uranium

The Commonwealth of Massachusetts, Department of Labor and Industries, DOH October 1959 inspection report (Monitoring, 1955-1966, pdf p. 48) states that urine samples were collected from workers handling natural uranium, EU, and beryllium. Approximately 50% of the employees were expected to provide urine samples at varying periods during the year. If the employees handled EU or beryllium, a urine sample was to be obtained before and after the job exposure. Urine samples were also to be collected following an accident.

The DOH inspection letter dated May 26, 1965, stated that very little work with EU was being carried out (Monitoring, 1955-1966, pdf p. 106). Work (CP-5) was being performed with uranium-aluminum alloy with 16% to 20% uranium with uranium enriched to 93%.

In 1968, Nuclear Metals, Inc. completed machining work for 350 gm of U-235 in the form of zirconium-uranium oxide (Inspection Report, Jul1968, pdf p. 6). Some work with natural uranium and DU also took place. Work making U-235 shot was planned. U-235 inventory on June 30, 1968 included: 25,372 gm of contract material (U-235, 75%) and 2,561 gm of U-235 (75%) under SNM-65 (Inspection Report, Jul1968, pdf p. 9). Records of urinalysis from 1968, if any are available, have not been located by NIOSH.

The AEC inspection report from inspections conducted in December 1969 (Inspection Report, Dec1969, pdf p. 2) noted that CP-5 (EU) fuel fabrication was in process. They also identified weakness in the Nuclear Safety and Health Physics programs. Nuclear Metals, Inc. failed to collect a number of surveys and air samples. All workers who came in direct contact with radioactive material were supposed to provide urine samples annually. Sample results were reviewed for January 1969 through October 1969. The samples that were analyzed by the fluorometric method were all < 5 μg/L. The individuals performing the CP-5 fuel element fabrication work were also sampled and the samples were analyzed by the radiometric method for U-235. The maximum sample result was 14.4 dpm/1 (Inspection Report, Dec1969, pdf p. 10). Existing inventory at the time of the inspection was 19.1 kg (42.1 lbs) of uranium with greater than 75% enrichment; 21,263 lbs (9,645 kg) of DU; zero natural uranium; and zero thorium.

An AEC Inspection Report dated August 5, 1970, stated that Nuclear Metals, Inc. completed work on CP-5 fuel in March 1970 (Inspection Report, Jul1970, pdf p. 2). There was no work with special nuclear material planned. Work performed was in progress manufacturing DU shielding devices for radiography sources. This same inspection report noted that bioassay results for the CP-5 fuel were available and that the results showed no problem with internal deposition. At the completion of the CP-5 fuel element contract on March 9, 1970, urine samples were collected from eleven personnel that had been involved with material handling. A review of the bioassay results revealed that the uranium sample result of 308 dpm/L was contaminated. The result of a resample on April 12, 1970 was 14 dpm/L. The report noted that all personnel working in the facility would be sampled during the calendar year 1970. The other sample results were less than 50 dpm/L (Inspection Report, Jul1970, pdf p. 10).

Uranium

There were 15 urinalysis results for November and December 1958.

Urinalysis for uranium was not performed from November 28, 1960 through most of 1961 (Monitoring, 1955-1966, pdf pp. 78, 92-102). There are records of 49 urinalyses for uranium performed in December 1961 (Monitoring, 1955-1966, pdf pp. 92-97).

Urine samples from all operational workers were collected from September 1962 through November 1962, and were analyzed for uranium by the AEC Laboratory (Monitoring, 1955-1966, pdf p. 96). The average excretion rate was 0.001 mg/L, with the highest being 0.015 and 0.020 mg/L.

Six sample results from 1965 indicated that the workers were handling uranium and thorium, but the samples were analyzed for uranium only. The results were analyzed using the fluorometric method, with the high value being 30 μg/L (Monitoring, 1960-1969, pdf p. 46). Starting in 1977, the samples were analyzed at Murray M. Bolton Jr. Company for uranium mass and gross beta-gamma activity, expressed in dpm.

In September 1965, each plant employee was given a urinalysis to determine the excretion rate of uranium. With the exception of a few, all results showed an excretion rate of less than 5 µg/L. According to the report, a few higher values were found among workers and non-exposed personnel such as guards. One guard showed a uranium excretion rate of 35 µg/L. A total of 144 urine sample results from 1965 have been located (Monitoring, 1955-1966, pdf p. 114).

An inspection report of a site visit on August 18, 1964, indicated that urinalysis for uranium had been completed for all personnel (154 people were checked). The report stated that one employee (a nurse who was not directly exposed) had the highest result of 0.005 mg/L, four employees results wee 0.002 mg/L, and ten employee results were 0.001 mg/L. The remaining results were below 0.001 mg/L (Monitoring, 1955-1966, pdf pgs. 101, 104).

A job involving 400-500 lbs of thorium for Savannah River was expected. There is a bioassay datasheet with six sample entries from June 11, 1965, indicating that the material being handled was uranium and thorium, but the samples apparently were only analyzed for uranium. Three samples were < 5µg/l, with the other results being 5, 20, and 30 µg/l (Monitoring, 1960-1969, pdf p. 46). NIOSH has not found information indicating the possible uranium/thorium ratios of the material.

A total of 12 personnel provided urine samples during the last six months of calendar year 1970. A review of the sample analyses records showed that all results were less than 15 dpm/1 (Inspection Report, May1971 pdf p. 8).

An April 1973 AEC inspection report noted 13 violations including failure to monitor for airborne, surface, and personnel contamination. Workers were found to be leaving the work area without monitoring. The latest entry in the records showed the urine samples were from May 31, 1972 with the maximum concentration of 8.4 +/- 2.2 d/m due to uranium. However, the actual results were not located by NIOSH (Inspection Report, Mar1973 pdf p. 11). Results of seven urine samples were analyzed for uranium in April. The results were analyzed by radiometric methods and reported in α dpm/L, which ranged from 3.0 to 8.1 α dpm/L. The same samples were analyzed by fluorometry with the results ranging from <1.0 to 6.0 µg/l. Another ten urine samples were analyzed in December. However, the December sample results do not identify what the urine samples were analyzed for (NIOSH assumes the analyte to be uranium). However, the results ranged from <1.0 to 7.5 µg/l (Monitoring, 1973-1977, pdf pp. 2-3).

During the inspection on December 27-29, 1973 the inspector stated:

> "Examination of bioassay records revealed that seven employees submitted urine samples on April 18, 1973 and that eleven employees submitted urine samples on August 23, 1973, all of which were analyzed. The maximum results determined by the radiometric method and the fluorometric method were 81 and 25 dpm alpha/liter, respectively. The previous urine samples were submitted on May 31, 1972. It appears possible, based on the degree of contamination control exercised by the licensee, that many of the samples submitted were contaminated. This coupled with the inability to determine when an uptake was received, if received, makes it apparent that it would be impossible to establish the degree of internal deposition which occurred in any case" (Inspection Report, Dec1973-Jan1974 pdf p.21).

There were a total of 25 uranium urinalysis sample results from 1974 (Monitoring, 1973-1977, pdf pp. 4-5; Monitoring, 1974-1977, pdf pp. 19-21). Of these 24 samples, three were dated February 28 and ranged from < 5 to 18 +/- 5 dpm/L; 11 samples that were dated September 16 ranged from <1 to 4.5 µg/L; and the other 11 samples were dated October 2 and ranged from < 1 to 4.8 µg/L. There were also three nasal smear results and nine fecal sample results for three workers collected and analyzed for uranium and gross beta and gamma from September (Monitoring, 1974-1977, pdf pp. 20-21).

The urinalysis results from 1975 have not been located. There were a total of 46 urinalysis results from 1976 (Monitoring, 1974-1977, pdf pp. 13-16). Most of these results were < 1 µg/L with the highest being 2.1 µg/L. There were datasheets from 1976 and 1977 listing 41 names without results (Monitoring, 1973-1977, pdf pp. 6 - 12). There were a total of 136 urinalysis results for uranium from 1977, with most of the results being < 1 µg/L and the highest result being 18 µg/L (Monitoring, 1974-1977, pdf pp. 2-12).

In a letter dated November 30, 1978, a health physics consultant stated that he recommended that the urinalysis frequency be increased during the first quarter of 1978 to a monthly basis as to check on the air sampling program (Levin, 1978, pdf p. 2). Following the analysis, the letter recommended increasing the urinalysis frequency for the CNC lathe workers to biweekly. There were a total of 368 uranium urinalysis results from 1978. These samples spanned the period from May to December and represented the frequency recommended by the consultant. A NIOSH inspection of the results indicated the months of June, July, August, and December had the highest average results (Monitoring, 1978, pdf pp. 2 - 17).

Depleted Uranium

The principal uranium work in August 1965 was to cast source holders using DU (Monitoring, 1955-1966, pdf p. 111). Approximately 5,000 lbs of DU was used from January to early August. Occasionally there were orders involving normal and EU for manufacturing the prototype fuel element. The August 1965 facility visit report (Monitoring, 1955-1966, pdf p. 111) noted that urinalysis results had been fairly constant with an average of less than 20 µg/L (Monitoring, 1955-1966, pdf p. 111). During this timeframe, very little work was done with EU.

A total of 19 uranium urine sample results were identified from 1966. With the exception of one result reported as 50 µg/L, all other results were <10 µg/L. For 1967, 107 urine sample results have been found; with all but three samples having results <5 µg/L (Monitoring, 1960-1969, pdf pp. 3-11, 14-16, 23). Additionally, there are 101 bioassay results from this period without the entry of the year the samples were obtained (indications are that the samples are from either 1966 or 1967) (Monitoring, 1960-1969, pdf pp. 17-27).

All 435 samples in 1983 were analyzed for uranium. The sample results were reported in µg/L and also in activity in units of µCi/L using the specific activity of depleted uranium (3.6×10^{-7} µCi/µg) as given in Appendix B of 10 C.F.R. 20. Approximately 12% of the samples were over 10 µg/L, of which 5 were > 20 µg/L (the highest being 41 µg/L) with the remainder being within the range of 1-10 µg/L (Monitoring, 1983a, pdf pp. 2-13).

Thorium

The thorium record for the Colonie Interim Storage Site from July 12, 1962, indicates that it received 560 lbs of thorium from Nuclear Metals, Inc. (Thorium Receipts, 1959-1962, pdf p. 2, line 12).

On June 23, 1970, the Feed Materials Production Center shipped 10,408 kg of thorium nitrate tetrahydrate (TNT) to Nuclear Metals, Inc. (Thorium Shipments, 1952-1985, pdf p. 115).
As noted above relative to uranium sampling: six sample results from 1965 indicated that the workers were handling uranium and thorium, but the samples were analyzed for uranium only; and a job involving 400–500 lbs of thorium for Savannah River was indicated with bioassay datasheets (June 1965) indicating that the material being handled was uranium and thorium, but the samples apparently were only analyzed for uranium.

NIOSH has not identified any bioassays for thorium.

6.1.2 Air Monitoring Data

The inspection reports by the regulatory agencies from the late 1950s through the mid-1970s refer to monthly air sampling and analyses. These inspection reports typically listed only the average and maximum concentrations found at various locations within the Nuclear Metals facility. Individual air sample datasheets from the period prior to 1980 have not been located. Results of airborne beryllium and uranium studies conducted by AEC at Nuclear Metals, Inc. in July 1959 and September 1960 were found (NMI, 1959, pdf p. 4; NMI, 1960, pdf p. 5). Table 6-2 shows the air sample results from the AEC studies and the captured inspection reports.

Table 6-2: Alpha Air Sample Results from AEC Studies and Inspection Reports (1959-1974)

Date	Concentration (µCi/ml)			SRDB Ref ID
	Average	Minimum	Maximum	
3/24/1959	8.00E-13	-	1.00E-12	10505, pdf p. 4
4/28/1960	-	-	7.00E-12	25090, pdf p. 57
7/11/1960	4.00E-14	-	1.00E-13	10497, pdf p. 5
7/24/1961	Negligible	Negligible	Negligible	25090, pdf p. 75
7/7/1961-10/16/1961	-	1.00E-14	9.93E-12	25090, pdf p. 81
5/14/1962-6/14/1962	-	2.00E-13	2.40E-12	25090, pdf p. 89
5/13/1963-7/8/1963	-	Negligible	3.70E-13	25090, pdf p. 97
12/24/1964*-2/1/1964	-	1.50E-12	5.30E-12	25090, pdf p. 107
2/1/1964-3/29/1964	-	2.00E-13	1.80E-12	25090, pdf p. 107
8/11/1965	1.00E-13	-	1.80E-13	25090, pdf p. 112
5/28/1965-7/28/1965	-	2.00E-14	2.50E-13	25090, pdf p. 115
2/7/1966-3/24/1966	-	1.00E-14	1.20E-13	25090, pdf p. 120
10/3/1969	1.00E-12	-	2.1E-12	105852, pdf p. 7
9/7/1973	-	-	3.00E-12	106825, pdf p. 11
Nov 1973-May 1974	9.00E-14	-	-	105872, pdf p. 8
February 1974	-	-	1.40E-13	105872, pdf p. 8

Notes:
Cells with a dash (-) indicate that there was no data available for the date specified.
“Negligible” entries are taken from the documents.
* This appears to be a typo. Most likely this was intended to be 12/24/1963.

An inspection report stated that in 1959 air samples were intended to be obtained during every operation involving EU or special jobs involving natural uranium (Monitoring, 1955-1966, pdf p. 48). Twelve monitors were located throughout the plant work areas and the paper-filter samples were to be changed every two weeks.

The AEC inspection reports from inspections conducted in December 1969 (Inspection Report, Dec1969, pdf p. 7) noted that there were eleven locations in the plant where air samples were collected continuously (i.e., 24 hours each day for seven days/week). The samples were to be collected and analyzed on a monthly frequency. The inspector further noted that the location of each of the in-plant samplers were observed and “the selected locations appear to provide a satisfactory general air sample of the work locations.”

A May13-14, 1971 inspection report stated that the fixed-air sampler results for December 1970 were a maximum of 1.4 x 10^{-12} uCi/ml and average of 5 x 10^{-14} uCi/ml. For the calendar year, the maximum air contamination level was 7 x 10^{-14} uCi/ml and the average was 3 x 10^{-14} uCi/ml. Contamination survey results were at low levels (Inspection Report, May1971).

In an April 1973 AEC inspection report, the inspector observed that there were two fixed-air monitors in the foundry area where DU was processed. One was located above the cubicle (hood) on the furnace platform. The other was about 8 ft above the floor at a location that was remote from the area in which the source material was processed (Inspection Report, Mar1973, pdf p. 10).

A February 1974 AEC inspection report states that Nuclear Metals, Inc. failed to make surveys necessary to assure that employees exposed to airborne uranium-238 and associated alpha, beta and gamma-emitting daughters were not exposed to concentrations exceeding those specified in 10 C.F.R. § 20.103, *Exposure of Individuals to Concentrations of Radioactive Material in Restricted Areas*. Specifically, the surveys Nuclear Metals, Inc. conducted did not measure alpha and beta-gamma concentrations in workers' breathing zones (Inspection Report, Dec1973-Jan1974, pdf p. 5).

Nuclear Metals, Inc. countered the inspection finding stating:

> “Our method of continuous in plant monitoring as described in our license application has been in effect for several years. Our sampling heads are located from six to eight feet above the floor, and sample air just above the breathing level of personnel. Program of air monitoring will continue, under new schedule/calendar control. Special air samples will be taken during June to provide data for correlation with normal sampling stations. This will be done periodically with portable air samplers” (Inspection Report, Dec1973-Jan1974, pdf p.10).

However, the inspector examined the corrective action taken and noted that the air sampling performed measured only alpha activity and did not measure workers' breathing zone air (Inspection Report, Dec1973-Jan1974, pdf p.10). The inspectors discussed the use of lapel air samplers with the licensee.

Use of a lapel air sampler was initiated on April 8, 1974 (Inspection Report, May1974, pdf p. 8). At the time of the inspection, the lapel samplers were used on four occasions by workers while machining penetrators. The maximum result on lapel was ~1,600 dpm beta-gamma/m^3.

Air sample results starting from 1980 through 1983 have been located (Monitoring, 1980-1983). The total number of breathing zone air sample results found in the database from 1980 through 1983 is approximately 15,300. The total in-plant stationary air sample results for the same period is approximately 12,800, with the combined total number of air samples of approximately 28,100 for the 1980 through 1983 period. Table 6-3 shows the number of air samples by year for 1980 through

1983. All air samples were analyzed for gross alpha, and nearly all were analyzed for gross beta also. No isotopic studies on air samples appear to have been performed.

Table 6-3: Number of Air Samples by Year (1980-1983)

	Breathing Zone (BZA)														
Year	**Butler (B3)**	**CAF**	**Charge Prep**	**CNC**	**Foundry**	**Machine Shop**	**Misc.**	**Reduction**	**Roof**	**1400 Ton Press**	**TOTAL BZA**		**In-Plant & CAF**		**TOTAL Air Samples**
1980	-	-	-	-	-	-	-	1,230	-	-	1,230		816		2,046
1981	37	999	-	-	1,266	258	-	3,327	78	-	5,965		11,852		17,817
1982	13	1,051	69	-	1,828	809	58	1,775	-	-	5,603		145		5,748
1983	131	213	-	45	1,064	-	486	312	157	94	2,502		-		2,502

Note:
Cells with a dash (-) indicate that there was no data available for the location specified.

NIOSH has determined that the information gained during recent data capture efforts warrant further analysis for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Because the continuing analysis affects only post-1979, NIOSH has determined that it is appropriate to proceed with the pre-1980 feasibility evaluation while continuing to analyze the impact that the data have on post-1979 dose reconstruction.

6.1.3 *In Vivo* Counting Bioassay Data

The workers at Nuclear Metals, Inc. were not *in vivo* counted until 1974. After the discovery of contamination on employee cars in 1974, an AEC senior radiation specialist discussed the possibility of whole-body counting (there were two whole-body counters located at MIT) those employees with potential exposure to airborne concentrations (Knapp, 1974). Nuclear Metals replied that the company intended to perform whole-body counting. An apparent AEC note and an AEC inspection report stated that five foundry workers who worked with DU were lung-counted on January 18, 1974, and the measured activity was at background level (Inspection Report, May1974, pdf p. 9; Monitoring, Feb1974). However, the actual *in vivo* count data and the information on the counting instrument have not been located.

Following a discovery of a probable overexposure of an individual to airborne concentrations of DU in April 1981, a whole-body count on the individual was performed in October 1981 (Incident, 1981, pdf p. 3). The whole-body count showed the presence of 8 mg of DU. The document does not reveal where the whole-body count was performed.

Starting in the summer of 1982, Nuclear Metals brought in a Helgeson Scientific Mobile Whole-Body Counter trailer in order to perform lung counting for selected workers. Approximately 500 lung counts were taken from 1982 through 1986 by Helgeson Scientific Services. Table 6-4 shows the results of the lung counts during this period. NIOSH has located the schedule for the 1982 lung counts (Monitoring, 1982-1983). The lung count spectrums were analyzed for U-235, DU, and Th-234 (Monitoring, 1982-1983). One employee showed a high count due to short-lived Th-234 and was subjected to work restriction pending investigation. NIOSH has access to 1983 lung count results (Monitoring, 1983b; Monitoring, 1982-1985).

Table 6-4: Lung Count Results by Year (1982-1986)

Year	No. of Lung Counts	DU (mg)				U-235 (µg)			
		Max	Min	Ave.	STD DEV	Max	Min	Ave.	STD DEV
1982	103	154.3	1.7	7.5	15.4	83.0	0.0	16.1	23.7
1983	106	11.0	2.0	4.6	1.9	63.0	0.0	5.4	15.2
1984	114	10.3	1.7	4.4	1.8	54.0	0.0	8.1	17.3
1985	78	8.6	2.0	4.6	1.4	74.0	0.0	5.9	17.2
1986	100	32.2	1.9	4.9	3.3	69.0	0.0	1.3	8.8

6.1.4 Surface Contamination Data

The DOH inspection report dated October 27, 1959, stated that contamination surveys were performed biweekly at posted stations, and the plan was to perform surveys at 66 stations, some of them daily (Monitoring, 1955-1966, pdf p. 48). Inspection reports noted that the surface contamination levels were low through 1960. The highest monthly wipe test reading was October 18, 1960, at 22 locations which showed a highest reading of 68 dpm/100 cm^2 (Monitoring, 1955-1966, pdf p. 71). The maximum fixed contamination was 750 dpm/100 cm^2. Though the inspection reports noted that contamination surveys were performed routinely, individual datasheets have not been located.

As with urinalysis and air sampling, the quality of the contamination monitoring and control program degraded after the mid-1960s. There were problems with spills and contaminations. The inspection report from February 10, 1964, noted that a significant uranium spill was found on the floor (Monitoring, 1955-1966, pdf p. 98). The workers were aware of the spill but did not report it to the Safety Department.

The AEC inspection report dated May 1, 1973, noted that lack of trained HP personnel and lack of a routine program for surveys for personnel and contamination was a shortcoming (Inspection Report, Dec1973-Jan1974). A February 15, 1974, inspection report noted that a significant amount of undetected beta-gamma contamination existed in the work area (Inspection Report, Dec1973-Jan1974). Management was unable to guarantee that employees always changed clothes before leaving the plant. Inspectors revisited the plant and visited employees' homes and found contamination (Inspection Report, Dec1973-Jan1974, pdf p. 24).

Petitioners stated that during the period from 1973 through 1975 there were no restrictions for entering the process area. The volume of DU increased after 1974, but the Health & Safety practices did not change. The 30-mm Ammunition Factory was set up on the 2nd floor of the H-shaped Building B. The DU chips were collected on carts, wheeled down the hallway and down the elevator. No effort was made to decontaminate the cart. Chip dust was embedded in the floor.

6.2 Available Nuclear Metals, Inc. External Monitoring Data

Discussed below are the available personnel and area monitoring data that are available to NIOSH.

6.2.1 Personnel Monitoring

Nuclear Metals, Inc. workers received regular film badge service beginning before operations were transferred to the Concord facility. External monitoring data available to NIOSH consist of film badge results covering the entire operational period under evaluation. Nuclear Metals, Inc. film badge service was provided by Tracerlab and Landauer while at the Cambridge facility. Prior to relocating to the new facility at West Concord, Nuclear Metals, Inc. switched to film badge service provided by Nucleonics Corporation of America (NCA) (Monitoring, 1955-1966, pdf p. 15). Controls for Radiation, Incorporated (CRI) were evaluated on a trial basis during this time period (Monitoring, 1958-1959). In February 1968, Nuclear Metals, Inc. switched to a film badge service provided by Landauer, who supplied film badges for the company up through the end of the evaluation period (Monitoring, 1966-1967; Monitoring, 1968-1969). Table 6-5 presents the dosimetry program information.

Table 6-5: Nuclear Metals, Inc. Dosimeter Program

Dosimeter Type	Dosimeter Provider	Period of Use	Exchange Frequency[a]	MDS[b] (mrem)	
				Skin	Deep
β/γ film	NCA	10/01/1958 - 10/26/1959	4 weeks	-	10
β/γ film	CRI	10/26/1959 - 05/01/1961	6 weeks	10	5
β/γ film	NCA	05/01/1961 - 02/07/1968	6.5 weeks	-	10
β/γ film	Landauer	02/07/1968 - 12/31/1983	4 weeks	10	40

Notes:
The dash (-) indicates that data were not provided.
[a] The exchange frequency was established from dosimetry reports.
[b] Estimated minimum detectable sensitivity (MDS) typical of film dosimeter capabilities (Monitoring, 1960-1961; Monitoring, 1961-1962; Monitoring, 1968-1969).

NIOSH has examined available external records and has determined that not all of the workers in the class under evaluation were monitored for external radiation exposure for the entire 1958 through 1983 period. External dosimetry used at Nuclear Metals, Inc. appears to have targeted professional-level staff employees who had a known potential for occupational exposure. Beginning in July 1960, all plant personnel, including administrative staff, wore film badges (Monitoring, 1955-1966, pdf p. 60). During this time period, badges were exchanged and processed twice a quarter with the exception of the badges worn by administrative staff. Administrative badges were serviced annually (Monitoring, 1955-1966, pdf p. 96). Sometime prior to August 9, 1964, the policy shifted toward badging all employees except for administrative personnel (Monitoring, 1955-1966, pdf p. 104). Table 6-6 provides a summary of dosimeter badges for the evaluated period, 1958 through 1983.

Table 6-6: Nuclear Metals, Inc. Number of Badges per Year						
Year	Number of Badges	SRDB Ref ID		Year	Number of Badges	SRDB Ref ID
1958	98[a]	25034		1971	604	25046
1959	341[b]	25034; 28468		1972	364	25046; 25054
1960	1424	28468		1973	433	25054
1961	1196	25038		1974	451	25054
1962	1071	25037		1975	368	25054
1963	828	25037		1976	462[e]	25054
1964	979[c]	25037		1977	811	25054; 25072; 113268; 113279
1965	1284	25037; 29184		1978	942	25054; 25055
1966	902	25045		1979	2615	25054; 25058
1967	617	25045		1980	4230	25054; 29132; 113198
1968	312[d]	25045; 28465		1981	5422	28481; 28483
1969	622	25040		1982	7078	28582; 28584
1970	688	25046		1983	7739	29151; 29154

Notes:
[a] Records prior to relocation to Concord are not included in this total.
[b] There are missing records for 9/5/1959 through 12/31/1959.
[c] There are missing records for 1/1/1964 through 2/24/1964, 3/30/1964 through 7/6/1964, and 8/19/1964 through 9/19/1964.
[d] There are missing records for 6/15/1968 through 9/23/1968. This is a transition period from Nucleonic to Landauer/Gardray badge service.
[e] There are missing records for the month of March.

In 1981, Nuclear Metals, Inc. initiated the use of a Harshaw TLD badge system, which combined the photo identification and a TLD. These TLDs were read in-house on a monthly exchange frequency. An NRC Renewal Application states that film badges and extremity badges were issued in addition to TLDs for any individuals expected to receive more than 25% of the 10 C.F.R. pt. 20 limits (NMI, 1981). NIOSH does not currently have access to the in-house TLD records.

Neutrons

NIOSH reviewed available Nuclear Metals, Inc. documentation to identify records related to neutron exposures. While Nuclear Metals received and processed both depleted and enriched uranium, 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. The AEC's 10 C.F.R. pt. 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. pt. 20). 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.

A technical basis exists to justify the lack of routine neutron monitoring. A NIOSH Hazard Evaluation Report for the Portsmouth Gaseous Diffusion Plant, that was cited and discussed in

Portsmouth Gaseous Diffusion Plant – Occupational External Dose, assessed neutron dose rates on contact and at one meter from high EU (ORAUT-TKBS-0015-6; Cardarelli, post-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.

Because NIOSH did not identify radiological survey records addressing neutron personnel exposures, the neutron dose at Nuclear Metals, Inc. will be estimated using other methods. Further discussion is provided in Section 7 of this report.

6.2.2 Area Monitoring

NIOSH identified records addressing the conduct of routine site radiation and contamination surveys in clear and contaminated areas of the Nuclear Metals plant. Surveys were required per the plant's Health Physics Manual and licensing requirements (Inspection Report, Jul1970; NMI, 1960; Monitoring, 1979-1982; AEC, 1973). Although Nuclear Metals, Inc. policies required the completion of biweekly direct-radiation surveys (NMI, 1960), NIOSH has access to only limited survey data.

A survey of the mezzanine packaging area conducted on September 17, 1979, consisted of 21 measurements. The highest two measurements of 20 and 25 mR/hr were recorded on the work benches. The next highest measurement of 2.0 mR/hr was recorded at a distance of 2 feet from loaded material carts (Monitoring, 1979-1982, pdf p. 2). The highest readings from a 1982 area radiation survey conducted in the cafeteria were 0.2 mrem/hr for β/γ and 0.08 mR/hr for only gamma (Monitoring, 1979-1982, pdf p. 7). A survey of the foundry area conducted in the same year yielded maximum readings of 15 mrem/hr for β/γ and 2.5 mR/hr gamma (Monitoring, 1979-1982, pdf p. 9).

At the request of the NRC, Oak Ridge Associated Universities conducted an environmental survey of the site in February 1983. The survey consisted of direct gamma exposure rate measurements acquired using a sodium iodide scintillator, as well as soil samples taken from on-site and off-site locations. The maximum exposure rate from the direct gamma surveys was 280 μR/hr. Out of 41 on-site soil samples, the highest concentrations were 2711 pCi/g, 36 pCi/g, and 3.9 pCi/g for U-238, U-235, and Th-232, respectively. Eleven additional soil samples were taken near the on-site holding basin, resulting in maximum radionuclide concentrations of 628 pCi/g (U-238), 12 pCi/g (U-235), and 2.8 pCi/g (Th-232). Samples taken offsite resulted in maximum concentrations of 1.4 pCi/g (U-238), 0.4 pCi/g (U-235), and 1.5 pCi/g (Th-232) (Rocco, 1983).

NRC compliance investigations suggest that Nuclear Metals, Inc. may not have maintained strict adherence to the survey requirements. In 1969, the company was cited for failing to obtain smears of designated floor areas on a biweekly or monthly basis (AEC, 1969). In a similar assessment conducted in 1973, the assessor noted that surveys were not being properly recorded in logbooks. Instead, the survey results were recorded on smear envelopes that were not retained after the samples were analyzed and the data recorded in a final report (AEC, 1973).

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. This approach is discussed in DCAS's SEC Petition Evaluation Internal Procedures which are available at http://www.cdc.gov/niosh/ocas. The next four major subsections of this Evaluation Report examine:

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00195 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Nuclear Metals, Inc. 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

The available internal monitoring data, based on urinalysis results located by NIOSH, are of sufficient quality, but the quantity is insufficient to adequately represent all potential exposures for the class under evaluation. As presented in Table 6-1 and Figure 6-1 in Section 6.1, bioassay data for the period under evaluation, except for the years 1968, 1972, and 1975 when little work was being performed, have been located.

NIOSH has not located any bioassay data for thorium. Therefore, an internal monitoring data sufficiency and pedigree evaluation is not possible for this data type.

The urine samples from the beginning of the monitoring period were analyzed by the AEC Laboratory. Sample results collected later are either hand-written or typed on Nuclear Medals, Inc. medical sample forms. Starting in September 1974, the samples were analyzed by a private consultant. These results are presented in printed reports or computer printouts.

The available urinalysis data from Nuclear Medals, Inc. are original reports, and are therefore primary data sources. They are mostly legible and use appropriate reporting units. Therefore, no additional pedigree review was performed for those data.

Nuclear Medals, Inc. initiated annual lung counts for approximately 100 select employees starting in the summer of 1982. The number of lung counts performed from 1982 through 1986 was 501. Helgeson Scientific analyzed the lung count spectrum for U-235, depleted uranium, and Th-234.

The lung count results from 1982 through 1986 are available in the original Helgeson computer printouts, therefore original data. As a result, no additional pedigree review was performed for those data.

The AEC inspection reports from the period under evaluation reference air samplers in use and presents average air sample results. Fixed-air samplers were located in the plant. Though air sample data sheets from 1958 to 1979 have not yet been located, the average alpha sample results extracted from the AEC inspection reports from 1959 through early 1974 are summarized in Table 6-2.

A large number of air sample results from 1980 through 1983 were located. All air samples from 1980 through 1983 were analyzed for gross alpha, and nearly all were analyzed for gross beta. Like urinalysis data, the number of air samples spiked in 1981.

The air sample data from 1980 through 1983 are contained in original reports, and are therefore primary data sources. Therefore, no additional pedigree review was performed for those data.

In summary, internal monitoring data are available to NIOSH, but NIOSH is unable to verify that all pertinent data have been located. The quality of the data available to NIOSH is sufficient, but the data available to NIOSH do not adequately represent all possible internal dose contributors for the Nuclear Metals, Inc. class under evaluation over the entire evaluation period. Minimal thorium-234 specific monitoring data (lung counts) have been found by NIOSH. No monitoring data specific to thorium-232, thorium progeny, or uranium progeny have been found by NIOSH.

7.1.2 External Monitoring Data Pedigree Review

The external monitoring data, based on film badge dosimetry results, are available in sufficient quality to adequately represent the class under evaluation. As mentioned previously, company policy with regard to issuance of dosimeters varied between providing dosimetry to all employees and limiting dosimetry to all employees with the exception of administrative staff (Monitoring, 1955-1966, pdf pp. 60, 104). However, NIOSH has been unable to determine whether the available film badge results constitute the entire collection of monitoring data. Limited description of the badging policy is available. Therefore, NIOSH is unable to determine the percentage of workers that are represented in the available data. With limited exceptions (some reported badge contaminations), no problems were reported by the analysis vendor in evaluating the film badges.

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. For all data available, results are identified by worker names. NIOSH believes that the available personnel monitoring data include data that represent the maximally-exposed work group and work scenario during the Nuclear Metals, Inc. operational period. NIOSH believes that external monitoring data obtained from workers associated with the production activities can be used to likely bound external exposures to all members of the class under evaluation.

In summary, the available external dosimetry monitoring data are available in sufficient quality to adequately represent external photon and beta dose for the Nuclear Metals, Inc. class under evaluation over the entire evaluation period, but NIOSH is unable to definitively judge the quantity of available monitoring data. The dosimetry data are the primary data source that will be used to calculate external dose for the Nuclear Metals, Inc. class under evaluation.

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 Nuclear Metals, Inc.

The principal source of internal radiation doses for members of the class under evaluation was the potential inhalation and ingestion of airborne natural uranium, EU, DU, uranium compounds, and thorium by employees directly involved in the foundry, machining, extrusion, welding, grinding, and reduction process in making DU derbies. Intake of radioactive material was also possible through wounds that may have occurred during the processing of these metals. Other employees were potentially exposed to the re-suspension of contamination on surfaces during the course of their work with non-radioactive materials, and inhalation of smoke and fumes from fires and explosions (Loewenstein, 1954; Incident, 1982a; Incident, 1982b; Incident, 1996). The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

As indicated in Section 6.1.2 above, NIOSH has determined that the information gained during recent data capture efforts warrant further analysis for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Because the continuing analysis affects only post-1979, NIOSH has determined that it is appropriate to proceed with the pre-1980 feasibility evaluation while continuing to analyze the impact that the data have on post-1979 dose reconstruction. NIOSH is therefore reserving its full assessment of the available post-1979 data and will continue to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

NIOSH located urinalysis data for 23 out of 26 years under evaluation. Except for the initial lung and whole-body counts performed in 1974 and 1981, results from the on-site lung counts performed from 1982 onward, using the on-site lung counter, are found in Helgeson Scientific reports. Air sample results from the period prior to 1980 have not been located, but the average and the maximum concentrations for the inspection periods from 1959 to 1974, as evaluated by AEC inspectors, are available in the inspection reports from that period.

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

7.2.1.1 Urinalysis Information and Available Data

In 1958 when Nuclear Metals, Inc. relocated to the Concord facility, a bioassay program was carried over from their Cambridge facility. The number of urinalyses varied year-to-year, but NIOSH has only identified urinalysis results for 23 out of 26 years. The number of urinalyses started to increase in 1977, and the maximum number of urinalysis results was 6,080 in 1982. The urinalysis program also included some on-site contractors. The urine samples were analyzed for uranium, DU, and EU. Other categories of workers who may have been exposed to airborne activities were not monitored routinely. Although many of the operations conducted with uranium at Nuclear Metals, Inc. were also conducted with thorium, none of the urine samples were analyzed for thorium and there is insufficient process information to relate potential thorium exposures to known or calculated uranium exposures.

NIOSH has identified 2,600 uranium urine bioassay results for the twenty-two year period 1958 through 1979; and 12,500 uranium urine bioassay results for the four year period 1980 through 1983. As presented in Section 5.1.3 above, the radiological operations at Nuclear Metals, Inc. prior to the 1980 era improvements in the Health Physics program resulted in multiple inspection deficiencies and incidents. Because of the noted deficiencies in the site radiological controls prior to 1980, NIOSH cannot verify that the sometimes sparse urine data available prior to 1980 represent the worst case possible exposures at the Concord site during that period. Furthermore, because the urine bioassay data for the period 1980 through 1983 represent the period of improving health physics practices at the site, NIOSH cannot verify that the preponderance of 1980-1983 data sufficiently represent potential uranium intakes that may have occurred during the earlier period of apparently more lax controls through 1979. Additionally, NIOSH has identified no urine bioassay specific for thorium. Therefore NIOSH has concluded that there is insufficient urinalysis data to support its ability to bound the internal dose from enriched uranium, thorium, uranium progeny, and thorium progeny for the period from October 29, 1958 through December 31, 1979. NIOSH is continuing to evaluate the adequacy of available urine bioassay data for estimating doses beginning in 1980.

7.2.1.2 Lung Counting Information and Available Data

The production rate for DU ammunition was at or near its maximum when Nuclear Metals, Inc. started to have annual lung counts performed on its production employees in 1982. The measured maximum lung burden in a worker was 154.3 mg of depleted uranium and 83.0 ug of U-235 in 1982. The highest average lung burden was 7.5 mg of DU, and 16.1 ug of U-235, again in 1982. The lung burdens measured after 1982 were substantially lower.

In contrast, the [redacted] workers who were lung-counted at MIT in 1974 were reported to have measured activity at background levels, and one [redacted] lung count in [redacted] following a suspected overexposure, had a measured activity of 8 mg of DU. Lung counts were only performed for 100 or so production workers annually starting in 1982. Workers prior to 1982 and other workers who may have been exposed to smoke and fume from numerous fires and explosions and re-suspended particles were not monitored. NIOSH has only limited lung count data for the period 1958 through 1979, and is continuing to evaluate the adequacy of available *in vivo* bioassay data for estimating doses beginning in 1980. NIOSH has concluded that the available lung count data are insufficient to support the ability to bound the internal dose from enriched uranium, thorium, uranium progeny, and thorium progeny for the period from October 29, 1958 through December 31, 1979.

7.2.1.3 Airborne Levels

In 1958 when Nuclear Metals, Inc. relocated to the Concord facility, Nuclear Metals, Inc.'s principal work was research and development. The quantities of the materials handled were limited. Nuclear Metals, Inc. installed twelve fixed-air samplers in the factory floor for monthly air sampling and analysis. The air samples were analyzed for gross alpha and gross beta. The original air sample data sheets from prior to 1980 have not been located. However, the maximum and average alpha air-sample concentrations for the inspection periods were found in the AEC inspection reports.

Nuclear Metals, Inc. shifted work from research and development to large-scale production in the 1970s, manufacturing weights and then DU ammunition for the military. The use of lapel air samplers was initiated at this time. With the increase in production, the number of air samples increased. NIOSH located over 28,000 fixed- and breathing-zone air sample data from 1980 through 1983. For the period prior to 1980, NIOSH has only inspection reports by the regulatory agencies from the late 1950s through the mid-1970s (see Table 6-2 above). Reports are available for only 31 of the 255 months during the period October 1959 through December 1979. Available reports refer to monthly air sampling and analyses and typically list only the average and maximum concentrations found at various locations within the Nuclear Metals facility. Individual air sample datasheets from the period prior to 1980 have not been located. NIOSH has determined that the air monitoring data available prior to 1980 are insufficient to support the ability to bound the internal dose from enriched uranium, thorium, uranium progeny, and thorium progeny for the period from October 29, 1958 through December 31, 1979.

As indicated in Section 6.1.2 above, NIOSH has determined that the information gained during recent data capture efforts warrant further analysis for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Because the continuing analysis affects only post-1979, NIOSH has determined that it is appropriate to proceed with the pre-1980 feasibility evaluation while continuing to analyze the impact that the data have on post-1979 dose reconstruction. NIOSH is therefore reserving its full assessment of the available post-1979 data and will continue to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983.

7.2.2 Methods for Bounding Internal Dose at Nuclear Metals, Inc.

Based on the evaluations presented above, NIOSH has been unable to locate sufficient urine bioassay data, lung count data, or air monitoring data adequate to support sufficiently accurate dose reconstruction of internal dose from enriched uranium, thorium, uranium progeny, and thorium progeny for the period from October 29, 1958 through January 31, 1979. NIOSH has reserved the period from January 1, 1980 through December 31, 1983 pending further evaluation of information gained during recent data capture efforts. NIOSH found that it may be feasible to reconstruct internal doses from natural and depleted uranium for employees during the recommended SEC period from October 29, 1958 through December 31, 1979 using available claimant and site monitoring data, and information in established procedures such as *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals*, Battelle-TBD-6000.

7.2.3 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has concluded that it did not locate sufficient data, including bioassay results and air monitoring data, to estimate with sufficient accuracy the total internal dose from exposures to enriched uranium, thorium, uranium progeny, and thorium progeny during the period from October 29, 1958 through December 31, 1979. NIOSH found that it may be feasible to reconstruct internal doses from natural and depleted uranium for employees during the recommended SEC period from October 29, 1958 through December 31, 1979 using available claimant and site monitoring data, and information in established procedures such as *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals*, Battelle-TBD-6000.

NIOSH has determined that the information gained during recent data capture efforts warrant further analysis for the years post-1979. NIOSH believes the availability of breathing zone data starting in 1980, along with increased bioassay monitoring beginning in the late 1970s, may impact post-1979 dose reconstruction feasibility determinations. Because the continuing analysis affects only post-1979, NIOSH has determined that it is appropriate to proceed with the pre-1980 feasibility evaluation while continuing to analyze the impact that the data have on post-1979 dose reconstruction. NIOSH is therefore reserving its full assessment of the available post-1979 data and will continue to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983.

Although NIOSH found that it is not possible to completely reconstruct internal radiation doses for the period from October 29, 1958 through December 31, 1979, NIOSH intends to use any internal monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Dose reconstructions for individuals employed at Nuclear Metals, Inc. during the period from October 29, 1958 through December 31, 1979, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.3 Evaluation of Bounding External Radiation Doses at Nuclear Metals, Inc.

The principal source of external radiation doses for members of the evaluated class was photon and beta (electron) radiation associated with AEC operational activities, including handling radioactive materials during production or research activities. Thorium, uranium metal, and uranium compounds from depleted and enriched uranium constituted the principal external radiation dose-producing material sources for members of the class.

As of the date of this evaluation, NIOSH has located individual external monitoring records for Nuclear Metals, Inc. employees associated with uranium material processing during the operational period under evaluation. Documentation retrieved from the site verifies that an established 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. A suggested approach to likely bound neutron dose in lieu of monitoring data is provided in Section 7.3.3.1.

Employment at Nuclear Metals, Inc. 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 external doses, methods for bounding doses, and the feasibility of external dose reconstruction.

7.3.1 Evaluation of Bounding Process-Related External Doses

NIOSH has located external monitoring records for beta and gamma radiation for Nuclear Metals workers 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 Nuclear Metals, Inc. class. As discussed in this evaluation, the available personnel monitoring data include data from uranium process workers that represent the maximally-exposed work group and work scenario during the Nuclear Metals, Inc. operational period (NMI, 1959, pdf p. 7; Fire Prevention, unspecified, pdf p. 4; Monitoring, 1955-1966, pdf p. 114). NIOSH believes that external monitoring data obtained from workers associated with the production activities can likely be used to bound external exposures to all members of the class under evaluation. However, no dosimetry data were identified related to potential personnel exposures to neutrons; therefore, an approach for bounding neutron doses is provided in Section 7.3.3.1.

NIOSH will use the appropriate methodology and external uranium dose reconstruction assumptions and approach described in Battelle-TBD-6000. NIOSH will also 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 likely bound external dose associated with Nuclear Metals, Inc. uranium operations.

The following subsections summarize the extent and limitations of information 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 Nuclear Metals, Inc. A routine external monitoring program for neutron exposure did not exist at the site.

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 Nuclear Metals, Inc. These data can be used to reconstruct dose for members of the class under evaluation. While external dosimetry data are not available for all members of the class under evaluation, monitoring data do exist for some Nuclear Metals employees within the class being evaluated. As discussed in this evaluation, the available personnel monitoring data include data that represent the maximally-exposed work group and work scenario during the Nuclear Metals, Inc. operational period. NIOSH believes that external monitoring data obtained from workers associated with the production activities can be used to likely bound external exposures to all members of the class under evaluation. Therefore, NIOSH has concluded that the available personnel monitoring data and information for Nuclear Metals, Inc. support its ability to likely 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 period, were used to evaluate not only whole-body photon doses, but also workplace beta doses. As discussed in this evaluation, the available personnel monitoring data include data that represent the maximally-exposed work group and work scenario over the Nuclear Metals, Inc. operational period. These data are likely sufficient to support bounding beta particle dose for members of the class under evaluation, as described in Section 7.3.3.1.

Neutron

A routine external monitoring program for neutron exposure did not exist at Nuclear Metals, Inc. 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 (Fire Prevention, unspecified, pdf p. 4).

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 7.3.3.1.

7.3.1.2 Area Monitoring Data

NIOSH identified records addressing the conduct of routine site radiation and contamination surveys in both clear and contaminated areas of the Nuclear Metals plant. Surveys were required per the plant's Health Physics Manual and licensing requirements (Inspection Report, Jul1970; NMI, 1960; Monitoring, 1979-1982; AEC, 1973). NIOSH does not intend to use these data as the primary source of information for the purpose of bounding external dose. However, these 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 Nuclear Metals, Inc. Occupational X-Ray Examinations

NIOSH has indications that Nuclear Metals Inc. employees received on-site annual physical exams that included a chest X-ray (Monitoring, 1955-1966, pdf p. 57). These radiographs were taken using a Picker X-ray machine and consisted of two views (presumably a lateral view and an anterior-posterior view) acquired with exposure times of one-tenth and one-twentieth of a second (Monitoring, 1955-1966, pdf pp. 60-62). Information presented to NIOSH during worker outreach meetings with previous site employees additionally indicated that medical X-ray examinations were also performed at local medical facilities. NIOSH has no further data regarding when medical X-ray examinations may have been performed on-site versus off-site. Due to the known performance of on-site medical X-ray examinations, per ORAUT-OTIB-0079, *Guidance on Assigning Occupational X-ray Dose Under EEOICPA for X-rays Administered Off Site*, NIOSH has determined that it is applicable to reconstruct occupational medical X-ray exposures for Nuclear Metals, Inc. workers during the period from October 29, 1958 through December 31, 1983.

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 Nuclear Metals, Inc. 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. Therefore, NIOSH concludes that it is likely feasible to reconstruct occupational medical dose for Nuclear Metals, Inc. workers with sufficient accuracy.

7.3.3 Methods for Bounding External Dose at Nuclear Metals, Inc.

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 (as applicable per Section 7.3.2)

7.3.3.1 Methods for Bounding Operational Period External Dose

Photon Dose

Photon doses can be reconstructed using available film badge summary reports for all years associated with the evaluated period. At times, badging extended to all site employees whether in process or non-process areas (NMI, 1960, pdf p. 7; Fire Prevention, unspecified, pdf p. 4). At other times, badges were only issued to uranium process workers (NMI, 1959, pdf p. 7). Reconstruction of unmonitored photon doses can likely be accomplished using co-worker data distributions and the bounding assumptions and applicable protocols specified in various complex-wide Technical Information Bulletins.

Beta Dose

Exposures to beta radiation were routinely recorded during the evaluated period as a component of the external dosimetry (i.e., film badging) program. NIOSH has not identified any data related to the description of the extremity badges.

Estimation of extremity dose would be necessary only if warranted by the specific parameters of an individual case. Sufficient dosimetry information exists to likely 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 potential neutron 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).

Because of the alpha-neutron reaction from alpha interactions with light elements, very low neutron radiation exposures to unmonitored workers may have occurred in buildings that processed uranium. NIOSH has considered the potential source of neutrons resulting from alpha-neutron reactions and determined that in the cases where NIOSH needs to apply unmonitored neutron dose for members of the class, it can apply the methods approved in ORAUT-OTIB-0024 to support bounding the neutron dose. The applicability of this method will be assessed on a case-by-case basis for individual dose reconstructions.

Medical X-ray Dose

Nuclear Metals, Inc. employees were required to have chest X-rays annually as part of their routine physical examination. 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. These values can be used to support bounding the medical X-ray dose for the time period under evaluation.

7.3.4 External Dose Reconstruction Feasibility Conclusion

Due to the availability of external personal monitoring data throughout the period under evaluation, NIOSH considers reconstruction of external radiation dose to be likely feasible for the Nuclear Metals, Inc. worker class for the period from October 29, 1958 through December 31, 1983. Such reconstruction can be accomplished using co-worker data distributions and the bounding assumptions and applicable protocols specified in various complex-wide Technical Information Bulletins. NIOSH also considers reconstruction of medical X-ray dose to be likely feasible.

7.4 Evaluation of Petition Basis for SEC-00195

The following evaluates the assertions made on behalf of petition SEC-00195 for Nuclear Metals, Inc.

Lack of Monitoring

Issue: The petitioner provided affidavits and supporting documents describing unmonitored uranium airborne and external exposures.

Response: NIOSH has reviewed the affidavits and supporting documents and has noted that there were many fires and explosions that subjected the workers to airborne uranium and were not monitored. The supporting documents and AEC inspections substantiate this claim. In addition, NIOSH has not identified any monitoring data for thorium. Therefore, as presented in Section 7.2 above, NIOSH has concluded the available data are insufficient to bound the total internal dose for the period from October 29, 1958 through December 31, 1979. NIOSH is reserving its full assessment of available post-1979 data and will continue to evaluate the feasibility of sufficiently accurate dose reconstruction for the period from January 1, 1980 through December 31, 1983.

7.5 Summary of Feasibility Findings for Petition SEC-00195

This report evaluates the feasibility for completing dose reconstructions for employees at Nuclear Metals, Inc. from January 1, 1958 through December 31, 1983. NIOSH found that the available monitoring records, process descriptions and source term data available are not sufficient to complete dose reconstructions for the evaluated class of employees for the period from October 29, 1958 through December 31, 1979.

Table 7-1 summarizes the results of the feasibility findings at Nuclear Metals, Inc. for each exposure source during the evaluated AWE time period from October 29, 1958 through December 31, 1983. As previously stated, the DOL has determined that the period from January 1, 1958 through October 28, 1958 is not included in the covered AWE designation for the Nuclear Metals, Inc., Concord facility (DOL, 2012).

Table 7-1: Summary of Feasibility Findings for SEC-00195 October 29, 1958 through December 31, 1983			
Source of Exposure	**Reconstruction Feasible**	**Reconstruction Not Feasible**	**Reserved for Further NIOSH Evaluation**
Internal[1]		**X** (October 29, 1958 through December 31, 1979)	**X** (January 1, 1980 through December 31, 1983)
- Natural and Depleted Uranium	X[2] (October 29, 1958 through December 31, 1979)		X (January 1, 1980 through December 31, 1983)
- Enriched Uranium		X (October 29, 1958 through December 31, 1979)	X (January 1, 1980 through December 31, 1983)
- Uranium Progeny		X (October 29, 1958 through December 31, 1979)	X (January 1, 1980 through December 31, 1983)
- Thorium		X (October 29, 1958 through December 31, 1979)	X (January 1, 1980 through December 31, 1983)
- Thorium Progeny		X (October 29, 1958 through December 31, 1979)	X (January 1, 1980 through December 31, 1983)
External	**X**[3]		
- Gamma	X		
- Beta	X		
- Neutron	X		
- Occupational Medical X-ray	X		

Notes:

[1] Internal dosimetry data are insufficient to determine the internal doses for the recommended SEC period, October 29, 1958 through December 31, 1979. However, an evaluation beyond December 31, 1979 is continuing due to further NIOSH assessment of information gained during recent data capture efforts.

[2] NIOSH found that it may be feasible to reconstruct internal doses from natural and depleted uranium for employees during the recommended SEC period from October 29, 1958 through December 31, 1979 using available claimant and site monitoring data, and information in established procedures such as Site Profiles for Atomic Weapons Employers that Worked Uranium Metals, Battelle-TBD-6000.

[3] External monitoring data available to NIOSH consist of film badge and thermoluminescent dosimeter results covering the entire operational period under evaluation. NIOSH has determined that reconstruction of external doses, including occupational medical doses, is likely feasible for the period from October 29, 1958 through December 31, 1983.

As of August 7, 2012, a total of 19 claims have been submitted to NIOSH for individuals who worked at Nuclear Metals, Inc. during the period under evaluation in this report. Dose reconstructions have been completed for 16 individuals (~84%).

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures). Therefore, dose reconstructions for individuals employed at

Nuclear Metals, Inc. during the period from October 29, 1958 through December 31, 1979, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

8.0 Evaluation of Health Endangerment for Petition SEC-00195

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 the sum of information available from available resources, NIOSH's evaluation determined that it is not feasible to estimate radiation dose with sufficient accuracy for members of the NIOSH-evaluated class for the time period from October 29, 1958 through December 31, 1979. Therefore, the resulting NIOSH-proposed SEC class must include a minimum required employment period as a basis for specifying that health was endangered for this time period. NIOSH is continuing to evaluate the period from January 1, 1980 through December 31, 1983.

9.0 Class Conclusion for Petition SEC-00195

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all Atomic Weapons Employees who worked at the facility owned by Nuclear Metals Inc. (or a subsequent owner) in West Concord, Massachusetts during the period from October 29, 1958 through December 31, 1979, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort. NIOSH is continuing to research Nuclear Metals, Inc. activities and further analyze information gained during recent data capture efforts for the post-1979 period; subsequently NIOSH has reserved the period from January 1, 1980 through December 31, 1983 pending further evaluation.

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-00195. 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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Monitoring, May1976-Oct1977, *Radiation Dosimetry Reports for May 1976 through October 1977*; Landauer; various dates from May 1976 through October 1977; SRDB Ref ID: 113279

Monitoring, Dec1976-1977, *Radiation Dosimetry Reports for December 1976 through December 1977*; Landauer; various dates from December 1976 through December 1977; SRDB Ref ID: 113268

Monitoring, 1977, *Film Badge Date for 1977*; Landauer; various dates throughout 1977; SRDB Ref ID: 25072

Monitoring, 1978, *Urine Analysis Results for May 1978 through December 1978*; various dates from May 1978 through December 1978; SRDB Ref ID: 29195

Monitoring, 1979a, *Urine Analysis Results for 1979*; various dates throughout 1979; SRDB Ref ID: 28442

Monitoring, 1979b, *Claimant Dosimetry File with Results from 1956 through 1985*; selected pages with 1979 results; SRDB Ref ID: 25049, pdf pp. 6-12

Monitoring, 1979c, *Film Badge Reports for 1979*; Landauer; various dates throughout 1979; SRDB Ref ID: 25055

Monitoring, 1979d, *Film Badge Reports for 1979*; Landauer; various dates throughout 1979; SRDB Ref ID: 25058

Monitoring, 1979-1982, *Radiation Surveys for 1979, 1981, and 1982*; surveys conducted October 1979, July 28, 1981, and February 3-4, 1982; SRDB Ref ID: 24996

Monitoring, Jan-Apr1980, *Personnel Exposure Reports for January 1980 through April 1980*; Landauer; various dates from January 1980 through April 1980; SRDB Ref ID: 113198

Monitoring, 1980a, *Radiation Dosimetry Reports for 1980*; Landauer; various dates throughout 1980; SRDB Ref ID: 29132

Monitoring, 1980b, *Urinalysis Results for 1980*; various dates throughout 1980; SRDB Ref ID: 29174

Monitoring, 1980-1983, *Various Breathing Zone Air Sample Records from Various Locations*; various dates from 1980 through 1983; SRDB Ref IDs: 26864, 26867, 28484, 28486-28488, 28490-28491, 29135, 29137-29138, 29214, 113136-113138, 113154, 113156-113157, 113159-113164, 113169 -113170, 113173, 113176, 113180, 113183, 113186, 113189, 113196, 113207, 113236, 113239, 113241-113242, 113247, 113249, and 113353-113354

Monitoring, Jun-Dec1981, *Air Sample Records for June 1981 through December 1981*; various dates from June 1981 through December 1981; SRDB Ref ID: 25085

Monitoring, Oct-Dec1981, *Air Sample Records for October 1981 through December 1981*; various dates from October 1981 through December 1981; SRDB Ref ID: 28484

Monitoring, 1981a, *Urinalysis Results for 1981*; various dates throughout 1981; SRDB Ref ID: 29175

Monitoring, 1981b, *Evaluation of Bioassay Data/Urinalysis Results for 1981*; various dates throughout 1981; SRDB Ref ID: 107973

Monitoring, 1981c, *Radiation Dosimetry Reports for 1981*; various dates throughout 1981; SRDB Ref ID: 28481

Monitoring, 1981d, *Radiation Dosimetry Reports TLD Including Rings*; Landauer; various dates throughout 1981; SRDB Ref ID: 28483

Monitoring, Jan-Jun1982, *Radiation Dosimetry Reports for January 1982 through June 1982*; Landauer; various dates from January 1982 through June 1982; SRDB Ref ID: 28584

Monitoring, Jul-Dec1982, *Radiation Dosimetry Reports for July 1982 through December 1982*; Landauer; various dates from July 1982 through December 1982; SRDB Ref ID: 28582

Monitoring, 1982, *Radiochemistry and Health Physics Urinalysis Results for 1982*; Bolton & Galanek, Inc.; various dates throughout 1982; SRDB Ref ID: 28443

Monitoring, 1982-1983, *Lung Counting Procedures and Results for 1982 through 1983*; various dates from 1982 through 1983; SRDB Ref ID: 25116

Monitoring, 1982-1985, *Lung Count Data for 1982 through 1985*; various dates from 1982 through 1985; SRDB Ref ID: 25063

Monitoring, Jan-Jun1983, *Radiation Dosimetry Reports for January 1983 through June 1983*; Landauer; various dates from January 1983 through June 1983; SRDB Ref ID: 29151

Monitoring, Jul-Dec1983, *Radiation Dosimetry Reports for July 1983 through December 1983*; Landauer; various dates from July 1983 through December 1983; SRDB Ref ID: 29154

Monitoring, 1983a, *Bioassay Data Results for 1983*; Bolton & Galanek, Inc.; various dates throughout 1983; SRDB Ref ID: 25074

Monitoring, 1983b, *NRC Correspondence on Internal Exposure Results for 1983, RWP, and ALARA Program*; various dates throughout 1983; SRDB Ref ID: 25112

NMI, 1959, *Occupational Exposure to Airborne Beryllium and Uranium*, HASL-68; Nuclear Metals, Inc. (NMI), Field Services Branch; July 21, 1959; SRDB Ref ID: 10505

NMI, 1960, *Occupational Exposure to Airborne Beryllium and Uranium: Safety and Fire Protection*, HASL-97; Nuclear Metals, Inc. (NMI); September 28, 1960; SRDB Ref ID: 10497

NMI, 1981, *Nuclear Metals, Inc. Renewal Application for Nuclear Regulatory Commission License SMB-179*; November 1981; SRDB Ref ID: 25115

NSWC, 1997, *1997 Tri-Service Conference on Corrosion*; conference organized by Naval Surface Warfare Center (NSWC); conference held from November 17-21, 1997; SRDB Ref ID: 106125

ORAUT-OTIB-0006, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures*, Rev. 03 PC-1; ORAU Team Dose Reconstruction Project for NIOSH; effective 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; ORAU Team Dose Reconstruction Project for NIOSH; effective April 7, 2005; SRDB Ref ID: 19445

ORAUT-OTIB-0079, *Guidance on Assigning Occupational X-ray Dose Under EEOICPA for X-rays Administered Off Site*, Rev. 00; ORAU Team Dose Reconstruction Project for NIOSH; effective January 1, 2011; SRDB Ref ID: 89563

ORAUT-TKBS-0015-6, *Portsmouth Gaseous Diffusion Plant – Occupational External Dose*, Rev. 01 PC-1; ORAU Team Dose Reconstruction Project for NIOSH; effective August 20, 2007; SRDB Ref ID: 34469

ORNL, 1996, *Site Summary Document for Nuclear Metals, Inc.*; Oak Ridge National Laboratory (ORNL); approved August 13, 1996; SRDB Ref ID: 106833

Personal Communication, 2012a, *Documented Communication with a Plant Engineer*; Telephone Interview by ORAU Team; March 5, 2012, 10:00 AM EST; SRDB Ref ID: 111249

Personal Communication, 2012b, *Documented Communication with a Plant Engineer*; Telephone Interview by ORAU Team; March 8, 2012, 3:30 PM EST; SRDB Ref ID: 111248

Personal Communication, 2012c, *Documented Communication with a Plant Manager*; Telephone Interview by ORAU Team; March 8, 2012, 10:00 AM EST; SRDB Ref ID: 111247

Personal Communication, 2012d, *Documented Communication with a Machine Operator*; Telephone Interview by ORAU/NIOSH Team; March 7, 2012, 2:00 PM EST; SRDB Ref ID: 111246

Personal Communication, 2012e, *Documented Communication with a REP Machine Operator*; Telephone Interview by ORAU Team; March 27, 2012, 12:00 PM EST; SRDB Ref ID: 114279

Personal Communication, 2012f, *Documented Communication with a Senior Health Physicist*; Telephone Interview by ORAU Team; April 17, 2012, 2:00 PM EST; SRDB Ref ID: 114280

Personal Communication, 2012g, *Documented Communication with a Health Physics Technician*; Telephone Interview by ORAU Team; March 27, 2012, 9:00 AM EST; SRDB Ref ID: 114281

Personal Communication, 2012h, *Documented Communication with a Foundry Worker*; Telephone Interview by ORAU Team; March 26, 2012, 11:00 AM EST; SRDB Ref ID: 114282

Production Order, 1960, *Production Orders for Shipment of 3% Enriched Uranium Scrap to Nuclear Metals, Inc.*; orders dated March 3, 1960 and December 6, 1960; SRDB Ref ID: 93116, pdf pp. 2-3

Progress Report, Jul-Dec1952, *Health Physics Progress Report for July 1, 1952 through December 31, 1952*; E. G. Struxness; February 8, 1954; SRDB Ref ID: 8602, pdf pp. 86-109

Quinn, 2001, *Beryllium and Uranium Work Performed by Nuclear Metals, Inc.*, correspondence to Roger Anders; Robert E. Quinn; October 11, 2001; SRDB Ref ID: 10485, pdf pp. 102-103

Rad Handbook, 1970, *Radiological Health Handbook*, Revised Edition; compiled and edited by the Bureau of Radiological Health and the Training Institute Environmental Control Administration; revised January 1970; SRDB Ref ID: 75017

Rad Handbook, 1998, *Handbook of Health Physics and Radiological Health*, 3rd Edition; editors include Bernard Schleien, Lester Slaback, and Brian Kent; 1998; SRDB Ref ID: 22737

Rocco, 1983, *Environmental Survey of Nuclear Metals, Inc.*, Final Report; B. B. Rocco; February 1983; SRDB Ref ID: 25126

Supporting Doc, 1974-2006, *Appendix A NRC/AEC Reports and Excerpts*; various documents and reports with dates ranging from 1974 through 2006; DSA Ref ID: 115098

Thorium, 2012, *Notes Regarding Thorium Work in Concord*, hand written notes; notes provided by [Name Redacted]; collected May 24, 2012; SRDB Ref ID: 114724

Thorium Shipments, 1952-1985, *FMPC Thorium Campaigns and Shipment Lists for 1952-1985*; shipments from 1952 through 1985; SRDB Ref ID: 41375 pdf pp. 104-124

Thorium Receipts, 1959-1962, *Receipts of Thorium at Colonie Interim Storage Site*; dates ranging from 1959 through 1962; SRDB Ref ID: 45268

Uranium Shipments, Oct1960, *Uranium Shipment to Nuclear Metals October 1960*; shipment from Atlas Steels Limited; October 4, 1960; SRDB Ref ID: 101273

Uranium Shipments, Dec1960, *Uranium Shipment from Nuclear Metals to Atlas Steels Limited December 1960*; December 1960; SRDB Ref ID: 101269

Attachment One: Data Capture Synopsis

Table A1-1: Data Capture Synopsis for Nuclear Metals, Inc.			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Primary Site / Company Name: Nuclear Metals, Inc.; BE 1954-1986; AWE 1958-1990; Residual Radiation 1991-October 2009 Alternate Site Names: Starmet, Inc. Whittaker Corp. Nuclear Metals Division NMI Physical Size of the Site: 46.4 Acres Site Population: Apparent peak of 650 (1984/85)	Aerial radiological survey, air sample data, ALARA control information, personnel radiological exposure, area dosimetry, area radiation surveys, urinalyses sample results, bioassay and air sampling program procedure, breathing zone and area air sample records, fluorometry laboratory procedures, company history, depleted uranium processing, dissolution rates of uranium from air samples, chest x-rays, environmental survey, GAU-8 program, in vivo counting for Nuclear Metals, Inc, incident reports, license documentation, NMI Views volumes, NRC inspection reports, proposed action levels for uranium urinalysis, radiological work permit system, safety precautions for depleted uranium powder production, site visit reports, summary of air emissions, summary of perimeter and off-site uranium air concentrations and calculated lung doses, thorium work in Concord, and TLD badge program information.	06/06/2012	305
State Contacted: MA Department of Public Health, Radiation Control Program [Phone no. redacted]	Airborne emissions report, ambient air monitoring data, personnel radiological exposure information, calculation of uranium inventory, drum excavation work plan, depleted uranium inventory, environmental survey, floor plans and site map showing location of drains and utilities, holding basin decommissioning project site specific health and safety plan, incident notifications, inspection reports, radiation dosimetry report, license amendments and other documentation, Massachusetts Environmental Radiation Laboratory sample procedure and radiation control program inspection report, site photographs, update to holding basin release abatement measure project, radioactive materials inventory, radiological survey data, registration of ionizing radiation sources, health and safety plan, disposal of industrial wastes, routing of radioactive waste shipments, time line of events, town of Concord air monitoring data, USEPA National Air and Radiation Environmental Laboratory thorium analyses, uranium emissions summary, ventilation information and air data at plant boundary, and waste disposal practices and shipments.	04/12/2012	84
Battelle Memorial Institute, King Avenue	Report on explosion of extruded thorium.	04/14/2011	1
Claimant Provided	Licensing and product information and employee work history.	07/05/2012	2

Table A1-1: Data Capture Synopsis for Nuclear Metals, Inc.			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Concord, MA Public Library	Description of bioassay program, use of asbestos, survey frequency, air sample data and uranium inventory.	10/06/2008	7
Concord, MA Town Hall	Beryllium monitoring, exposure investigation, personnel intake evaluations, personnel dosimetry reports, and personnel rosters and photographs.	10/07/2008	35
Department of Labor / Paragon	Uranium requests and thorium slugs from extruded rod.	01/23/2012	3
DOE Germantown	Site description and beryllium related material.	09/11/2002	3
DOE Legacy Management - Grand Junction Office	Report to Congress excerpt, research in support of Savannah River, material receipts, waste classification, thorium procurement, and uranium shipment documentation.	08/25/2011	25
DOE Legacy Management - Morgantown	Special Nuclear Material accountability station symbols, Fernald agreements, production orders, ALARA program development and division highlight reports.	03/02/2011	7
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Weekly progress report, thorium receipts and campaigns, actinium inventory, tritium release, and a report on normal uranium scrap materials.	09/08/2008	6
DOE Office of Scientific and Technical Information (OSTI)	Thorium receipts, zirconium cladding of uranium, and a trip report.	03/26/2012	3
Federal Record Center (FRC) - Boston	Urine sample collection data, breathing zone air samples, radiation dosimetry reports, general area air sample results, personnel termination exposure records, and quality control information.	05/30/2012	389
Hagley Museum and Library	Trip reports and research programs in support of Savannah River.	10/28/2010	2
Hanford	Monthly processing and operations reports. NOTE: Cannot submit requested documents from search results until funding issues at Hanford are resolved.	OPEN	13
HASL - EML	Thorium sampling and storage.	03/08/2005	1
Interlibrary Loan	M.I.T. beginnings, "The Legacy of Nuclear Metals, Inc."	05/15/2008	1
Internet - Defense Technical Information Center (DTIC)	Nuclear Metals site history, feasibility of recycling penetrators, filtration of molten depleted uranium, depleted uranium reclamation report, machining depleted uranium, techniques for cleaning depleted uranium derbys, dies for extrusion of complex shapes of steel and refractory alloys, disposal of depleted uranium, compatibility studies of molten uranium and thorium alloys, and development of high strength columbium and tantalum alloy tubing progress report.	02/04/2012	37
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant documents identified.	07/09/2012	0

Table A1-1: Data Capture Synopsis for Nuclear Metals, Inc.

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded To SRDB
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	Monthly processing and operations reports.	10/24/2008	11
Internet - DOE Legacy Management Considered Sites	Considered sites listing.	03/15/2012	1
Internet - DOE National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant documents identified.	03/20/2012	0
Internet - DOE OpenNet	No relevant documents identified.	03/20/2012	0
Internet - DOE OSTI Energy Citations	Progress reports, report on low exposure irradiation of enriched seven-rod cluster in KER loop, extrusion program summary report, and thorium 1.4 wt percent uranium-235 metal fuel tubes fabrication.	04/03/2012	8
Internet - DOE OSTI Information Bridge	Departmental monthly reports, decommissioning management plan, grain refinement of case uranium by heat, trip reports, evaluation of thorium - uranium alloys, irradiation of uranium 2% zirconium fuel tube, effects of irradiation, Mound Laboratory monthly report, stockpile management quarterly report, and heavy water moderated power reactors progress reports.	03/15/2012	56
Internet - DOE OSTI Information Bridge / SC&A	Preparation and characterization of uranium oxides.	03/15/2012	1
Internet - Environmental Protection Agency	Waste site cleanup and reuse and removal of contaminated buildings.	03/24/2012	2
Internet - Google	Criticality safety inspections, depleted uranium technical brief, drum excavation, engineering evaluation and cost analysis for disposition of structures and contents, enriched uranium liquid sludge transfer, environmental assessments, evaluation of zircaloy clad tubes, evaluation of tantalum bimetallic tubing fabrication, groundwater and surface water sampling and analysis, holding basin characterization, licensing documentation, monthly and bi-annual monitoring data, decommissioning plan for the holding basin, process for removing uranium and other metals from wastes, processing and applications of depleted uranium alloy products, production of high-value fluoride gas from uranium tetrafluoride, radiation exposure information, radiological incidents, radiological surveys, safeguards inspection, scope of work Nuclear Metals, Inc. Superfund site, site characterization report, uranium contamination at Nuclear Metals plant, and whole body counts contamination monitoring.	06/24/2012	257
Internet - Health Physics Journal	No relevant documents identified.	07/09/2012	0
Internet - Journal of Occupational and Environmental Hygiene	No relevant documents identified.	07/09/2012	0
Internet - National Academies Press (NAP)	No relevant documents identified.	03/20/2012	0

Table A1-1: Data Capture Synopsis for Nuclear Metals, Inc.			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Internet - NIOSH	Report on residual radioactive beryllium contamination.	01/25/2007	1
Internet - NRC Agencywide Document Access and Management (ADAMS)	Amendments to vendor reported dosimetry, decommissioning cost estimate, evaluation of bioassay data, examination and analysis of three fired depleted uranium penetrators, exclusion boundaries fissile material storage, feasibility reports, guidelines for transferring solid depleted uranium product, holding basin remediation plan, incident reports including notification and corrective actions, inspection reports, notifications and violations, license amendment and termination documentation, material status report, ORNL site summary, placarding of shipment violation, notification of banning radioactive waste shipments, radiological safety inspection, record of shipment forms, requirements for uranium conversion and deconversion facilities, holding basin characterization report, site decommissioning management plan, skin dose report, Starmet Corporation fact sheet, decommissioning program annual report, urinalysis data, zero power experiments with U-235 enriched thoria and thorium metal lattices.	08/23/2012	158
Internet - USACE/FUSRAP	No relevant documents identified.	03/20/2012	0
Internet - US Transuranium and Uranium Registries	No relevant documents identified.	03/20/2012	0
Iron Mountain	Survey of control over source and special nuclear materials.	09/11/2006	1
Massachusetts Department of Environmental Protection	Remediation photographs, documented communication, extrusion, groundwater contamination investigation, and consequences of using depleted uranium.	06/14/2012	9
National Archives and Records Administration (NARA) - Atlanta	Thorium explosion and a proposal for work on solid duel liquid metal cooled aircraft propulsion reactor.	05/20/2008	2
National Institute for Occupational Safety and Health (NIOSH)	History of USAEC and the establishment of EEOICPA.	12/12/2011	2
New South Associates	The 300/M area fuel and target fabrication.	08/08/2009	1

Table A1-1: Data Capture Synopsis for Nuclear Metals, Inc.			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded To SRDB**
Nuclear Regulatory Commission Public Document Room	Soil monitoring program and soil analyses, potential airborne releases, certificate of disposition of materials, disposal of low level waste at Envirocare of Utah, dose rate evaluations for exposure to copper metal contaminated with depleted uranium, environmental summary report, extrapolation chamber measurements, ground water report, site historical information brochure, license application, amendment, renewal and termination documentation, minimum requirements for entrance into restricted areas, air sampling program documentation, annual lung counting program, notice of violation and proposed imposition of civil penalties, pre-construction radiological assessment and decontamination of a depleted uranium waste handling site, regulatory operations routine inspection, request for approval to use the Clive, Utah repository, transportation violations, and a trip report.	05/21/2012	119
ORAU Team	Documented communications.	04/17/2012	14
R. S. Landauer	NOTE: Request submitted to Landauer by NIOSH; awaiting response.	OPEN	NA
Sandia National Laboratories, New Mexico / SC&A	Radiological surveys.	09/15/2010	3
Savannah River Site	Classified reports received for 1957, dosimetry visitors cards, extrusion of electrolytic thorium, monthly progress report, radiation survey logsheets, symposium on high temperature fuel processing, and thorium metal requirements.	06/06/2012	25
Science Applications International Corp (SAIC)	Radiation exposure summary.	09/02/2004	3
Southern Illinois University	Nuclear fuels and materials development and an off-site extrusion program summary.	11/08/2008	2
Unknown	Air, stack, water, and urine samples, building contamination, employee radiological summary, occupational exposure record, breathing zone air samples, and occupational exposure to airborne beryllium and uranium.	06/08/2009	20
TOTAL			**1,620**

Table A1-2: Databases searched for Nuclear Metals, Inc.			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**

Table A1-2: Databases searched for Nuclear Metals, Inc.			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**
NOTE: Database search terms employed for each of the databases listed below are available in the Excel file called "Nuclear Metals Rev 00, (83.13) 07-25-12"			
Defense Technical Information Center (DTIC) https://www.dtic.mil/ COMPLETED 11/08/2012	See Note above	1,479	23
DOE CEDR http://cedr.lbl.gov/ COMPLETED 07/09/2012	See Note above	0	0
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 03/20/2012	See Note above	0	0
DOE Legacy Management Considered Sites http://csd.lm.doe.gov/ COMPLETED 03/20/2012	See Note above	6	2
DOE NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 03/20/2012	See Note above	18	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 03/20/2012	See Note above	224	11
DOE OSTI Energy Citations http://www.osti.gov/energycitations/ COMPLETED 03/20/2012	See Note above	2,385	7
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 03/20/2012	See Note above	1,644	18
Google http://www.google.com COMPLETED 03/31/2012	See Note above	22,494,928	497
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 07/09/2012	See Note above	4	0

Table A1-2: Databases searched for Nuclear Metals, Inc.			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**
Journal of Occupational and Environmental Health http://www.ijoeh.com/index.php/ijoeh COMPLETED 07/09/2012	See Note above	0	0
National Academies Press http://www.nap.edu/ COMPLETED 03/20/2012	See Note above	5,879	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 03/20/2012	See Note above	807	107
USACE/FUSRAP http://www.lrb.usace.army.mil/fusrap/ COMPLETED 03/20/2012	See Note above	4	4
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 03/20/2012	See Note above	0	0

Table A1-3: DTIC Documents Requested for Nuclear Metals, Inc.			
Document Number	**Document Title**	**Requested Date**	**Received Date**
NA	Extrusion of DU Penetrator Alloys Using the Canned Billet Technique	11/14/2011	
NA	Investment Casting of Uranium Alloy Penetrators	11/14/2011	
NA	An Investigation of (1) Stabilizing the Carbon Content of Investment Cast Performs for Phalanx Penetrators (2) Dual-Hardness Phalanx Penetrators	11/11/2011	NA - Request denied
NA	Fundamental and Applied Research and Development in Metallurgy	11/11/2011	11/22/2011 - Not relevant
NA REF ID: 105845	Reclamation/Recycle of Depleted Uranium and Heavy Metal Alloy Residue for Soils	11/11/2011	12/19/2011
NMI-9709.13 REF ID: 105847	Development of Processing Techniques for the Extrusion of Metal Powders dated December 1967	11/08/2011	12/16/2011
ARCCD-CR-87006 REF ID: 104924	Filtration of Molten Depleted Uranium dated June 24, 1987	11/08/2011	11/28/2011

Table A1-3: DTIC Documents Requested for Nuclear Metals, Inc.			
Document Number	**Document Title**	**Requested Date**	**Received Date**
ARLCD-CR-83018 REF ID: 104927	M774 Machine Chip Recycling	11/08/2011	11/28/2011
AFATL-TR-82-49 REF ID: 104926	Depleted Uranium Test Range Fragment Reclamation dated July 1982	11/08/2011	11/28/2011
ARCCD-CR-86010 REF ID: 104929	Recycle Process for Depleted Uranium Machining Chips by Vacuum Induction Remelt dated May 1987	11/08/2011	11/28/2011
ARCCD-CR-86008 REF ID: 104930	Atmosphere Assisted Machining of Depleted Uranium (DU) Penetration dated May 1987	11/08/2011	11/28/2011
ARCCD-CR-87004 REF ID: 104932	Established Techniques for Cleaning Depleted Uranium Derby in Lieu of Nitric Acid Pickling dated May 1987	11/08/2011	11/28/2011

Table A1-4: Interlibrary Loan Documents Requested for Nuclear Metals, Inc.			
Document Number	**Document Title**	**Requested Date**	**Received Date**
NA	Proceedings of the High Density Alloy Penetrator Materials Conference, April 1977	11/28/2011	