SEC Petition Evaluation Report
Petition SEC-00164

Report Rev #: 0 Report Submittal Date: July 19, 2010

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Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00164	83.13	January 26, 2010	March 18, 2010	Revere Copper and Brass

Petitioner Class Definition

Extruders and Shapes Specialists who worked in the Rod and Shape Mill at Revere Copper and Brass, Detroit, Michigan from 1943 through 1984.

Class Evaluated by NIOSH

All workers who worked at Revere Copper and Brass, Detroit, Michigan from July 24, 1943 through December 31, 1954 and for the residual period from January 1, 1955 through December 31, 1984.

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

All Atomic Weapons Employer employees who worked at Revere Copper and Brass, Detroit, Michigan, from July 24, 1943 through December 31, 1954, 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
None			

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
None	

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Evaluation Report Summary: SEC-00164, Revere Copper and Brass

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-00164 was received on January 26, 2010 and qualified on March 18, 2010. The petitioner requested that NIOSH consider the following class: *Extruders and Shape Specialists who worked in the Rod and Shape Mill at Revere Copper and Brass, Detroit, Michigan from 1943 through 1984.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH divided the petitioner-requested class. NIOSH evaluated the following class: All workers who worked at Revere Copper and Brass, Detroit, Michigan from July 24, 1943 through December 31, 1954 and the residual period from January 1, 1955 through December 31, 1984. These operational dates represent the beginning of the first extrusions performed for the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC) through the end of the last year that extrusions took place. January 1, 1955 represents the beginning of the residual period, which continued through the end of 1984, the year the facility was demolished.

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

Based on its full research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class includes all Atomic Weapons Employer employees who worked at Revere Copper and Brass, Detroit, Michigan, from July 24, 1943 through December 31, 1954, 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 divided (see Section 3.0 below) because although NIOSH has not obtained sufficient internal or external monitoring data for bounding doses during the operational period, NIOSH has a methodology for bounding doses for the residual period.

Feasibility of Dose Reconstruction

NIOSH finds it is not feasible to estimate internal and external exposures with sufficient accuracy for all workers at the site from July 24, 1943 through December 31, 1954. NIOSH determined there was no monitoring program at Revere and insufficient data are available to determine the external and internal doses received by workers during the period under evaluation. With the exception of this class, per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances; or (2) estimate radiation doses more precisely than an estimate of maximum dose. Available information and resources are sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during the specified period January 1, 1955 through December 31, 1984.

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

- NIOSH finds that it is likely feasible to reconstruct occupational medical dose for Revere workers with sufficient accuracy.

- Principal sources of internal radiation for members of the proposed class included exposures to natural uranium and thorium metals existing either separately or as alloys. The modes of exposure were inhalation and ingestion during the processing of these metals.

- Based on lack of sufficient data for Revere workers or operations, internal dose reconstruction for the Revere operational period is not feasible; however, NIOSH has identified sufficient information and data to support bounding internal dose for the residual period using available methodologies.

- 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 uranium and thorium metals existing either separately or as alloys. The modes of exposure were direct radiation, submersion in potentially-contaminated air, and exposure to contaminated surfaces.

- Except for medical X-ray dose, NIOSH has determined that reconstruction of external doses for Revere workers is not feasible for the operational period from July 1, 1943 through December 31, 1954. NIOSH has determined that reconstruction of external doses is feasible for the residual period (January 1, 1955 through December 31, 1984) using the assumptions and approaches presented in Battelle-TBD-6000.

- 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 or any area monitoring data (that can be interpreted using existing NIOSH dose reconstruction processes or procedures) to support partial dose reconstructions for the operational period at the site. Therefore, dose reconstructions for individuals employed at Revere Copper and Brass during the period from July 24, 1943 through December 31, 1954, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

Health Endangerment Determination

Per EEOICPA and 42 C.F.R. § 83.13(c)(3), a health endangerment determination is required because NIOSH has determined that it does not have sufficient information to estimate dose for the members of the proposed class from July 24, 1943 through December 31, 1954.

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 and beta 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 their employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

For the period January 1, 1955 through December 31, 1984, a health endangerment determination is not required because NIOSH has determined that it has an established methodology for estimating dose.

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SEC Petition Evaluation Report for SEC-00164

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all workers who worked at Revere Copper and Brass, Detroit, Michigan from July 24, 1943 through December 31, 1954 and the residual period from January 1, 1955 through December 31, 1984. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created Special Exposure Cohort (SEC).

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

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

2.0 Introduction

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

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

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

[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.

during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

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

3.0 SEC-00164 Revere Copper and Brass Class Definitions

The following subsections address the evolution of the class definition for SEC-00164, Revere Copper and Brass. When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of petitioner’s class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00164 was received on January 26, 2010 and qualified on March 18, 2010. The petitioner requested that NIOSH consider the following class: *Extruder and Shape Specialists who worked in the Rod and Shape Mill at Revere Copper and Brass, Detroit, Michigan from 1943 through 1984.*

The petitioner provided information and affidavit statements in support of the petitioner’s belief that accurate dose reconstruction over time is impossible for the Revere workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00164 for evaluation:

> The petitioner stated that, to the best of his knowledge, Revere Copper and Brass never used any type of monitoring device to detect radiation at the facility.

[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.

Based on its Revere Copper and Brass research and data capture efforts, NIOSH determined that it has access to a limited number of air sample and smear survey results for Revere during the time period under evaluation. However, NIOSH also determined that medical records, bioassay data, and external monitoring results are not available. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that internal and external radiation exposures and radiation doses were not adequately monitored at the Revere site, 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.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH divided the petitioner-requested class because it was able to determine the end of the operational period, and thus, the duration of the residual period. Therefore, NIOSH defined the following class for further evaluation: All workers who worked at Revere Copper and Brass, Detroit, Michigan from July 24, 1943 through December 31, 1954 and for the residual period from January 1, 1955 through December 31, 1984.

The operations start date was changed from 1943 to July 24, 1943 when the first extrusion was performed for the MED. The last extrusion performed for the AEC was on October 19, 1954; for the purposes of this evaluation, the operational period end date was extended to the end of 1954. January 1, 1955 represents the beginning of the residual period, which continued through the end of 1984, the year the facility was demolished.

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

Based on its research of the class under evaluation, NIOSH has defined a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH-proposed class to be added to the SEC includes all Atomic Weapons Employer employees who worked at Revere Copper and Brass, Detroit, Michigan, from July 24, 1943 through December 31, 1954, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

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

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

4.1 Site Profile Technical Basis Documents (TBDs)

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

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

- *TBD: Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals, Appendix AS – Copperweld Steel Co.*, Battelle-TBD-6000, App. AS, Rev. 0; Battelle; July 16, 2007; SRDB Ref ID: 74751

- *TBD: Hanford Site – Site Description*, ORAUT-TKBS-0006-2, Rev. 2; Oak Ridge Associated Universities; February 22, 2010; SRDB Ref ID: 79424

4.2 Technical Information Bulletins

A Technical Information Bulletin is a general working document that provides guidance for preparing dose reconstructions at particular sites or categories of sites. NIOSH reviewed the following Technical Information Bulletins as part of its evaluation:

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

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

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

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

4.3 Facility Employees and Experts

To obtain additional information, NIOSH conducted seven interviews with four former Revere Copper and Brass employees.

- Personal Communication, 2010a, *Personal Communications with Former Lab Worker*; Telephone Interviews by ORAU Team; April 13, 2010; follow-up call June 8, 2010; SRDB Ref ID: 81007

- Personal Communication, 2010b, *Personal Communications with Former Chemist*; Telephone Interviews by ORAU Team; April 15, 2010; follow-up call June 8, 2010; SRDB Ref ID: 81008

- Personal Communication, 2010c, *Personal Communication with Former Tester*; Telephone Interview by ORAU Team; April 16, 2010; SRDB Ref ID: 81009

- Personal Communication, 2010d, *Personal Communications with Former Draftsman*; Telephone Interviews by ORAU Team and NIOSH staff; April 14, 2010; follow-up call June 7, 2010; SRDB Ref ID: 81010

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of May 25, 2010)

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

Description	Totals
Total number of claims submitted for dose reconstruction	8
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1943 through December 31, 1984).	8
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	8
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	0

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. NIOSH has not identified any internal or external dosimetry data for these claimants. The Computer Assisted Telephone Interview (CATI) documentation indicated that interviewees stated: (1) there was no monitoring; or (2) they did not know if monitoring was provided or if bioassay or biological samples were taken.

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 hundred thirty-nine documents in this database were identified as pertaining to Revere Copper and Brass. These documents were evaluated for their relevance to this petition. The documents include process descriptions, discussions of radiation hazards associated with uranium, medical program descriptions, air sample data, experimental procedures for determination of extrusion parameters, and plant descriptions.

4.6 Documentation and/or Affidavits Provided by Petitioners

In qualifying and evaluating the petition, NIOSH reviewed the following document submitted by the petitioner:

- *Affidavit from Survivor Representative*; January 21, 2010; OSA Ref ID: 110730

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

ATTRIBUTION: Section 5.0 and its related subsections were completed by Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following subsections summarize the radiological operations at the Revere Copper and Brass site from July 1943 through December 1954 and the information available to NIOSH to characterize particular processes and radioactive source materials. The residual period from January 1955 through December 1984 is also discussed. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of some radionuclides 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 Revere Copper and Brass Plant and Process Descriptions

The primary radioactive materials at Revere were natural uranium and thorium metals existing either separately or as alloys. Revere's main function was the extrusion of uranium billets into rods and various other shapes for use by Hanford, Savannah River Site, and Oak Ridge National Laboratory (ORNL). During 1943 and 1944, under the MED contract, Revere extruded approximately 2,695,205 lbs. of billets. Even though there was strict accountability of the metal, the total quantity of material processed over the period under evaluation is not accurately known. Thorium was extruded on an intermittent basis and the amount of thorium extruded is also not known. Additional work on the extrusion, shaping, and machining of uranium and thorium was done intermittently through 1954 (Fisher, 1954; Montenyohl, 1952; Various Authors, 1949-1952).

Revere Copper and Brass was formed in 1928 from a merger of six small copper and brass companies. Soon after its inception it was one of the largest copper manufacturers in the United States, producing copper pipes, bars, tubes, and sheets as well as cookware. The Revere site was located at 5851 W. Jefferson Street in Detroit, Michigan. The plant consisted of four buildings, including the Foundry building, the physical/chemical labs/machine shop building, the Extrusion Area building, and a smaller building that may have been used for offices. The portions of the site that are of particular interest in terms of potential radiological contamination are two extrusion presses and a furnace, all housed in the Extrusion Area building, as well as the high bay area of the Extrusion Area building that would have been susceptible to the accumulation of radioactive dust due to airborne contamination (DOE, 1990). Figure 5-1 shows the buildings and equipment locations at the Revere site (ANL, 1981).

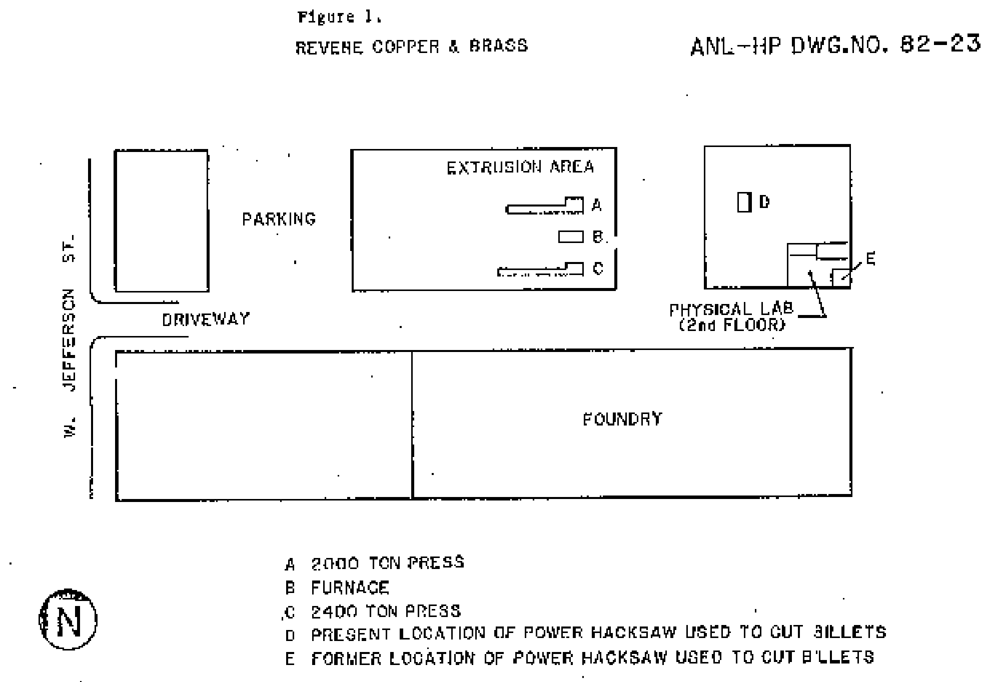

Figure 5-1: Buildings and Equipment at Revere Copper and Brass

When the United States entered World War II, Revere turned its production from house wares to war materials. In 1942, Revere began making cartridge cases, rocket cases, and smoke bombs. In 1943, E. I. du Pont de Nemours and Company contracted with the MED to extrude natural uranium. In turn, DuPont issued purchase orders to Revere from July 24, 1943 through 1944 to extrude approximately 1200 tons of natural uranium and to conduct special experiments (DuPont, 1945).

In December 1944, a MED letter stated that all Revere uranium extrusion operations had been terminated and a survey had been made to ascertain that all possible remaining metal had been recovered (Johnson, 1944). However, a June 21, 1946 MED monthly report (Schumar, 1946) stated that "extrusion of myrnalloy [uranium-thorium][4] rods and beryllium shapes was conducted at Revere on June 6, 1946." This was an attempt to extrude two myrnalloy 6 ½-inch diameter billets into 1 ¾-inch rods. Nevertheless, during the 1943-1944 time frame, the vast majority of the MED work consisted of uranium extrusion.

Revere had a separate contract with the AEC from mid-1949 through mid-1954 for extruding uranium and thorium for research activities. The amount of material handled for the AEC contract is unknown. Revere also performed other experimental extrusions for the AEC between 1947 and 1949 (Kattner, 1947a; Kattner, 1947b; Kattner, 1947c; Kattner, 1947d). Documentation available to NIOSH indicates that the extrusion of thorium was done on an intermittent basis and appears to have consisted

[4] The Hanford Site Profile defines myrnalloy as thorium (ORAUT-TKBS-0006-2). However, the Argonne National Laboratory survey group referred to myrnalloy as a mixture of uranium and thorium (ANL, 1981). This evaluation report employs the ANL definition.

of smaller quantities (as compared to the production quantities of uranium). One example is the extrusion of three bare and/or unsheathed thorium billets on November 5 and 6, 1952 (Various Authors, 1949-1952). In addition to natural uranium and thorium, Revere extruded alloys of these two elements that included stable fission elements such as columbium (niobium), molybdenum, zirconium, lanthanum, and ruthenium (Foote, 1944a; Foote, 1944b; Order Request and Shipping Receipt, 1944).

When Revere became involved in the extrusion of uranium in 1943, the methods for the extrusion of uranium were being developed. The beginning of this effort and the associated problems encountered are best described in the DuPont document, *The Metal Fabrication Program for the Clinton Engineer Works and the Hanford Engineer Works* (DuPont, 1945). This document describes the DuPont Engineering Department program to produce uranium slugs. These slugs, each one a small cylindrical mass of uranium enclosed within an aluminum jacket, were used as the charge in the atomic pile to manufacture, through nuclear processes, minute quantities of plutonium for the atomic bomb project.

Prior to the production-scale extrusion program at Revere, the use of uranium (referred to in correspondence variously as T-metal, Tuballoy, X-metal, DuPont Special Alloy, Chemicals NO1BN, and C-105) had been generally limited to small amounts (grams) in the laboratory. At that time, little was known about uranium's commercially-adaptable physical properties. The accelerated fabrication of hundreds of tons of uranium required the inauguration of an arduous series of experimental and developmental programs to determine not only the extrudability, machinability, and other physical characteristics of the metal, but also the influence of microscopic quantities of impurities on these characteristics (DuPont, 1945). Revere played a significant role in these efforts.

The DuPont Engineering Department realized early on the health hazards attendant to the fabrication of this metal. On March 20, 1943, prior to starting work on the slug program, they asked the University of Chicago Metallurgical Laboratory (Met Lab) for information about the precautions to be taken to protect the health of all individuals exposed to uranium. The Met Lab advised the use of masks, respirators, and gloves as well as a complete physical examination of each employee prior to exposure to the metal. Entrance, periodic, and exit physical examinations were made by the plant physician, by a retained physician, or by members of the DuPont staff, as best fitted each vendor. Due to security requirements, the cost of all protective measures incurred by Revere (and other vendors) as a result of Met Lab and DuPont recommendations were reimbursable from the DuPont Engineering Department. This included the installation of adequate ventilation where necessary.

When the fabrication program expanded to embrace machining, outgassing and straightening, canning, and rolling of the metal, the Met Lab medical group visited the program vendors and made further recommendations and tests. Among the latter was the determination of the dust count in the air near each of the operating machines. On the basis of these findings, a suggested tolerance limit of 150 micrograms of uranium per cubic meter ($\mu g\ U/m^3$) of air was adopted. This figure later was reduced to 120 ($\mu g\ U/m^3$) after continued study confirmed the need to reduce the tolerance limit (DuPont, 1945).

Many dust counts taken at Revere, particularly those taken in areas of high local concentration, greatly exceeded the limit. After the first few extrusion runs at Revere, the Met Lab determined that ventilating equipment was needed at this location to reduce the dust count to a level below the tolerance limit. The DuPont Engineering Department confirmed this recommendation and further proposed that a dust collector be installed in the system to save metal and to prevent the free discharge of uranium dust to the Detroit atmosphere; both were installed.

When the uranium slug program drew to a close in August 1944, strict accountability records for all scrap uranium material were required. To this end, an accounting was taken of all uranium sample pieces and scrap. The ventilating and dust-collecting systems at Revere were also cleaned to collect all possible deposits of uranium metal.

The Initial Revere Extrusion Effort

Revere performed production-level work with natural uranium ingots from 1943 to 1944 and with natural uranium metal and uranium oxides from 1946 to the mid-1950s (FUSRAP, 2000). Table 5-1 lists the dates, the number of billets and rods, and the weight of the billets that were processed for the MED at Revere from July, 1943 to August 31, 1944 (DuPont, 1945). On three occasions (April 18, May 11, and May 18, 1944), Revere extruded uranium alloys that contained stable fission elements such as molybdenum, niobium (columbium), lanthanum, ruthenium, and zirconium on an experimental basis as requested by DuPont or the Metallurgical Laboratory (Foote, 1944a; Foote, 1944b; Order Request and Shipping Receipt, 1944). These alloys were classified as either Type I or Type II metals. Revere also extruded alloys of uranium-beryllium, uranium-thorium, and other uranium during the period under evaluation (ANL, 1981; Foote, 1944a; Foote, 1944b; FUSRAP, 2010; Order Request and Shipping Receipt, 1944; Schumar, 1946).

NIOSH has not identified any radioactive material processed after October 19, 1954. However, residual contamination may have existed on the equipment that was previously used for radioactive work.

The first extrusion runs at Revere were performed on Saturday and Sunday, July 24-25, 1943. According to the documentation (DuPont, 1945, pdf pp. 39, 54-55), all Revere runs were made on weekends because security limitations prevented their execution during the normal workweek. However, it is noted that several runs were also made on weekdays. Revere extrusion runs are shown in Table 5-1. This initial extrusion effort continued until August 20, 1944.

Table 5-1: Uranium Extrusions Performed at Revere for the MED, 1943-1944

Dates	No. of Billets	No. of Rods	Billet Weight (lbs.)
Year 1943:			
7/24-25	400	399	37,434.75
7/31, 8/1	500	498	46,219.75
8/14-15	620	614	56,673.25
8/21-22	309	309	29,356.25
8/21-22	205	205	19,864.75
8/29	5	5	438.5
8/28-29	590	589	51,587.00
9/4-5	600	596	53,061.50
9/11-12	550	543	50,628.00
9/18-19	580	578	56,974.00

Table 5-1: Uranium Extrusions Performed at Revere for the MED, 1943-1944			
Dates	**No. of Billets**	**No. of Rods**	**Billet Weight (lbs.)**
10/2-3	416	410	41,098.75
10/9-10	550	549	52,838.50
10/16-17	590	588	60,280.25
10/23-24	500	498	50,932.00
11/6-7	570	567	57,690.63
11/13-14	630	513	53,355.00
		100	10,489.88
11/19-21	1032	41	4,216.00
		160	16,738.00
		821	84,599.63
12/4-5	462	453	46,909.86
12/10-11	710	701	74,510.19
12/18-19	630	605	65,167.68
Year 1944:			
1/8-9	535	526	63,321.87
1/22-23	679	625	78,697.13
2/5-6	333	332	35,985.95
	20	20	2,138.38
2/12-13	570	557	82,417.93
2/19-20	381	349	44,840.00
3/4-5	612	607	73,976.91
3/11-12	306	306	36,729.19
3/24-25	607	605	73,358.13
3/31, 4/1	616	613	78,867.89
4/14-15	554	553	66,202.46
4/29	330	329	39,055.57
5/6-7	596	596	70,479.00
5/13	324	324	39,298.69
5/19-21	962	962	118,942.14
6/2-4	939	938	112,989.99
6/9-10	648	648	76,729.56
6/17-18	600	591	71,698.03
6/23-25	940	938	113,626.80
6/30, 7/1	640	639	71,804.53
7/15-16	657	656	78,199.63
7/29-30	654	653	79,459.26
8/12-13	620	620	74,963.21
8/19-20	676	676	84,357.89
Total	**24,248**	**24,005**	**2,695,204.90**

Outgassing and Straightening

In 1943, the DuPont Engineering Department determined that it wanted extruded rods outgassed and straightened. Outgassing involves removing hydrogen from the rod material. This was done by packing the rods in 10-inch diameter steel tubes, capping the ends of the tubes, and leaving a small opening at each end. In order to outgas hydrogen, argon gas was passed through the steel tubes while they were being heated in a furnace to 1200 degrees F. (DuPont, 1945; Battelle-TBD-6000, App. AS).

Revere was not initially involved with the outgassing and straightening program. However, DuPont felt that if these processes were performed at the extrusion facility, it would expedite delivery and result in a pronounced savings to the government by eliminating shipment to a third party with the associated security costs. Accordingly, Revere started outgassing Hanford-size rods on September 11-12, 1943. From the end of November 1943 to August 1944, the outgassing procedure was standardized with little or no difficulty (DuPont, 1945, pdf pp. 77-79).

Alpha Phase Extrusion Experiments

Additional experimental work was performed at Revere for the AEC to determine the optimum conditions for alpha phase extrusion of uranium rods. Between room temperature and its melting point (2070 degrees F.) uranium metal exists in three crystalline forms known as the alpha, beta, and gamma phases. Experiments were performed by Revere to determine the optimum conditions for alpha phase extrusion of uranium rods (Hanford Works, 1948; Kattner, 1947a; Kattner, 1947b; Kattner, 1947c; Kattner, 1947d). These experimental procedures are similar to the normal extrusion procedures and could have resulted in personnel exposures. These experiments were conducted on September 17-18, October 10, and November 3, 1947. In addition, the Massachusetts Institute of Technology (MIT) conducted some extrusion experiments at Revere on October 23-24, 1947 that involved the extrusion of beryllium and of uranium in the alpha phase (Kattner, 1947c).

Thorium Extrusions

Thorium extrusions were conducted at Revere on an experimental and intermittent basis in contrast to the production levels of uranium. NIOSH has identified the following thorium extrusion operations at Revere:

- October 8, 1946: Thorium rods were requested by Clinton Laboratories. Five of the best rods were chosen, indicating that more than five rods were extruded (Mecherey, 1947).

- August 13-15, 1952: Two billets were expected to be extruded on an experimental basis. Documentation of completion of these extrusions has not been found (Hayes, 1952).

- November 5 and 6, 1952: Three thorium billets were extruded (Various Authors, 1949-1952).

- November 14, 1952: Thorium billets were extruded; the total quantity is not stated but sufficient thorium was extruded for the production of 200 slugs (Montenyohl, 1952; Noto, 1952).

- October 19, 1954: Thorium rod was extruded for machining into slugs; half were shipped to Savannah River and half were shipped to Sylvania Electric Products (Fisher, 1954).

The 1954 thorium extrusion operation ended the extrusion program at Revere. The residual period started on January 1, 1955 and continued until December 31, 1984, the year the facility was demolished.

5.2 Radiological Exposure Sources from Revere Operations

The primary sources of external exposure to Revere workers were due to direct radiation from handling and processing uranium and thorium as well as submersion in the air contaminated with these metals. Inhalation and ingestion of contaminated air resulting from re-suspension of surface contamination, during both operations and the residual period, was the primary source of internal exposure.

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

5.2.1 Internal Radiological Exposure Sources from Revere Operations

Inhalation of airborne contamination during the various extrusion processes and inhalation of airborne contamination re-suspended during both operations and the residual period were the primary sources of internal exposure to Revere workers.

5.2.1.1 Uranium

During the operations under the MED contracts (July 24, 1943 to August 31, 1944), the primary radionuclide of concern was uranium, also known as tuballoy, X-metal, T-metal, DuPont special alloy, and chemicals NO1BN and C-105. Revere was under a separate contract with the AEC to perform experimental work on rod extrusion as well as the development of slugs for the Clinton Engineer Works and the Hanford Engineer Works.

The principal sources of internal exposure to radionuclides at the Revere site was from the inhalation of dust or fumes generated during various processes, including billet extrusion and shaping, quenching, rod straightening, butt removal, machining and cutting, outgassing, and handling during storing and shipping. Most of these operations were conducted in either the building that housed the furnaces and extrusion equipment, or in the building containing the machine shop and physical and chemical labs. Both the furnace and the extrusion machine were equipped with hoods. However, the hood over the extrusion machine was of questionable adequacy and, over time, the hood became warped, resulting in a large gap between the side wall and the hood. During the extrusion operations, large clouds of smoke poured out of the opening. In addition, there was a lack of maintenance on this hood (Nickson, 1944). Handling and storage of incoming material took place in a building called the DuPont compound. It is not clear where on site this building was. However, the material was trucked from that compound to the fabrication area.

During the fabrication process, the billets would first pass through a gas furnace where they were heated to the desired temperature. They were then removed and taken to the extrusion machine. After extrusion, they went to a rolling table where they were partially straightened and allowed to cool to a certain extent. Following partial cooling, they were quenched in a water-filled basin, after which they were placed in another tank containing a 10 % sulfuric acid solution to remove the oxide that was formed during extrusion. At times, the operator used a brush to clean the oxides from the rods. The rods were then hosed off with fresh water. The rods were then removed to a rack where they were numbered and then packaged in boxes for shipping (Nickson, 1944).

During each of these processes there was the possibility of airborne dust or fumes that potentially contained uranium metal. In particular, during the extrusion process and the brushing of the rods to remove the oxides, uranium oxides were a significant source of airborne contamination and potential internal exposure to workers.

5.2.1.2 Thorium

Thorium extrusions were performed on a developmental and experimental basis in contrast to the production levels of uranium. Therefore, the workers' internal exposure to thorium was significantly less than their exposure to uranium. However, the possibility of direct exposure to radiation from thorium as well as inhalation and ingestion of thorium dust and fumes did exist.

5.2.1.3 Residual Period

The primary source for internal exposure during the residual period could have been from working with the contaminated equipment used during the operational period, eating in the work area, and re-suspension of contamination. Several air samples were taken during the operational period both for uranium and thorium, as indicated in Section 6.1, Tables 6.1 and 6.2. The highest air sample result for uranium was 3300 µg/m^3. All thorium air samples were within the tolerance level of 70 dpm/m^3. However, the source term for the residual period was assumed to consist of both uranium and thorium in equal amounts at the maximum air concentration determined from the air sample results. As discussed in Sections 6 and 7, the highest uranium air concentration value was used to evaluate the contamination levels that could have existed at the beginning of the residual period, and ultimately, the air concentrations during the residual period.

5.2.2 External Radiological Exposure Sources from Revere Operations

The principal source of external exposure during the operational period (other than medical X-rays) was the direct exposure to natural uranium and thorium metal during the extrusion process, submersion in air potentially-contaminated with uranium and thorium metal, and exposure to contaminated surfaces. Uranium and thorium alloys were also extruded. Tables 5-2 and 5-3 list the radionuclides of concern for external radiation from uranium and thorium during the operational period.

Table 5-2: Principal Radiation Emissions from Natural Uranium and Its Short-lived Decay Products

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

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

Table 5-3: Principal Radiation Emissions from Th-232 and its Short-Lived Decay Products			
Radionuclide	**Half-life**	**Beta Energy (MeV Max)**	**Photon (x or •) 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 • s)	---
Th-228	1.9116 years	None	0.084 (1.19%)
			0.132 (0.11%)
			0.166 0.08%)
			0.216 (0.27%)
Bi-212	60.55 minutes	1.59 (8%)	0.040 (1%)
		2.246 (48.4%)	0.727 (11.8$)
		---	1.620 (2.75%)
Tl-208	3.1 minutes	1.28 (25%)	0.277 (6%)
		1.52 (21%)	0.5108 (21.6%)
		1.80(50%)	0.583 (85.8%)
		---	0.860 (12%)
		---	2.614 (100%)

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

5.2.2.1 Photon

The majority of the photons from natural uranium metals are in the 30-250 keV energy range. Solid uranium objects provide considerable shielding of the lower-energy photons and harden the spectrum, causing the majority of the photons emitted from a solid uranium object (such as 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 5-2 shows the primary isotopes and photon energies associated with the uranium metal. Exposure to these photons was possible during all phases of the extrusion process from direct radiation during metal-handling and to submersion in metal-contaminated air.

Thorium has a significant number of higher-energy photons in the Th-232 decay chain. Based on the half lives of the progeny, only a partial equilibrium is possible; therefore, it is conservative to state that equilibrium would be reached in this decay chain. It has been assumed that Ra-228 and Th-228 progeny were in equilibrium with Th-232. Therefore, air concentrations were assumed equal for all progeny. Under this assumption, the progeny are the major source of both penetrating and non-penetrating external exposure. Table 5-3 shows the primary isotopes and photon energies associated with thorium and its progeny.

5.2.2.2 Beta

Tables 5-2 and 5-3 show the principal beta emitters and their energies for the uranium and thorium metal used during the extrusion process. As indicated in these tables, there are a significant number of high-energy beta radiations that represent a shallow dose exposure concern to site workers. Workers who handled the uranium and thorium metal would have received shallow dose exposures. The primary exposure areas would have been the hands and forearms, the neck and face, and other areas of the body that might not have been covered.

5.2.2.3 Neutron

Neutrons were not measured at Revere and were not expected to be a source of exposure for the class under evaluation. However, neutrons could arise from the • -n reaction with light elements (e.g., beryllium), interactions with the oxides, and through spontaneous fission. According to Battelle-TBD-6000, uranium oxides would be the most common generators of (• ,n) reactions. However, the quenching and the brushing off of the rods would minimize this source of neutrons. Although beryllium was extruded by MIT at Revere (DuPont, 1943; Kelley, 1949), the available documentation indicates that only one uranium-beryllium rod was extruded on June 6, 1946 (Schumar, 1946). Spontaneous fission yields and (• ,n) yields in oxides are provided in Table 3.5 of Battelle-TBD-6000. Based on its analysis, NIOSH concludes that none of these sources would be sufficient to result in a significant neutron exposure to Revere workers.

5.2.2.4 Residual Period

During the residual period, January 1, 1955 to December 31, 1984, workers were potentially exposed to direct radiation from surface contamination as well as exposure resulting from submersion in air contaminated with re-suspended residual uranium and thorium. This would include re-suspension from incidental removal of residual contamination (e.g., via housekeeping and personnel and equipment movement). A survey was performed on April 22, 1981 at Revere in three areas where operations with uranium and thorium were conducted (ANL, 1981, pdf pp. 3-4). The survey included direct radiation measurements and smear surveys. The survey results are presented in Section 6.1.

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

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

6.1 Available Revere Internal Monitoring Data

ATTRIBUTION: Section 6.1 was completed by Eugene Potter, Mel Chew & Associates; and Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

Medical Records

Under the early uranium program, the DuPont Company had the responsibility for directing the medical examinations and all medical records were to be turned over to them (DuPont, 1945, pdf p. 16; Wirth, 1945, pdf p. 6). These records have not been located or recovered.

Bioassay Data

No bioassay data are available for Revere. References in the site documentation to periodic urine samples were probably about non-radiological medical tests as part of medical monitoring (Nickson, 1944). Most of Revere's uranium work was performed in 1943-1944 (DuPont, 1945). Fluorometric measurement techniques for uranium were not in use until the late 1940s (Stannard, 1988, pdf p. 132).

Blood counts were part of the required physical examinations before starting work; they were repeated at three-month intervals (Norwood, 1944). Moderate anemia (low count of healthy red blood cells) was noted in the pre-employment examinations for two of the employees (Quigley, 1943). Blood counts were used in the early years to monitor potential radiation damage to the hematopoietic system. Note: Blood count information is not normally used as bioassay data for the purpose of radiological dose reconstruction.

Whole Body Counting Data

Whole body counting, a technique employed to monitor photon-emitting radionuclides in the body, was not developed until the early to mid-1960s; by that time, radioactive work had concluded at Revere.

Air Sample Data

A limited number of uranium air sample results were discovered for the Revere operational period. They are listed in Table 6-1 along with their source documents. All results are from MED consultants who visited the site to review health and safety practices. Initially, medical doctors from the Met Lab were assigned to conduct dust studies and to recommend ventilation improvements and the use of protective devices, such as respirators (DuPont, 1945, pdf p. 18). There is no indication that an in-house air sampling program existed. Radioactive material extrusions were performed in the same areas as normal plant operations but under MED supervision. These operations were conducted during off-hours and weekends when most of the workforce was not present.

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

Sample Date	Sample Location	Result ($\mu g/m^3$)	SRDB Ref ID
July 24, 1943	East of the furnace	580	10782, 11207
	North of the extrusion press operator	230	10782, 11207
	Point of false butt removal	2320	10782, 11207
August 21, 1943	Northeast corner of the roll table	2200	10782, , 11207, 17357
	Outlet of the extruder	1100	10782, 11207, 17357
	Furnace outlet where the operator cleans billet with wire brush	3300	10782, 11207, 17357
	East side of furnace	100	10782, 11207, 17357
September 17-19, 1943	Outlet gas from outgassing furnace	0	10782, 17357
	South of point where dummy butts are pounded off	120	10782, 17357
	Corner where south edge of dry roll table abuts rolls leading from extruder	240	10782, 17357
	South of extruder valve operator, side of extruder	2500	10782, 11207, 17357
	Inlet to rod straightening machine	2500	10782, 11207, 17357
	Outlet to rod straightening machine	2600	10782, 11207, 17357
February 5, 1944	Extruder operator	1650	11207
	Edge of hood at outlet of extruder	100	11207
May 5, 1944	Four locations – illegible	Partially illegible[a]	80176
May 7, 1944	Four locations – illegible	Partially illegible[b]	80176
November 16, 1944	Next to the extrusion apparatus (numerical result not given)[c]	<150	80439
	Next to the butt removal procedure (numerical result not given)[c]	<150	80439
December 21, 1949	General air result: 0.9 alpha dpm/m^3	0.59[d]	10773

[a] Three values are four digits; one value is three digits.
[b] Three values are three digits; one value is four digits.
[c] The author stated: “In neither instance was a tolerance figure obtained on the samples.”
[d] Calculated assuming a conversion factor of 1.52 dpm/μg of natural uranium. This value is consistent with the statement in the source document that the result was less than 2% of tolerance (<3 $\mu g/m^3$).

The available air sampling results for thorium operations are also limited. The only results NIOSH has obtained are for samples taken during thorium extrusion performed on November 5-6, 1952 (Various Authors, 1949-1952). This work was under the supervision of the AEC (which replaced the MED on January 1, 1947). Apparently, the monitored thorium operation was part of “development work” and was not production-related. Health and safety support was provided by MIT personnel who took the air samples. The report lists the results in units of counts per minute per cubic meter. No conversion factor from counts per minute to disintegrations per minute was provided. The author noted that the thorium tolerance limit was 70 disintegrations per minute and stated that the results were well below this level (Various Authors, 1949-1952). The thorium results appear in Table 6-2. It is assumed that the term “covered,” which is used in the reference, refers to the fact that the billets were clad with some other metal before extrusion.

Table 6-2: Available Thorium Air Samples for the Revere Operational Period

Sample Date	Description: Units Given	Result (dpm/m^3)[a]	SRDB Ref ID
November 5, 1952	No extrusions (background): 2.4±2.4 counts/min/m^3	<70	10773
	Covered thorium: 0±2.4 counts/min/m^3	<70	
	Uncovered thorium: 4.8±4.8 counts/min/m^3	<70	
November 6, 1952	Uncovered thorium: 9.6±2.4 counts/min/m^3	<70	
	Background ½ hour later: 8.4±2.4 counts/min/m^3	<70	

[a] Calibration factors were not published. All results were termed “well within tolerance” (70 dpm/m^3). This implies that the calibration factor was in the range of 4-6 dpm/cpm.

Operational Survey Data

Smear surveys may have been done routinely during the operational period by the MED/AEC or their consultants. However, only a few records have been located. The results are listed in Table 6-3.

Table 6-3: Available Smear Surveys for the Revere Operational Period

Sample Date	Sample Location	Result (• dpm/100 cm^2)	SRDB Ref ID
December 21, 1949	Surface of extrusion press previously used for uranium work	24	10773
	Under runout table	11	
	Beta thickness gauge	25	
	Die in storage (previously used for uranium work)	2700	

Residual Survey Data

There is one record of a "preliminary survey" during the residual period conducted by Argonne National Laboratory on April 22, 1981 (ANL, 1981). This survey "found no evidence to indicate that an immediate radiological hazard exists." Figure 6-1 shows the general area where the Extrusion Area survey was performed.

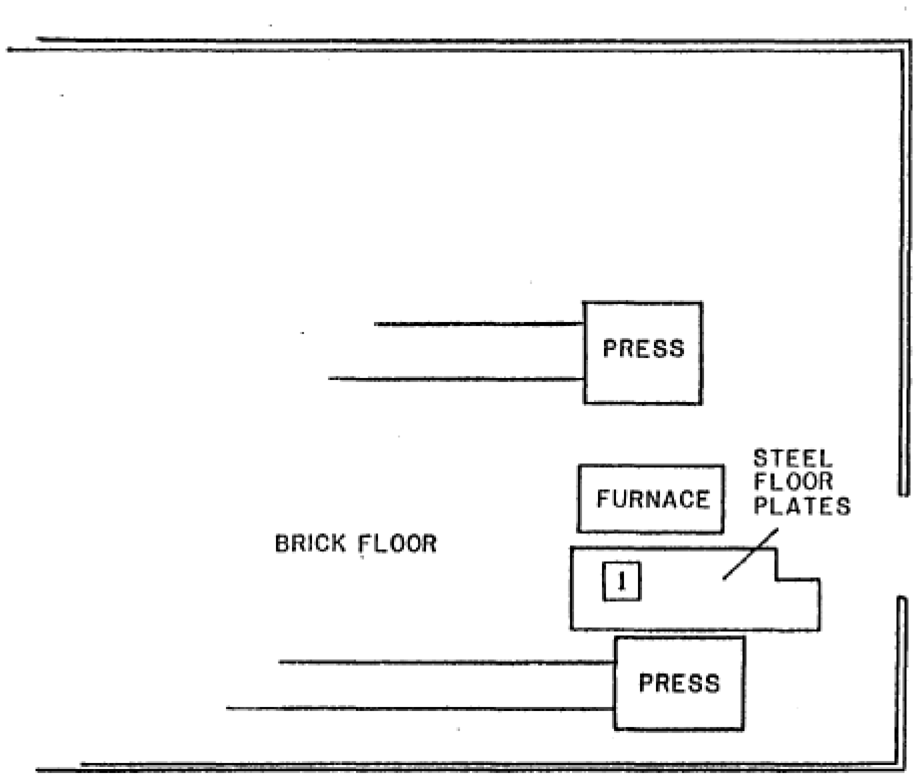

Figure 6-1: Survey Area in the Revere Extrusion Area

The results of ANL's direct radiation measurements and smear samples are shown in Table 6-4. Alpha survey instruments did not show detectable contamination in the Extrusion Area or the Physical Laboratory where uranium billets were stored and where a power saw had been used to cut extruded rods. Smear surveys were taken of the steel floor and glazed tiles in the Extrusion Area and of the power saw in the Physical Laboratory. From the context of the source document (ANL, 1981), the box labeled "1" in Figure 6-1 is likely the "Radioactive Anomaly on the Steel Floor" referred to in Table 6-4. The smears indicated background levels. The furnace and one of the extrusion presses was in operation and could not be surveyed. However, the furnace was not the one that had been used for uranium and thorium work. The surveyors were not aware that some ventilation equipment had been used during these operations and speculated that contamination had likely migrated to the overhead members and vents in the roof, which was of steel bridge truss construction. A more thorough survey was recommended (ANL, 1981). The recommended re-survey was never conducted, and when DOE officials visited the site in 1989, they found that it had been demolished. A "cursory radiological survey" conducted during this visit did not find any levels above background (DOE, 1990).

Table 6-4: ANL Survey Results for Revere Copper and Brass – April 22, 1981			
Area 1 – Physical Laboratory (former storage area for uranium billets)			
Survey Meters	**Glazed Wall Tile**	**General Floors & Tile**	**Background in Area**
PRM-7(A)	15 µR/h	8-9 µR/h	8-9 µR/h
PRM-5-3	1500-2000 cpm	1000 cpm	1000 cpm
PAC-4G-3	< 50 cpm • 400 cpm • •	< 50 cpm • 250 cpm • •	< 50 cpm • 250 cpm • •
Area 2 – Power Hacksaw Used to Cut Billets			
Survey Meters	**Present and Former Location of Power Hacksaw**		
PRM-7, PRM-5-3, PAC-4G-3	All readings indicated background level		
Area 3 – Extrusion Area			
Survey Meters	**Spot on Steel Floor**	**Floor Bricks**	**Background in Area**
PRM-7(A)	7 µR/h (contact)	3-4 µR/h	3-4 µR/h
PRM-5-3 (B)	3000 cpm	1500-2000 cpm	500- 1000 cpm
PAC-4G-3 (C)	< 50 cpm • 7500 cpm • •	< 50 cpm • 200 cpm • •	< 50 cpm • 220 cpm • •
Smear Results	**"Radioactive Anomaly on the Steel Floor"**	**Glazed Tile**	**Power Hacksaw**
	background level	background level	background level

6.2 Available Revere External Monitoring Data

ATTRIBUTION: Section 6.2 was completed by Ray Clark and Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

Operations Period

NIOSH has found no external personnel monitoring results (including medical X-ray records) for the Revere operations period from 1943 through 1954.

Residual Period

NIOSH has found little survey data for Revere during the residual period from 1955 through 1984. A preliminary (screening) survey was conducted on April 22, 1981 by the Argonne National Laboratory Radiological Survey Group (ANL, 1981). Although the preliminary survey revealed no evidence of an immediate radiological hazard, the group recommended that a complete radiological assessment be conducted of the entire facility when the furnace and extrusion presses were shut down and in a cold condition. NIOSH has found no evidence that this follow-up survey was conducted.

On September 13, 1989, a DOE official and "representatives" visited the site and observed that it had been demolished. A cursory radiological survey revealed no areas with direct radiation levels above background levels. Preliminary survey results of a facility in the Detroit area used for similar purposes, whose structures were intact, did not identify any areas of residual contamination. Based on this information, DOE concluded that there was little or no potential for radiological exposure beyond background radiation; therefore, additional investigations were deemed unnecessary (DOE, 1990).

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

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

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.5. 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-00164 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Revere Copper and Brass 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

ATTRIBUTION: Section 7.1.1 was completed by Eugene Potter, Mel Chew & Associates; and Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

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

The air sampling and survey data from the MED/AEC are contained in original reports, and are therefore primary data sources, as are the survey results reported by ANL in 1981. Therefore, no additional pedigree review was performed for those data.

Air samples were taken on six occasions from July 24, 1943 to November 16, 1944 during the uranium production runs. However, during the research and development work (1944-1954), air sample results were only recovered for one small thorium run and those results were reported in "counts" with no conversion factor to activity. No results were found for the bulk of the operations during this period. Because of the nature of research and development work, no conclusion could be drawn about the representativeness of the single thorium sample for the operational period at the site.

During the residual period, information is also lacking. All indications are that the residual contamination was at background levels for all but a single smear measurement from a die that had been used during uranium operations. However, the possibility exists that the survey data were not representative of all areas of the site. Because ventilation improvements were made throughout the production period, and the amount of material processed during the research and development period was smaller relative to the uranium operations, the worst-case air contamination conditions are known.

7.1.2 External Monitoring Data Pedigree Review

<u>ATTRIBUTION</u>: Section 7.1.2 was completed by Ray Clark and Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

NIOSH did not locate any external monitoring data for the operational period under evaluation (July 24, 1943 through December 31, 1954). Therefore, a data sufficiency and pedigree evaluation is not possible for this data type for this period.

NIOSH has identified limited data for the residual period (January 1, 1955 through December 31, 1984). These data are the results of a survey performed by ANL in 1981 (ANL, 1981). This was the original report and no additional pedigree review was performed.

There were several uranium air samples and one thorium air sample taken during the operational period. NIOSH has concluded that using the maximum air sample result, determining the surface contamination and resultant re-suspended air concentration would be sufficient for bounding the external dose during the residual period.

7.2 Evaluation of Bounding Internal Radiation Doses at Revere

<u>ATTRIBUTION</u>: Section 7.2 and its related subsections were completed by Eugene Potter, Mel Chew & Associates. These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The principal source of internal radiation doses for members of the class under evaluation was the potential inhalation and ingestion of airborne natural uranium and thorium by employees directly involved in the extrusion, quenching, straightening, and cutting of the materials. Other employees were potentially exposed to the re-suspension of contamination on surfaces during the course of their work with non-radioactive materials. The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

Because NIOSH did not locate urinalysis or other bioassay monitoring data for the period under evaluation, internal exposure must be determined based on radiological source term and area monitoring data. Workers not directly involved in the extrusion operations were potentially exposed to the re-suspension of contamination that may have been incompletely removed following radioactive material operations performed primarily during off-shift hours or weekends.

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 Airborne Levels

Early in the operational period, air samples were taken on six occasions during uranium extrusions (see Section 6.1). The air samples were not consistently taken in the same areas; furthermore, information is lacking on the relationship of the sample locations to the areas occupied by workers. Initially, the air concentrations were quite high (up to 22 times the "tolerance" value of 150 µg U/m^3). Gradually, ventilation improvements were made, but sample results still remained above the tolerance level.

During non-MED work, the workers would have been potentially exposed to re-suspended uranium from incompletely-decontaminated surfaces. Workers directly involved in MED extrusions generally wore respirators (Cantril, 1944); however, respirators were probably not required during non-MED work when re-suspension could have produced exposures.

As indicated in Section 5.1, the "development" period did not involve production-level quantities. In a 1989 letter to the Mayor of Detroit, DOE stated: "…the contract with AEC included extruding small amounts of uranium and thorium for research purposes…" (DuPont, 1945; Fiore, 1989). However, the exact workload data for this period has not been located. A number of references to the uranium or thorium work were located (Fisher, 1954; Hayes, 1952; Kattner, 1947a; Kattner 1947b; Kattner, 1947c; Mecherey, 1947; Montenyohl, 1952; Schumar, 1946; Schumar, 1947; Various Authors, 1949-1952). This information seems to indicate that the development work was occasional and probably did not exceed two days per month during this period. The only available operational air samples were from one of the thorium operations and were well below tolerance levels (see Table 6-2). These results may or may not have been typical of the other MED/AEC operations given that the work was developmental and each operation could have presented unique exposure conditions. A single uranium air sample was taken in 1949 as a follow-up to suspected alpha contamination (Various Authors, 1949-1952); however, this sample was not taken during the performance of AEC extrusion operations.

NIOSH has identified methods in Battelle-TBD-6000 to support bounding internal uranium dose for the type of metal work performed during the operational period at Revere Copper and Brass. However, NIOSH has not identified sufficient information or data to support bounding the thorium exposures for the operational period.

In light of the above information, NIOSH has concluded that sufficient data are not available to estimate a bounding internal dose for the operations period from July 1943 through December 1954.

7.2.2 Evaluation of Bounding Residual Period Internal Doses

During the residual period, January 1, 1955 to December 31, 1984, workers were potentially exposed to re-suspended uranium and thorium contamination. Worst-case residual period air concentrations can be based on the available data for the uranium production work early in the operational period. The data in Table 6-1 show that ventilation improved with time and that the air concentrations were reduced. The workload during research and development was much smaller. Techniques are available to determine bounding residual period intakes from airborne contamination. Therefore, there is sufficient information to support bounding internal dose during the residual period.

7.2.3 Methods for Bounding Internal Dose at Revere

7.2.3.1 Methods for Bounding Operational Period Internal Dose

Based on the evaluation in Section 7.2.1, a limited amount of airborne sample results are the only available data for bounding internal dose during the operational period. Battelle-TBD-6000 provides methods for bounding internal uranium dose for the type of metal work performed during the operational period at Revere Copper and Brass; however, NIOSH has found the available data insufficient to bound internal thorium dose.

7.2.3.2 Methods for Bounding Residual Period Internal Dose

Internal dose estimates for the residual period (January 1, 1955 through December 31, 1984) were based on inhalation and ingestion resulting from re-suspension of residual contamination from uranium and thorium extrusion operations. This would include re-suspension from incidental removal of residual contamination (e.g., via housekeeping and personnel and equipment movement). Intakes from the residual period can be bounded using the available data and the methods provided in Battelle-TBD-6000 and ORAUT-OTIB-0070. Battelle-TBD-6000 uses a default assumption for the initial air concentration at the start of the residual period. This Revere assessment used the site-specific maximum available air contamination value during the operational period of (3300 µg/m^3 on August 21, 1943). The concentrations of uranium and Th-232 at the start of the residual period were each assumed to be equal to this value. This assumption is conservative because improvements were made to the ventilation system during uranium production operations. For example, the uranium concentration measured at the extrusion operator's position on February 5, 1944 was 1650 µg/m^3, half of what is being employed in this current calculation. While the amount of uranium and thorium processed during research and development activities is not known, the amount is known to be considerably less than the multi-ton quantities of uranium initially processed during the operations period. The airborne activities of natural uranium and Th-232 at the start of the residual period were calculated by multiplying 3300 µg/m^3 by their specific activities (0.683 pCi/µg for uranium; 0.109 pCi/µg for Th-232) (Rad Handbook, 1970).

In order to determine a surface contamination level, an indoor settling velocity of 7.5 x 10^{-4} m/s was applied over a one-year operating period. Settling was assumed to occur 20 hours per day for 250 operating days. The result is an estimated surface contamination of 3.05 E7 pCi/m^2 of uranium and 4.86 E6 pCi/m^2 of Th-232. A re-suspension factor of 1 x 10^{-6}/m was applied to the surface contamination level to obtain an estimated airborne concentration of 30.5 pCi/m^3 for uranium and 4.86 pCi/m^3 for Th-232. A respiration rate of 12 m^3 per 10-hour day was applied to calculate the daily intake rates. These rates were normalized to 365 days (250 pCi/d for uranium; 40 pCi/d for Th-232) for the first year of the residual period. The Ra-228 and Th-228 daughters were assumed to be in equilibrium with Th-232; equal intake rates were assigned to them.

A total alpha air concentration value (uranium, Th-232, and Th-228) was calculated for the start of the residual period. The calculated value, 89 dpm/m^3, compares favorably with the alpha air concentration of 0.9 dpm/m^3 measured in 1949. This measurement was made during the operational period, but when AEC operations were not taking place. Thus, NIOSH is confident that the air concentrations at the start of the residual period were not higher than the model employed for this evaluation. Exposure will be evaluated on a case-by-case basis for individual claims, but the available data and methods described here support NIOSH's ability to bound internal dose for the evaluated class during the site's residual period.

The daily intake is based on source term data from large-scale operations and is likely to be significantly higher than intakes encountered at Revere at the start of the residual period. In order to account for the continued depletion of the operational source term during the residual period, two methods were considered, as discussed below.

Method 1: A source term depletion of 1% of the surface activity per day is assumed to occur during the first year (1955); the resulting adjustment of 0.03 is applied for the second year (1956). Likewise, a source term depletion of 1% of the surface activity per day is assumed to occur during the second year, and the resulting adjustment of 0.0007 is applied to the third year (1957). For the remainder of the residual period, the source term is assumed to remain constant (ORAUT-OTIB-0070, Table 3-1). Table 7-1 shows the adjustments used in this method to account for the depletion of the source term during the residual period and the resulting intake rates.

Table 7-1: Source Term Depletion Adjustments for the Revere Residual Period (1% Per Day)

Year	Depletion Adjustment	U-Natural Intake (pCi/d)	Th-232 Intake (pCi/d)	Ra-228 Intake (pCi/d)	Th-228 Intake (pCi/d)
1955	1	250	40	40	40
1956	0.03	7.5	1.2	1.2	1.2
1957 – 1984	0.0007	0.18	0.028	0.028	0.028

Method 2: A notional exponential depletion constant was calculated to account for the reduction in the source term. In the deposition scenario previously described, the alpha surface contamination at the start of the residual period was calculated to be approximately 893,000 dpm/100 cm^2 (uranium, Th-232, and Th-228). This is clearly an overestimate. The alpha surface contamination measured in 1981 was background. The background of the alpha instrument used was 50 cpm (see Table 6-4). The probe area would have been either 325 cm^2 (floor probe) or 51 cm^2 (wall probe). The conversion factor from cpm to dpm was approximately 5.9 according to a survey performed by the same Argonne National Laboratory team at another site in 1978 (Argonne, 1982). Using the favorable probe size (51 cm^2), a potential alpha surface contamination of approximately 580 dpm/100 cm^2 was calculated. From the two alpha surface contamination levels (893,000 and 580 dpm/100 $cm^{2)}$, a depletion constant of approximately 0.28 yr^{-1} and a depletion half-time of approximately 2.5 years were calculated based on the delay time of 9,608 days (January 1, 1955 to April 22, 1981). Table 7-2 shows the adjustments used in this method to account for the depletion of the source term during the residual period and the resulting intake rates. This method is recommended for use since it is generally more favorable to claimants. Since the intake rate calculated by this method is less for 1982-1984, it is favorable to use a depletion adjustment of 0.0007 for these years in accordance with the first method.

Table 7-2: Source Term Depletion Adjustments for the Revere Residual Period (Exponential)					
Year	**Depletion Adjustment**	**U-Natural Intake (pCi/d)**	**Th-232 Intake (pCi/d)**	**Ra-228 Intake (pCi/d)**	**Th-228 Intake (pCi/d)**
1955	1.0	250	40	40	40
1956	0.76	189	30	30	30
1957	0.57	143	23	23	23
1958	0.43	108	17	17	17
1959	0.33	82	13	13	13
1960	0.25	62	10	10	10
1961	0.19	47	7.5	7.5	7.5
1962	0.14	36	5.7	5.7	5.7
1963	0.11	27	4.3	4.3	4.3
1964	0.081	20	3.3	3.3	3.3
1965	0.062	15	2.5	2.5	2.5
1966	0.047	12	1.9	1.9	1.9
1967	0.035	8.8	1.4	1.4	1.4
1968	0.027	6.7	1.1	1.1	1.1
1969	0.020	5.0	0.8	0.8	0.8
1970	0.015	3.8	0.6	0.6	0.6
1971	0.012	2.9	0.46	0.46	0.46
1972	0.0087	2.2	0.35	0.35	0.35
1973	0.0066	1.7	0.26	0.26	0.26
1974	0.0050	1.3	0.20	0.20	0.20
1975	0.0038	0.95	0.15	0.15	0.15
1976	0.0029	0.72	0.11	0.11	0.11
1977	0.0022	0.54	0.087	0.087	0.087
1978	0.0016	0.41	0.066	0.066	0.066
1979	0.0012	0.31	0.050	0.050	0.050
1980	0.00094	0.23	0.038	0.038	0.038
1981	0.00071	0.18	0.028	0.028	0.028
1982*	0.00054*	0.13*	0.022*	0.022*	0.022*
1983*	0.00041*	0.10*	0.016*	0.016*	0.016*
1984*	0.00031*	0.077*	0.012*	0.012*	0.012*

* The intake rate calculated by the exponential method results in lower values for 1982-1984; therefore, it is favorable to use a depletion adjustment of 0.0007 for these years in accordance with the 1% per day depletion method.

Ingestion intakes can be calculated by applying the methodology present in *Estimation of Ingestion Intakes*, OCAS-TIB-009. The resulting daily intake values from both inhalation and ingestion are assumed to be the geometric means of lognormal distributions with a GSD of 5 (Battelle-TBD-6000).

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

Although there are methods available to NIOSH in Battelle-TBD-6000 to support bounding internal uranium dose for the operational period at Revere Copper and Brass, NIOSH has not identified sufficient information or data to support bounding the thorium exposures for the operational period. Based on lack of bioassay or other monitoring data for Revere workers, this evaluation concludes that internal dose reconstruction for the Revere operational period is not feasible; however, the internal dose for the residual period can be bounded using the available data and other parameters from Battelle-TBD-6000 and the methodologies discussed in ORAUT-OTIB-0070.

Although NIOSH found that it is not possible to completely reconstruct internal radiation doses for the period from July 24, 1943 through December 31, 1954, NIOSH intends to use any internal monitoring data that may become available for an individual claim or any area monitoring data (that can be interpreted using existing NIOSH dose reconstruction processes or procedures) to support partial dose reconstructions for the operational period at the site. Dose reconstructions for individuals employed at Revere Copper and Brass during the period from July 24, 1943 through December 31, 1954, 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 Revere

ATTRIBUTION: Section 7.3 and its related subsections were completed by Ray Clark and Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The principal source of external radiation doses, other than medical X-rays, for members of the proposed class was exposure to gamma and beta radiation associated with handling and working in proximity to uranium and uranium compounds. Additionally, thorium rods were extruded intermittently between 1946 (Mecherey, 1947) and 1954, which would result in exposure to thorium during that period (Fisher, 1954; Various Authors, 1949-1952).

Documentation available to NIOSH indicates that the extrusion of thorium was done on an experimental basis and appears to have consisted of smaller quantities (as compared to the production quantities of uranium). One example is the extrusion of three bare and/or unsheathed thorium billets on November 5-6, 1952 (Various Authors, 1949-1952). Radionuclides of interest include Th-232 and its decay progeny (e.g., Ra-224, Ac-228, Th-228, Bi-212, and Tl-208). As indicated, thorium was extruded on an intermittent basis until 1954 and the amount extruded is not known (see Section 5.2.1.2). Through a review of available documentation, NIOSH identified air sample collections in November 1952 specifically conducted to detect the presence of thorium.

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

7.3.1 Evaluation of Bounding Process-Related External Doses

NIOSH has not identified any external monitoring records or personal dosimetry data associated with the uranium and thorium processing conducted during the period under evaluation. This was a unique project for which there were no operational logs, minimal descriptions of activities, and little corresponding radiological data. The sources of exposure at Revere were the beta, gamma, and X-ray radiation from the uranium, thorium, and their oxides. NIOSH has not identified any radiological surveys during the period under evaluation. However, NIOSH has identified several gross alpha air monitoring results from 1943, 1949, 1950, and 1952, along with several smear survey results (see Table 6.1) (AEC, 1949-1961; AEC, 1950; AEC, 1952; Cantril, 1944; Quigley, 1943; Various Authors, 1949-1952). No other area monitoring data have been identified.

NIOSH has identified methods in Battelle-TBD-6000 to support bounding external uranium dose for the type of metal work performed during the operational period at Revere Copper and Brass. However, NIOSH has not identified sufficient information or data to support bounding the external exposures associated with the thorium work during the operational period.

In light of the above information, NIOSH has concluded that sufficient data are not available to estimate a bounding external dose for the operational period from July 1943 through December 1954.

7.3.2 Evaluation of Bounding Residual Period External Doses

With the exception of the radiological survey performed by ANL in 1981, and a cursory survey in 1989 when the buildings were demolished, there were no other surveys conducted during the residual period. NIOSH has not identified any external dosimeter results during this period. Nevertheless, personnel were subjected to direct external exposure from surface radioactive contamination and to submersion in contaminated air as a result of re-suspension of surface contamination. Using the air contamination data obtained during the operational period and the methods in Battelle-TBD-6000, there are sufficient data and methods to support bounding the external dose during the residual period.

7.3.3 Revere Occupational X-Ray Examinations

Documents indicate that all new employees received physical exams prior to the start of work. In addition, ". . . urinalysis, blood tests, and X-rays of the chest" were included (Cantril, 1944; Perry, 1943, pdf pp. 6-7). To date, NIOSH has found no records of the X-rays, the X-ray machine parameters used, or any indication that follow-up X-ray examinations were performed.

Occupational X-ray examinations were performed every six months during the operational period (Cantril, 1944). Medical dose for Revere workers can likely be bounded by using the assumptions in the complex-wide Technical Information Bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT-OTIB-0006).

7.3.4 Methods for Bounding External Dose at Revere

Except for medical X-ray dose, NIOSH has determined that external doses for the Revere operational period from July 1, 1943 through December 31, 1954 cannot be bounded. NIOSH has determined that external dose can be bounded during the residual period (January 1, 1955 through December 31, 1984). The following subsections address the ability to bound the external dose for the Revere site.

7.3.4.1 Methods for Bounding Operational Period External Dose

NIOSH has not identified any external monitoring records or personal dosimetry data associated with the uranium and thorium processing conducted during the period under evaluation. This was a unique project for which there were no operational logs, minimal descriptions of activities, and little corresponding radiological data. Other than several gross alpha air monitoring and smear results, no other area monitoring data have been identified. Therefore, NIOSH has concluded that external doses for the operational period of July 1, 1943 through December 31, 1954 for Revere cannot be bounded.

Pre-employment chest X-rays were required for Revere workers (Perry, 1943). ORAUT-OTIB-0006 provides information and guidance for reconstructing doses for the early years for which specific data are unavailable. NIOSH believes this methodology supports its ability to bound occupational medical X-ray doses for the class under evaluation.

7.3.4.2 Methods for Bounding Residual Period External Doses

External dose estimates for the residual period are based on exposure to direct radiation from residual surface contamination and submersion in contaminated air resulting from re-suspension of surface contamination from previous operations. The external dose caused by residual contamination can be bounded by determining the surface contamination using the maximum air sample results recorded during operations at the beginning of the residual period.

NIOSH employed two methods for determining external dose from contamination during the residual period, as described below.

Method 1: Employing the methodology in Battelle-TBD-6000, the Revere analysis uses the maximum air concentration from the available operational air sample results in Table 6-1 (i.e., 3300 $\mu g/m^3$). It is assumed that this air concentration exists at the beginning of the residual period and consists of uranium and Th-232 in equal amounts. Battelle-TBD-6000 provides a method for determining the surface contamination for uranium and thorium and their progeny and for the re-suspension of that surface contamination. NIOSH is aware that, in some cases, equilibrium cannot be attained; this only ensures that the final estimate is indeed bounding.

The assumptions used in the Revere assessment consist of a settling velocity of 7.5×10^{-4} $m\text{-}s^{-1}$ for 20 hours per day for one year, and a re-suspension factor of 1×10^{-6}/m. Specific activity is given as 1.52 dpm/µg for natural uranium and 0.242 dpm/µg for Th-232. Applying these factors results in surface contamination levels of 6.77×10^7 dpm/m^2 (3.05×10^7 pCi/m^2) for uranium and 1.08×10^7 dpm/m^2 (4.86×10^6 pci/m^2) for Th-232. To determine the submersion dose, the values for the air concentration after applying the re-suspension factor of 1×10^{-6}/m are 30.5 pCi/m^3 for uranium and 4.86 pCi/m^3 for thorium. Assuming the Th-232 and progeny are in equilibrium (see Table 5-3), and using the dose conversion factors in *External Exposure to Radionuclides in Air, Water, and Soil* (Federal Guidance No. 12, 1993), the external dose due to surface contamination and the submersion dose resulting from re-suspension can be determined.

ORAUT-OTIB-0070 discusses depletion of the source term during a residual period and suggests a depletion factor of 1% of the surface activity per day. This 1% depletion per day results in a depletion adjustment of 1 for the first year, 0.03 for the second year, and 0.0007 for the third year, after which the values remain constant. These adjustments can be applied in order to maintain calculation consistency within this evaluation report; however, such application is unnecessary since the resulting external dose estimate would still be bounding.

Table 7-3 shows the daily doses for a 10-hour workday that Revere personnel would receive from direct radiation from residual contamination for each year over the residual period for the class under evaluation.

Submersion doses are not presented because they are over a factor of 1000 lower than for direct radiation

Table 7-3: Revere Residual Period Daily Effective Dose (1% Per Day)
(based on a 10-hour workday)

Residual Year(s)	Depletion Factor	Uranium Total Including Progeny (mrem/d)	Thorium Total Including Progeny (mrem/d)
1955	1	1.02	2.65
1956	0.03	0.0263	0.0681
1957-1984	0.0007	0.0190	0.0491

Method 2: A second method was developed using the maximum contamination levels at the beginning of the residual period, the contamination levels provided by ANL in 1981, and correction factors provided by ANL in a report on a survey conducted at another site in 1978 (Argonne, 1982)

As discussed in Section 7.2.3.2, *Methods for Bounding Residual Period Internal Dose*, a theoretical exponential depletion constant was calculated to account for the depletion of the source term during the period from 1955 through 1981. For the 1982, 1983, and 1984, the values from Method 1 in that section were used since they provide higher dose rates.

As noted previously, ANL performed a survey at another site in 1978 (Argonne, 1982) using the same instrumentation employed for their 1981 Revere survey. In its 1982 survey report, ANL provided various correction factors for the probes (with a window area of either 325 cm^2 or 51 cm^2) used in their 1978 survey. For consistency and simplicity, the depletion factor used for determining the internal intake calculations were also used for the external dose rate calculations.

The results of the dose rate calculations are presented in Table 7-4. These values incorporate the dose conversion factors for the uranium and thorium progeny provided in *External Exposure to Radionuclides in Air, Water, and Soil* (Federal Guidance No. 12, 1993).

Table 7-4: Residual Period Daily Dose Rates Due to Uranium and Thorium (Exponential)				
Year	**Depletion Factor**	**Uranium Total (mrem/day)**	**Thorium Total mrem/day**	**Total dose mrem/day**
1955	1.000	1.02	2.65	3.67
1956	0.76	0.772	2.05	2.82
1957	0.57	0.584	1.55	2.13
1958	0.43	0.442	1.17	1.61
1959	0.33	0.335	0.886	1.22
1960	0.25	0.253	0.671	0.924
1961	0.19	0.192	0.508	0.699
1962	0.14	0.145	0.384	0.529
1963	0.11	0.110	0.291	0.400
1964	0.081	0.0830	0.220	0.303
1965	0.062	0.0628	0.166	0.229
1966	0.047	0.0475	0.126	0.173
1967	0.035	0.0360	0.0953	0.131
1968	0.027	0.0272	0.0721	0.0993
1969	0.020	0.0206	0.0545	0.0751
1970	0.015	0.0156	0.0413	0.0569
1971	0.012	0.0118	0.0312	0.0430
1972	0.0087	0.00892	0.0236	0.0326
1973	0.0066	0.00675	0.0179	0.0246
1974	0.0050	0.00511	0.0135	0.0186
1975	0.0038	0.00387	0.0102	0.0141
1976	0.0029	0.00293	0.00775	0.0107
1977	0.0022	0.00221	0.00586	0.00808
1978	0.0016	0.00167	0.00444	0.00611
1979	0.0012	0.00127	0.00336	0.00462
1980	0.00094	0.000959	0.00254	0.00350
1981	0.00071	0.000726	0.00192	0.00265
1982*	0.00054*	0.000549*	0.00145*	0.00200*
1983*	0.00041*	0.000415*	0.00110*	0.00152*
1984*	0.00031*	0.000314*	0.000833*	0.00115*

* The dose rate calculated by the exponential method results in lower values for 1982-1984; therefore, it is favorable to use a depletion adjustment of 0.0007 for these years in accordance with the 1% per day depletion method.

7.3.5 External Dose Reconstruction Feasibility Conclusion

Although there are methods available to NIOSH in Battelle-TBD-6000 to support bounding external uranium dose for the operational period at Revere Copper and Brass, NIOSH has not identified sufficient information or data to support bounding the thorium exposures for the operational period. During this period, NIOSH was unable to determine a worker's actual work locations or whether a worker was restricted to one location. Workers may have been able to move about freely; therefore, all workers' exposures will be treated similarly. Therefore, except for medical X-ray dose, NIOSH has determined that reconstruction of external doses for Revere workers is not feasible for the operational period from July 1, 1943 through December 31, 1954.

NIOSH has determined that reconstruction of external doses is feasible for the residual period from January 1, 1955 through December 31, 1984 using the assumptions and approaches presented within the preceding section of this report.

Although NIOSH found that it is not possible to completely reconstruct external radiation doses for the period from July 24, 1943 through December 31, 1954, NIOSH intends to use any external monitoring data that may become available for an individual claim or any area monitoring data (that can be interpreted using existing NIOSH dose reconstruction processes or procedures) to support partial dose reconstructions for the operational period at the site. Dose reconstructions for individuals employed at Revere Copper and Brass during the period from July 24, 1943 through December 31, 1954, but who do not qualify for inclusion in the SEC, may be performed using these data as appropriate.

7.4 Evaluation of Petition Basis for SEC-00164

ATTRIBUTION: Section 7.4 was completed by Ed Scalsky, Oak Ridge Associated Universities (ORAU). These conclusions were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

The following assertion was made on behalf of petition SEC-00164 for the Revere site:

SEC-00164: The petitioner stated that, to the best of his knowledge, Revere Copper and Brass never used any type of monitoring device to detect radiation at the facility.

NIOSH determined that it has access to only a limited number of air sample and smear survey results for Revere during the time period under evaluation. Medical records, bioassay data, and external monitoring results are not available. NIOSH has concluded that the available information is insufficient bound the internal and external dose for the Revere operational period; however, the internal dose for the residual period can be bounded using the available data and other parameters as discussed within this evaluation report.

7.5 Summary of Feasibility Findings for Petition SEC-00164

This report evaluates the feasibility for completing dose reconstructions for employees at Revere Copper and Brass from July 24, 1943 through December 31, 1954 (operations) and from January 1, 1955 through December 31, 1984 (residual period). NIOSH found that the available monitoring records, process descriptions and source term data available are not sufficient to complete dose reconstructions for the operations period. Doses for the residual period can be bounded.

Table 7-5 summarizes the results of the feasibility findings at Revere Copper and Brass for each exposure source during the time period July 24, 1943 through December 31, 1954 (operations) and from January 1, 1955 through December 31, 1984 (residual period).

Table 7-5: Summary of Feasibility Findings for SEC-00164

July 24, 1943 through December 31, 1954 (operations);
January 1, 1955 through December 31, 1984 (residual period)

Source of Exposure	July 24, 1943 through December 31, 1954 (operations)		January 1, 1955 through December 31, 1984 (residual period)	
	Reconstruction Feasible	Reconstruction Not Feasible[1]	Reconstruction Feasible[2]	Reconstruction Not Feasible
Internal		**X**	**X**	
- Uranium	X		X	
- Thorium		X	X	
External		**X**	**X**	
- Gamma		X	X	
- Beta		X	X	
- Neutron		X	N/A	
- Occupational Medical X-ray	X		X	

[1] NIOSH has identified methods to support bounding internal uranium dose for the type of metal work performed during the operational period at Revere Copper and Brass. However, NIOSH has not identified sufficient information or data to support bounding the thorium exposures for the operational period.

[2] Exposures will be evaluated on a case-by-case basis for individual claims, but the method described here supports NIOSH's ability to bound the dose for the evaluated class during the site's residual period.

As of May 25, 2010, a total of eight claims have been submitted to NIOSH for individuals who worked at Revere Copper and Brass and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for eight individuals (100%).

Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures) for the purpose of partial dose reconstructions. Therefore, dose reconstructions for individuals employed at Revere Copper and Brass during the period from July 24, 1943 through December 31, 1954 (operations) and from January 1, 1955 through December 31, 1984 (residual period), 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-00164

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

Due to a lack of internal and external monitoring data, NIOSH's evaluation determined that it is not feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy for the operations period (July 24, 1943 through December 31, 1954). Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is required. For the residual period (January 1, 1955 through December 31, 1984), a health endangerment determination is not required because NIOSH has determined that it has an established methodology for estimating dose.

9.0 Class Conclusion for Petition SEC-00164

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 Employer employees who worked at Revere Copper and Brass, Detroit, Michigan from July 24, 1943 through December 31, 1954, 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 SEC. The class under evaluation was divided because although NIOSH has not obtained sufficient internal or external monitoring data for bounding doses during the operational period, NIOSH has a methodology for bounding doses for the residual period.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database (SRDB), for information relevant to SEC-00164. 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.

10.0 References

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Attachment 1: Data Capture Synopsis

Table A1-1: Data Capture Synopsis for Revere Copper and Brass			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Primary Site/Company Name: Revere Copper and Brass BE 1946-1950; AWE 1943-1950s; Residual Radiation 1960-1984 Other Site Names: Revere Copper Products (Successor Company)	Revere Copper Products does not hold old Revere Copper and Brass records. Per the successor contact they most likely were destroyed.	05/05/2010	0
Michigan State contacted	A description of how Revere collected and handled machining scrap, trip reports, and the DOE's 1981 investigation into ownership of the site.	04/16/2010	6
Chicago Federal Records Center	No relevant data identified.	04/23/2010	0
Dayton Federal Records Center	No relevant data identified.	05/18/2010	0
Department of Labor/Paragon	1954 AEC memos, including an order to ship thorium slugs from Revere to the FMPC.	12/30/2008	1
DOE Argonne National Laboratory - East	No relevant data identified.	05/07/2010	0
DOE Environmental Measurements Laboratory records collection, now located at DOE Legacy Management - Grand Junction Office	New potential data source recently identified by DOE Headquarters. A data capture has been scheduled for the week of 06/07/2010.	OPEN	0
DOE Germantown	A summary AEC report identifying Revere as having processed thorium metal and the DOE's initial investigation into former thorium processing sites.	Unknown	2
DOE Hanford	New potential data source recently identified by NIOSH. A request for a search of Hanford's records databases was made on 05/19/2010.	OPEN	0
DOE Legacy Management - Grand Junction Office	Materials transfer and shipment reports, FUSRAP documents and correspondence, and FUSRAP elimination reports.	05/01/2010	33
DOE Legacy Management - Morgantown	Awaiting DOE Legacy Management response.	OPEN	0
DOE Office of Scientific and Technical Information	A 1949 report regarding a beryllium extrusion test.	03/29/2010	1
Hagley Museum (DuPont records repository)	No relevant data identified.	05/10/2010	0
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant data identified.	03/23/2010	0

Table A1-1: Data Capture Synopsis for Revere Copper and Brass			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	Hanford progress reports referring to extrusion runs at Revere, materials transfer and shipment reports, correspondence regarding Revere's status as a DuPont subcontractor. NOTE: 7 of the 16 Hanford DDRS documents were added to Revere by site association reviews and 9 documents were chosen from the specific search of DDRS for documents pertaining to Revere.	03/23/2010	16
Internet - DOE OpenNet	New York Operations Office progress reports, the medical program from the Manhattan District History, references to work at Revere in Linking Legacies, and Hanford's history of operations.	03/23/2010	7
Internet - DOE OSTI Energy Citations	No relevant data identified.	03/29/2010	0
Internet - DOE OSTI Information Bridge	Reports on aluminum flat plate bonded fuel jacket and beryllium extrusions at Revere.	03/23/2010	2
Internet - Google	Newspaper articles on contaminated atomic weapons employer sites, monthly reports, contract documentation, the FUSRAP Authority Review, a flat plate bonded fuel element progress report, and site description.	03/22/2010	17
Internet - National Academies Press (NAP)	No relevant data identified.	03/23/2010	0
Internet - National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant data identified.	03/23/2010	0
Internet - NRC Agencywide Document Access and Management (ADAMS)	No relevant data identified.	03/23/2010	0
Internet - Washington State University (U.S. Transuranium and Uranium Registries)	No relevant data identified.	03/23/2010	0
Michigan State University	No relevant data identified.	05/07/2010	0
NARA Atlanta	Materials transfer and shipment reports, accountability reports, a report outlining health measures at Revere, a health and safety inspection, and radiological surveys.	05/12/2010	29
NARA Chicago	No relevant data identified.	04/23/2010	0
New York State Department of Environmental Conservation	An order for the machining of thorium slugs at the FMPC from rods that had been extruded at Revere.	02/25/2008	1
ORAU Team	Project spreadsheet and documented communications with former Revere workers.	04/16/2010	5
ORO Vault	Medical examinations of Revere workers and surveys of airborne metal dust concentrations.	05/13/2004	1
Savannah River Site	Reports listing revere as the source for thorium slugs used in the Thorium Irradiation Program.	07/22/2008	2

Table A1-1: Data Capture Synopsis for Revere Copper and Brass			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
University of Detroit - Mercy	No relevant data identified.	05/07/2010	0
University of Michigan	No relevant data identified.	05/07/2010	0
Unknown	New York Operations Office progress reports, beryllium studies, a discussion of the health hazards of thorium extrusion, a contamination investigation, a claim against Revere, airborne radioactivity surveys, and monthly thorium accountability reports.	07/09/2004	16
US Army Corps of Engineers, Buffalo District	New potential data source recently identified by NIOSH. A data capture has been scheduled for the week of 06/21/2010.	OPEN	0
Wayne State University	No relevant data identified.	05/07/2010	0
TOTAL			**139**

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
DOE CEDR http://cedr.lbl.gov/ COMPLETED 03/23/2010	"Revere Copper"	0	0
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 03/23/2010	"Revere Copper"	9	9
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 03/23/2010	"Revere Copper"	16	7
DOE OSTI Energy Citations http://www.osti.gov/energycitations/ COMPLETED 03/29/2010	"Revere Copper"	28	0
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 03/23/2010	"Revere Copper"	21	2

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
Google http://www.google.com COMPLETED 03/22/2010	"Revere Copper" "air count" "Revere Copper" "air dust" "Revere Copper" "air filter" "Revere Copper" "airborne test" "Revere Copper" "belgian congo ore" "Revere Copper" "black oxide" "brown oxide" "green salt" "orange oxide" "yellow cake" UO2 UO3 UF4 UF6 C-216 C-616 C-65 C-211 U3O8 "uranium extraction" "uranium dioxide" "uranium hexafluoride" "uranium tetrafluoride" "uranium trioxide" "Revere Copper" "body burden" "Revere Copper" "chest count" "Revere Copper" "derived air concentration" DAC "Revere Copper" "dose" "Revere Copper" "Ether-Water Project" "Revere Copper" "F machine" "Revere Copper" "feed material" "Revere Copper" "Formerly Utilized Sites Remedial Action Program" FUSRAP "Revere Copper" "gas proportional" "Revere Copper" "gaseous diffusion" "Revere Copper" "highly enriched uranium" HEU "Revere Copper" "in vitro" "Revere Copper" "in vivo" "Revere Copper" "isotopic enrichment" "Revere Copper" "JS Project" "Revere Copper" "K-65" "Revere Copper" "liquid scintillation" "Revere Copper" "low enriched uranium" LEU "Revere Copper" "lung count" "Revere Copper" "maximum permissible concentration" MPC "Revere Copper" "mixed fission product" MFP	249,021	17

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
	"Revere Copper" "nasal wipe" "Revere Copper" "nose wipe" "Revere Copper" "nuclear track emulsion type A" NTA "Revere Copper" "occupational radiation exposure" "Revere Copper" "operating standard" "processing standard" "Revere Copper" "ore concentrate" "Revere Copper" "PC Project" "Revere Copper" "phosphate research" "Revere Copper" "pocket ion chamber" PIC "Revere Copper" "Radiological Survey Data Sheet" RSDS "Revere Copper" "retention schedules" "Revere Copper" "solvent extraction" "Revere Copper" "sump cake" "Revere Copper" "thermal diffusion" "Revere Copper" "thermoluminescent dosimeter" TLD "Revere Copper" "Tiger Team" "Revere Copper" "tolerance dose" "Revere Copper" "uranyl nitrate hexahydrate" UNH "Revere Copper" "whole body count" WBC "Revere Copper" "working level" WL "Revere Copper" accident "Revere Copper" alpha "Revere Copper" americium Am241 Am-241 "Am 241" 241Am 241-Am "241 Am" "Revere Copper" beta "Revere Copper" bioassay bio-assay "Revere Copper" breath "breathing zone" BZ "Revere Copper" calibration "Revere Copper" columnation "Revere Copper" contamination "Revere Copper" curie "Revere Copper" denitration "denitration pot" "Revere Copper" derby regulus		

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
	"Revere Copper" dosimeter "Revere Copper" dosimetric "Revere Copper" dosimetry "Revere Copper" electron "Revere Copper" environment "Revere Copper" exposure "exposure investigation" "radiation exposure" "Revere Copper" external "Revere Copper" fecal "Revere Copper" femptocurie "Revere Copper" film "Revere Copper" fission "Revere Copper" fluoroscopy "Revere Copper" gamma-ray "gamma ray" "Revere Copper" health "health instrument" "health physics" H.I. HI HP "Revere Copper" hydrofluorination "Revere Copper" incident "Revere Copper" ingestion "Revere Copper" inhalation "Revere Copper" internal "Revere Copper" investigation "Revere Copper" ionium Th230 Th-230 "Th 230" 230Th 230-Th "230 Th" "Revere Copper" isotope "Revere Copper" isotopic "Revere Copper" Landauer "Revere Copper" log "log sheet" "log book" "Revere Copper" metallurgy		

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
	"Revere Copper" microcurie "Revere Copper" millicurie "Revere Copper" monitor "air monitoring" "Revere Copper" nanocurie "Revere Copper" neptunium Np237 Np-237 "Np 237" 237Np 237-Np "237 Np" palm palmolive "Revere Copper" neutron "Revere Copper" nuclear "Chicago-Nuclear" "nuclear fuels" "Revere Copper" occurrence "Revere Copper" oralloy "Revere Copper" permit "radiation work permit" "safe work permit" "special work permit" RWP SWP "Revere Copper" photon "Revere Copper" picocurie "Revere Copper" pitchblende "Revere Copper" plutonium Pu-238 Pu238 "Pu 238" 238Pu 238-Pu "238 Pu" Pu-239 Pu239 "Pu 239" 239Pu 239-Pu "239 Pu" Pu-240 Pu240 "Pu 240" 240Pu 240-Pu "240 Pu" Pu-241 Pu241 "Pu 241" 241Pu 241-Pu "241 Pu" "Revere Copper" polonium Po210 Po-210 "Po 210" 210Po 210-Po "210 Po" "Revere Copper" postum "Revere Copper" problem "Revere Copper" procedure "Revere Copper" protactinium Pa-234m Pa234m "Pa 234m" 234mPa 234m-Pa "234m Pa" "Revere Copper" radeco		

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
	"Revere Copper" radiation "Revere Copper" radioactive "Revere Copper" radioactivity "Revere Copper" radiograph "Revere Copper" radiological "Revere Copper" radionuclide "Revere Copper" radium Ra-226 Ra226 "Ra 226" 226-Ra 226Ra "226 Ra" Ra-228 Ra228 "Ra 228" 228Ra 228-Ra "228 Ra" "Revere Copper" radon Rn-222 Rn222 "Rn 222" 222Rn 222-Rn "222 Rn" "Revere Copper" raffinate "Revere Copper" reactor "Revere Copper" respiratory "Revere Copper" roentgen "Revere Copper" sample "air sample" "dust sample" "general area air sample" "Revere Copper" sampling "air sampling" "dust sampling" "general area air sampling" "Revere Copper" source "sealed source" "Revere Copper" spectra "Revere Copper" spectrograph "Revere Copper" spectroscopy "Revere Copper" spectrum "Revere Copper" strontium Sr-90 Sr90 "Sr 90" 90-Sr 90Sr "90 Sr" "Revere Copper" survey "building survey" "routine survey" "special survey" "Revere Copper" "technical basis"		

Table A1-2: Database Searches for Revere Copper and Brass			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded**
	"Revere Copper" thorium thoria Th232 Th-232 "Th 232" 232Th 232-Th "232 Th" "Z metal" Z-metal myrnalloy "chemical 10-66" "chemical 1066" "chemical 10 66" "chemical 18-12" "chemical 1812" "chemical 18 12" "chemical 10-12" "chemical 1012" "chemical 10 12" UX1 UX2 Th-234 Th234 "Th 234" 234-Th 234Th "234 Th" "Revere Copper" thoron Rn-220 Rn220 "Rn 220" 220Rn 220-Rn "220 Rn" "Revere Copper" tritium H3 H-3 mint HTO "Revere Copper" tuballoy "Revere Copper" uranium U233 U-233 U 233 233U 233-U 233 U U234 "U 234" U-234 234U 234-U "234 U" U235 "U 235" U-235 235-U 235U "235 U" U238 "U 238" U-238 238-U 238U "238 U" U308 "U 308" U-308 308-U 308U "308 U" "Revere Copper" urinalysis "Revere Copper" urine "Revere Copper" X-ray "X ray" Xray Revere Copper & Brass		
National Academies Press http://www.nap.edu/ COMPLETED 03/23/2010	"Revere Copper"	0	0
NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 03/23/2010	"Revere Copper"	0	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 03/23/2010	"Revere Copper"	15	0
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 03/23/2010	"Revere Copper"	0	0

Table A1-3: OSTI Documents Requested for Revere Copper and Brass			
Document Number	**Document Title**	**Requested Date**	**Received Date**
AECD-3852; MIT-SVA-18 Ref ID: 80196	Extrusion at Revere Copper and Brass, Inc., March 1, 1949 dated 10-31-1956	03/12/2010	03/29/2010