SEC Petition Evaluation Report
Petition SEC-00223

Report Rev #: 1 Report Submittal Date: June 3, 2015

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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-00223	83.13	November 19, 2014	February 2, 2015	The Carborundum Company (Buffalo Avenue, Niagara Falls NY)

Petitioner-Requested Class Definition

All employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January 1, 1943 through December 31, 1976.

Class Evaluated by NIOSH

All employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January 1, 1943 through December 31, 1976.

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

None

Related Petition Summary Information

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

Related Evaluation Report Information

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

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Evaluation Report Summary: SEC-00223, Carborundum Company

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-00223 was received on November 19, 2014, and qualified on February 2, 2015. The petitioner requested that NIOSH consider the following class: *All employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January, 1, 1943 through December 31, 1976.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. NIOSH evaluated the following class: All employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January, 1, 1943 through December 31, 1976.

NOTE: In the DOE's Office of Environment, Health, Safety and Security facility description for the Carborundum Company, there are two operational periods (1943-1944 and 1959-1967) and two residual periods (1945-1958 and 1968-1992). Because there are no identified dose reconstruction infeasibilities for the site, NIOSH has limited its evaluation to the petitioner's requested class period from 1943 through 1976.

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

Based on its full research of the class under evaluation, NIOSH has obtained sufficient information on material types, material quantities, and some processing methods. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

Feasibility of Dose Reconstruction

Per EEOICPA and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class; or (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. Information from available resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the evaluated class under plausible circumstances during the specified period.

Health Endangerment Determination

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

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SEC Petition Evaluation Report for SEC-00223

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

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January 1, 1943 through December 31, 1976. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

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

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

2.0 Introduction

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

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

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

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

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

3.0 SEC-00223 Carborundum Company Class Definitions

The following subsections address the evolution of the class definition for SEC-00223, Carborundum Company (Buffalo Avenue). When a petition is submitted, the requested class definition is reviewed as submitted. Based on its review of the available site information and data, NIOSH will make a determination whether to qualify for full evaluation all, some, or no part of the petitioner-requested class. If some portion of the petitioner-requested class is qualified, NIOSH will specify that class along with a justification for any modification of the petitioner's class. After a full evaluation of the qualified class, NIOSH will determine whether to propose a class for addition to the SEC and will specify that proposed class definition.

3.1 Petitioner-Requested Class Definition and Basis

Petition SEC-00223 was received on November 19, 2014, and qualified on February 2, 2015. The petitioner requested that NIOSH consider the following class: *All employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January 1, 1943 through December 31, 1976.*

[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.

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Carborundum Company, Buffalo Ave., workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00223 for evaluation:

> Petition Basis: Radiation exposures and radiation doses potentially incurred by members of the proposed class were not monitored either through personal monitoring or through area monitoring.
>
> Petitioner Statement: *To the best of my knowledge the plant was not monitored for radiation during the time of employment as the attached papers state my dad was exposed to various forms of radiation throughout the plant during the years he worked there.*

Based on its Carborundum Company documentation reviews and research relating to the SEC petition, NIOSH determined that it had limited monitoring data or process information for Carborundum workers during the petitioner-requested time period. Specifically, NIOSH determined that air sampling, radiological surveys, and dosimetry data records are not complete for all radionuclides during the petitioner-defined periods. 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 Carborundum Company, either through personal monitoring or area monitoring. The information and statements provided by the petitioner qualified the petition for further consideration by NIOSH, the Board, and HHS. The details of the petition basis are addressed in Section 7.4.

3.2 Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. Therefore, NIOSH defined the following class for further evaluation: All employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January, 1, 1943 through December 31, 1976.

NOTE: The DOE's Office of Environment, Health, Safety and Security maintains a Facility List Database that provides summaries of EEOICPA-covered facilities. As shown below, the facility description for the Carborundum Company specifies two operational periods and two residual periods. Because there are no identified dose reconstruction infeasibilities for the site, NIOSH has limited its evaluation to the petitioner's requested class period from 1943 through 1976.

> ***1 - Carborundum Company***
>
> ***State:*** *New York Location: Niagara Falls*
> ***Time Period:*** *AWE 1943-1944; 1959-1967; Residual Radiation: 1945-1958; 1968-1992*
> ***Facility Type:*** *Atomic Weapons Employer*
>
> ***Facility Description:*** *In 1943 and 1944 the Carborundum Company at its Globar Plant and Buffalo Avenue locations was engaged in various phases of Manhattan Engineer District (MED) programs to determine suitable methods for engineering and shaping uranium rods. This work also involved the forming, coating, and canning of uranium rods for the MED pile. From 1959 through 1967, the company used powder fabrication techniques to manufacture uranium,*

plutonium, and carbide pellets for an AEC research program. The Hanford facility supplied Carborundum with materials during that period.

Carborundum also performed work during the 1950s that is not covered under EEOICPA, including fabricating nuclear fuel elements for commercial purposes and producing zirconium, hafnium, and titanium for AEC's special reactor materials program.

During the period of residual contamination, as designated by the National Institute for Occupational Safety and Health and as noted in the dates above, employees of subsequent owners and operators of this facility are also covered under EEOICPA.

(https://ehss.energy.gov/Search/Facility/ViewByName.aspx)

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

Based on its research, NIOSH has obtained information on material types, material quantities, and processing methods that allow dose reconstruction to be performed with sufficient accuracy for the evaluated period at the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY based on guidance in Battelle-TBD-6000, ORAUT-OTIB-0070, internal/external/medical X-ray dose reconstruction methodologies discussed herein, and the currently-available process and area monitoring data for the Carborundum Company facility. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

4.0 Data Sources Reviewed by NIOSH to Evaluate the Class

As is standard practice, NIOSH completed an extensive database and Internet search for information regarding the Carborundum Company, Buffalo Ave, Niagara Falls, NY. The database search included the DOE Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet search included OSTI OpenNet Advanced searches, OSTI Information Bridge Fielded searches, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) web searches, the DOE Office of Human Radiation Experiments website, and the DOE-National Nuclear Security Administration-Nevada Site Office-search. Attachment 1 contains a summary of Carborundum Company documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

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

4.1 Site Profile Technical Basis Documents (TBDs)

A Site Profile provides specific information concerning the documentation of historical practices at the specified site. Dose reconstructors can use the Site Profile to evaluate internal and external dosimetry data for monitored and unmonitored workers, and to supplement, or substitute for, individual monitoring data. A Site Profile consists of an Introduction and five Technical Basis Documents (TBDs) that provide process history information, information on personal and area monitoring, radiation source descriptions, and references to primary documents relevant to the radiological operations at the site. The Site Profile for a small site may consist of a single document. A Site Profile for the Carborundum Company does not exist. As part of NIOSH's evaluation detailed herein, it examined the following TBD for insights into Carborundum Company operations or related topics/operations at other sites:

- Battelle-TBD-6000, *Technical Basis Document: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals,* Rev 1, Battelle Memorial Institute; June 17, 2011; SRDB Ref ID: 101251

4.2 ORAU Technical Information Bulletins (OTIBs) and Procedures

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

- *OTIB: Dose Reconstruction from Occupational Medical X-Ray Procedures*, ORAUT-OTIB-0006, Rev. 04; Oak Ridge Associated Universities; June 20, 2011; SRDB Ref ID: 98147

- *OTIB: Technical Information Bulletin: Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0070, Rev 01, Oak Ridge Associated Universities Team, March 5, 2012, SRDB Reference ID 108851.

- *OTIB: Guidance on Assigning Occupational X-ray Dose Under EEOICPA for X-rays Administered Off Site*, ORAUT-OTIB-0079, Rev. 00; Oak Ridge Associated Universities; January 3, 2011; SRDB Ref ID: 89563

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed six former Carborundum employees. NIOSH attempted to conduct interviews for the first operational period (1943-1944), but were not able to locate former workers from that period. As a result, there are no interviews that cover Carborundum site workers or operations during the 1943-1944 operational period. The six former Carborundum employees interviewed worked at Carborundum after the 1950s.

- Personal Communication, 2015a, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; February 13, 2015; SRDB Ref ID: 142192
- Personal Communication, 2015b, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; February 13, 2015; SRDB Ref ID: 142173
- Personal Communication, 2015c, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; February 16, 2015; SRDB Ref ID: 142172
- Personal Communication, 2015d, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; February 16, 2015; SRDB Ref ID: 142193
- Personal Communication, 2015e, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; February 17, 2015; SRDB Ref ID: 142174
- Personal Communication, 2015f, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; February 23, 2015; SRDB Ref ID: 142194
- Personal Communication, 2015g, *Personal Communication with former Carborundum Company [job title redacted]*; Telephone Interview by ORAU Team; April 27, 2015; SRDB Ref ID: 144379

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (referred to as NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of March 16, 2015)

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

Description	Totals
Total number of claims submitted for dose reconstruction	120
Total number of claims submitted for energy employees who worked during the period under evaluation (January 1, 1943 through December 31, 1976).	106
Number of dose reconstructions completed for energy employees who worked during the period under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	90
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. As noted in Table 4-1, NIOSH has not received external or internal monitoring data from the Carborundum Company for any claimants.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. Two hundred twenty documents in this database were identified as pertaining to the Carborundum Company. These documents were evaluated for their relevance to this petition. The documents include historical background on program descriptions (e.g., air dust monitoring, radiological controls, program information, medical monitoring, process materials, and process descriptions).

4.6 Other Technical Sources

- DCAS-IG-003, *Radiation Exposures Covered for Dose Reconstructions under Part B of the Energy Employees Occupational Illness Compensation Program Act*, Rev 01, NIOSH, Division of Compensation Analysis and Support; October 5, 2010; SRDB Ref ID: 88929

- DCAS-TIB-0010, *Technical Information Bulletin: Best Estimate External Dose Reconstruction for Glovebox Workers,* Rev 04, NIOSH, Division of Compensation Analysis and Support; November 28, 2011; SRDB Ref ID: 104815

4.7 Documentation and/or Affidavits Provided by Petitioners

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

- SEC Petition Form B, received November 19, 2014; DSA Ref ID: 120430 (Petition, 2014)

- Affidavit from one of two survivors asserting that the plant was not monitored for radiation during the deceased worker's time of employment. The survivor states the deceased was exposed to various forms of radiation throughout the plant during the years worked there; received November 19, 2014; DSA Ref ID: 120430 (Affidavit, 2014)

- Attachment to Form B: Two pages from the deceased worker's dose reconstruction; received November 19, 2014; DSA Ref ID: 120430, PDF pp. 7-8 (Attachment, 2014)

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The Carborundum Company site on Buffalo Avenue has two operational periods and two residual periods. These periods will be addressed in chronological order, as listed below:

- First Operational Period: 1943-1944
- First Residual Period: 1945-1958
- Second Operational Period: 1959-1967
- Second Residual Period: 1968-1992

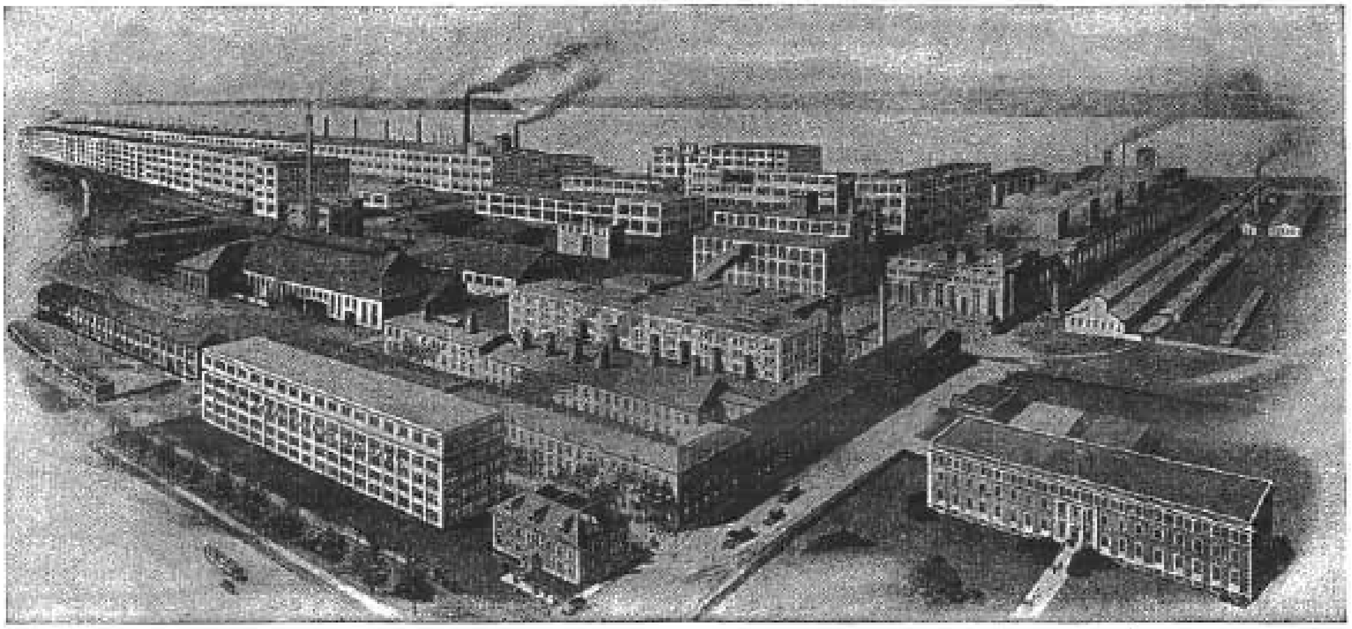
NOTE: The evaluation and feasibility conclusions in this report only extend to 1976 based on the petitioner's requested class of 1943-1976 and the results of the feasibility findings in this report.

The following subsections summarize both radiological operations at the Carborundum Company from January 1, 1943 to December 31, 1976 and the information available to NIOSH to characterize particular processes and radioactive source materials. Although the DOE's Facility Description (provided in Section 3.2) indicates a variety of uranium activities from 1943-1944, references available to NIOSH indicate that Carborundum performed limited experimental work on uranium metal in 1943, as described in Section 5.1.1. NIOSH has identified source term quantities for this work, but has discovered no radiological monitoring data for the first operational period (1943-1944). The work in the second operational period involved the synthesis and study of carbide fuel compounds. NIOSH has limited radiological monitoring information on the activities that were performed at the Carborundum Company site on Buffalo Ave. during this operational period (1959-1967). The information included within this evaluation report is intended only to be a summary of the available information for the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January 1, 1943 through December 31, 1976, consistent with the direction for the EEOICPA process and the requested class defined in the SEC petition associated with this evaluation report.

5.1 Carborundum Company Plant and Process Descriptions

The Carborundum Company was located at 1920 Buffalo Avenue (address on file from 1921-2001) in Niagara Falls, NY. The company was founded on Sept. 21, 1891 following the discovery of crystal stones that chemical analysis revealed to be silicon carbide. Because the silicon carbide powder was considered an excellent abrasive material, the company became known as the electro-chemical and electro-metallurgical center of the world. The abrasive products appeared on grinding wheels, sharpening stones, and sandpaper. The Carborundum Company developed newer and softer man-made abrasives and before long it was a national and international enterprise (Carborundum History, 1991).

No documentation has been found regarding the exact physical size of the facility or the exact number of buildings for any period at the site. From interviews, it is estimated that approximately 30-50 buildings were on site at Buffalo Avenue (Personal Communication, 2015f; Personal Communication, 2015c) by the second operational period; one interviewee suggested that, at that time, the site encompassed about 200 acres (Personal Communication, 2015a). In 1953, new modern quarters for the Research and Development Division were completed; these quarters occupied over 60,000 square feet in Building 1. This facility included complete laboratory and mechanical equipment; a battery of experimental, high-temperature electric furnaces; high-temperature and electronic microscopes; an analytical X-ray installation; sonic graders; a research machine shop; an extensive technical library; and one of the most comprehensive patent reference departments in the country (Carborundum History, 1991).



MAIN OFFICES AND PLANT, THE CARBORUNDUM COMPANY, NIAGARA FALLS, N. Y.

Source: Romance of Carborundum, 1960s, PDF p. 12

Figure 5-1: The Carborundum Company Site at Niagara Falls, NY

Records show that the Carborundum Company employed approximately 6,000-7,000 employees during the mid-to-late 1940s. Limited documentation has been found regarding the number of employees in later years up to the point in 1983 when the plant was closed and the remaining employees at the site lost their jobs (Kostoff, 2008).

The Carborundum Company, at its Buffalo Avenue plant, was involved with the Manhattan Engineer District (MED) programs in 1943, and was involved with centerless-grinding testing using grinding wheels and different abrasives. NIOSH presumes this work could have been performed at the Buffalo Avenue location, although no information on the location is currently available. Carborundum was also involved in various phases of fuel development work during the 1959-1967 time period. The processes involved during these two operational periods varied considerably. The following sections discuss the available information on Carborundum Company's operations during these two periods.

The Globar Plant is also listed in the covered facility definition for Carborundum. During the 1920s, the Wireless Resistor Company of America, based in Milwaukee, pioneered the use of silicon carbide in an electric heating element called "Globar." In 1927, Carborundum purchased that company, by then called the Globar Corporation, and moved its production to Niagara Falls. A new facility was constructed on Hyde Park Boulevard and the transfer was complete in August 1928 (Carborundum Company, 2015, PDF p. 3; Carborundum History, 1991, PDF p. 44; Globar, 2009). The Globar plant is not part of this SEC petition because it is not located at the Buffalo Avenue site. Therefore, it will not be discussed further in this evaluation report.

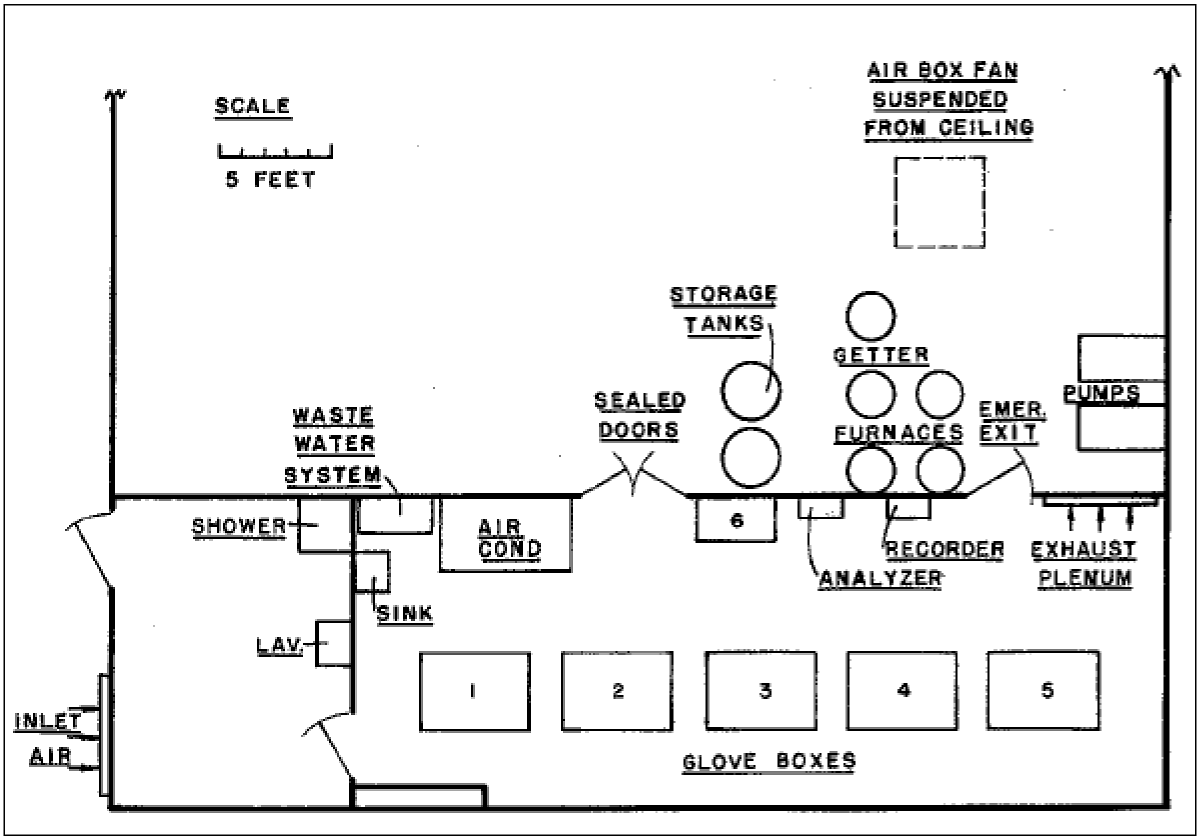
DuPont, on behalf of the U.S. Government, subcontracted different companies to perform various types of work turning uranium billets into finished slugs for use in the Clinton and Hanford piles. In May 1943, DuPont had unfinished slugs delivered to Carborundum to determine the type of abrasive wheel and optimum speeds appropriate for production grinding; this experimental grinding was performed in June 1943.

Throughout the late 1940s and 1950s, between the first and second covered operational periods, Carborundum became a very successful company in the field of industrial technology and grew more sophisticated and complex, attracting many talented research scientists to Niagara Falls. In 1953, the company completed modern new quarters for its Research and Development Division, which developed new products such as Fiberfrax, a ceramic-fiber high-temperature insulation.

In 1959, under Contract No. AT (40-1)-2558, Carborundum did work for the U.S. Atomic Energy Commission (AEC) as part of the AEC Fuel Cycle Development Program. The objective of this work was to develop refractory uranium materials possessing sufficient advantage over uranium dioxide to warrant their use as reactor fuels. The initial contract covered the period from May 1959 through December, 1960 (Refractory Uranium, 1959-60, PDF p. 7). The contract was modified and extended to continue this work. Memos dated September 19, 1962 and November 2, 1962 discuss inventory and instructions for disposal of the government-owned Source and Special Nuclear Materials with regards to the close-out of this contract (Contract Closeout, 1962, PDF p. 2).

In 1960, the Carborundum Company completed a Central Laboratory facility upgrade for investigating the synthesis and fabrication of refractory materials containing plutonium in such forms as carbides, silicides, oxides, and nitrides, which was an addition to Carborundum's uranium contract work. These materials are toxic and some are very sensitive to oxygen and moisture, especially in a finely-divided form. To be able to work with these materials, a leak-tight glove-box system was required. In addition, a decision to fabricate mainly by sintering at atmospheric pressure, rather than in a vacuum, required the glove box to have a carefully-controlled inert atmosphere. The facility was also protected by alarms and safety devices that were in continuous operation. The facility operated on a one-shift, five-day week basis (Refractory Plutonium, 1962). This facility was located in the Central Laboratory; it was 15 feet wide, 48 feet long and 8.5 feet high with enameled steel-paneled walls and ceiling and vinyl floor covering (See Figure 5-2). This area had a change room (11 by 15 feet) and a work space (15 by 37 feet). A helium purification and recirculation system serviced the building and occupied a 12 by 24 foot space in an adjacent room (Refractory Plutonium, 1962, PDF p. 3). The Central Laboratory (aka as the Central Facility) refers to the fourth floor of Building 1.

Of the glove boxes indicated in Figure 5-2, #1, #2, and #6 operated with an air atmosphere, and #3, #4, and #5 operated with high-purity helium atmosphere. The glove boxes averaged 3 feet high, 3.5 feet wide, and 5 feet long. They were constructed of welded aluminum plate with full side safety-plate glass windows. The air and helium glove box systems were connected by a vacuum lock located between #2 and #3, while the remaining boxes (with the exception of #6) were connected by two-layered flexible plastic tubing. Materials could be moved into or out of the box system by the pouching technique (which may also be referred to as bag outs), or directly through the O-ring-sealed sliding door of #1 box, which was maintained at a low level of contamination (Refractory Plutonium, 1962).



Source: Refractory Plutonium, 1962, PDF p. 3

Figure 5-2: Carborundum Facility for Investigating Refractory Materials

During the second operational period, the Carborundum Company was a subcontractor to United Nuclear Corporation (UNC), formerly known as Nuclear Development Corporation of America (NDA), from 1959-1965 under various contracts. UNC performed conceptual design, fuel evaluation, and fuel irradiation. Carborundum Company fabricated the fuel. Both companies operated plutonium-handling facilities (Carbide Fuel, May1963).

From Feb. 1, 1964 through Oct. 30, 1965, the Carborundum Company was subcontracted to UNC to study uranium-plutonium monoxides. This work was sponsored jointly by the U.S. Atomic Energy Commission and the Joint U.S.-Euratom Research and Development Program (Monoxides, 1966).

The Carborundum Company performed work with the AEC under contract No. AT (30-1)-3713. The contract years were from May 23, 1966 through February 28, 1967. The work studied the preparation of mixed-carbide fuel using co-precipitation and the synthesis of (UPu)C (Final Report, 1967).

During the mid-1960s and into the late 1970s, upon completion of Carborundum's AEC-related work in its second covered operational period, the company refocused on its core ceramic technology, moving beyond the capital goods market into the steel, paper, plastics, pollution control, and china industries. In the mid-1970s, the Carborundum Company began the development of pressureless sintered alpha silicon carbide, which marked its entry into the world of structural ceramics. At the same time, Carborundum fought off a hostile takeover attempt by Eaton Corp, only to be purchased by Kennecott Copper Corporation. Through the 1980s, Carborundum's name was changed twice before returning to the Carborundum name in 1988. During this time, the company was reorganized into three operating companies. Silicon carbide continued to be one of the company's core minerals with the development of Hexoloy alpha silicon carbide products. The company resumed its traditional investment focus in research, development, and capital expansion; the company moved into development of materials for the growing semiconductor industry. A significant change occurred in 1983 when the Buffalo Ave plant was closed and 650 people lost their jobs. In 1987, British Petroleum acquired Standard Oil and its Carborundum subsidiary. During this time, the company developed aluminum nitride substrates and ceramic packages for the semiconductor industry and continued developing new uses for its Fiberfrax technology while maintaining global leadership in sales of its Globar heating elements. By 1990, St. Gobain purchased the Carborundum abrasives unit (Carborundum Company, 2015; Carborundum Timeline, 2006).

A response memo dated June 23, 1993 provides follow-up information to a March 8, 1993 memo regarding potentially-contaminated sites from ORNL Region 1. The response memo states that the Carborundum Company Research Center, Buffalo Ave., was surveyed at the time of closure and that additional information was required to remove this site from the list (Sites, 1993). Subsequent information for the nuclear material license number at Carborundum indicates the site was cleared from the ORNL list in 1993 (ORNL, 1999).

5.1.1 First Operational Period (1943-1944) Process Descriptions

The 1943 Carborundum experimental grinding operation performed for DuPont was for the purpose of determining the type of abrasive wheel to use and the optimum speeds to maintain during a production grinding job. The project report (Clinton, 1945) has a list of project correspondence that indicates there was a letter issued May 17, 1943, granting approval to send one uranium rod to Carborundum for centerless grinding experiments. Details in the text of the report and shipping records do not indicate that a rod was sent, but indicates that ten Clinton-sized unfinished slugs were shipped in May 1943 to Carborundum for experimental grinding to determine the type of abrasive wheel to use and the optimum speeds to maintain during a production grinding job. Shipping and receiving and accountability records for that project show Carborundum taking receipt of 30 pounds of slugs from Herring-Hall-Marvin Safe Company (HHM Safe Co. - one of the DuPont subcontractors) on June 1, 1943. Based on the most common size of Clinton slugs provided in the report (finish size: 1.1" diameter by 4" long), 30 pounds of unfinished slugs would be nominally equivalent to ten slugs (Clinton, 1943, PDF p. 14; Clinton, 1945, PDF pp. 89, 103, 233, 273).

The shipping and receiving records indicate that Carborundum actually returned 33 pounds of slugs to HHM Safe Co. on Sept. 27, 1943, which is three pounds more than received in June. The three-pound discrepancy was noted in accountability records, and presumably could be from differences in measured weights, or possibly contaminated residues added to the return shipment (both the project report text and shipping records indicate that sweepings, machine turnings, and residues from various subcontractors had to be recovered and returned, although there is no such detailed information for the limited machining work done by Carborundum). Table 5-1 presents the information associated with the slug-grinding operation (Accountability, 1944; Clinton, 1943; Clinton, 1944; Clinton, 1945, PDF p. 273).

Table 5-1: Carborundum Radiological Work During the First Operational Period				
Type of Work	**Radionuclides**	**Amounts**	**Report Type (SRDB Ref ID)**	**Project No.**
Grinding to determine the appropriate type of abrasive wheel and optimum speed for production grinding (June 1943).	Uranium (U was physically on site from June 1943-Sept. 1943.)	Ten unfinished slugs totaling 30 pounds	Metal Fabrication Program Dummy Slug Program and Unbounded Slug Program (33190, PDF p. 103)	Clinton Engineer Works Project 1553

In a letter to DuPont on July 2, 1943, Carborundum reported on centerless grinding tests using a specific grinding wheel and various set-ups and abrasives. Although some chatter still existed after a particular test, various dressing speeds were tried. By using a 26" per minute traverse of the diamond, seven pieces were ground without chatter. Two other pieces were used at a slower traverse speed. The letter also states that there was one smaller piece. Carborundum returned ten pieces per DuPont instructions. This document only reported on the results obtained and did not include the actual set-up, radiological exposure potential, or airborne potential (Centerless Grinding, 1943, PDF p. 5).

5.1.2 First Residual Period (1945-1958)

During World War II (the first operational period at the site), the Carborundum Company was involved with centerless-grinding testing using grinding wheels and different abrasives. (Centerless Grinding, 1943). The residual radioactive materials that remained from covered radiological operations occurring during the first operational period are all that must be accounted for in the first residual period. The subsequent operations that occurred between the first and second operational periods at the Buffalo Avenue facility are discussed in the following paragraphs.

After the war, Carborundum embarked on an ambitious commercial expansion plan. Improvement of traditional product lines was part of this expansion. The company upgraded and expanded facilities in order to make the company more competitive in the postwar era. The Niagara Falls facilities were modernized and new facilities were built or purchased in other areas across the United States and Canada.

Carborundum was involved with many projects during the first residual period, many not specifically located at the Buffalo Ave. plant. Carborundum began development of its Fiberfrax ceramic fiber and, in 1952, began to market its first commercial applications (Carborundum Company, 2015). In the 1952-1953 time-frame, Carborundum began experiments to commercially produce a grade of boron carbide suitable for the fabrication of Boral (Site Inspection, 1990). This work was non-radiological. In October 1954, a new line of tool room wheels known as the V-40 line made a debut. The development of the V-40 wheels at the Bonded Abrasives Division was based on input and suggestions gathered in the field from grinding machine operators. (Carborundum History, 1991, PDF p. 73).

Beginning in 1955, Carborundum was involved with the production of silicon carbide for structural materials for the Aircraft Nuclear Propulsion Department of General Electric Company. The GE contract went from September 28, 1955 to September 27, 1956. Carborundum proposed and was granted an extension to September 28, 1957 (Silicon Carbide, 1956). A second extension was given into 1958 (Silicon Carbide, 1957). A second periodic report was issued in May 1956 (Silicon Carbide, 1958). This contract was identified as commercial work and therefore, is not included in the covered period evaluation.

NIOSH interviewed several former Carborundum employees who worked during the first residual period. One former employee stated he worked in different departments in the Diamond Wheel Department and also worked on a lathe. He made diamond insets to cut different kinds of metals (Personal Communication, 2015b). The other former employee stated he was involved with the synthesis of ceramic materials, borides, carbides, nitrides, and silicides. He handled enriched Boron-10 and processed over 2000 pounds that was converted to boron carbide, which was not radioactive. He also stated he made thorium oxide and thorium carbide in the early stages of his work (~1955) (Personal Communication, 2015d).

5.1.3 Second Operational Period (1959-1967) Process Descriptions

During the second operational period, the Carborundum Company worked as a prime or subcontractor on many contracts for the AEC, including United Nuclear Corporation (formerly Nuclear Development Corporation of America). Table 5-2 lists the contracts within this operational period with brief descriptions of the work. Some of these contracts are discussed in more detail in the subsequent text. There were seven contracts that covered the work during this second operational period (1959-1967).

Synthesis and Fabrication of Uranium Refractory Compounds:

- Contract AT-(40-1)-2558 covered uranium work from May 1959 through December 1960. The purpose of this work was to develop methods to synthesize the materials UN, UC, and U_3Si_2. Many batches of UC were made with batch sizes ranging from about 30 grams to 6 pounds. This work was part of the AEC Fuel Development Program (Refractory Uranium, 1959-60, PDF p. 13). This was the beginning of the uranium contract work and covered AEC work for the second operational period.

Synthesis and Study of Uranium/Plutonium Carbide Pellets:

- Contract AT-(30-1)-2303 was part of the Carbide Fuel Development Program initiated in May 1959. Design and construction of a facility for carbide fabrication at the Carborundum Company was completed in 1960. The equipment was tested by work with UC prior to the start-up of operations with plutonium in March 1961 (first shipment of Pu received in June 1960). Seven batches of PuC were made by mixing PuO_2 and carbon, then furnacing at differing temperatures and hold times (Carbide Fuel, 1961, PDF p. 14).

- Contract AT-(30-1)-2899 covered work from May 15, 1959 through October 15, 1965. As part of the Carbide Fuel Development Program, this work was concerned with the technology of UC-PuC fuels. The major goals were to produce (UPu)C and obtain data on its irradiation behavior for long burn-ups and at high-power generation rates. Four hundred grams of $(U_{0.95}Pu_{0.5})C_{0\ 98}$ powder was synthesized for fabrication (Final Report, 1965).

Synthesis and Study of Uranium/Plutonium Monoxides:

- Contract AT-(30-1)-3305 covered work from February 1, 1964 through October 30, 1965. Carborundum was the subcontractor to United Nuclear Corporation and conducted fabrication studies of uranium and plutonium monoxides in helium. Mixtures of UO_2-PuO_2 were used to synthesize U-Pu monoxide compositions (Monoxides, 1966, PDF pp. 5-6).

- Contract AT(30-1)-3713 was associated with the AEC Fuel Cycle Development and studied the preparation of mixed carbide fuel using co-precipitation and the synthesis of (UPu)C. This contract covered the period May 23, 1966 through February 28, 1967 (Mixed Carbide Fuel, 1966; Final Report, 1967). The end date of this contract corresponds to the end of the AEC contract work and second operational period at Carborundum.

Out-of-Pile Properties of Mixed Uranium Plutonium Carbides:

- Contract AT-(30-1)-3118 covered the time period from February 6, 1962 through December 6, 1963 and was closely coordinated with the AEC-sponsored Carbide Fuel Development Program. Carborundum was a subcontractor to United Nuclear Corporation whereby UNC performed the property determinations and Carborundum prepared the fuel samples. Four 100-gram synthesis batches were prepared from UO_2, PuO_2, (UPu)C. Also, a total of 550 grams of UO_2, PuO_2, and carbon powder was synthesized in 70-100-g batches (Out-of-Pile Progress, 1963, PDF pp. 17, 22)

- Contract AT-(30-1)-3254 was closely coordinated with the Carbide Fuel Development Program. The goal under this contract was to determine the out-of-pile properties of (UPu)C which have the most significant effect on the operational characteristics of the fuel. The powder fabrication initiated under AT (30-1)-2889 continued with this contract (Out-of-Pile Final, 1963, PDF pp. 10, 14).

During this second operational period, a great deal of research was conducted at the Buffalo Avenue facility. This research began in May 1959 with uranium work. In 1960, a facility was completed for the synthesis and fabrication of UC-PuC fuels. As noted by the contracts information, the first plutonium shipment was received in June 1960 and plutonium work began in March 1961. Carborundum was contracted to mix uranium and plutonium fuels as part of their work on the Carbide Fuel Development program in support of UNC. While different mixtures were possible, the most common carbide mixture included 95% uranium and 5% plutonium. All work with radioactive material was done in the Central Research Laboratory, which was specifically constructed to support this work. The classified work with plutonium was conducted on the fourth floor in a secure room that required an escort for entry (Personal Communication, 2015c).

Several former employees were interviewed to discuss the work that they performed at Buffalo Avenue. Some of the work consisted of mixing uranium and plutonium oxides together in relatively small amounts (mg to gm) to make pellets. The results of each experiment were recorded in log books and the pellets were sent for spectroanalysis to determine the specific compounds that resulted (Personal Communication, 2015a). Much of the work with the uranium and plutonium mixtures was performed in glove boxes. One interviewee stated that he worked with small amounts because of a limitation imposed by the site based on the limitations of the available equipment. It was stated that there were glove boxes, small tube furnaces, and a large high-frequency furnace that were used to make uranium carbide (Personal Communication, 2015d). In addition, there was classified work that employed a special room requiring an escort for entry. One interviewee noted that the plutonium for the classified project was restricted to 200 mgs at any one time. The interviewee who discussed this operation was not aware how many experiments were performed using 200 mgs of plutonium (Personal Communication, 2015c).

Table 5-2: Carborundum Radiological Contract Work During the Second Operational Period						
Contract No.	**Years Reported**	**Type of Work**	**Radionuclides (SRDB Ref ID)**	**Amounts (SRDB Ref ID)**	**Comments (SRDB Ref ID)**	**Report Type (SRDB Ref ID)**
AT-(40-1)-2558	5/59-12/60	Synthesis and fabrication of refractory U compounds: Three phases: (1) development of methods for synthesis of compounds; (2) fabrication of synthesized materials; and (3) determination of properties, such as thermal conductivity, thermal expansion, high-temperature strength. Purpose: To develop methods to synthesize the materials UN, UC, and U_3Si_2. Purpose was to develop methods of fabrication and to study various properties of the compounds for use as reactor fuel.	UO_2, U_3O_8, UN (powder), U_3Si_2 Request for 10 pounds of U shot (46756) Many batches" of UC were made; batch sizes ranged from about 30 g to 6 lb. (140519)	1500 gm batch of UN 1200 gms of UN was made (140489) 3 lb lot of UC was prepared by the carbon reduction of UO_2 100 gms of U metal shot was acid treated (140492)	Part of the AEC Fuel Development Program The goal was to develop refractory uranium materials possessing a sufficient advantage over UO_2. Initial contract period was 5/13/59 through 11/1/60. No work done during May/June for facility improvements. Carborundum had to replace a glove box that was being used for some of the uranium work on this contract. (140489)	Summary Report (140519) 4th Quarterly Report (140516) 5th quarterly report (140518) Monthly report (140489) Report 8 (140492) Report 10 (140496) Report 11 (140498)
	3/1/61-5/31/61	Synthesis and fabrication of refractory U compounds. Sintering of U monocarbide.	Depleted UO_2; Thermax Thermatomic Carbon	453.6 g of UO_2; 60.5 g of carbon for each synthesis experiment.	Purpose of work: develop refractory U materials possessing sufficient advantages over UO_2 to warrant their use as reactor fuels. The UC was a powder. Depleted UO_2 from ORNL; Thermax Thermatomic Carbon from R.T. Vanderbilt Co. Two modifications were made to this contract to go beyond 12/60.	First Quarterly Report (45329)

Table 5-2: Carborundum Radiological Contract Work During the Second Operational Period						
Contract No.	**Years Reported**	**Type of Work**	**Radionuclides (SRDB Ref ID)**	**Amounts (SRDB Ref ID)**	**Comments (SRDB Ref ID)**	**Report Type (SRDB Ref ID)**
AT(30-1)-2303	6/6/60	Fabrication of plutonium carbide pellets using some of the following methods: ball milling, chemical analyses, crushing, cold pressing, sintering, grinding pellets.	PuO_2, UO_2	3 kg of Pu over 3 years; the first and only shipment in 1960 will be 500 g of Pu from Hanford.	Carbide Fuel Development. Report states that if there is any external radiation exposure it will be to the hands. All Pu compounds will be handled on a containment basis. Maximum amount of contained Pu will not exceed 600 g. No more than 200 g of Pu shall be in process.	Feasibility Report (19739)
	2/1/61-4/30/61	Fuel Fabrication and Evaluation: Explore various methods of fuel preparation and fabrication into cylindrical pellets, beginning with powders. Evaluate pellet density measurements.	Pu, Pu+U-235, PuC-UC, UO2	Synthesis of PuC from PuO_2. Seven batches of PuC were made by mixing PuO_2 and carbon then furnacing at differing temperatures and hold times.	The Pu facility started operations in March 1961. Prior to 1961, the equipment was tested by work with UC. Six reports are listed in covering 10/15/59 to 2/28/61 (61981); these reports are currently unavailable.	Progress Report (61981)
AT(30-1)-3118	2/6/61-12/6/63	Out-of-pile properties of mixed U-Pu carbides. Goal is to determine the properties of (UPu)C.	Pu, U Materials produced. 80% UC-20% PuC solid solutions	Four 100 gm synthesis batches were prepared from UO2, PuO2, (UPu)C. A total of 550 gm of UO_2, PuO_2 and carbon powder was synthesized in 70-100- gm batches	Prepared fuel samples. This program was closely coordinated with the Carbide Fuel Development program (AT30-1)-2899.	Final Report (65005)

Table 5-2: Carborundum Radiological Contract Work During the Second Operational Period						
Contract No.	**Years Reported**	**Type of Work**	**Radionuclides (SRDB Ref ID)**	**Amounts (SRDB Ref ID)**	**Comments (SRDB Ref ID)**	**Report Type (SRDB Ref ID)**
AT(30-1)-2899	5/1959-10/15/65**	UNC* provided conceptual design, fuel evaluation, and fuel irradiation. The Carborundum Company performed fuel fabrication.	UC, PuC All work investigated mixed carbides at 20 w/o PuC, except property measurements which were made at 5 w/o PuC fuel.	400 g of $(U_{0.95} Pu_{.0.5})C_{0.98}$ powder was synthesized for fabrication (70 pellets were fabricated).	The Carbide Fuel Development Program was concerned with the technology of the entire UC-PuC fuel cycle. The major goals were to produce (UPu)C and obtain data on its irradiation behavior for long burn-ups and at high-power generation rates. Other areas of the fuel cycle were explored to discover possible problems. Program initiated in May 1959; continued for 4.5 years.	Final Report (53617) Six reports were published under this contract, Phases I-VI
	9/15/61-12/31/61	Explore methods for preparation of fuel from powders and its fabrication into cylindrical pellets, evaluate pellets by density measurement, chemical analysis, X-ray diffraction, hardness.	UC-PuC powder was synthesized from oxides and carbons	Produce $(U_{0.8}Pu_{0.2})C_{0.95}$	NOTE: Comment in report says Pu facilities continued satisfactory operation at zero contamination levels NOTE: Pu is lost during synthesis or sintering and a small amount of Pu being lost during annealing.	(61996)
	1/1/62-3/31/62	AEC fuel-cycle development program concerned with entire UC-PuC fuel cycle. Fuel fabrication done by Carborundum.	Pu, U UC-PuC pellets	Sintering experiments with $(U_{0.8}Pu_{0.2})C_{0.95}$	Carbide Fuel Development, part of AEC Fuel Cycle Development Program. Fuel made of UC and PuC had a potential of reducing fuel-cycle cost of existing fast-breeder reactors.	Progress Report (61995)

Table 5-2: Carborundum Radiological Contract Work During the Second Operational Period						
Contract No.	**Years Reported**	**Type of Work**	**Radionuclides (SRDB Ref ID)**	**Amounts (SRDB Ref ID)**	**Comments (SRDB Ref ID)**	**Report Type (SRDB Ref ID)**
AT(30-1)-2899 (cont.)	4/1/62-6/30/62	Fabrication of the UC-PuC irradiation tests	UC, PuC, UC-PuC pellets	All powder required for the NU was synthesized Reaction to the 760 gm batch of PuO_2-UO_2-C yielded ~580 g of single phase $(U_{0.2}Pu_{0.2})C0_{.95}$ solid solution	There are 10 previous reports listed in this progress report.	Progress Report (61990)
	9/15/61-9/30/62	Performing conceptual design, fuel evaluation and fuel irradiation.	Powder containing normal U, EU, Pu	760 gm batch of PuO_2-UO_2-C yielded ~580 g of $(U_{0.8}Pu_{0.2})C_{0.95,}$ 200 g of $(U_{0.8}Pu_{0.2})C_{0.95}$ powder were produced in 40 gm lots Each specimen contained 16 fuel pellets.	Carbide Fuel Development, this project is sponsored by the USAEC Division of Reactor Development. Goal was to produce UC-PuC to obtain data on irradiation behavior for long burn-ups and at high-power generation rates. Goal was to develop method for preparation of high density pellets for irradiation studies Experiments were run with both normal and enriched U. 11 previous reports listed	Phase IV Report (65097)

Table 5-2: Carborundum Radiological Contract Work During the Second Operational Period						
Contract No.	**Years Reported**	**Type of Work**	**Radionuclides (SRDB Ref ID)**	**Amounts (SRDB Ref ID)**	**Comments (SRDB Ref ID)**	**Report Type (SRDB Ref ID)**
AT(30-1)-2899 (cont.)	10/1/62-3/31/63	Produce (UPu)C and obtain data on its irradiation behavior for long burn-ups and at high-power generation rates.	(UPu)C	Synthesis of about 400 g of $(U_{0.95}Pu_{0.05})C_{0.98}$	50 gm reaction mixes of PuO_2, UO_2 were blended and cold pressed. There were 8 synthesis experiments.	Progress Report (65092) 12 NDA and UNC* progress reports listed prior to this report from 10/15/59-3/31/63
AT(30-1)-3254	2/6/62-10/31/62	Out-of-pile properties of mixed U-Pu carbides. Carborundum prepared the fuel samples. Powder fabrication initiated under AT(30-1)-2889 is being continued.	(UPu)C 80% UC-20% PuC	Sintering experiments with $(U_{0.8}Pu_{0.2})C_{0.95}$	This program was closely coordinated with the Carbide Fuel Development program. The studies were a continuation of work performed under AT(30-1)-2899 8 previous reports listed	Progress Report (64284)
AT(30-1)-3305	2/1/64-10/30/65	Study of U-Pu Monoxides. U-Pu monoxide compositions were synthesized by carbon and U reduction methods.	U, Pu Depleted UO_2, PuO_2, UHx, UC, UN	Started with UO_2-PuO_2 mixtures to synthesize U-Pu monoxide type materials	Two synthesis routes: (1) reduction of mixed PuO_2 and UO_2 with carbon; (2) reduction of mixed dioxides with U metal: carried out in helium and vacuum at temps from 1450-1900^{0}C. Previous progress in reports: UNC*: 5096, 5102, 5117, 5132, 5138, covering years: 2/1/64-9/30/65	Final Summary Report (65007)
	7/1/65-9/30/65	Study of U-Pu monoxides	Materials containing as high as 85 w/o of a (UPu)(OC) composition	Synthesis of $(U_{0.8}Pu_{02})C$	Related reports: AT(30-1)3254, 2/6/62-10/31/62 (see above)	Quarterly Progress Report (65010)

Table 5-2: Carborundum Radiological Contract Work During the Second Operational Period

Contract No.	Years Reported	Type of Work	Radionuclides (SRDB Ref ID)	Amounts (SRDB Ref ID)	Comments (SRDB Ref ID)	Report Type (SRDB Ref ID)
AT(30-1)-3713	9/1/66-11/30/66	Part of the AEC Fuel Cycle Development Program Studies of the preparation of mixed carbide fuel utilizing co-precipitation; synthesis of (UPu)C. X-ray analysis used.	U as UO_2; Pu Concentration of the U or U,Pu in the nitrate solutions was ~0.15 g/ml	$(U_{0.8}Pu_{0.2})C$	Object is to extend the technology to the preparation of (UPu)C fuels Uranyl nitrate and Pu nitrate solutions were mixed to yield 4/1 ratio of U to Pu.	Quarterly Progress Report No. 2 (53582)
	11/23/66-2/28/67	Part of the AEC Fuel Cycle Development Program Study of synthesis (UPu)C compounds utilizing the co-precipitation of the carbon and metal-bearing materials from a common solvent.	(UPu)C	Started with $(U_{0.8}Pu_{0.2})C$	Object is to extend the technology to the preparation of (UPu)C fuels	Final Report May 23, 1966-February 28, 1967 (143094)

*United Nuclear Corporation (UNC), Development Division, was formerly Nuclear Development Corporation of America (NDA). The subcontractor is the Carborundum Company. UNC performed the conceptual design, fuel evaluation, fuel irradiation, and irradiated fuel examination. Carborundum fabricated the fuel. Both companies operated plutonium-handling facilities.

**X-ray diffraction analyses were not made on this program due to the carbide oxidizing on the planchet.

An abstract published in *Reactor Technology* on liquid metal fast breeder reactors discusses the Carbide Fuel Development Phase 1 Report for the period from May 15 to September 15, 1959 (Reactor Technology, 1960s, PDF p. 85). The abstract references contract AT(30-1)-2303 between the Nuclear Development Corporation of America (NDA) and the Carborundum Company. Subsequently, the Carbide Fuel Development project was the subject of a letter dated March 30, 1960, to the Nuclear Safety Board from the Radiation Branch, Environmental Sciences Division, Health and Safety Laboratory. This letter discusses the proposal for the Carborundum Company to manufacture ceramic pellets containing PuC mixed with UC (normal enrichment) at their Central Research Laboratories in Niagara Falls, New York. Over a period of three years, a total of approximately three kilograms of plutonium were to be fabricated into pellets. The first shipment of plutonium from Hanford (the only shipment during 1960) was to consist of 500 grams (Feasibility Report, 1960).

The following processes were to be involved in the fabrication of PuC pellets (operational details unspecified):

1. Weighing the PuO_2 Powder as received from the supplier
2. Chemical analysis
3. Addition of UO_2 and carbon
4. Ball milling
5. Heating to form the monocarbides
6. Crushing
7. Chemical and X-ray analysis
8. Ball milling
9. Cold pressing into pellets
10. Sintering into dense form
11. Grinding pellets
12. Inspection and shipment

The results of the Carbide Fuel Development project are documented in many reports, as indicated in the listings in the Foreword section of each progress report (Carbide Fuel, 1961, PDF p. 6).

Handling standards for plutonium were established in a planning document, which consisted of the following requirements:

1. All plutonium handling would be done in a glove box.

2. Any waste or scrap generated in the glove box would be removed using the “pouch” method.

3. The maximum amount of contained plutonium in storage shall not exceed 600 grams at any one time.

4. No single container could contain more than 200 grams of plutonium.

5. No more than 200 grams of plutonium or uranium/plutonium mix could be in-process at any one time.

6. No more than 100 grams of plutonium could be used in any single batch in process, with a maximum of two simultaneous batches in operation at any given time.

Each phase of the operation of fuel fabrication and testing was performed in an inert helium atmosphere.

The minimum critical mass for a water-reflected solution containing Pu-239 was identified as 510 grams, and the recommended safe mass was listed as 250 grams. Considering this information, the Carborundum Company pellet process was recommended for approval because the maximum of 200 grams of plutonium that would be stored per container or be in process at any one time (Feasibility Report, 1960).

Carborundum was involved as a prime contractor or a subcontractor in several phases of the AEC's Fuels Cycle Development Program. One aspect of this work is described in the Summary Report, *Synthesis and Fabrication of Refractory Uranium Compounds*, dated February 1961 (Refractory Uranium, 1959-60). The report covers the period from May 1959 through December 1960.

The object of the investigation was the development of refractory uranium materials possessing sufficient advantage over uranium dioxide to warrant their use as reactor fuels (Refractory Uranium, 1959-60). To this end, the various properties of these materials had to be examined. The materials chosen for examination consisted of uranium monocarbide (UC), uranium mononitride, and the silicide U_3Si_2 - all of which have higher densities than UO_2 (Refractory Uranium, 1959-60).

The work program was divided into three phases: (1) the development of methods for synthesis of the compounds; (2) fabrication of the synthesized materials into bodies suitable for testing; and (3) the determination of properties of the materials such as thermal conductivity, thermal expansion, and high-temperature strength (Refractory Uranium, 1959-60, PDF p. 10).

The majority of the work was conducted on small samples of various solutions of the uranium. For example, the chemical analysis included a representative batch of 1500 grams of UC was prepared from a non-pelletized mix of uranium, combined carbon, uncombined carbon, nitrogen, iron, and oxygen. It appears that, at various stages of the experimentation, it was necessary to use different furnaces or enclosures. The types of furnaces and enclosures that were available included: atmosphere induction furnaces, muffle furnaces, a vacuum induction furnace, nitriding furnaces, a quench furnace, a hot-pressing furnace, a thermal conductivity furnace, a high-temperature modulus-of-rupture apparatus, a high-temperature furnace, and glove boxes (Refractory Uranium, 1959-60).

Another aspect of the work involved synthesis experiments with UC. Three approaches were considered for the preparation of UC:

1. Reduction of an oxide (UO_2 or U_30_8) by carbon: For this experiment, carbon was heated with both UO_2 and U_3O_8 to produce UC. The reaction mixture was usually prepared for furnacing as follows: the oxide and carbon were mixed by dry ball-milling for 24 hours in a rubber-lined mill with stainless steel balls and then pressed into pellets measuring 5/8 inches by 5/8 inches. This was done at 15,000 - 20,000 pounds per square inch using about 2 percent of water as a temporary binder (Refractory Uranium, 1959-60, PDF p. 11). It is unknown how many experiments were run or how much uranium was used for each experiment. However, many batches of UC were made by heating stoichiometric mixtures of UO_2 and carbon in the vacuum induction furnace at 1750-1800°C. The size of the batches varied from about 30 grams to 6 pounds (Refractory Uranium,

1959-60, PDF p. 13). The resulting mixtures underwent an X-ray analysis to determine the characteristics of the resulting compounds.

2. Reaction of ammonium diuranate and carbon: The experiment was based on the assumption that ammonium diuranate would decompose to U_30_8 under the reaction conditions and the carbon would then react with the U_30_8 to form uranium carbide (uranium monocarbide). The pellets were heated in a ceramic tube furnace in an argon atmosphere. A temperature of about 700°C was reached in approximately 20 minutes and the maximum temperature of 1700°C in about 3 to 4 hours. The pellets were held at 1700°C for one hour and then allowed to cool in argon to room temperature (Refractory Uranium, 1959-60, PDF p. 14).

3. Reaction of Uranium and Carbon: This method of preparation was used exclusively in connection with a simultaneous synthesis and fabrication process described above for fabrication of uranium carbide (uranium monocarbide) (Refractory Uranium, 1959-60, PDF p. 14).

These experiments and others were all part of the Carbide Fuel Development Program, which was concerned with the technology of the entire UC-PuC fuel cycle. The major goal of the program was to produce (UPu)C and to obtain data on its irradiation behavior for long burn-ups and at high-power generation rates. The program was initiated in May 1959 and, as originally outlined, covered a period of about 4-1/2 years (Carbide Fuel, May1963, PDF p. 18).

Many of the overall experiments consisted of the following: synthesizing compounds and fabricating them into pellets; determining the coefficients of expansion; measuring melting points and vapor pressures; checking compatibility with other elements at various high temperatures; and performing irradiation tests (X-ray diffraction). These procedures involved handling of the radioactive material in one form or another in order to mix the chemicals and make transfers between the many enclosures for individual tests; this handling provided potential opportunities for exposure.

The exact quantities used in each experiment are not known. However, NIOSH does have information from a September 19, 1962 contract closeout notification in which Carborundum notified the Nuclear Regulatory Commission (NRC) of the radioactive material quantities on-hand and requested disposal instruction prior to the closeout of contract AT(40-1)-2558 (Contract Closeout, 1962). Section 5.2.2.3 lists the radioactive material that Carborundum had at that time. However, one of the steps in the fuel fabrication and evaluation was the preparation of powder for synthesizing the uranium, plutonium, and carbide mixture as well as the fabrication of test specimens. This process used a total of about 400 grams of a powdered mixture of uranium, plutonium, and carbide (Carbide Fuel, May1963, PDF p. 12).

This program was to evaluate the out-of-pile properties of mixed uranium-plutonium carbides at the 5% Pu level. A total of about 400 g of $(U_{0.95}\ Pu_{0.5})\ C_{0.98}$ powder was synthesized for the fabrication of test specimens.

Fifty-gram reaction mixes of PuO_2, UO_2, and carbon were blended and cold-pressed without a binder at about 5000 psi (pieces about 0.2 in. in diameter), and then heated in helium to 1625°C with a hold time of 5-1/2 hours. The reaction end-point was determined by monitoring the exhaust gas drawn from the heated furnace for CO. The results of analyses for total carbon and X-ray diffraction, as determined on the pulverized reaction products, showed the percent total carbon to be 4.94, 4.88, 4.74, 4.66, 4.78, 4.76, 4.73, and 4.79 respectively for the eight experiments (400 total grams split into 50 gram portions).

It was also stated that normal uranium was used in this synthesis. The carbide powders resulting from the eight synthesis experiments were combined and subsequently ball-milled for 24 hours in a rubber-lined mill using stainless steel balls and then sent for X-ray diffraction (Carbide Fuel, May1963, PDF p. 12).

X-Ray Diffraction

The ceramic pellets containing PuC-UC were manufactured by Carborundum as a subcontractor to United Nuclear Corporation, Inc. The fuels were evaluated by various means, including X-ray diffraction analysis (XRD) (Breslin, 1960). The X-ray powder diffraction method is used very extensively for compound or phase identification (Gundaker, 1971). Carborundum used this method to analyze the fuel as part of the fuel fabrication process.

In XRD, a very small beam of low-energy monochromatic X-rays irradiated a sample of matter – mixed-oxide fuel (PuC-UC) in the case of Carborundum. The X-rays are scattered by the individual atoms in the sample. In crystalline samples, the atoms are arranged in a lattice pattern. The scattered X-rays from the sample will interfere with each other, causing scattered X-rays to be emitted only in some directions and not others. This causes a diffraction pattern that can be recorded and analyzed, providing specific information about the atomic structure of the sample.

5.1.4 Second Residual Period (1968-1976[4])

All covered AEC work at the Carborundum Company was completed in 1967, which marks the end of the second operational period and beginning of the second residual period. The residual radioactive materials that remained from covered operations occurring during the second (and first) operational period(s) are all that must be accounted for in the second residual period. The operations that occurred between the second operational period and the end of the evaluated (covered) period at the Buffalo Avenue facility are of no radiological consequence; these interim operations are discussed in the following paragraphs.

There was some information on the non-radiological work that continued at the Carborundum Company during the second residual period, which included the following:

- In 1968, Carborundum manufactured some boron carbide powder for GE Atomic Power. Some of this material was tested for composition and density by ORNL in 1969, but the Carborundum work was not radiological (Fabrication, 1970).

- In 1968, Carborundum did some studies for Westinghouse Astronuclear Laboratory (WANL) on niobium carbide, but the work was not radiological (Niobium, 1969).

[4] As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time-frame, which extends only through 1976.

- In 1972, Carborundum produced some un-irradiated cylindrical pellets of boron carbide for testing as part of the EBR II program (EBR II, 1972).

NIOSH interviewed several former Carborundum employees who worked during the second residual period. One former employee stated that he worked in the mid-1970s and made bullet-proof vests and armor for PT boats. The base product was carbon. The material was put into ovens to make the plating for the armor. Sometimes the plating would be cracked. If the plating could be fixed, it would need grinding and smoothing; this created a lot of dust. Masks were not used during this process and there was no ventilation (Personal Communication, 2015b). The plates for the armor vests were made for the Vietnam War and this work was done in Building 14. This building had a firing range to test the armor plating (Personal Communication, 2015f).

Although the Carborundum Company is mentioned by name in numerous documents because of their grinding wheels, NIOSH did not find any information on any other potentially-covered radiological operations after 1967.

There are Carborundum Company annual reports available to NIOSH for 1971, 1972, and 1973 that discuss overall sales and expenditures; however, these reports do not discuss any further ongoing AEC-related processes (Annual Report, 1971; Annual Report, 1972; Annual Report, 1973).

5.2 Radiological Exposure Sources from Carborundum Company Operations

The following subsections provide an overview of the internal and external exposure sources for the Carborundum Company class under evaluation. Carborundum performed a great deal of research and development with mixtures of uranium oxide and plutonium oxide to develop fuel pellets, synthesize chemicals, and fabricate fuels.

The radionuclide-specific source terms that may be applicable to operational and residual radioactivity periods at Carborundum are uranium and plutonium. The following subsections describe the radioactive materials applicable to the time-period discussions within this section of this report.

In December 1960, a paper, *Status of Carbide Fuel Development at the Carborundum Company*, was presented at the third AEC Uranium Carbide meeting at Oak Ridge. This paper described the work done since the previous meeting, the future work that was planned, and some of the changes that were to be made in the uranium carbide–plutonium carbide fuel development program. Plutonium carbide was to be synthesized from plutonium oxide (PuO_2) that was prepared by Dow Chemical by the oxidation of plutonium metal. The oxide contained approximately 240 ppm of impurities. Table 5-3 shows the isotopic analysis of the PuO_2 (Carbide Fuel, 1960, PDF p. 8).

Table 5-3: Isotopic Analysis of PuO_2	
Isotope	**Percent**
Pu-238	0.00
Pu-239	93.50
Pu-240	5.90
Pu-241	0.60
Pu-242	0.00

As indicated in the October 15, 1965 document, *Carbide Fuel Development Final Report* (Final Report, 1965, PDF p. 48), Carborundum used PuO_2 from Dow Chemical in the study of the preparation of (UPu)C powder. The impurities in this powder was stated as <400 ppm; these impurities would contain traces of Pu-240 and Pu-241.

In addition, the 1966 Final Summary Report of the *Study of Uranium-Plutonium Monoxides* (Monoxides, 1966), indicated that the goal of the study was to find a uranium-plutonium monoxide-type fuel for water-cooled thermal reactors that would have a heat-generation capability better than, and water-corrosion resistance equivalent to, $Pu0_2$ and $(UPu)0_2$.

Plutonium enrichment was employed in this study in anticipation of the day when sufficient plutonium would be available to reduce reliance on uranium isotope enrichment facilities. Although early core loadings would use Pu-239, subsequent ones could use increasing amounts of Pu-240 to increase the reactivity burn-up limit of the reactor. Total plutonium concentrations of up to 10% would be introduced into the uranium fuel (Monoxides, 1966, PDF p. 14). In addition to Pu-239, Pu-240 and Pu-241 could also be sources of exposure.

Natural uranium refers to uranium consisting of approximately 99.3% U-238, 0.7% U-235, and a very small amount of U-234, by weight. In terms of radioactivity, natural uranium contains approximately equal percentages of U-238 (48.6%) and U-234 (49.2%). These radionuclides emit alpha particles with primary emission energies of 4.20 MeV and 4.15 MeV (U-238), and 4.77 MeV and 4.72 MeV (U-234) (Rad Handbook, 1970). The radioactivity contribution from U-235 is much smaller (approximately 2.2%) relative to U-238 or U-234. U-235 emits alpha particles with energies of 4.40 MeV and 4.37 MeV. Plutonium provides a source of alpha activity. Pu-239 emits alphas with primary emission energies of 5.11 MeV (11%) and 5.16 MeV (88%). Pu-240 emits alphas with primary emission energies of 5.12 MeV (24%) and 5.17 MeV (76%). Pu-241 emits alphas with primary emission energies of 4.85 MeV (0.0003%) and 4.90 MeV (0.0019%). (Rad Handbook, 1970).

Many of the contracts involving Carborundum overlapped for various periods of time and involved different process materials. Table 5-4 presents Carborundum contracts in parallel timelines; the corresponding process materials represent the respective source terms for the periods.

Table 5-4: Summary of Carborundum Exposure Sources Over the Contract Timelines													
Contract/Type of Work (SRDB Ref ID)	**Years**												
	1943	**1944**	**1945-1954**	**1955-1958**	**1959**	**1960***	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**
Clinton Engineer Works Project 1553: Metal Fabrication Program, Dummy Slug Program and Unbounded Slug Program (machining, grinding, grooving). (33190)	U	---	---	---	---	---	---	---	---	---	---	---	---
AT-(40-1)-2558: Synthesis and Fabrication of Refractory U Compounds. (140519) (45329)	---	---	---	---	UO_2, U_3O_8, UN powder, U_3Si_2	UO_2, U_3O_8, UN powder, U_3Si_2	Depleted UO_2;	---	---	---	---	---	---
AT(30-1)-2899: Carbide Fuel Development Program: Fuel Fabrication. (53617)	---	---	---	---	UC	UC, Pu	UC, PuC Powder containing normal U, Eu, Pu	UC, PuC Pellets Powder containing normal U, Eu, Pu	UC, PuC	UC, PuC Mixed carbides	UC, PuC Mixed carbides	---	---
AT(30-1)-2303: Carbide Fuel Development (61981) (53617)	---	---	---	---	---	UC, UO_2, Pu	---	---	---	---	---	---	---
AT(30-1)-3118; closely coordinated with AT(30-1)-2899 (65005)	---	---	---	---	---	---	U-Pu carbides	---	---	---	---	---	---
AT(30-1)-3254; closely related to AT(30-1)-1. Studies were a continuation of AT(30-1)-2889. (64284)	---	---	---	---	---	---	---	(UPu)C 80% UC-20% PuC	---	---	---	---	---

Table 5-4: Summary of Carborundum Exposure Sources Over the Contract Timelines													
Contract/Type of Work (SRDB Ref ID)	**Years**												
	1943	**1944**	**1945-1954**	**1955-1958**	**1959**	**1960***	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**
AT(30-1)-3305: Study of U-Pu Monoxides; UNC Project-2321 (65007)	---	---	---	---	---	---	---	---	---	U, Pu Depleted UO_2, PuO_2, UHx, UC, UN	U, Pu Deplete d UO_2, PuO_2, UHx, UC, UN	---	---
AT (30-1)-3713; Associated with the AEC Fuel Cycle Development Program: Studies of the preparation of mixed carbide fuel utilizing co-precipitation; synthesis of (UPu)C. (53582)	---	---	---	---	---	---	---	---	---	---	---	UO_2; Pu (UPu)C	UO_2; Pu (UPu)C

Three hyphens (---) mean there was no corresponding contract activity during this period.
* The sources of Pu in 1960 were limited to a shipment received in late 1960; processing did not begin until March 1961.

5.2.1 Internal Radiological Exposure Sources from Carborundum Co. Operations

The primary potential source of internally-deposited radioactivity resulting from Carborundum Company operations was inhalation and ingestion of natural, depleted, and enriched uranium and plutonium. Uranium was present at the site as a powder. In addition, plutonium-239 was present during the second operational period.

5.2.1.1 First Operational Period (1943-1944)

As indicated previously, Carborundum was involved with centerless-grinding testing using grinding wheels and different abrasives. This effort also included performing work on uranium slugs. The quantity of material identified in the first operational period is approximately 30 lbs of uranium (10 slugs) that were shipped between Carborundum and HHM Safe Company (Clinton, 1943, PDF pp. 9, 14). It was also noted that one rod was authorized to be sent to Carborundum on May 17, 1943 for centerless grinding experiments (Clinton, 1945, PDF p. 273). Based on the shipping records and description of work performed during the first operational period, NIOSH has concluded that Carborundum received 10 slugs. The slugs were received on June 1, 1943; the grinding work was done that month and results were reported on July 2, 1943. Return shipment of the slugs was not made until September 27, 1943. DuPont reported that there was no health supervision required because of the limited work performed (T-metal, 1944, PDF p. 13). Although the work was limited, centerless grinding of uranium has been known to produce significant levels of airborne radioactivity, creating an inhalation and ingestion hazard.

5.2.1.2 First Residual Period (1945-1958)

Only the residual materials that were considered a primary source during the first operational period need to be considered during the first residual period. Therefore, only natural uranium is considered to be a source that must be accounted for during the residual period from 1945-1958.

5.2.1.3 Second Operational Period (1959-1967)

Work at Carborundum during the second operational period (1959-1967) consisted of research and development. During this period, Carborundum worked with uranium and plutonium powders and chemicals to synthesize fuel pellets, and to develop refractory uranium materials possessing sufficient advantage over uranium dioxide to warrant their use as reactor fuels. Carborundum fabricated test samples of these materials and performed a variety of tests to verify their economic viability and their ability to replace uranium dioxide fuels. Although much of the experimentation and testing was conducted in enclosures, there was a potential for internal exposure (inhalation or ingestion) during the handling of uranium and plutonium powders and chemicals.

At its Central Research Laboratories in Niagara Falls, the Carborundum Company manufactured ceramic pellets that contained PuC mixed with UC (normal enrichment). During a three-year period, approximately three kilograms of plutonium were fabricated into pellets. The first plutonium shipment came from Hanford in 1960 and was 500 grams (Feasibility Report, 1960). The plutonium source term for this period is assumed to be the 10-year-aged 12% plutonium mix that has been used to bound the doses (see Section 7.2.2.1)

According to an interviewee, the plutonium work he did was classified and he was the only one in the room making pellets with a mixture of uranium and plutonium (Personal Communication, 2015c). NIOSH has not identified the specific procedures employed for this individual's work but it is assumed to be the same or similar chemical analysis discussed previously for making fuel pellets. Consequently, there would have been some potential for internal exposures to chemicals and powders. At the time Carborundum closed out contract AT(40-1)-2558 for source and special nuclear material, it had in its possession various amounts of depleted and 10% enriched uranium powder (Contract Closeout, 1962). These forms of uranium were used in the preparation of UC pellets and various-sized pieces were used for testing physical properties in connection with the Carbide Development Program (Carbide Fuel, 1960).

5.2.1.4 Second Residual Period (1968-1976[5])

As is the case with the first residual period, only the residual materials considered a primary source during the second operational period (and any carryover from the first operational period) need to be considered during the second residual period. Therefore, uranium and plutonium are considered to be sources that must be accounted for during the second residual period from 1968-1976, as evaluated in this report.

5.2.2 External Radiological Exposure Sources from Carborundum Co. Operations

Based on information and documentation available to NIOSH, as discussed in this evaluation report, the potential for external radiation doses from uranium, uranium decay products, and plutonium existed at the Carborundum Company. The following subsections discuss the external exposure sources for the Carborundum Company workers evaluated in this report. The external sources result in photon and beta radiations represented in Table 5-5, as well as some potential neutron exposures.

[5] As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time frame, which extends only through 1976.

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

Radionuclide	Half-life	Beta Energy (MeV Max)	Photon (x or γ) Energy (MeV)
U-238	4.468×10^9 years	None	x: 0.013 (8.8%)
Th-234	24.1 days	0.096 (25%)	x: 0.013 (9.6%)
		0.189 (73%)	γ: 0.063 (3.8%)
			γ: 0.093 (5.4%)
Pa-234m	1.17 minutes	2.28 (98.6%)	γ: 0.765 (0.2%)
		~1.4 (1.4%)	γ: 01.001 (0.6%)
U-235	7.038×10^8 years	None	x: 0.013 (31%)
			x: 0.090-0.105 (9.3%)
			γ: 0.144 (10.5%)
			γ: 0.163 (4.7%)
			γ: 0.186 (54%)
			γ: 0.205 (4.7%)
Th-231	25.5 hours	0.206 (15%)	x: 0.013 (71%)
		0.288 (49%)	γ: 0.026 (14.7%)
		0.305 (35%)	γ: 0.084 (6.4%)
U-234	244,500 years	None	x: 0.013 (10.5%)
			γ: 0.053 (0.2%)

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

Photon

Carborundum conducted work with natural, depleted, and enriched uranium as well as plutonium. External exposures to photon radiation would have resulted from the immediate daughter radionuclides in the uranium decay chain. The uranium progeny that result in the most significant photon exposures include Th-234 and Pa-234m (Rad Handbook, 1970). Note that these isotopes have relatively-short half-lives and can be assumed to be in equilibrium with the parent U-238. Because of their short half-lives, the exposure potential from these isotopes would travel with the parent and will not be considered separately. Plutonium itself is not a major contributor to photon dose. However, Pu-239 decays by alpha emission to U-235, whose short-lived daughters do contribute to total photon exposure. Table 5-5 shows the primary isotopes, principal emissions, and photon energies associated with natural uranium and short-lived decay products.

Beta

Radiation fields from uranium are frequently dominated by contributions from daughter-product radionuclides. For example, nearly the entire beta radiation field from DU comes from the daughter radionuclide Pa-234m, and to a lesser extent, from Th-234.

Table 5-5 shows the principal beta emitters and their energies for uranium. Because Pu-239 decays directly to U-235, the beta-emitters present in this decay chain are already accounted for in Table 5-5. As indicated, there are a significant number of high-energy beta radiations that represent a shallow dose exposure concern for site workers. Workers who handled the uranium would have received shallow dose exposures. The primary exposure areas would have been the hands and forearms, the neck and face, and other areas of the body that might not have been covered.

Neutron

The source of neutrons would result from the work with uranium and plutonium that was conducted in the glove boxes during the second operational period. Neutron doses for Carborundum were calculated using the MCNPX software. Dose rates were calculated at 30 centimeters and one meter from the face of the glove box. Based on the nature of the work and the forms of the materials being handled during operations at Carborundum, neutrons are only considered to be a potential external exposure source during the second operational period.

5.2.2.1 First Operational Period (1943-1944)

As indicated previously, Carborundum was involved with centerless-grinding testing using grinding wheels and different abrasives. This work was performed on 10 uranium slugs that were shipped between Carborundum and HHM Safe Co. (Clinton, 1943, PDF pp. 9, 14). Therefore, Carborundum's experimental grinding of T-metal (uranium) in June 1943 included an external uranium exposure hazard (T-metal, 1944, PDF p. 13).

5.2.2.2 First Residual Period (1945-1958)

Based on the removal of the exposure sources from the site during the first residual period, the external doses and potential for external exposures are considerably lower than that of the associated operational period. There is further discussion and analysis of the external exposures during the first residual period in Section 7 of this report.

5.2.2.3 Second Operational Period (1959-1967)

The second operational period included quantities of both uranium and plutonium that contributed to the on-site source term. Between 1959 and 1967, Carborundum had seven contracts for a variety of experimental procedures. The contracts included work with both uranium and plutonium.

The experimental procedures during the second operational period included different research and development methods, such as: synthesis and fabrication of refractory uranium compounds; fabrication of plutonium pellets; fuel fabrication; evaluation of mixed uranium-plutonium carbide fuels; and fuel irradiation. Shipping and receipt records, contract descriptions, and licensing information provide an indication of the quantities of radioactive material that was on the Carborundum site. Quantities included three kg of Pu over a three-year period, 1500 grams of UN, three pounds of UC, and various batches of different U-Pu alloy carbides. Table 5-2 lists known quantities.

Although most of the experimental work was conducted in glove boxes, they were potential sources of exposure for the workers. The work involved the investigation of methods for synthesizing the compounds, fabrication of the materials for testing, and determining the properties of these materials. Another major effort was the carbide fuel development program, which involved fabrication and testing uranium and plutonium fuel pellets and studying out-of-pile properties of mixed U/Pu carbides. This work also included performing conceptual design, fuel evaluation, and irradiation.

While many of the procedures mentioned above do not provide the amounts of radioactive material used, several other experiments do provide that information. Please note that the dates indicated in the parentheses in the bullets below are approximate dates that are based on progress/summary reports.

- During the synthesis of uranium monocarbide a representative batch of UC consisted of 1500 grams (1959-1960) (Refractory Uranium, 1959-60, PDF p. 11).

- In another experiment designed to determine the effect of the thermal history of the UC powder (time and temperature used in the synthesis) on its subsequent sinterability, each experiment used 453.6 grams of UO_2 (Refractory Uranium, 1961, PDF p. 7). The number of experiments conducted has not been stated (1961).

- During the synthesis of thermal conductivity specimens a total of 550 grams of UO_2, PuO_2 and carbon powder was synthesized in 70 -100 gram batches (1961-1963) (Out-of-Pile Final, 1963, PDF p. 22).

- One of the steps in the evaluation of the out-of-pile properties of mixed uranium-plutonium carbides at the 5% PuC level was the preparation of the powder. In this procedure, about 400 grams of $(U_{0.95}\ Pu_{0.05})C_{0.98}$ powder was synthesized for the fabrication of test specimens (1959-1965) (Final Report, 1965, PDF p. 77; Carbide Fuel, May1963, PDF p. 12).

- Other experiments during the fuel development program consisted of the fuel synthesis for the fabrication of UC-PuC irradiation testing. In one experiment, the natural uranium powder required for the natural uranium irradiation specimens was synthesized. Reaction of the 760-gram batch of PuO_2-UO_2-C yielded approximately 580 grams of an essentially single-phase $(U_{0.8}Pu_{0,2})_{C0.95}$ solid solution. In its synthesis, the reaction batch was divided into 16 lots of about 50 grams each (1962-1963) (Carbide Fuel, 1962, PDF p. 11; Carbide Fuel, Mar1963, PDF p. 19).

Other material that was available at Carborundum was contained in their letter to the NRC. On September 19, 1962, Carborundum notified the Nuclear Regulatory Commission (NRC) of the closeout of contract AT(40-1)-2558 and to obtain their instructions for the disposal of the radioactive material they possessed (Contract Closeout, 1962). Table 5-6 lists the radioactive material that Carborundum had at that time.

Table 5-6: Carborundum Radioactive Material Inventory in 1962	
Material Category and Uranium Type	**Amount**
Contract: Normal Uranium	
As metallic uranium in powder form, as received	9,260 grams of U
As uranium monocarbide in powder form, as received	44 grams of UC
As uranium nitride in powder form, as received	27 grams of UN
As chemical residues	14 grams of U
Contract: Depleted Uranium	
As uranium dioxide in powder form, as received	13,379 grams of U
As U_3O_8 in powder form contains carbon as an impurity	3,170 grams of U
Contract: 10% Enriched Uranium	
As metallic uranium in powder form, as received	54 grams of U
As uranium dioxide in powder form, as received	829 grams of U
As U_3O_8 in powder form contains carbon as an impurity	609 grams of U
As UC, on wipers, used containers and crucibles (questionable recovery)	72 grams of U
License: Depleted Uranium as Metallic Turnings	340 grams of U
Depleted Uranium Monocarbide as shot	47 grams of U

X-Ray Diffraction Machines

An additional external exposure source that must be accounted for during the second operational period is from the X-ray Diffraction Machines in use to analyze the UC-PuC materials being produced. The greatest hazard from XRD machines is from external exposure from the primary beam. This can occur most commonly during alignment procedures, where the target must be aligned with the output port, the sample with the primary beam, and the detector or film holder with the reflected beam (Lubenau, 1969). If the X-ray beam is inadvertently turned on during alignment, the operator's fingers or hands may be inadvertently exposed to the primary beam. Historically, these types of accidents are the primary hazard from XRD machines (Thomas, 1971, PDF p. 145). No evidence of these types of radiation accidents has been found at Carborundum.

The scattered radiation is also of low energy and occurs in small, directional beams. Any leakage of radiation from the device through small cracks in shielding or other components would also tend to be of low energy, and in small, directional beams. Operators usually sit safely nearby the device during normal operation. Operators are not usually monitored for radiation exposure, because of the small likelihood of the very small beams interacting with the small dosimeter device (Blatz, 1971, PDF p. 76).

5.2.2.4 Second Residual Period (1968-1976[6])

As in the case of the first residual period, based on the removal of the exposure sources from the site during the second residual period, the external doses and potential for external exposures are considerably lower than that of the associated operational period. There is further discussion and analysis of the external exposures during the second residual period in Section 7 of this report.

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

The following subsections provide an overview of the state of the available internal and external monitoring data for the Carborundum Company class under evaluation.

6.1 Available Carborundum Company Internal Monitoring Data

NIOSH has not found any radiological surveys conducted during the two operational periods at the Carborundum Company, nor has NIOSH found any bioassay data for any Carborundum personnel during the period under evaluation (January 1, 1943 through December 31, 1976).

NIOSH has obtained limited air dust monitoring results for the second operational period under evaluation (Sample Results, 1947-1961, PDF pp. 172-176). A total of nine readable uranium air dust samples were taken in November 1959 (with one control sample) and in April 1961 (see Table 6-1). Sixteen plutonium air dust samples were taken in April and June 1961 (with one control sample) (see Table 6-2).

Uranium:

- On November 9, 1959, a series of six general area dust samples were taken. One sample had a positive result of 6 dpm/m^3.

- On April 5, 1961, a second series of three general area samples was collected, all with positive results. The highest result was 21 dpm/m^3.

NIOSH has not found any documentation to support why these samples were taken on these dates or if people were present in the room.

[6]As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time frame, which extends only through 1976.

Table 6-1: Carborundum Uranium Air Dust Samples		
Sample Location and No.	**Sample Date**	**Sample Result (dpm/m^3)**
GA -Rm 17 NW- uranium canning area Sample #11	April 5, 1961	21
GA- Rm 17 - C work aisle Sample # 12	April 5, 1961	5.2
GA- (unreadable) area Sample # 13	April 5, 1961	10
Not Readable	April 19, 1961	Not Readable
GA Hood Room	Nov. 9, 1959	---
GA Hood Room	Nov. 9, 1959	---
GA Furnace Room	Nov. 9, 1959	---
GA Furnace Room	Nov. 9, 1959	6
GA Source Room	Nov. 9, 1959	---
GA Source Room	Nov. 9, 1959	---
Control	Nov. 9, 1959	---

Three hyphens (---) indicate that no result was given for the specified sample.

<u>Plutonium:</u>

- On April 5, 1961, a series of eight air dust general area and breathing zone samples was taken. All samples on this date had positive results with the highest result of 22 dpm/sample.

- On June 7, 1961, a second series of eight air dust general area and breathing zone (not including the control) samples was collected. Four of the samples (three breathing zone samples and one general area sample) had positive results. The highest result was 0.76 dpm/sample.

NIOSH has not found any documentation to support why these samples were taken on these dates.

Table 6-2: Carborundum Plutonium Air Dust Samples		
Sample Location	**Sample Date**	**Sample Result (α dpm/sample)**
Sample 1C-GA- 4 ft high at Box #6 unreadable	April 5, 1961	0.6
Sample 1F Sample description not specified	April 5, 1961	0.2
Sample 2C BZ (GA) Between Boxes 2 and 3	April 5, 1961	22.0
Sample 2F Sample description not specified	April 5, 1961	0.1
Sample 3C GA- 4 ft high at Box #6 unreadable	April 5, 1961	0.8
Sample 3F Sample description not specified	April 5, 1961	0.2
Sample 4C BZ (GA) Between Boxes 2 and 3	April 5, 1961	2.2
Sample 4F Sample description not specified	April 5, 1961	0.1
BZ Box #2 cyclone-operator performing (text not readable)	June 7, 1961	0.57
BZ Box #2 adjacent to 3034-0 (Location/sample 3034-0 is near Box # 2)	June 7, 1961	0.00
GA Adjacent to Schmidt Sampler	June 7, 1961	0.76
BZ Box #5 Operator observing vacuum furnace operation	June 7, 1961	0.76
BZ (GA) Box #3 cyclone	June 7, 1961	0.38
BZ (GA) Box # 2 Adjacent to 3034-4 (Location/sample 3034-4 is near Box # 2)	June 7, 1961	0.00
GA Same as 3034-2 (location/sample 3034-2 unknown)	June 7, 1961	0.00
BZ Same as 3034-3 (location/sample 3034-3 unknown)	June 7, 1961	0.00
Control	June 7, 1961	0.00

6.2 Available Carborundum Company External Monitoring Data

NIOSH has not identified Carborundum Company or DOE documentation that would show that the operational areas or the workers were monitored for external radiation, either during the two AWE operational periods or the two residual radiation periods.

7.0 Feasibility of Dose Reconstruction for the Class Evaluated by NIOSH

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

In determining feasibility, NIOSH begins by evaluating whether current or completed NIOSH dose reconstructions demonstrate the feasibility of estimating with sufficient accuracy the potential radiation exposures of the class. If the conclusion is one of infeasibility, NIOSH systematically evaluates the sufficiency of different types of monitoring data, process and source or source term data, which together or individually might assure that NIOSH can estimate either the maximum doses that members of the class might have incurred, or more precise quantities that reflect the variability of exposures experienced by groups or individual members of the class as summarized in Section 7.4. 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-00223 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Carborundum Company Data

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

7.1.1 Internal Monitoring Data Pedigree Review

NIOSH has not identified any urinalysis, whole-body counts, or lung counts for either the two operational periods or the two residual periods. Therefore, an internal monitoring data sufficiency and pedigree evaluation is not possible for these types of data.

However, NIOSH has identified uranium and plutonium air sample data during the second operational period (1959-1967) that are original reports and are, therefore, primary data sources. The reports are mostly legible and use appropriate reporting units. NIOSH believes these data to be sufficient to assess a bounding internal exposure scenario. Considering this information, no additional pedigree review was performed for these data.

7.1.2 External Monitoring Data Pedigree Review

NIOSH has not located any external monitoring data for the Carborundum Company for the two operational periods and two residual periods under evaluation. Therefore, a complete external data sufficiency and pedigree evaluation is not possible for the period from January 1, 1943 through December 31, 1976.

7.2 Evaluation of Bounding Internal Radiation Doses at Carborundum Company

The principal source of internal radiation doses for members of the class under evaluation was the potential inhalation and ingestion of natural, depleted, and enriched uranium, and plutonium. For the Manhattan Project and the AEC, natural uranium was used during the early years. Some low-enriched uranium began to be used in reactor fuels (Battelle-TBD-6000, PDF p. 14) and some AWE sites, including Carborundum, did use some enriched uranium. NIOSH has not found any information regarding the use of enriched uranium at Carborundum other than the contract information listed in Table 5-2 of this report, which appears to be a limited-scope operation performed under contract AT (30-1)-2899. During the first operational period (1943), the uranium was in the metallic form.

For the second operational period, the form included metals and oxides as well as forms of plutonium. The grinding and processing operations performed at Carborundum could have caused some of the uranium (or plutonium in the second period) to go airborne, resulting in personnel internal exposures from inhalation or ingestion of airborne radioactive materials. A former Carborundum employee who worked at the facility during the second operational period stated that the uranium that came into the facility had to be ground to a small powder (Personal Communication, 2015d). In addition, based on the closeout of contract AT(40-1)-2558 (Contract Closeout, 1962), during the second operational period the uranium was received in powder form, as indicated in Table 5-6 above. There was also a potential for personnel exposure due to re-suspension of contamination during the operational and residual radioactivity periods. The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

The Carborundum bioassay program may have been different for selected personnel. One individual stated he had urine samples every 3-6 months while the plutonium workers were sampled more often (Personal Communication, 2015d). The individual who worked with plutonium stated he provided both urine and blood samples every 2-3 weeks (Personal Communication, 2015c). However, NIOSH has not found any urine sample data or radiological surveys, with the exception of the air dust samples in November 1959 and April and June 1961, for any of the covered periods evaluated in this report.

NIOSH has identified uranium and plutonium dust sample results, as listed in Tables 6-1 and 6-2 and discussed below. As previously discussed in this report, Carborundum did experimental work on types of abrasive wheels and the speed with which the grinding was done to optimize the grinding process. Carborundum did not do centerless grinding on a production schedule. However, because the same type of work was performed on a production scale and schedule at other facilities, it was determined that the airborne activity identified at those companies and the guidance in Battelle-TBD-6000 could be used to support bounding Carborundum internal doses.

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

First Operational Period (1943–1944)

NIOSH has not identified any bioassay data for Carborundum employees or airborne data for the first operational period (1943-1944). Internal doses from uranium intakes during the first operational period are estimated using the data from the pre-1951 "Machining" operation in Tables 7.8 and 7.9 of the *Technical Basis Document: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000).

The work performed at Carborundum was done for the purpose of experimentally determining the appropriate type of abrasive wheel and the optimum speeds to maintain. Carborundum was not the site where the actual final uranium production grinding operation was performed. The information from this operational period at Carborundum (as discussed in Section 5) denotes that the scale of this uranium operation was very limited (30 pounds of slugs) and conducted in June 1943. The 30 pounds consisted of ten slugs that were shipped from HHM Safe Co. to Carborundum in May 1943 and returned to HHM Safe Co. in September 1943. Based on its review of the available data as well as the methodology identified for bounding dose, NIOSH concludes that the Battelle-TBD-6000 methodology is based on large-scale and large-quantity operations, and therefore, serves to support bounding internal exposures for Carborundum's first operational period.

First Residual Dose Period (1945–1958)

NIOSH has not identified any monitoring data or post-operational survey data that would support assessing personnel doses to residual radioactivity during the first residual period (1945-1958). Doses from residual uranium are determined using the adjustments found in the *Technical Information Bulletin: Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). This approach is deemed sufficient to bound the residual period exposures because the approach is based on the radiological source term from the first operational period. As discussed, the operations during the first operational period were limited in scope of radiological work and involved a very limited radiological source term.

Second Operational Period (1959–1967)

NIOSH has identified air sample results for uranium and plutonium for the second operational period, as discussed below and shown in Tables 6-1 and 6-2. Because the operations were of an experimental nature and the sample data are limited in scope, a statistical analysis was performed on both the uranium and plutonium sample results to determine their respective doses. However, two former employees stated that the work was done in glove boxes. The first individual (SRDB ID: 142192) was a lab technician who worked with small amounts (mg to gm quantities) of uranium oxides and plutonium oxides. He indicated he worked in glove boxes that were used to contain acid fumes. The second individual (SRDB ID: 142193) was a lab technician, and later, an engineer who worked with depleted uranium synthesizing uranium carbide. He stated they had glove boxes and small tube furnaces. He also indicated they had a susceptor furnace about 12 inches in diameter that heated up the unit. He stated they could only make small quantities of the enriched-uranium-carbide reaction because it needed to go to a high temperature range. This was not in a glove box, but in a room under negative pressure. Finally, it was indicated that very few workers were involved in this operation; the interviewee stated he was the only one in the area during his shift because of security clearance requirements (Personal Communication, 2015c).

- Uranium: Doses are assigned based on dust sampling data found for November 1959 and April 1961 (Sample Results, 1947-1961). On November 9, 1959, a series of six general area dust samples were taken. A second series of three samples, all with positive results, was collected on April 5, 1961. One other sample was taken; the sample date is unknown, but it was received on April 19; it is not legible. Uranium doses are assigned as 100% U-234 for the purposes of individual uranium dose evaluation.

- Plutonium: On April 5, 1961, a series of eight dust samples was taken. Two were identified as general area samples, two were identified as breathing zone samples, and four were either without description or the description was illegible. All samples on this date had positive results. On June 7, 1961, a second series of eight samples was collected. Six of the samples were identified as breathing zone samples, while two were identified as general area samples. Four of the samples had positive results. Plutonium intakes are assessed based on dust sampling data found for April 1961 and June 1961 (Sample Results, 1947-1961) and assigned as 12% 10-year aged plutonium.

Second Residual Dose Period (1968–1976[7])

As was the case for the first residual period, NIOSH has not identified any monitoring data or post-operational survey data that would support assessing personnel doses to residual radioactivity during the second residual period. However, doses from residual uranium and plutonium are determined using the adjustments found in the *Technical Information Bulletin: Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). This approach is again deemed sufficient to bound the residual period exposures because the approach is based on the radiological source term from the associated second operational period, as well as any carryover from the first operational period. As discussed, the operations during the first and second operational periods were limited in scope and source term, including a limited number of personnel assigned to specific AEC-related work areas.

- Uranium: Doses from residual uranium are determined using the adjustments found in the *Technical Information Bulletin: Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). Bounding uranium doses are assigned as 100% U-234.

- Plutonium: Intakes are assigned in the same manner as uranium intakes, using the adjustment factors for the residual period, as reflected in ORAUT-OTIB-0070. Bounding plutonium intakes are assigned as 12% 10-year aged plutonium.

[7] As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time frame, which extends only through 1976.

7.2.2 Methods for Bounding Internal Dose at Carborundum Company

7.2.2.1 Methods for Bounding Operational Period Internal Dose

First Operational Period (1943–1944)

For the first operational period, there are no bioassay data for Carborundum employees. Internal doses from uranium intakes during the first operational period are estimated using the data from the pre-1951 "Machining" operation in Tables 7.8 and 7.9 in the TBD, *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). Because of the chemical and physical forms of uranium used at the site, only Type M or S solubility was evaluated.

Second Operational Period (1959–1967)

It is not possible to accurately separate which worker worked with only uranium or only plutonium. In addition, the carbide mixture is a combination of uranium and plutonium. Therefore, in order to be claimant-favorable for the second operational period and its associated residual period, both uranium and plutonium should be concurrently assigned.

- Uranium: For the second operational period (1959-1967), uranium doses are assigned based on dust sample data found for November 1959 and April 1961 (Sample Results, 1947-1961). On November 9, 1959, a series of six general area dust samples were taken. A second series of three samples was collected on April 5, 1961. A statistical analysis of these samples results in a GM of 1.666 dpm/m^3, a GSD of 2.5111, and a 95th percentile of 7.578 dpm/m^3. Considering the controls on the operations (i.e., use of glove boxes, ventilation, and information from interviewees denoting the very radiologically-clean nature of the work).

  The general area air concentrations are suitable for radiological production support personnel and, after adjustment, for supervisors and other worker categories. Therefore, these values will be doubled (or scaled-up from the values used for support personnel), consistent with DR methods and approaches using similar data, to estimate exposures for operators. Uranium doses are assigned as 100% U-234.

- Plutonium: Plutonium doses are assigned based on dust sampling data found for April 1961 and June 1961 (Sample Results, 1947-1961). On April 5, 1961, a series of eight dust samples was taken. Four were identified as general area samples, two of which were also identified as breathing zone samples, and four were either without description or the description was illegible. On June 7, 1961, a second series of eight samples and one control sample was collected. Six of the samples were identified as breathing zone samples; two were identified as breathing zone and general area samples. Two samples were identified as general area samples. A statistical analysis of these samples results in a GM of 0.022 dpm/m^3, a GSD of 7.244, and a 95th percentile of 0.578 dpm/m^3. Considering the controls on the operations (i.e., use of glove boxes, ventilation, and information from interviewees denoting the very radiologically-clean nature of the work).

  Similar to the uranium approach, the general area and breathing zone air concentrations are suitable for radiological production support personnel and, after adjustment, for supervisors and other worker categories. Therefore, to include all workers and to be favorable to the claimants, these values will be doubled (or scaled-up from the values used for support personnel), consistent with DR methods and approaches using similar data, to estimate exposures for operators. Plutonium intakes are assigned as 12% 10-year aged plutonium.

7.2.2.2 Methods for Bounding Residual Period Internal Dose

First Residual Dose Period (1945–1958)

For the first residual period, doses from residual uranium resulting from the first operational period are depleted over the residual period using the adjustments found in the Technical Information Bulletin, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). Inhalation and ingestion uranium doses were calculated for production areas and non-production areas. Uranium doses are assigned as 100% U-234.

Second Residual Dose Period (1968–1976[8])

- Uranium: For the second residual period, doses from residual uranium resulting from the second operational period are depleted over the residual period using the adjustments found in the Technical Information Bulletin, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). As during the first residual period, inhalation and ingestion intake values have been calculated for production areas and non-production areas. Uranium doses are assigned as 100% uranium-234.

- Plutonium: For the second residual period, doses from residual plutonium resulting from the second operational period are depleted over the residual period using the adjustments found in the Technical Information Bulletin, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). As during the first residual period, inhalation and ingestion intake values have been calculated for production areas and non-production areas. Plutonium intakes are assigned as 12% 10-year-aged plutonium.

7.2.3 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has concluded that it is feasible to reconstruct internal doses at the Carborundum Company, Buffalo Avenue facilities in Niagara Falls, New York, using the following approaches:

- First Operational Period (1943-1944): Use the information in the *Technical Basis Document: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000).

- First Residual Period (1945-1958): The intakes for the first residual period will be extended through 1992, as the operations in the first operational period occurred in a separate location from the second operational period. Use the adjustments found in the *Technical Information Bulletin: Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070).

[8] As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time frame, which extends only through 1976.

- Second Operational Period (1959-1967): Use the uranium and plutonium air sample data identified for 1959 and 1961.

- Second Residual Period (1968-1976[9]): Using the ORAUT-OTIB-0070 methodology, during the second residual period, the more claimant-favorable exposure between the first residual period that extends into the second residual period (i.e., intakes derived from the first operational period but extended into the second residual period) and the second residual period itself (i.e., intakes derived from the second operational period) will be assigned.

NIOSH may choose to employ a more refined approach when reconstructing individual doses based on information obtained during the evaluation of individual claims. The NIOSH example dose reconstruction methodologies, to be provided separately from this evaluation report, will demonstrate the applicable bounding approaches for reconstructing doses for the applicable residual and operational periods at Carborundum.

7.3 Evaluation of Bounding External Radiation Doses at Carborundum Company

The principal source of external radiation doses for members of the evaluated class was photon and beta (electron) radiation associated with research and development of uranium and plutonium carbide materials, and the development of fuel for AEC operational activities, including depleted and enriched uranium. The X-ray powder diffraction method was used extensively for compound or phase identification (Gundaker, 1971); Carborundum used this method to analyze the fuel as part of the fuel fabrication process.

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 or plutonium processing that occurred, nor has NIOSH been able to identify any radiation surveys or area monitoring data for the period from January 1, 1943 through December 31, 1976.

Shipping and receipt records, contract descriptions, and licensing information provide an indication of the quantities of radioactive material that was on the Carborundum site during the periods under evaluation. These quantities are discussed in preceding sections of this evaluation report and, in the absence of more definitive data, can be used to support bounding the external dose from exposure to these materials.

Based on the machining (grinding) work performed at Carborundum, slug production was selected from the processes found in Battelle-TBD-6000 to evaluate and bound Carborundum doses.

[9] As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time frame, which extends only through 1976.

Individual external doses are assigned based on the specific work performed, using the categories described below:

- Operators: Individuals who operated process equipment and/or routinely handled radiological materials.
- General Labor/Radiological Work Support Personnel: Individuals who were in close contact with the radiological materials product for a portion of the working day. This category would include maintenance workers, laboratory workers, and health physics monitors.
- Supervisor/Non-Radiological Work Production Personnel: Individuals who routinely worked in the production areas and periodically may have been in the vicinity of processing. This includes supervisory staff, engineers, and individuals who were not in contact with the radiological materials but who worked routinely in the production areas.
- Clerk/Other: Individuals who worked in the environment outside the production areas where radiological work was being performed. This includes office workers and non-radiological production workers that are clearly documented to be in a physically different location than the radiological work (e.g., a different building).

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

7.3.2 Carborundum Company Occupational X-Ray Examinations

NIOSH has not found any evidence of active medical supervision at the Carborundum Company. NIOSH did find evidence that medical supervision was not necessary for the first operational period (T-metal, 1944, PDF p. 13). NIOSH has not found any data relevant to medical X-rays at Carborundum for the second operational period. Medical X-rays are not required to be considered during residual radiation periods. Per ORAUT-OTIB-0006 and ORAUT-OTIB-0079, in the absence of information to the contrary, NIOSH assumes that medical X-ray examinations were performed on site during the second operational period.

- First Operational Period (1943-1944): In a letter dated October 11, 1944 from the E.I. du Pont Engineering Department to the Medical Director discussing the companies that performed work on T metal, it is stated that Carborundum performed experimental grinding of T metal in June 1943. It further states that there was very limited exposure with no medical supervision necessary (T-metal, 1944, PDF p. 13). Therefore, NIOSH will not assess medical X-rays for the first operational period.

- Second Operational Period (1959-1967): NIOSH has not identified information that indicates medical X-ray examinations were NOT performed at the Carborundum Company. Therefore, NIOSH will assume that pre-employment, annual, and termination PA radiographic chest X-ray screenings were performed for workers during the second operational period. NIOSH will bound doses using the methodology defined in ORAUT-OTIB-0006.

7.3.3 Methods for Bounding External Dose at Carborundum Company

There is an established protocol for assessing external exposure when performing dose reconstructions:

- Photon Dose
- Beta Dose
- Neutron Dose
- Other (XRD)
- Medical X-ray Dose (as applicable per Section 7.3.2)

However, NIOSH has determined that, for Carborundum, it is more appropriate to discuss bounding external doses for identified operational and residual time periods that encompass the rationale for the stated radiation types. Although no external monitoring data are available to NIOSH for the Carborundum Company, the tables and discussions in Battelle-TBD-6000 and ORAUT-OTIB-0006, as well as the calculated doses for plutonium, can be used to bound the various operational period external doses at Carborundum. The following sections provide the details for bounding the external doses for Carborundum operational and residual periods.

7.3.3.1 Methods for Bounding Operational Period External Dose

The following subsections discuss the methods for bounding the external doses to Carborundum workers according to the operational time periods.

External doses for uranium exposures during the operational periods are assessed using the exposure, R, dose equivalent organ DCF (dose conversion factor). All penetrating doses are assigned as 30–250 keV photons. Shallow doses are assigned as >15 keV electrons (Battelle-TBD-6000).

External doses for plutonium exposures during the operational periods are assessed using the deep, Hp(10), dose equivalent organ DCF (dose conversion factor). Photon/neutron energy distributions associated with plutonium will be based on the dose calculations from the MCNPX software using the restrictions for plutonium within the Carborundum glove box complex. Shallow doses are assigned as <30 keV photons (Battelle-TBD-6000).

First Operational Period (1943-1944)

In the absence of personnel-specific external dosimetry records during the first operational period, external dose from uranium will be estimated using the data found in the TBD, *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). These estimates are bounding because the work at Carborundum was of an experimental nature and not performed on a production schedule. Specifically, the section of Tables 7.8 and 7.9 pertaining to pre-1951 dose rate for “Machining” should be used. These doses are limited to the time the slugs were on site (June 1, 1943 to September 27, 1943).

As indicated in Section 5.2.2 of this report, based on the nature of the work and the forms of the materials being handled during operations at Carborundum, neutrons are not evaluated for the first operational period; they are only considered to be a potential external exposure source during the second operational period.

As previously discussed, because no medical monitoring was required for Carborundum, no Occupational Medical X-ray dose will be assigned for the first operational period at the site.

Second Operational Period (1959-1967)

Uranium photons

In the absence of personnel-specific external dosimetry records during the second operational period, external dose from uranium during this period will be estimated using the data found in the TBD, *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000); specifically, the section of Tables 7.8 and 7.9 pertaining to “1956 on” for “Machining.”

External doses from uranium exposure during this period are corrected using the deep dose equivalent organ DCF (dose conversion factor) and are assigned as a lognormal distribution with a GSD (geometric standard deviation) of 5.0. All penetrating doses are assigned as 30–250 keV photons, whereas all shallow doses are assigned as >15 keV electrons (Battelle-TBD-6000).

Plutonium photons

In addition to the external doses from uranium described above, photon doses from plutonium are assigned to all Operators and General Laborers during the second operational period (1959–1967) unless definitive information is provided for an energy employee that indicates the individual was not involved with the plutonium-processing operation. A dose calculation (using the MCNPX software) was performed, based on the restrictions for plutonium use within the glove box complex at Carborundum. The site plutonium operating limits were 100 grams per batch with a maximum of two simultaneous batches per operation.

Dose rates were calculated at 30 centimeters and one meter from the face of the glove box. The 30-centimeter dose will be assigned to Operators. It is assumed that support workers would have spent the majority of their time at the one-meter distance. Uncorrected photon dose from plutonium to General Laborers, Supervisors, and others workers was calculated to be less than 1 millirem/year (<0.001 rem/year).

External photon doses from plutonium exposure during this period are corrected using the deep dose equivalent organ DCF and assigned in IREP as a lognormal distribution with a GSD of 5. Photon energy distributions associated with plutonium will be based on the dose calculations from the MCNPX software using the restrictions for plutonium within the Carborundum glove box complex. All photon doses are assigned as acute.

Neutrons

The source of neutrons would result from the work with uranium and plutonium that was conducted in the glove boxes. Neutron doses for Carborundum were calculated using the MCNPX software. Neutron dose rates were calculated at 30 centimeters and one meter from the face of the glove box. The 30-centimeter dose will be assigned to Operators. It was assumed that support workers would have spent the majority of their time at the one-meter distance. Neutron energy distributions associated with plutonium will be based on the dose calculations from the MCNPX software using the restrictions for plutonium within the Carborundum glove box complex. They are multiplied by the deep dose equivalent organ DCF and assigned in IREP as a lognormal distribution with a GSD of 5. All neutron doses are assigned as chronic.

X-Ray Diffraction

NIOSH has not identified any information that discusses the X-ray diffraction units nor have any radiation surveys been found. However, NIOSH has previously approved a method for estimating dose from diffracted X-ray beams (NIOSH, 2007, PDF p. 17). The method was applied as a bounding approach in cases where class members indicated that they operated an X-ray diffraction unit with makeshift shielding over the diffraction chamber (or similar discussions). The method was site-specific, based on detailed accounts of the equipment and technical factors; however, the same level of detail has not been found for Carborundum.

Lubenau provides measurements of scatter from a survey of XRD units in the state of Pennsylvania in 1966 (Lubenau, 1969). Scatter measurements for three XRD units with copper targets are provided, ranging from 0.5-2.0 mR/hour at the table (i.e., bench top) edge. These measurements are reported as maximum scatter values from the respective machines during operation. The highest scatter measurement of 2.0 mR/hour can be used as the starting point for dose assessment for Carborundum since technical details (kV, mA, etc.) have not been found. The following assumptions can be used to determine doses due to the X-ray diffraction units:

XRD Assumptions:

1. The worker (operator) is seated at bench top, which supports the XRD machine, for 20 hours/week.

2. Only the upper, anterior portion of the body is exposed in this AP geometry (about 25% of total body surface area).

3. The worker (operator) is exposed to only the scattered, diffracted beam, not the primary beam. Accidents involving the primary beam would have to be assessed separately on a case-by-case basis.

4. The diffracted beam from the copper target contains characteristic X-rays from copper, with a K_α energy of 8.1 keV.

5. The fraction of time that tissue is exposed to the diffracted beam is proportional to the ratio of the diffracted beam size (area) to the area potentially exposed (front upper torso).

Medical X-ray Dose

NIOSH has not found any evidence of active medical supervision at the Carborundum Company. Per ORAUT-OTIB-0006 and ORAUT-OTIB-0079, in the absence of information to the contrary, NIOSH assumes that medical X-ray examinations were performed on site during the second operational period (1959-1967) and can be bound using these documents.

7.3.3.2 Methods for Bounding Residual Period External Doses

There are two residual contamination periods (1945–1958 and 1968-1992). However, the second residual period has been evaluated to 1976, the end of the time period requested by the petitioner. Medical X-rays are not required to be considered during residual radiation periods.

First Residual Period (1945–1958)

External doses during the residual contamination periods were estimated using the Exposure-to-Dose Coefficients in EPA-FGR-12 and the estimated surface and air contamination levels at Carborundum. External doses for the non-operational areas are assumed to be 10% of the operational areas, per guidance found in the TBD, *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). For the residual periods, all data were assigned as a constant distribution, and all doses were determined to be less than 0.001 rem/year.

Second Residual Period (1968-1976)

As is the case with the first residual period, external doses during the residual contamination periods were estimated using the Exposure-to-Dose Coefficients in EPA-FGR-12 and the estimated surface and air contamination levels at Carborundum. External doses for the non-operational areas are assumed to be 10% of the operational areas, per guidance found in the TBD, *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). For the residual periods, all data were assigned as a constant distribution, and all doses were determined to be less than 0.001 rem/year.

Because plutonium operations covered under the Energy Employees Occupational Illness Compensation Program Act stopped at the end of the second operational period, the potential neutron and photon dose rates from residual contamination were determined to be less than 0.001 rem/year. Therefore, no external doses from plutonium are assigned during the second residual period.

7.3.4 External Dose Reconstruction Feasibility Conclusion

NIOSH has concluded that it is feasible to reconstruct external doses at the Carborundum Company, Buffalo Avenue facilities in Niagara Falls, New York, using the following approaches:

- First Operational Period (1943-1944): External doses for uranium exposures during the operational periods are assessed using the exposure, R, dose equivalent organ DCF (dose conversion factor). All penetrating doses are assigned as 30–250 keV photons. Shallow doses are assigned as >15 keV electrons. External dose from uranium during the operational period will be estimated using the data found in *TBD: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000).

- First Residual Period (1945-1958): External doses during the residual contamination periods were estimated using the Exposure-to-Dose Coefficients in EPA-FGR-12 and the estimated surface and air contamination levels at Carborundum. External doses for the non-operational areas are assumed to be 10% of the operational areas, per guidance found in the *TBD, Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). For the residual periods, all data were assigned as a constant distribution, and all doses were determined to be less than 0.001 rem/year.

- Second Operational Period (1959-1967): External dose from uranium during the operational period will be estimated using the data found in *TBD: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). External photon doses from plutonium exposure during this period are corrected using the deep dose equivalent organ DCF and assigned in IREP as a lognormal distribution with a GSD of 5. Photon/neutron energy distributions associated with plutonium will be based on dose calculations from the MCNPX software using the restrictions for plutonium within the Carborundum glove box complex. All photon doses are assigned as acute. They are multiplied by the deep dose equivalent organ DCF and assigned in IREP as a lognormal distribution with a GSD of 5. All neutron doses are assigned as chronic. Medical X-ray dose will be reconstructed using the methodology defined in ORAUT-OTIB-0006; XRD dose will be reconstructed using the previously-discussed methodology for estimating dose from diffracted X-ray beams (NIOSH, 2007, PDF p. 17).

- Second Residual Period (1968-1976): External doses during the residual contamination periods were estimated using the Exposure-to-Dose Coefficients in EPA-FGR-12 and the estimated surface and air contamination levels at Carborundum. External doses for the non-operational areas are assumed to be 10% of the operational areas, per guidance found in *TBD, Site Profiles for Atomic Weapons Employers That Worked Uranium Metals* (Battelle-TBD-6000). For the residual periods, all data were assigned as a constant distribution, and all doses were determined to be less than 0.001 rem/year.

NIOSH may choose to employ a more refined approach when reconstructing individual doses based on information obtained during the evaluation of individual claims. The NIOSH example dose reconstruction methodologies, to be provided separately from this evaluation report, will demonstrate the applicable bounding approaches for reconstructing doses for the applicable residual and operational periods at Carborundum.

7.4 Evaluation of Petition Basis for SEC-00223

The following assertion was made on behalf of petition SEC-00223 for the Carborundum Company:

SEC-00223: *To the best of my knowledge the plant was not monitored for radiation during the time of employment as the attached papers state my dad was exposed to various forms of radiation throughout the plant during the years he worked there.*

As indicated in Section 6.2, NIOSH has not found any personal or area monitoring data for the Carborundum Company for the period under evaluation. However, NIOSH will use the methodology defined in this evaluation report to reconstruct personnel dose in the absence of personnel or area monitoring data for Carborundum.

SEC-00223: Determine the location and scope of the Globar Plant.

The Globar Plant, initially located in Milwaukee, pioneered the use of silicon carbide in an electric heating element call "Globar." In 1927, Carborundum purchased that company, by then called Globar Corporation, and moved its production to Niagara Falls. The Globar plant is not part of this SEC petition because it is not located at the Buffalo Ave site (Carborundum Company, 2015).

SEC-00223: There appears to be no monitoring data.

No monitoring data were found for the Carborundum Company. Six former employees were interviewed. Three former employees indicated they wore radiation badges (Personal Communication, 2015a; Personal Communication, 2015c; Personal Communication, 2015d). One former employee stated he gave a urine sample every 2-3 weeks and went to the doctor to get a white blood cell count (Personal Communication, 2015c). Another former employee stated he gave urine samples about every 3-6 months (Personal Communication, 2015d). Two former employees stated that all notes were kept in log books, but the notes have been destroyed (Personal Communication, 2015c; Personal Communication, 2015d). However, NIOSH will use the methodology defined in this evaluation report to reconstruct personnel dose in the absence of personnel or area monitoring data for Carborundum.

SEC-00223: Lack of Specific detail in the SRDB documents.

NIOSH was able to locate an additional ninety-two documents during its data capture efforts. Many of these documents provided relevant information on Carborundum.

SEC-00223: Carborundum Contracts

With the additional data capture, NIOSH has been able to review the work Carborundum was responsible for as a subcontractor under different contracts during the two operational and two residual periods. This has been addressed throughout the evaluation report.

SEC-00223: Medical X-rays

During its research, NIOSH learned that medical X-rays were not necessary during the first operational period. NIOSH has not found any data relevant to medical X-rays at Carborundum for the second operational period. Reconstruction of medical X-ray dose is not applicable to the residual radioactivity periods at Carborundum.

SEC-00223: Sources of material from ORNL

NIOSH learned that ORNL provided small amounts of radioactive material to Carborundum. ORNL provided depleted UO_2 which was ball-milled for 24 hours in a rubber-lined ball mill with stainless steel balls to an average particle size of less than one micron (Refractory Uranium, 1961).

SEC-00223: Sources of Plutonium from Hanford

NIOSH learned that Hanford provided plutonium to Carborundum over a three-year period totaling approximately three kilograms, which was fabricated into pellets. The first and only shipment in 1960 consisted of 500 grams (Breslin, 1960).

SEC-00223: X-Ray Diffraction

Carborundum used XRD extensively for compound or phase identification to analyze fuel as part of the fuel fabrication process. Due to the scattering of the X-rays, this method causes a diffraction pattern that can be recorded and analyzed, providing specific information about the atomic structure of the samples. NIOSH has previously approved a method for estimating dose from diffracted X-ray beams. This method could be applied to Carborundum using certain assumptions (see Section 7.3.3.1).

7.5 Summary of Feasibility Findings for Petition SEC-00223

This report evaluates the feasibility for completing dose reconstructions for employees at the Carborundum Company from January 1, 1943 through December 31, 1976. NIOSH found that the available monitoring records, process descriptions, and source term data available are sufficient to complete dose reconstructions for the evaluated class of employees in conjunction with Battelle-TBD-6000 and the dose reconstruction methodology.

Table 7-1 summarizes the results of the feasibility findings at the Carborundum Company for each exposure source during the time periods 1943-1944 and 1959-1967 (operational periods) and 1945-1958 and 1968-1976[10] (residual periods).

[10] As previously discussed, the second residual period as defined by DOE ends in 1992; however, based on the feasibility findings presented in this evaluation report, the assessment of the second residual period is limited to the petitioner-requested class time frame, which extends only through 1976.

Table 7-1: Summary of Feasibility Findings for SEC-00223 1943-1944 and 1959-1967 (operational periods); 1945-1958 and 1968-1976 (residual periods)				
Source of Exposure	**Operational Periods** **Jan. 1, 1943 through Dec. 31, 1944** **Jan. 1, 1959 through Dec. 31, 1967**		**Residual Periods** **Jan. 1, 1945 through Dec. 31, 1958** **Jan. 1, 1968 through Dec. 31, 1976**	
	Reconstruction Feasible	**Reconstruction Not Feasible**	**Reconstruction Feasible**	**Reconstruction Not Feasible**
Internal[1]	**X**		**X**	
- Uranium	X		X	
- Plutonium	X		X	
External	**X**		**X**	
- Gamma	X		X	
- Beta	X		X	
- Neutron	N/A (1943-1944) X (1959-1967)	N/A (1943-1944)	N/A	N/A
- X-ray Diffraction	N/A (1943-1944) X (1959-1967)	N/A (1943-1944)	N/A	N/A
- Occupational Medical X-ray	N/A (1943-1944) X (1959-1967)	N/A (1943-1944)	N/A	N/A

[1] Internal includes an evaluation airborne dust data.

As of March 16, 2015, a total of 106 claims have been submitted to NIOSH for individuals who worked at the Carborundum Company during the period under evaluation in this report. Dose reconstructions have been completed for 90 individuals (~85%).

8.0 Evaluation of Health Endangerment for Petition SEC-00223

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.

NIOSH has sufficient information on the types and quantities of material processed at the Carborundum Company as well as sufficient air monitoring data to bound internal and external exposures. NIOSH's evaluation determined that it is feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Therefore, a health endangerment determination is not required.

9.0 Class Conclusion for Petition SEC-00223

Based on its full research of the class under evaluation, NIOSH found no part of said class for which it cannot estimate radiation doses with sufficient accuracy. This class includes all employees who worked in any area of the Carborundum Company facility on Buffalo Avenue, Niagara Falls, NY from January 1, 1943 through December 31, 1976.

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-00223. In addition, NIOSH reviewed its NOCTS dose reconstruction database to identify EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation.

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

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Status, 1959, *Status of Materials for Use Under Fuel Cycle Development Program*, letter from D. Cope (Reactor Division) to J. Ruch (Feed Materials Division); July 23, 1959; SRDB Ref ID: 47808, PDF p. 22

Thomas, 1971, *Radiation Safety: Objectives and Considerations*, J. W. Thomas; U.S. Department of Health Education and Welfare; 1971; SRDB Ref ID: 32635, PDF p. 145

T-metal, 1944, *T-metal Fabricatio*n, memo by Dr. G. H. Gehrmann; E.I. du Pont de Nemours & Company; October 11, 1944; SRDB Ref ID: 21831

Transfer, 1959, *Transfer of SS Material to: The Carborundum Company, Niagara Falls, N.Y. and Union Carbide Metals Company, Niagara Falls, N.Y.*, memo from M. Eisenbud (NYOO) to S. Sapirie (OROO); June 16, 1959; SRDB Ref ID: 47808, PDF p. 13

Attachment 1: Data Capture Synopsis

Table A1-1: Data Capture Synopsis for Carborundum Company

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded to SRDB
Primary Site/Company Name: Carborundum Company AWE 1943-1944; 1959-1967; Residual Radiation 1945-1958; 1968-1992 Alternate Site Names: NA Physical Size of the Site: No documentation has been found regarding the physical size of the facility or the number of buildings on site. From interviews, it is estimated that approximately 30-50 buildings were on site; one interviewee suggested that the site encompassed about 200 acres. The Research and Development Building (also known as Building 1 and the Nuclear Building) was the only building that had radioactive materials. This building had four stories that occupied over 60,000 square feet. Population of the Site: Records show that the Carborundum Company employed approximately 6,000-7,000 employees during the 1940s. No other documentation has been found regarding the number of employees in later years. Note: The Buffalo Avenue plant closed in 1983, at which time over 650 employees lost their jobs.	Existing successors have been contacted with no relevant data identified to date. The following companies have been in the succession of some part of the Carborundum Company: - Kennecott Copper Corp (mid 1970's) located in London and dissolved - Standard Oil of Ohio (1981) - Norton (~1983) - British Petroleum (1987 - bought SOHIO) - St. Gobain (1995) - Unifrax (1996) - Washington Mills Electric Minerals (Not successor, used part of site)	03/23/2015	0
State Contacted: NY State Dept. of Environmental Conservation	Contract AT(40-1)-2558 source and special nuclear materials documents and status of carbide fuel development at the Carborundum Company.	04/06/2015	5
Battelle Memorial Institute - King Avenue	Hazards subcommittee concerning SP-3.	09/20/2011	1
British Petroleum (BP)	No relevant documents identified.	09/29/2008	0
Cincinnati Public Library	Monoxide type compounds of uranium and plutonium and research facility information for the synthesis and fabrication of refractory plutonium materials.	01/16/2009	2
Department of Labor / Paragon	Waste disposal in Niagara Falls area and DOD analysis of the NY interim report on toxic substances.	12/30/2008	6

Table A1-1: Data Capture Synopsis for Carborundum Company			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
DOE Germantown	Carborundum Company feasibility report for fabrication of plutonium carbide pellets.	11/21/2005	1
DOE Legacy Management - Grand Junction Office	Contract between the Carborundum Metals Company, Inc. and the Atomic Energy Commission, dense silicon carbide quarterly report, material accountability, inspection report with release survey, orange oxide shipments, Parkersburg site operations chronology, processing of thorium ore, source material license, and an elimination recommendation and listed references.	08/30/2011	27
DOE Legacy Management - Morgantown	No relevant documents identified.	03/16/2015	0
DOE Oak Ridge Operations Office	Radiological survey of Guterl Specialty Steel.	11/18/2003	1
DOE Oak Ridge Operations, Records Holding Task Group	Monthly accountability reports and a security survey.	03/06/2015	7
DOE Office of Scientific and Technical Information (OSTI)	Studies of the preparation of mixed carbide fuel using co-precipitation.	11/06/2008	1
Environmental Measurements Laboratory (EML) / HASL	Site visits, annual report, thorium sampling and storage, and the symposium V on aerosols.	03/08/2005	1
Federal Records Center (FRC) - Kansas City	Historical documents compiled for FUSRAP related review.	07/14/2008	1
Hanford	Irradiation processing monthly report, DOE investigation, and a material balance report. OPEN - Hanford Data Request 109 requesting key word searches.	OPEN	5
Interlibrary Loan	Synthesis and fabrication of refractory plutonium materials and the story of the Carborundum Company.	02/04/2015	2
Internet - Defense Technical Information Center (DTIC)	No relevant documents identified.	03/18/2015	0
Internet - DOE Comprehensive Epidemiologic Data Resource (CEDR)	No relevant documents identified.	03/18/2015	0
Internet - DOE Environmental Management	Linking Legacies Chapter 3: Wastes.	10/28/2007	1
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	Centerless grinding and a Hanford operations monthly report.	06/27/2013	3
Internet - DOE Legacy Management Considered Sites	No relevant documents identified.	01/20/2015	0
Internet - DOE National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant documents identified.	03/18/2015	0
Internet - DOE OpenNet	Manhattan District History Book and an H-Division progress report.	01/19/2015	2
Internet - DOE OSTI Energy Citations	Out-of-pile properties of mixed uranium-plutonium carbides progress reports, and a study of uranium-plutonium monoxides final summary report.	05/12/2009	12

Table A1-1: Data Capture Synopsis for Carborundum Company			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Internet - DOE OSTI Information Bridge	The metal fabrication program, Hanford operation monthly report, quarterly report on synthesis and fabrication of refractory uranium compounds, Chemical Processing Department monthly reports, Carbide Fuel Development final report, and residual radioactivity in the vicinity of formerly utilized med/aec sites.	11/17/2011	10
Internet - DOE OSTI SciTech Connect	Synthesis and fabrication of refractory uranium compounds, monthly progress reports 1960, steam-cooled power reactor evaluation, fabrication of non-fuel core components for SEFOR, effects of composition and processing on the properties of niobium carbide - graphite composite material, and investigations of materials compatibility relevant to the EBR-II system.	03/25/2015	12
Internet - Energy Employees Claimant Assistance Project (EECAP)	No relevant documents identified.	04/07/2015	0
Internet - Google	British scientists visit to Carborundum plant, assessment of failure mechanisms for GFR vented fuel pins using hexoloy cladding, company profile, business description, site history and background, film implementation of a neutron detector, Carborundum timeline, magnetic trapping of ultracold neutrons, mapping waste - setting the stage to clean-up Niagara, molten-salt reactor program semiannual progress report, neutron radiography (nrad), poisoned workers and poisoned places, the bomb that fell on Niagara, and uranium monocarbide and method of preparation.	03/13/2015	51
Internet - Health Physics Journal	No relevant documents identified.	03/18/2015	0
Internet - Journal of Occupational and Environmental Health	No relevant documents identified.	03/18/2015	0
Internet - National Academies Press (NAP)	No relevant documents identified.	01/20/2015	0
Internet - National Environmental Publications Information System (NEPIS)	No relevant documents identified.	01/20/2015	0
Internet - NIOSH	Report on residual beryllium and radioactive contamination.	08/31/2011	3
Internet - NRC Agencywide Document Access and Management (ADAMS)	Loose material licenses reviewed by the regions or transferred to an agreement state, staff evaluation of sites identified in the USA Today article, legal information, spent fuel pool scoping study, and monitoring degradation of phenolic resin-based neutron absorbers in spent nuclear fuel pools.	01/20/2015	11
Internet - USACE/FUSRAP	No relevant documents identified.	01/20/2015	0

Table A1-1: Data Capture Synopsis for Carborundum Company			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Internet - Washington State University (U.S. Transuranium and Uranium Registries)	No relevant documents identified.	01/20/2015	0
National Archives and Records Administration (NARA) - Atlanta	Subcontractors that worked on uranium fabrication, and contracts and reports 1958-1963.	03/17/2015	3
National Archives and Records Administration (NARA) - Kansas City	Niagara Falls area radiological measurements and information related to Love Canal contamination.	08/14/2008	3
New York Environmental Protection Agency Office	No relevant documents identified.	03/16/2015	0
New York State Archives	Shipment and disposition of contaminated sludge at LOOW.	03/19/2012	1
National Institute of Occupational Safety and Health (NIOSH)	Annual report to Congress and Carborundum history.	08/27/2014	5
Niagara County Historian Office	No relevant documents identified.	01/23/2015	0
Niagara Falls Fire Department	No relevant documents identified.	02/02/2015	0
NRC Public Document Room	No relevant documents identified.	02/20/2015	0
Oak Ridge National Laboratory (ORNL)	Source and special nuclear material accountability report.	03/19/2014	5
ORAU Team	Documented communication with former employees and estimate of maximum plausible dose at AWE's.	03/31/2015	8
S. Cohen & Associates (SC&A)	Activities and discussion related to the Hematite Plant area.	04/07/2011	1
Savannah River Site	Dosimetry visitor cards.	08/26/2008	1
St. Gobain (NY)	No relevant documents identified.	10/28/2008	0
Unifrax	No relevant documents identified.	06/18/2008	0
University of Buffalo	Carborundum Company annual report, projected proposal to examine adsorptive materials, zirconium - hafnium - titanium joint feasibility study, presentation of New York society of security analysis, metal progress, refractory fibrous materials, and the Romance of Carborundum.	03/26/2015	18
University of Utah (Kennecott Collection)	No relevant documents identified.	08/07/2008	0
Unknown	Integrated safety management evaluation, site summary and accounting control and correspondence on nuclear materials, dust hazards, and Fernald recycled uranium receipts and shipment.	08/28/2003	9
Washington Mills Electro Minerals	No relevant documents identified.	03/23/2015	0
TOTAL			**219**

Table A1-2: Databases Searched for Carborundum Company			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**
Google http://www.google.com COMPLETED 02/20/2015	See Note above	12,402,199	53
HP Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 03/18/2015	See Note above	0	0
Journal of Occupational and Environmental Health http://www.ijoeh.com/index.php/ijoeh COMPLETED 03/18/2015	See Note above	15	0
National Academies Press http://www.nap.edu/ COMPLETED 01/20/2015	See Note above	20	0
National Environmental Publications Information System (NEPIS) http://nepis.epa.gov/ COMPLETED 01/20/2015	See Note above	516	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 01/19/2015	See Note above	298	4
United States Army Corps of Engineers (USACE) http://www.usace.army.mil/ COMPLETED 01/20/2015	See Note above	0	0
United States Army Corps of Engineers (USACE) - Buffalo District http://www.lrb.army.mil/ COMPLETED 01/20/2015	See Note above	0	0
United States Army Corps of Engineers (USACE) - New York District http://www.nan.usace.army.mil/ COMPLETED 01/20/2015	See Note above	0	0
United States Army Corps of Engineers (USACE) - Pittsburgh District http://www.lrp.usace.army.mil/ COMPLETED 01/20/2015	See Note above	0	0

Table A1-2: Databases Searched for Carborundum Company			
Database/Source	**Keywords / Phrases**	**Hits**	**Selected**
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 01/20/2015	See Note above	0	0

Table A1-3: Interlibrary Loan Documents Requested for Carborundum Company			
Document Number	**Document Title**	**Requested Date**	**Received Date**
NA Ref ID: 52405	Research Facility for the Synthesis and Fabrication of Refractory Plutonium Materials from Transactions of the American Nuclear Society (U.S.); Vol: 5:325-326 dated November 1962	10/20/2008	10/20/2008
NA Ref ID: 56948	Research Facility for the Synthesis and Fabrication of Refractory Plutonium Materials from Proceedings of the 10th Hot Laboratory Equipment Conference in 1962	10/20/2008	01/07/2009
NA Ref ID: 140976	The Scratch Heard 'Round the World; The Story of the Carborundum Company	01/26/2015	02/03/2015
NA	Note On the System Magnesia-Thoria-Hafnia	03/18/2015	