SEC Petition Evaluation Report
Petition SEC-00154

Report Rev #: 0 Report Submittal Date: November 2, 2010

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Site Expert(s):	N/A

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Receipt Date	Qualification Date	DOE/AWE Facility Name
SEC-00154	83.13	November 5, 2009	January 22, 2010	Linde Ceramics Plant

Petitioner Class Definition

All employees who worked in any area at Linde Ceramics in Tonawanda, New York, from November 1, 1947 through December 31, 1953.

Class Evaluated by NIOSH

All employees who worked in any area at the Linde Ceramics Plant in Tonawanda, New York, from November 1, 1947 through December 31, 1953.

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
SEC-00044	83.14	Linde Ceramics Plant	SEC class 1942-47
SEC-00106	83.13	Linde Ceramics Plant	Closed
SEC-00107	83.13	Linde Ceramics Plant	Sent to Board
SEC-00112	83.13	Linde Ceramics Plant	Merged w/SEC-00107
SEC-00127	83.13	Linde Ceramics Plant	Merged w/SEC-00107

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
SEC Petition Evaluation Report for SEC-00044	Linde Ceramics Plant
SEC Petition Evaluation Report for SEC-00107	Linde Ceramics Plant

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SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	11/3/2010 *Date*
SEC Evaluation Approved By:	[Signature on file] *Stuart Hinnefeld*	11/4/2010 *Date*

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Evaluation Report Summary: SEC-00154, Linde Ceramics

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-00154 was received on November 05, 2009, and qualified on January 19, 2010. The petitioner requested that NIOSH consider the following class: *All employees who worked in any area at Linde Ceramics in Tonawanda, New York, from November 1, 1947 through December 31, 1953.*

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 at the Linde Ceramics Plant in Tonawanda, New York, from November 1, 1947 through December 31, 1953.

NIOSH-Proposed Class to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has obtained uranium urinalysis results, film badge reports, air monitoring data, and radiation contamination survey data for the time period evaluated. Based on its analysis of these available resources, NIOSH found no part of the class under evaluation for which it cannot estimate radiation doses with sufficient accuracy.

Feasibility of Dose Reconstruction

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

Health Endangerment Determination

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

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SEC Petition Evaluation Report for SEC-00154

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all employees who worked in any area at the Linde Ceramics Plant in Tonawanda, New York, from November 1, 1947 through December 31, 1953. 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*, OCAS-PR-004.[1]

2.0 Introduction

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

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

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring 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

[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.

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

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

3.0 SEC-00154, Linde Ceramics Plant Class Definitions

The following subsections address the evolution of the class definition for SEC-00154, Linde Ceramics Plant. 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-00154 was received on November 5, 2009, and qualified on January 22, 2010. The petitioner requested that NIOSH consider the following class: *All employees who worked in any area at Linde Ceramics in Tonawanda, New York, from November 1, 1947 through December 31, 1953.*

The petitioner provided information and affidavit statements in support of the petitioner's belief that accurate dose reconstruction over time is impossible for the Linde workers in question. NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00154 for evaluation:

> The petition and its ten supporting documents, including four affidavits from two former workers and NIOSH interviews with two former workers, were intended to support the petition bases F.1 and F.3. NIOSH's review of the petition documentation found insufficient support for these bases in those documents for the petitioner-proposed class. However, based on its research and reviews of available information and documentation conducted to date for the Linde Ceramics Plant, NIOSH determined that although internal and external monitoring was performed for members of the petitioner-proposed class, this monitoring did not adequately assess all potential exposures or

[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.

exposure periods. Based on this information, NIOSH concluded that the F.1 basis is sufficiently supported.

Based on its Linde Ceramics Plant research and data capture efforts, NIOSH determined that it has access to area monitoring, exposure scenario information, personnel dosimetry data, and internal dosimetry data for Linde Ceramics Plant workers during the time period under evaluation. However, NIOSH also determined that internal and external personnel monitoring records are not complete for all time periods or for all radionuclides. NIOSH concluded that there is sufficient documentation to support, for at least part of the requested time period, the petition basis that internal and external radiation exposures and radiation doses were not adequately monitored at Linde Ceramics, 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 because NIOSH was unable to locate personal and area monitoring data for portions of the proposed time period and has reason to believe, based on the nature of activities during the time period following the cessation of operations, that workers were unmonitored during a portion of the period under evaluation. Therefore, NIOSH defined the following class for further evaluation: All employees who worked at the Linde Ceramics plant in Tonawanda, New York, from November 1, 1947 through December 31, 1953.

3.3 NIOSH-Proposed Class to be Added to the SEC

Based on its research, NIOSH has obtained urinalysis data, personnel monitoring data, air monitoring data, and contamination survey data specific to the Linde Ceramics Plant that can be used to bound exposures for all members of the class under evaluation. 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 a standard practice, NIOSH completed an extensive database and Internet search for information regarding the Linde Ceramics Plant. The database search included the DOE Legacy Management Considered Sites database, the DOE Office of Scientific and Technical Information (OSTI) database, the Energy Citations database, the Atomic Energy Technical Report database, and the Hanford Declassified Document Retrieval System. In addition to general Internet searches, the NIOSH Internet search included OSTI OpenNet Advanced searches, OSTI Information Bridge Fielded searches, Nuclear Regulatory Commission (NRC) Agency-wide Documents Access and Management (ADAMS) web searches, the DOE Office of Human Radiation Experiments website, and the DOE-National Nuclear Security Administration-Nevada Site Office-search. Attachment Two contains a summary of Linde Ceramics Plant documents. The summary specifically identifies data capture details and general descriptions of the documents retrieved.

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

4.1 Site Profile Technical Basis Documents (TBDs)

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

- *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, ORAUT-TKBS-0025; Rev. 01 PC-1; November 10, 2009; SRDB Ref ID: 76972

4.2 Technical Information Bulletins (TIBs) and Procedures

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

- *TIB: Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 01; October 7, 2005; SRDB Ref ID: 19438

- *TIB: Estimation of Neutron Dose Rates from Alpha-Neutron Reactions in Uranium and Thorium Compounds*, ORAUT-OTIB-0024, Rev. 00; April 07, 2005; SRDB Ref ID: 19445

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

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed five former Linde Ceramics Plant employees and reviewed the eight former Linde employee interviews conducted in 2008 as part of the evaluation process for SEC-00107. The NIOSH interviews conducted for the SEC-00154 evaluation included:

- Personal Communication, 2010a, *Personal Communication with Maintenance Helper/Millwright/Electrician*; Telephone Interview by ORAU Team HP; March 4, 2010; SRDB Ref ID: 80052

- Personal Communication, 2010b, *Personal Communication with Chemical Operator/Shipping and Receiving Clerk/Trades Foreman*; Telephone Interview by ORAU Team HP; March 4, 2010; SRDB Ref ID: 80053

- Personal Communication, 2010c, *Personal Communication with Trades Assistant/Electrician/Maintenance Mechanic/Millwright/Scarfing Machine Operation Supervisor/Maintenance Superintendent*; Telephone Interview by ORAU Team HP; March 10, 2010; SRDB Ref ID: 80055

- Personal Communication, 2010d, *Personal Communication with X-Ray Operator/Lead Inspector*; Telephone Interview by ORAU Team HP; March 10, 2010; SRDB Ref ID: 80054

- Personal Communication, 2010e, *Personal Communication with Trades Helper/Pipefitter/Maintenance Mechanic/Millwright/Temporary Foreman/Foreman/Senior Foreman*; Telephone Interview by ORAU Team HP; March 11, 2010; SRDB Ref ID: 80056

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH DCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of April 8, 2010)

Table 4-1: No. of Linde Ceramics Plant Claims Submitted Under the Dose Reconstruction Rule

Description	Totals
Total number of claims submitted for dose reconstruction	244
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (November 1, 1947 through December 31, 1953)	139
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation (i.e., the number of such claims completed by NIOSH and submitted to the Department of Labor for final approval).	95
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	4
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	8

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. Forty-two of the submitted claims are covered under the previously-approved SEC period for Linde Ceramics Plant (NIOSH, 2005). For each of the claims with dosimetry data, the data were collected during Step III of the Linde uranium separation process (the fluorination of UO_2 to UF_4).

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the assessment of the evaluated class. Seven hundred eighty-six documents in this database were identified as pertaining to the Linde Ceramics Plant. These documents were evaluated for their relevance to this petition. The documents include historical background on the operational process, process materials, equipment removal, dust sampling, air monitoring, and site clean-up.

4.6 Documentation and/or Affidavits Provided by Petitioners

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

- *Linde Ceramics Special Exposure Cohort Application: November 1, 1947 through December 31, 1953*; SEC petition; received November 5, 2009; OSA Ref ID: 110180 (Petition, 2009)

- *Affidavits from Former Linde Ceramics Employees*; November 5, 2009; OSA Ref ID: 110180 pp. 18-22; 27-29 (Affidavits, 2009)

- *SEC-00107 Linde Ceramics Plant Interviews – [Name Redacted]*; Interview conducted in support of SEC-00107; September 11, 2008; OSA Ref ID: 110180 (SEC-00107 Interview, 2008a)

- *SEC-00107 Linde Ceramics Plant Interviews – [Name Redacted]*; Interview conducted in support of SEC-00107; September 11, 2008; OSA Ref ID: 110180 (SEC-00107 Interview, 2008b)

- *Personal Correspondence Between [Name Redacted] and [Name Redacted], Consultant to Praxair Inc.*; Contains a request for personal records; July 22, 2009; OSA Ref ID: 110180 pdf pp. 23 (Correspondence, 2009a)

- *Personal Correspondence Between [Name Redacted], Consultant to Praxair Inc., and [Name Redacted]*; response to a request for personal records. Includes a CARDEX work history; August 19, 2009; OSA Ref ID 110180 pdf pp. 24-26 (Correspondence, 2009b)

- *Draft Assessment of the Disposition of SC&A's Linde Site Profile Review Issues in Response to SEC Petitioner Concerns*; S. Cohen and Associates (SC&A); August, 2009; OSA Ref ID 110180 pp. 30-103 (SC&A, 2009)

- *Linde Ceramics SEC Petitions Addendum SEC Tracking Numbers: SEC00106 and SEC00107—Additional Issues and Supplementary Evidence Supporting Linde Ceramics Petitions SEC00106 and SEC00107*; March 28, 2008; OSA Ref ID: 105723 and 105687, pdf pp. 28-33 (Supplementary Evidence, 2008a)

- *Linde Ceramics SEC Petition Application: November 1, 1947 through December 31, 1953*, supporting document from the petitioner; March 28, 2008; OSA Ref ID: 105724 and 105687, pdf pp. 3-27 (SEC Petition Narrative, 2008)

- *Additional Issues and Supplementary Evidence Supporting Linde Ceramics SEC Petitions SEC00106 November 1, 1947 through December 31, 1953 and SEC00107 January 1, 1954 through July 31, 2006*, supporting document from the petitioner; April 25, 2008; OSA Ref ID: 105849 (Supplementary Evidence, 2008b)

- *Additional Issues and Supplementary Evidence Supporting Linde Ceramics SEC Petition SEC00107 January 1, 1954 through July 31, 2006*, supporting document from the petitioner; May 20, 2008; OSA Ref ID: 106080 (Supplementary Evidence, 2008c)

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

ATTRIBUTION: Section 5.0 and its related subsections were completed by Jason Davis and Monica Harrison-Maples, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

The following subsections summarize both radiological operations at the Linde Ceramics Plant from November 1, 1947 through December 31, 1953 and the information available to NIOSH to characterize particular processes and radioactive source materials. From available sources NIOSH has gathered process and source descriptions, information regarding the identity and quantities of each radionuclide of concern, and information describing processes through which radiation exposures may have occurred and the physical environment in which they may have occurred. The information included within this evaluation report is intended only to be a summary of the available information.

5.1 Linde Ceramics Plant and Process Descriptions

During the period from 1942 through 1949, Linde Air Products Corporation (the company that ran the Linde Ceramics Plant and the Linde Air Facility in Buffalo, New York) was contracted by the Manhattan Engineer District (MED) and its successor the Atomic Energy Commission (AEC) to perform uranium separation. Linde Air Products Corporation was selected because of the expertise it acquired from working in the ceramics business, processing uranium to produce the black, yellow, green, and brown "salts" used for coloring ceramic glazes.

The contracted MED/AEC activities took place at Linde Ceramics Plant in Buildings 14, 30, 31, 37, and 38. Building 14 was built by Union Carbide in the mid-1930s. Buildings 30, 31, 37, and 38 were built by the MED on land owned by Union Carbide. With the termination of the AEC contract in 1954, ownership was transferred to Linde Air Products Corporation. Table 5-1 presents Linde activities and operations by building.

Under the MED/AEC contract, seven different sources of uranium were processed at Linde Ceramics: four African ores (three low-grade pitchblendes and a torbernite) and three domestic ores (carnotites from Colorado). Some of the domestic ores were actually tailings from vanadium processing and were pre-processed in order to concentrate the uranium prior to shipment from the western states. The majority of the radium in these ores was removed during the pre-processing. The African ores were unprocessed and contained all members of the uranium decay series, including radium in secular equilibrium with the uranium. As a result of the radium content, the African ores produced substantially higher levels of radon gas than the domestic ores.

In 1943, following laboratory and pilot-plant studies, uranium processing began at Linde Ceramics. The uranium ores and tailings were processed in three steps: Step I involved uranium oxide (U_3O_8)

being separated from the feedstock by acid digestion followed by precipitation and filtration. Step II involved converting uranium oxide to uranium dioxide. Residues from Step II were recycled to Step I. In Step III, uranium dioxide was converted to uranium tetrafluoride (Bechtel, 1990). Table 5-2 shows the types of feed material used in the Linde Ceramics operation.

Table 5-1: Activities and Operations at Linde Ceramics

Building	Activities/Operations Description
14	Facility: Built in the mid-1930s by Union Carbide. Vacated in March 2004. Demolition began April 30, 2004. Operations: Served as a location of laboratory studies. Served as a pilot plant for uranium separation in the early part of MED/AEC operations.
30	Facility: Built by the MED on Union Carbide-owned land. Step II process equipment dismantled starting in March 1948; completed in April 1948. Step I process equipment dismantled in stages throughout 1949. D&D reported complete as of March 29, 1950. Ownership transferred to Linde Air Products Corporation with termination of the AEC contract in 1954. Demolished September 5-19, 1998. Operations: Served as the primary processing building for Step I (ores to U_3O_8) and Step II (U_3O_8 to UO_2) uranium processing during MED/AEC operations. Also used as the location for some processing of metallic nickel with nitric acid to produce nickel salt.
31	Facility: Built by the MED on Union Carbide-owned land. Ownership transferred to Linde Air Products Corporation with termination of the AEC contract in 1954. Decontaminated in 1997. Operations: Served as a location of Step III (fluorination of UO_2 to UF_4) uranium separation processing during MED/AEC operations (November 1, 1947 through June 30, 1949).
37	Facility: Built by the MED on Union Carbide-owned land. Ownership transferred to Linde Air Products Corporation with termination of the AEC contract in 1954. Demolished in 1981. Operations: Used for Step III (fluorination of UO_2 to UF_4). Although no details have been found, the 16 ft x 36 ft building footprint indicates a minor role in Step III processes (November 1, 1947 through June 30, 1949).
38	Facility: Built by the MED on Union Carbide-owned land. D&D began in November 1952. Ownership transferred to Linde Air Products Corporation with termination of the AEC contract in 1954. Demolished in 1996. Operations: Served as a location for Step III (fluorination of UO_2 to UF_4) uranium separation processing during MED/AEC operations (November 1, 1947 through June 30, 1949).

Sources: SEC-00107 E-mail, 2004; Army Corps, 1998; Bechtel, 1993; ORAUT-TKBS-0025, Section 2.6

Table 5-2: Types of Feed Material Used in the Linde Ceramics Operation			
Type of Material	**Code**	**Time Period when Processed**	**Assay of U_3O_8[a]**
Colorado concentrates	L-19	June 1943 – November 1943	12% - 14%
African pitchblende	L-30	November 1943 – September 1944	8.2%
African pitchblende	L-50	October 1944 – November 1944	4% - 6%
Colorado concentrates	L-19	November 1944 – January 1946	16% - 18%
African pitchblende	R-10	February 1946 – June 1946	2% - 3%
Torbernite	Q-20	-	~8.2%
Torbernite	Q-20	June 10, 1946 – June 13, 1946	14.4 tons
Residues and scrap	N/A	June 1943 – June 1946	Varying

Notes:

Source: Reformatted version of attachment included in reference document (ORAU, 1981).

[a] Assay of uranium = Assay of U_3O_8 x 0.842

- Indicates "unknown"

Colorado concentrates were processed about 50% of the time of Linde operation.

The maximum quantity of ore processed in any week was 1.5 million pounds of R-10.

Step I processes were terminated July 31, 1946 and Step II processes ended on March 8, 1944 (Aerospace, 1981). Step III shutdown occurred on June 30, 1949, and Linde Ceramics Plant clean-up began sometime before Step III shutdown. Some Step II equipment located in Building 30, including processing tanks and process piping, was removed in March and April of 1948 (Kent, 1948b). Dismantling of Step I and remaining Step II equipment in Building 30 had begun by May 1949 (ORAUT-TKBS-0025). In general, lumber and metal removed as part of the dismantling operations were surveyed for contamination and contaminated pieces were shipped offsite for storage (Heatherton, 1949f).

The Linde site was, and continues to be, serviced by a series of underground tunnels that house gas, electrical, water, steam, telephone, and other utility lines. Tunnels were a maximum dimension of 8-10 feet (ft) high and 15 ft wide. Each tunnel had exhaust fans (approximately 6 ft in diameter) that pulled air through the tunnels (Personal Communication, 2010b; Personal Communication, 2010c; Army Corps, 2002). The average air exchange rate within any particular tunnel section was estimated by the Atomic Energy Commission (AEC) as approximately one every 10 hours. The tunnels have few stairway access points and several locations where covered manways may be used to access the tunnel (Army Corps, 2002). These tunnels are routinely inspected and accessed for maintenance activities. However, no uranium process piping was ever installed in these tunnels (Army Corps, 2002). Documentary evidence indicates that the utility tunnel sections near the Ceramics Plant (Buildings, 30, 31, 37 and 38) were constructed in 1957 and 1961, which is after the December 31, 1953 end date of the covered period (Coutts, 2005). There was also a utility tunnel section running between Building 14 (the "Tonawanda Laboratory") and Building 8 (the "Power House") that was assumed to be in existence during the SEC period.

Uranium ore processing from the 1940s resulted in contamination of Linde site building surfaces, soils, building sumps, and sanitary sewer system. In addition, approximately 55 million gallons of liquid-waste effluent was injected into seven wells from February 27, 1945 through mid-July 1946.

The wells were in two general areas: three wells near Building 8 and four wells in the area associated with Buildings 30 and 38. These wells were drilled approximately 150 ft deep and passed through a clay formation into a gravel and sand layer and the bedrock layer. Soil could have been contaminated by (1) uranium processing going on at the facility, (2) backflow of the injection wells as personnel were trying to pump effluent into the wells, and/or (3) clogs in the well/material blowing-out during attempts to clean the wells. It has been suggested that water runoff (e.g., from rain or snow melt) could have picked up radiological contamination in the soils and flooded the service tunnels throughout the lifetime of the Linde site, resulting in a constant contamination level (NIOSH, 2010).

The utility tunnels would have been routinely accessed by inspectors and maintenance personnel throughout the site history. While there is limited information on the number of hours a worker may have worked in these tunnels, according to the Army Corps of Engineers 2002 report, *Dose Assessment for the Existing Surface Contamination Within the Linde Utility Tunnel Complex*, approximately two months a year are needed for annual maintenance (e.g., sump pump replacement, condensate pump repair, lighting repairs) (Army Corps, 2002). This report also provides an estimate of the effort required for tunnel inspection each year; this estimate is supported by worker interviews (Personal Communication, 2010a; Personal Communication, 2010b; Personal Communication, 2010c). There were stairwells from the tunnels leading up to Buildings 2, 14, and 30. However, none of the records indicate that it was general practice for employees to use the tunnels to get from one building to another; such a practice was not condoned by the company (Personal Communication, 2010c) and was against company policy.

Shortly after the shutdown of Step III production, a comprehensive clean-up effort was undertaken to reduce levels of radioactivity in Building 30 so it could be released to Linde for unrestricted use (Heatherton, 1950). After removal of the bulk of the process equipment, the entire building was vacuum-cleaned and flushed with water. Afterwards, a systematic radiation survey was conducted to identify areas of contamination. Decontamination was accomplished primarily by removing contaminated parts of the building (e.g., portions of the second-floor balcony on which process operators had been stationed) and by abrading surfaces (mostly by sandblasting, although oxygen acetylene torches were also used). In instances where sandblasting was ineffective (i.e., on brick or cinder-block walls and rough concrete floors), a pneumatic hammer was used to remove contaminated material (Heatherton, 1950). After each area was decontaminated, it was again cleaned and flushed, and a final radiation survey was performed.

In November 1952, a contamination survey of the Step III processing areas was conducted for the purpose of evaluating the release of the work space back to Linde following termination of Contract AT-(30-1)-GEN-165 (Harris, 1952). An amendment to the contract, dated October 31, 1953, required the decontamination of the Step III process area floors and miscellaneous equipment. A February 11, 1954, survey showed that the radiation levels of the floor and some of the equipment were still above the specified standards and would need to be either removed or, in the case of the floor, covered with asphalt tile (Belmore, 1954). The building was declared suitable for release following a subsequent survey performed April 11-15, 1954 (Harris, 1954).

In 1976, in the earliest stages of the Formerly Utilized Sites Remedial Action Program (FUSRAP), the Oak Ridge National Laboratory surveyed the Linde Tonawanda site (ORNL, 1978). This survey, conducted from October 18, 1976 through November 5, 1976, included both the Linde Ceramics MED/AEC process buildings and the Tonawanda Lab. The purpose of the survey was to determine if remediation would be required. Radiation and radioactive contamination measurements were taken inside Buildings 14, 30, 31, 37, and 38, on the property outside of the buildings, and at nearby offsite locations.

The Bechtel 1993 Remedial Investigation Report (Bechtel, 1993) shows that areas of residual radioactive contamination were also associated with areas in or near Buildings 57, 58, and 90. The highest indoor radiation levels were found in the principal production buildings, Buildings 30 and 38.

Table 5-3 shows selected events at Linde Ceramics for the period under evaluation.

Table 5-3: Linde Ceramics Timeline for the Period Under Evaluation

Year[a]	Event(s)
1947	Step III production resumes.
1948	Steps I and II process equipment dismantling begins.
1949	Step III production ends. Decontamination of Building 30 continues.
1950	Decontamination of Building 30 complete.
1952	Step III dismantlement begins.
1954	AEC contractual work comes to an end with completion of clean-up activities. Building 38 released to Linde.

Note:

[a] Dates are identified as specifically as possible based on current information.

5.2 Radiological Exposure Sources from Linde Ceramics Plant Operations

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

5.2.1 Internal Radiological Exposure Sources from Linde Ceramics Plant Operations

The primary source of internal radiological exposure resulting from Linde Ceramics Plant processing operations was inhalation and/or ingestion of uranium dioxide and/or uranium tetrafluoride. For non-process workers, the primary source of internal radiological exposure was inhalation and/or ingestion of uranium ore contamination re-suspended as a result of daily plant activities as well as decontamination activities performed during this period. The hazards represented from uranium-bearing dust in the air were well-documented, particularly in the years preceding 1948 (Kent, 1948a).

The radiological hazard presented by uranium and uranium progeny results primarily from alpha particles emitted by U-238 (4.15 MeV and 4.20 MeV) and its isotopes U-235 (4.37 MeV, 4.40 MeV, and 4.58 MeV) and U-234 (4.72 MeV and 4.77 MeV). Naturally occurring uranium is 0.71% (w/w) U-235 and 0.0055% (w/w) U-234. Linde Ceramics did not receive or process uranium enriched in the U-235 isotope; therefore, the uranium oxide and uranium hexafluoride are assumed to contain uranium in the same isotopic ratios as natural ore. On an activity basis (i.e., dpm/gram) the U-235 will be present in negligible amounts at these enrichment levels, but the U-234 activity will be at a level that is essentially equal to U-238 due to its much shorter half-life (2.46E05 years for U-234 and 4.47E09 years for U-238, respectively).

Other alpha-emitting radionuclides occur naturally as part of the U-238 decay process. These would have been removed during the Step I processing of uranium feed materials for uranium tetrafluoride production. Sufficient time would not have elapsed to allow appreciable in-growth of these progeny so that an additional hazard would have been posed to Linde personnel. However, continued lower-level exposures to uranium progeny and radon can be assumed because some radioactive waste was disposed of onsite and initial clean-up was not completed until the end of 1954 (ORAUT-TKBS-0025).

As previously discussed, the utility tunnel sections near the Ceramics Plant (Buildings, 30, 31, 37 and 38) were constructed in 1957 and 1961, which is after the December 31, 1953 end date of the covered period (Coutts, 2005, pdf p. 2). Because of this, there is no source term for underground radon exposure in this area of the site during the time period evaluated for this SEC petition. Although it cannot be definitively established, the utility tunnel section running between Building 14 (the "Tonawanda Laboratory") and Building 8 (the "Power House") was assumed to be in existence during the SEC period. While Building 14 was known to have processed ore to produce uranium pigments prior to WWII, such ores were pre-processed Colorado Plateau ores that contained little or no radium (Linde, undated). Unprocessed African ores were refined in Building 30 of the ceramics Plant. The Tonawanda Laboratory is known to have handled smaller quantities of unprocessed African ores as a pilot program for the production facility, particularly in the period from October 11, 1943 through December 15, 1943 (Jenness, undated). The documentary evidence is supplemented by 1976 borehole measurement data of soil contamination that show radium levels that do not exceed background levels, an indication that African ores were not a significant contaminant around Building 14, in contrast to samples taken in the area of the Ceramics Plant, which show elevated radium levels in the first few feet of soil in many places.

5.2.2 External Radiological Exposure Sources from Linde Ceramics Plant Operations

Employees could have received external radiation exposures from uranium and uranium progeny. The uranium content of mined uranium ores varied based on the assay of the rock being mined. Much of the potential for external exposure to workers was due to uranium progeny.

5.2.2.1 Photon

External exposures to photon radiation would have resulted from emissions from uranium and uranium progeny. Photon exposure during the operation of the Step III process would have been primarily limited to the immediate short-lived uranium progeny (Th-234 and Pa-234m).

5.2.2.2 Beta

Exposure to beta sources for Linde Ceramics Plant employees would have resulted principally from uranium decay products. In the uranium-series decay scheme, beginning with U-238, the short-lived isotope Pa-234m emits the most energetic beta particle (2.28 MeV). It is this beta particle that accounts for the shallow-dose hazard associated with handling uranium and uranium tetrafluoride.

5.2.2.3 Neutron

There was a small potential for personnel neutron exposures from the uranium operations at Linde Ceramics. As described in Section 5.2.1, site personnel received and handled uranium tetrafluoride. Low-atomic-number elements such as fluorine emit neutrons with an average energy of about 1.5 MeV when struck by alpha particles (referred to as alpha-neutron [• -n"] reactions). The intensity of the radiation field from these reactions increases as a function of the enrichment. Because only uranium with a natural isotopic ratio ("natural enrichment") was used at Linde, the radiation field was significantly lower than for the beta or gamma components, and as such, neutron radiation is not considered a significant exposure concern.

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

ATTRIBUTION: Section 6.0 and its related subsections were completed by Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

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

6.1 Available Linde Ceramics Plant Internal Monitoring Data

Documents suggest that tentative arrangements had been made for uranium urinalysis of certain groups of Linde employees as early as 1944 (Ferry, 1944); however, no records are available to indicate that these early analyses were performed. A page titled, "Schedule of Examinations, Contract AT-30-1-GEN-165," which was scheduled to begin in 1947, indicates that 60 cm^3 of urine from each employee was to be sent monthly to the University of Rochester for analysis (Rennich, 1947). Pre-employment urine sample results are available for 75 different workers. An additional 566 sample results are available for 113 employees, covering the time period from 1948 through January 1950 (AEC, 1947-1950a; AEC, 1947-1950b; AEC 1951; Harris, 1952). All sample result data are identified by name and some results are additionally identified by job title. Limited uranium urinalysis data have been identified for Linde workers after the cessation of Step III operations (fluorination of uranium dioxide to uranium tetrafluoride). A summary of the available bioassay records by year is provided in Table 6-1.

Table 6-1: Number of Available Linde Bioassay Records Per Year

Year	# of Samples
1947	75
1948	372
1949	183
1950	11

Uranium fusion photofluorimetry urinalysis was performed initially by the University of Rochester and later by the AEC New York Operations Office (Wolf, 1948). The recorded results of Linde uranium urinalysis during Step III production ranged from 0 to 3.10 mg/L, with many of the higher results reported in the November to December 1947 samples collected as “pre-employment urines.” Because preparation activities for the resumption of Step III production occurred before collection of these samples, it is possible that the elevated urinalysis results represented exposures received either during rehabilitation of the Step III equipment or from exposures to less-soluble uranium during earlier operations.

NIOSH has access to breathing zone data, general air sampling data, and contamination surveys that establish source term information for onsite uranium and uranium progeny during the operational period (AEC, 1947-1951; AEC, 1954b; Harris, 1952; Heatherton, 1948e, f; Heatherton, 1949c, d, e; Klevin, 1948; Klevin, 1949). A summary of the individual air sampling data are presented in Table 6-2. As discussed, NIOSH also has data from radiological surveys conducted during Step III operations and during the decontamination of the Linde facilities that followed the cessation of operations and removal of source term materials (Harris, 1952; Harris, 1954; Klevin, 1954a; Weinstein, 1954). In addition, NIOSH has access to dust samples (AEC, 1954a), contamination smear samples (AEC, 1954b), and post-remedial action data (Harris, 1952; Heatherton, 1950; Klevin, 1954a) documenting site contamination for the period under evaluation in this report.

Table 6-2: Number of Available Air Monitoring Records Per Year

Year	# of Samples	
	General Air	Breathing Zone
1947	6	0
1948	57	50
1949	150	109
1950	37	19

Details regarding the various analyses used and the associated minimum detectable activities are presented in the Technical Basis Document *An Exposure Matrix for the Linde Ceramics Plant (including Tonawanda Laboratory)* (ORAUT-TKBS-0025).

6.2 Available Linde Ceramics Plant External Monitoring Data

For part of the period from 1947 to 1949, weekly film badge measurements of beta and gamma exposure were available in the form of a database printout (Film Badge Dataset, 1948-1949). The printout data have been de-identified by removal of personnel names (Wallace, 2003), but many of the records are labeled with a job title. The data file contains about 6,000 records from January 7, 1948 through December 12, 1949. By comparison with a copy of a laboratory film badge report (AEC, 1949), it was determined that the listed date specifies the beginning of the week the film badge was worn.

Supplementing this database printout, NIOSH has access to two weekly film badge reports covering the weeks of March 28, 1949 and April 4, 1949 (Ceramics Film Badge Report, 1949). These reports list individual badge numbers and are identified by name and social security number. In addition, NIOSH has access to summary film badge reports which list the total number of film badges issued as well as the exposure ranges for the covered time period (AEC, 1949; Hayden, 1948; Heatherton, 1947; Heatherton, 1948a, b, c, d; Kent, 1947; Kent, 1949b).

No personnel external dosimetry data have been identified for Linde Ceramics workers prior to the start or after the cessation of Step III operations. However, NIOSH does have access to radiological dose rate and contamination data documenting site contamination for the period under evaluation in this report (AEC, 1954a; AEC, 1954b; Harris, 1952; Heatherton, 1950; Klevin, 1954a).

Details regarding the various analyses used and the associated minimum detectable activities are presented in the Technical Basis Document *An Exposure Matrix for the Linde Ceramics Plant (including Tonawanda Laboratory)* (ORAUT-TKBS-0025).

6.3 Available Linde Ceramics Plant Utility Tunnel External Monitoring Data

Limited radiological characterizations of the utility tunnels were conducted during the 1976 and 1981 Formerly Utilized Sites Remedial Action Program (FUSRAP) surveys of the Linde site (ORNL, 1978; Bechtel, 1982). A detailed characterization of these tunnels was performed in the summer of 2001 (Army Corps, 2002). During the remedial investigation (Bechtel, 1993, Section 4), data were collected to determine the nature and extent of subsurface contamination. Borehole samples were analyzed, including borehole B29R23, located just northwest of Building 30 near a former injection well found just inside the building. This borehole was sampled at three intervals and showed low-level Ra-226 concentration in the first interval (Bechtel, 1993, Section 4-25), possibly as a result of spilled effluent at the injection well site. The concentration decreased at the deeper sample interval.

The detailed radiological characterization performed in 2001 (Army Corps, 2002) was based on beta surface contamination levels. Six to eight circumferential measurements were taken in one-meter increments along the tunnel. In addition, hot spot readings were collected. The maximum result was recorded. The beta contamination levels were then converted to individual isotopic activities based on gamma spectroscopy analysis of soil samples taken during site remediation. The associated data analysis performed by the Army Corps of Engineers is presented in Table 6-3 below (Army Corps, 2002).

Table 6-3: Radionuclide Fraction Calculation Using Average Linde Soil Concentrations

Isotope	Soil Concentration Gamma Spec (pCi/gm)	Uranium Fraction F(U)	Soil Concentration Isotopic (pCi/gm)	Source Fraction (f_S)	Beta Emission

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 ensure 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 7.6. 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-00154 as submitted by the petitioner. (Section 7.4)

7.1 Pedigree of Linde Ceramics Plant Data

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

7.1.1 Internal Monitoring Data Pedigree Review

ATTRIBUTION: Section 7.1.1 was completed by Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

NIOSH located limited bioassay monitoring data for the period prior to the start and after the termination of Step III production. Therefore, an internal monitoring data sufficiency and pedigree evaluation is not possible for the internal monitoring data outside the 1947-1949 time period. Similarly, NIOSH did not locate any radon monitoring data for the period under evaluation; therefore, a data sufficiency and pedigree evaluation is not possible for radon monitoring data during the 1947-1953 time period.

Urinalysis data associated with Step III productions are contained in original typed reports and typed and handwritten sample data log sheets; these are legible primary data sources. As mentioned in Section 6.1, all of the data available are identified by employee name and, in some cases, by specific job title. Out of the 43 employees explicitly identified as Step III process workers, NIOSH has urinalysis data for 41 employees. The available urinalysis data are reflective of the maximum-exposure scenario (i.e., process workers from the Step III conversion process) for the class under evaluation and are of sufficient quantity and quality to support the assessment provided in this evaluation report.

Similarly, the air sampling and survey data associated with the decontamination and decommissioning activities of the 1949-1953 time period are contained in original typed summary reports and handwritten and typed sample log sheets; these are therefore considered primary data sources. The available general air sampling data contain notes pointing to specific locations within the processing areas. Available breathing zone air sampling data contain notes that describe tasks being performed during sampling and, in some cases, the job titles of those individuals carrying out those tasks. Data obtained in the Step III operations are measurements of samples taken during production operations and are reflective of the maximum-exposure scenario for the class under evaluation, and are of sufficient quantity and quality to support the assessment provided in this evaluation report.

7.1.2 External Monitoring Data Pedigree Review

ATTRIBUTION: Section 7.1.2 was completed by Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

NIOSH did not locate any external personnel monitoring data for the period following the termination of Step III production. Therefore, an external monitoring data sufficiency and pedigree evaluation is not possible for these data outside the 1947-1949 time period. As described in Section 6.2, NIOSH has access to a database printout of approximately 6,000 weekly film badge results for the Step III operations/production period. The printout contains beta and gamma measurements; neutron monitoring was not performed during this time period. The data in this printout have been de-identified by removal of personnel names, preventing direct correlation between the records and individual workers. However, the data are identified by job title, allowing for the correlation of the highest recorded doses with specific categories of workers. NIOSH compared these data with the only available original laboratory film badge report and confirmed that the dates on the printout specify the beginning of the week the film badge was worn (AEC, 1949). As the materials handled and the methods used did not change during the covered operational period, these data may be used to estimate external radiation exposure for all workers for this time period. NIOSH intends to use this information and exposure data to support its ability to bound external dose for the class under evaluation.

7.2 Evaluation of Bounding Internal Radiation Doses at Linde Ceramics Plant

ATTRIBUTION: Section 7.2 and its related subsections were completed by Jason Davis, Oak Ridge Associated Universities, and Mutty Sharfi, MJW Corporation. The rationales for all conclusions in this document are explained in the associated text.

The principal sources of internal radiation doses for members of the class under evaluation were: (1) the inhalation of uranium-bearing dust during the conversion of uranium dioxide into uranium tetrafluoride from 1947-1949; and (2) the potential inhalation or ingestion of residual contamination in the uranium processing buildings (i.e., Buildings 14, 30, 31, 37, and 38) during dismantling and decontamination activities from 1947-1953 (Bechtel, 1993; ORAUT-TKBS-0025). The following subsections address the ability to bound internal doses, methods for bounding doses, and the feasibility of internal dose reconstruction.

7.2.1 Evaluation of Bounding Process-Related Internal Doses

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

7.2.1.1 Urinalysis Information and Available Data

As discussed in Section 6.1, individual uranium urinalysis data from November 1947 to 1950 are available for 41 out of 43 workers identified as Step III process workers (Sample Log Sheets, 1947-1961; Logbook, 1947-1949; AEC, 1947-1950a; AEC, 1947-1950b; AEC, 1951; Klevin, 1948; Klevin, 1949). This period covers Step III production in Building 38. Additionally, individual uranium urinalysis data are available for 70 workers that cannot be positively identified as Step III process workers (Sample Log Sheets, 1947-1961; Logbook, 1947-1949; AEC, 1947-1950a; AEC, 1947-1950b; AEC, 1951). However, no employee roster has been located to confirm what percentage of the total worker population is represented in the urinalysis data. Because every employee during this time period may not have been monitored, NIOSH does not intend to base its ability to bound the internal dose solely on the available bioassay data. NIOSH does intend to use the bioassay data and ORAUT-OTIB-0019 methodology to assess bounding internal dose estimates for unmonitored workers in the class under evaluation.

7.2.1.2 Airborne Levels

NIOSH has been able to locate air sample data providing gross alpha analytical results for the Step III operational period. These data are in the form of sample log sheets (AEC, 1947-1951; Heatherton, 1948j; Sample Log Sheets, 1947-1961), weekly progress reports that present sampling data (Heatherton, 1947; Heatherton, 1949a, b, c, d, e; Kent, 1949a,), and two prepared reports that detail the dust hazards present during Step III operations (Klevin, 1948; Klevin, 1949). These last two reports detail the general area samples taken as well as breathing zone samples for different stages in the processing operation. Data are presented for each of four job groups involved in the Step III operations, including foremen and operator groups A-C. Within these job groups, the Progress Report for week ending March 27, 1949, provides individual job titles (Kent, 1949a). The final page of each Progress Report for the weeks ending in March 27, 1949 and July 24, 1949, includes a list of employees who worked in the Step III operations area (Kent, 1949a; Kent, 1949b).

Heatherton describes various methods for decontaminating hard surfaces at the Linde Ceramics Plant in Building 30 (Heatherton, 1950). Included in Table V of Heatherton's survey is a data summary showing the minimum, maximum, and average air concentrations measured during the evaluation of different decontamination options. Thirty-eight air dust samples were collected while vacuum-cleaning rafters covered with radioactive dust, while sandblasting, and while using the oxygen blow pipe (Heatherton, 1950). NIOSH has access to the original sample data logs that provide not only the air sample results but also the processes being carried out while sampling was conducted (AEC, 1947-1951).

Another decontamination option was the removal of contaminated concrete brick and cinder-block with a pneumatic hammer. In order to estimate the radioactivity hazards in performing this work, dust samples were taken and analyzed for alpha activity. The alpha activity data present values in terms of exposure in MACs, where one MAC = 70 dpm/meter^3 alpha. Eighteen dust samples were collected in the general area of the operation and in the breathing zone (Heatherton, 1950).

Dust samples were also collected in the general area during the decontamination of the Step III processing area (AEC, 1954b). A memo written at this time points out that the dust concentrations observed during this decontamination effort are lower than those observed during the Step I and Step II decontamination efforts (Klevin, 1954b).

Waste materials (raffinates) were transported offsite (to LOOW and/or Ashland) prior to the end of operations (Aerospace Corporation, 1981; Argonne, 1987; Anderson, 1945; Malone, 1956; Robinson, 1945; Robinson, 1973; Thornton, 1976). Therefore, workers outside the operational period would have had minimal exposure potential to this material in its concentrated form. To determine the exposure potential from residual surface contamination on the site, a review of available isotopic data was conducted. Isotopic data from soils and sediments on site are summarized in Attachment One of this evaluation report and can be used to determine exposure from uranium progeny.

NIOSH believes that the available air sample and bioassay data, and the methodology in ORAUT-TKBS-0025, are sufficient to support bounding internal dose estimates for unmonitored workers in the class under evaluation. NIOSH concludes that it can establish a bounding internal dose estimate from airborne particulates containing the isotopes of uranium (i.e., U-238, U-234, and U-235). As mentioned in Section 5.2, exposure to radon and other uranium progeny are not believed to be a significant source of internal exposure due to the age of the source and product materials, and the fact that the processing residues were shipped offsite for storage. However, continued lower-level exposures to uranium progeny and radon can be assumed because some radioactive waste was disposed of onsite and initial clean-up was carried out in stages and was not completed until 1954 (Harris, 1954; ORAUT-TKBS-0025).

7.2.2 Evaluation of Bounding Ambient Environmental Internal Doses

Ambient environmental internal doses could have resulted from the inhalation of radionuclides in locations outside of the Linde Ceramics process/operations areas. NIOSH has identified no specific indication that ambient air particulate levels were monitored at Linde Ceramics. However, the ambient environmental exposures would be included and accounted for in the occupational monitoring data available for site personnel. Based on this information and the available data and documentation associated with Linde operations, NIOSH has concluded that ambient environmental internal doses associated with ambient environmental airborne exposures outside of the process areas are accounted for, and can be bounded by application of operational internal dose assessment methods. Therefore, further analysis and evaluation of the ability to bound (reconstruct dose with sufficient accuracy) ambient environmental internal dose is not included in this report.

7.2.3 Methods for Bounding Internal Dose at Linde Ceramics Plant

NIOSH intends to use the available bioassay data whenever data for an individual is available. To account for unmonitored personnel, NIOSH analyzed the available uranium urinalysis records per ORAUT-OTIB-0019 to develop tables of assigned doses based on co-worker bioassay results. These tables are presented as Tables 3-1 and 3-2 in ORAUT-TKBS-0025. The available data, coupled with the co-worker assessment, supports NIOSH's ability to bound internal dose for the class under evaluation.

7.2.3.1 Methods for Bounding Internal Dose for Site Workers

Individual bioassay data may be used in conjunction with the co-worker data and progeny-to-uranium ratio tables presented in ORAUT-TKBS-0025 to support bounding internal exposures for the class under evaluation. The intake rate data presented in the co-worker data tables are intended to cover all workers for the entire period from November 1, 1947 through December 31, 1953. The uranium urinalysis data used to create these tables are from the Step III operational period, which represents the maximum exposure scenario for the class under evaluation. NIOSH intends to apply this method as a bounding approach for reconstructing internal dose for the class, which includes dismantlement/decontamination workers.

7.2.3.2 Methods for Bounding Internal Radon Dose for Site Workers

During Ceramics Plant production, the only source of radon was African ore processing. No direct radon measurements during the period of Step III operations are available. An estimate was made based on the lowest measured indoor concentrations at the Linde site during African ore processing. Approximately 20% of the measurements in the Linde ore-processing building yielded results of 10 pCi/L or less, with most of these results at or near 10 pCi/L. Therefore, 10 pCi/L was assumed to be outdoor air concentration. After the end of African ore processing, radon concentration in the main ore-processing building (Building 30) and all other Linde Ceramics Plant buildings was assumed to remain at the 10-pCi/L level due to the removal of uranium ores and their raffinates. Concentrations in other Linde buildings were also assumed to be 10 pCi/L until the end of clean-up in those buildings.

Because the locations of many workers are likely to be unknown, it was assumed that all workers were exposed to 10 pCi/L of radon from November 1, 1947, through December 31, 1953. As mentioned in Section 5.2, exposure to radon and other uranium progeny are not believed to be a significant source of internal exposure due to the age of the source and product materials, and the fact that the processing residues were shipped offsite for storage. Because there is a lack of source material to increase the radon concentration during the evaluated period, the assumption of a 10 pCi/L radon concentration represents a sufficiently accurate estimate for the purposes of bounding internal exposures for the class under evaluation.

As discussed in Section 5.2.1, there is no evidence of an increased radium source-term for soils near the utility tunnel section running between Building 14 (the "Tonawanda Laboratory") and Building 8 (the "Power House"), which was assumed to be in existence during the SEC period. Therefore, NIOSH believes that a 10 pCi/L radon level that has been established for surface buildings in the Ceramics Plant will be bounding for these worker exposures during the SEC-00154 petition period.

7.2.3.3 Methods for Bounding Internal Dose for Linde Tunnel Workers

In order to bound the dose for workers that may have had occasion to enter the service utility tunnels, NIOSH has converted beta contamination levels from the radiological characterization of the tunnels performed in 2001 to individual isotopic activities based on gamma spectroscopy analysis of soil samples taken during site remediation. Using the data in Table 6-3 above, the following equations can be used to convert the gross beta surface contamination levels to isotopic activities:

- Ra-226: (dpm/m^2

Using the equations above and the 95th percentile gross beta surface contamination level, the isotopic contamination levels were calculated. Results are shown in Table 7-2.

Table 7-2: Isotope Contamination Levels in the Linde Utility Tunnel Complex

Isotope	Surface Activity (dpm/m^2)
Ra-226	2.90E+05
Th-230	3.30E+05
U-238	1.29E+06
U-235	6.17E+04
U-234	1.38E+06

These contamination levels were assumed to be uniformly present on all tunnel surfaces for all years. This source term is considered bounding for the following reasons:

- The beta measurements are based on the highest observed measurements.
- The beta measurements include both fixed and removable contamination. (It is typically estimated that contamination is only 10% removable and, therefore, a contributor to airborne contamination. Including both fixed and removable contamination is overestimating the contamination available for re-suspension).
- Hot spot contamination levels were treated as uniformly-distributed contaminated surfaces and included in the distribution.
- The tunnels were reportedly a damp environment, which would have the effect of preventing re-suspension of material.

Based on the 95th percentile beta surface contamination level (shown above), an air concentration activity was calculated based on guidance provided in ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities*. The following work assumptions were made:

- Breathing Rate: 1.2 m^3/hour
- Work Year: 8 hours/day for 250 days/yr, prorated to 2 months/yr
- Re-suspension Factor: 1 x 10^{-6}

The calculated intakes based on these work assumptions are provided in Table 7-3.

Table 7-3: Intake Rates Derived from Surface Contamination Data				
Isotope	**Surface Activity (dpm/m^2)**	**Air Concentration (dpm/m^3)**	**Annual Intake Rate (dpm/year)**	**Annual Ingestion Rate (dpm/year)**
Ra-226	2.90E+05	0.29	116	2.4
Th-230	3.30E+05	0.33	132	2.8
Th-238	1.29E+06	1.29	517	10.8
U-235	6.17E+04	0.06	24.7	0.5
U-234	1.38E+06	1.38	552	11.5

The values in Table 7-3 were compared to co-worker data calculated from contamination data collected by Heatherton (Heatherton, 1950) as follows: during the renovation years (1954-1970), the internal exposure potential is based on an air concentration of 2.3 Maximum Acceptable Concentration (MAC) (1 MAC = 70 dpm). This is about 50 times higher than the estimated air concentrations for the tunnels. Assuming a re-suspension factor of 1×10^{-6}, 2.3 MAC would result from an average surface contamination of about 1.6×10^6 dpm / 100 cm^2. This is a level of contamination that would have been easily detected and would have required remediation. However, there is no indication that contamination was ever detected at these levels in the tunnels. Therefore, prior to 1971, assigning the exposure values associated with the renovation is a higher bounding estimate than assigning the exposure potential for the tunnels. Based on this result, NIOSH intends to use the higher intake values from ORAUT-TKBS-0025 as a bounding approach for employees who performed work in the utility tunnels during the period evaluated in this report.

7.2.4 Internal Dose Reconstruction Feasibility Conclusion

NIOSH has sufficient internal monitoring data, air monitoring data, and area survey data to support bounding internal exposures for uranium and uranium progeny during the period from November 1, 1947 through December 31, 1953. Radioactive operations terminated in 1949 and source-term materials were removed from the site. The application of the survey and air monitoring data as outlined in ORAUT-TKBS-0025 will result in conservative estimates of exposure for the Linde Ceramics activities conducted during the period under evaluation (November 1, 1947 through December 31, 1953). The use of operational period urinalysis data in co-worker exposure tables will result in claimant-favorable maximum exposure estimates for non-process workers, including decontamination/decommissioning workers. Analysis of both the urinalysis data and utility tunnel contamination data shows that operational intake rates based on the bioassay analysis resulted in higher daily intake rates than the tunnel exposure scenario. Therefore, operational period urinalysis data are also bounding for service workers who may have worked in the underground utility tunnels.

7.3 Evaluation of Bounding External Radiation Doses at Linde Ceramics Plant

ATTRIBUTION: Section 7.3 and its related subsections were completed by Joseph Guido and Mutty Sharfi, MJW Corporation, and Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

The principal sources of external radiation doses for members of the evaluated class were: (1) direct beta/gamma exposure from uranium and uranium progeny contained in Step III process materials (uranium oxide and uranium tetrafluoride compounds); and (2) residual contamination present on building surfaces and inside equipment and components resulting from Step III and all other site operations.

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

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

7.3.1.1 Personnel Dosimetry Data

As described in Section 6.2, NIOSH has access to a database printout of approximately 6,000 weekly film badge results (Film Badge Dataset, 1948-1949). These data have been de-identified by removal of personnel names, thus preventing direct correlation between the respective dose records and individual workers. The tables do, however, provide a correlation between personnel job classifications and the measured doses.

The computer file had three columns of data. The third data column was obviously the total radiation dose. By comparison with a laboratory film badge report (AEC, 1949), the first data column was determined to be beta radiation and the second was determined to be gamma radiation. The report states both the beta and gamma units to be “exposure, mr.” Progress reports by the Linde health physicist refer to the film badge results sometimes as “mr” and sometimes as “mrep” (Heatherton 1949d, e), but these are essentially equivalent. The beta units are designated in ORAUT-TKBS-0025 as mrem and are assumed for purposes of dose reconstruction to be equivalent to shallow dose at 0.07 mm. ORAUT-TKBS-0025 further assumes that gamma radiation units were equivalent to milliroentgen. In all cases, results reported as “0”, “*”, or “**” are interpreted as meaning “less than the limit of detection” (LOD). Before March 15, 1948, a beta value below the limit of detection was reported as "<80." After March 15, 1948, the limit of beta detection was not explicitly stated, but it was deduced to be 35 mrem from an examination of the data (ORAUT-TKBS-0025). For records before March 15, 1948, a gamma value below the limit of detection (LOD) was reported as "0" or "<50." For records after March 15, 1948, the limit of gamma detection was not explicitly stated but was deduced to be 45 mR from an examination of the data (ORAUT-TKBS-0025).

Sufficient job category and workgroup information is contained within the external dosimetry database described above to allow for the statistical analysis of the data by job activity and also by work area. This information supports the bounding of external doses for individual occupational groups. Such an analysis is presented in ORAUT-TKBS-0025.

7.3.1.2 Alternative Data Sources for Bounding External Dose

Results of radiation surveys performed at the end of the operational period (Blatz, 1949; Heatherton, 1950; Wolf, 1949) can be used along with the results of the initial FUSRAP site surveys (ORNL, 1978) to establish bounding external radiation levels within Linde buildings during standby periods and for outdoor areas. The rationale (presented in ORAUT-TKBS-0025) is that survey data from Building 30 prior to decontamination would provide a bounding estimate of radiation levels for other site buildings and for outdoor areas based on the fact that Building 30 was the most contaminated building on the Linde site, as determined at the time of the 1976 FUSRAP survey. Detailed analysis, presented in ORAUT-TKBS-0025, uses more limited surveys in 1949 (performed prior to vacuuming and flushing of the building) to establish a scaling factor (determined to be 3) for adjusting the 1950 survey data (Heatherton, 1950) to account for the fact that the measurements taken during the more comprehensive 1950 survey occurred after the facility vacuum-and-flushing operation.
An estimate of neutron exposure during operations involving fluorine is also presented in ORAUT-TKBS-0025. This estimate is based on activities specific to Linde and makes use of information on neutron radiation generated from alpha radiation documented in ORAUT-OTIB-0024.

7.3.2 Evaluation of Bounding Ambient Environmental External Doses

Ambient environmental external doses could have resulted from low-level exposures to radioactive materials in locations outside of the process/operations areas at Linde Ceramics. There is no specific indication that ambient radiation levels were monitored at the Linde site. However, the ambient environmental exposures would be included and accounted for in the occupational monitoring data available for site personnel. In addition, this site managed only a single radioactive source (natural abundance uranium) and had no operations involving other radioactive materials prior to the evaluated period. Based on this information and the available data and documentation associated with Linde Ceramics Plant operations, NIOSH has concluded that ambient environmental external doses associated with exposures outside the direct vicinity of Linde process areas are accounted for and can be bounded by application of operational external dose assessment methods. Therefore, further analysis and evaluation of the ability to bound (reconstruct dose with sufficient accuracy) ambient environmental external dose is not included in this report.

7.3.3 Linde Ceramics Plant Occupational X-Ray Examinations

ORAUT-TKBS-0025 provides detailed information on the nature and extent of the occupational medical X-ray examination program in place at Linde during the period under evaluation. In summary, annual and termination 14 x 17 inch chest X-rays were provided for all plant employees. Additionally, pelvic X-ray examinations were also provided to personnel starting in November or December 1947 (ORAUT-TKBS-0025) and two additional pelvic X-ray examinations were conducted at termination.

7.3.4 Methods for Bounding External Dose at Linde Ceramics Plant

There is an established protocol for assessing external exposure when performing dose reconstructions (these protocol steps are discussed in the following subsections):

- Photon Dose
- Beta Dose

- Neutron Dose
- Medical X-ray Dose

Linde Ceramics Site Worker Photon and Beta Dose

External monitoring data summarized in Section 7.3.1.1 can be used as the basis to bound external photon and beta exposure for Linde site workers. Adjustments to these data to account for specific job categories and work areas can be made based on job description and category information that is also contained within the dataset. Adjustments for what are termed "high-" and "low-" risk employees are provided in ORAUT-TKBS-0025; however, additional adjustments can be made using the available dataset, as appropriate, based on individual claim dynamics. Additional adjustments that have been incorporated into the analysis documented in ORAUT-TKBS-0025 include consideration of missed dose and ambient environmental dose.

Bounding estimates of photon and beta dose during periods when operations were not ongoing (i.e., during standby periods, and at the Tonawanda Laboratory Facility) can be made using the analysis of building radiation levels documented in ORAUT-TKBS-0025. ORAUT-TKBS-0025 divides the workers during the period following Step III operations into three classes:

- Clean-up Worker: Worker who was directly engaged in the removal of radioactive equipment, components, or contamination for a substantial portion of the workday.

- Clean-up Support Worker: Worker who spent a substantial portion of the workday in the building or area being decontaminated to support the cleanup activities, but was not actively engaged in the removal activities.

- Non Clean-up Worker: All other workers.

Table 4-24 of ORAUT-TKBS-0025 lists the dose rates for each of worker class, for each year following the cessation of Step III processing.

Linde Ceramics Tunnel Worker Photon and Beta Dose

For employees who performed work in the tunnels, external contamination and submersion dose coefficient factors (DCFs) from the Federal Guidance Report, *External Exposure to Radionuclides in Air*, *Water*, *and Soil*, were used to calculate skin and effective dose rates by radionuclide (Eckerman, 1993). These dose rates are shown in Table 7-4. The DCFs used are based on a single plane exposure model. However, considering that the 95th percentile surface contamination level (including hotspot activities in the distribution) is being applied to the entire length of the tunnel, this approach supports NIOSH's ability to bound any dose that would be associated with contamination on the tunnel ceiling and walls.

Table 7-4: Calculated Skin and Effective Dose Rates by Radionuclide				
Isotope	**Effective Contaminated Dose Rate (rem/hr)**	**Effective Submersion Dose Rate (rem/hr)**	**Skin Contaminated Dose Rate (rem/hr)**	**Skin Submersion Dose Rate (rem/hr)**
Ra-226	2.90E-06	1.54E-10	4.47E-05	6.24E-10
Th-230	1.49E-09	3.45E-14	2.84E-08	1.79E-13
U-238	2.34E-07	1.06E-11	1.46E-04	8.67E-10
U-235	2.20E-07	1.03E-11	7.92E-06	7.16E-11
U-234	6.19E-09	6.32E-14	1.51E-07	7.04E-13

Using the dose rates above, and assuming two months per year and the calculated surface activity and air concentrations calculated in Section 7.2.3, an external dose potential was estimated. These potential external annual doses are listed in Table 7-5. An assumed energy distribution of 100% 30-250 keV photons for the WB dose and 100% >15 keV electrons for the skin dose is recommended as a bounding assumption.

Table 7-5: Calculated Annual Doses by Radionuclide		
Isotope	**Effective WB Annual Dose (rem/year)**	**Skin Annual Dose (rem/year)**
Ra-226	9.66E-04	1.49E-02
Th-230	4.95E-05	9.47E-06
U-238	7.81E-05	4.87E-02
U-235	2.06E-05	6.91E-5
U-234	2.06E-06	5.02E-05
Total	0.001	0.064

Based on these DCFs, external dose potentials were estimated and compared to the information collected by Heatherton (Heatherton, 1950). The external exposure potential during the renovation years (1954-1970) is 0.068 rem/yr gamma and 0.326 rem/yr beta. These values are based on a survey of the radiation levels in Building 30 made in 1949 in conjunction with its decontamination (Heatherton, 1950). Another survey of Building 30 was made in 1976 (ORNL, 1978), the results of which were similar to the post-decontamination results. This indicates there was little change in the Building 30 contamination conditions between the two surveys. As with the intake data, the external dose potential resulting from work performed in the tunnel was well below the exposure rates tabulated in ORAUT-TKBS-0025. Based on this result, NIOSH intends to use the higher exposure rate values from ORAUT-TKBS-0025 as a bounding approach for employees that performed work in the utility tunnels.

Neutron Dose

As noted in Section 5.2.2.3, based on the source material present during the period under evaluation, neutrons are not expected to be a significant source of exposure requiring dose reconstruction. As individual cases warrant, bounding estimates of neutron exposure may be performed using the analysis of potential neutron radiation levels contained in ORAUT-TKBS-0025.

Medical X-ray Dose

The bounding approach for reconstruction of medical X-ray dose is defined in the complex-wide Technical Information Bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT-OTIB-0006), using the site-specific parameters presented in ORAUT-TKBS-0025, as summarized above in Section 7.3.3.

7.3.5 External Dose Reconstruction Feasibility Conclusion

Based on the available external monitoring data and area radiation survey data, and the information in ORAUT-TKBS-0025, NIOSH has the necessary data to support bounding external exposures for uranium and uranium progeny during the period from November 1, 1947 through December 31, 1953. Application of the methodology in ORAUT-TKBS-0025 supports NIOSH's ability to bound dose for the Linde Ceramics Plant worker class under evaluation during the period from November 1, 1947 through December 31, 1953.

7.4 Evaluation of Petition Basis for SEC-00154

ATTRIBUTION: Section 7.4 and its related subsections were completed by Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

The following subsections evaluate the assertions made on behalf of petition SEC-00154 for the Linde Ceramics Plant.

7.4.1 Lack of Individual Monitoring

SEC-00154: The petitioner asserted that Linde Ceramics Plant workers were not monitored for radiation exposure.

NIOSH has located external dosimetry data for the time period from 1947 through 1949 and internal dosimetry data for the time period from 1947 through 1950. Linde Ceramics Plant workers employed after the cessation of Step III operations were not radiation workers. A radiation worker was an employee who had received specific training and qualifications allowing the worker to have unescorted access into the controlled area and to perform work of a radiological nature.

Following the cessation of Step III uranium processing, personnel dosimetry was only required for those employees who would be spending more than four hours a week in an area with known contamination (Kent, 1948b). In retrospect, in light of available information regarding the contamination and possible exposure pathways at the Linde site, NIOSH determined that an evaluation of the data available to support dose reconstruction was warranted; consequently, NIOSH pursued the evaluation of the petitioner-proposed class presented in this report.

7.4.2 Adequacy of Data

SEC-00154: The petitioner asserted that the draft *Assessment of the Disposition of SC&A's Linde Site Profile Review Issues in Response to SEC Petitioner Concerns* documented limitations of existing records that might prevent the completion of dose reconstructions for members of the proposed class (SC&A, 2009).

Response: SC&A's *Draft Review of the NIOSH Site Profile for the Linde Ceramics Plant and Tonawanda Laboratory, Tonawanda, New York* (SC&A, 2006) noted the need for clarification within the Linde Ceramics Site Profile, and offered suggestions for improving the accuracy of dose reconstruction for former Linde workers. The draft report did not document any specific limitations of the DOE records that would imply any infeasibility of dose reconstruction for any member of the petitioner-proposed class. The limitations, as documented in the report, have been addressed to the satisfaction of the Advisory Board on Radiation and Worker Health, as outlined in Table 4 of the draft SC&A report (SC&A, 2009).

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

ATTRIBUTION: Section 7.5 was completed by Jason Davis, Oak Ridge Associated Universities. The rationales for all conclusions in this document are explained in the associated text.

During the feasibility evaluation for SEC-00154, a number of issues were identified that needed further analysis and resolution. The issues and their current status are:

- ISSUE: During the initial review of the petition and supporting information, ORAUT/DCAS raised the issue of whether radon monitoring records exist for the time period under evaluation.

  RESPONSE: NIOSH has been unable to find radon monitoring records for the time period from November 1947 through December 1953. However, ORAUT-TKBS-0025 presents a method for estimating radon exposures to Linde Ceramics workers for this time period. A summary of this method is presented in Section 7.2.3.

- ISSUE: During an interview with NIOSH, a former worker indicated that the utility tunnels running beneath the Linde Ceramics Plant may have been contaminated and may have presented an exposure potential for certain workers.

  RESPONSE: Documentary evidence indicates that the utility tunnel sections near the Ceramics Plant (Buildings, 30, 31, 37 and 38) were constructed in 1957 and 1961, which is after the December 31, 1953 end date of the covered period (Coutts, 2005). Because of this, there is no source term for underground radon exposure in this area of the site during the time period evaluated for this SEC petition. Although it cannot be definitively established, the utility tunnel section running between Building 14 (the "Tonawanda Laboratory") and Building 8 (the "Power House") was assumed to be in existence during the SEC period. While Building 14 was known to have processed ore to produce uranium pigments prior to WWII, such ores were pre-processed Colorado Plateau ores that contained little or no radium (Linde, undated). Unprocessed African ores were refined in Building 30 of the ceramics Plant. The Tonawanda Laboratory is known to have handled smaller quantities of unprocessed African ores as a pilot program for the production facility, particularly in the period from October 11, 1943 through December 15, 1943 (Jenness, undated). The documentary evidence is supplemented by 1976 borehole measurement data of soil contamination that show radium levels that do not exceed background levels, an indication that African ores were not a significant contaminant around Building 14, in contrast to samples taken in the area of the Ceramics Plant, which show elevated radium levels in the first few feet of soil in many places. Because there is no evidence of an increased radium source-term for soils near this section of tunnel, NIOSH believes that a 10 pCi/L radon level that has been established for surface buildings in the Ceramics Plant will be bounding for worker exposures during the SEC-00154 petition period.

NIOSH has formulated a method to address the exposure potential of Linde Ceramics Plant employees who may have performed work in the utility tunnels. However, as described in Sections 7.2.3 and 7.3.4, exposures received as a result of performing process work or decontamination/decommissioning work would have been in excess of those exposures received as a result of tunnel occupation. Because of this, the methods presented for bounding doses for other classes of workers will be applied to maintenance workers who may have worked in the underground utility tunnels during the period under evaluation. This will result in a claimant-favorable overestimate of both internal and external exposures.

7.6 Summary of Feasibility Findings for Petition SEC-00154

This report evaluates the feasibility for completing dose reconstructions for employees at the Linde Ceramics Plant from November 1, 1947 through December 31, 1953. NIOSH found that the available monitoring records, process descriptions and source term data are sufficient to complete dose reconstructions for the evaluated class of employees.

Table 7-5 summarizes the results of the feasibility findings at the Linde Ceramics Plant for each exposure source during the time period November 1, 1947 through December 31, 1953.

Table 7-5: Summary of Feasibility Findings for SEC-00154
November 1, 1947 through December 31, 1953

Source of Exposure	Reconstruction Feasible	Reconstruction Not Feasible
Internal[1]	**X**	
- U (total) and associated progeny	X	
- Radon	X	
External	**X**	
- Gamma	X	
- Beta	X	
- Neutron	X	
- Occupational Medical X-ray	X	

Note:

[1] Internal includes an evaluation of urinalysis (in vitro) and airborne dust data.

As of April 8, 2010, a total of 139 claims have been submitted to NIOSH for individuals who worked at the Linde Ceramics Plant and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for 95 individuals (~68.3%).

8.0 Evaluation of Health Endangerment for Petition SEC-00154

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

Based on available monitoring data, knowledge of residual contamination, and surveys conducted throughout the period under evaluation, NIOSH's evaluation determined that it is feasible to estimate radiation dose for members of the NIOSH-evaluated class with sufficient accuracy based on the sum of information available from available resources. Modification of the class definition regarding health endangerment and minimum required employment periods, therefore, is not required.

9.0 Class Conclusion for Petition SEC-00154

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 at the Linde Ceramics Plant in Tonawanda, New York during the period from November 1, 1947 through December 31, 1953.

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-00154. 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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Attachment One: Data Sources on Uranium Progeny Concentrations in Linde Materials

Data Sources on Uranium Progeny Concentrations in Linde Materials

SRDB Ref ID	Date	Location	Description	U-238	U-234	U-235	Total U	Th-230	Ra-226	Th-232	Th-228	Ac-227	Pa-231	Units	Th-230/U	Ra-226/U	Th-232/U	Ac/U	Pa/U
16294	1995	Bldg. 14	dry valve pit (dust)	1038	1068	53.8	2159.8*	354.7	15.3	2.3	1.7			pCi/g	0.16*	0.01*	0.00*		
			sump (dust)	1.4	1.7	0.07	3.17*	0.72	0.52	0.2	0.22			pCi/g	0.23*	0.16*	0.06*		
			corridor overhead (dust)	369	378.8	11.6	759.4*	60.2	0.14**	5	0.67			pCi/g	0.08*	0.00*	0.01*		
			corridor wall (terra cotta block)	3.2	3.2	0.14	6.54*	1.7	1.4	1.4	1.4			pCi/g	0.26*	0.21*	0.21*		
14620	1978	Bldg. 30	air samples during D&D				1.90E-08	2.10E-09	1.10E-09					pCi/ml	0.11*	0.06*	0.00*		
9009	1981	Sediment, onsite & offsite	Ellicott Creek	0.82		0.05	1.69*	0.6	0.55	0.7				pCi/g	0.36*	0.33*	0.41*		
			Creek 1	0.95		0.05	1.95*	0.7	0.7	0.8				pCi/g	0.36*	0.36*	0.41*		
			Twomile Creek-upstream	4.3		0.1	8.7*	0.92	0.69	0.01				pCi/g	0.11*	0.08*	0.00*		
			Twomile Creek-Linde discharge	0.71		0.06	1.48*	0.02	0.52	0.02				pCi/g	0.01*	0.35*	0.01*		
			Twomile Creek-downstream	1.5		0.05	3.05*	0.96	0.59	0.48				pCi/g	0.31*	0.19*	0.16*		
			Storm Sewer	6.47		0.19	13.13*	1.4	1.35	0.62				pCi/g	0.11*	0.10*	0.05*		
			Storm Sewer	99		4.57	202.57*	18	6.93	0.51				pCi/g	0.09*	0.03*	0.00*		
			Storm Sewer	13		0.52	26.52*	2	1.59	0.65				pCi/g	0.08*	0.06*	0.02*		
			Storm Sewer	116		4.1	236.1*	9.9	0.89	0.34				pCi/g	0.04*	0.00*	0.00*		
			Storm Sewer	4.5		0.17	9.17*	0.2	0.64	0.39				pCi/g	0.02*	0.07*	0.04*		
			Sanitary Sewer	362		13	737*	1.33	1.94	0.11				pCi/g	0.00*	0.00*	0.00*		
			Sanitary Sewer	0.51**		0.05	1.07*	0.34	0.38	0.21				pCi/g	0.32*	0.36*	0.20*		
9026	1990	Linde soil	area 1-mean	11.2			22.4*	7.8	4.3	1.6				pCi/g	0.35*	0.19*	0.07*		
			area 2-mean	12.7			25.4*	5.7	3.4	1.4				pCi/g	0.22*	0.13*	0.06*		
			area 3-mean	17.1			34.2*	24.4	9.4	1.4				pCi/g	0.71*	0.27*	0.04*		
			area 4-mean	46.8			93.6*	30.7	9.8	1.4				pCi/g	0.33*	0.10*	0.01*		
8828	1981	Linde soil & sediment	near disposal well-subsurface (loc 11)	24.05		0.84	48.94*	5.9	5.53	0.92		14.25	0.73	pCi/g	0.12*	0.11*	0.02*	0.29*	0.01*
			test well debris (loc 13)	26.4		1.09	53.89*	3.53	0.82	0.51		2.1	0.29**	pCi/g	0.07*	0.02*	0.01*	0.04*	0.01*
			sanitary sewer (loc 15)	362		12.93	736.93*	1.33	1.14	0.11		5.54	0.95	pCi/g	0.00*	0.00*	0.00*	0.01*	0.00*
			storm sewer (loc 19)	99.2		4.57	202.97*	17.7	6.93	0.51		14.29	1.14	pCi/g	0.09*	0.03*	0.00*	0.07*	0.01*
			storm sewer (loc 21)	116		4.1	236.1*	3.89	0.89	0.34		3.07	0.39**	pCi/g	0.02*	0.00*	0.00*	0.01*	0.00*

Notes:
* calculated value
** <MDA, MDA shown

Attachment Two: Data Capture Synopsis

Table A3-1: Data Capture Synopsis for Linde Ceramics Plant

Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Primary Site/Company Name: Linde Ceramics Plant AWE/DOE* 1942-1953; Res. Rad. 1954-1987; 1993-1995; 1997-July 2006; DOE 1988-1992; 1996 (remediation) Other Site Names: Linde Air Praxair	Documents relating to the renovation of Building 30, amendments to New York State radioactive materials license 1983-0143. 01/27/2010: A request was sent to Karen Ginnane, Praxair Site Manager, for any documents relating to the tunnels under Buildings 14 and 30, and documents that would clarify the completion date for the early AEC decontamination of the site. She has found some documents pertaining to the tunnels. The documents are undergoing a review by Praxair's General Counsel's Office.	Open item	19
State Contacted: Robert Snyder of the New York State Bureau of Environmental Radiation Protection and Environmental Exposure Investigations confirmed that the NYS records are their copies of DOE and US ACE FUSRAP reports.	No relevant data not already in the SRDB identified.	10/02/2008	0
City of Tonawanda Public Library	No data from the operational period identified.	03/11/2010	0
Claimant	New York State assembly report on military sources of Buffalo area contamination, public meetings, FUSRAP characterization of Building 14, Building 31 remediation, FUSRAP documents, hearing transcripts, and epidemiologic studies.	04/18/2005	20
Department of Energy (DOE) HQ, Germantown	Report of Blixt-Massett sludge dumping, hazard assessments, internal dosimetry data and procedures, source term data, waste disposal records, AEC licensing material, accountability reports, and thorium processing reports.	03/05/2004	13
Department of Labor/Paragon	Progress reports, Tonawanda area site plans, a description of Tonawanda area residues, LOOW FUSRAP plans which refer to Linde residues.	12/30/2008	33
DOE EML/HASL	Trip reports.	03/08/2005	1
DOE Legacy Management - Grand Junction Office	Health physics reports, progress reports, dust sample results, shipping data, FUSRAP reports, medical hazards of radium-containing sludges, and a vicinity property survey.	01/18/2010	149

Table A3-1: Data Capture Synopsis for Linde Ceramics Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
DOE Legacy Management - MoundView (Fernald Holdings, includes Fernald Legal Database)	Epidemiology studies, 1950 survey, waste processing reports, LOOW characterization which mentions Linde as a source of stored residues, and a production report.	05/21/2008	9
DOE Oak Ridge Operations Vault	Environmental surveys of vicinity properties and mobile gamma scanning, process information including African ores, process knowledge interviews, job descriptions and schedules, epidemiologic studies with reviews and responses, former employee searches, health physics reports, and external exposure data. **NOTE:** A review of holdings in the ORO vault on 03/08/2010 did not uncover any additional relevant records.	03/08/2010	51
DOE OSTI (Physical Data Capture)	Results of ORNL independent verification surveys of Buildings 14 and 31 and a survey of irradiation facilities.	09/25/2006	3
Federal Records Center - Kansas City	Remediation period bioassay, contamination survey, and air sampling results, FUSRAP health and safety plans, and Tonawanda area history.	03/06/2009	75
Internet - Comprehensive Epidemiologic Data Resource (CEDR)	No relevant data identified.	01/15/2010	0
Internet - Department of Labor	EEOICPA circular modifying the covered facility building definitions.	12/26/2007	1
Internet - DOE Hanford Declassified Document Retrieval System (DDRS)	No relevant data identified.	01/15/2010	0
Internet - DOE Legacy Management Considered Sites Database	Mobile gamma scanning results.	10/25/2007	1
Internet - DOE OpenNet	An NYOO progress report for January 1949, Manhattan District History, Book I, Volume 7, and Linking Legacies. **NOTE**: These documents were added by site association reviews on 10/22/2008 and 03/13/2010.	01/15/2010	3
Internet - DOE OSTI Energy Citations	No relevant data identified.	01/15/2010	0
Internet - DOE OSTI Information Bridge	Stannard's Radioactivity and Health, FUSRAP reports on recycling, innovative technical approaches to remediation, and soil characterization.	01/15/2010	4
Internet - Google	Uranium enrichment newsletter, DOE finding aid, safety of Linde residues at LOOW, report on determining remediation goals, and media coverage of remediation.	03/22/2010	19
Internet - National Academies Press (NAP)	No relevant data identified.	01/15/2010	0

Table A3-1: Data Capture Synopsis for Linde Ceramics Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Internet - National Nuclear Security Administration (NNSA) - Nevada Site Office	No relevant data identified.	03/22/2010	0
Internet - NRC Agencywide Document Access and Management (ADAMS)	Emails regarding USACE planned final soil remediation levels and the dismissal of a stakeholder group lawsuit.	01/15/2010	2
Internet - U.S. Army Corps of Engineers	FUSRAP project updates, records of decision, links to site boundary monitoring, and a discussion of final remediation goals for soil contamination.	07/14/2008	16
Internet - Washington State University (U.S. Transuranium and Uranium Registries)	No relevant data identified.	01/15/2010	0
Missouri Department of Natural Resources	St. Louis area documents which mention Linde residues and FUSRAP activities.	10/03/2008	2
NARA Atlanta	Process information, inspections, internal dosimetry data, dust sample data, radiological surveys, procedures, progress reports, hazard assessments, accident reports, shipping and receiving reports, accountability reports, product sample analyses, and external dosimetry results.	06/20/2008	211
NARA Kansas City	Historical information on Afrimet residues, solid waste treatment data, contract closeout with 11/17/1952 radiation survey, historical information on Linde residues at LOOW, and a decontamination report.	06/24/2005	8
NIOSH	Review of the site profile, addition of a class to the SEC, decision to change building status, process knowledge interviews, and notice of the commencement of the CERCLA five-year review.	01/25/2010	13
ORAU Team	Exposure matrices, ORAU Project spreadsheet, documented process knowledge interviews, dust and gas samples, medical procedures, personnel records including medical records, health physics reports, work reports, remedial investigation reports, dust and contamination surveys, and FUSRAP documents.	12/07/2009	54
R.S. Landauer	Radiation dosimetry reports for remediation workers, 2000-2003.	08/19/2008	1
Sanford Cohen & Associates (SC&A)	SC&A assessment of NIOSH response to TBD issues and process knowledge interview notes.	02/05/2010	6
Savannah River Site (SRS)	Dosimetry visitors cards from the 1950s.	08/26/2008	1
Southern Illinois University	Observations on early uranium exposures from an ERDA report.	10/18/2008	1
University of California, San Diego	1941 letter informing Columbia University that Linde could not supply a uranium dioxide requirement.	Unknown	1

Table A3-1: Data Capture Synopsis for Linde Ceramics Plant			
Data Capture Information	**General Description of Documents Captured**	**Date Completed**	**Uploaded to SRDB**
Unknown	Process information, liquid effluent data, procedures, epidemiologic data, process knowledge interviews, safety and health requirements for residue handling, personnel medical records, external dosimetry data, source term and accountability data, health physics reports, DOE remediation surveys and plans, dust samples, occupational exposures to airborne dust, health hazards at NYOO uranium facilities, and Tonawanda area reports.	12/06/2004	74
TOTAL			**791**

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
CEDR http://cedr.lbl.gov/ COMPLETED 01/15/2010	Linde Ceramics in title Tonawanda in Title Linde Air Linde	2	0
DOE Hanford DDRS http://www2.hanford.gov/declass/ COMPLETED 01/15/2010	Linde Ceramics in title Tonawanda in Title Linde Air in Title Linde in any field	110	0
DOE OpenNet http://www.osti.gov/opennet/advancedsearch.jsp COMPLETED 01/15/2010	Linde Ceramics in Title Tonawanda in Title Linde Ceramics in full text Linde Ceramics" in full text Linde Air Products in full text Linde in any field	233	3

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
DOE OSTI Energy Citations http://www.osti.gov/energycitations/ COMPLETED 01/15/2010	"Linde Ceramics" in any field Linde Ceramics in any field Tonawanda in Title Linde in any field	2,492	0
DOE OSTI Information Bridge http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 01/15/2010	"Linde Ceramics" in any field Linde Ceramics in any field Tonawanda in any field "Linde Ceramics" in title "Linde Air Products" in title "Linde Air Products" in any field "Linde" in any field	1,992	4
Google http://www.google.com COMPLETED 03/22/2010	"Linde Ceramics" "Linde Ceramics" oralloy "Linde Ceramics" postum "Linde Ceramics" tuballoy "Linde Ceramics" "uranyl nitrate hexahydrate" OR UNH "Linde Ceramics" "K-65" "Linde Ceramics" "sump cake" "Linde Ceramics" "uranium dioxide" "Linde Ceramics" "uranium tetrafluoride" "Linde Ceramics" "uranium trioxide" "Linde Ceramics" "uranium hexafluoride" "Linde Ceramics" accident "Linde Ceramics" "air count" "Linde Ceramics" "air dust" "Linde Ceramics" "air filter"	116,999	19

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"Linde Ceramics" alpha "Linde Ceramics" "belgian congo ore" "Linde Ceramics" bioassay OR "Linde Ceramics" bio-assay "Linde Ceramics" breath OR "Linde Ceramics" "breathing zone" OR "Linde Ceramics" BZ "Linde Ceramics" calibration "Linde Ceramics" columnation "Linde Ceramics" contamination "Linde Ceramics" curie "Linde Ceramics" "denitration" OR "Linde Ceramics" "denitration pot" "Linde Ceramics" derby OR "Linde Ceramics" regulus "Linde Ceramics" dose "Linde Ceramics" dosimeter "Linde Ceramics" dosimetric "Linde Ceramics" dosimetry "Linde Ceramics" electron "Linde Ceramics" environment "Linde Ceramics" "Ether-Water Project" "Linde Ceramics" exposure OR "Linde Ceramics" "exposure investigation" OR "Linde Ceramics" "radiation exposure" "Linde Ceramics" external		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	Keywords / Phrases	Hits	Uploaded to SRDB
	"Linde Ceramics" "F machine" "Linde Ceramics" fecal "Linde Ceramics" "feed material" "Linde Ceramics" femptocurie "Linde Ceramics" film "Linde Ceramics" fission "Linde Ceramics" fluoroscopy "Linde Ceramics" "Formerly Utilized Sites Remedial Action Program" OR "Linde Ceramics" FUSRAP "Linde Ceramics" gamma-ray "Linde Ceramics" "gas proportional" "Linde Ceramics" "gaseous diffusion" "Linde Ceramics" health OR "Linde Ceramics" "health instrument" OR "Linde Ceramics" "health physics" OR "Linde Ceramics" H.I. OR "Linde Ceramics" HI OR "Linde Ceramics" HP "Linde Ceramics" "highly enriched uranium" OR "Linde Ceramics" HEU "Linde Ceramics" hydrofluorination "Linde Ceramics" "in vitro" "Linde Ceramics" "in vivo" "Linde Ceramics" incident "Linde Ceramics" ingestion "Linde Ceramics" inhalation "Linde Ceramics" internal		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	“Linde Ceramics" investigation "Linde Ceramics" isotope "Linde Ceramics" isotopic "Linde Ceramics" "isotopic enrichment" "Linde Ceramics" "JS Project" "Linde Ceramics" Landauer "Linde Ceramics" "liquid scintillation" "Linde Ceramics" log OR "Linde Ceramics" "log sheet" OR "Linde Ceramics" "log book" "Linde Ceramics" "low enriched uranium" OR "Linde Ceramics" LEU "Linde Ceramics" "maximum permissible concentration" OR "Linde Ceramics" MPC "Linde Ceramics" metallurgy "Linde Ceramics" microcurie "Linde Ceramics" millicurie "Linde Ceramics" "mixed fission product" OR "Linde Ceramics" MFP "Linde Ceramics" monitor OR "Linde Ceramics" "air monitoring" "Linde Ceramics" nanocurie "Linde Ceramics" "nasal wipe" "Linde Ceramics" neutron "Linde Ceramics" "nose wipe" "Linde Ceramics" nuclear OR "Linde Ceramics" "Chicago-Nuclear" OR "Linde Ceramics" "nuclear fuels"		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"Linde Ceramics" "nuclear track emulsion" OR "Linde Ceramics" "type A" OR "Linde Ceramics" NTA		
	"Linde Ceramics" "occupational radiation exposure"		
	"Linde Ceramics" occurrence		
	"Linde Ceramics" "ore concentrate"		
	"Linde Ceramics" "PC Project"		
	"Linde Ceramics" "phosphate research"		
	"Linde Ceramics" photon		
	"Linde Ceramics" picocurie		
	"Linde Ceramics" pitchblende		
	"Linde Ceramics" "pocket ion chamber" OR "Linde Ceramics" PIC		
	"Linde Ceramics" problem		
	"Linde Ceramics" permit OR "Linde Ceramics" "radiation work permit" OR "Linde Ceramics" "safe work permit" OR "Linde Ceramics" "special work permit" OR "Linde Ceramics" RWP OR "Linde Ceramics" SWP		
	"Linde Ceramics" "retention schedules"		
	"Linde Ceramics" procedure		
	"Linde Ceramics" radeco		
	"Linde Ceramics" radiation		
	"Linde Ceramics" radioactive		
	"Linde Ceramics" radiograph		
	"Linde Ceramics" radiological		
	"Linde Ceramics" "Radiological Survey Data Sheet" OR "Linde Ceramics" RSDS		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"Linde Ceramics" radeco "Linde Ceramics" radiation "Linde Ceramics" radioactive "Linde Ceramics" radiograph "Linde Ceramics" radiological "Linde Ceramics" "Radiological Survey Data Sheet" OR "Linde Ceramics" RSDS "Linde Ceramics" radionuclide "Linde Ceramics" raffinate "Linde Ceramics" reactor "Linde Ceramics" respiratory "Linde Ceramics" roentgen "Linde Ceramics" sample OR "Linde Ceramics" "air sample" OR "Linde Ceramics" "dust sample" OR "Linde Ceramics" "general area air sample" "Linde Ceramics" sampling OR "Linde Ceramics" "air sampling" OR "Linde Ceramics" "dust sampling" OR "Linde Ceramics" "general area air sampling" "Linde Ceramics" "solvent extraction" "Linde Ceramics" source OR "Linde Ceramics" "sealed source" "Linde Ceramics" spectra "Linde Ceramics" spectrograph "Linde Ceramics" spectroscopy "Linde Ceramics" spectrum		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"Linde Ceramics" standard OR "Linde Ceramics" "operating standard" OR "Linde Ceramics" "processing standard"		
	"Linde Ceramics" survey "building survey" OR "Linde Ceramics" "routine survey" OR "Linde Ceramics" "special survey"		
	"Linde Ceramics" "technical basis"		
	"Linde Ceramics" "thermal diffusion"		
	"Linde Ceramics" "Tiger Team"		
	Linde Ceramics" "thermoluminescent dosimeter" OR "Linde Ceramics" TLD		
	"Linde Ceramics" "tolerance dose"		
	"Linde Ceramics" urinalysis		
	"Linde Ceramics" urine		
	"Linde Ceramics" "whole body count" OR "Linde Ceramics" WBC		
	"Linde Ceramics" "working level" OR "Linde Ceramics" WL		
	"Linde Ceramics" "X-ray" OR "Linde Ceramics" "X ray" OR "Linde Ceramics" Xray OR "Linde Ceramics" "X-Ray Screening"		
	"Linde Ceramics" americium OR Am241 OR Am-241 OR "AM 241" OR 241Am OR 241-Am OR "241 Am"		
	"Linde Ceramics" ionium OR Th230 OR Th-230 OR "Th 230" OR 230Th OR 230-Th OR "230 Th"		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"Linde Ceramics" neptunium OR Np237 OR Np-237 OR "Np 237" OR 237Np OR 237-Np OR "237 Np" "Linde Ceramics" polonium OR Po210 OR Po-210 OR "Po 210" OR 210Po OR 210-Po OR "210 Po" "Linde Ceramics" thorium OR Th232 OR Th-232 OR "Th 232" OR 232Th OR 232-Th OR "232 Th" OR "Z metal" OR myrnalloy OR "chemical 10-66" OR "chemical 10-12" OR ionium OR UX1 OR UX2 "Linde Ceramics" Th-230 OR Th230 OR "Th 230" OR 230-Th OR "230 Th" OR 230Th OR Th-234 OR Th234 OR "Th 234" OR 234-Th OR 234Th OR "234 Th" "Linde Ceramics" neptunium OR Np237 OR Np-237 OR "Np 237" OR 237Np OR 237-Np OR "237 Np" "Linde Ceramics" uranium OR U233 OR U-233 OR "U 233" OR 233U OR 233-U OR "233 U" OR U234 OR "U 234" OR U-234 OR 234U OR 234-U OR "234 U" OR U235 OR "U 235" OR U-235 OR 235-U “Linde Ceramics" 235U OR "235 U" OR U238 OR "U 238" OR U-238 OR 238-U OR 238U OR "238 U" OR U308 OR "U 308" OR U-308 OR 308-U OR 308U OR 308 U OR "uranium extraction" "Linde Ceramics" "black oxide" OR "brown oxide" OR "green salt" OR "orange oxide" OR "yellow cake" OR UO2 OR UO3 OR UF4 OR UF6 OR C-216 OR C-616 OR C-65 OR C-211 OR U3O8		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"Linde Ceramics" plutonium OR Pu-238 OR Pu238 OR Pu 238 OR 238Pu OR 238-Pu OR "238 Pu" OR Pu-239 OR Pu239 OR "Pu 239" OR 239Pu OR 239-Pu OR "239 Pu" "Linde Ceramics" Pu-240 OR Pu240 OR "Pu 240" OR 240Pu OR 240-Pu OR "240 Pu" OR Pu-241 OR Pu241 OR "Pu 241" OR 241Pu OR 241-Pu OR "241 Pu" "Linde Ceramics" radium OR Ra-226 OR Ra226 OR Ra 226 OR 226-Ra OR 226Ra OR 226-Ra OR Ra-228 OR Ra228 OR Ra 228 OR 228Ra OR 228-Ra OR 228 Ra "Linde Ceramics" radon OR Rn-222 OR Rn222 OR Rn 222 OR 222Rn OR 222-Rn OR 222 Rn "Linde Ceramics" thoron OR Rn-220 OR Rn220 OR "Rn 220" OR 220Rn OR 220-Rn OR "220 Rn" "Linde Ceramics" protactinium OR Pa-234m OR Pa234m OR "Pa 234m" OR 234mPa OR 234m-Pa OR "234m Pa" "Linde Ceramics" strontium OR Sr-90 OR Sr90 OR "Sr 90" OR 90-Sr OR 90Sr OR "90 Sr" Linde Ceramics "Linde Ceramics" AND "Tunnel" "Linde Air" AND "Utility Tunnel" "Linde" AND "Utility Tunnel" "Ceramics Plant" AND "Tunnel" "linde site" AND "1950"		

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
	"linde site" AND "Decontamination" AND "1953" "linde site" AND "Decontamination" AND "1950" "linde site" AND "Remediation" AND "1953" "linde site" AND "Remediation" AND "1950" "tonawanda" AND "utillity tunnel" "union carbide" AND "utility tunnel" AND "Linde" "building 14" AND "linde site" "linde plant" AND "building 14" "linde plant" AND "building 30" "linde" AND "AEC" Praxair Praxair and Linde		
National Academies Press http://www.nap.edu/ COMPLETED 01/15/2010	"Linde Ceramics" Linde Ceramics Tonawanda "Linde Air Products" Linde	440	0
NNSA - Nevada Site Office www.nv.doe.gov/main/search.htm COMPLETED 03/22/2010	"Linde Ceramics" Tonawanda Linde Praxair	0	0
NRC ADAMS Reading Room http://www.nrc.gov/reading-rm/adams/web-based.html COMPLETED 01/15/2010	"Linde Ceramics" in title Linde Ceramics in title Tonawanda in Title Linde Tonawanda Linde in any field	957	2

Table A3-2: Database Searches for Linde Ceramics Plant			
Database/Source	**Keywords / Phrases**	**Hits**	**Uploaded to SRDB**
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 01/15/2010	Tonawanda Linde	0	0

Table A3-3: OSTI Documents Requested for Linde Ceramics Plant			
Document Number	**Document Title**	**Requested Date**	**Received Date**
OSTI ID 4371773	Proposed Method of Production of High Purity Uranium Ore Concentrates	01/15/2010	
OSTI ID 6883076	Composition of Linde E95 (AW500) Zeolite Fraction of Sludge	02/02/2010	
OSTI ID 10146442	Travel to the Development Library of Linde Air Products Company for Discussions Concerning the Welding of Unbounded Pieces, Trip Report, January 15, 1952	02/02/2010	