SEC Petition Evaluation Report
Petition SEC-00107

Report Rev #: 1 Report Submittal Date: January 28, 2011

Subject Expert(s):	David Allen, Thomas Tomes
Site Expert(s):	Frank C. Crawford

Petition Administrative Summary

Petition Under Evaluation

Petition #	Petition Type	Petition Qualification Date	DOE/AWE Facility Name
SEC-00107	83.13	July 1, 2008	Linde Ceramics Plant

Petitioner Class Definition

All employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the applicable covered residual radiation period from January 1, 1954 through July 31, 2006.

Class Evaluated by NIOSH

All Department of Energy and Atomic Weapons Employer employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the period from January 1, 1954 through July 31, 2006.

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

None

Related Petition Summary Information

SEC Petition Tracking #(s)	Petition Type	DOE/AWE Facility Name	Petition Status
SEC-00106, SEC-00107, SEC-00112, and SEC-00127	83.13	Linde Ceramics Plant	SEC-00106—Closed SEC-00107 and SEC-00112 have been merged SEC-00127—Preparing qualification

Related Evaluation Report Information

Report Title	DOE/AWE Facility Name
NA	NA

DCAS Health Physicist: Frank C. Crawford

Peer Review Completed By:	[Signature on file] *LaVon B. Rutherford*	1/28/2011 *Date*
SEC Petition Evaluation Reviewed By:	[Signature on file] *J. W. Neton*	1/28/2011 *Date*
SEC Evaluation Approved By:	[Signature on file] *Stuart L. Hinnefeld*	1/28/2011 *Date*

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Evaluation Report Summary: SEC-00107, Linde Ceramics Plant

This is a revised evaluation report by the National Institute for Occupational Safety and Health (NIOSH) addressing 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*. The revised document has been updated by NIOSH to reflect additional information and conclusions that were reached during deliberations of the Linde Working Group. Most notably, NIOSH has incorporated a revised methodology for reconstructing dose during the building renovation period, and has also added a method for bounding radon exposures in the underground utility tunnels.

Petitioner-Requested Class Definition

Petition SEC-00107, qualified on July 1, 2008, requested that NIOSH consider the following class: *All employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the applicable covered residual radiation period from January 1, 1954 through July 31, 2006.*

Class Evaluated by NIOSH

Based on its preliminary research, NIOSH accepted the petitioner-requested class. NIOSH evaluated the following class: All Department of Energy and Atomic Weapons Employer employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the period from January 1, 1954 through July 31, 2006.

NIOSH-Proposed Class to be Added to the SEC

Based on its full research of the class under evaluation, NIOSH has obtained air monitoring data, soil sampling data, and radiation contamination survey data from the clean-up period occurring prior to 1954, and for the time period evaluated in this report. 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 proposed 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 proposed class.

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SEC Petition Evaluation Report for SEC-00107

ATTRIBUTION AND ANNOTATION: The original (Rev. 0) version of this document has been revised by Frank C. Crawford (NIOSH) to reflect additional information and conclusions reached during a series of Linde Working Group meetings conducted since the original Evaluation Report was issued. Conclusions in this Rev. 1 version were peer-reviewed by the individuals listed on the cover page. The rationales for all conclusions in this document are explained in the associated text.

1.0 Purpose and Scope

This report evaluates the feasibility of reconstructing doses for all Department of Energy and Atomic Weapons Employer employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the period from January 1, 1954 through July 31, 2006. It provides information and analyses germane to considering a petition for adding a class of employees to the congressionally-created SEC.

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

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

2.0 Introduction

Both EEOICPA and 42 C.F.R. pt. 83 require NIOSH to evaluate qualified petitions requesting that the Department of Health and Human Services (HHS) add a class of employees to the SEC. The evaluation is intended to provide a fair, science-based determination of whether it is feasible to estimate with sufficient accuracy the radiation doses of the class of employees through NIOSH dose reconstructions.[1]

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

Under 42 C.F.R. § 83.13(c)(3), if it is not feasible to estimate with sufficient accuracy radiation doses for members of the class, then NIOSH must determine that there is a reasonable likelihood that such radiation doses may have endangered the health of members of the class The regulation requires NIOSH to assume that any duration of unprotected exposure may have endangered the health of

[1] NIOSH dose reconstructions under EEOICPA are performed using the methods promulgated under 42 C.F.R. pt. 82 and the detailed implementation guidelines available at http://www.cdc.gov/niosh/ocas.

members of a class when it has been established that the class may have been exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. If the occurrence of such an exceptionally high-level exposure has not been established, then NIOSH is required to specify that health was endangered for those workers who were employed for at least 250 aggregated work days within the parameters established for the class or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).

NIOSH is required to document its evaluation in a report, and to do so, relies upon both its own dose reconstruction expertise as well as technical support from its contractor, Oak Ridge Associated Universities (ORAU). Once completed, NIOSH provides the report to both the petitioner(s) and to the Advisory Board on Radiation and Worker Health (Board). The Board will consider the NIOSH evaluation report, together with the petition, petitioner(s) comments, and other information the Board considers appropriate, in order to make recommendations to the Secretary of HHS on whether or not to add one or more classes of employees to the SEC. Once NIOSH has received and considered the advice of the Board, the Director of NIOSH will propose a decision on behalf of HHS. The Secretary of HHS will make the final decision, taking into account the NIOSH evaluation, the advice of the Board, and the proposed decision issued by NIOSH. As part of this decision process, petitioners may seek a review of certain types of final decisions issued by the Secretary of HHS.[2]

3.0 SEC-00107, Linde Ceramics Plant Definitions

The following subsections address the progression of the class definition for SEC-00107, Linde Ceramics Plant. When a petition is submitted by a claimant, the requested class definition is evaluated as submitted. If the available site information and data justify a change in the petitioner's class definition, NIOSH will specify a modified class to be fully evaluated. After a complete analysis, 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-00107, qualified on July 1, 2008, requested that NIOSH consider the following class for addition to the SEC: *All employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the applicable covered residual radiation period from January 1, 1954 through July 31, 2006.*

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 Ceramics Plant workers in question. During the qualification of Petition SEC-00107, NIOSH deemed the following information and affidavit statements sufficient to qualify SEC-00107 for evaluation:

> The petition, received on March 3, 2008, and the six supporting documents, including 11 affidavits from 8 former workers, were intended to support the petition bases F.1, F2, F.3, and F.4.

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

NIOSH's review of the documentation found that insufficient support for the bases was provided in the petition package. However, based on a review of the available records for Linde Ceramics claimants who were employed during the period included in the proposed class definition, NIOSH found that personal monitoring data was unavailable.

During the qualification of Petition SEC-00107, NIOSH captured some personnel monitoring data for workers at Linde Ceramics between 2000 and November 2003, part of the period under evaluation, and uploaded that data into the NIOSH Site Research Database (SRDB) (IT Corporation, 2000-2003). Based on its Linde Ceramics Plant research and data capture efforts, NIOSH determined that it has access to area monitoring and exposure scenario information for Linde Ceramics Plant workers during the time period under evaluation. However, NIOSH also determined that limited personnel monitoring records are available for the time period being evaluated. NIOSH concluded that there is sufficient documentation to support the petition basis that internal and external radiation exposures and radiation doses were not adequately monitored at Linde Ceramics, for at least part of the proposed time period. While it seemed likely that exposures during the residual period could be bounded using exposure data from the operational period in conjunction with the comparison of process knowledge and source term information from the operational and residual periods, that assumption required the validation of a rigorous evaluation. NIOSH 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-proposed class because NIOSH was unable to locate personal monitoring data for members of the proposed class and has reason to believe, based on the nature of activities during the residual period, that workers were unmonitored during the period proposed for evaluation. Therefore, NIOSH defined the following class for further evaluation: All Department of Energy and Atomic Weapons Employer employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the period from January 1, 1954 through July 31, 2006.

3.3 NIOSH-Proposed Class to be Added to the SEC

Based on its research, NIOSH has obtained air monitoring data, soil sampling data, and radiation contamination survey data specific to the Linde site, which can be used to bound exposures to all members of the proposed class. 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

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 Exposure Matrix Site Profile

An Exposure Matrix 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. 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. 00 PC-1; January 19, 2006; SRDB Ref ID: 22268 (ORAUT-TKBS-0025)

4.2 Technical Information Bulletin (TIB)

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

- *TIB: Estimation of Ingestion Intakes*, OCAS-TIB-009; April 13, 2004; SRDB Ref ID: 22397 (OCAS-TIB-009)

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

4.3 Facility Employees and Experts

To obtain additional information, NIOSH interviewed 8 former Linde Ceramics employees and reviewed a 1981 memorandum that included ORAU interview questions and responses from a former Linde Ceramics employee.

- Personal Communication, 2008, *Personal Communication with Inventory Clerk/Rigger*; Telephone Interview by ORAU Team HP and NIOSH HP; September 3, 2008; SRDB Ref ID: 48679 (Name Two, September 3, 2008)
- Personal Communication, 2008, *Personal Communication with Trades Helper/Pipefitter*; Telephone Interview by ORAU Team HP; September 4, 2008; SRDB Ref ID: 48680 (Name Three, September 4, 2008)
- Personal Communication, 2008, *Personal Communication with Tool Maintenance/Inspector/Truck Lift Operator*; Telephone Interview by ORAU Team HP; September 11, 2008; SRDB Ref ID: 48675 (Name Four, September 11, 2008)
- Personal Communication, 2008, *Personal Communication with Chemical Operator/Storesman*; Telephone Interview by ORAU Team HP; September 11, 2008; SRDB Ref ID: 48676 (Name Five, September 11, 2008)
- Personal Communication, 2008, *Personal Communication with Chemical Operator*; Telephone Interview by ORAU Team HP; September 11, 2008; SRDB Ref ID: 48677 (Name Six, September 11, 2008)

- Personal Communication, 2008, *Personal Communication with Technologist*; Telephone Interview by ORAU Team HP; September 12, 2008; SRDB Ref ID: 48678 (Name Seven, September 12, 2008)
- Personal Communication, 1981; *Interview with [Name Eight Redacted], A Former Linde Employee*, Oak Ridge Associated Universities Memorandum with attachments; April 10, 1981; SRDB Ref ID: 3745 (Name Eight, April 10, 1981)
- Personal Communication, 2004, *Email Communication with [Name Nine Redacted]*, email with attachment; October 8, 2004; SRDB Ref ID: 14580 (Name Nine, October 8, 2004)
- Personal Communication, 2008, *Personal Communication with [Name Ten Redacted]*, Telephone Interview by ORAU Team HP; September 22, 2008; SRDB Ref ID: 49406 (Name Ten, September 22, 2008)
- Personal Communication, 2010, *Personal Communication with Electrician*, Telephone Interview by ORAU Team HP; March 4, 2010; SRDB Ref ID: 80052 (Name Eleven, March 4, 2010)
- Personal Communication, 2010, *Personal Communication with Maintenance Staff Member*, Telephone Interview by ORAU Team HP; March 10, 2010; SRDB Ref ID: 80055 (Name Twelve, March 10, 2010)
- Personal Communication, 2010, *Personal Communication with Maintenance Staff Member*, Telephone Interview by ORAU Team HP; March 11, 2010; SRDB Ref ID: 80056 (Name Thirteen, March 11, 2010)

4.4 Previous Dose Reconstructions

NIOSH reviewed its NIOSH OCAS Claims Tracking System (NOCTS) to locate EEOICPA-related dose reconstructions that might provide information relevant to the petition evaluation. Table 4-1 summarizes the results of this review. (NOCTS data available as of January 26, 2011)

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	247
Total number of claims submitted for energy employees who meet the definition criteria for the class under evaluation (January 1, 1954 through July 31, 2006)	210
Number of dose reconstructions completed for energy employees who meet the definition criteria for the class under evaluation.	166
Number of claims for which internal dosimetry records were obtained for the identified years in the evaluated class definition	0
Number of claims for which external dosimetry records were obtained for the identified years in the evaluated class definition	0

NIOSH reviewed each claim to determine whether internal and/or external personal monitoring records could be obtained for the employee. While there are several cases with dosimetry data, all data are from the operational period, prior to the residual radiation period under evaluation.

4.5 NIOSH Site Research Database

NIOSH also examined its Site Research Database (SRDB) to locate documents supporting the evaluation of the proposed class. Five hundred and sixty-four documents in this database were identified as pertaining to Linde Ceramics. These documents were evaluated for their relevance to this petition. The documents include historical background on process description, process materials, dust sampling, air monitoring, site cleanup, and Formerly Utilized Sites Remedial Action Program (FUSRAP) information.

4.6 Other Technical Sources

The Linde Remedial Action Project maintains a website containing a summary of the monthly air sample data (from July 2000 through December 2002) collected at eleven locations around the perimeter of the Linde Ceramics/Praxair facility in Tonawanda, New York. The summary includes alpha spectroscopy results from radium-226, thorium-230, and uranium-238 for each air sampler. The web address is: http://web.ead.anl.gov/corps/linde/mondata/index.cfm.

4.7 Documentation and/or Affidavits Provided by Petitioners

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

- *Affidavits from Former Linde Ceramics Employees*; May 2008; OSA Ref ID: 106081 pp. 16-24; OSA Ref ID: 105687 pp. 70-85 (Affidavits, 2008)
- *Linde Ceramics Special Exposure Cohort Application: January 1, 1954 through July 31, 2006*, Form B Non-standard; Name One; March 3, 2008; OSA Ref ID: 105432 (Name One, March 3, 2008)
- *Linde: Burlap Bag Issue Technical Call Notes*, teleconference with SC&A, NIOSH, ORAU, Advisory Board, Linde Worker, and petitioner; notes created by S. Cohen and Associates (SC&A); February 13, 2008; OSA Ref ID: 105687 p. 40 (SC&A, February 2008)
- *Experimentation on High-Grade Ores at the Linde Air Products Company*, correspondence; Hadlock; February 26, 1944; OSA Ref ID: 105687 p. 43 (Hadlock, 1944)
- *Experimentation on High-Grade Ores at the Linde Air Products Company*, correspondence regarding previous letter on same subject; E. L. Van Horn; March 6, 1944; OSA Ref ID: 105687 p. 44 (Van Horn, 1944)
- *Handling Drums*, correspondence; author not legible; March 11, 1949; OSA Ref ID: 105687 pp. 45-46 (Unknown author, 1949)
- *Rehabilitation of Lake Ontario Ordnance Works*; R, C. Heatherton; October 14, 1949; OSA Ref ID: 105687 pp. 47-49 (Heatherton, 1949)

- *Reducing Exposures*, single-page write-up; W. B. Harris; February 26, 1951; OSA Ref ID: 105687 p. 50 (Harris, 1951)
- *Monthly Status and Process Report for March 1949*, W. E. Kelley; April 7, 1949; OSA Ref ID: 105687 pp. 51-61 (Kelley, 1949)
- *Health Hazards in NYOO Facilities Producing and Processing Uranium*, select pages only; Atomic Energy Commission (AEC); April 18, 1949; OSA Ref ID: 105687 pp. 62-65 (AEC, 1949)
- *Regarding Dust Hazards in the Ceramics Plant*, correspondence; E. C. Kent; July 13, 1948; OSA Ref ID: 105687 p. 66 (Kent, 1948)
- *Decontamination of Buildings Used for Processing Alpha Emitters*, select pages only; Paul B. Klevin, William B. Harris, and Hanson I. Blatz; April 29, 1954; OSA Ref ID: 105687 pp. 67-68 (Klevin, 1954)
- *Linde Ceramics SEC Petitions Addendum SEC Tracking Numbers: SEC00106 and SEC00107—Additional Issues and Supplementary Evidence Supporting Linde Ceramics Petitions SEC00106 and SEC00107*; Name One; March 28, 2008; OSA Ref ID: 105723; OSA Ref ID: 105687 pp. 28-33 (Name One, March 28, 2008a)
- *Linde Ceramics SEC Petition Application: November 1, 1947 through December 31, 1953*, supporting document from the petitioner; Name One; March 28, 2008; OSA Ref ID: 105724; OSA Ref ID: 105687 pp. 3-27 (Name One, March 28, 2008b)
- *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; Name One; April 25, 2008; OSA Ref ID: 105849 (Name One, April 25, 2008)
- *Additional Issues and Supplementary Evidence Supporting Linde Ceramics SEC Petition SEC00107 January 1, 1954 through July 31, 2006*, supporting document from the petitioner; Name One; May 20, 2008; OSA Ref ID: 106080 (Name One, May 20, 2008)
- *Correspondence Regarding the Addition of a Class of Employees to the Special Exposure Cohort*, correspondence between OCAS and the Department of Health and Human Services (DHHS); OCAS and DHHS; January 12, 2006 and February 23, 2006; OSA Ref ID: 106081 pp. 2-5 (OCAS/DHHS, 2006)
- *FUSRAP Considered Sites Database Report*, printout; Department of Energy (DOE); April 30, 2008; OSA Ref ID: 106081 pp. 6-9 (DOE, 2008)
- *Report on Residual Radioactive and Beryllium Contamination at Atomic Weapons Employer Facilities and Beryllium Vendor Facilities*, select pages only; National Institute for Occupational Safety and Health (NIOSH); December 2006; OSA Ref ID: 106081 pp. 10-12 (NIOSH, 2006)
- *Manhattan: The Army and the Atomic Bomb*, select pages only; Vincent C. Jones; 1985; OSA Ref ID: 106081 pp. 13-15 (Jones, 1985)
- *Linde: Radiation Exposure to Ore-Containing Burlap Bags—Revision 1*, Working Draft; S. Cohen & Associates (SC&A); June 10, 2008; OSA Ref ID: 106340 (SC&A, June 2008)

5.0 Radiological Operations Relevant to the Class Evaluated by NIOSH

The following subsections summarize radiological conditions at the Linde Ceramics Plant for the periods from 1942 through 1953 and from January 1, 1954 through July 31, 2006. The subsections describe the information available to NIOSH to characterize particular exposure routes and radioactive contamination materials. The plant process descriptions for the operational years are provided for historical perspective and to help frame the picture of how the radiological conditions during the residual period came to be. From available sources NIOSH has gathered these process and source descriptions pertaining to the DOE-related radiological operations at Linde Ceramics, information regarding the identity and quantities of each radionuclide of concern, and information describing activities during which radiation exposures may have occurred, including 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 1948, Linde Air Products Corporation (the company that ran the Linde Ceramics Plant and the Linde Air Facility in Buffalo, New York) was contracted to perform uranium separation. Linde Air Products Corporation was selected because of the expertise it acquired from working in the ceramics business. Linde Ceramics Plant processed uranium to produce the black, yellow, green, and brown "salts" used for coloring ceramic glazes.

The following five buildings were involved in the MED activities that took place at the Linde Ceramics Site:

- Building 14
- Building 30
- Building 31
- Building 37
- Building 38

Building 14 was built by Union Carbide in the mid-1930s. Buildings 30, 31, 37, and 38 were built by MED on land owned by Union Carbide. With the termination of the MED contract in 1954, ownership was transferred to Linde Air Products Corporation. Building information is provided in Table 5-1.

Table 5-1: Activities and Operations at Linde Ceramics	
Building	**Activities/Operations Description**
14	Built in the mid-1930s by Union Carbide; vacated in March 2004; demolition began April 30, 2004. Served as a location of laboratory studies. Served as a pilot plant for uranium separation in the early part of MED operations. Most recently (before demolition) used for offices, research laboratories, and fabrication facilities.
30	Built by MED on Union Carbide-owned land; ownership transferred to Linde Air Products Corporation; demolished September 5-19, 1998. 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 operations. Also used as the location for some processing of metallic nickel with nitric acid to produce nickel salt. D&D reported complete as of March 29, 1950.
31	Built by MED on Union Carbide-owned land; ownership transferred to Linde Air Products Corporation; decontaminated in 1997. Served as a location of Step III (fluorination of UO_2 to UF_4) uranium separation processing during MED operations. Currently used for maintenance activities and offices; houses the Army Corp of Engineers FUSRAP operations offices.
37	Built by MED on Union Carbide-owned land; ownership transferred to Linde Air Products Corporation; demolished in 1981. Used for Step III (fluorination of UO_2 to UF_4). Although no details have been found, the 16’X36’ footprint of the building indicates a minor role in Step III processes.
38	Built by MED on Union Carbide-owned land; ownership transferred to Linde Air Products Corporation; demolished in 1996. Served as a location for Step III (fluorination of UO_2 to UF_4) uranium separation processing during MED operations. D&D began in November 1952.

Sources: Name Nine, October 8, 2004; U.S. Army Corps, 1998; Bechtel, 1993; ORAUT-TKBS-0025, Section 2.6

Under the MED 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 the final step of processing at Linde, Step III, uranium dioxide was converted to uranium tetrafluoride (Bechtel, 1990). Table 5-2 shows the types of feed material that were used in the operation of the Linde Ceramics Plant.

Table 5-2: Types of Feed Material Used in the Operation of the Linde Ceramics Plant			
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%
Residues and scrap	NA	June 1943 – June 1946	Varying

Notes:
Source: Reformatted version of Attachment included in Personal Communication, April 10, 1981.
Colorado concentrates were processed during about 50% of the time of operation of the Ceramics Plant.
The maximum quantity of ore processed in any week was 1.5 million pounds of R-10
[a] Assay of uranium = Assay of U_3O_8 X 0.842

Step III shutdown occurred on June 30, 1949, and Linde Ceramics Plant cleanup began sometime before Step III shutdown. Some Step II equipment located in Building 30 was removed in March and April of 1948 (Heatherton, 1948, p. 108). Dismantling of Step I and remaining Step II equipment in Building 30 had begun by May 1949 (ORAUT-TKBS-0025). Shortly after the shutdown of Step III production, a comprehensive clean-up effort was undertaken to reduce levels of radioactivity in Building 30 to enable its release 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 (such as 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). After each area was decontaminated, it was again cleaned and flushed, and a final radiation survey was performed. These activities were concluded prior to the release of the Linde facilities to Linde Air for private use in 1954, the start of this evaluation period.

In 1976, in the earliest stages of the FUSRAP, the Oak Ridge National Laboratory (ORNL, 1978[3]) surveyed the Linde Tonawanda site, which included both the Linde Ceramics MED process buildings and the Tonawanda Lab, from October 18, 1976 through November 5, 1976. 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.

According to the ORNL 1978 survey report, by the mid-1970s, Building 37 was no longer used and was seldom entered. Building 30 had been renovated and converted into a warehouse for shipping and receiving. Building 14 housed fabrication facilities, research laboratories, and offices. Buildings 30 and 14 had occupancy of 20-30 employees during normal working hours. Building 31 housed fabrication facilities offices and storage areas with a normal working hour occupancy of 12-20

[3] The survey was conducted by ORNL in 1976; however, the report was not written until 1978. The survey conducted in 1976 is referenced as ORNL, 1978 (the date of the report).

employees. Building 38 became a warehouse that was occupied for short intervals during a normal work week.

Linde was designated as a FUSRAP site in 1980. Building 37 was demolished in August 1981. The FUSRAP remediation period for Linde Ceramics was from 1988 through 1992 and again in 1996. In August 1996, as part of the remediation, Building 38 was demolished. Since 1976, the site has undergone various attempts at remediation and is still undergoing remediation by the Army Corps of Engineers. Building 30 was demolished as of September 19, 1998. In March 2004, Building 14 was vacated and demolition commenced in June 2004. Building 31 is the only remaining MED process building still onsite, and is no longer occupied by Linde employees.

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, Building 30 and Building 38.

Table 5-3 shows selected events at Linde Ceramics for the period evaluated in this report.

Table 5-3: Linde Ceramics Timeline for the Evaluated Period

Year	Event(s)
	1954-AEC contractual work comes to an end with completion of clean-up activities.
1955	
	1962-1970-Major renovation of Building 30. Former workers indicate that this was a period of almost continuous disruption within the
1965	building activities that could have potentially released and resuspended formerly inaccessible contamination.
1975	
	1976-ORNL performed a survey (surveyed Buildings 14, 30, 31, 37, 38, as well as external soil) as part of the FUSRAP program. **1980-**Linde designated as a FUSRAP site. **August 1981-**Demolition of Building 37 is completed by Union Carbide Corporation.
1985	**1988-1992-**FUSRAP remediation period.
1995	
	1996-FUSRAP remediation period. Demolition of Building 38 was completed by the DOE in August 1996 (Name Nine, October 8, 2004) **September 19, 1998-**Demolition of Building 30 complete (U.S. Army Corps, 1998). **March 2004-**Building 14 vacated for demolition.
2005	Building demolition began in June 2004.
	2008-Building 31 occupied by ACE and currently used for office space.

Note: Dates are identified as specifically as possible based on current information.

5.2 Radiological Exposure Sources at the Linde Ceramics Plant

The following subsections provide an overview of the internal and external exposure sources for the Linde Ceramics Plant class under evaluation. Historical surveys and remediation investigation results indicate that the Linde property had four sources of MED-related radioactive contamination: (1) radioactive contamination in surface and subsurface soils, (2) residual radioactivity, primarily in the uranium processing buildings (Buildings 14, 30, 31, 37 and 38), (3) processing effluents disposed of onsite in injection wells and open pits, and (4) radioactive contamination in sediments found in building sumps and the storm and sanitary sewer systems. Waste materials (raffinates) were transported offsite (to Lake Ontario Ordnance Works and/or Ashland) prior to the end of operations (Argonne, 1987; Thornton, 1976; Aerospace Corporation, 1981; Anderson, 1945; Robinson, 1945; Malone, 1956; Robinson, 1973). Therefore, workers outside the operational period would have had minimal exposure potential to these materials in their concentrated form. The primary contaminants in the soil and sediments were uranium and uranium progeny.

5.2.1 Internal Radiological Exposure Sources

Linde used two types of starting materials for Step I (ore to U_3O_8) processing, generally referred to in Linde-related literature as African ore and domestic ore. Most of the African ore was pitchblende; some was torbernite (Aerospace Corporation, 1981, p. 819). Neither the pitchblende nor the torbernite underwent chemical preprocessing before being shipped to Linde. Therefore, besides uranium, the ores also contained all members of the uranium decay series, including radium and its progeny (ORAUT-TKBS-0025). From an internal exposure perspective, these radionuclides could have been present as residual radioactivity on surfaces at the Linde Ceramics site and could have become airborne during post-operation activities and subsequently inhaled or ingested by workers at the site.

5.2.2 External Radiological Exposure Sources

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. Measured floor and wall surface contamination levels in 1976 in Building 30 were similar to 1950 post-decontamination measurements.

5.2.2.1 Photon

Photon emissions from uranium ore and concentrates potentially present during the evaluation period would include emissions from uranium and uranium progeny (mainly radium-226 and radium progeny).

5.2.2.2 Beta

Beta exposure would have resulted from uranium and its progeny. The dominant beta radiation source was from the uranium. In the uranium decay scheme, there is a short-lived isotope, protactinium-234m. This isotope decays by emitting an energetic 2.28 MeV beta particle. It is this beta particle that accounts for shallow-dose hazard associated with the uranium.

5.2.2.3 Neutron

NIOSH has determined that there was no significant neutron exposure concern at Linde Ceramics for the timeframe being evaluated (ORAUT-TKBS-0025). Therefore, due to the absence of neutron generating source material at the site, further assessment of potential neutron exposures for the proposed worker class is not included in this evaluation report.

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

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

6.1 Available Internal Monitoring Data

No personnel bioassay monitoring results have been identified for Linde Ceramics workers during the residual period; however, NIOSH does have access to survey data, including air monitoring data, for both the decontamination activities at Linde (conducted just prior to the start of the residual radiation period) and several distinct, major investigations during the residual radiation period. The residual period surveys include soil characterizations, building surveys, and air sampling results.

NIOSH has access to source term information for onsite uranium and uranium progeny during the operational period. As discussed, NIOSH also has radiological survey data from surveys conducted during the decontamination of the Linde facilities, following the cessation of operations and removal of source term materials (Kirk, 1954; Weinstein, 1954; Belmore, 1952; Klevin, 1954). Additionally, NIOSH has access to dust samples (AEC, 1954a), contamination smear samples (AEC, 1954b), FUSRAP remedial investigations (ORNL, 1978; Bechtel, 1993), final status surveys (IT Corporation, February 2002a; IT Corporation, February 2002b; IT Corporation, February 2002c; IT Corporation, February 2002d; IT Corporation, February 2002e; Shaw, February 2005a; Shaw, February 2005b; Shaw, February 2005c; Shaw, March 2005; Shaw, January 2005a; IT Corporation, January 2002a; IT Corporation, January 2002b; IT Corporation, March 2002; IT Corporation, September 2002;), and post remedial action data (Belmore, 1952; Klevin, 1954; Heatherton, 1950; McKenzie, 2000) documenting site contamination during the period evaluated in this report.

6.2 Available External Monitoring Data

Limited personnel external dosimetry data have been located for Linde Ceramics workers during the residual period. Area monitoring data and contamination surveys performed as part of the FUSRAP and remediation surveys are available and provide information regarding potential external exposures to workers who worked at the site during the period evaluated in this report (Bechtel, 1993).

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

- The sufficiency and reliability of the available data. (Section 7.1)
- The feasibility of reconstructing internal radiation doses. (Section 7.2)
- The feasibility of reconstructing external radiation doses. (Section 7.3)
- The bases for petition SEC-00107 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

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

It should be noted that the air sampling and survey data associated with the decontamination and decommissioning activities of 1949-1954 are contained in original reports, and are therefore primary data sources, as are the air samples and survey results reported by ORNL. Therefore, no additional pedigree review was performed for those data. The FUSRAP air monitoring results have been reviewed as part of the comparison performed for the feasibility determination in this report.

Soil sampling data was reported by ORNL and the FUSRAP program. Again, considering the information is contained in original reports, and that the FUSRAP program has a robust and rigorous Quality Assurance program in place for its laboratory analysis, further pedigree assessment of those data was not performed for this evaluation.

7.1.2 External Monitoring Data Pedigree Review

NIOSH located limited external personnel dosimetry data for the period under evaluation. NIOSH has radiation dosimetry reports from Landauer, pertaining to IT Corp. Praxair workers from 2000 through 2003. Landauer is currently and at the time of these reports, accredited by the National Institute of Standards and Technology through the National Voluntary Laboratory Accreditation Program. However, NIOSH did not locate any other external personnel dosimetry data for the period under evaluation. Therefore, an external data sufficiency and pedigree evaluation was not performed for the external monitoring data type.

7.2 Evaluation of Bounding Internal Radiation Doses

The principal source of internal radiation doses for members of the class under evaluation was the potential inhalation or ingestion of residual contamination in the uranium processing buildings (Buildings 14, 30, 31, 37, and 38) (Bechtel, 1993). Workers could have been exposed by the resuspension of uranium and uranium progeny contamination within the buildings. Outside the buildings, the potential resuspension of contaminated soils on the Linde site could also have exposed workers to uranium and uranium progeny.

In all cases, ingestion intake rates can be estimated using OCAS-TIB-009. This method supports the estimation of the ingestion rate, in terms of dpm for an 8-hour workday by multiplying the air concentrations (in activity per cubic meter) by a factor of 0.2.

ORAUT-TKBS-0025 assessed fifty-five measurements of radon progeny concentration that were taken in 1976 and 1981 in the Tonawanda site buildings, which were used in MED/AEC work (ORNL, 1978, pp. 17 and 84; Bechtel, 1982, p. B-24). The 1981 survey results were more comprehensive and yielded significantly higher concentrations; thus, the 1976 results were not used to assess radon exposure during the residual period. As discussed in ORAUT-TKBS-0025, Building 31 had the highest radon progeny concentration. Based on the assessment of the dose, as discussed in ORAUT-TKBS-0025, applying a maximum exposure scenario using worst case conditions, radon exposures in all cases during the period evaluated in this report period can be bounded using the method defined in ORAUT-TKBS-0025.

7.2.1 Methods for Bounding Internal Doses

Since NIOSH did not locate urinalysis, chest counting, or other bioassay monitoring data for the period under evaluation, internal exposure must be determined based on radiological source term and area monitoring data. Potential internal exposures from uranium and progeny for the class under evaluation can be divided into the following exposure scenarios: 1) exposure during general building occupancy (no renovation or remediation activities), 2) exposure from outdoor soil contamination, 3) exposure during building renovation, and 4) exposure during site remediation (FUSRAP). Evaluation of exposures for scenario one (general building occupancy) is based on methodology contained in ORAUT-TKBS-0025.

7.2.1.1 Exposure During General Building Occupancy (no renovation or remediation activities)

As previously discussed in this report, the indoor radiological conditions (as reported in ORNL, 1978) were reviewed and determined to be comparable to 1950 post-decontamination conditions. ORAUT-TKBS-0025 assesses the residual period internal dose from uranium and progeny (for workers other than renovation/remediation workers) based on Building 30, the primary uranium processing building and the building determined in 1976 to be the most contaminated on the site. Because this method applies a maximum exposure scenario for work other than renovation/remediation work during the residual period, this method can be applied as a bounding approach for reconstructing internal dose for the proposed worker class, which includes workers other than renovation/remediation workers, evaluated in this report. After the end of the renovation period in 1969, NIOSH will use a straight-line decline of airborne contamination from 1970 to reach the levels measured in 1978 during the first FUSRAP survey.

7.2.1.2 Exposure from Outdoor Soil Contamination

A 1992 analysis (Murray, 1992) of the large soil mound (approximately an acre in area with vertical peaks, above-grade, of about four feet) on the Linde site, created by surface soils removed during site remediation, indicates that soil did not significantly contribute to exposures of site workers either as a result of direct exposure or through internal intakes from dust resuspension. The average soil concentration was less than the DOE guidelines in DOE 5400.5 for uranium and radium residual radioactivity in soil; the soil pile was recommended for unrestricted use.

7.2.1.3 Exposure During Building Renovation

Former Linde Ceramics Plant workers noted that Building 30 renovation occurred from 1954 through 1969, although specific work details, including documentation of the actual start and end dates of renovation, dust control measures, location of work, and occupancy of areas are not available. Activities that could have caused the resuspension of fixed contamination occurred as part of Building 30 renovation. It is reasonable to assume that this renovation work could have resulted in elevated airborne radioactivity; however, specific assessment of the potential doses associated with this work was not included in ORAUT-TKBS-0025. For the purposes of this evaluation and assessing the ability to bound radiological exposures for members of the proposed worker class, the renovation work will be compared to the operational period D&D work, which is included and assessed in ORAUT-TKBS-0025.

For the purpose of this evaluation, NIOSH is using the decontamination and decommissioning air sampling data, a highly conservative approach, to over-estimate the elevated airborne radioactivity associated with renovation work in Building 30 from 1954 to 1969. Given the nature of the original decontamination and decommissioning (D&D) activities, and the data associated with the original D&D work that indicate a reduction in overall contamination levels, it is reasonable to assume that the renovation activities of the 1960s would have resulted in lower airborne contamination levels than that measured during the original D&D work.

Heatherton (1950) describes various methods for decontaminating hard surfaces at the Linde Ceramics Plant in Building 30. Included in Table V of Heatherton is summary data, showing the minimum, maximum, and average air concentrations measured during the evaluation of different decontamination options. Air dust samples were collected while vacuum cleaning rafters covered with radioactive dust, while sandblasting, and while using an oxygen blow pipe (Heatherton, 1950). In addition, 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 gross alpha activity. The alpha activity data present values in terms of exposure in multiples of the Maximum Allowable Concentration (MACs), where a MAC is 70 dpm/meter^3 alpha. Dust samples were collected both in the general area of the operation and in the breathing zone (Heatherton, 1950).

Heatherton (1950) documents the results of air dust samples collected during six different kinds of D&D operations conducted in Building 30. NIOSH reviewed the operations for which dust samples were collected, as well as the number of samples per operation. The decontamination operation that consisted of pneumatic hammering of surfaces in Building 30 after previous sandblasting, was selected as the most similar to renovation work between 1954 and 1969. This type of activity was selected because: (1) former workers have indicated that jack hammering occurred during the building renovation period; (2) jack hammering represents an activity with the potential to raise significant levels of dust; and (3) dust raised by jack hammering conducted during the later renovation work on previously-decontaminated surfaces would most accurately be represented by the available breathing zone air sample. Heatherton records that breathing zone radioactive dust levels were found to reach a maximum level of 2.3 MAC. For purposes of dose reconstruction, NIOSH will use this dust level for workers in the Ceramics Plant at all times from 1954 through 1969. This is considered to be a very conservative exposure estimate for the following reasons:

- Breathing zone levels would likely only be achieved by workers doing actual heavy renovation activities, such as jackhammering. At all other times, exposures would be much less. Measurements made in 1949/50 showed that, only 30 minutes after jackhammering ceased, airborne contamination fell by a factor of 22. In addition, general area exposures would be much less, even during jackhammering.

- This exposure scenario assumes that renovation work in the Ceramics Plant buildings was a 24 hr/day activity for a continuous period of 15 years. It is unlikely that an actual industrial facility could undergo such continuous renovation.

- Decontamination activities, by their very nature, concentrated on the most-contaminated surfaces in the buildings. Renovation work would only involve the most-contaminated areas by random chance and are, thus, likely to produce much less airborne contamination overall.

Klevin (1954) documents the results of a preliminary and post-decontamination survey of Building 30. The survey results clearly show a significant reduction in contamination levels.

Waste materials (raffinates) were transported off site (to LOOW and/or Ashland) prior to the end of operations (Argonne, 1987; Thornton, 1976; Aerospace Corporation, 1981; Anderson, 1945; Robinson, 1945; Malone, 1956; Robinson, 1973). 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 1 of this evaluation report and can be used to determine exposure from uranium progeny.

7.2.1.4 Exposure During Site Remediation (FUSRAP)

In 1980, Linde Ceramics was designated as part of FUSRAP and work under this program was performed during 1988-1992, and then again in 1996. The 1982 Bechtel preliminary evaluation of the Linde site reviewed the radiological health effects to remediation workers and concluded that the radiation protections in place would keep the internal exposures to a small fraction of the allowable limits (Bechtel, 1982, p. 17). NIOSH has determined that it would therefore be bounding to assess internal dose for remediation workers using the same methodology applied to renovation workers as discussed in Section 7.2.1.3 of this report.

7.2.1.5 Exposure in the Utility Tunnel Complex

The Linde site had a system of utility tunnels, constructed at different times, to carry steam, electricity, water, telephone lines, and other utilities from one part of the plant to another (Linde Drawing, 1937; Linde Drawing, 1957; Linde Drawing, 1961; Shaw, January 2005b). Documentary evidence shows that the first tunnel section was built in 1937 and ran from the powerhouse (Building 8) past the Tonawanda Laboratory (Building 14, also called the Proving Laboratory) to Building 10. This part of the tunnel complex was not found to be contaminated with radium because the pre-war uranium-refining operations in Building 14 used pre-processed ores from the Colorado Plateau vanadium deposits, which did not contain radium. Borehole data from the site cited in the 1978 and 1982 FUSRAP surveys confirmed that no excess radium was found in the soils near this section of tunnel (ORNL, 1978; Bechtel, 1982). Another section of tunnel was constructed in 1957 near Buildings 57, 58, and 31 in the northeastern area of the Ceramics Plant, and an extensive addition to the tunnel system was done in 1961 when the 1937 and 1957 tunnels were linked by new tunnels that ran between Buildings 30 and 31 and then branched south to Building 8 and west past Buildings 70, 2, and 2A. The 1957 and 1961 tunnel sections ran through areas of soil that were contaminated by radium-bearing ore and were subject to radon infiltration from this source.

Exposure to radioactive airborne particulate matter in the utility tunnels was estimated based on residual surface contamination found in the 2002 Army Corps of Engineers study (U.S. Army Corps, 2002). Although the tunnel system was only significantly contaminated in certain sections, NIOSH assumed that the entire tunnel system was uniformly contaminated at the 95^{th} percentile level of measured contamination to bound the exposure from this source. Attachment 2 is an assessment of internal exposure from this source. During the renovation period, building levels of airborne radioactive particulate matter are considerably higher than utility tunnel levels; after 1970, this situation gradually reverses.

The underground tunnels may contain radon due to the radium contamination present in the tunnels and the surrounding soils. An upper estimate of the radon concentration in the utility tunnels was calculated to be 99.3 pCi/L based on a modified source-term method that was originally proposed by Sanford, Cohen & Associates. See Attachment 3 for details of this approach.

7.2.2 Internal Dose Reconstruction Feasibility Conclusion

Based on available Linde D&D survey data and residual radiation surveys conducted in association with FUSRAP activities, NIOSH has the necessary data to support bounding internal exposures for uranium, uranium progeny, and radon during the residual period. Radioactive operations terminated at the end of the operational period and source-term materials were removed from the site. The application of this survey data will result in overestimates of exposure and doses during the general activities and will result in conservative estimates of exposure during the highest-risk activities at Linde Ceramics during the period evaluated in this report (January 1, 1954 through July 31, 2006).

7.3 Evaluation of Bounding External Radiation Doses

The principal source of external radiation doses for members of the proposed class, other than medical X-rays required as a condition of employment, was direct beta-gamma exposures from residual contamination that was generated by uranium processing (Buildings 14, 30, 31, 37, and 38). Cleanup of the Linde Ceramics Plant facilities began before June 30, 1949 when Step III production was shutdown. As detailed in Section 5.1 of this evaluation report, decontamination and FUSRAP remediation investigations determined that residual radiation was located in various buildings across the Linde Ceramics site. Contamination was identified as fixed or transferable contamination within facilities and locations. Buildings were decontaminated in the late 1940s and early 1950s, prior to release for non-MED work; however, contamination located in unoccupied areas, such as the rafters, was not originally removed. Over time and with more restrictive clean-up standards, additional decontamination and/or demolition was required to meet facility release and/or occupancy requirements.

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

7.3.1 Methods for Bounding External Doses

No personnel dosimetry data, other than the 2000 to 2003 monitoring data referenced in Section 3.1 exist for the post-operational period. The radiological requirements of the residual radiation period did not require monitoring and/or providing dosimeters to site workers. Likewise, area survey monitoring was not generally performed at Linde after the cessation of processing, other than the remedial investigation surveys described in Section 5 of this evaluation report.

As previously discussed in this report, the indoor radiological conditions (as reported in ORNL, 1978) were reviewed and determined to be comparable to 1950 post-decontamination conditions. ORAUT-TKBS-0025 assesses the external dose from uranium and progeny, based on Building 30, the primary uranium processing building and the building determined in 1976 to be the most contaminated on the site. Because this method applies a maximum external exposure scenario for any work at the Linde Ceramics site during the period evaluated in this report, this method can be applied as a bounding approach for reconstructing external dose for the proposed worker class, evaluated in this report.

7.3.2 Linde Ceramics Plant Occupational X-Ray Examinations

Pre-employment, repeat, and termination chest X-rays were required for at least some Linde Ceramics Plant workers. On certain occasions, pelvis X-rays were also required during the operational period (ORAUT-TKBS-0025). However, occupational X-ray examinations did not apply to the residual period under evaluation, and therefore are not considered in this evaluation report.

7.3.3 External Dose Reconstruction Feasibility Conclusion

NIOSH has established that it can bound the external exposures to Linde Ceramics workers during the period evaluated in this report (from January 1, 1954 through July 31, 2006), based on the available remedial investigation (FUSRAP) radiological surveys of the Linde facility. Given the half-lives of the source materials, NIOSH believes that the data collected during the residual period are conservative and adequate to bound the external doses to workers from 1954 through 2006.

7.4 Evaluation of Petition Basis for SEC-00107

The following subsections evaluate the assertions made on behalf of petition SEC-00107 for the Linde Ceramics Plant.

7.4.1 Dosimetry Data Concerns

SEC-00107: It was asserted that the dosimetry data available to NIOSH for Linde residual radiation workers were deficient, unreliable, and incomplete.

Response: Linde Ceramics workers employed during the period under evaluation 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.

With the decision to formally return the site to the control of Linde Air Products, further regulatory requirements for personnel dosimetry monitoring were neither required nor believed necessary. In retrospect, with information regarding the contamination and possible exposure pathways at Linde Ceramics, NIOSH determined that an evaluation of the data available to support dose reconstruction was warranted, and NIOSH has pursued the evaluation of the proposed class.

7.4.2 Alpha-Emitting Dust

SEC-00107: It was asserted that the residual radiation workers that conducted renovation work were exposed to dangerous levels of alpha-emitting dust that would have resulted from uranium processing during the Linde operational time period.

Response: This evaluation has taken into careful consideration the degree of contamination workers could potentially have been exposed to as a result of work activities during renovation of Linde process buildings, as described in the petitioner's affidavit and interview. Using available survey and air monitoring data, an overestimating approach is available to NIOSH to bound the potential exposures of workers during renovation activities, as described in Sections 7.2 and 7.3.

7.5 Summary of Feasibility Findings for Petition SEC-00107

This report evaluates the feasibility for completing dose reconstructions for employees at the Linde Ceramics Plant from January 1954 through July 2006. NIOSH found that the available monitoring records, process descriptions, and source term data available are sufficient to complete dose reconstructions for the evaluated class of employees.

Table 7-1 summarizes the results of the feasibility findings at Linde Ceramics for each exposure source during the time period January 1954 through July 2006.

Table 7-1: Summary of Feasibility Findings for SEC-00107
January 1954 through July 2006

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	

[1] Internal includes an evaluation of airborne dust.

As of January 26, 2011, a total of 210 claims have been submitted to NIOSH for individuals who worked at Linde Ceramics and are covered by the class definition evaluated in this report. Dose reconstructions have been completed for 166 individuals (~79%).

8.0 Evaluation of Health Endangerment for Petition SEC-00107

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

Based on available data, knowledge of residual contamination levels and activities, and surveys conducted both at the start of and during the period evaluated in this report, NIOSH's evaluation determined that it is feasible to estimate radiation dose for members of the proposed 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 NIOSH-Proposed Class for Petition SEC-00107

Based on the entirety of its 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 January 1, 1954 through July 31, 2006.

NIOSH has carefully reviewed all material sent in by the petitioner, including the specific assertions stated in the petition, and has responded herein (see Section 7.4). NIOSH has also reviewed available technical resources and many other references, including the Site Research Database (SRDB), for information relevant to SEC-00107. 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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10.0 References

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Attachment 1: Data Sources on Uranium Progeny Concentrations in Linde Materials

Table A1-1: 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

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Attachment 2: Bounding Internal Dose from Particulates in the Linde Utility Tunnels

Exposure to Radioactive Airborne Particulate Matter

The Linde site is serviced by a series of underground tunnels that house gas, electrical, water, steam, telephone, and other utility lines. The maximum dimensions of the tunnel system were 8-10 ft high and 15 ft wide, with exhaust fans (approximately six feet in diameter) that pulled air through the tunnels (Name Eleven, March 4, 2010; Name Twelve, March 10, 2010; Name Thirteen, March 11, 2010). These tunnels were routinely inspected and accessed for maintenance activities. However, no uranium-process piping was ever installed in these tunnels (U.S. Army Corps, 2002).

The processing of uranium ore in the 1940s, resulted in contamination of the site building surfaces, soils, building sumps, and sanitary sewer system. In addition, liquid waste effluent was injected into the subsurface injection wells. Runoff water contaminated from these sources routinely flooded these service tunnels throughout the lifetime of the site resulting in a constant contamination level. These utility tunnels are routinely accessed by inspectors and maintenance personnel.

A detailed radiological characterization performed in 2001 was based on beta surface contamination levels (U.S. Army Corps, 2002). The 95th percentile gross beta surface contamination level was determined based on an analysis of all of the gross beta survey data. Although the majority of this activity was likely fixed (as supported in the 1978 survey [ORNL, 1978]), 100% of the measured activity was assumed to be removable, and this was used to calculate an air concentration activity based on guidance provided in Technical Information Bulletin, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (ORAUT-OTIB-0070). The resultant intakes are summarized in the Table A2-1 below.

Table A2-1: Uranium and Uranium Progeny Exposure Summary for the Linde Utilities Tunnels

Radionuclide	Intake rates (dpm/year)	Ingestion rates (dpm/year)
Ra-226	116.071[a,b]	2.418[a,b]
Th-230	132.124[a,b]	2.753[a,b]
U-238	517.381[a,b]	10.779[a,b]
U-235	24.696[a,b]	0.514[a,b]
U-234	551.956[a,b]	11.499[a,b]

[a] Values listed are assigned as a constant distribution.
[b] Prorated for two months per year.

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Attachment 3: Bounding Radon Dose in the Linde Utility Tunnels

A December 5, 2010 SC&A document, *Clarification of SC&A Position on Radon in Utility Tunnels at Linde*, included a proposed approach to bounding radon in the Linde tunnels based on the known distribution of radon concentrations in basements in the area near the Linde facility (SC&A, December 2010). In response, NIOSH performed a follow-up simulation using an expanded data set and soil sample data for Erie County, as opposed to the Niagara County numbers used in the original version of this evaluation report. NIOSH will refer to the model used for the radon simulation as the Modified Source-term Model in the text below.

The data set was expanded by using all the available measurements from the same set of boreholes used in the SC&A document. Previously, only the data from the top four feet of soil was used, even though some boreholes were carried down to eleven feet. Because radon can enter the tunnels from all depths (not just the first four feet), it was considered reasonable to expand the data set to include these additional measurements. It should also be noted that the original borehole samples were positively biased because they were taken at the most contaminated locations identified during surface gamma surveys.

The original SC&A evaluation inappropriately used the geometric mean and geometric standard deviation for radon measurements taken in Niagara County basements; the Linde site is actually located just south of the county line in Erie County. The Niagara County statistics for radon in basements have a geometric mean of 1.09 pCi/L and a geometric standard deviation of 2.66 pCi/L; the corresponding Erie County figures are 1.68 pCi/L and 3.95 pCi/L. The source of these statistics is: *Measured Basement Screening Radon Levels by County – October 2010*, published the New York State Department of Health (http://www.health.ny.gov/environmental/radiological/radon/county.htm).

The following text describes NIOSH's simulation using the Modified Source-term Model and the expanded data set. The Rn-222 (radon) concentration in Linde Ceramics tunnels ($Rn_{tunnels}$) was estimated using the following equation:

$$Rn_{tunnels} = Rn_{Erie\ Co\ basements} * Ra_{Linde}/Ra_{Erie\ Co}$$

Where:

$Rn_{Erie\ Co\ basements}$ = Radon concentration reported for basements in Erie County

Ra_{Linde} = Ra-226 concentration in soils at Linde Ceramics

$Ra_{Erie\ Co}$ = Ra-226 concentration in soils in Erie County

The Erie County Ra-226 soil concentration is taken to be 0.636 pCi/g and is applied as a constant value. This number was derived from the number for Niagara County that SC&A calculated, using 1.81 ppm of uranium, and then proportionally increasing the result, using the Erie County figure of 1.89 ppm. (Source: Lawrence Berkeley National Laboratory, http://eetd.lbl.gov/IEP/high-radon/data/uranium.txt).

The Ra-226 concentration in soils at Linde Ceramics was taken from 51 soil sample results from an aggregate 59 feet of soil samples. Discrete probabilities were assigned for each foot of soil by assuming the concentration reported for each foot of soil had a 0.0169 (1/59) probability of occurrence. Identical soil sample results were combined resulting in the 51 discrete concentrations and probabilities shown in Table A3-1.

Table A3-1: Ra-226 Concentrations in Soils at Linde Ceramics

Ra-226 (pCi/g)	Probability	Ra-226 (pCi/g)	Probability
0.12	0.0169	0.86	0.0169
0.13	0.0169	0.88	0.0169
0.20	0.0169	1.00	0.0169
0.23	0.0169	1.03	0.0169
0.26	0.0169	1.06	0.0339
0.31	0.0169	1.19	0.0169
0.35	0.0169	1.20	0.0508
0.39	0.0339	1.35	0.0169
0.42	0.0169	1.50	0.0339
0.43	0.0169	1.54	0.0169
0.45	0.0339	1.66	0.0169
0.54	0.0169	2.12	0.0169
0.55	0.0169	2.20	0.0169
0.56	0.0169	2.40	0.0339
0.57	0.0169	2.50	0.0678
0.59	0.0169	2.60	0.0339
0.67	0.0169	3.20	0.0169
0.70	0.0169	3.44	0.0169
0.76	0.0169	14.1	0.0169
0.78	0.0339	39.1	0.0169
0.80	0.0339	213	0.0339
0.82	0.0508		**SUM =1.0000**

The computer application @Risk was used to solve the equation for radon concentration in Linde Ceramics tunnels. Input parameters were applied according to the distribution described above. To solve the equation, ten simulations were run with 10,000 iterations each, with differing random seed numbers. Outputs of various percentile concentrations were averaged and are provided in Table A3-2.

Table A3-2: Calculated Radon Concentrations in Linde Tunnels

Percentile	pCi/L
5	0.17
10	0.32
15	0.48
20	0.66
25	0.87
30	1.12
35	1.41
40	1.76
45	2.19
50	2.70
55	3.34
60	4.16
65	5.26
70	6.73
75	8.84
80	12.26
85	18.20
90	32.52
95	99.31

NIOSH proposes that the 95th percentile value of 99.31 pCi/L provides a plausible upper bound estimate for radon exposure in the Linde utility tunnels for all years at the Linde site beginning from the first MED production through the present time.