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National Institute for Occupational Safety and Health

Review of the Linde Ceramics Plant Special Exposure Cohort (SEC) Petition 00107 and the NIOSH SEC Petition Evaluation Report

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ABBREVIATIONS AND ACRONYMS

ABRWH or the Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AP	Anterior-posterior
AWE	Atomic Weapons Employer
BNI	Bechtel National, Inc.
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
Ci	Curie: unit of activity
D&D	Decontamination & Decommissioning
DF	Decontamination Factor
DOE	Department of Energy
DOL	Department of Labor
dpm	Disintegrations per Minute
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ER	(SEC Petition) Evaluation Report
FR	Federal Register
FUSRAP	Formerly Utilized Sites Remedial Action Program
GM	Geometric Mean
GSD	Geometric Standard Deviation
HASL	Health & Safety Laboratories
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
L	Liter
LAPC	Linde Air Products Company
LOD	Limit of Detection
MAC	Maximum Allowable Concentration
MED	Manhattan Engineering District
mg	Milligram
mR	milli-Roentgen
mrep	milli-Roentgen Equivalent Physical

NIOSH	National Institute for Occupational Safety and Health
NYOO	New York Operations Office (of the Atomic Energy Commission)
ORAUT	Oak Ridge Associated Universities Team
ORNL	Oak Ridge National Laboratory
pCi	pico-Curie
R	Roentgen: unit of exposure
rad	unit of absorbed dose
rem	unit of dose equivalent
SC&A	S. Cohen & Associates
SEC	Special Exposure Cohort
SRDB	Site Research Database
SRQD	(NIOSH) Site Research Query Database
TBD	Technical Basis Document
TIB	Technical Information Bulletin
μR	Micro Roentgen
WLM	Working Level Month: measure of radon exposure

EXECUTIVE SUMMARY

The Advisory Board on Radiation and Worker Health (the Board or ABRWH) directed SC&A to perform a review of the Linde SEC Petition 00107 (SEC-107 2008) and NIOSH's response to it in its SEC Petition Evaluation Report (NIOSH 2008a). The petition called for adding the worker class, defined as "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." NIOSH qualified the petition on July 1, 2008, and produced its evaluation report on November 3, 2008, in which it asserted the following:

> *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.*

SC&A examined the petition, the NIOSH evaluation report, and a number of supporting documents, primarily to assist the Board in assessing the degree to which NIOSH can "estimate radiation doses with sufficient accuracy," using the criteria of 42 CFR 83. This report presents the results of SC&A's investigations with regard to this matter. Our findings are summarized in Table 1. The table gives only a short description of each finding, and the main body of this report (cited in the table) should be consulted for a full explanation. All findings relate to the reconstruction of internal exposure. We have no findings related to external, occupational medical, or environmental exposures.

Table 1. Summary of Findings

No.	Internal/ External	Section	Description
1	I	3.2.1 "Bounding Radon Exposures"	The observation that data taken after decontamination of Building 31 were higher than before decontamination calls into question the quality of the radon measurements. This finding is supported by a statement made by the authors of Bechtel 1982 that the radon data from Building 31 were "unconfirmed," again indicating concerns about data quality.
2	I	3.2.1 "Bounding Radon Exposures"	Use of the geometric mean (GM) rather than the 95th percentile as the appropriate exposure metric needs to be justified for use in a bounding calculation, particularly since measurements taken in 1976 are used to characterize the entire residual period beginning in 1954. Use of 1976 data for a much earlier period needs to be justified by demonstration of equivalent (or less contaminated) radiological conditions.
3	I	3.2.1 "Bounding Radon Exposures"	Use of measurements taken in 1981 to characterize radon exposures up to 28 years earlier may not be bounding. Use of such data needs to be technically justified.

Table 1. Summary of Findings

No.	Internal/ External	Section	Description
4	I	3.2.2.1 “Exposure During General Building Occupancy”	The NIOSH assumption that a single air sample taken in the 1970s can be used to bound plausible internal exposures to uranium, Th-230, and Ra-226 for over 50 years beginning in 1954 is highly questionable.
5	I	3.2.2.1 “Exposure During General Building Occupancy”	NIOSH assumes that the geometric standard deviation (GSD) of the lognormal distribution is 5, when guidance in Battelle 2007 recommends a value of 10 for site-wide estimates. The placement of the single sample on the lognormal distribution could lead to substantial errors and cannot be reliably done.
6	I	3.2.2.1 “Exposure During General Building Occupancy”	NIOSH’s use of a constant air concentration, rather than an exponentially declining concentration, is not claimant favorable and is not consistent with the guidance in ORAUT-OTIB-0070. Back extrapolation needs to be technically justified by examination of potential site-specific changes in residual contamination.
7	I	3.2.2.3 “Exposure During Building Renovation”	The process selected to establish the pre-decontamination dust level does not appear to be claimant favorable, based on the cited data source (Heatherton 1950).
8	I	3.2.2.3 “Exposure During Building Renovation”	The assumed decontamination factor of 8 is based on pre- and post-decontamination values taken in different areas. Examination of the full dataset suggests that the differences in the potential internal exposures between the early and later decontamination activities may be negligibly small.
9	I	3.2.2.3 “Exposure during Building Renovation”	It is not clear that the bounding approach used in the SEC-00107 Petition Evaluation Report is more claimant favorable than that proposed in TBD-6001.
10	I	3.2.2.3 “Exposure During Building Renovation”	The mix of alpha-emitting radionuclides in the airborne dust needs to be quantified for renovation activities, taking into consideration that raffinates might have been present.
11	I	3.2.3 “Application of Bounding Approach”	NIOSH needs to explain how internal exposures should be apportioned among the various exposure scenarios.

1.0 INTRODUCTION

1.1 SCOPE AND PURPOSE OF SEC REVIEW

During the meeting of the Advisory Board on Radiation and Worker Health (the Board or ABRWH) held in Albuquerque, New Mexico, on February 19, 2009, S. Cohen and Associates (SC&A) was directed by the Board to perform a review of the Linde Special Exposure Cohort (SEC) Petition-00107 (SEC-107 2008) and the NIOSH SEC Petition Evaluation Report (ER) (NIOSH 2008a), which responds to that petition (ABRWH 2009, pg. 117). This report presents the results of our review of the Linde SEC Petition and the NIOSH ER.

The scope of this review addresses specific issues of concern raised in the petition and NIOSH's response to these concerns, as given in the ER. In addition, SC&A identified issues that we believe need to be addressed, but were not explicitly identified by petitioners:

- Documents that were referenced in the petition
- Documents referenced/cited in the ER and site profile (also known as the TBD)
- Documents contained in the NIOSH Site Research Query Database (SRQD)

The purpose of this review is to provide the Board with an independent assessment of issues and concerns that surround the petition and NIOSH's response and proposed methods for accommodating these issues/concerns. Findings identified in SC&A's review are intended to provide the Board with an overview of potential issues that may impact the feasibility of dose reconstruction. Following a formal, multi-step issues resolution process, any unresolved findings may then be used by the Board for determining whether radiation doses can be estimated with sufficient accuracy, as defined in 42 CFR §83.13(c)(1); since this final determination lies within the purview of the Board and occurs at the end of a formal issues resolution process, SC&A does not draw conclusions from its findings in this report with respect to whether doses can be reconstructed with sufficient accuracy.

1.2 TECHNICAL APPROACH AND REVIEW CRITERIA

The approach used by SC&A to perform this review follows the protocols described in the draft report prepared by SC&A entitled, *Board Procedures for Review of Special Exposure Cohort Petitions and Petition Evaluation Reports,* Revision 1 (SC&A 2006b), and the *Report to the Working Group on Special Exposure Cohort Petition Review* (SC&A 2006a). The latter is a set of draft guidelines prepared by a Board-designated work group for evaluation of SEC petitions performed by NIOSH and the Board. The former is a set of draft procedures prepared by SC&A and approved by the Board for use by SC&A on an interim basis (ABRWH 2006, pg. 132). The procedures are designed to help ensure compliance with Title 42, Part 83, of the *Code of Federal Regulations* (42 CFR 83) and implement the guidelines provided in the report of the working group.

Key review criteria identified in the report of the work group include the following:

- Timeliness
- Fairness
- Understandability
- Consistency
- Credibility and validity of datasets, including pedigree of the data, methods used to acquire the data, relationship to other sources of information, and internal consistency
- Representativeness and completeness of the exposure data with respect to the area of the facility, the time period of exposure, the types of workers, and processes covered by the data

The individual criteria have differing degrees of applicability depending on the details of a particular SEC petition and evaluation report.

The work group guidelines also recommend that NIOSH include in its SEC evaluation a demonstration that it is feasible to reconstruct individual doses for the cohort, including sample dose reconstructions.

SC&A's implementation of the SEC review process includes the following steps:

(1) Conduct a critical review of the petition and relevant reports, documents, and data that are enclosed and/or referenced in the petition/reports

(2) Interview petitioners, claimants, workers, etc. Note that this was done as part of the site profile review process and SC&A did not find it necessary to perform additional interviews in support of this report

(3) Identify additional issues/concerns that emerged from SC&A's document review, which are independent of those stated in the petition

(4) As part of the SEC review, develop a technical position for issues identified in the petition, as well as SC&A's independent findings

SC&A's report with its findings will subsequently undergo a multi-step issues resolution process. Resolution includes a transparent review and discussion of draft findings with members of the Board's working group, petitioners, claimants, and interested members of the public. This resolution process is intended to ensure that each finding is evaluated on its technical basis in a fair and impartial manner.

1.3 BACKGROUND INFORMATION

The NIOSH Linde Site Profile (NIOSH 2008b) presents extensive background information on the history and operations of the Linde plant; a brief summary is presented here for the purpose of orientation. In October 1942, the Linde Ceramics Plant, located in Tonawanda, New York, was contracted by the U.S. government to develop appropriate facilities and methods to perform large-scale processing of domestic and African uranium ores for the Manhattan Engineer District (MED) as part of its mission to develop nuclear weapons. The Linde site was selected for the MED contract because of its experience in the ceramics business, which involved processing uranium to produce salts used to color ceramic glazes. The operational period at Linde continued until 1949. Beginning in 1949, the Linde site underwent decontamination and cleanup, and in 1954, the site was released for private use. The post-1954 era at the Linde site is known as the *residual period*, and it is during this time that the various buildings at the site began to undergo renovation and remediation; the SEC 00107 petition is concerned with this time period. In 1976, Oak Ridge National Laboratory (ORNL) performed a radiological survey, and in 1980, Linde was designated as a FUSRAP (Formerly Utilized Sites Remedial Action Program) site. Linde then underwent two periods of FUSRAP remediation, from 1988–1992 and in 1996. All of the uranium processing buildings except Building 31 were demolished during this remediation period (NIOSH 2008a).

It should be noted that the SEC petition in question, SEC 00107, covers the residual time period, from January 1, 1954 through July 31, 2006. A previously approved SEC petition covers the time period from October 1, 1942, through October 31, 1947.

1.4 ORGANIZATION OF THE REPORT

Following this introductory section, Section 2 of the report presents an overview of SEC Petition 00107 and identifies the issues that it raises, and also presents a summary of NIOSH's evaluation report responding to the petition. Section 3 constitutes SC&A's assessment of the petition and NIOSH's response, and Section 4 contains a list of documents referenced in this report. The body of the report is followed by two appendices. Appendix A is a table presenting for reference purposes a line-by-line comparison of the Revision 01 and Revision 00 versions of the site profile (there was also a Rev. 00 PC-1 version between them), and Appendix B contains a memo and attachments from an SEC petitioner to SC&A related to the concentration of African ore feedstock during the operations period.

2.0 OVERVIEW OF THE SEC PETITION 00107 AND THE NIOSH EVALUATION REPORT

On July 1, 2008, NIOSH qualified SEC Petition 00107 (the petition under consideration here) for the Linde Ceramics Plant with the following 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* (NIOSH 2008a, pg. 3).

NIOSH performed an evaluation of the petition in November 2008 and determined that there is sufficient data to estimate the radiation doses to workers during the residual period. Section 3.3 of NIOSH 2008a states the following:

> *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**.*

NIOSH's conclusion in the preceding quotation is highlighted here in bold for emphasis. The authors of the petition raised numerous concerns and issues relating to both external and internal radiation exposures incurred by workers at Linde during the residual period. Table 2 summarizes these issues, along with NIOSH's response to those issues in the evaluation report. Due to the fact that many of the issues interconnect and overlap, as they are restated in several different places in the petition, often in somewhat differing language, SC&A identified nine distinct issues raised. We are not addressing them on a point-by-point basis, because our review of the NIOSH ER and related materials allows SC&A to assess them from the point of view of the adequacy of the information available to estimate the internal and external exposures to workers during the residual period; this is the underlying concern. As noted in Table 2, NIOSH did not address the issue of document destruction raised in the Petition in its ER. The investigation of this issue could be complex and may delay consideration of the significant number of technical issues analyzed in this report. In the interest of a timely initiation of the process of comment resolution, we are submitting this review of technical issues, while continuing to pursue the issue of document destruction, starting with a further interview with petitioners.

Table 2. Summary of Linde SEC 00107 Petition Issues and NIOSH Responses

Linde Petition Issue	NIOSH SEC Evaluation Report
1. Inability to evaluate the precise grade levels of the pitchblende African ore processed at Linde during its operational period from 1942–1953.	Table 5-2. Types of Material used in the Operation of the Linde Ceramics Plant (pg. 15).

Table 2. Summary of Linde SEC 00107 Petition Issues and NIOSH Responses

Linde Petition Issue	NIOSH SEC Evaluation Report
2. The deficient, unreliable, and incomplete dosimetry data available to NIOSH for Linde residual radiation workers.	"No personnel bioassay monitoring data has 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" (pg. 19).
3. The destruction of Linde documents described in an affidavit.	Not specifically addressed by NIOSH in the ER.
4. Internal exposure to uranium dust during renovation/construction activities.	"It is reasonable to assume that this renovation work could have resulted in elevated airborne radioactivity; however, specific assessment of the potential dose associated with this work has not been 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" (pg. 22). "Heatherton (1950) documents the results of air dust samples collected during six different kinds of D&D operations conducted in Building 30" (pg. 23).
5. Internal dose exposure estimates that rely on air concentration data for the residual radiation period are unreliable, due to a tendency to underestimate internal dose exposure.	"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 exposures and doses during the general activities and will result in conservative [sic] estimates of exposure during the highest-risk activities at Linde Ceramics during the period evaluated in this report" (pg. 24).
6. Raffinate-related exposures were not evaluated in the site profile.	"Waste materials (raffinates) were transported offsite (to Lake Ontario Ordnance Works and/or Ashland) prior to the end of operations. Therefore, workers outside the operational period would have had minimal exposure potential to these materials in their 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" (pg. 23).
7. Exposure from contaminated burlap bags in the storage area of Building 30. (Includes possible exposure from radium and radon gas, and pro-actinium, actinium, and thorium from the African ore stored in those bags.)	This issue is not specifically addressed by NIOSH in the ER, but it has been addressed by NIOSH and the Board in Work Group meetings and discussed in Attachment E of Revision 1 of the Linde Site Profile (NIOSH 2008b).

Table 2. Summary of Linde SEC 00107 Petition Issues and NIOSH Responses

Linde Petition Issue	NIOSH SEC Evaluation Report
8. Air concentration data used are based on results of random air samples in general area and breathing zones, but not in continuous area sampling in high risk or high dose areas.	"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 exposures 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)" (pg. 24).
9. Failure to account for vanadium tailings from concentrated sludge in 15%–20% black uranium oxide, yellow cake concentrated sludge containing 10%–15% U_3O_8, and incineration of burlap and paper bags.	See issues 6 and 7.
Issue to note: Redesignation of the Linde site (Buildings 30, 31, 37, and 38) as a DOE facility. "Consequently, the NIOSH defined residual radiation time period for Linde workers employed in these buildings is now eliminated from compensation coverage under Part B of EEOICPA. Any Linde worker who began working at the Linde facility in one of these buildings after 1953 is no longer eligible for compensation."	Not specifically addressed by NIOSH in the ER.

One additional issue will be addressed here. Appendix B contains a memorandum of June 4, 2009 ([Name Redacted] 2009), to SC&A from a Linde SEC petitioner, attaching four memoranda from 1944, and asserting that, contrary to NIOSH's assumption in its site profile of 8%–12% U_3O_8 content for African pitchblende feedstock, "65% Belgian Congo ore was processed at Linde during the operational time period." After examining how NIOSH reconstructed exposures for the residual period, SC&A observes that, regardless of the validity of the petitioner's assertion, estimated radon levels in the residual period are based on actual measurements, not on calculations from assumed feedstock concentrations, and, thus, the feedstock concentration issue does not appear to be germane to the SEC evaluation issues and will not be addressed further in this report. This issue may become relevant if NIOSH decides to use indirect means, such as ore composition or data from other sites, to address the radon measurement issues raised in this review.

3.0 ASSESSMENT OF NIOSH'S ABILITY TO RECONSTRUCT EXPOSURES DURING THE RESIDUAL PERIOD

3.1 INTRODUCTION

The SEC Petition raises a number of issues (summarized here in Table 1) related to reconstructing internal and external exposures to workers during the residual period. No issues were raised with respect to occupational medical or environmental exposures. The internal and external exposure information and estimation procedures are discussed and assessed in the following two subsections. It should be noted that NIOSH provides guidance for reconstructing doses during the residual period in the 2 1/2 pages of Section 6.0 of its Linde site profile (NIOSH 2008b).

3.2 INTERNAL EXPOSURE

There is clearly a measure of subjectivity involved in deciding whether sufficient information is available for NIOSH to do bounding calculations, per EEOICPA and 42 CFR § 83.13(c)(1), 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." In the case of SEC-00107 for the Linde Ceramics Plant, NIOSH has stated that bounding internal exposures for the residual period can be calculated:

> *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* (NIOSH 2008a, pg. 3).

However, we note that the NIOSH estimation of the maximum internal dose associated with general building occupancy is based on a single air concentration measurement taken 22 years after the beginning of the residual period.

In another SEC petition (SEC-00079), for the Dow Madison Plant, NIOSH concluded that doses could not be reconstructed, stating that, "NIOSH lacks sufficient personal and workplace monitoring data to adequately determine the potential intake of thorium radionuclides, making reconstruction of internal thorium doses infeasible" (NIOSH 2007, pg. 3).

In justifying its position that reconstruction of internal thorium doses at the Dow plant is infeasible, NIOSH notes the following (NIOSH 2007, pg. 14):

> *Some thorium air monitoring results have been identified as well as information on thorium source quantities handled at Dow Madison through July 1, 1960 (Dow, 1957; Dow, 1959; AEC, 1960). While the air monitoring data and source term information are suitable to define work processes, these data are not adequate to reconstruct with sufficient accuracy potential doses received from exposure to thorium. In general, only one sample result is available for a sampling location, representing a single sampling campaign during the covered*

> *period. NIOSH does not have enough documentation to ensure that all conditions that could affect exposure levels were similar to those represented by the available air monitoring data.*

In the case of Dow Madison, NIOSH had multiple air monitoring samples and source term data, but determined that dose reconstruction was not feasible while, in the case of Linde, NIOSH determined that a bounding analysis could be conducted based on a single air sample. NIOSH should address this apparent inconsistency in the decision-making process. It should be noted, however, that the analogy is not exact, since the Dow time period that was granted an SEC was during actual thorium alloying operations, which were complex, and not during the residual period.

The ensuing discussion on bounding internal exposures at Linde during the residual period considers two intertwined issues:

- Whether or not adequate information exists to perform plausible bounding calculations, both in terms of number of samples and adjustment of the data for back extrapolating over a long period of time
- Whether or not the approach taken by NIOSH in the SEC-00107 Petition Evaluation Report is indeed bounding

3.2.1 Bounding Radon Exposures

The SEC-00107 Petition Evaluation Report, Section 7.2, "Evaluation of Bounding Internal Radiation Doses," states the following (NIOSH 2008a):

> *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.*

The radon exposure during the residual period was 0.201 WLM/yr, as described in Section 6.1 of ORAUT-TKBS-0025 (NIOSH 2006). This value is the geometric mean (GM) of 12 measurements taken in 1981 in Building 31; the geometric standard deviation (GSD) was 1.89. The calculated GM was verified in the current review. A description of the radon sampling methods is not provided in the source document for the measurements (Bechtel 1982).

The NIOSH position in the SEC-00107 report is that these radon exposures are representative of the maximum exposure scenario using worst-case conditions and can, therefore, be assumed bounding. However, NIOSH has not provided robust arguments that the reported values capture the worst case. We recognize that NIOSH chose the more conservative of two available radon surveys made during the residual period to estimate radon exposures. As stated in ORAUT-TKBS-0025, "The 1981 survey was more comprehensive and yielded significantly higher concentrations, so the 1976 results were ignored" (NIOSH 2006, pg. 73). One possible inference from the preceding statement is that the 1976 survey missed sampling high radon areas. It is certainly possible that the 1981 survey was also incomplete and not a bounding representation of the radon levels.

It is important to note that Building 31 was decontaminated between the time of the 1976 ORNL radon survey and the 1981 survey (Bechtel 1982, pg. 11). In spite of the decontamination work, radon levels were higher in 1981. The authors of Bechtel 1982 raise questions about the quality of the radon survey reported in that document, noting the following:

> *Information from FB&DU* [i.e., Appendix B] *includes some unconfirmed data on radon and radon daughter concentrations in Building 31. A review of this data determined that it could not support a conclusion that Building 31 requires further remedial action consideration* (Bechtel 1982, pg. 12).

We also note that the proposed basis for bounding radon exposures relies on the GM of the limited database taken at one point in time. SC&A had previously commented on this in its review of ORAUT-TKBS-0025 (Rev. 00), as summarized in Finding 11 from that document (SCA 2006c):

> *Finding 11. Unless there is good reason to believe that a given worker was exposed to the full distribution of the measured concentrations and could not have experienced protracted exposures to higher than average radon concentrations, it may be more appropriate to use the upper 95th percentile as the default exposure level. NIOSH's use of the GSD approach may not address very high, short-term, episodic exposures; short-term exposure during incidents; and radon intakes during the performance of tasks with a potential for high transient air concentrations.*

To develop additional perspective on the proposed radon exposure level of 0.201 WLM/yr for the residual period, we also examined exposures during the operational period. The following is noted in Section 3.5.1 of NIOSH 2006:

> *After the end of African ore processing, concentration in the main ore processing building, Building 30, was assumed to remain at the 10-pCi/L level that was measured during the second period of domestic ore processing until the end of cleanup of Building 30. Concentrations in other Ceramics Plant buildings were also assumed to be 10 pCi/L until the end of cleanup 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 July 7, 1954.*

A value of 10 pCi/L is equivalent to 0.48 WLM/yr, assuming an equilibrium factor of 0.4.

During the period February 25, 1944, through June 6, 1946, 289 radon samples were collected. No other radon data have been uncovered for the balance of the operational period (i.e., through July 7, 1954). The value of 10 pCi/L was based on the following rationale (NIOSH 2006, Section 3.5.1):

> *During Ceramics Plant preproduction and initial production (which involved only domestic ore processing), the only source of radon was African ore processing at Tonawanda Laboratory. The indoor and outdoor radon concentrations to which Ceramics Plant workers were exposed were assumed to equal the outdoor concentration from Tonawanda Laboratory work. No direct measurement of this was available. An estimate was made based on the lowest measured indoor concentrations at the Ceramics Plant during African ore processing. These were viewed as indicating the upper limit to the outdoor concentration because outdoor air was drawn indoors for ventilation. Approximately 20% of the measurements in the Ceramics Plant 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 taken as the estimated outdoor concentration.*

As stated by NIOSH, the value of 10 pCi/L is based on the lowest measured indoor concentrations at the Ceramics Plant during processing of African ores. The value was carried forward for the balance of the operational period from November 1, 1947, through July 7, 1954, for purposes of dose reconstruction (ORAUT-TKBS-0025, Table 3-5).

It is not apparent why radon measurements made in the 1970s and 1980s can be considered representative of the radon concentrations in the 1950s. Based on the discussions provided above, we do not believe that NIOSH had made a scientifically sound case for the proposed approach to bounding radon exposures during the residual period. In summary, we have made the following findings about NIOSH's approach:

Finding 1: The observation that data taken after decontamination of Building 31 were higher than before decontamination calls into question the quality of the radon measurements. This finding is supported by a statement made by the authors of Bechtel 1982 that the radon data from Building 31 were "unconfirmed," again indicating concerns about data quality.

Finding 2: Use of the GM rather than the 95th percentile as the appropriate exposure metric needs to be justified for use in a bounding calculation, particularly since measurements taken in 1976 are used to characterize the entire residual period beginning in 1954. Use of 1976 data for a much earlier period needs to be justified by demonstration of equivalent (or less contaminated) radiological conditions.

Finding 3: Use of measurements taken in 1981 to characterize radon exposures up to 28 years earlier may not be bounding. Use of such data needs to be technically justified.

Taking guidance from the approach of ORAUT-OTIB-0070, it would seem that the most claimant-favorable and scientifically valid approach for quantifying the radon concentrations during the residual period would be to use data taken just prior to the residual period as representative of the radon concentration at the beginning of the residual period. These levels could be assumed to remain constant during the residual period, or assumed to decline at a rate that is consistent with the measurements made at the end of the residual period.

3.2.2 Bounding Internal Doses

As described by NIOSH in Section 7.2.1 of SEC-00107 (NIOSH 2008a):

> *Since NIOSH did not locate urinalysis, chest counting, or other bioassay monitoring data for the period under evaluation [the residual period], 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.*

3.2.2.1 Exposure during General Building Occupancy

In its review of the Linde site profile, SC&A had commented on the limited availability of data during the residual period noting the following:

> ***Observation 13: Inappropriate Application of Residual Contamination Data (Section 5.1.2) –*** *Data used for reconstructing potential missed internal and external doses during years of residual contamination are not representative of actual conditions. For example, 1976 Building 30 air concentration data were used for missed internal dose estimation for the entire residual period…*(SCA 2006c).

This comment remains valid.

The single air sample was assumed to be from a lognormal distribution with an assigned GSD of 5, presumably based on guidance provided in Battelle-TIB-5000 (Battelle 2007). However, we note in that document (Section 2.1.2.5) that a GSD of 5 is recommended for data describing a single process, while a GSD of 10 is recommended for data describing an entire site. Since the datum from ORNL 1978 is used to characterize the entire site, NIOSH should provide an explanation as to why a GSD of 5 was appropriate for a bounding calculation. Moreover, a single sample cannot be reliably located on a probability distribution, and substantial errors could be introduced by this assumption.

Building 30 was determined to be the most contaminated building on the Linde site during the 1976 ORNL survey (ORNL 1978) and, consequently, NIOSH selected an airborne dust sample from this building as the bounding value for the residual period. However, it should be emphasized that the airborne uranium concentration of 1.9×10^{-2} pCi U/m^3 was based on only one measurement. NIOSH does not provide convincing arguments that, because this single air sample was taken from the most-contaminated building in a 1976 survey, the results are bounding for the period from 1954 through mid-2006 for all workers except those involved in renovation/remediation.

We note that, in justifying the availability of sufficient data to bound internal exposure, NIOSH took a different approach for the Madison Plant of Dow Chemical Company. As described in SEC-00079, Addendum 2, NIOSH assumed that air concentrations of thorium at Dow Madison existing at the end of operations in 1961 declined exponentially to air concentrations measured during cleanup in 2006. Use of exponential decline is consistent with the guidance provided in ORAUT-OTIB-0070. The exponential decay approach may be bounding for all worker exposures at Linde during the residual period prior to 1976, as compared to the constant concentration approach taken in SEC-00107. It may also be bounding for some cases if the worker exposure included time periods before and after 1976. It should be noted, however, that disturbances, such as cleaning, washing, painting of surfaces, etc., may render the exponential decay approach not conservative at all. We further note that airborne concentrations were measured near the end of the operational period during decontamination of the Step III Plant (Klevin 1954). The average dust level was 78 dpm/m^3, with a minimum of 1 dpm/m^3 and a maximum of 720 dpm/m^3. These data could be considered as a starting point for estimating dust levels during the residual period. In short, a technically supportable estimate of the diminution of residual contamination due to the various factors operative at the Linde plant is an essential element necessary for the use of back extrapolation.

In summary, we have made the following findings regarding the NIOSH approach for the bounding general building occupancy exposures during the residual period:

Finding 4: The NIOSH assumption that a single air sample taken in the 1970s can be used to bound plausible internal exposures to uranium, Th-230, and Ra-226 for over 50 years beginning in 1954 is highly questionable.

Finding 5: NIOSH assumes that the GSD of the lognormal distribution is 5, when guidance in Battelle 2007 recommends a value of 10 for site-wide estimates. The placement of the single sample on the lognormal distribution could lead to substantial errors and cannot be reliably done.

Finding 6: NIOSH's use of a constant air concentration, rather than an exponentially declining concentration, may be not be claimant favorable and is not consistent with the guidance in ORAUT-OTIB-0070. Back extrapolation needs to be technically justified by examination of potential site-specific changes in residual contamination.

3.2.2.2 Exposure from Outdoor Soil Contamination

The author(s) of the SEC-00107 Petition Evaluation Report determined that soil contamination was not an issue, noting that a soil pile on the site was recommended for unrestricted use (NIOSH 2008a, Section 7.2.1.2). This position is supported by information presented in Section 6.1 of ORAUT-TKBS-0025, where data are provided on outdoor air contamination measurements for U-238, Ra-226, and Th-230 taken during 2000–2004 showing that airborne concentrations are two to four orders of magnitude below the limits in 10 CFR 20. Thus, outdoor exposures are not important contributors to the dose, and SC&A did not spend time looking further into this exposure pathway.

3.2.2.3 Exposure during Building Renovation

According to worker recollection, renovation work was conducted on Building 30 during the period 1962 through 1970, although specific dates and process details are unknown (NIOSH 2008a, pg. 22). The approach taken in the SEC-00107 Evaluation Report to estimate inhalation dose during renovation in the residual period was to use data obtained from prior renovation of the same building during the 1948–1949 cleanup period and scale the results to the later time period. A basic premise of this model is that the 1948–1949 cleanup reduced contamination to such levels that airborne dust generated during subsequent building renovation in 1962–1970 was proportionately reduced. NIOSH needs to provide convincing arguments that, during residual period renovation, workers would not uncover pockets of contamination during equipment and wall removal that were not decontaminated previously.

The SEC petition states the following regarding the 1948–1949 cleanup activities:

> *The vacuum cleaning operation was selected as an activity that is representative of the renovation work in Building 30 from 1962 through 1970, as that work was described by former workers. The vacuum cleaning was a dusty operation commensurate with what could reasonably be expected to result from renovation activities. The vacuum cleaning operation provided the additional benefit of having the highest number (17) of samples for a given operation. The mean measured alpha concentration in Building 30 during D&D is 84 dpm/m^3. The estimated median concentration is equal to the measured mean. The GSD is 2.46, calculated by assuming the measured maximum to be the 95th percentile value of a lognormal distribution (Battelle-TIB-5000, p. 17).* (SEC-00107, Section 7.2.1.3)

The dust concentration data were obtained from Table V of Heatherton (1950), who reported average and maximum exposures of 1.2 and 5.3 maximum allowable concentration (MAC), respectively, for vacuum cleaning operations. NIOSH assumed that cleanup in 1948–1949 would reduce the air concentration during the 1962–1970 renovation by the amount that the surface activity was reduced during the course of the 1948–1949 cleanup. Klevin et al. 1954, Table IX,[1] reported that the contact β/γ dose was reduced from 30 mrep/hr before decontamination to 3.6 mrep/hr after decontamination, resulting in a decontamination factor

[1] NIOSH identified Plant A in Klevin et al. 1954 as Linde Building 30.

(DF) of about 8. Thus, exposure during renovation was fixed by NIOSH at a median value of 10.4 dpm/m^3 (84 dpm/m^3 ÷ 8 DF) with a GSD of 2.46. This is equivalent to 31 pCi/calendar-day for a 40-hr work-week (10.4 dpm/m^3 × 9.6 m^3/workday × 1 pCi/2.22 dpm × 250 workdays/365 calendar days).

NIOSH states that vacuum cleaning was selected as representative of renovation work in Building 30 during 1962–1970, without indicating why this process was chosen in preference to other processes documented during the 1948–1949 cleanup. Other processes produced higher dust concentrations and, since the purpose of the SEC-00107 Report is to produce bounding results, justifying the basis for process selection is important. Dust loadings taken from general area sampling during various cleanup operations are compared in Table 3 (based on Table V of Heatherton 1950). It is apparent that selection of any of the other processes would have been more conservative. However, the larger question is whether any of the measurements in Table 3 are illustrative of plausible circumstances for developing sustainable air concentrations during that portion of the residual period when renovations were conducted. All are reflective of transient operations.

Table 3. Air Concentrations Measured During 1948–1949 Clean-up of Building 30

Process	Number of Measurements	Air Concentration (MAC alpha dust)		
		min.	max.	avg.
Vacuum cleaning	17	0.1	5.3	1.2
Removing concrete floor with pneumatic hammer	6	4.2	25	10
Flame cleaning	6	1.7	13	6.6
Sandblasting	5	7.0	49	22
One-half hour after sandblasting	3	1.0	1	1

Klevin (1954) reports that 40 general area air samples (presumably taken in 1954 during the decontamination of the Step III Plant [Building 38]) averaged 78 dpm/m^3, with a maximum value of 720 dpm/m^3 and a minimum value of 1 dpm/m^3. While the average airborne concentration of 78 dpm/m^3 is similar to the value of 84 dpm/m^3 observed during vacuum cleaning operations in Building 30, no details are available in Klevin 1954 as to the nature of the Step III Plant decontamination operations. Klevin (1954) does note that "These dust concentrations, much lower than those found during the previous decontamination operations in Step I and Step II, demonstrate the results of good supervision of the cleanup operations."

Review of Klevin et al. 1954 suggests that the decontamination factor of 8 may be overstated. It appears that the pre-contamination value of 30 mrep/hr is the worst spot on the floor in the East Area of Building 30 (Klevin et al. 1954, Table I), while the post-decontamination value of 3.6 mrep/hr is the high value reported for the West Area of the building. Thus, the decontamination factor was based on measurements in different areas of Building 30 that might have had differing proclivities for decontamination. A comparison of all the decontamination data is presented in Table 4, based on data from Tables I and II in Klevin et al. 1954. In this table, we have calculated the decontamination factors for average and high contact exposure measurements. For pre-decontamination characterization, we have selected data for the worst spot on the floor or the worst spot on the wall (whichever was higher) from Table I of Klevin et al. 1954.

Table 4. Decontamination Factors for Building 30 during 1948–1949 Cleanup

Area	Average			High		
	Pre-Decon (mrep/h)	Post-Decon (mrep/h)	Decon Factor	Pre-Decon (mrep/hr)	Post-Decon (mrep/hr)	Decon Factor
Shipping & Receiving	N/A	1.0	---	9.0	1.5	6.0
Step I						
Moore	0.33	0.44	<1	3.5	2.0	1.8
West	0.11	0.39	<1	3.6	3.6	1.0
East	0.4	0.44	<1	30.0	3.0	10
Main Balcony	0.1	0.27	<1	3.8	1.2	3.2
Step II						
Main	0.4	0.33	1.2	20.0	2.2	9.1
Balcony	N/A	0.48	---	5.0	2.1	2.4

It can be discerned from Table 4 that the "average" values show little or no reduction in contamination. Decontamination factors of 1 to 10 were calculated based on the "high" values, with the average of the "high" decontamination factors being 4.8. This is about 60% of the value proposed by NIOSH.

The use of 10.4 dpm/m^3, based on average air concentrations (from vacuum cleaning) during cleanup and a decontamination factor of 8, appears to be at odds with guidance provided in TBD-6001 (Battelle 2006); although, as we have discussed previously, this guidance is confusing (SCA 2008). The authors of TBD-6001 (Battelle 2006, Table 6.2) propose using 20.7 pCi/ calendar day, with a GSD of 5 for the residual period at facilities where uranium was refined. Without running a hypothetical IMBA/IREP case, it is not possible to decide whether assuming an intake of 31 pCi/calendar day (GSD - 2.46) is more claimant favorable than an intake of 20.7 pCi/day (GSD-5). Both possibilities are based on very limited data.

We note that the data in Heatherton 1950 are based on "MAC's total alpha dust." NIOSH does not provide any basis for estimating how the alpha counts are distributed among various radionuclides. Since the uranium was chemically separated from the ore at Linde, U-238 was not in equilibrium with its chemically different progeny. The ratio of Th-230 and Ra-226 to U-238 would be expected to vary from location to location, depending on specific unit operations at each location. NIOSH needs to address this issue. The dose to specific organs can vary widely, depending on the particular radionuclide and the type of lung absorption assumed, as shown in Table 5 (ICRP no date). Discussion in Section 3.2.2.1, "Exposure During General Building Occupancy," indicates that widely differing ratios of Th-230/U and Ra-226/U have been reported in ORNL 1978 and USACE 2004. NIOSH needs to define the radionuclide mix for the period of building renovation.

Table 5. Comparison of Dose Conversion Factors for Various Organs from Inhalation of Alpha-Emitting Radionuclides (30 years after intake)

Radionuclide	Absorption Type	Organ Dose Conversion Factor (Sv/Bq)				
		Bone Surface	Lungs	Brain	Colon	Pancreas
U-234	M	2.4E-06	1.6E-05	6.1E-08	7.4E-08	6.1E-08
U-234	S	2.2E-07	4.0E-05	5.2E-09	2.0E-08	5.2E-09
Th-230	M	1.0E-03	1.7E-05	1.0E-06	1.0E-06	1.0E-06
Th-230	S	8.2E-05	3.9E-05	8.3E-08	9.7E-08	8.3E-08
Ra-226	M	7.8E-06	1.7E-05	2.9E-08	5.7E-08	2.8E-08

In summary, we have the following findings about the proposed bounding estimates for the renovation period:

Finding 7: The process selected to establish the pre-decontamination dust level does not appear to be claimant favorable, based on the cited data source (Heatherton 1950).

Finding 8: The assumed decontamination factor of 8 is based on pre- and post-decontamination values taken in different areas. Examination of the full dataset suggests that the differences in the potential internal exposures between the early and later decontamination activities may be negligible.

Finding 9: It is not clear that the bounding approach used in the SEC-00107 Petition Evaluation Report is more claimant favorable than that proposed in TBD-6001.

Finding 10: The mix of alpha-emitting radionuclides in the airborne dust needs to be quantified for renovation activities, taking into consideration that raffinates might have been present.

3.2.2.4 Exposure During Site Remediation

NIOSH proposed the same approach for site remediation as for building remediation. FUSRAP activities occurred at Linde from 1988–1992 and again in 1996. The comments summarized in Section 3.2.2.3 apply to the selected treatment of exposure during site remediation.

3.2.3 Application of Bounding Approach

NIOSH does not provide any explanation as to how the internal exposures from general building occupancy, building renovation, and site remediation are to be apportioned during the residual period.

Finding 11: NIOSH needs to explain how internal exposures should be apportioned among the various exposure scenarios.

3.3 EXTERNAL EXPOSURE

Although the majority of the Linde SEC-00107 issues pertain to internal exposures, NIOSH also evaluated potential external exposures received during work performed at Linde in the residual period. NIOSH states the following regarding the methods for bounding external doses in Section 7.3.1 of the ER:

> *As previously discussed in this report, the indoor radiological conditions (as reported in ORNL 1978) were reviewed and determined to be comparable to the 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.*

Section 6.2 of NIOSH 2006 (ORAUT-TKBS-0025) states the following:

> *Because the radiation levels seemed to remain fairly constant, and because the levels were fairly low, the Tonawanda Laboratory post-cleanup exposures, based on Building 30 contamination levels, were used to estimate the external exposure rate. No adjustments for changes in work hours were made. Table 6-2 summarizes the results. The radiation energy distributions were assumed to be the same as those during the operational period.*

Table 6-2 of NIOSH 2006 lists NIOSH's bounding estimate of external exposure to penetrating radiation during the residual period as 0.068 R/yr, with a lognormal GSD of 3. NIOSH's bounding estimate of external exposure to non-penetrating radiation is 0.326 rem/yr, with a GSD of 3.

Although it is not clear how NIOSH derived its estimates of external dose, it appears that they used data from two radiological surveys of Building 30, which include Heatherton 1950 and ORNL 1978. NIOSH chose to use the survey data from Building 30, since that building was determined to be the most contaminated building on the Linde site. The first survey, published in Heatherton 1950, presents the results of a 1949 radiological survey performed before and after decontamination of Building 30. The results of that survey are summarized here as Table 6 and represent total beta plus gamma radiation dose rates measured in various parts of Building 30 at both contact and 3 feet from surfaces. Table 6 shows that there were hundreds of external dose rate measurements made in all areas of the building. NIOSH describes some of their analysis of the 1949 data in Section 6.2 of NIOSH 2006:

> *The beta dose rate at 3 feet above the ground that corresponds to the adopted value of gamma exposure rate was estimated as 4.38×10^{-1} mrem/hr, which is 4.66 times the gamma rate where 4.66 is the ratio of beta mrem/hr at 3 feet to*

gamma mR/hr at 3 feet for the floors and walls in Building 30 after decontamination (Table 4-1).[2] *It is assumed that the GSD for the beta dose rate would be the same as for the photon dose rate.*

In order to evaluate the bounding external doses presented in Table 6-2 of NIOSH 2006, SC&A performed hand calculations using the data in Table 6. From looking at the final survey results for the Moore Area, the mean beta-gamma dose rate at 3 feet is seen as 0.13 mrep/hr, with the highest reading at 0.4 mrep/hr. We consider the Moore Area mean dose rate of 0.13 mrep/hr at 3 feet useful for evaluating external exposure rates in Building 30, because the means of all the different areas presented in Table 6 at 3 feet range from 0.09 to 0.2 mrep/hr. Inspection of the original data reported by Heatherton (1950) revealed that, following decontamination in 1949, 91% of the readings (366 of 403 readings) in the Moore Area were less than 1 mrep/hr. Using the Moore Area as the example area, and assuming 2,000 hours per year, the mean beta-gamma dose rate of 0.13 mrep/hr translates to 0.26 rep/yr. Applying the beta-gamma ratio of 4.66, the gamma dose estimate using the Moore Area data is about 0.056 rep/yr. This can be compared to the external penetrating dose estimate of 0.068 R/yr that was adopted by NIOSH for use in reconstructing the external doses during the residual period.

The second and later survey, published in ORNL 1978, presents the results of a 1976 radiological survey performed in various buildings of the Linde site. Hundreds of external measurements of both the beta-gamma dose rates (mrad/hr) and the direct external gamma exposure rate (μR/hr) were taken. Figure 17 of ORNL 1978 shows all of the direct gamma readings taken at 1 meter, which exceeded 20 μR/hr, with a high reading of 63 μR/hr. Figure 17 is reproduced below as Figure 1. The mean of these 91 measurements that exceeded 20 μR/hr is approximately 29 μR/hr. This value is an overestimate of the actual mean, since it does not take into account all of the values below 20 μR/h. Using this value in the example calculation, and assuming 2,000 hours per year, the external gamma dose estimate is 0.058 R/yr, as compared to NIOSH's value of 0.068 R/yr. These hand calculations confirm NIOSH's statement that the 1950 conditions in Building 30 are similar to those in 1976.

The comparisons of external exposure rate measurements made following decontamination activities in 1949, and then again in 1976, reveal that NIOSH has selected a claimant-favorable and scientifically sound value for reconstructing external doses during the residual period.

[2] Table 4-1 of ORAUT 2006 presents some statistical analysis of the 1949 survey data using the program LOGNORM4.

Table 6. Summary of 1949 Post-Decontamination Survey Results for Building 30
(Heatherton 1950)

		Initial survey (mreps/hr)[a]					Final survey (mreps/hr)[b]				
		# of Readings	**% <1.0**	**Lowest**	**Highest**	**Mean**	**# of Readings**	**% <1.0**	**Lowest**	**Highest**	**Mean**
Shipping & receiving	contact	124	81	0.1	9	0.73			0	1.5	1
	at 3'								0	0.3	0.2
Step I											
Part I Moore Area	contact	86	40	0.2	3.5	1.3	403	91	0	2	0.44
	at 3'			0.08	0.43	0.33			0	0.4	0.13
Part II West Area	contact	264	83	0	3.6	0.41	1153	95	0	3.6	0.39
	at 3'			0	0.3	0.1			0	0.4	0.11
Part III East Area	contact	250	80	0	30	0.63	1020	97	0	3	0.44
	at 3'			0	1	0.4					
Moore Balcony	contact	78	31	0.3	2.8	1.2					
	at 3'			0.2	0.6	0.4					
West Balcony	contact	135	77	0	3.8	0.4	499	99	0	1.2	0.27
	at 3'			0	0.3	0.1			0	0.2	0.09
Upper East Balcony	contact	65	58	0	4	0.9					
	at 3'										
Lower East Balcony	contact	94	48	0	20	1.1					
	at 3'			0.1	0.8	0.4					
Pachuca tanks and comp. room	contact						128	74	0	2.6	0.84
	at 3'								0	0.6	0.27
Step II - Floor	contact	88	34	0	20	2.2	1057	96	0	2.2	0.33
	at 3'			0	1	0.4				0.6	0.12
Step II - Balcony	contact						387	87	0	2.1	0.48
	at 3'									0.4	0.14

a Taken from Table III of Heatherton 1950. Results after the building was vacuum cleaned and flushed.
b Taken from Table IV of Heatherton 1950. Results after decontamination and each area cleaned and flushed with water.

												26
												25
												24
26	30	30	30									23
26	22	30	28		22							22
34	63	37	22		22							21
26	37	37	24		22		20	20				20
											20	19
							20				22	18
												17
				20	22	22						16
					22							15
						20						14
				24	26	24	20	20			20	13
												12
				20								11
				20					35	20		10
20	23	25	26	20	23		48	48				9
							41	38				8
			20		36	41	51	41	33	51	51	7
30	30	30	30	36	36	35	51	35	63	61	20	6
				38	23	20	20	20	56	35	20	5
			20	20	20				30	20		4
							22	23	30			3
							20	20	35	20		2
							23	33				1
A	B	C	D	E	F	G	H	I	J	K	L	M

Figure 1. External Gamma Readings (in μR/hr) of 20 μR/hr or Higher at 1 Meter in Building 30 (Re-typed from Figure 17 of ORNL 1978)

Radiation Exposure to Ore-Containing Burlap Bags

During an SC&A technical call that took place on February 13, 2008, a Linde worker described possible exposures of Linde workers in the 1950s to African ore-containing burlap bags that may have been left near the workers' lunch area. The worker also explained that the Linde workers may have stood near and rested on these bags during their lunch breaks (SC&A 2008b). This issue, popularly referred to as the "burlap bag issue" and included in the SEC petition under Issue 9, was extensively analyzed and modeled by both NIOSH and SC&A during the Linde Site Profile review and resolution process. Both parties determined that, if this scenario needed to be addressed in future dose reconstructions involving Linde site workers, plausible and bounding external exposures to those individuals could be estimated. As such, the burlap bag issue was closed. In fact, Appendix E of the latest version of the Linde site profile (NIOSH 2008b) discusses at length the evolution of the burlap bag issue. After reviewing the history of the issue and performing a dose assessment calculation, the appendix concludes the following:

> *Based on the weight of the available evidence (tabulated below), it is unlikely that two pallets of uranium ore (which was last processed at Linde in 1946) would have been in Building 30 in 1951 (5 years after the cessation of processing of uranium ore). The current external exposure model for the period in question incorporates uncertainty in the external dose assignment by application of a lognormal distribution with a GM of 1.85 and a GSD of 4.04. This assumed distribution (with a 95th-percentile value of 18.5 R/yr) accounts for possible deviation of the actual worker exposure of the magnitude that would result from the assumption that two pallets of uranium ore were in Building 30 in 1951* (NIOSH 2008b, App. E, pg. 4).

SC&A concludes that this issue is resolved. In addition, if it is determined at a later date that external exposure to burlap bags was plausible during the residual period, scientifically valid external dosimetry models can be used to place a plausible upper-bound on such exposures.

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APPENDIX A: COMPARISION OF AN EXPOSURE MATRIX FOR LINDE CERAMICS PLANT (INCLUDING TONAWANDA LABORATORY), ORAUT-TKBS-0025, REVISION 01 TO REVISION 00

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
Publication Record	Additional information on revisions to Document 01		Approved revision to change from a page change revision (Rev. 00 PC-2-B) to a total rewrite (Rev. 01-A) as a result of formal NIOSH review. Revised to incorporate (1) change in facility designation, (2) DOL interpretation of applicability of residual period to Ceramics Plant, (3) resolution of Advisory Board Working Group comments, and (4) clarified the implementation instructions for SEC00044 for the period October 1, 1942 through October 31, 1947. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Task Manager. Initiated by Joseph S. Guido.
1.0 Introduction	Rev. 01 has additional language indicating disclaimers to designations of DOE/Atomic Weapons Facilities.	N/A	In this document, the word “facility” is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an “atomic weapons employer facility” or a “Department of Energy [DOE] facility” as defined in the Energy Employees Occupational Illness Compensation Program Act [EEOICPA; 42 U.S.C. § 7384l(5) and (12)]. EEOICPA defines a DOE facility as “any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the Department of Energy (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)” [42 U.S.C. § 7384l(12)]. Accordingly, except for the exclusion for the Naval Nuclear Propulsion Program noted above, any facility that performs or performed DOE operations of any nature whatsoever is a DOE facility

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
			encompassed by EEOICPA. For employees of DOE or its contractors with cancer, the DOE facility definition only determines eligibility for a dose reconstruction, which is a prerequisite to a compensation decision (except for members of the Special Exposure Cohort). The compensation decision for cancer claimants is based on a section of the statute entitled "Exposure in the Performance of Duty." That provision [42 U.S.C. § 7384n(b)] says that an individual with cancer "shall be determined to have sustained that cancer in the performance of duty for purposes of the compensation program if, and only if, the cancer … was at least as likely as not related to employment at the facility [where the employee worked], as determined in accordance with the POC [probability of causation1] guidelines established under subsection (c) …" [42 U.S.C. § 7384n(b)]. Neither the statute nor the probability of causation guidelines (nor the dose reconstruction regulation, 42 CFR Part 82) define "performance of duty" for DOE employees with a covered cancer or restrict the "duty" to nuclear weapons work (NIOSH 2007a). The statute also includes a definition of a DOE facility that excludes "buildings, structures, premises, grounds, or operations covered by Executive Order No. 12344, dated February 1, 1982 (42 U.S.C. 7158 note), pertaining to the Naval Nuclear Propulsion Program" [42 U.S.C. § 7384l(12)]. While this definition excludes Naval Nuclear Propulsion Facilities from being covered under the Act, the section of EEOICPA that deals with the compensation decision for covered employees with cancer [i.e., 42 U.S.C. § 7384n(b), entitled "Exposure in the Performance of Duty"] does not contain such an exclusion. Therefore, the statute requires NIOSH to include all occupationally derived radiation exposures at covered facilities in its

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			dose reconstructions for employees at DOE facilities, including radiation exposures related to the Naval Nuclear Propulsion Program. As a result, all internal and external occupational radiation exposures are considered valid for inclusion in a dose reconstruction. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction. NIOSH, however, does not consider the following exposures to be occupationally derived (NIOSH 2007a): • Background radiation, including radiation from naturally occurring radon present in conventional structures • Radiation from x-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons Under EEOICPA, employment at an AWE facility is categorized as either (1) during the DOE contract period (i.e., when the AWE was processing or producing material that emitted radiation and was used in the production of an atomic weapon), or (2) during the residual contamination period (i.e., periods that NIOSH has determined there is the potential for significant residual contamination after the period in which weapons-related production occurred). For contract period employment, all occupationally derived radiation exposures at covered facilities must be included in dose reconstructions. This includes radiation exposure related to the Naval Nuclear Propulsion Program and any radiation exposure received from the production of commercial radioactive products that were concurrently manufactured by the AWE facility during the covered period. NIOSH does not consider the following exposures to be occupationally derived (NIOSH 2007a): • Background radiation, including radiation from naturally occurring radon present in conventional

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
			structures • Radiation from x-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons For employment during the residual contamination period, only the radiation exposures defined in 42 U.S.C. § 7384n(c)(4) [i.e., radiation doses received from DOE-related work] must be included in dose reconstructions. Doses from medical x-rays are not reconstructed during the residual contamination period (NIOSH 2007a). It should be noted that under subparagraph A of 42 U.S.C. § 7384n(c)(4), radiation associated with the Naval Nuclear Propulsion Program is specifically excluded from the employee's radiation dose. This exclusion only applies to those AWE employees who worked during the residual contamination period. Also, under subparagraph B of 42 U.S.C. § 7384n(c)(4), radiation from a source not covered by subparagraph A that is not distinguishable through reliable documentation from radiation that is covered by subparagraph A is considered part of the employee's radiation dose. This site profile covers only exposures resulting from nuclear weapons-related work. Exposures resulting from non-weapons-related work, if applicable, will be covered elsewhere.
1.1	Purpose Added to Rev. 1 Also disclaimers on infeasibility of dose reconstruction prior to 1947		This site profile document provides an exposure matrix for workers at the Tonawanda Laboratory and Linde Ceramics Plant facilities of the Linde Air Products Company (LAPC) in Tonawanda, New York. NIOSH has determined, and the Secretary, Health and Human Services has concurred, that it is not feasible to reconstruct internal radiation dose for "Atomic weapons employees who worked at the Linde Ceramics Plant from October 1, 1942, through October 31, 1947, and who were employed for a

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			number of work days aggregating at least 250 work days either solely under this employment or in combination with work days occurring within the parameters (excluding aggregate work day requirements) established for other classes of employees included in the SEC" (HHS 2005). Subsequent correspondence (Elliott 2006) confirms that the Tonawanda Laboratory (as well as all other buildings on the Linde Site) are included in this class designation (cohort). Reconstruction of external exposure (including medical x-ray examinations) has been determined to be feasible (HHS 2005). For any claim referred to NIOSH regarding an employee, (1) who was employed during the Cohort period, but because of limited employment during this period, is not a member of the Cohort, or (2) who is a member of the Cohort and whose cancer is not defined as a specified cancer under EEOICPA (and so is not eligible for compensation under EEOICPA without a dose reconstruction), NIOSH will continue to attempt to complete a dose reconstruction for the exposure period based solely on external and medical x-ray radiation sources. However, because of the SEC determination (HHS 2005) that it is infeasible to adequately reconstruct internal dose during the period October 1, 1942 through October 31, 1947, dose estimates for this period are considered partial dose estimates.
1.2	Scope Added to Rev. 1		This document covers both facilities. The information in this site profile supports the assumed operational and residual contamination periods listed below. DOL has determined that the residual contamination period for the Tonawanda Laboratory is also applicable to the Ceramics Plant (Turcic 2008). Although cleanup activities at the Ceramics Plant continued into July of 1954, the designated covered period for this facility ends in 1953. Post-

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			1953 exposures are also covered under the EEOICPA, but this period is termed the residual exposure period. Because the activities and exposure potential at the Ceramics Plant during the first part of 1954 (January 1 through July 7) are the same as in the immediately previous period (1950 to 1953), information on reconstruction of dose for the period from January 1 through July 7 is included in the operational period section of this document. The instructions in this document for reconstruction of dose at the Ceramics Plant during the residual period (as defined by DOL as starting on January 1, 1954) pertain to exposures starting after July 7, 1954. July 7, 1954 is used as the definitive end of the decontamination period at the Ceramics Plant, based on the date of the final survey of the facility, which is documented in a memorandum from the New York Operations Office (NYOO) to Union Carbide that asserts that the decontamination requirements of the contract were fulfilled (Eisenbud 1954). Section 2.0 describes the site and its operational history. Sections 3.0 and 4.0 describe estimation of internal and external exposure from 1942 to July 7, 1954, respectively. Section 5.0 describes occupational medical exposure. Section 6.0 provides information on exposures during the residual contamination period after 1953. Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 7.0. Attachment A contains data that was used in analyzing exposures of workers to beta radiation. Attachment B lists codes and special terminology in the LAPC records. Attachment C shows data sources on uranium progeny concentrations, and Attachment D provides a uranium coworker assessment for November 1947 to January 1950.

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			Attachment E provides an assessment of dose consequences from uranium ore bag that were stored on the site during the post-operations period.
2.6	Additional Narrative on Decontamination During MED/AEC contract period doesn't appear in Rev. 1	This document assumes the end date of the Ceramics Plant cleanup period to be the date of turnover of the four Ceramics Plant production buildings to Linde for its use. This date is sometimes stated as 1953 (see, for example, ACE Buffalo 2004a, Response to Question 4). However, Harris (1954) indicates that the decontamination of Building 38 was not complete as of April 1954. For dose reconstruction, it is assumed that turnover did not occur until December 31, 1954.	
3.0	Change in estimation of Internal exposure to remove dates prior to 11-1-1947. Also change in last sentence.	This section develops parameters for reconstruction of doses due to internal exposures from October 1, 1942, the assumed start date of MED work at Linde, until December 31, 1954, the assumed date of initial cleanup completion and building turnover from MED/AEC to Linde. …..Continued lower level exposures to uranium progeny and to radon are assumed, because some radioactive waste was disposed on site and because initial cleanup was not completed until the end of 1954; however, for the Ceramics Plant, the uranium exposures would have dominated during the 1947 to 1954 period.	This section develops parameters for reconstruction of doses due to internal exposures from November 1, 1947, until July 7, 1954. HHS has determined, and NIOSH has concurred, that it is not feasible to reconstruct internal exposure prior to November 1, 1947 (HHS 2005). …Continued lower-level exposures to uranium progeny and to radon were assumed, because some radioactive waste was disposed of on the site, and because initial cleanup was not completed until the end of 1954; however, for the Ceramics Plant, the uranium exposures would have dominated during the post-1946 period.
3.1	Detail from Rev. 00 removed from Rev. 01, including dose reconstruction standards.	As of this writing, the pre-1947 operational period intakes are reserved. Therefore, the pre-1947 information is provided only as a description of what the likely upper bound exposures might have been, and is not currently planned for use in Linde dose reconstruction. Document No. ORAUT-TKBS-0025 Revision 00, Effective Date: 05/31/2005 Page 28 of 94 for the pre-1947 period, the MAC would have been	After the ore processing, Linde began a standby period. It was assumed that exposures decreased to 0.1 MAC at the Tonawanda Laboratory after cleanup in 1946 until December 31, 1953. Based on reviews of later air concentrations at Linde and reviews of air concentration data from other sites, most workers' exposures would have been much lower during these periods.

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		assumed to be based on inclusion of uranium's alpha emitting progeny. Although short-term exposures might have exceeded 300 MAC, it is very unlikely that long-term exposures would have. A review of the predicted urinalyses, kidney burdens, and lung burdens, indicate that it is highly unlikely that an individual would have sustained exposures like these for any length of time. Evidence of sustained exposure to the more soluble uranium compounds might have shown up in the medical urinalyses, as increases in proteins and glucose in the urine (note that other conditions can also account for these increases). The assumption of air concentrations at 300 MAC seems adequate to provide a quick estimate of exposure, and although the Type F uranium bioassay results are high, they do not seem inconceivable for some workers during this early period. However, it is also likely that Linde workers were exposed to a mixture of uranium absorption types. The analysis of radium exposures in Section 3.8 is partially based on the assumption of alpha activity air concentrations of 300 MAC during Linde's ore processing period. After the ore processing, Linde began a standby period. It was initially and arbitrarily assumed that exposures decreased to 1 MAC during the standby period at the Ceramics Plant, and that exposures decreased to 0.1 MAC at the Tonawanda Laboratory after cleanup in 1946 until the end of cleanup at the Ceramics Plant in 1954. Based on reviews of later air concentrations at Linde, and reviews of air concentration data from other sites, it is believed that most workers' exposures would have been much lower during these periods. The standby period at Linde Ceramics was assumed to end on September 14, 1947. Rehabilitation of the Step III process was assumed	The standby period at Linde Ceramics was assumed to end on September 14, 1947. Rehabilitation of the Step III process was assumed to begin on September 15, 1947, and continue through October 31, 1947.

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		to begin on September 15, 1947 and continue through October 31, 1947. Intakes from the standby and rehabilitation periods are eserved. Beginning November 1, 1947 at Linde Ceramics, workers were assumed to be exposed to 33 MAC and it was assumed this exposure continued through cleanup in 1954. Uranium progeny are not included in this later period, because only refined uranium was used and because the dose from intakes of contamination left from earlier work would have been insignificant compared to the dose to uranium during operations. To simplify calculations, it assumed that the workweek was 40 hours long during all years, although it is likely that the workweek for many was in excess of 40 hours especially during the earlier years. The assumed air concentrations are sufficiently large to account for any differences in actual hours exposed. Dose reconstructions should assume International Commission on Radiological Protection (ICRP) Publication 66 default parameters for particle deposition (ICRP 1994).	
3.2.1	Rewording of sentence	Note that it is possible that the January 1948 determination level of 0.1 mg/L is a typographical error, because this is the same as the determination level reported for (nonradioactive) fluoride urinalysis, and because there seems to be no change in the format of the numbers reported.	The January 1948 determination level of 0.1 mg/L is assumed to be a typographical error because this is the same as the determination level reported for (nonradioactive) fluoride urinalysis and because there seems to be no change in the format of the reported numbers.
3.2.1	Additional data in Rev. 01	NA	Analysis of Coworker Bioassay Data for Internal Dose Assignment (ORAU 2005d) describes the general process used for analyzing bioassay data for assigning doses to individuals based on coworker results. Bioassay results described above were analyzed in accordance with this procedure

<table>
<tr><th>Item Description</th><th>Comment</th><th>ORAUT-TKBS-0025 Rev. 0 Text</th><th>ORAUT-TKBS-0025 Rev. 1 Text</th></tr>
<tr><td></td><td></td><td></td><td>(Attachment D). The results of this analysis are presented in Tables 3-1 and 3-2. Individual uranium urinalysis results should be used to determine internal exposure to the individual when they are available. Where individual results are not available, the coworker data included in Attachment D and summarized in Tables 3-1 and 3-2 are to be used to estimate internal exposures that are favorable to claimants.

Table 3-1. Chronic intake rate for Type M uranium (pCi/d).
<table>
<tr><th>Start date</th><th>End date</th><th>50th-percentile value</th><th>GSD</th></tr>
<tr><td>11/01/1947</td><td>07/07/1954</td><td>74</td><td>4.0</td></tr>
</table>
Table 3-2. Chronic intake rate for Type S uranium (pCi/d).
<table>
<tr><th>Start date</th><th>End date</th><th>50th-percentile value</th><th>GSD</th></tr>
<tr><td>11/01/1947</td><td>07/07/1954</td><td>1884</td><td>4.3</td></tr>
</table>
</td></tr>
<tr><td>3.3</td><td>Disclaimer on Radium in Rev. 01</td><td>All radium compounds are lung absorption Type M. Radon breath analyses have been used to provide information on the amount of radium in the body and are available for some Linde workers.

Assignment of radium exposures when radon breath analyses are not available or cannot be interpreted is addressed below in Section 3.4.</td><td>HHS has determined, and NIOSH has concurred that it is not feasible to reconstruct internal exposure prior to November 1, 1947 (HHS 2005). Information on radon exposure prior to November 1, 1947, is provided only as a basis for extrapolation afterwards and is not intended to be used during the period in which reconstruction of internal dose has been determined to be infeasible.</td></tr>
</table>

<table>
<tr><th>Item Description</th><th>Comment</th><th>ORAUT-TKBS-0025 Rev. 0 Text</th><th>ORAUT-TKBS-0025 Rev. 1 Text</th></tr>
<tr>
<td>3.4</td>
<td>Data on Uranium Progeny in Rev. 00 deleted and replaced by disclaimer in Rev. 01.</td>
<td>In the absence of data on exposures to uranium progeny, their intake rates are determined by assuming secular equilibrium. Table 5 lists equilibrium-based ratios for uranium progeny of particular interest in dose reconstruction. Absorption types for their likely chemical forms are also shown. The intake ratios provide reasonably realistic estimates of intakes of progeny due to dust from African ore.

The uranium activity fractions overestimate relative intakes of most progeny when the dust is from preprocessed domestic ore. They may underestimate intakes of progeny when the dust is from filter cakes or waste products that contain uranium progeny, but very little uranium. The ratios in Table 5 are for use for the entire 1943–1946 production period for all workers, even though only about 70% of the ore processed was African ore (see Section 2.3.2) and many workers handled only refined uranium materials. This, along with the claimant-favorable assumptions made in the estimation of worker dust exposures, is judged to provide sufficient overestimation to balance any underestimation associated with the handling of waste products.

Note that the uranium fractions are applied when the activity of uranium is known. The activity fractions for gross alpha are applied to data measured as alpha activity.

Table 5. Intake ratios and absorption types for uranium progeny.
<table>
<tr><th>Nuclide</th><th>Uranium activity fractions</th><th>Gross alpha activity fractions</th><th>Absorption type</th></tr>
<tr><td>U-natural</td><td>1</td><td>4.02E-01</td><td>F, M, S</td></tr>
<tr><td>Th-230</td><td>4.89E-01</td><td>1.96E-01</td><td>M, S</td></tr>
<tr><td>Ra-226</td><td>4.89E-01</td><td>1.96E-01</td><td>M</td></tr>
<tr><td>Po-210</td><td>4.89E-01</td><td>1.96E-01</td><td>F,M</td></tr>
<tr><td>Pa-231</td><td>2.28E-02</td><td>9.16E-03</td><td>M, S</td></tr>
<tr><td>Ac-227</td><td>2.28E-02</td><td>9.16E-03</td><td>F, M, S</td></tr>
</table>
</td>
<td><u>Ceramics Plant 1943 to 1946 Production, and Tonawanda Laboratories</u>

HHS has determined, and NIOSH has concurred, that it is not feasible to reconstruct internal exposure prior to November 1, 1947 (HHS 2005).</td>
</tr>
</table>

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
3.4	More detail on production and cleanup in Rev. 01	**<u>Ceramics Plant 1947–1949 Step III Production, and Subsequent Initial Cleanup</u>** During this period, refined uranium materials were handled. None of the progeny listed in Table 5 would have been present in significant quantities, compared to the uranium at the Ceramics Plant.	**<u>Ceramics Plant 1947 to 1949 Step III Production and Subsequent Initial Cleanup</u>** During this period, refined uranium materials were handled. None of the uranium progeny would have been present in significant quantities in the refined uranium materials but, to account for uranium progeny potentially present from past activities and resuspended during decontamination and decommissioning (D&D) activities, data from the postoperations period was reviewed to determine bounding activity ratios (Attachment E). Table 3-3 presents bounding indoor uranium progeny ratios. Document No. ORAUT-TKBS-0025 Revision No. 01 Effective Date: 11/04/2008 Page 32 of 102 for use for dose reconstruction for the period from November 1, 1947, through July 7, 1954. The values in this table were the highest observed values from the indoor and storm sewer sampling locations. Table 3-3. Progeny to uranium ratios. Progeny/U (total) — Ratio to uranium Th-230/U — 0.26 Ra-226/U — 0.21 Po-210/U[a] — 0.21 Ac-227/U — 0.29 Pa-231/U — 0.01 a. Po-210 activity not reported, assumed to be the same as parent (Ra-226)
3.5	Disclaimer on Radon added to Rev. 01		HHS has determined, and NIOSH has concurred that it is not feasible to reconstruct internal exposure prior to November 1, 1947 (HHS 2005). Information on radon exposure prior to November 1, 1947 is provided only as a basis for extrapolation afterwards and is not intended to be used during the period in which reconstruction of internal dose has been determined to be infeasible.
3.5.1	Detail on analysis methodology not carried through to Rev. 01	To simplify, this analysis assumes that workers, who were likely to spend the majority of their time	N/A

<table>
<tr><th>Item Description</th><th>Comment</th><th>ORAUT-TKBS-0025 Rev. 0 Text</th><th>ORAUT-TKBS-0025 Rev. 1 Text</th></tr>
<tr><td></td><td></td><td>
in process areas, or in boxcars (where some of the highest radon levels were measured, about 200 times tolerance), or whose jobs were unknown, were exposed to 99.3 pCi/L of radon for 2,040 hours (12 work-months) per year prior to standby. Workers who did not work or have their offices in the process buildings are assumed to have been exposed to 22.4 pCi/L of radon prior to standby.
Because a job in current times might not be in or near a process area, does not mean the same held true 60 years ago. Nurses, some stenographers, launderers and seamstresses, and some clerical workers had jobs or locations that put them in contact with the uranium and progeny (Homes 1944b).
The initial period of African ore processing was followed by a second period of domestic ore processing. Thirteen measurements of radon concentration during the domestic ore processing were available. The GM of the measurements, assuming the <LOD values were equal to the LOD, was 9.1 pCi/L. To estimate exposure during this domestic ore processing period, both indoor and outdoor radon concentrations were assumed to be 10 pCi/L.
Table 7. Ceramics Plant worker radon exposures rates, 1942-1954.
<table>
<tr><th>Period/work location</th><th>Time-weighted concentration (pCi/L)</th><th>Exposure rate (WLM/y)</th></tr>
<tr><td>10/1/1942 to 7/31/1946</td><td></td><td></td></tr>
<tr><td>In process and research areas</td><td>99.3</td><td>4.76</td></tr>
<tr><td>Not in process and research areas</td><td>22.4</td><td>1.08</td></tr>
<tr><td>8/1/1946 to 12/13/1954</td><td></td><td></td></tr>
<tr><td>All workers</td><td>10.0</td><td>0.480</td></tr>
</table>
</td><td></td></tr>
<tr><td>3.5.1</td><td>Pre-1947 Radon rates deleted from table in Rev. 01</td><td>
Table 8 summarizes the assumed radon concentrations and resulting exposures.
Table 8. Tonawanda Laboratory radon exposure rates, 1942-1954
<table>
<tr><th colspan="2">Period</th><th rowspan="2">Time-weighted concentration pCi/L</th><th rowspan="2">Exposure rate (WLM/y)</th></tr>
<tr><th>Start</th><th>End</th></tr>
<tr><td>R&D and cleanup</td><td></td><td></td><td></td></tr>
<tr><td>10/01/42</td><td>12/31/46</td><td>42.5</td><td>2.04</td></tr>
<tr><td>Post-cleanup</td><td></td><td></td><td></td></tr>
<tr><td>01/01/47</td><td>12/31/54</td><td>—</td><td>0.202</td></tr>
</table>
</td><td>
Table 3-5. Ceramics Plant worker radon exposures rates, 1947 to 1954.
<table>
<tr><th>Period/work location</th><th>Time-weighted concentration (pCi/L)</th><th>Exposure rate (WLM/yr)</th></tr>
<tr><td colspan="3">11/01/1947–07/07/1954</td></tr>
<tr><td>All workers</td><td>10.0</td><td>0.480</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Item Description</th><th>Comment</th><th>ORAUT-TKBS-0025 Rev. 0 Text</th><th>ORAUT-TKBS-0025 Rev. 1 Text</th></tr>
<tr><td>3.6</td><td>Pre-1947 Inhalation Intake Estimates of Particulates Removed from Rev. 01</td><td>Table 9. Assumed airborne concentrations used to estimate intakes.
<table>
<tr><th>Start</th><th>End</th><th>Activity description</th><th># MAC</th><th>alpha dpm/m³</th><th>Source</th></tr>
<tr><td>Ceramics plant</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10/1/1942</td><td>7/31/1946</td><td>Uranium ore processing</td><td>Reserved</td><td>Reserved</td><td>Uranium and progeny</td></tr>
<tr><td>8/1/1946</td><td>9/14/1947</td><td>Standby</td><td>Reserved</td><td>Reserved</td><td>Uranium and progeny</td></tr>
<tr><td>9/15/1947</td><td>10/31/1947</td><td>Rehabilitation</td><td>Reserved</td><td>Reserved</td><td>Reserved</td></tr>
<tr><td>11/1/1947</td><td>12/31/1954</td><td>Step III processing</td><td>33</td><td>2,310</td><td>Uranium</td></tr>
<tr><td>Tonawanda plant</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10/1/1942</td><td>12/31/1946</td><td>Uranium ore research</td><td>Reserved</td><td>Reserved</td><td>Uranium and progeny</td></tr>
<tr><td>1/1/1947</td><td>12/31/1954</td><td>Post</td><td>0.1</td><td>7</td><td>Uranium and progeny</td></tr>
</table></td><td>Table 3-7. Assumed airborne concentrations used to estimate intakes at the Tonawanda Laboratory.
<table>
<tr><th>Start</th><th>End</th><th>Activity description</th><th># MAC</th><th>α dpm/m³</th><th>Source</th></tr>
<tr><td>11/01/1947</td><td>12/31/1953</td><td>Postcleanup</td><td>0.1</td><td>7</td><td>Uranium and progeny</td></tr>
</table></td></tr>
<tr><td>3.6</td><td>Different constants in alpha fraction of uranium resulting in difference in annual inhalation intake calculations</td><td>For example, the annual uranium inhalation intake due to chronic exposure at 0.1 MAC is estimated by multiplying the air concentration of 7 dpm/m³ by the alpha fraction of uranium, 0.402; the ICRP 66 (ICRP 1994) recommended breathing rate of 1.2 m3/h; and the assumed 2000 work-hours per calendar year. This results in an annual chronic inhalation intake of 6.75E+03 dpm, which is equal to a daily intake rate of 18.5 dpm/day. For the assumed exposure at 33 MAC, no alpha activity is apportioned to progeny, so the daily uranium intake would be 1.52E+04 dpm/day.</td><td>For example, the annual uranium inhalation intake due to chronic exposure at 0.1 MAC was estimated by multiplying the air concentration of 7 dpm/m³ by the alpha fraction of uranium (0.489), the ICRP Publication 66 (ICRP 1994) recommended breathing rate of 1.2 m³/hr, and the assumed 2,000 workhours per calendar year. This results in an annual chronic inhalation intake of 8..215 × 103 dpm, which is equal to a daily intake rate of 22.5 dpm/d.</td></tr>
<tr><td>3.7</td><td>Ingestion Intake Estimates at Tonawanda Laboratories have different computation.</td><td>In the case where inhalation intakes are calculated from air concentrations, ingestion intakes are also to be considered. NIOSH (2004) indicates that the ingestion rate, in terms of dpm for an 8-hour workday, can be estimated by multiplying the air concentration in dpm per cubic meter by a factor of 0.2, so the uranium ingestion rate based on an air concentration of 7 alpha dpm/m³ would be 0.563 dpm/workday. To adjust this to ingestion intake per calendar day, 0.563 dpm/workday is multiplied by 250 workdays per year and divided by 365 days per year, which equals 0.385 dpm/day. For the assumed exposure at 33 MAC, no alpha activity is apportioned to progeny, so the daily uranium intake would be 316 dpm/day. In accordance with NIOSH 2004, the f1-value used for inhalation dose calculations is to be used for ingestion dose calculations.</td><td>In the case where inhalation intakes are calculated from air concentrations, ingestion intakes are also to be considered. NIOSH (2004) indicates that the ingestion rate, in terms of dpm for an 8-hour workday, can be estimated by multiplying the air concentration in dpm per cubic meter by a factor of 0.2, so the uranium ingestion rate based on an air concentration of 7 alpha dpm/m³ would be 0.563 dpm/wd. To adjust this to ingestion intake per calendar day, 0.685 dpm/wd was multiplied by 250 wd/yr and divided by 365 d/yr, which equals 0.469 dpm/d. In accordance with NIOSH (2004), the f1-value used for inhalation dose calculations is to be used for ingestion dose calculations.</td></tr>
<tr><td>3.8</td><td>Consideration of Bioassay Data removed from Rev. 01.</td><td>Predicted uranium urinalysis results, provided in Table 10, were calculated for the last day of</td><td>N/A</td></tr>
</table>

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text

assumed chronic intake periods of 30 and 60 days, 0.5 years, 1 year and extended annually thereafter through the end of operations, assuming the estimated inhalation and ingestion intakes of natural uranium were based on a uranium air concentration of 33 MAC. A cursory review of the highest uranium urinalysis data from facilities that handled uranium in large quantities (Mallinckrodt, Harshaw, Hanford, ORNL, K-25, Paducah, and Portsmouth) indicates that results exceeding 10 mg/L are rare and that most results are less than 1 mg/L. At the Ceramics Plant, where the first Linde uranium bioassays were performed after standby, [Redact] of the available urinalysis results exceeded 1 mg/L. Subsequent results from these individuals were much lower. From November 1947 through January 1950, most Linde uranium urinalyses (about 95%) were less than 0.1 mg/L, but it is notable that exposures would likely have been lower during this period than in the earlier days of operations.

The predicted results in Table 10 do not seem inconsistent with the limited Linde urinalyses.

Table 10. Predicted uranium urinalyses from Ceramics Plant assumed inhalation and ingestion chronic uranium intake from November 1, 1947 to December 31, 1954 based on 33 MAC in air.

Bioassay date	Type M		Type S	
	dpm/d	mg/L	dpm/d	mg/L
12/[redacted]/1948	566	0.3	18	0.01
12/[redacted]/1948	661	0.3	20	0.01
5/[redacted]/1949	853	0.4	28	0.01
11/[redacted]/1948	961	0.5	36	0.02
11/[redacted]/1949	1,013	0.5	48	0.02
11/[redacted]/1950	1,022	0.5	57	0.03
11/[redacted]/1951	1,026	0.5	64	0.03
11/[redacted]/1952	1,028	0.5	70	0.03
11/[redacted]/1953	1,031	0.5	74	0.03
11/[redacted]/1954	1,033	0.5	77	0.04
12/[redacted]/1954	1,033	0.5	78	0.04

*Mass results assume natural uranium exposure

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
		Given a chronic exposure to uranium and its alpha emitting progeny at 300 MAC, the activity fraction of Ra-226 would be 0.196, which means that the chronic inhalation rate would be 2.7E+04 dpm/d. This gives a whole-body activity of 2.6E+05 dpm at one year, and about 4.0E+05 dpm at 4 years (calculated using IMBA Expert (OCAS), Version 3.2.20). The Ra-226 body activity was estimated using the largest breath radon result found for Linde, 2.2 pCi/L, by multiplying the radon result by a conversion factor of 2.52E+05 pCi/(pCi/L) (ORAUT 2005). This gives a body activity of 5.5 E+05 pCi, which is equal to 1.2 E+06 dpm, and is within a factor of 3 of the estimated intake from a 4-year chronic exposure to 300 MAC. Because other Linde radon breath analyses are lower, and because a chronic exposure scenario may not best represent a worker's exposure pattern, the assumption of 300 MAC chronic exposure was believed to be adequate for reconstructing doses in the pre-1947 research and production period, but at this time this period is reserved.	
3.8	**<u>Occupational Internal Dose Reconstruction Assumptions and Summary</u>** Disclaimer added in Rev. 01.		HHS has determined, and NIOSH has concurred, that it is not feasible to reconstruct internal exposure prior to November 1, 1947 (HHS 2005).
3.8	Summary table for 00 starts at 1942, Rev. 01 starts at 1947.		
4.0	ESTIMATION OF EXTERNAL EXPOSURE, 1942–1954 Dislaimer for pre-1947 data in Rev. 01		Because of the SEC determination (HHS 2005) that it is infeasible to adequately reconstruct internal dose during the period October 1, 1942 through October 31, 1947, dose estimates for this period are considered partial dose estimates.
4.0	Additional statement on measurement assumptions for		For the purpose of calculation of organ dose, all exposure geometries are assumed to be

<table>
<tr><th>Item Description</th><th>Comment</th><th>ORAUT-TKBS-0025 Rev. 0 Text</th><th>ORAUT-TKBS-0025 Rev. 1 Text</th></tr>
<tr><td></td><td>Beta Radiation in Rev. 01</td><td></td><td>anteriorposterior (AP).</td></tr>
<tr><td>4.1.1</td><td>Differing titles, subparagraph (typo?)</td><td><u>4.1.1 Post-production Radiation in Building 30</u>
Little information was available on radiation levels in Ceramics Plant buildings during periods of nonproduction. Estimates for these periods were based on measurements made after the end of production in Building 30, the main processing building.</td><td><u>4.1.1 Preproduction, 1942 to 1943</u></td></tr>
<tr><td>4.1.2.3</td><td>Cleanup section placed at end of section in Rev. 01</td><td></td><td></td></tr>
<tr><td>4.1.2.2</td><td>New information in Rev. 01 for “Gamma”</td><td></td><td>Film badges were provided by the Medical Section of the MED (presumably the University of Rochester).</td></tr>
<tr><td>4.1.3</td><td>Standby Section only in Rev. 01</td><td></td><td><u>4.1.3 Standby, 1946 to 1947</u>
Little information is available about the status of activities during the standby period. It is likely that the onsite staff consisted primarily of a small number of management and janitorial personnel— both of whom worked primarily in an office environment—and guards. For dose reconstruction, each worker during standby was classified as either a guard or a general worker, and worker time was assumed to have been spent in an office building, in production buildings, and outdoors. Averaged over the entire standby period, each worker's allocation of time was assumed to have been as indicated by the occupancy factors in Table 4-13.

Table 4-13. Ceramics Plant beta and gamma radiation rates during standby.
<table>
<tr><th rowspan="2">Parameter</th><th colspan="3">Category</th><th colspan="2">Time-weighted radiation rate[a]</th></tr>
<tr><th>Office</th><th>Production</th><th>Outdoors</th><th>Beta (rem/yr)</th><th>Gamma (R/yr)</th></tr>
<tr><td>Beta (mrem/hr)</td><td>0.000</td><td>0.676</td><td>0.676</td><td>(b)</td><td>(b)</td></tr>
<tr><td>Gamma (mR/hr)</td><td>0.000</td><td>0.131</td><td>0.131</td><td>(b)</td><td>(b)</td></tr>
<tr><td colspan="6">Occupancy factor</td></tr>
<tr><td>General worker</td><td>0.833</td><td>0.111</td><td>0.056</td><td>3.04E-01</td><td>5.91E-02</td></tr>
<tr><td>Guard</td><td>0.756</td><td>0.111</td><td>0.133</td><td>4.46E-01</td><td>8.67E-02</td></tr>
</table>
a. Based on 9.0 hr/d exposure, 6 d/wk, 50 wk/yr. Based on the underlying data and judgment, a GSD of 3 is assigned. The beta and gamma rates are for the whole body.
b. Not applicable.

Measurements were made at 1 in. from the surface of interest. The results were reported as 0 R/8 hr for four of the locations and 0.005 R/8 hr (0.625 mR/hr)</td></tr>
</table>

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
			for the other two locations (each near an ore dumping grill) (Howland 1946). Because the dumping grill was one of the most contaminated spots in the plant, the exposure rate there was not considered typical of the conditions that would have been encountered upon occasional entry during standby. Instead, the indoor gamma and beta levels for a production building were taken as the values in Table 4-1 before vacuum cleaning and flushing. Outdoor gamma and beta levels were taken as equal to the indoor rates based on the reasoning used above in the discussion of the preproduction period. The gamma and beta radiation rates in an office building were assumed to be zero. Table 4-13 summarizes the calculation of annual radiation rates based on the above parameters. Because there would have been little need for direct handling of radioactive materials by Ceramics Plant workers in this period, beta dose rate to the hands and forearms was taken as equal to the beta dose rate to the remainder of the body.
4.4	**External Dose Reconstruction Summary, October 1, 1942, to July 7, 1954**, disclaimer in Rev. 01 about dosages prior to Oct. 31, 1947		Because of the SEC determination (HHS 2005) that it is infeasible to adequately reconstruct internal dose during the period October 1, 1942 through October 31, 1947, dose estimates for this period are considered partial dose estimates.
5.0	**Occupational Medical Exposure** disclaimer on dose estimates prior to Oct. 31, 1947		Because of the SEC determination (HHS 2005) that it is infeasible to adequately reconstruct internal dose during the period October 1, 1942 through October 31, 1947, dose estimates for this period are considered partial dose estimates.
5.1.1	**Bases of Assumptions.** Slightly different wording on one sentence under "Applicability"	Therefore, the general assumption for dose reconstruction is that all employees were subject to the same chest x-ray imaging requirements.	Therefore, the general assumption for dose reconstruction is that all employees were subject to the same chest x-ray requirements.
5.1.1	**Bases of Assumptions** "Period."	Production work at the Ceramics Plant is assumed	Production work at the Ceramics Plant is assumed to

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
	Different dates between Rev. 00 and Rev. 01	to have ended on June 30, 1949; cleanup work is assumed to have ended on December 31, 1954.	have ended on June 30, 1949; cleanup work is assumed to have ended on December 31, 1953.
5.1.3	**X-ray Dose Reconstruction Guidelines**. Markedly different wording in introductory paragraphs	Dose reconstruction should be based on information specific the subject to the extent that it is available and adequate. The guidelines in this section are for use when the records for an individual worker are not available or are incomplete. The guidelines are for use only to the extent that they are not inconsistent with the worker's records. For example, if the medical records are complete and indicate a lower or higher examination frequency than stated in the assumptions provided above, the data in the medical records should be used. X-ray doses shall be determined in accordance with the latest revision of the project technical information bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* (current version is ORAU Team 2003) when applicable.	Dose reconstruction should consider information specific to the subject to the extent that it is available, adequate, and is representative of x-ray screening examinations covered under the EEOICPA (i.e., dose from x-ray examinations conducted as a result of occupational injuries are not to be included in dose reconstructions). The guidelines in this section are for use when the records for an individual worker are not available or are incomplete. The guidelines are for use only to the extent that they are not inconsistent with the worker's records. For example, if the medical records are complete and indicate a lower or higher examination frequency than stated in the assumptions provided above, the data in the medical records should be used. X-ray doses shall be determined in accordance with the latest revision of the project technical information bulletin, *Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (current version is ORAUT 2005b) when applicable.
6.0	**Estimation of Exposures from Residual Contamination after 1954 (1953 in Rev. 01)** Different dates.	This section develops parameters for reconstruction of doses due to internal and external exposures of Ceramics Plant and Tonawanda Laboratory workers after December 31, 1954, the assumed completion date of cleanup at the Ceramics Plant. Both facilities were on Linde's Tonawanda, New York, site. Initial cleanup of the Tonawanda Laboratory is assumed to have been completed on December 31, 1946. Tonawanda Laboratory workers' radiation exposures from January 1, 1947 to December 31, 1954 are discussed in Sections 3.0 and 4.0. The assumed Ceramics Plant initial cleanup date is December 31, 1954. Beginning on January 1, 1955, It is assumed that	This section develops parameters for reconstruction of doses due to internal and external exposures at the Ceramics Plant starting July 8, 1954, and Tonawanda Laboratory starting January 1, 1954. Initial cleanup of the Tonawanda Laboratory was assumed to be complete on December 31, 1946. Tonawanda Laboratory worker radiation exposures from January 1, 1947, to December 31, 1953, are discussed in Sections 3.0 and 4.0. It was assumed that beginning on January 1, 1954, Tonawanda Laboratory employees could have been exposed to residual contamination for 2,000 hr/yr.

Item Description	Comment	ORAUT-TKBS-0025 Rev. 0 Text	ORAUT-TKBS-0025 Rev. 1 Text
		Linde employees could have been exposed to residual contamination for 2000 hours per year.	
6.1.2	**External Beta and Gamma Exposure** different dates	The total number of readings ≥25 μR/h reported by BNI was 16. The net readings (after subtraction of 8 μR/h to correct for background) had a GM of 94.0 μR/h and a GSD of 3.95. This was taken as an estimate of worker exposure rate when outdoors. This estimate was assumed to apply from January 1, 1955 to the present (2005).	The total number of reported readings ≥25 μR/hr was 16. The net readings (after subtraction of 8 μR/hr to correct for background) had a GM of 94 μR/hr and a GSD of 3.95. This was taken as an estimate of worker exposure rate when outdoors. This estimate was assumed to apply starting January 1, 1954, at the Tonawanda Laboratory and July 8, 1954, at the Ceramics Plant.
Attachment C	Not in Rev. 0		**Attachment C** **Data Sources on Uranium Progeny Concentrations in Linde Materials**
Attachment D	Not in Rev. 0		**Attachment D** **Linde Uranium Coworker Assessment for November 1947 to January 1950**
Attachment E	Not in Rev. 0		**Attachment E** **Focused Assessment of Dose Consequences from Uranium Ore Bags on the Site During the Post-Operations Period**

APPENDIX B: MEMORANDUM FROM SEC PETITIONER TO SC&A

Memorandum

To: John Mauro and Steve Ostrow
From: [Name Redacted], Linde Ceramics SEC Petitioner SEC00107
Re: Feed Material Memoranda for Linde Ceramics Facility 1944
Date: June 4, 2009

The 2006 and 2008 Linde Site Profiles indicate that L-30 Belgian Congo pitchblende ore processed at Linde is estimated to have contained between 8 and 12% uranium ore (U_3O_8).[3] The following four attached memoranda, dated February 17, 1944, February 22, 1944, February 26, 1944, and March 6, 1944, all indicate that 65% Belgian Congo ore was processed at Linde during the operational time period.

These memoranda should be evaluated along with the following references listed in the Linde Site Profiles.

1. Pilot Plant Operations on African Ore – Wiesendanger, dated May 26, 1944: Laboratory research on the extraction of uranium from African pitchblendes had indicated satisfactory methods using high grade African ore (25% and 75% U_3O_8)

2. E.O. Brimm: Processing of African Ores, dated May 7, 1943: 1300 pound sample of Katanga ore was tested in Building 14 with a U_3O_8 assay content of 68.8% and also a lower grade Belgian Congo pitchblende with the percent of U_3O_8 at 24.8%

Furthermore, NIOSH has based its radon exposure model on 13 radon measurements from domestic ore processing in 1944. This data ignores the African ore processing. Moreover, Dr. Joseph Guido from ORAU wrongly stated at the January 8, 2008 Linde Working Group meeting that African ore processing ceased after 1944[4], when African ore was processed in 1946.[5] Does NIOSH's reliance on data that can only account for domestic ore processing significantly reduce the ability to account for radon progeny?

---

[3] L-30 African pitchblende ore; estimated to contain 8%–12% U_3O_8: (Aerospace 1981, Table B-1)

[4] Linde Working Group meeting January 8, 2008, at pages 31–32

[5] Linde processed domestic ore at 110% capacity for 52 tons of black oxide per month until December 1943; Belgian Congo ore [10% and 6%] from December 1943 through November 1944 at 162% capacity for 52 tons of black oxide per month; Spring 1944 225% design capacity; after November 1944 changes in production design resulted in an increase of uranium extraction from ore from 95 to 98%; from December 1944 through January 1946 capacity was at 150%; *February 1946 3% African ore [10,250 tons] to July 1946 at 110% capacity yielding 2428 tons of black oxide. Manhattan District History, Book VII Feed Materials, Special Procurement, and Geographical Exploration -Volume 1 – Feed Materials and Special Procurement, Section 7.6 through 7.8*

CONFIDENTIAL

L-30 Ship

WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
TONAWANDA AREA OFFICE
P. O. Box 8
KENMORE, N. Y.

IN REPLY REFER TO:

THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NUMBER 1 OF 4 COPIES, SERIES A

17 February 1944

RECEIVED
A. R. HOLMES
ASS'T. SUPERINTENDENT
THE LINDE AIR PRODUCTS CO.
CERAMICS PLANT, TONAWANDA, N. Y.

The Linde Air Products Company
Ceramics Plant
E. Park Drive and Woodward Ave.
Tonawanda, N. Y.

Attention: Mr. A. R. Holmes.

Gentlemen:

This office has been notified that 2,485 pounds of high grade (65%) L-30 ore have been shipped to you by railway express. When this material is received, you are to prepare a twenty-five pound sample of it and forward same to the Electro Metallurgical Company, Niagara Falls, New York, Attention: Mr. Andrew Gailey.

The other 2,460 pounds of the material is to be stored in an isolated place in your plant until the necessary experimenting has been carried out at Electromet, at which time plant scale experiments in your Step II equipment may be tried.

Due regard will be given to radiation hazard in handling and storing this material.

For the Area Engineer:

Very truly yours,

Handled by
L. Naumann

Walter G. Thomas

WALTER G. THOMAS,
Captain, Corps of Engineers,
Chief, Operations Unit.

RECEIVED
A. R. HOLMES
ASS'T. SUPERINTENDENT
FEB 23 1944

CONFIDENTIAL

XXXXXXXXXX EIDMM-3 XXXXXXXXX MANHATTAN DISTRICT

MD. ~~726.2~~ 729.3 radiation

22 February 1944 JLF:mrb

J.L.F.

Subject: Processing of high grade ores at the Linde Air Products Co.

To: The Area Engineer, Madison Square Area, New York. (Attention: Major J. E. Vance).

1. Reference your memorandum, EIDM 0-227-MS, dated 14 January 1944, subject as above.

2. Discussions with Dr. Hale and Dr. Failla indicate that use of 65% ore in place of 10% ore, effectively increases the radiation to personnel and the Mz content of the atmosphere by approximately 8 times.

3. In general, it is considered that laboratory operations will be quite safe.

4. It is felt that the problem of radiation will not be great and that our present film monitoring will provide assurance of safety for the workmen.

5. It seems almost certain that additional means of ventilation would be necessary to keep the Mz concentration at a safe level, particularly at the Ball Mill. It was recommended at a previous visit that additional exhaust ventilation be provided at this point, and tests will be made to determine the adequacy of this measure.

For the Medical Section:

DISTRIBUTION:
Copy No. 1 & 2 – Addressee
3 – Col. S. L. Warren
4 – Capt. Ferry W/d
5 – Reading File
6 & 7 – Class. File

1st Sec Destroyed 3-16-44 MB

JOHN L. FERRY,
Captain, Medical Corps.,
Assistant.

Cc: Col. S. L. Warren

File copies rec'd 3-4-44
orig. dispatched 2-24-44
register #43965

SECRET

Special Rereview
Final Determination
Unclassified
By: K. A. Walter
Date: 1980
T. F. Davis

Exhibit 4

EIDM 0-227-b-MS

26 February 1944

Subject: Experimentation on high-grade ores at the Linde Air Products Company

To: The Area Engineer, Tonawanda Area, Tonawanda, New York

1. Information has been received from the Medical Section to the effect that the use of 65% ores in place of the 10% ores effectively increases the radiation to personnel and the Ms content of the atmosphere by approximately eight times. In general, it is considered by the Medical Section that laboratory operations will be quite safe and that the problem of radiation will not be great; the present film monitoring will provide assurance of safety for the workmen.

2. It is understood that a previous visit by the Medical Section resulted in a recommendation that additional exhaust ventilation be provided at the ball mill. This recommendation should be put in effect.

3. It is requested that information be forwarded to this office on whether or not the wearing of film badges has been instituted. It is felt that any laboratory workers experimenting on the 65% ores should be cautioned that the wearing of such film badges is an essential safety measure.

For the Area Engineer:

Yellow Copy destroyed 4/10/44

CANFIELD HADLOCK
Major, Corps of Engineers,
Assistant.

Copies 1 & 2 - Addressee
3 - Read. File
4 - Class. File

CLASSIFIED FILES
U. S. ENGINEER OFFICE
MADISON SQUARE

Exhibit 5

SECRET

THIS DOCUMENT CLASSIFIED FILE(S)
NUMBER 1 U.S. ENGINEER OFFICE MADISON SQUARE AREA a
RECEIVED
MAR 6 1944
7,8,9,10,11,12,1,2,3,4,5,6 PM
A

Subject: Experimentation on high-grade ores at the Linde Air Products Company. (26 February 1944.)

EIDM T-12 1st. Ind.

Office of the Area Engineer, Tonawanda Area, Tonawanda, N.Y., 2 March 1944. To: The Area Engineer, Madison Square Area, New York, N.Y. (Attention: Major Canfield Hadlock).

3/5

1. Reference paragraph 2 basic communication, exhaust ventillation was installed and first operated about 13 February.

2. Reference paragraph 3 basic communication, first distribution of film-containing badges was made on 31 January. Seventeen badges were issued to thoseworkers who were most likely to come in contact with tolerance doses of exposure. Issuance of new badges is made weekly to the following:

2 Moore Operators
1 Moore Tailings Operator
Ball Mill Operator
Foreman
9 Loaders
1 Loader Foreman
1 Sampler
1 Pachuca Digest Operator

3. Laboratory experiments on the 65% ore have been temporarily discontinued. It is possible that no more experiments will be done, but if work is resumed, it will probably continue no longer than three or four weeks. We, therefore, feel that establishment of a film-containing badge survey would hardly be worthwhile.

E. L. Van Horn

E. L. VAN HORN,
Captain, Corps of Engineers,
Area Engineer.

Special Review
Final Determination
Unclassified
By: K. A. Walter
Date: Aug. 6, 1980
T. F. Davis