DRAFT

ADVISORY BOARD ON RADIATION AND WORKER HEALTH

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

A REVIEW OF NIOSH'S PROGRAM EVALUATION REPORT DCAS-PER-042, "LINDE CERAMICS PLANT TBD REVISION"

Contract No. 211-2014-58081
SCA-TR-PR2014-0088, Rev. 0

Prepared by

U. Hans Behling, PhD, MPH
Ron Buchanan, PhD, CHP
S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, VA 22182

August 2014

Disclaimer

This document is made available in accordance with the unanimous desire of the Advisory Board on Radiation and Worker Health (ABRWH) to maintain all possible openness in its deliberations. However, the ABRWH and its contractor, SC&A, caution the reader that at the time of its release, this report is pre-decisional and has not been reviewed by the Board for factual accuracy or applicability within the requirements of 42 CFR 82. This implies that once reviewed by the ABRWH, the Board's position may differ from the report's conclusions. Thus, the reader should be cautioned that this report is for information only and that premature interpretations regarding its conclusions are unwarranted.

S. COHEN & ASSOCIATES: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-PR2014-0088 Effective Date: Draft – August 19, 2014
A REVIEW OF NIOSH'S PROGRAM EVALUATION REPORT DCAS-PER-042, "LINDE CERAMICS PLANT TBD REVISION"	Page 2 of 25
Task Manager: _____ Date: _____ U. Hans Behling, PhD, MPH	Supersedes: N/A
Project Manager: _____ Date: _____ John Stiver, MS, CHP	Reviewers: U. Hans Behling, PhD, MPH Ron Buchanan, PhD, CHP John Stiver, MS, CHP

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	08/19/2014	Initial issue

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

Advisory Board or Board	Advisory Board on Radiation and Worker Health
AWE	Atomic Weapons Employer
DCAS	Division of Compensation Analysis and Support (formerly OCAS)
DHHS	(U.S.) Department of Health and Human Services
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
dpm/m^3	disintegrations per minute per cubic meter
DR	dose reconstruction
GSD	geometric standard deviation
hr	hour
LAPC	Linde Air Products Company
LCP	Linde Ceramic Plant
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support (now DCAS)
ORAUT	Oak Ridge Associated Universities Team
pCi/l	picocuries per liter
PEP	Program Evaluation Plan
PER	Program Evaluation Report
POC	probability of causation
R	Roentgen
rem	Roentgen equivalent man
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
TBD	technical basis document
TIB	technical information bulletin
U_3O_8	yellowcake; an impure mixture of uranium oxides obtained during the processing of uranium ore
UF_4	uranium tetrafluoride
UO_2	uranium dioxide
wd	work day
wk	week

WLM	working level month
yr	year

1.0 STATEMENT OF PURPOSE

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) have assembled a large body of guidance documents, workbooks, computer codes, and tools. In recognition of the fact that all of these supporting elements in DR may be subject to revisions, provisions exist for evaluating the effect of such programmatic revisions on the outcome of previously completed DRs. Such revisions may be prompted by document revisions due to new information, misinterpretation of guidance, changes in policy, and/or programmatic improvements.

The process for evaluating potential impacts of programmatic changes on previously completed DRs has been proceduralized in OCAS-PR-008, *Preparation of Program Evaluation Reports and Program Evaluation Plans* (OCAS 2006), Revision 2, dated December 6, 2006. This procedure describes the format and methodology to be employed in preparing a Program Evaluation Report (PER) and a Program Evaluation Plan (PEP).

A PER provides a critical evaluation of the effect(s) that a given issue/programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact(s) on the Probability of Causation (POC) of previously completed DRs with POCs of <50%.

During a teleconference by the Advisory Board's Procedures Subcommittee meeting on April 16, 2014, SC&A was tasked by the Board to conduct reviews of three PERs. Included among the PERs is DCAS-PER-042, *Linde Ceramics Plant TBD Revision* (DCAS 2012). In conducting a PER review, SC&A is committed to perform the following five subtasks, each of which is discussed in this report:

Subtask 1: Assess NIOSH's evaluation/characterization of the "issue" and its potential impacts on DR. Our assessment intends to ensure that the "issue" was fully understood and characterized in the PER.

Subtask 2: Assess NIOSH's specific methods for corrective action. In instances where the PER involves a technical issue that is supported by document(s) [e.g., white papers, technical information bulletins (TIBs), procedures] that have not yet been subjected to a formal SC&A review, Subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, Subtask 2 will simply provide a brief summary/conclusion of this review process.

Subtask 3: Evaluate the PER's stated **approach** for identifying the universe of potentially affected DRs, and assess the **criteria** by which a subset of potentially affected DRs was selected for re-evaluation. The second step may have important implications in instances where the universe of previously denied DRs is very large and, for reasons of practicality, NIOSH's re-evaluation is confined to a subset of DRs that, based on their scientific

judgment, have the potential to be significantly affected by the PER. In behalf of Subtask 3, SC&A will also evaluate the timeliness for the completion of the PER.

Subtask 4: Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. (It is assumed that the selection of the DRs and the total number of DR audits per PER will be made by the Advisory Board.)

Subtask 5: Prepare a written report that contains the results of DR audits under Subtask 4, along with our review conclusions.

2.0 SUBTASK 1: ASSESS NIOSH'S IDENTIFICATION OF THE ISSUES AND THEIR IMPACT ON DR

NIOSH has issued a technical basis document (TBD) for the Linde Ceramic Plant (LCP), along with a number of revisions. As stated in DCAS-PER-042, these documents have been utilized to perform DRs for claims from the LCP. The TBD has been through several revisions. Although some of the revisions only added annotation and attribution or corrected errors that did not affect the DR methods, there were a number of substantial changes made that could affect the outcome of a DR, such as the revised dose assignments in the tunnels, and reassessment of intakes for trades workers during 1955–1969. In preparation of DCAS-PER-042, the technical changes made in the revisions of the TBD were reviewed to determine if the re-evaluation of any previously completed DR would result in an increased dose using the current methods as recommended in Rev. 03, July 26, 2012, of the TBD.

A summary of the LCP TBD (ORAUT-TKBS-0025) revisions are listed below:

- 05/31/2005, Rev. 00 (ORAUT 2005)
- 01/19/2006, Rev. 00 PC-1 (ORAUT 2006)
- 11/04/2008, Rev. 01 (ORAUT 2008)
- 11/10/2009, Rev. 01 PC-1 (ORAUT 2009)
- 07/15/2011, Rev. 02 (ORAUT 2011)
- 07/26/2012, Rev. 03 (ORAUT 2012b)

2.1 RELEVANT BACKGROUND INFORMATION PERTAINING TO FACILITY OPERATIONS, OPERATIONAL HISTORY, HEALTH PHYSICS PRACTICES, AND RESIDUAL CONTAMINATION/DECONTAMINATION EFFORTS

The Department of Energy (DOE) designated the entire **Linde Ceramics Plant** as an Atomic Weapons Employer (AWE) facility, while the Department of Labor (DOL) determined that a portion of this facility constitutes a DOE facility, which is referred to in ORAUT-TKBS-0025 as **Tonawanda Laboratory**. Table 1 identifies respective operational periods and the residual contamination period.

Table 1. Operational and Residual Contamination Periods

Facility	Operational Period	Residual Contamination Period
Linde Ceramics	10/01/1942–10/31/1953	01/01/1954–07/2006*
Tonawanda Laboratory	1988–1992; 1996 (remediation)	

* Excluding years 1988–1992 and 1996

In 1942, Linde Air Products Company (LAPC) had been producing U_3O_8 as a coloring agent for ceramics. Due to Linde's experience, the facility was contracted to develop chemical processes to produce large amounts of uranium ore. Under contract, LAPC changed its name to the Linde Ceramic Plant and employed two types of source materials:

- Refined uranium materials and partially refined domestic ores

- Unprocessed African ores (pitchblende) containing significant amounts Th-230, Ra-226, and Rn-222

Operations at the Linde Ceramics Plant included three different uranium production activities identified as Steps I, II, and III. Step I involved the production of U_3O_8 from June 1943 through July 1946; Step II involved he production of UO_2 from April 1943 through March 1944; and Step III involved production of UF_4 from July 1943 to June 1946 and resumed in 1947 until June 1949. Table 2 summarizes operational cleanup periods along with work schedules for the LCP.

Table 2. Ceramics Plant Assumed Work Schedule (including lunch and breaks), 1942 to December 31, 1953

Period	Start	End	hr/wd	wd/wk	wk/yr
Preproduction	10/01/1942	04/26/1943	9.0	6	50
Production	04/27/1943	07/31/1946	9.0	6	50
Standby	08/01/1946	09/14/1947	8.5	6	50
Rehabilitation and production	09/15/1947	06/30/1949	8.5	6	50
Cleanup	07/01/1949	12/31/1950	8.5	6	50
Cleanup[a]	01/01/1951	12/31/953	8.5	5	50

[a] Assumed date of transition from 6- to 5-day workweek (based on Dupree 1983b, p. 4)
Source: ORAUT-TKBS-0025, Rev. 03, Table 2-4

2.2 CIRCUMSTANCES THAT NECESSITATED THE NEED FOR DCAS-PER-042

DCAS-PER-042 states that ". . . This PER considered the changes that were made between the current revision (Revision 3) and **all previous versions** of the TBD" [i.e., ORAUT-TKBS-0025: *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory*]. [Emphasis added.]

Presented below is a timeline since the issue of Rev. 00 of ORAUT-TKBS-0025, subsequent revisions to ORAUT-TKBS-0025, and a brief summary of salient changes that characterize these revisions.

Rev. 00 of ORAUT-TKBS-0025 was issued on May 31, 2005. SC&A was tasked to review Rev. 00 and issued its report on July 15, 2006 (SC&A 2006). SC&A's review identified a total of 11 findings, which were first presented to the Linde Work Group of the Advisory Board on Radiation and Worker Health on March 26, 2007. These findings centered on issues used to estimate internal exposures, use of unsupported/assumed parameter values assigned to dose models, and misuse of surrogate data.

Rev. 00 PC-1 of ORAUT-TKBS-0025 was issued on January 19, 2006. This revision incorporated comments/issues raised during a Linde Worker Outreach meeting, which included dates that designated Ceramic Plant workers who received internal exposures prior to 1947, as part of the Special Exposure Cohort (SEC).

Rev. 01 of ORAUT-TKBS-0025 was issued on November 4, 2008. Rev. 01 included a change in facility designation, resolution of the Board's Work Group's recommendations, changes that

addressed inclusion of SEC-00044 for the period October 1, 1942, through October 31, 1947, and formal internal and NIOSH review comments.

Rev. 01 PC-1 of ORAUT-TKBS-0025 was issued on November 20, 2009. The principal revision involved resolution of the Board's Work Group concern pertaining to potential exposures of Linde workers to contaminated burlap bags used to transport uranium ore.

Rev. 02 of ORAUT-TKBS-0025 was issued on July 15, 2011. Changes include the resolution of SEC-00107, which addressed exposure scenarios for utility tunnels and external exposures during and after the renovation period corresponding to years 1954 to 1969.

Rev. 03 of ORAUT-TKBS-0025 was issued on July 26, 2013. Revisions included changes to and resolution of SEC-00154. Thus, the three SEC classes that were added correspond to a total SEC time period that spans from October 1, 1942, through December 31, 1969, and is based on the inability to reconstruct **internal radiation doses**.

SC&A Comments Pertaining to the Development of DCAS-PER-042

As briefly summarized above, successive revisions to Rev. 00 of ORAUT-TKBS-0025 incorporated numerous changes that either increased, decreased, or both increased and decreased estimates of dose. Most notable among the changes was the decrease in potential internal exposures due to insufficient monitoring data, which resulted in the addition of three SEC classes for the period of October 1, 1942, through December 31, 1969. Changes (inclusive of the addition of SEC classes) that were sequentially incorporated in various revisions and culminating in Rev. 03 of ORAUT-TKBS-0025 were extensively discussed and resolved in a total of 20 conference/teleconference meetings over a 5-year period. These meetings were conducted by the Board's Linde Ceramics Work Group with participation by NIOSH and its contractor and SC&A personnel. During the **last teleconference** in June of 2012, the Linde Work Group, NIOSH, and SC&A agreed that all **TBD issues had been resolved**. Rev. 03 of ORAUT-TKBS-0025 was issued 6 weeks later on July 26, 2012 (ORAUT 2012b), and was followed by DCAS-PER-042 on November 16, 2012.

SC&A has no findings pertaining to Subtask 1 of our review of DCAS-PER-042.

3.0 SUBTASK 2: ASSESS NIOSH'S SPECIFIC METHODS FOR CORRECTIVE ACTIONS

In instances where a PER involves technical issues that are supported by a document that has been formalized and previously subjected to review by SC&A, Subtask 2 will be limited to a focused review process.

As stated in Section 2.0 above, SC&A not only conducted an extensive review of Rev. 00 of the Linde Ceramic TBD, but participated in the 20 conference/teleconference meetings of the Board's Linde Work Group, which resolved all technical issues (inclusive of SC&A's findings) leading up to, but excluding, the final Rev. 03 of ORAUT-TKBS-0025.

Based on the numerous changes that were incorporated in the four revisions, Section 3.0 *Plan for Resolution or Corrective Action* of DCAS-PER-042, NIOSH stated the following:

> *The number of changes that either increased or decreased the assigned dose affects nearly every previously completed claim. It was therefore not possible to narrow the population of claims that were potentially affected. Because three separate SEC classes were designated for the Linde Ceramics Plant; however, a number of claims have been awarded compensation without the need for a dose reconstruction. Claims in that category would* ***not*** *need a new dose reconstruction . . .*
>
> *The selection criteria resulted in* ***78 claims*** *requiring further evaluation. For those claims, the dose was recalculated using* ***all current*** *dose reconstruction methods including the current version of the TBD.* [Emphasis added.]

In brief, NIOSH used the latest TBD to re-evaluate **all previous claims** and excluded only those that were compensated under SEC criteria. Thus, PER-042 differs from previous PERs for which discrete TBD changes affecting DR were identified in order to select only those claims that were potentially impacted.

Given SC&A's involvement in the resolution of technical issues up to the time of the TBD's final revision implies that for PER-042, Subtask 2 requires a restrictive assessment of numerical values for potential exposures described in Rev. 03 of ORAUT-TKBS-0024, excluding those exempted by the SEC classes.

3.1 INTERNAL EXPOSURES FOR THE PERIOD NOVEMBER 1, 1947, THROUGH DECEMBER 31, 1953

The primary sources of internal exposures at Linde were **natural uranium** and its progeny that for African ore included **Ra-226, Rn-222, and short-lived daughters**. Due to insufficient internal monitoring data, three SEC classes were added that represented the time period of October 1, 1942, through December 31, 1969.

Uranium. In spite of the paucity of bioassay data, the TBD acknowledged that uranium bioassays are available for a limited number of workers for the period of November 1947 through January 1950; and if uranium bioassays are available for a worker, they should be used to reconstruct an individual's dose.

Radium. NIOSH determined that internal exposure to radium is not feasible before 1947. However, a limited number of radon breath analyses were performed and are available for some Linde workers and should be used for those workers using guidance in Section 3.3 of ORAUT-TKBS-0025, Rev. 03.

Radon Exposures. Although there were 200+ radon measurements taken between 1942 and 1946, NIOSH considered them insufficiently accurate for estimating exposures prior to November 1, 1947. However, they were considered adequate for deriving extrapolated radon doses for the period November 1, 1947, through December 31, 1953, as summarized in Table 3.

Table 3. Radon Exposures at the Linde Ceramic Plant and Tonawanda Laboratory for November 1, 1947, through December 31, 1953

Facility	Rn-222 Exposure (WLM/yr)	GSD
Linde Ceramics Plant	0.480	3.43
Tonawanda Laboratory	0.202	3.43

SC&A Comments/Findings

SC&A reviewed statements in the text and compared these to numerical values cited in Tables 3-1 through 3-5 for consistency and accuracy.

SC&A found no inconsistencies and no errors for **partial** internal dose estimates for the time period November 1, 1947, through December 31, 1953.

3.2 EXTERNAL EXPOSURES TO LINDE CERAMIC WORKERS FOR THE PERIOD OCTOBER 1, 1942, THROUGH DECEMBER 31, 1953

Film badges were used to monitor some workers for beta radiation during select time periods when African ore was processed. Additionally, worker dose estimates were also based on models using source term data and workplace surveys taken at various times.

Beta Doses for Years 1943 to 1946. Beta exposures were defined by worker category/job and for hands/forearms and remainder of body, as summarized in Table 4-6 of Rev. 03 of the TBD and reproduced below as Table 4.

Table 4. Assigned Beta Dose Rates, 1943 to 1946

Category/job	Median dose rate (rem/yr)		GSD
	Hands and forearms	Remainder of body	
High	**Varies[a]**	**74**	
Ball mill operator	221	74	1.52
Step I process operator	221	74	1.52
Weighmaster	221	74	1.52
Step II process operator	158	53	1.52
Loader	26	26	1.52
Medium	**17.6**	**5.85**	
Chemist/lab technician	17.6	5.85	2.65
Engineer	17.6	5.85	2.65
Janitor	17.6	5.85	2.65
Laundry worker	17.6	5.85	2.65
Maintenance worker	17.6	5.85	2.65
Ore sampler	17.6	5.85	2.65
Seamster, seamstress	17.6	5.85	2.65
Step III process operator	17.6	5.85	2.65
Tool crib worker	17.6	5.85	2.65
Low	**3.00**	**3.00**	
Draftsman	3.00	3.00	2.65
Fire inspector	3.00	3.00	2.65
Guard	3.00	3.00	2.65
Nickel operator	3.00	3.00	2.65
Nurse	3.00	3.00	2.65
Office worker	3.00	3.00	2.65
Plant superintendent, asst. supt.	3.00	3.00	2.65
Shipping and receiving clerk	3.00	3.00	2.65
Storekeeper	3.00	3.00	2.65
Tank farm operator	3.00	3.00	2.65

[a] See Section 4.1.2.1.3

Gamma Doses for Years 1943 to 1946. For select time periods, gamma film badges were assigned to a sample set of workers. For Step I workers, who processed African ore, the annual gamma dose (i.e., for a full 12-month period) of 5.35 R with a geometric standard deviation (GSD) of 2.61 was estimated. As a conservative measure, the same annual dose of 5.35 R was assigned to Step I and Step II workers, as well as to **all** Ceramic Plant employees.

External Doses to Linde Ceramic Workers for Other Time Periods. Separate doses for external beta and gamma doses were derived for the following three time periods:

(1) Standby: 1946–1947. Based on location and occupancy factors, time-weighted annual beta and gamma exposures were derived from empirical survey measurements as defined in Table 4-13 of Rev. 03 of the TBD.

(2) Rehabilitation and Production: 1947–1949. By means of 6,000 film badge records, beta and gamma doses were analyzed and categorized by job categories as low and medium exposure levels.

(3) Cleanup: 1949–1953. Survey measurements taken at the start and end of the cleanup as well as dosimeter data were used to model estimates of beta and gamma doses for cleanup workers, cleanup support workers, and non-cleanup workers, as given in Table 4-20 of the TBD.

3.3 BETA/GAMMA EXTERNAL EXPOSURES TO TONAWANDA LABORATORY WORKERS FOR THE PERIOD OCTOBER 1, 1942, THROUGH DECEMBER 31, 1953

External doses for beta and gamma radiation were modeled for two classes of Tonawanda Laboratory workers, research and office workers, and for three time periods; R&D, October 1, 1942–July 3, 1946; Cleanup, August 1,1946–December 31,1946; and Post-cleanup, January 1, 1947–December 31, 1953.

In the absence of monitoring data, modeled doses were largely based on relative/fractional dose estimates assigned to Linde Ceramic workers during contemporary time periods, as cited in the footnotes to Table 4-21 of the TBD.

3.4 NEUTRON DOSES FOR YEARS 1942–1953

Because no neutron exposure measurements were available, potential exposures to neutrons generated by alpha-neutron reactions were based on assumed source term quantities of uranium, exposure distance, and exposure times. For **Linde Ceramic** workers, a **maximum annual** neutron dose of 0.5 rem was derived; and for **Tonawanda Laboratory**, a **maximum annual** neutron dose of 0.144 rem was estimated. These maximum annual neutron doses were conservatively assumed for **all** workers for each respective facility.

3.5 SUMMARY OF EXTERNAL DOSES FOR USE IN DOSE RECONSTRUCTION FOR OCTOBER 1, 1942, TO DECEMBER 31, 1953

For external DR, NIOSH simplified/consolidated Tables 4-1 through 4-23 into a single Table 4-24 for all years from 1942 through 1953 by regrouping various jobs/workers into high, medium, and low exposure groups (see Table 4-24 of TBD) or by descriptive work activities. Simplification also eliminated select options for assigning dose by conservatively defaulting to the highest dose, as explained in footnotes *b* and *m* to Table 4-24. To further aid the dose reconstructor, for select years that were less than full years, NIOSH prorated doses, as given in footnotes *i, j, k, l, o,* and *q* to Table 4-24.

As a convenience to the reader, Table 4-24 of ORAUT-TKBS-0025, Rev. 03 is reproduced herein as Table 5.

Table 5. Summary of Annual External Exposure from AWE Operations, 1942 to 1953

Year[a]	Work Category	Beta (rem)[a]		Gamma (R)[a]	Neutron (rem)[a,b]
		Hands & forearms	Rest of body		
Ceramics Plant (Buildings 30, 31, 37, and 38)					
1942[c]	All workers	2.55E–02	2.55E–02	4.97E–03	(d)
1943[e]	High	1.51E+02[f]	5.05E+01	3.65E+00	3.41E–01[g]
		5.05E+01[h]			
	Medium	1.20E+01	3.97E+00		
	Low	2.08E+00	2.08E+00		
1944 1945	High	2.21E+02[f]	7.40E+01	5.35E+00	5.00E–01[g]
		7.40E+01[h]			
	Medium	1.76E+01	5.85E+00		
	Low	3.00E+00	3.00E+00		
1946[i]	High	1.28E+02[f]	4.32E+01	3.11E+00	3.33E–01[g]
		4.32E+01[h]			
	Medium	1.04E+01	3.59E+00		
	Low	1.93E+00	1.93E+00		
1947[i]	Medium	2.04E+00	8.91E-01	5.37E-01	1.48E–01[g]
	Low	6.10E-01	6.10E-01	2.03E-01	
1948	Medium	5.85E+00	1.95E+00	1.61E+00	5.00E–01[g]
	Low	1.00E+00	1.00E+00	4.80E-01	
1949	Medium/Low[k]	6.85E+00	2.28E+00	1.73E+00	3.74E–01[g]
	Cleanup				(d)
	Non-cleanup[l]	6.60E-01	6.60E-01	2.94E-01	
1950 1951 1952 1953	Cleanup[m]	7.83E+00	2.61E+00	1.85E+00	(d)
	Non-cleanup[n]	3.26E-01	3.26E-01	1.11E-01	
Tonawanda Laboratory (Building 14)					
1942[c]	Research	2.80E+01	9.33E+00	1.35E+00	3.63E-02
	Office	7.56E-01	7.56E-01		
1943	Research	1.11E+02	3.70E+01	5.35E+00	1.44E-01
	Office	3.00E+00	3.00E+00		
1944 1945	Research	1.11E+02	3.70E+01	5.35E+00	1.44E-01
	Office	3.00E+00	3.00E+00		
1946	Research	6.78E+01	2.26E+01	3.88E+00	8.36E-02[p]
	Office	1.78E+00	1.78E+00	3.15E+00	
1947 1948 1949 1950 1951 1952 1953	All workers	3.26E-01	3.26E-01	6.80E-02	(d)

a. Total annual exposure (dose) for the designated year. Prorated based on calendar year and applicable notations below.
b. Because of the possible difficulty in determining whether a worker was working with oxide or fluoride materials, each worker was assigned the larger neutron dose due to fluorides.
c. Exposure for the period from October 1 through December 31, 1942, only.
d. Neutron dose rate was negligible.

e. Values prorated: For January 1 through April 26, 1943 (preproduction period), applicable values from Table 4-1 applied; for April 27 to December 31, 1943, applicable 1944 to 1945 values applied. (Example calculation: 1943 high-ball mill operator = 0.315 × 1.01E-01 + 0.685 × 2.21E+02 = 1.51E+02).
f. Based on 221 rem/yr for ball mill operator, Step I and Step II process operators, and weighmaster.
g. The Building 38 neutron dose rate for Step III processing was assumed to apply from April 27, 1943, to August 31, 1946, and from September 15, 1946, to September 30, 1949. The neutron dose rate was negligible from September 1, 1946, to September 14, 1949 (standby), and after September 30, 1949 (cleanup and post-cleanup). The period of neutron exposure extended beyond the end of production in 1946 and 1949 due to remaining inventory of UF_4.
h. Based on 74 rem/yr for loader per Section 4.1.2.1.3.
i. Values prorated: For January 1 to July 31, 1946, applicable 1944 to 1945 values applied; for August 1 to December 31, 1946 (standby period), applicable values from Table 4-4 (guard) applied.
j. Values prorated: For January 1 to September 14, 1947 (standby period), applicable values from Table 4-4 (guard) applied; for September 15 to December 31, 1947, applicable 1948 values applied.
k. Values prorated: For January 1 to June 30, 1949 (Step III production), applicable 1948 medium values applied; for July 1 to December 31, 1949, 1950 to 1953 cleanup values applied.
l. Values prorated: For January 1 to June 30, 1949 (Step III production), applicable 1948 low values applied; for July 1 to December 31, 1949, 1950 to 1953 non-cleanup values applied.
m. All cleanup workers and cleanup support workers as defined in Section 4.1.5 are assigned to the cleanup exposure category. Parameters are those of the cleanup worker for a 6-day week in Table 4-20.
n. All non-cleanup workers as defined in Section 4.1.5 are assigned to the non-cleanup exposure category. Parameters are those of the non-cleanup worker for a 6-day week in Table 4-20.
o. Values prorated: For January 1 to July 31, 1946, applicable 1944 to 1945 values applied; for August 1 to December 31, 1946, applicable values from Table 4-21 (cleanup-R&D scenario) applied.
p. Includes neutron exposures through July 31, 1946.
q. Values prorated: For January 1 to July 31, 1946, applicable 1944 to 1945 values applied; for August 1 to December 31, 1946, applicable values from Table 4-21 (cleanup-office scenario) applied.

SC&A Comments/Findings Pertaining to Exposures at the Linde Ceramics Facility for Years 1942 through 1953

The reconstruction of internal and external doses for Linde workers by standard protocols is hampered by the near absence of internal monitoring data that led to the addition of three SEC classes and the limited amount of external monitoring data that mandated the development of dose models representing a combination of empirical data (e.g., episodic dosimeter data, source term and process knowledge, job classifications, work schedules, etc.) and reasonable/claimant-favorable assumptions.

For external dose estimates, these models were described and quantified in Tables 4-1 through 4-23 for discrete time periods, radiation sources, radiation type, and worker job/classification.

To reduce the level of complexity, NIOSH simplified these datasets by consolidating worker groups and conservatively assigning the higher/highest dose values, as shown in Table 5 above.

SC&A reviewed the technical basis along with selected/assumed model parameters used by NIOSH to estimate external doses for years 1942–1953. Given the paucity of available data, SC&A concludes that NIOSH employed reasonable assumptions and default values for deriving summary dose estimates shown in Table 4-24 of the TBD that should be considered **claimant favorable**.

For external dose estimates representing years 1942–1953, SC&A has **no findings**, but the following observation.

Observation #1. SC&A recommends the correction of two errors in the TBD:[1]

- Table 4-6 erroneously cites the value 26 rem/yr to "Hands and forearms" for the "Loader" worker category. The correct value is 74 rem/yr, as given in the **fourth bullet** on page 45 of the TBD.

- **Third bullet** on Page 45 of the TBD incorrectly cites 221 rem/yr to "Hands and forearms" to the **Step II process operator**. The correct value is 158 rem/yr, as shown in Table 4-6.

3.6 ESTIMATION OF EXPOSURES FROM RESIDUAL CONTAMINATION AFTER 1953

Section 6.0 of the Linde Ceramics TBD starts with the following statements:

> *This section develops parameters for reconstruction of doses due to **internal** and **external** exposures at the Ceramics Plant **starting January 1, 1954**.*
>
> *NIOSH has determined, with concurrence from the Secretary of DHHS, that **internal** doses at the Linde Ceramic Plant cannot be reconstructed with sufficient accuracy from the **beginning of 1954 through the end of 1969** (Sebelius 2011). If monitoring data are available for workers who are included in the SEC class, dose is to be assigned as appropriate based on such data. However, such dose reconstructions are still considered partial dose reconstructions because NIOSH has determined that internal exposures during the SEC class period (1954 through 1969) **cannot be bounded**.* [Emphasis added.]

3.6.1 Estimates of Internal Exposures

For the above-stated reason, NIOSH elected to avoid estimating internal exposures for the 16-year period of 1954 through the end of 1969.

Uranium. Skipping years 1954–1969 and starting with the year 1970, internal exposure to uranium (and progeny), NIOSH employed the following information/assumptions for deriving inhalation intakes for years1970 through 2009:

- During renovation/remodeling of Buildings 30 and 31, a maximum air concentration of 161 dpm/m^3 was observed in **1950**.

- In **1976**, a survey of Building 30 showed an air concentration of 0.0422 dpm /m^3.

[1] Important to note, however, is that these two errors were **not** transferred to the summary dose estimates of Table 4-24 of the TBD, which are recommended for dose reconstruction.

For deriving air concentrations for the years 1970 and after, NIOSH stated the following:

> *. . . an exponential interpolation was made between the uranium air concentrations that were assumed for the remediation period (161 dpm/m^3)* [taken in **1950]** *and the levels that were measured in the **1976** survey (4.22 × 10^{-2} dpm/m^3).* [Emphasis added.]

Thus, for the year **1970**, the **daily inhalation** of 1,556 dpm α activity was based on the following data and assumptions:

(1) U and progeny air concentration of 161 dpm/m^3 taken in 1950
(2) Breathing volume of 1.2 m^3/hr
(3) 8 hr/workday
(4) Progeny to uranium ratios as given in Table 6-1 of ORAUT-TKBS-0025

Daily inhalation values for individual radionuclides and all years of up to 2009 are presented in Table 6-2 of the TBD.

Radon. Because there are no radon survey data for the 1954–1969, NIOSH employed the Rn-222 air concentration value of 10 pCi/l and radon exposure rate of 0.480 WLM/yr (that had been assumed for Linde workers for the years **1947 through 1953**) without adjustment for source depletion as the Rn-222 air concentration and exposure rate for year **1970**.

By means of a subsequent Rn-222 survey measurement taken in **1981** that yielded an exposure rate of 0.201 WLM/yr, a depletion rate was calculated that corresponded to years between 1970 and 1981. The resultant radon exposure rates for years between 1970 and 2010 are shown in Table 6-4 of the TBD.

SC&A Comments/Findings Pertaining to Internal Dose Estimates from Residual Contamination After 1953

For both **uranium** (and progeny) and **radon**, NIOSH derived inhalation exposures by employing air sample data that **predate** the beginning of the residual contamination period starting January 1, 1954, and, **without** adjusting values, assigned these values to the year 1970 (the first year that post-dates the end of the SEC period).

In doing so, NIOSH "eliminated" internal exposures to uranium/radon for the years 1954 through 1969. For the years post-1970, annual exposures were derived by the exponential interpolation between the **"assigned" 1970 sample values and subsequent air samples**.

SC&A questions the underlying justification/logic behind the failure to assign internal exposures for uranium and radon for years 1954–1969 due to the availability of air sampling data representing the **operational period** and **residual period**, which satisfy criteria defined in ORAUT-OTIB-0070 (ORAUT 2012a).

Finding #1. SC&A questions NIOSH's restrictive methodology for deriving internal exposures to Ceramic Plant workers from residual contamination. The availability of data that satisfy criteria cited in ORAUT-OTIB-0070 allow for the assignment of internal exposures to uranium

and radon, inclusive of years 1954 through 1970, in spite of the fact that this time period is part of the SEC period. In support of SC&A's contention, Section 1.3 of ORAUT-TKBS-0025, Rev. 03, states the following:

> *All Atomic Weapons Employees who worked in any area at the Linde Ceramics Plant in Tonawanda, New York, from November 1, 1947 through December 31, 1953, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the SEC.*
>
> *This SEC class includes all workers during the SEC class period. Because of the identified dose reconstruction infeasibility, all dose reconstructions for all workers having employment during the SEC class period are considered partial dose reconstructions. If monitoring data are available for workers included in the SEC class, dose is to be assigned as appropriate based on such data; however, such dose reconstructions are still considered partial dose reconstructions because NIOSH has determined that internal exposures during the SEC class period cannot be bounded.*

3.6.2 Utility Tunnel Exposures

By means of survey measurements that assessed beta activities on tunnel **surfaces**, NIOSH derived internal and external exposures using the 95th percentile activity levels for U-234, U-235, Th-230, and Ra-226, as shown in Table 6-7 of the TBD.

Internal Exposure to U and Progeny. Surface contamination levels (Table 6-7 of the TBD) were used to model inhalation and ingestion intake rates (dpm/yr) that assumed breathing rate (1.2 m^3/hr), a resuspension factor (1×10^{-6} m^{-1}), and annual exposure times (1,000 hrs/yr for Trade Workers and 100 hrs/yr for Others).

Radon Exposure. NIOSH derived radon concentrations and worker exposure for two source terms: (1) Ra-226 surface contamination inside tunnels, and (2) Ra-226 levels in soil surrounding tunnels.

Radon exposures from **surface contamination** were based on the air concentration of 18.35 pCi/l, an equilibrium fraction of 0.5, and the following stated yearly exposure times:

> *For Trade Workers & Laborer* [sic] *it is assumed that they worked in these tunnels doing maintenance **50%** of their time . . . For all other workers, an occupancy factor of **5%** was assumed . . . This results in the exposure rates provided in Table 6-11.* [Emphasis added.]

Table 6-11 of ORAUT-TKBS-0025 identifies annual radon exposure rates of 0.540 WLM and 0.054 WLM, which correspond to occupancy factors 1,000 hrs/yr (or 50%) and 100 hrs/yr (or 5%) for trade workers and all others, respectively.

Radon exposures due to **contaminated soils** were based on Ra-226 soil sample data and the 95th percentile resultant radon air concentration of 99.31 pCi/l in the Linde utility tunnels. For deriving annual radon exposure rates for trade workers and all other workers, NIOSH provided the following information regarding **occupancy factors**:

> *It is assumed that trade workers and laborers worked in these tunnels doing maintenance for 8 hr/wd (2 months of the year) and for the other 10 months, a transit time of 10 min/wd using the tunnels to get between buildings. For all other workers only the transit time of 10 min/wd should be applied year-round. This results in the exposure rates in Table 6-12.*

Table 6-12 identifies radon exposure rates of 2.921 WLM/yr and 0.292 WLM/yr for trade workers and all other workers, respectively.

A simple calculation shows that radon exposure rates assigned to contaminated soils cited in Table 6-12 correspond to the correct occupancy factors of 1,000 hr/yr and 100 hr/yr and **not** to the estimates 375 hr/y and 41.7 hr/yr occupancy factors mistakenly cited by NIOSH on page 75 of ORAUT-TKBS-0025.

Finding #2. The assigned radon exposure rates in Tables 6-11 and 6-12 are correctly based on the **identical occupancy** factors of 50% and 5% (or 1,000 hr/yr and 100 hr/yr) for trade workers and all others, respectively, and **not** by the stated occupancy factors described in the text. NIOSH, therefore, needs to correct the wording/definition of occupancy factors in behalf of radon exposures due to "surrounding contaminated soil."

Tunnel External Exposures. Using the 95th percentile of surface contamination survey data inside utility tunnels (USAEC 2002), NIOSH derived yearly effective whole-body and beta skin doses for the trade workers/laborers and all other workers. Annual doses were based on occupancy factors of 50% and 5% for trade workers/laborers and all other workers, respectively.

There are no findings associated with external dose estimates in utility tunnels.

4.0 SUBTASK 3: EVALUATE THE PER'S STATED APPROACH FOR IDENTIFYING THE NUMBER OF DRS REQUIRING RE-EVALUATION OF DOSE

NIOSH considered all LCP claims that could be impacted by the changes in the TBD. NIOSH eliminated the claims that qualified for the LCP SECs (and had only SEC-covered cancers) and other claims with previous DRs resulting in POC ≥50%. These selection criteria, as stated in Section 3.0 of DCAS-PER-042, resulted in 78 claims requiring further evaluation.

4.1 SC&A'S EVALUATION OF NIOSH'S IDENTIFICATION OF CLAIMS

Because of the dynamic status of the claims, it is difficult to determine exactly the details of the number of claims in each category at the time the new TBD (Rev. 03, July 26, 2012) was issued (i.e., how many had been SEC pulled, administratively pulled, had DRs performed, had POC <50%, POC >50%, etc.); some claims may fit into more than one category, or change categories with time. SC&A did analyze the current LCP claims on the NOCTS database and found that approximately 300 claims had been filed as of July 2014. Of these total claims, 62 had been pulled for the SECs, 3 had been administratively pulled before DRs were performed, 139 had DRs with POC <50%, 95 had DRs with POC ≥50%, and 3 recent cases had not had a DR performed yet. This information was not in conflict with the data provided by NIOSH in DCAS-PER-042 and SC&A's analysis of the claims that were potentially impacted by DCAS-PER-042, which is summarized as follows:

- At the time DCAS-PER-042 was issued (November 16, 2012), it appears that approximately **250** LCP claims had been filed.

- Of these 250 claims, **116** of these claims had been filed and had previous DRs with the POC <50%. (Other LCP claims that already had been processed with resulting POC ≥50% would not be impacted by this PER, and were not considered in this evaluation.)

- Of these 116 claims, **38** were qualified to be covered under the LCP SECs of October 1, 1942–December 31, 1969 (none of these 38 claims contained non-covered cancers under the SECs).

- That left **78** claims that had DRs completed prior to the issuance of Rev. 03 (July 26, 2012) of the LCP TBD, and which originally had a POC below 50%. (These 78 claims included 5 claims that had **both** SEC-covered cancers and non-SEC cancers, because these claims may need to be re-evaluated for medical benefits.)

- Of these 78 claims, **74** claims were re-evaluated and found to have POCs of <50% (of these 74 claims, 3 had **both** SEC-covered cancers and non-SEC cancers).

- Of these 78 claims, **4** claims were re-evaluated and found to have POCs of ≥50%.

- Of these 4 claims with new POCs ≥50%, **2** claims had **both** SEC-covered cancers and non-SEC cancers and qualified for the SEC, and **2** claims did not qualify for the SECs.

- Of the 2 claims that did not qualify for the SECs, **1** claim had a new POC ≥50% and was eligible for consideration of compensation; however, **1** claim had an original POC<50%, then under DCAS-PER-042 a re-evaluated POC ≥50%, then a recent re-evaluated POC <50% when revised employment dates from DOL were used.

4.2 CONCLUSIONS

SC&A found that DCAS-PER-042 sufficiently addressed the changes in the LCP TBD and implemented an appropriate corrective action plan by re-evaluating all potential impacted claims processed prior to July 26, 2012. However, SC&A had findings (see Section 3.6 of this report) concerning Rev. 03 of the LCP TBD that need to be addressed and resolved before implementation of DCAS-PER-042 can be considered complete.

5.0 SUBTASK 4: CONDUCT AUDITS OF A SAMPLE SET OF DRs AFFECTED BY DCAS-PER-042

Selection of DRs to audit – Because NIOSH has completed the evaluation of the 78 potentially impacted claims under DCAS-PER-042 and found 71 claims that had a re-evaluated POC <50% (and did not qualify for the SECs), it is recommended that SC&A audit **2** of the applicable 71 claims and evaluate them to verify that the DR was performed according to correct protocol and Rev. 3 of the TBD (this should consist of a complete audit, as opposed to a focused audit, because of the many changes in Rev. 03 of the LCP TBD). These two cases can be selected by the Work Group in conjunction with NIOSH and assigned to SC&A to audit.

Additionally, since 1 of the 4 cases that was re-evaluated consisted of an original POC <50%, then under DCAS-PER-042 a re-evaluated POC ≥50%, then a recent re-evaluated POC <50% (when revised employment dates from DOL were used), it is suggested that SC&A audit this case to verify that the latest DR was performed according to correct protocols and Rev. 3 of the TBD. This case can be considered by the Work Group and assigned to SC&A to audit, if acceptable.

6.0 REFERENCES

42 CFR 82, 2002. *Methods for Radiation Dose Reconstruction under the Energy Employees Occupational Illness Compensation Program Act of 2000*; Final Rule, Federal Register/Vol.67, No. 85/Thursday, May 2, 2002, p. 22314.

DCAS 2012. *Linde Ceramics Plant TBD Revision*, Rev. 0, NIOSH's Office of Compensation Analysis and Support, Cincinnati, Ohio. November 16, 2012.

Dupree, B., 1983b, "Meeting with Six Linde Employees Who Worked in the Ceramics Plant: (Revised)," AU0004820 CD, memorandum to Linde File, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 25. [SRDB Ref ID: 3908, p. 4]

OCAS 2006. *Preparation of Program Evaluation Reports and Program Evaluation Plans*, OCAS-PR-008, Revision 2, NIOSH's Office of Compensation Analysis and Support, Cincinnati, Ohio. December 6, 2006.

ORAUT 2005. *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, Rev. 00, Oak Ridge Associated Universities Team, Cincinnati, Ohio. May 31, 2005.

ORAUT 2006. *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, Rev. 00 PC-1, Oak Ridge Associated Universities Team, Cincinnati, Ohio. January 19, 2006.

ORAUT 2008. *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, Rev. 01, Oak Ridge Associated Universities Team, Cincinnati, Ohio. November 4, 2008.

ORAUT 2009. *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, Rev. 01 PC-1, Oak Ridge Associated Universities Team, Cincinnati, Ohio. November 10, 2009.

ORAUT 2011. *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, Rev. 02, Oak Ridge Associated Universities Team, Cincinnati, Ohio. July 15, 2011.

ORAUT 2012a. *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0070, Rev. 01. Oak Ridge Associated Universities Team, Cincinnati, Ohio. March 5, 2012.

ORAUT 2012b. *An Exposure Matrix for Linde Ceramics Plant (Including Tonawanda Laboratory)*, Rev. 03, Oak Ridge Associated Universities Team, Cincinnati, Ohio. July 26, 2012.

SC&A 2006. *Review of the NIOSH Site Profile for the Linde Ceramics Plant and Tonawanda Laboratory, Tonawanda, New York*, SCA-TR-TASK1-0014, Rev. 0. SC&A, Inc., Vienna, Virginia, and Saliant, Inc., Jefferson, Maryland. July 15, 2006.

Sebelius, K. G., 2011. *HHS Designation of Additional Members of the Special Exposure Cohort under the Energy Employees Occupational Illness Compensation Program Act, Designating a Class of Employees, Linde Ceramics Plant, Tonawanda, New York*, U.S. Department of Health and Human Services, Office of the Secretary, Washington, D.C., April 21. [SRDB Ref ID: 95101]

USACE (U.S. Army Corps of Engineers), 2002b, *Dose Assessment for the Existing Surface Contamination Within the Linde Utility Tunnel Complex, FUSRAP Linde Remedial Action, Tonawanda, New York*, Buffalo, New York; January. [SRDB Ref ID: 49892]