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ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

A REVIEW OF NIOSH'S PROGRAM EVALUATON REPORT DCAS-PER-059, "NORTON COMPANY"

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SC&A, INC.: ***Technical Support for the Advisory Board on Radiation and Worker Health Review of NIOSH Dose Reconstruction Program***

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TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

Advisory Board or Board	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AWE	Atomic Weapons Employer
Bi	bismuth
cpm	counts per minute
DCAS	Division of Compensation Analysis and Support
D&D	decontamination and decommissioning
dpm	disintegrations per minute
DR	dose reconstruction
µc/cc	microcuries per cubic centimeter
$\mu Ci/cm^3$	microcuries per cubic centimeter
µCi/ml	microcuries per milliliter
MeV	mega-electron volts
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
pCi	picocurie
pCi/L	picocuries per liter
Pb	lead
PER	program evaluation report
Po	polonium
POC	probability of causation
R&D	research and development
SEC	Special Exposure Cohort
SRDB	Site Research Database
TIB	technical information bulletin
WL	working level
WLM	working level month

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* (NIOSH 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.

A PER provides a critical evaluation of the effects 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 on the probability of causation (POC) of previously completed DRs with POCs of <50%.

During a teleconference of the Advisory Board on Radiation and Worker Health (Advisory Board or Board) on January 26, 2017, the Board tasked SC&A to conduct a review of DCAS-PER-059, *Norton Company* (NIOSH 2015; hereafter "PER-059"). 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. SC&A's 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 documents [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 and 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 reevaluation. 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 reevaluation 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 SC&A's review conclusions.

2.0 RELEVANT BACKGROUND INFORMATION

DCAS-PER-059 states that the Norton Company, located in Worcester, Massachusetts, began as an Atomic Weapons Employer (AWE) facility in September 1944 by working with beryllium under contract to the Manhattan Engineering District through 1956. For the year 1957, the company also worked with thorium and uranium.

Starting in 1958, continued contracts involved non-radioactive materials, which no longer qualified the Norton Company as an AWE facility. However, it was not until 1962 that the Norton site performed decontamination and decommissioning (D&D) of equipment and materials. Thus, the period of *residual contamination*, which extends from January 1, 1958, through October 2009, represents the following two discreet time periods for worker exposure to residual contamination that is covered under the Energy Employees Occupational Illness Compensation Program Act:

1) Period of residual contamination prior to D&D that extends from January 1, 1958, to October 10, 1962.

2) Period of residual contamination post D&D that corresponds to October 1962 through October 2009.

3.0 SUBTASK 1: IDENTIFY THE CIRCUMSTANCES THAT NECESSITATED DCAS-PER-056

No technical basis document has been developed for DRs of workers at the Norton Company; however, a "previous" template had been developed for guidance to assess exposures in behalf of claimants. The issue date of the "previous" template is unknown to SC&A, and SC&A had no prior knowledge of its existence.

The "previous" template of Norton Company was revised on September 16, 2011 (NIOSH 2011a), primarily due to the following two reasons:

1) The addition of a second class of employees to the Special Exposure Cohort (SEC-00173), which corresponds to a portion of the residual contamination of January 1, 1958, to October 10, 1962.

2) The revision to ORAUT-OTIB-0070, Revision 00, which was originally issued on March 10, 2008 (NIOSH 2008). A key change made in Revision 01 to ORAUT-OTIB-0070 (NIOSH 2012) was the adoption of a lower depletion rate of 0.067% per day for residual contamination starting October 10, 1962, and extending to 2009.

<u>SC&A's Comments</u>

Programmatic revisions that may affect the outcome of previously completed DRs and mandate the need for a PER include the addition of a new class of workers to the SEC and any revisions to guidance documents that may result in the assignment of a higher dose.

SC&A regards (1) the addition of the SEC-00173 class and (2) the adoption of a reduced depletion rate during the residual period as justification for the revision of the Norton Company template and the need for the reevaluation of worker doses as defined in PER-059.

SC&A concurs with NIOSH's decision to issue PER-059, and there are no findings.

Important to note, however, is that SC&A's approach for its review of PER-059 is affected by the following facts:

1) The aforementioned two principal reasons that required the revision of the Norton template, which in turn necessitated issuance of DCAS-PER-059, pertain to the following procedural documents that have already been reviewed by SC&A:

   – On August 29, 2008, SC&A issued its draft report, *Review of ORAUT-OTIB-0070: Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*.

   – On July 7, 2011, SC&A issued its draft report, *A Focused Review of the Norton Company SEC Petition Evaluation Report SEC-00173 Concerning the Use of ORAUT-OTIB-0070 for the Reconstruction of Doses from Residual/Post-Operational Contamination*.

2) SC&A has reviewed neither the "previous" nor the revised Norton Company templates.

Therefore, SC&A's review of DCAS-PER-059 will include an evaluation of the Norton Company template for its guidance of internal and external dose reconstruction.

4.0 SUBTASK 2: ASSESS NIOSH'S SPECIFIC METHODS FOR CORRECTIVE ACTION

Due to SEC-00148 and SEC-00173 class designations, no internal or external doses can be derived with sufficient accuracy for the years 1945 through October 10, 1962. Thus, the principal changes for the reevaluation of dose in behalf of DCAS-PER-059 involves the use of the revised contamination depletion rate of 0.067% per day for claimants excluded from SEC status and with employment during the residual period after October 10, 1962.

SC&A Comments

Because the principal justification for the reevaluation of doses pertaining to the revised contamination depletion rate (adopted in ORAUT-OTIB-0070, Revision 01) was previously assessed and approved by the Subcommittee for Procedure Reviews, there are no findings regarding its use for the reevaluation of worker doses affected by DCAS-PER-059. However, as mentioned above, there is a need to assess the application of the revised contamination depletion factor as part of SC&A's review of the Norton Company template.

A review of the template identifies use of the revised depletion factor of ORAUT-OTIB-0070 for deriving the following doses during the residual period for years 1962 through 2009:

- Annual external exposure rates
- Annual uranium intake rates
- Annual thorium intake rates
- Annual thoron exposure rates

4.1 ANNUAL EXTERNAL EXPOSURE RATES

The revised template provides the following information:

> *Individual external monitoring data is* [sic] *not readily available during the residual period.* ***A limited amount of air dust results during the operational period (SRDB RefID 10412, 32669, 32687, 78700, 78702, 78720, 78722, 78724, and 78725)****. The 95th percentile of the gross alpha air dust results was calculated to estimate the contamination levels for the start of the residual period (**1958**) through the decontamination and decommissioning of AEC equipment and materials (**1962**). It is assumed that the material deposited on the floor with a deposition velocity of 0.00075 m/s for a period of one year without cleanup and then remained at that level of contamination for the duration of operations and through the cleanup done in 1962. This would be a* ***contamination level of*** $\boldsymbol{1.83\times10^{6}}$ ***dpm/m***$^{\boldsymbol{2}}$*. Using these assumptions, the daily doses can be calculated based on the maximizing potential radionuclide.* [emphasis added]

<u>SC&A's Comments</u>

In an attempt to verify the derived surface contamination level at the 95th level of 1.83×10^6 disintegrations per minute per square meter (dpm/m^2), SC&A reviewed the above-cited Site Research Database (SRDB) references for data pertaining to air monitoring data for uranium and thoron. Based on the exact wording above, all nine referenced documents would be expected to contain air monitoring data from the operational period prior to 1958.

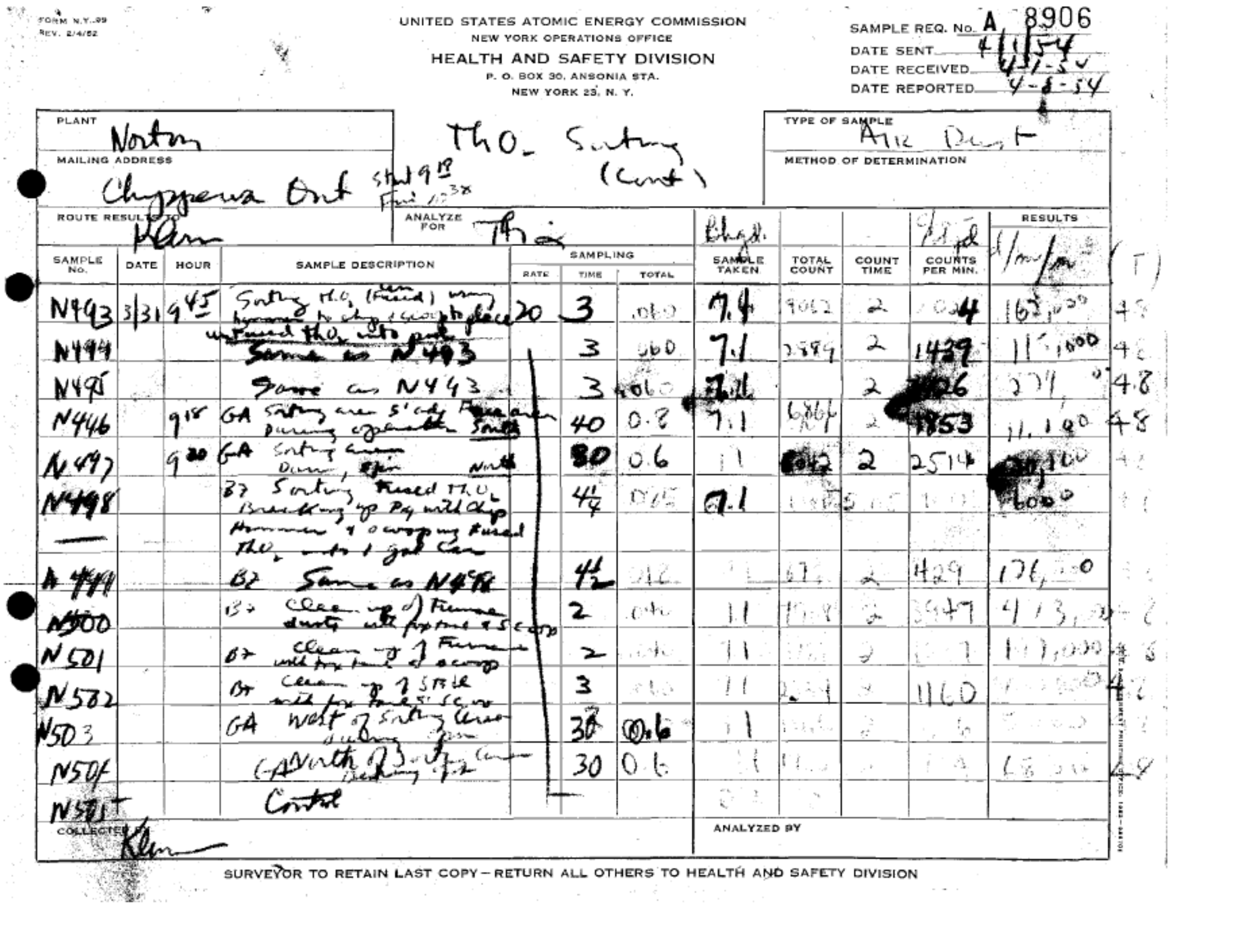
4.1.1 Summary of Operational Survey Data

SC&A's review of the nine documents, however, shows that only *four* documents (i.e., SRBD Ref. IDs 10412, 78702, 78720, and 78725) contain survey data taken prior to 1958 during the operational period.

<u>SRDB Ref. ID 10412</u> (AEC 1957) contains a total of twelve handwritten survey sheets representing about 70 air samples. A significant fraction of samples indicate high alpha air concentrations greater than 100,000 dpm/m^3. However, due to the poor quality of these handwritten air survey measurements, a quantitative assessment of these data is not possible.

For illustration, Figure 1 identifies 12 "air dust" samples taken on March 31, 1954, in areas where ThO_2 sorting was performed. While some of the data are legible, other are not.

Figure 1. Air Dust Samples Taken March 31, 1954
(Source: AEC 1957; SRDB Ref. ID 10412)


FORM N.Y.-99
REV. 2/4/52

UNITED STATES ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS OFFICE
HEALTH AND SAFETY DIVISION
P. O. BOX 30, ANSONIA STA.
NEW YORK 23, N. Y.

SAMPLE REQ. No. A 8906
DATE SENT 4/1/54
DATE RECEIVED
DATE REPORTED 4-8-54

PLANT Norton
MAILING ADDRESS Chippewa Ont
TYPE OF SAMPLE Air Dust
METHOD OF DETERMINATION
ROUTE RESULTS TO
ANALYZE FOR

SAMPLE No.	DATE	HOUR	SAMPLE DESCRIPTION	RATE	TIME	TOTAL	SAMPLE TAKEN	TOTAL COUNT	COUNT TIME	COUNTS PER MIN.	RESULTS
N493	3/31	9 45	[illegible]	20	3	.060	7.4	4062	2	2024	[illegible]
N494			Same as N493		3	.060	7.1	[illegible]	2	1439	[illegible]
N495			Same as N493		3	.060	[illegible]		2	[illegible]	[illegible]
N496		9 18	[illegible]		40	0.8	[illegible]	[illegible]	2	[illegible]	[illegible]
N497		9 30	[illegible]		30	0.6	[illegible]	[illegible]	2	2514	[illegible]
N498			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N499			Same as N498		[illegible]	[illegible]	[illegible]	[illegible]	2	429	[illegible]
N500			[illegible]		2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N501			[illegible]		2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N502			[illegible]		3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N503			[illegible]		30	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N504			[illegible]		30	0.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N505			Control								

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Among the legible samples shown in Figure 1 is the first sample, N493, which involves the sorting of ThO_2 and represents the following information:

- Air sampling rate: 20 liters/minute
- Air sampling time: 3 minutes
- Total volume of air sample: 0.06 m^3
- Background α counts: 7.4 counts per minute (cpm/min)
- Total sample count for 2 minutes: 4,062 counts/0.06 m^3
- Total net sample count rate: 2,024 cpm/0.06 m^3
- Total net sample count rate per m^3: 33,733 cpm
- Counting efficiency: 4.8 dpm/cpm

Air concentration corresponding to data for Sample N493	= 61,918 dpm/m^3 of air
	= 0.162×10^{-1} dpm/cm^3
Sample N493 air concentration	= 7.29×10^{-8} µCi/cm^3

Important to note is that the air concentration for Sample N493 of 7.29×10^{-8} microcuries per cubic centimeter (µCi/cm^3) (and a significant, but unknown, number of others among the ~70 air samples cited in SRDB Ref. ID 10412) are several orders of magnitude higher than air sample concentrations cited in the other eight references summarized below.

SRDB Ref. ID 78720 (dated June 1955) is a typewritten letter forwarded to the Atomic Energy Commission [AEC], which identifies two "general room" air samples with modest alpha activities of ~4.5×10^{-13} µCi/cm^3 (Harris 1955).

This letter contains survey data taken on June 3, 1955, which included two general area "air dust" samples taken in the manufacturing and research and development (R&D) facilities. These yielded air concentrations of 4.5×10^{-13} µCi/cm^3 and 4.0×10^{-13} µCi/cm^3, respectively.

SRDB Ref. ID 78725 contained subsequent survey data, which included three pairs of air samples taken in July, August, and October 1955 for the Norton Company's Manufacturing and R&D facilities. Air concentrations remained largely unchanged and ranged from 4×10^{-14} µCi/cm^3 to 5.5×10^{-13} µCi/cm^3 (Norton 1955).

SRDB Ref. ID 78702 (Elkins 1957) cites air survey data taken on July 11, 1957, near the end of the AWE operational time period. This survey identifies long-lived alpha activity levels at 14 different locations (see Figure 2). With the exclusion of air Sample 6, air concentrations within work areas ranged from 0.3×10^{-11} microcuries per milliliter (µCi/ml) to 51×10^{-11} µCi/ml, with an average value of **11.9×10^{-11} µCi/ml**.

Figure 2. Air Sampling Data Taken July 11, 1957
(Source: Elkins 1957; SRDB Ref. ID 78702)

Karl T. Benedict, M. D.
Medical Director
Norton Company
Worcester 6, Massachusetts

Dear Dr. Benedict:

The results of the air tests which were made in your plant on July 11, 1957, by Mr. Bavley, Mr. Pagnotto, and myself, are summarized in Table 1.

TABLE 1.

Sample Number	Time	Location	Alpha emitters Uc/Ml. Short-lived	Alpha emitters Uc/Ml. Long-lived
1	60 min.	Bench opposite screening box	67 x 10^{-11}	2.3 x 10^{-11}
2	82 min.	General air by magnetic separator	29 x " "	4.3 x " "
3	35 min.	Operator's exposure, inspecting fuel elements	30 x " "	2.9 x " "
4	60 min.	General air by magnetic separator	34 x " "	5.7 x " "
5	45 min.	General air beyond hood from screening box	20 x " "	0.3 x " "
6	5 min.	Inside screening box *Not important*	230 x " "	25 x " "
7	60 min.	Screening, vicinity of operator	12 x " "	0.6 x " "
8	60 min.	Screening, vicinity of operator	24 x " "	7 x " "
9	75 min.	Screening, operator's exposure	100 x " "	13 x " "
10	75 min.	Screening, operator's exposure	31 x " "	13 x " "
11	31 min.	Crushing, operator's exposure	37 x " "	51 x " "
12	31 min.	Crushing, operator's exposure	30 x " "	40 x " "
13	35 min.	Screening, operator's exposure	21 x " "	9 x " "
14	35 min.	General air, near fuel element area *Important* *exactly where? **	13 x " "	6 x " "
Important		Maximum Allowable Concentration	1000 x 10^{-11}	5 x 10^{-11}

Short exposure mask worn by operator

Please note that sample No. 3 was taken in the fuel element area. Sample no. 6 was taken inside the screen box, after operations had ceased. Sample No. 5 was in the general air on the side of the hood away from the screen box. The other samples represent conditions in the area where thoria was being screened or crushed.

These samples were taken on filter paper, and counted for alpha activity on a scintillation counter. The efficiency of the counter had been previously determined to be 24 percent.

** R. Johnson: taken at southeast corner of fuel element area at top of partition*

4.1.2 Summary Post-Operational Survey Data

Summarized below are post-1957 air dust survey data in chronological order for the remaining five documents referenced in the Norton Company template. (Note: These documents and their data are referenced below in Finding 1.)

SRDB Ref. ID 78700 (Pagnotto 1958): Conducted on May 13, 1958, this survey assessed "*the atmosphere in the areas where* ***uranium*** *and* ***thorium*** *are* ***handled***" (emphasis added) and yielded the following values for long-lived alpha emitters:

- Average of 7 thoria area samples: 0.21×10^{-11} µCi/ml
- Average of 2 uranium area samples: 0.1×10^{-11} µCi/ml
- Average of 10 screening and crushing samples: 1.1×10^{-11} µCi/ml

SRDB Ref. ID 78724 (Liberty Mutual 1958): This document cites airborne radioactivity representing two breathing zone values for [redacted] employees engaged in the following activities on [redacted] 1958:

- 1.5×10^{-11} µCi/ml for employee weighing and mixing [redacted]
- 8.2×10^{-12} µCi/ml for employee weighing [redacted] in [redacted]

SRDB Ref. ID 32669: On February 2, 1962, two effluent air samples were assessed for alpha activity along with the following explanation:

> 1. *One effluent air sample was taken from the exhaust duct discharging effluent air from **Laboratory Bench** #24181, as Thoria was being milled through a 100 mesh screen. The reading obtained was 5.0 × 10^{-11} µc/cc of air.*
>
> 2. *One effluent air sample was taken from the exhaust duct discharging air from Aeroturn Duct Collector #24528, as **Thoria was screened in the box screener**. The reading obtained was 2.5 × 10^{-12} µc/cc.* [Norton 1962; emphasis added]

SRDB Ref. ID 32687: On [redacted], 1963, a single breathing zone air sample was taken in behalf of an operator weighing and pressing [redacted]. Each brick weighed approximately 1.5 pounds. The operator's breathing zone air concentration was 9.5×10^{-13} microcuries per cubic centimeter (µc/cc) (Norton 1963).

SRDB Ref. ID 78722: On [redacted], 1964, a survey was conducted of the Thoria handling operations of the Norton Company's Industrial Building. The survey included two air samples that were identified and described as follows (Liberty Mutual 1964).

Sample 1:

> *General area, breathing zone level – sample taken of operator scooping and crushing [redacted]. Also included in this sample is screening operation which is in an enclosed and exhausted screen box.*

The air concentration was given as "*1.6 × 10^{-11} µc/cc*."

Sample 2:

> *General room area sample – North of Thoria bench #24181.*

The air concentration was given as "*5.4 × 10^{-11} µc/cc*."

Note: Based on dates and described operational activities, these five data sets do not appear to correspond to the residual period.

From air survey data assumedly contained in these nine referenced documents, NIOSH derived the 95th percentile values and applied a deposition value of 0.00075 m/s for a year in order to arrive at a surface contamination of 1.83×10^{-6} dpm/m^2 for the start of the residual period of 1962. Annual external penetrating and shallow doses were based on this initial surface contamination using the "*maximizing potential radionuclide*."

For the first year of the residual period (i.e., 1962), NIOSH identified an annual deep dose of 26 millirem (mrem) and a shallow dose of 233 mrem.

<u>SC&A's Comments and Findings</u>

The limited and ambiguous wording regarding the use of air dust samples in the nine referenced documents cited in the Norton Company template raise multiple questions about their use for defining the 95th percentile air concentration.

For example, the largest number of available air samples are those in SRDB Ref. ID 10412. Even more important is the fact that this data set includes air concentrations that are several orders of magnitude higher than those cited in any other survey documents. Unfortunately, a significant fraction of this sample set is illegible (see Figure 1).

The potential inclusion of other air samples may be inappropriate based on sample location and/or time. For example, based on location, air Sample No. 6 shown in Figure 2 above, as well as "effluent air samples" cited in SRDB Ref. ID 32669, should clearly not be included. Equally, air samples taken after 1962 (NIOSH's designated beginning of the "Residual Period"), which include air samples cited in SRDB Ref. ID 32687 and SRDB Ref. ID 78722, may not be appropriate.

In the absence of additional data, SC&A is unable to identify air dust data used by NIOSH in order to calculate the 95th percentile air concentration, which, in turn, NIOSH used to determine the starting "residual" surface contamination of 1.83×10^{-6} dpm/m^2 and the resulting external deep dose of 26 mrem/yr and shallow dose of 233 mrem/yr for 1962.

By simple back-calculation of the 1.83×10^{-6} dpm/m^2 surface contamination, NIOSH would have identified a 95th percentile air concentration of 3.48×10^{-11} µCi/cm^3, as demonstrated below:

$$\text{95th \% air concentration} = \frac{1.83 \times 10^{-6}\ dpm/m^2}{(0.00075\frac{m}{s})(3.15 \times 10^{7}\frac{s}{yr})}$$

$$= 77.372\ \text{dpm/m}^3$$

$$= 3.48 \times 10^{-11}\ \mu\text{Ci/cm}^3$$

Finding 1. There is insufficient information in the Norton Company's template for identifying critical data and parameters needed to (1) duplicate and/or (2) confirm NIOSH's model for the estimation of external deep and shallow doses starting with the residual period of 1962.

Under the template's "Time Period" and "Facility Description" sections, NIOSH states the following:

> ***Time Period:***
> *BE 1944 – 1956; AWE 1945 – 1957; Residual Radiation 1958 – 2009*
>
> ***Facility Description***
> *…Work with thorium and uranium continued through 1957 at Norton's Worcester location.*
>
> *Norton continued to manufacture refractory products until at least 1965 for the AEC weapons complex, including Rocky Flats, Hanford and Y-12. However, after 1957 these contracts specified that the refractory products were to be made out of magnesium oxide. Since magnesium oxide is not radioactive, Norton's work with it does not qualify it as an Atomic Weapons Employer for these years.*

Finding 2. Our review of the template's cited references for "air dust" survey data identifies five of the nine references containing "operational" thoria and uranium data with dates starting in 1958 and continuing through 1964 (see the preceding discussion). Operational survey data for thoria/uranium after 1957 are in contradiction with the template's designated "operational" time period that ends in 1957.

4.2 RESIDUAL PERIOD INTERNAL DOSE

NIOSH's protocol for the assignment of internal dose from the inhalation/ingestion of uranium and thorium is described as follows (NIOSH 2011a):

> *In order to determine the feasibility of bounding potential internal doses received from exposures to residual radiation received after the burial of AWE materials, NIOSH evaluated air monitoring data in the form of long-lived gross-alpha results obtained on May 13, 1958 by the Massachusetts Department of Labor and Industries (**Pagnotto, 1958**) to derive the air concentration starting on October 11, 1962 through the end of the residual radiation period, October 31, 2009. The average of the long-lived alpha results was calculated from the data shown to estimate the starting air concentration on October 11, 1962. This resulted in an air concentration of **2.96 dpm/m^3** and **4.66 dpm/m^3** for the for the uranium and thorium areas, respectively.*
>
> *Average daily intake rates for inhalation and ingestion were calculated based on an inhalation rate of 1.2 m^3/hr, 8-hour workday, and 250 workdays per year, resulting in a value of **19.463 dpm/day** for the uranium areas and **30.654 dpm/day** for the thorium areas. Intake rates for the following years through October 31, 2009 have been adjusted due to source term depletion per guidance in ORAUT-OTIB-0070. Ingestion intakes are calculated based on OCAS-TIB-009.* [emphasis added]

SC&A's Comments

The above-cited air concentrations of 2.96 dpm/m^3 and 4.66 dpm/m^3 for uranium and thorium areas, respectively, are values reported by Pagnotto (1958) and reproduced here as Figure 3.

Figure 3. Pagnotto Memo (Source: SRDB RefID 78700)

58-58 May 28, 1958

To: Dr. Elkins
From: Mr. Pagnotto and Mr. Bavley
Subject: Norton Company, Worcester
Persons Interviewed: Dr. Karl Benedict, Medical Director
Mr. Richard S. Johnson, Industrial Hygienist
Date of visit: May 13, 1958

This visit was made to check the atmosphere in the areas where uranium and thorium are handled. The results are as follows:

TABLE I

Sample Number	Time sampling completed	Location	Alpha emitters Uc/Ml. Short-Lived	Alpha emitters Uc/Ml. Long-Lived
1M	9.20	End of hood - thoria area	3.3×10^{-11}	$.04 \times 10^{-11}$
7M	2.50	End of hood - thoria area	4.0×10^{-11}	$.04 \times 10^{-11}$
13	2.50	End of hood - thoria area	3.6×10^{-11}	$.2 \times 10^{-11}$
5M	1.15	Thoria processing area	4.2×10^{-11}	$.2 \times 10^{-11}$
3	10.00	General air on bench	5.2×10^{-11}	$.2 \times 10^{-11}$
7	11.20	Hood - thoria area	4.1×10^{-11}	$.1 \times 10^{-11}$
11	2.00	Bench near thoria oven	22.6×10^{-11}	$.2 \times 10^{-11}$
14	2.50	By glass cutting wheel	3.1×10^{-11}	$.7 \times 10^{-11}$
		Average - thoria area samples	6.2×10^{-11}	$.2 \times 10^{-11}$
3M	10.40	Uranium pressing	2.3×10^{-11}	$.1 \times 10^{-11}$
4M	11.70	Laboratory hood area	$.2 \times 10^{-11}$	.00
6M	2.00	Near kiln 140, uranium area	4.8×10^{-11}	$.1 \times 10^{-11}$
		Average - uranium area	2.6×10^{-11}	$.1 \times 10^{-11}$
10	1.15	Bench, among thoria castings	54.3×10^{-11}	$.3 \times 10^{-11}$
1	9.70	Operator's exposure crushing	5.6×10^{-11}	$.9 \times 10^{-11}$
2	9.70	Operator's exposure crushing	4.2×10^{-11}	$.6 \times 10^{-11}$
2M	10.00	Operator's exposure crushing	5.2×10^{-11}	1.4×10^{-11}
4	10.00	Operator's exposure crushing	4.1×10^{-11}	$.3 \times 10^{-11}$
5	10.40	Operator's exposure screening	4.7×10^{-11}	$.8 \times 10^{-11}$
6	10.40	Operator's exposure screening	4.4×10^{-11}	$.9 \times 10^{-11}$
8	11.70	Operator's exposure crushing	5.0×10^{-11}	2.2×10^{-11}

Figure 3 shows that for the eight thoria air samples, the average air concentration for long-lived alpha emitters was 0.21×10^{-11} µCi/ml. This converts to an air concentration of 4.66 dpm/m^3 with a corresponding daily inhalation value of 30.654 dpm/day for thorium.

For uranium air samples, Figure 3 identifies three sample locations (by numbers 3M, 4M, and 6M) with long-lived alpha activities of 0.1×10^{-11} µCi/ml, 0.00×10^{-11} µCi/ml, and 0.1×10^{-11} µCi/ml, respectively. The average air concentration value for the three uranium air samples is

0.067×10^{-11} µCi/ml, which converts to the air concentration of 1.49 dpm/m^3 and a daily inhalation values of 9.80 dpm/day for uranium.

Finding 3. While SC&A's 1962–1963 air concentration and daily intake values for thorium match those derived by NIOSH, corresponding values for uranium derived by SC&A are a factor of two lower than values derived/assigned for uranium air concentration and intakes.

Note: SC&A realizes that the authors of this survey ignored the "0.00×10^{-11} µCi/ml" value of sample No. 4M and derived the average value of 0.1×10^{-11} µCi/ml based only on samples 3M and 6M. However, NIOSH's value of 0.1×10^{-11} µCi/ml is still in error. (For Pagnotto's average value of 0.1×10^{-11} µCi/ml, the correct air concentration corresponds to 2.22 dpm/m^3.)

4.3 ANNUAL THORON EXPOSURE RATES

For deriving potential inhalation exposure to thoron gas, NIOSH provided the following explanation in the revised Norton Company template:

> *NIOSH does not consider radon as an exposure source, as Norton Co. only had uranium metals and associated dust onsite. NIOSH has identified thoron monitoring data in the form of short-lived thoria results obtained on* ***May 13, 1958 (Pagnotto, 1958)****.* ***NIOSH used the reported average short-lived values as actual values of thoron, as provided in Table 7-3*** *to calculate the intake rate of thoron from the end of the burial operation through December 31, 1963. Working level months (WLM) were calculated for each result and for the average of the reported short-lived results. Intake rates for the following years have been adjusted due to source term depletion as described above.* [emphasis added]

The above reference to the "*reported average short-lived values as actual values for thoron as provided in Table 7-3*" is puzzling because there is no Table 7.3 in the revised template. However, SC&A concluded that this value refers to the average of the eight short-lived alpha emitters identified as samples numbers 1M, 7M, 13, 5M, 3, 7, 11, and 14 in Figure 3.

Thus, NIOSH assumed a thoron air concentration value of 6.26×10^{-11} µCi/ml as a starting air concentration in 1962. By means of this air concentration value, NIOSH derived a yearly thoron exposure rate of 0.0932 WLMs for the first year of the residual period (1962–1963). No further explanation or data were provided in deriving this value.

SC&A Comments/Findings

SC&A derived the working level (WL) of thoron based on first principles. By definition, a WL is defined as any combination of short-lived radon or thoron decay products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 mega-electron volts (MeV) of potential alpha energy. For thoron, short-lived daughters include polonium-216 (Po-216), lead-212 (Pb-212), bismuth-212 (Bi-212), and Po-212. The assessment of total potential alpha energy that may be released requires the determination of the total number of atoms for each of the short-lived daughters (that are assumed to exist in full equilibrium with thoron) and are assumed herein to have a concentration of 6.26×10^{-11} µCi/ml or 6.26×10^{-2} picocuries per liter (pCi/L). Table 1 summarizes the calculation that converts the assumed thoron concentration of 6.26×10^{-11} µCi/ml to the potential alpha energy of 1105.4 MeV per liter of air. This implies that, for thorium-220 (in secular equilibrium with its short-lived daughters), a WL corresponds to a concentration of 7.4 pCi/L. The potential alpha energy of 1105.4 MeV per liter of air corresponds to 8.50×10^{-3} WL and for a 2,000-hour per year exposure yields an annual thoron exposure of 0.100 WLM. SC&A's value of 0.100 WLM is virtually identical to NIOSH's derived value of 0.0982 WLM.

Applying first principles, SC&A matched NIOSH's calculation of potential thoron exposures during the residual period at the Norton Company. There are no findings associated with assigned exposures to thoron.

Table 1. Estimate of Thoron Working Level for Year 1962

Nuclide	Half-life	No. of Atoms per 6.26×10^{-2} pCi/L	Potential Alpha Energy (MeV per Atom)	Total Potential Energy (MeV/6.26×10^{-2} pCi)
Po-216	0.158 sec	~ 0	14.8*	~ 0
Pb-212	10.64 hours	127.8	7.9**	1009.5
Bi-212	60.6 min	12.2	7.9**	95.9
Po-212	3×10^{-7} sec	~ 0	8.78	~ 0

* 14.8 MeV is the combined α energy of 6.9 MeV for Po-216.
** 7.9 MeV is the weighted sum of the α decay energy of Bi-212 and Po-212:
(0.337)(6.206 MeV) + (0.663)(8.78 MeV) = 6.9 MeV

5.0 SUBTASK 3: EVALUATE THE PER'S STATED APPROACH FOR IDENTIFYING THE UNIVERSE OF POTENTIALLY AFFECTED DOSE RECONSTRUCTIONS

Selection of cases requiring reevaluation of dose by NIOSH was based on the following criteria:

- A total of 54 previously completed claims with POC values ≤50% were identified for further evaluation.
- Nine of the 54 claims had employment periods that were confined to years prior to 1962 and were therefore not impacted by PER-059.
- Two additional claims were removed: one claim had recently been completed using the revised template and the other had been returned by DOL and was reevaluated by NIOSH as required by PER-059.
- The remaining 43 claims have been reevaluated by NIOSH in accordance with the revised Norton Company template and all applicable/approved dose reconstruction protocols. All 43 revised dose reconstruction yielded POC values of below 45%.

SC&A's Comments

SC&A concurs with NIOSH's selection criteria for defining the 43 claims requiring reevaluation of dose. There are no findings under Subtask 3.

6.0 SUBTASK 4: CONDUCT AUDITS OF A SAMPLE SET OF DOSE RECONSTRUCTIONS AFFECTED BY DCAS-PER-059

SC&A's assessment suggests that the impact of DCAS-PER-059 and the implementation of DR under the revised template issued September 16, 2011, involves assignment of the template-prescribed annual values for (1) external doses and (2) internal intake rates for uranium, thorium, and thoron for each year of employment after 1961.

Pending the resolution of Findings 1, 2, and 3, and given the template's prescriptive assignments of external doses and internal intakes for each specific year of employment post-1961, SC&A recommends that only a single claim from among the 43 cases be selected for audit.

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