Draft White Paper

REVIEW OF PROPOSED NIOSH METHODS FOR RECONSTRUCTING THORIUM DOSES AT FERNALD (1979–2006)

Contract No. 211-2014-58081
Revision 0

Prepared by

Bob Barton
Joyce Lipsztein
S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, VA 22182

November 2014

S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No.: Review of NIOSH Thorium Reconstruction Methods Effective Date: Draft – November 24, 2014 Revision No.: 0 (Draft)
Review of Proposed NIOSH Methods for Reconstructing Thorium Doses at Fernald (1979–2006)	Page 2 of 50
Task Manager: ________________________ Date: ________ John Stiver, MS, CHP	Supersedes: N/A
Project Manager: ________________________ Date: ________ John Stiver, MS, CHP	Reviewers: John Stiver

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	11/24/2014	Initial issue

TABLE OF CONTENTS

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

Advisory Board or ABRWH	Advisory Board on Radiation and Worker Health
BZ	breathing zone
CATI	Computer-Assisted Telephone Interview
DAC	derived air concentration
DCAL	Dose and Risk Calculation Software
DL	detection limit
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
FERMCO	Fernald Environmental Restoration Management Corporation
FMPC	Feed Materials Production Center
H&S	Health and Safety
HEPA	high efficiency particulate air
ITO	industrial truck operator
IVEC	In Vivo Examination Center
kg	kilogram
LANL	Los Alamos National Laboratory
MDA	minimum detectable activity; minimum detectable amount
µCi/ml	microcurie per milliliter
MIVRML	Mobile In-Vivo Radiation Monitoring Laboratory
mrem	millirem
MT	Metric Tons
nCi	nanocuries
ND	not detected
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH/OCAS Claims Tracking System
OCAS	Office of Compensation Analysis and Support
OPOS	One Person – One Sample
ORAUT	Oak Ridge Associated Universities Team
PAPR	Powered Air-Purifying Respirator
pCi/g	picocuries per gram

POC	probability of causation
QA	quality assurance
RF	release fraction
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRDB	Site Research Database
TLD	thermoluminescent dosimeter
WLM	working level month

1.0 INTRODUCTION AND EXECUTIVE SUMMARY

On June 24, 2014, the National Institute for Occupational Safety and Health (NIOSH) transmitted a white paper titled, *Fernald Dose Reconstruction Methodology for the Post Special Exposure Cohort (SEC) Period, 1979–2006 Rev. 02* (NIOSH 2014a), which contains the proposed dose reconstruction methods for assigning internal thorium doses to unmonitored workers.[1] Subsequent to this, SC&A was tasked with reviewing the white paper to assess whether the proposed methods represent a plausible, sufficiently accurate and claimant-favorable approach to assigning coworker intakes. The contents of NIOSH 2014a were also presented and discussed during the Fernald Work Group meeting on September 3, 2014 (ABRWH 2014), which facilitated preliminary points of clarification regarding the coworker model.

This document presents SC&A's review of the proposed approach to assigning thorium doses in the post-Special Exposure Cohort (SEC) period (1979–2006). The dose reconstruction methods presented in NIOSH 2014a can be separated into three time periods: 1979–1989, 1990–1994, and 1995–2006. Section 2 of this report provides a summary description of the three methods presented in NIOSH 2014a to assign thorium intakes by period. Section 3 provides some additional information identified by SC&A on the historical sources of thorium exposure potential that were not necessarily discussed in NIOSH 2014a. SC&A had previously performed an evaluation of the completeness and adequacy of in vivo monitoring records in the 1979–1989 period (SC&A 2012); the salient points from that review are discussed in Section 4. Section 5 discusses the current method of interpreting thorium in vivo measurements in terms of the thorium intake analysis during the 1979–1989 period. Section 6 reviews the proposed method of assigning unmonitored thorium intakes based on predefined worker job types and includes a review of a number of sampled claimants who might be affected. Sections 7 and 8 review the proposed dose reconstruction methods for after 1989 which include the use of the derived air concentration (DAC) in place in the 1990–1994 period, as well as the use of worker breathing zone (BZ) samples from 1995–2006, respectively.

Based on SC&A's review, the following seven findings were noted:

Finding 1: While it appears that the majority of the thorium exposure potential at Fernald in the post-SEC period was related to redrumming and repackaging activities, some evidence exists that small-scale handling and possibly production may have occurred after 1979. Given that it is currently infeasible to identify which workers were involved in these operations and potentially exposed, and by extension whether those workers were properly monitored, NIOSH should assign unmonitored thorium intakes for all workers who may have entered radiological areas and been exposed to thorium materials.

Finding 2: Given that the monitoring program does not appear to be directly focused on areas where thorium exposure potential existed, coupled with the inability to effectively identify which workers may have handled thorium materials, NIOSH should instruct the dose reconstructors to assign the 95th percentile coworker intake value to all unmonitored claimants who may have been directly involved in thorium operations.

[1] Coworker dose assessment is only proposed through 1994 in NIOSH 2014a; after this time, only monitored worker doses are reconstructed.

Finding 3: Given the broad work locations and duties contained among worker job types not currently defined as a thorium worker in NIOSH 2014a, NIOSH should provide explicit instructions to the dose reconstructor that thorium coworker intakes should be assigned unless sufficient evidence exists that the claimant did not enter radiological areas where thorium exposure potential may have existed.

Finding 4: Unless sufficient evidence exists that thorium exposure potential at Fernald was restricted to solubility class "W," NIOSH should consider using the more conservative and claimant favorable DAC value for solubility class "Y."

Finding 5: NIOSH should not restrict the assignment of thorium intakes to workers who submitted pre-employment fecal samples, but rather assign intakes based on the potential for radiological exposure (see discussion in Section 6).

Finding 6: The underlying assumptions employed in NIOSH 2014a to reconstruct doses to thoron appear to be arbitrary and are not well established or referenced. The assumptions concerning thorium source term inventory, release fraction, equilibrium factor, occupancy time, and specific activity of thoron should be more carefully defined based on credible documentation and site specific records.

Finding 7: It is necessary that NIOSH evaluate the thoron/thoron daughters' exposures due to Ra-228. Independent of the time assumed after separation, it is necessary to evaluate whether workers could have worked in areas where Ra-228 was handled or stored and consider the associated thoron exposures. As stated on page 105 of NIOSH 2014a, Ra-228 has a half–life long enough to permit its presence in the workplace for years independent of the original parent isotope (Th-232).

In addition, during the course of this review, SC&A documented the following seven observations:

Observation 1: It appears that the monitoring program was focused towards job categories that had the highest exposure potential, as evidenced by the large proportion of in vivo results attributed to chemical operators.

Observation 2: Workers who registered above MDA results for either Pb-212 or Ac-228 were resampled approximately 10 times faster than workers who had results below the MDA.

Observation 3: SC&A agrees with the following claimant-favorable assumptions presented in NIOSH 2014a: triple separation of thorium; adjustment for bias on the chest counts of Ac-228 and Pb-212; Pb-212 monitoring results should be used to calculate thorium intakes; and chest counts with a high Ac-228:Pb-212 ratio (greater than 1.5:1) be interpreted as intakes of a mixture of triple-separated thorium and unsupported Ra-228.

Observation 4: Given that discussions related to the method for analyzing coworker data are ongoing, a complete review of the in vivo coworker analysis is inappropriate until the time-weighted OPOS methodology is accepted by the Advisory Board.

Observation 5: Based on the review of the DOE records, CATI Reports, and associated job descriptions of 22 unmonitored claimant records, it is highly unlikely that the workers would have been continually exposed to airborne thorium levels above 10% of the DAC for the entire duration of their employment in the 1990–1994 period.

Observation 6: NIOSH should cite the aforementioned review and/or provide additional discussion of the underlying evidence that BL-13, BL-65, Cell 8, KS-65 and RT-210 are representative of thorium material.

Observation 7: It is not immediately clear what the temporal criteria was for collecting and analyzing breathing zone samples; however, it is evident that they were not necessarily collected on a daily basis. One likely possibility is that the breathing zone sample was measured over longer periods of time. However, documentation or other evidence should be provided to sufficiently establish that the breathing zone data are complete and represent comprehensive monitoring for thorium activities.

2.0 PROPOSED APPROACH FOR RECONSTRUCTION OF THORIUM INTERNAL DOSES

It should be noted that prior to 1979, it was determined that reconstruction of internal thorium doses was infeasible and therefore two separate SECs were recommended by the Advisory Board on Radiation and Worker Health on May 29, 2012 (ABRWH 2012) and August, 28, 2013 (ABRWH 2013b). The internal thorium dose reconstruction methods for unmonitored workers post-1978 can effectively be split into three time periods: 1979–1989, 1990–1994, and 1995–2006. These three time periods delineate different approaches to assigning doses to both monitored and unmonitored workers. An unnumbered table contained on pages 12 and 13 of NIOSH 2014a (presented here as Table 1) summarizes the proposed methods for thorium dose assignment.

Table 1. Internal Thorium Dose Reconstruction Methods by Time Period

Timeframe	In Vivo Data Exist (Yes/No)	Evaluation Method	Source/Basis
1979–1994	Yes	In Vivo Results	[a]LaBone documents
1979–1989	No	Coworker Data	[b]Thorium In Vivo Coworker Study
1990–1994	No	10% Th-232 Class W DAC	[c]Thorium Inh/Ing intake from air limit calculation (DOE 5480.11 & Project 2 documentation)
1995–2006	Yes - may use to decide if in vivo results reflect a lung burden that had been previously identified from earlier exposure. Positive in vivo is used in place of negative BZ results unless it is an artifact of an earlier detected lung burden. For in vivo results below MDA use BZ results. No – use BZ data	BZ Air Monitoring results	10 CFR 835 compliance and thorium bioassay technology shortfall (SRDB Ref ID: 3545 & HIS-20 database)

a Evaluation of Fernald Ac-228/Pb-212 Chest Count Data, 04/18/2013; Activity Ratios for various types of Thorium, 06/21/2013; Approximate Evaluation of Pb-212 Chests Counts Following Intakes of Thorium, 07/19/2013; and Using Ac-228 and Pb-212 to Measure Intakes of Th-232, 09/18/2013 (see Attachments B.1-4 of NIOSH 2014a).

b *Thorium In Vivo Coworker Study* (in development), Attachment C of NIOSH 2014A.

c Thorium Inhalation/Ingestion intake from air limit calculation, Attachment D of NIOSH 2014A.

Source: NIOSH 2014a, pp. 12 and 13.

As seen in Table 1, the prime method for reconstructing thorium doses for monitored workers is to utilize available in vivo records from 1978 through 1994. After 1994, the dose reconstructor is to use the in vivo records only if it can be established that the positive in vivo result is not a reflection of intakes occurring in the prior timeframe (1979–1994). If no in vivo results are available for a given worker, then the application of coworker intakes would be applied for the 1979–1989 period based on the available in vivo data. An overview of the in vivo data available for coworker modeling in the 1979–1989 timeframe can be found in Section 4 of this report. According to NIOSH 2014a, coworker intakes will only be applied to workers with the following job types: chemical operators, fork truck drivers, laborers, transportation laborers, operations, production workers, and maintenance personnel.

For 1990–1994, in vivo data will be used when it is available for the worker. For unmonitored workers, potential internal exposure is modeled by assuming that the given worker was exposed to airborne concentrations of thorium equal to 10% of the derived air concentration (DAC). The stated DAC value of 5×10^{-13} µCi/ml is based on Department of Energy Order 5480.11 Appendix A (DOE 1988) for Th-232 of solubility type "W." The ingestion component is estimated using OCAS 2014, which calculates ingestion based on contaminated food/drink, as well as inadvertent ingestion from the potentially contaminated hands of the worker. For each pathway, OCAS 2014 estimates the ingestion intake is 10% of the contaminant air concentration (for a combined 20%). Based on NIOSH 2014a, unmonitored thorium exposures will be applied in cases for which the worker submitted a thorium fecal sample. Specifically, NIOSH 2014A states on page 16:

> *1990–1994: Thorium workers with no in vivo results, but with pre-job fecal sample results during this employment period at Fernald are recommended to be assigned a dose based on a thorium air concentration of 5×10-14 µCi/ml (10% DAC), as a maximum potential exposure.*

It is not clear based on Table 1 and the above quote whether thorium exposures would be assigned for 1990–1994 only if pre-job fecal samples were obtained.

After 1994, NIOSH proposes to use available BZ data where available. Unmonitored workers are assumed to have not been exposed to thorium and will not be assigned a thorium coworker dose. Presumably, the unmonitored workers will be assigned ambient environmental intakes in accordance with ORAUT 2014a, Table 4-2. During the September 3, 2014, Fernald Work Group meeting, NIOSH stated the following concerning the post 1994 period (ABRWH 2014):

> MR. HINNEFELD: *And then for the, and then Fluor instituted a 100 percent BZ air sampling regimen for thorium work while they were there. But it appears to me that that wasn't fully in effect until '95 even though Fluor got there in, like, '92. The 100 percent BZ, we haven't found that it's completely 100 percent implemented until '95. So from '95 until 2006, which was site closure, everyone who worked around thorium, every person wore a BZ sampler and we do have that BZ sampling database, all the data from that. So we would propose to use the BZ sampling database for individuals from '95 to 2006.* (ABWRH 2014, pg. 70)

Table 1 indicates the following when a particular claimant has both BZ and in vivo monitoring data:

> *Positive in vivo is used in place of negative BZ results unless it is an artifact of an earlier detected lung burden. For in vivo results below MDA use BZ results.*

This was further clarified during the September 3, 2014, Work Group meeting:

> *Now, we also have in vivo data from there* [during the period from 1995–2006] *so, you know, in this case if we have positive data from in vivo it would trump negative data from BZ and vice versa, I mean, a negative in vivo, if you've got less in vivo, then you use the BZ data for the person.* – Stu Hinnefeld (ABRWH 2014, pp. 70–71)

So it appears that the method for reconstructing doses to monitored workers is to select the method (in vivo or BZ) that results in the highest thorium intake on a case-by-case basis, the only caveat being that the in vivo monitoring is discarded if it is clear that the positive lung burden is reflective of an intake that occurred before the period of interest.

NIOSH 2014a also presents methods for reconstructing doses to thoron which may have occurred during repackaging and stewardship activities at Fernald, as well as limited production activities. Table F-7 of NIOSH 2014a presents the calculated thoron exposures for 3 locations and/or activities, this table is recreated below for convenience.

Table 2. Thoron Exposure Recommendations

Time Period*	Area/Plant	WLM**/year
1977–1979	Pilot Plant	0.03
1972–1989	Storage facilities, repackaging, etc.	1.6
1972–2006	Closure Various Storage	0.5

* Note that because thoron exposures are associated with thorium exposures, they are not assigned during the thorium SEC periods, (1954–1967 and 1968–1978).

** WLM = Working Level Month

Source: NIOSH 2014a, Table F-7

In the case of thoron exposures, NIOSH does not specify a particular job category or work location in which doses should apply and states:

> *The dates and bounding levels of calculated potential exposures represent recorded operational history. However, thorium was present on site for most of its history. For unknown work locations and time periods of concern, Dose Reconstructors should assume that thoron exposure potential existed, as a claimant favorable assumption, and assign thoron doses based on the guidance from the table.* (NIOSH 2014a, pg. 19)

3.0 ADDITIONAL INFORMATION ON THORIUM PROCESSING/PRODUCTION ACTIVITIES POST-1979

The section titled "Post Production Thorium Activities" in NIOSH 2014A provides a detailed description of the types of activities involving thorium post-1979. Attachment A of that same report also provides an annotated timeline of thorium-related activities beginning with the cessation of production activities. Specifically, NIOSH 2014A notes:

> *An inventory of thorium production orders shows that there were no orders after 1985 and only a few from 1979–1985. It is likely that most or all of these production orders involved just taking stored material out of the warehouse and shipping it to a customer.*

A summary of these production orders is listed in Attachment 3 of Bonfer 1988 and is presented in Table 3:

Table 3. Excerpt from Bonfer 1988 Listing Thorium Production Orders Post-1979

Production Order Number	Description	Date Order Issued	Date Completed
D-649	ThO_2 for Sandia	5/15/1981	Unknown
D-650	ThO_2 – Los Alamos	5/15/1981	Unknown
D-651	ThO_2 to Lawrence Livermore	5/18/1981	Unknown
D-656	ThO_2 Powder to Public Service of Colorado	10/27/1981	Unknown
D-659	ThO_2 to Sandia (Bettis Material)	1/15/1982	Unknown
D-660	ThO_2 Samples (Bettis Material) Public Service of Colorado	1/26/1982	Unknown
D-661	Surplus Bettis Oxide (9 lots) to Public Services of Colorado	3/11/1982	Unknown
D-663 (RI)	Thorium Oxide for EG&G, Idaho	9/24/1982	Unknown
D-667	Th to LANL (150 kg.)	8/23/1982	Unknown
D-668	ThO_2 for LANL (1,000 kg.)	9/24/1982	Unknown
D-713	ThO_2 samples for PCC[2]	11/19/1984	Unknown
D-714	ThO_2 Samples for MEI[1]	11/19/1984	Unknown
M-572	ThO_2 for Precision Castparts Corp.	Unknown	4/9/1985
M573	Thoria for 3M Co.	Unknown	6/14/1985
M-574	Thorium Nitrate for 3M Co.	Unknown	8/15/1985

Interestingly, the completion dates on the majority of the orders shown in Table 3 are unknown, as the source document simply leaves that column blank. During the September 3, 2014, Fernald Work Group meeting, production operations were described by NIOSH as follows:

> Mr. Hinnefeld: *There were a handful of task orders. When you talk about thorium work, there were a handful of task orders after 1979 up through maybe '85 or so, not very many. But those appear to be small amounts to a particular customer and I believe what was going on there was they were taking material out of storage. Some of the stuff was good-quality product, thorium oxide that had been made for shipping or for their thorium reactor but had never been sent. It*

[2] Unclear what "MEI" and "PCC" represent, though it is likely they are commercial facilities.

> *was good quality and well packaged. Those containers held up fine.* (ABRWH 2014)

SC&A identified additional information concerning the sale of thorium materials to Public Service of Colorado in 1982 (see items D-660 and D-661 in Table 3). The sale was described in a late 1985 report as follows:

> *Principal customers* [for thorium material] *included government laboratories for refractory development, fuels, and other applications, Public Service of Colorado for fuel production by General Atomics, the development of casting refractories. The largest sale, 6.76 MT, occurred in 1982 when surplus Bettis ThO_2 was sold to Public Services of Colorado for a price of $27.46 per kilogram of thorium (including $4.50 for intrinsic thorium value, $15.50 for purification and oxide conversion, with the remainder for packaging, freight, depreciation, and DOE burden charges).* (Leist 1985)

Leist 1985 also contains a list of thorium sales inquiries made at Fernald for the period of interest; these are presented in Attachment 1 of this report. Furthermore, the *FY-1985 Issue Environmental, Safety and Health Plan* (Rixner 1984) described plans for more significant thorium processing work:

> *A total of 423.6 MT Th high-grade residues and impure thoria gel will be processed to a pure dense oxide for industry needs. All processing equipment located in the Pilot Plant for purification, precipitation, drying and calcination via the sol gel process must be reactivated. Improvements will be needed for personnel protection during the drying and calcining operations.* (Rixner 1984)

This would indicate that significant processing and production operations were planned to occur in the Pilot Plant at Fernald during this later period; however, additional information was not located. SC&A agrees that any production operations would only likely affect a very small portion of the worker population. However, given the inability to accurately identify all Fernald workers who may have been involved, significant care must be taken to assure that all potentially exposed workers are appropriately assigned thorium coworker intakes.

Finding 1: While it appears that the majority of the thorium exposure potential at Fernald in the post-SEC period was related to redrumming and repackaging activities, some evidence exists that small-scale handling and possibly production may have occurred after 1979. Given that it is currently infeasible to identify which workers were involved in these operations and potentially exposed, and by extension whether those workers were properly monitored, NIOSH should assign unmonitored thorium intakes for all workers who may have entered radiological areas and been exposed to thorium materials.

4.0 OVERVIEW OF IN VIVO RECORD COMPLETENESS AND ADEQUACY ANALYSIS (1979–1989)

On November 26, 2012, SC&A released the white paper, *Completeness and Adequacy of Thorium In-Vivo Records (1979–1989)* (SC&A 2012), which provided an in-depth review of the available in vivo records from 1979 through 1989.

SC&A 2012 was separated into 3 main sections:

1. A review of historical documentation and relevant reports to define thorium operations during the period of interest
2. An evaluation of the completeness of the available in vivo data for 1979–1988
3. An evaluation of the technical adequacy of the available thorium in vivo data

The historical information contained in Section 1 of SC&A 2012 has mainly been discussed in the previous section of this report (Section 3), and will not be duplicated here. This section summarizes SC&A's completeness analysis (item 2 above). An updated discussion of the adequacy of the thorium in vivo records (item 3) can be found in Section 5.

Table 4 shows the number of available in vivo samples by year. As seen in the table, only a small portion of the available data contained results above the minimum detectably activity (MDA).[3] As expected, the highest percentage of positive results occurred in 1979 and 1980 when the last major thorium processing campaigns ended. For all other years, nearly 95% of the available data was below the assumed MDA.

Table 4. Overview of Available In Vivo Data 1979–1988

Year	# Samples	# Samples with both Ac and Pb Results above the MDA[3]	# Samples with Only the Ac Result above the MDA[3]	# Samples with Only the Pb Result above the MDA[3]	# Samples with no Results above the MDA[3]
1979	177	26 (14.7%)	4 (2.3%)	2 (1.1%)	145 (81.9%)
1980	188	13 (6.9%)	14 (7.4%)	1 (0.5%)	160 (85.1%)
1981	141	8 (5.7%)	3 (2.1%)	1 (0.7%)	129 (91.5%)
1982	180	8 (4.4%)	1 (0.6%)	5 (2.8%)	166 (92.2%)
1983	169	4 (2.4%)	1 (0.6%)	1 (0.6%)	163 (96.4%)
1984	371	9 (2.4%)	3 (0.8%)	0 (0.0%)	359 (96.8%)
1985	382	2 (0.5%)	3 (0.8%)	4 (1.0%)	373 (97.6%)
1986	463	4 (0.9%)	2 (0.4%)	5 (1.1%)	452 (97.6%)
1987	562	4 (0.7%)	1 (0.2%)	5 (0.9%)	552 (98.2%)
1988	108	1 (0.9%)	1 (0.9%)	0 (0.0%)	106 (98.1%)
All In Vivo Data (1979–1988)	2741	79 (2.9%)	34 (1.2%)	24 (0.9%)	2604 (95.0%)

[3] The MDA for Ac-228 and Pb-212 were assumed to be 0.24 and 0.23 nCi, respectively, in accordance with SC&A 2012. Alternate detection limits were derived in Attachment B-1 of NIOSH 2014a; however, the report also notes: "For simplicity, a single DL of 0.12 nCi will be adopted for both nuclides for all years. If a minimum detectable amount (MDA) is need [sic] for dose reconstruction purposes, a value of 2DL=0.24 nCi should be used for both nuclides." (NIOSH 2014a, pg. 32)

SC&A also analyzed the available data by job type and work area; the results can be seen in Tables 5 and 6, respectively. Based on the job title analysis, it is clear that the highest proportion of in vivo results were taken for workers classified as "chemical operators" (55% of the total samples). This job category also had the highest numerical results when evaluated at the 95th percentile.

Observation 1: It appears that the monitoring program was focused towards job categories that had the highest exposure potential, as evidenced by the large proportion of in vivo results attributed to chemical operators.

Table 5. Comparison of In Vivo Results by Job Title (1979–1988)

Job Title	# of Samples (% of Total)	Magnitude of Results	
		95th Percentile* (Ac-228)	95th Percentile* (Pb-212)
Chemical Operator	1207 (55.0%)	0.387	0.330
Unknown	549 (25.0%)	0.150	0.160
Construction Trades	248 (11.3%)	0.096	0.056
Other Operator	156 (7.1%)	0.278	0.194
Millworker	141 (6.4%)	0.100	0.020
Engineer/Technician	81 (3.7%)	0.100	0.030
Supervisor	73 (3.3%)	0.186	0.200
Industrial Truck Operator (ITO)	68 (3.1%)	0.120	0.113
Laborer	59 (2.7%)	0.104	0.071
Inspection/QA	53 (2.4%)	0.084	0.050
Oiler/Degreaser	28 (1.3%)	0.097	0.070
Health and Safety	21 (1.0%)	0.090	0.260
Administrative	20 (0.9%)	0.061	0.057
Mechanic	16 (0.7%)	0.073	0.040
Security	12 (0.5%)	0.183	0.282
Laundry	10 (0.5%)	0.081	0.000

**95th percentile evaluated using Microsoft Excel's Percentile Function*

As seen in Table 6, the highest proportion of in vivo results was not generally attributable to a specific plant, with over 37% associated with "other areas."[4] This might suggest that the monitoring program was not focused on any specific area, but rather on a diverse cross section of work locations at Fernald. The Pilot Plant (where the last major thorium processing campaigns took place) exhibited the highest observed in vivo results at the 95th percentile; however, this constituted only about 4% of the observed samples. The main thorium storage facilities (Buildings 64, 65, 67, and 68, as well Plant 8 Bin and Silos) were not specifically listed for any of the in vivo results.

While the sampling criteria by work area appear somewhat ambiguous, it does not appear that in vivo monitoring for thorium was unduly biased towards plant areas with lower exposure potential. However, considering the inability to associate specific workers and monitoring results with the thorium handling and redrumming operations, it is important that any doses

[4] Locations designated as "other areas" include Administration Buildings, Safety and Health, Inspection, Garage, Laundry, Maintenance, Mechanical, Medical, Production, Quality Assurance, Security, Services, Tank Farm, Technology Area, Transport, and Water Treatment.

assigned via a coworker model properly bound the potential exposures to these unidentified workers.

Finding 2: Given that the monitoring program does not appear to be directly focused on areas where thorium exposure potential existed, coupled with the inability to effectively identify which workers may have handled thorium materials, NIOSH should instruct the dose reconstructors to assign the 95th percentile coworker intake value to all unmonitored claimants who may have been directly involved in thorium operations.

Table 6. Comparison of In Vivo Results by Plant Area (1979–1988)

Plant Area	# of Samples (% of Total)	Magnitude of Results	
		95th Percentile* Ac-228	95th Percentile* Pb-212
Other Areas	1,033 (37.7%)	0.150	0.170
Plant 5	650 (23.7%)	0.320	0.210
Plant 9	189 (6.9%)	0.146	0.086
Unknown	168 (6.1%)	0.157	0.167
Plant 6	156 (5.7%)	0.143	0.150
Plant 4	152 (5.5%)	0.230	0.180
Plant 1	111 (4.0%)	0.221	0.238
Pilot Plant	99 (3.6%)	0.355	0.305
Plant 2/3	94 (3.4%)	0.110	0.063
Plant 8	90 (3.3%)	0.136	0.121

**95th percentile evaluated using Microsoft Excel's Percentile Function*

SC&A also analyzed the number of days that elapsed between samples for the monitored worker population, the summary of which can be seen in Table 7. The average number of days between consecutive in vivo samples was 463, although the geometric mean and rank-ordered median are somewhat lower and closer to 1 year. When only positive samples (samples above the assumed MDAs for Pb-212 and Ac-228 of 0.24 and 0.23 nCi) are considered, the time elapsed between the positive result and the next result drops considerably. When considering the geometric mean and rank ordered median, the elapsed time to the next sample is approximately a factor of 10 shorter for positive samples than for samples that were less than the MDA. This indicates that workers who registered positive results were resampled much more quickly than workers who had results less than the MDA.

Observation 2: Workers who registered above MDA results for either Pb-212 or Ac-228 were resampled approximately 10 times faster than workers who had results below the MDA.

Table 7. Number of Days Elapsed for Workers with Samples Above or Below the MDA

Sample Type	Number of Days Elapsed to Next Sample		
	Arithmetic Average	Geometric Mean	Rank-Ordered Median
All Samples	463	331	377
Positive Samples	106	36	31
Samples Less than the MDA	479	364	384

5.0 SC&A REVIEW OF THE INTERPRETATION OF IN VIVO MONITORING RESULTS FOR THORIUM IN TERMS OF INTAKES

SC&A is in general agreement with NIOSH's proposed method for estimating Th-232/Th-228 intakes using Pb-212 chest count results. However, concerns had been expressed in SC&A 2012 about the relative amounts of Ac-228 and Pb-212 measured in some observed chest counts. Specifically, SC&A 2012 states:

> *SC&A agrees that the triple separation hypothesis (Th-228/Th-232=0.19) is claimant favorable, for the period 1979–1988, when Pb-212 results are used to calculate the doses. Ac-228 activities in the lung are not affected by the number of separations, but are very sensitive to the time after purification. Nonetheless, SC&A believes that the use of Pb-212 results instead of Ac-228 remains problematic. Most of the Th-232 progeny results above the MDA are for Ac-228, and in most cases Ac-228 activities are higher than the Pb-212 activities in the lung. While SC&A recognizes that the triple separation assumption is intended to mitigate some of the uncertainties associated with the Pb-212 measurements, NIOSH has not explicitly addressed this problem.*

Subsequent to SC&A 2012, NIOSH calculated an adjustment for the observed bias in the chest counts of Ac-228 and Pb-212. SC&A agrees with the adjustments for bias using a method that had previously been proposed during work group deliberations. Plots of chest burdens where both Ac-228 and Pb-212 are greater than the DL are presented in NIOSH 2012 and show that most measurements, after bias adjustments, indicate equal quantities of Ac-228 and Pb-212 in the chest (to within measurement uncertainty).

In Attachment B-2 of NIOSH 2014a, NIOSH justifies that the chest counts with a high Ac-228:Pb-212 ratio (greater than 1.5:1) can be interpreted as intakes of a mixture of triple-separated thorium and unsupported Ra-228. NIOSH 2014a states:

> *During the Fernald working group call on June 17, it was suggested that we should instead interpret these chest counts as being the result of intakes of some form of freshly separated thorium.*

However, SC&A believes this is a misinterpretation of the discussions during the June 17, 2013, work group meeting. It is assumed the author is referring to the quote on page 192 of the transcript (ABRWH 2013a):

> Dr. Lipsztein: *Okay. So after the production years, then we have measurements of lead and actinium. While lead-212 is very sensitive to the number of separations that the source had, immediately after the exposure, after the source is separated while actinium, it's not a fact that by the number of separations because it comes just after thorium-232 and radium, but it is very sensitive to the lag of time between measurement and separations.*

During that meeting, SC&A also stated that one plausible scenario for Ac-228 being higher than Pb-212 is to assume a long time between thorium exposures and thorium monitoring. Depending on the number of separations, Ac-228 might be higher than Pb-212 if monitoring occurs after 1 year after separation. On page 193, SC&A stated that in vivo monitoring that takes place a long time after exposure is a plausible scenario, because there is evidence that the main processing campaigns for thorium ended in 1979. Measurements for many workers could have been performed several years after separation, when Ac-228 can be expected to be higher than Pb-212. The first three plots in Attachment B-2 of NIOSH 2014a are in agreement with SC&A's position. As seen in the plots, the red line crosses the blue line (relative activity of Ac-228 becomes higher than that for Pb-212) and becomes higher some years after exposure, the time lag depending on the number of separations.

SC&A has conducted a similar study to Attachment B-2, although SC&A assumed a continuous exposure of Th-232 for 1 year (see Section 5 of SC&A 2012). The one-step separation requires 5 years for Ac activities in the body to be higher than Pb, the two-step separation requires 3 years and the three-step separation requires 1 year.

Note that the graphs in Attachment B-2 show that Pb-212 should be higher than Ac-228 if measurements occurred right after separation. This contradicts the graphs in Attachment B-1 (Appendix B) of NIOSH 2014a which contain plots of Ac-228 versus Pb-212 for various years with results >0.12 nCi. These figures show that most of the results corrected for bias show similar quantities of Ac-228 and Pb-212.

In the section "Discussion of Ac-228 and Pb-212 in Chest Counts" on page 33 of NIOSH 2014a, NIOSH states:

> *In Figure B-4, chest burdens from 1978, where both Ac-228 and Pb-212 are greater than the DL, are presented. These data are considered to be above the level of analytical noise and represent actual material in the chest.*[5] *The diagonal blue line has a slope of 1 and an intercept of 0. Data falling exactly on this line have equal quantities of Ac-228 and Pb-212. All of these measurements, except for one, are considered to indicate equal quantities of Ac-228 and Pb-212 in the chest (to within measurement uncertainty)."*

Thus on one hand, there is the hypothesis of unsupported Ra-228 present, and on the other hand, there is the hypothesis that the separation occurred a long time before the monitoring. As noted in SC&A 2012, the hypothesis of monitoring a long time after separation does not explain why many workers show results higher than the MDA at random years after the production period, without continuity.

Attachment B-3 of NIOSH 2014a suggests ways to adjust intakes and intake rates of Th-232 and Th-228 calculated from Pb-212 chest burdens, so that the intakes and intake rates will not underestimate those calculated with exact methods using the Dose and Risk Calculation Software (DCAL). Attachment B-4 discusses the use of Ac-228 and Pb-212 to measure intakes of thorium. SC&A agrees with most statements in this attachment.

Observation 3: SC&A agrees with the following claimant-favorable assumptions presented in NIOSH 2014a: triple separation of thorium; adjustment for bias on the chest counts of Ac-228 and Pb-212; Pb-212 monitoring results should be used to calculate thorium intakes; and chest

---

[5] If one looks at the Ac-228 to Pb-212 ratio and includes results that are basically noise, one can expect to see quite a range of ratios beyond the anticipated 1:1 that will be very difficult to interpret in a meaningful way.

counts with a high Ac-228:Pb-212 ratio (greater than 1.5:1) be interpreted as intakes of a mixture of triple-separated thorium and unsupported Ra-228.

In addition to NIOSH 2014a, coworker intakes were evaluated in a companion document: *1979–1989 Thorium In Vivo Coworker Study for Fernald – A Proposed Attachment for ORAUT-TKBS-0017-5 Rev. 2* (NIOSH 2014b). Sections 1 and 2 of this document summarize important information already contained in the NIOSH 2014a. Section 3 of NIOSH 2014b states:

> *…those workers with the highest uranium and thorium exposure potential would be counted most frequently and those with virtually no exposure potential would not be routinely counted at all.*

While SC&A did find that workers with positive lead and actinium in vivo results were generally recounted quicker than workers with no positive result, monitoring data for the SEC period has shown that many times workers were probably selected for monitoring based on uranium exposure potential. Many workers that were repeatedly monitored presented high U-235 lung burdens, while their Pb-212 results were below DLs. Table 8 shows a few examples of monitoring results with high U-235 chest counts.

Table 8. Examples of In Vivo Monitoring Results in nCi with High U-235 Chest Burdens

Worker	Date	U-235	U	Pb-212
A	6/11/1979	40	15.4	0.1
A	10/8/1979	67	17.2	0.1
B	3/20/1979	73	13.6	0.02
B	10/15/1979	132	15.4	0.04
C	3/26/1979	107	11.8	0.1
C	10/8/1979	34	7.6	-0.1
D	1/2/1979	36	16.6	0.1
D	3/12/1979	90	45.8	
D	10/8/1979	57	15.3	-0.01
D	12/19/1979	17	27.2	0.05
E	5/19/1980	47.1	2.7	-0.8
E	6/18/1980	45	3.7	-0.07
F	2/1/1980	53	6.1	-0.11
F	6/27/1980	95.8	10.8	-0.01

In Section 3.2 of NIOSH 2014b, NIOSH utilizes a time-weighted One Person – One Sample (OPOS) methodology described in ORAUT 2014b to derive the 50th and 84th percentile chest burdens of the monitored worker population. Note that at the time that this report was delivered, the time-weighted approach was still under discussion. SC&A has suggested the use of a variation of the time-weighted approach (pre-weighted) in coworker modeling (SC&A 2014).

In that document, SC&A argues that the time-weighting methodology gives a better estimate of the intake if the time-weighted OPOS is calculated using the product of the sample measurement with the number of days between that measurement and the prior sample. In addition, it is important to decide on the use of zero and negative bioassay results and on the use of results below the DL.

NIOSH has pointed out, in the June 23, 2014, white paper that if one looks at the Ac-228 to Pb-212 ratio and includes results that are basically noise, one can expect to see quite a range of ratios beyond the anticipated 1:1 that will be very difficult to interpret in a meaningful way. Despite the uncertainties, NIOSH has used results that are below the DL to calculate the time-weighted OPOS and the annual 50th percentile lung burden for the monitored worker population. An overview of the time-weighted OPOS in relation to the presumed detection limit is reproduced in Table 9.

Table 9. 50th Percentile Time-Weighted OPOS Compared to the Pb-212 Detection Levels Given in NIOSH 2014a

Year	Effective Bioassay Date	# of Time-weighted OPOS Results	50th percentile (nCi)	DL (nCi)	84th percentile (nCi)
1979	6/30/1979	124	0.039	0.156	0.129
1980	6/30/1980	149	0.032	0.123	0.116
1981	6/30/1981	129	0.035	0.108	0.121
1982	6/30/1982	167	0.054	0.121	0.147
1983	6/30/1983	167	0.036	0.122	0.120
1984	6/30/1984	322	0.042	0.1112	0.107
1985	6/30/1985	355	0.041	0.117	0.103
1986	6/30/1986	433	0.037	0.128	0.103
1987	6/30/1987	523	0.038	0.123	0.097
1988	6/30/1988	108	0.045	0.181	0.104

Observation 4: Given that discussions related to the method for analyzing coworker data are ongoing, a complete review of the in vivo coworker analysis is inappropriate until the time-weighted OPOS methodology is accepted by the Advisory Board.

6.0 REVIEW OF JOB TITLES SELECTED FOR COWORKER INTAKE ASSIGNMENT

Page 16 of NIOSH 2014a specifies that coworker intakes are assigned to unmonitored workers with the following job designations: chemical operators, fork truck drivers, laborers, transportation laborers, operations, production workers and maintenance personnel. During the September 2014 Fernald work group meeting, the specification of who would be assigned thorium coworker intakes was further discussed; specifically, ABRWH 2014 pg. 66-68 states:

> Mr. Hinnefeld: *So for individuals then who have in vivo data, and that's a lot of people because anybody who got in vivo'ed in the mobile counter or anybody who got in vivo'ed is going to have an in vivo result. We intend to use the in vivo data and missed doses and things like that if they are a job category that could have been involved in the repackaging. And we'd be pretty encompassing about that. You figure almost anybody in operations could have done that, most anybody in maintenance. Transportation could have been involved in it. You could have safety and health people. Might have security people there. So you've got to be pretty inclusive about the kinds of people that you would include in that.* ***Even if it's only probably a small group of people who actually did the overpacking, we don't want to miss someone who should be included. So we would include in those, those people who might have been involved in some sort of exposure****."* [Emphasis added.] (ABRWH 2014, pp. 66–68)[6]

It should be noted that "health and safety" as well as "security" job classifications were not included in the original list of "thorium workers" as defined in NIOSH 2014a.

Additional discussion during the September 2014 meeting further expounded on the application of coworker doses from 1979–1994:

> Mr. Hinnefeld: *Yes. I think it's going to be a pretty wide net [of workers who would be applied thorium coworker intakes] because, you know, to avoid excluding people that should be included.*
>
> Mr. Barton: *It almost seems like it would have been better to just go from the other direction and say everybody gets it unless you were clearly an administrative worker, that kind of thing, because I mean --*
>
> Mr. Hinnefeld: *Well, I think that's probably, I mean, we put some examples of jobs here that, and the jobs we listed were jobs that were identified I think by the training roster, right?' But I think in actuality the approach will be unless this person was clearly administrative or cafeteria worker or, you know, someone who clearly is not going to be in a process area, unless it's somebody like that, they're going to be in.*

[6] For additional discussion of job title inclusion from ABRWH 2014, please refer to Attachment 2.

Based on these statements, it appears that the list of occupations in NIOSH 2014a may not be exclusive for the purposes of coworker model application. In order to gain better understanding of the practical application of the thorium coworker model based on occupation, SC&A examined the NIOSH/OCAS Claims Tracking System (NOCTS) files of Fernald claimants for job title information in relation to potential exposures. Claimants were selected to encompass the periods of interest (1978–1994) in addition to currently being designated with a probability of causation (POC) that is less than 50% (i.e., the claimants who would be effected by the application of coworker intakes). In the following analysis, SC&A has assumed that the job classifications of "security" and "health and safety" would be included in thorium coworker assignment per the first quote from ABRWH 2014 shown above.

SC&A classified worker job titles into four main categories based on the current guidance concerning coworker intake assignment:

- Category 1 – Not likely to be assigned intakes: the job title indicates an administrative-type worker for which entrance to radioactive areas is not probable.
- Category 2 – Likely to be assigned intakes: the claimant job title qualifies as one of the aforementioned "thorium workers" (chemical operators, fork truck drivers, laborers, transportation laborers, operations, production workers, maintenance, security, health and safety personnel).
- Category 3 – Unknown: these job types generally were similar to the job types in Category 2, but did not match exactly (for example: a "dump truck driver" which is similar to a "transportation laborer"). Additionally, job types that were actually designated as "unknown."
- Category 4 – Potentially assigned intakes: job titles are such that they have the potential to enter radiological areas and incur thorium intakes, but are not specifically delineated under Category 2.

It is the fourth category that is the focus of this section, although select claims that fall into Category 3 were also examined. An overview of the number of claims that were included in each of the above categories is shown in Table 10. As shown, a little over one quarter of eligible claimants would be assigned unmonitored coworker intakes based on the current list of job titles in NIOSH 2014a (Category 2). Based on SC&A's judgment, nearly 50% of eligible claimants fall into Categories 3 and 4, where it is unclear whether coworker intakes would be assigned based on the current job title.

Table 10. Breakdown of Job Types for Claimants Employed 1979–1994 with a POC of Less than 50%

Job Type Category	Potential for Thorium Exposure	Number of Claims (% of Total)
1	Not likely	94 (24.5%)
2	Likely	108 (28.2%)
3	Unknown	25 (6.5%)
4	Potentially	156 (40.7%)

Table 11 breaks down the claimant job types that fell into Category 2 (thorium intakes assigned to unmonitored works). "Laborer/Trades" workers made up the highest portion of Category 2 claimants, with "chemical operator," "maintenance," and "health and safety" each comprising approximately 17% of the total. "Production workers" are showing no claimants; however, this is largely because these types of workers were subsumed by the other job types in Table 11, such as "chemical operator" or general "operations."

Table 11. Breakdown of Category 2 Claimants by NIOSH 2014a Job Types[7]

NIOSH 2014a Thorium Worker Types	Total Claimants (% of Total)
Chemical Operator	18 (16.7%)
Fork Lift Operator	4 (3.7%)
Laborer/Trades	27 (25.0%)
Transportation	5 (4.6%)
Operations	7 (6.5%)
Production Workers	0 (0.0%)
Maintenance	19 (17.6%)
Health and Safety	19 (17.6%)
Security	9 (8.3%)

Table 12 contains a summary of 20 claimant files that SC&A classified as part of Categories 3 or 4. As can be seen in the table, these job categories include: engineers, fire protection, technicians, analytical chemists, supervisors, inventory control, clerks, laundry, and various trades workers. Many of the sampled claimants indicated the potential for exposure to thorium in their Computer-Assisted Telephone Interview (CATI) reports. Additionally, many of the claimants who worked after 1988 were monitored via the In Vivo Examination Center (IVEC) facility, but were not monitored (or monitored sporadically) via the Mobile In-Vivo Radiation Monitoring Laboratory (MIVRML) prior to this time. Several claimant interviews also illustrate that individuals often worked in a variety of locations and capacities at Fernald, and it would be difficult to sufficiently establish that they did not enter areas where thorium exposure potential may have existed.

Finding 3: Given the broad work locations and duties contained among worker job types not currently defined as a thorium worker in NIOSH 2014a, NIOSH should provide explicit instructions to the dose reconstructor that thorium coworker intakes should be assigned unless sufficient evidence exists that the claimant did not enter radiological areas where thorium exposure potential may have existed.

[7] As noted previously, "security" and "health and safety" were not included in NIOSH 2014A, but were mentioned in ABRWH 2014.

Table 12. Survey of Claimants with Job Titles Not Currently Included in NIOSH 2014A and a POC Less than 50%

Ref #	NOCTS Job Title(s)	Employment Start	Employment End	Information Found in CATI	DOE/DOL Information
1	[Redacted] Engineer, Engineer II, [Redacted] Engineer, [Redacted] Coordinator, [Redacted] Coordinator	[Redact]/1955	[Redact]/1986	Claimant indicates potential exposure to thorium. Work locations: *"all over plant"*	No in vivo monitoring. DOL Job titles during pertinent period (1979+) [Redacted] Coordinator (1979-1984) and [Redacted] Engineer (remaining employment) Description of duties during latter part of employment is cut off.
2	[Redacted] specialist, [Redacted] specialist	[Redact]/1970	[Redact]/1993	Claimant indicates potential exposure to thorium. Worked in every building and every room Very descriptive job duties by area, notes that he performed thorium work in Pilot Plant building on a frequent basis.	MIVRML In Vivo monitoring in 1971 and 1972 (results are in mg Th). Job listed as [Redacted], Plant listed H&S IVEC monitoring results found for 1990–1995 Claimant was in [Redacted] until 1993. DOL: Affidavit from former supervisor states: *"[Redacted]."* DOL page 13 indicates worker was in the Health And Safety Department during the entire employment (specifies [Redacted] specialist only on the hire date)
	[Redacted] Specialist	[Redact]/1993	[Redact]/1995		
	[Redacted] Specialist	[Redact]/1995	[Redact]/1995		
3	Technician III (part time)	[Redact]/1974	[Redact]/1977	Claimant indicates potential exposure to thorium. Main duties described as *"analyzing uranium samples"*	No In Vivo monitoring via MIVRML In Vivo monitored in IVEC facility 5/89 (ND) NOTE from DOL: Flour Fernald defines technician duties that are closer to a radtech or health physicist (2001, see page 42) It appears all work was done in either the analytical lab or the medical department laboratory
	Technician III/technologist I (full time)	[Redact]/1977	[Redact]/1989		

Table 12. Survey of Claimants with Job Titles Not Currently Included in NIOSH 2014A and a POC Less than 50%

Ref #	NOCTS Job Title(s)	Employment Start	Employment End	Information Found in CATI	DOE/DOL Information
4	Technical Assistant/ Technologist II	[Redact]/1981	[Redact]/1989	Claimant doesn't know if they were exposed to thorium. Description of Location/Duties: *"Technical building/lab, analytical/wet chemistry side, and at times was in the plant…. During production, analyzed production samples for levels of U235. During cleanup mode, analyzed environmental samples."*	IVEC In Vivo result in August 1989 (< 0.68 nCi) NOTE: significantly higher than MDA for MIVRML
5	Lab tech, technologist III	[Redact]1957	[Redact]/1960	Claimant indicates potential exposure to thorium. Work locations were the *"spec lab"* and *"radiochem lab."* Incident in mid 1980s exposed while retrieving uranium and thorium standards which were displaced when the lab building's basement flooded. *"first part of 1980s (until production ceased),* [Redacted]. *This was in a very fine powder form which had to be weighed. They had to put the powder in capsules which were put on an instrument that mixed them. The capsules were not sealed tightly and dust would come out of them during the mixing process. This work was done on an open bench with no hood."*	Earliest in vivo results for thorium were in 1990 using the IVEC system (all results were "ND")
	Analytical chemist	[Redact]/1982	[Redact]/1996		
6	Engineer, manager of [Redacted], project engineer II	[Redact]/1983	[Redact]/1996	CATI indicates potential exposure to thorium *"They went through various buildings and* [Redacted] *in these buildings. Under this contract, he had to go into the Thorium Warehouse and this warehouse was in really poor condition... He said building 64 and 65 was the Thorium Warehouse (around 1985) this building was full, stacked three high of drums on skids."* CATI contains a very lengthy and descriptive account of duties and conditions.	Claimant was not monitored via the MIVRML IVEC In Vivo monitoring in '91, '95, and '96 (Th-232 was "ND") No breathing zone samples were available for this claimant
7	[Redacted] Supervisor, Engineer, [Redacted] Scientist	[Redact]/1984	[Redact]/2001	Claimant indicates potential exposure to thorium. Worked throughout the site, though noted most production work he was involved in occurred in Plant 5.	In Vivo MIVRML count on 6/87 (0.17 nCi, Pb-212). In Vivo by IVEC starting in 1989 and on a near yearly basis until (all were ND) Four Breathing Zone results from 1996–1998 for U-238 only DOL file states claimant was also exposed to thorium

Table 12. Survey of Claimants with Job Titles Not Currently Included in NIOSH 2014A and a POC Less than 50%

Ref #	NOCTS Job Title(s)	Employment Start	Employment End	Information Found in CATI	DOE/DOL Information
8	[Redacted] Engineer - [Redacted] Staff Engineer	[Redact]/1982	[Redact]/1989	CATI performed with survivor. Locations: Plants 2, 3, 5, 6, and 9 Duties: *"He did [Redacted] in the different plants from 1985-89. [Redacted]."*	MIVRML In Vivo in 1984 and 85 (positive Ac-228 result 0.23 nCi, recounted same day to 0.07 nCi) IVEC In Vivo result in June 1989 (Ac-228 results <1.5 to <2.7 nCi) DOL file has descriptions of exposure scenarios but not indication directly to thorium was made.
9	Pipe Fitter, [Redacted] Engineer	[Redact]/1982	[Redact]/2005	CATI indicates potential exposure to thorium. *"Claimant said while working in Building 64 where the thorium repacking project was going to take place they did not have to wear PPE; they were working right next to the drums. He said when the process began workers were not permitted to enter the area without being behind a 2 foot concrete wall and working with robotics."* Duties: Thorium Storage Tank (First Street) - they welded supports 1992 (lasted 3 months) Building 64 and 65 Thorium Repacking Project: 1991 (lasted 6 months)	No MIVRML results located. IVEC In Vivo result from 2001 (0.104 nCi, MDA listed as 0.536 nCi), 2000 (0.128 nCi, MDA 0.536), 1999 (0.247 nCi, MDA 0.557), 1998 (<0.46 nCi), 1997 (<0.47 nCi), 1994 (<0.4 nCi), 1994 (<0.85 nCi), 1992 (<1.2 nCi), 1991 (<10 nCi), 1991 (<0.9 nCi), 1991 (<1 nCi), 1990 (<1 nCi) BZ results in 1996 for U-238, no thorium DOL File states facilities worked in: "Buildings 2, 3, 5, 6, 8, 9, 13, 45, 51, 64, 65, Silos, Pilot Plant, Tank Farm and thorium tanks and service building"
10	Hazardous Waste	[Redact]/1982	[Redact]/2001	CATI performed with survivor. Locations: *"All locations as required"* Job titles: Electrician, Heating/Air Conditioning Maintenance	BZ results in 1995 and 1996 for U-238 in Plant 6 IVEC In Vivo: '90, '93-'95, '97-'01 (all "ND") MIVRML In Vivo: '84 and '86 (Pb results are negative)
11	Sheet Metal Worker	[Redact]/1981	[Redact]/1986	CATI indicates potential exposure to thorium. *"[Claimant] [Redacted]. This was during his whole time of employment."* Worked in Plants 1 and 6 during early employment period.	No MIVRML monitoring records. Monitored in the IVEC facility in 1995.
	Millwright	[Redact]/1994	[Redact]/1998		
12	[Redacted]	[Redact]/1960	[Redact]/1971	Claimant indicates potential exposure to thorium. *"[Claimant] said [Redacted] was around the Quonset hut where the thorium was stored. [Redacted] said if they were around it when it was being moved s[Redacted]would have to wear a pencil dosimeter."* *"[Claimant] said they always went in the backside and parked their bikes and went into the Pilot Plant to do different work. [Redacted] there were barium and thorium tanks in this area. [Redacted] said years later after the plant was closed down, people could not go into the area without a respirator and full protective clothing."*	Claimant was not monitored via the MIVRML Annual IVEC In Vivo monitoring beginning in 1995 through 1999. U238 BZ results cover a 1 month period in 1995
	[Redacted] Control Tech	[Redact]/1973	[Redact]/2003		

Table 12. Survey of Claimants with Job Titles Not Currently Included in NIOSH 2014A and a POC Less than 50%

Ref #	NOCTS Job Title(s)	Employment Start	Employment End	Information Found in CATI	DOE/DOL Information
13	Technician	[Redact]/1980	[Redact]/1982	*"[Survivor] said her* [Redacted] *went out in the field to gather samples"*	Claimant was monitored in June 1980 in the MIVRML.
14	Cable splicer ([Redacted])	[Redact]/1980	[Redact]/1990	Claimant indicates potential exposure to thorium. Work locations: *"All over the site, every man hole, building, closet, basement, lab, lab basement, Plant 6, K-65 Silos."* Claimant was badged every day on site. *"*[Redacted]*."*	Claimant was not monitored.
15	[Redacted] Mechanic	[Redact]/1979	[Redact]/2000	Claimant indicates potential exposure to thorium. Work Locations: *"Plant 1, 2, 3, 4, 5, 6, 9, Building 64, 65, Pilot Plant Storage, Lab Building, Laundry, Building 55"* *"He had to go into the 64 and 65 buildings to* [Redacted]*. This was a high contamination area. The truck was used to grab the barrels of thorium from Manhattan Project days."* *"He had the in-vivo/whole body counts once per year starting in the middle 1980's."*	Claimant was not monitored in the MIVRML facility. IVEC monitoring results found in '89, '94, '95, '97, and '98. U238 BZ results from April to August 1995.
16	Laboratory technician: I, II, III: laboratory technician [Redacted]: [Redacted] supervisor	[Redact]/1963	[Redact]/2001	Claimant indicates potential exposure to thorium. Worked mainly in Laboratory, Water Plant, and Advanced Waste Water Treatment. *"Urine tests were given every month. Fecal samples were required only after some specific jobs. Whole body counts and breath samples were required twice per year."*	Not monitored via MIVRML. IVEC In Vivo monitoring in 1991 and 1995 through 2001. U-238 breathing zone samples starting in 1996.
17	Insulator	[Redact]/1949	[Redact]/1950	Claimant doesn't know if they were exposed to thorium.	Claimant was not monitored.
	Insulator	[Redact]/1951	[Redact]/1964		
	Insulator	[Redact]/1966	[Redact]/1980		
18	Clerk, Clerk III, [Redacted] Clerk, Supervisor, [Redacted] Supervisor, [Redacted]Supervisor	[Redact]/1956	[Redact]/1993	CATI was declined.	Claimant was not monitored via MIVRML. Claimant monitored in the IVEC facility from 1989 to 1993.

Table 12. Survey of Claimants with Job Titles Not Currently Included in NIOSH 2014A and a POC Less than 50%

Ref #	NOCTS Job Title(s)	Employment Start	Employment End	Information Found in CATI	DOE/DOL Information
19	Manager, [Redacted], [Redacted] Rep	[Redact]/1952	[Redact]/1988	Claimant indicates potential exposure to thorium. Work location is listed as the Health and Safety Building, Administration Building, Laboratory Job duties during period of interest involved being the [Redacted] of nuclear material control. *"He opened and observed drums of U_3O_8, UO_3, UF_4, Uranium and Thorium metal and residues."*	Claimant was not monitored via In Vivo.
20	[Redacted]	[Redact]/1952	[Redact]/1993	CATI performed with survivor. Survivor does not know if they were exposed to thorium.	Claimant has MIVRML in vivo monitoring result in 1986 IVEC In Vivo monitoring in 1990, 1992 and 1993.

7.0 REVIEW OF COWORKER ASSIGNMENTS BASED ON DAC MODEL (1990–1994)

As outlined in NIOSH 2014a and summarized in Section 2, NIOSH proposes to use 10% of the derived airborne concentration (DAC) value that was in place during the 1990–1994 period. NIOSH 2014a cites the value of 5×10^{-13} µCi/ml as listed in DOE Order 4085.11 and 10 CFR 835 Appendix A (U.S. 2014) for solubility class "W." However, the DAC value for solubility class "Y" is a factor of two higher (1×10^{-12} µCi/ml).

Finding 4: Unless sufficient evidence exists that thorium exposure potential at Fernald was restricted to solubility class "W," NIOSH should consider using the more conservative and claimant favorable DAC value for solubility class "Y."

Many workers were also monitored via the IVEC facility during this time period. In order to gain insight as to the number of unmonitored but potentially exposed workers at Fernald during this time, SC&A examined the monitoring records of claimants employed during this time who had POC values less than 50%. Overall, there were 252 claimants examined during the 1990–1994 period,[8] with nearly 75% monitored via the IVEC in vivo monitoring system. There were 490 total IVEC monitoring results for these claimants, and SC&A only observed 3 results that were flagged as positive measurements.[9]

Of the 67 claimants that were unmonitored via the IVEC system in the 1990–1994 period, 45 can be considered job classifications that would have little (if any) exposure potential. These job titles include clerk, secretary, contract administrator, HR representative, computer programmer, occupational health nurse, contract attorney, mail courier, intermittent auditor, estimator, and data entry/analyst.

The remaining unmonitored claimants had job titles which potentially could have been exposed to thorium. These job titles included trades workers (laborers, maintenance, painters, iron workers, heavy equipment operators), technologist, quality assurance, health physics, and engineers. SC&A closely examined these claims for evidence of unmonitored exposure to thorium that may not be bounded by the proposed approach of assigning 10% of the DAC. Each of these 22 claims is summarized in Table 13. Some key observations from Table 13 include:

- Many claimants indicated that they worked "all over the site" during their employment (see cases 3, 4, 6, 8, 11, 12, 14, 15, and 18).
- Some cases indicated that exposure in radiological areas where thorium exposure potential existed was intermittent or non-existent (see cases 1, 2, 4, 7, 10, 12, and 16–20).
- External film badging was intermittent to non-existent in some cases, indicating the claimant did not enter radiological areas (see cases 6, 8, 11, 12, and 14–19).

[8] Claimants with less than 3 months of employment during the 1990–1994 period were not included in this analysis; there were 19 claimants out of 271 that were excluded.

[9] Curiously, the results flagged as positive (0.799, 0.46, and 0.68 nCi) were below the most commonly observed censoring level (~1.3 nCi).

- Many claimants monitored for external radiation and internal uranium exposure do not appear to have been exposed, since the film badge readings are zero and uranium urinalysis values are less than the MDA (see cases 1–7, 9, 10, 13–15, 20).
- One claimant indicated involvement in the thorium overpacking operations for approximately 1 year. This claimant stated that a respirator and two pairs of anti-contamination suits were worn. While the date of the overpacking operation is not stated, the claimant has extensive BZ samples for thorium for approximately a 1-year period from 1996–1997 (see Section 8 for more discussion of this claim).

Observation 5: Based on the review of the DOE records, CATI Reports, and associated job descriptions of 22 unmonitored claimant records, it is highly unlikely that the workers would have been continually exposed to airborne thorium levels above 10% of the DAC for the entire duration of their employment in the 1990–1994 period.

As noted in Section 2, NIOSH 2014a seems to indicate that thorium exposure to unmonitored workers would be restricted to claimants who had submitted a pre-job fecal sample, based on the quote from page 16:

> *1990–1994: Thorium workers with no in vivo results, but with pre-job fecal sample results during this employment period at Fernald are recommended to be assigned a dose based on a thorium air concentration of 5×10-14 µCi/ml (10% DAC), as a maximum potential exposure.*

However, the table on pages 12–13 of NIOSH 2014a does not delineate who is to be assigned thorium doses based on 10% of the DAC value.

Finding 5: NIOSH should not restrict the assignment of thorium intakes to workers who submitted pre-employment fecal samples, but rather assign intakes based on the potential for radiological exposure (see discussion in Section 6).

Table 13. Examination of 22 Unmonitored Claimants in the 1990–1994 Period with Occupations with the Potential for Thorium Exposure

Ref #	Job Title	Emp. Start	Emp. End	Relevant Information
1	[Redacted] Chemist	[Redact]/1993	[Redact]/1996	CATI Work Location: Lab bldg. Routine Duties: "Updated analytical procedures, -anion exchange chromatography," "Procedures for compliance with the terms of radiation work permits were implemented and followed only in the last few months of [Claimant]'s employment" External monitoring until up through 1993 (no accrued dose), IVEC monitoring in March '95 and April '96 Access Logs only indicate permission to access laboratory bldg.
2	Program Manager ([Redacted])	[Redact]/1993	[Redact]/2002	CATI report only covers prior employment at Mound. Claimant was badged but no external dose was accrued. Access logs indicate entry into radiological areas for "auditing" purposes.
3	[Redacted] Engineer	[Redact]/1994	[Redact]/2000	CATI Work Location: All areas as required. Film badged and uranium bioassayed throughout employment, no recorded dose.
4	Technologist	[Redact]/1954	[Redact]/1995	CATI Work Location: All locations as required, esp. Technical lab bldg. CATI Job 1990: [Redacted] engineer - production, 1991–1995: [Redacted] technical program specialist. No external dose accrued after 1986, all urinalysis was less than the MDA during this time.
5	[Redacted] engineer	[Redact]/1993	[Redact]/1993	CATI was declined. No external dose accrued at Fernald.
6	Insulator	[Redact]/1982	[Redact]/1990	CATI Work Location: Every building, inside and out. CATI Job Duties: "Insulated lines and other equipment indoors and outdoors: heating, ventilating and air-conditioning lines, tanks, vessels, steam lines; removed and replaced insulation" Film badge in 1990 was either "not assigned" or "not worn" for 8 of 12 months, the remaining months had zero recorded external dose. All uranium bioassay were below detection limits.
7	Health Physics Technician	[Redact]/1994	6/17/2002	CATI Job Title: "Analytical Technician" CATI Work Locations: H&S/Bioassay Lab (1994-1998), Lab Bldg (1998+, worked in clean area) No external dose accrued during employment, all uranium bioassay samples were below MDA.
8	Painter	[Redact]/1989	[Redact]/1990	CATI Work Locations: All over facility, painted inside and out. CATI and DOL files indicate claimant was badged during period but that physical employment at Fernald 1989-1990 was not constant. No internal or external monitoring during 1990.
9	Painter	[Redact]/1994	[Redact]/1994	CATI Job Duties: Painter - Did grinding on rusty surfaces, did sandblasting and spray painting. [Redacted], later in CATI report states [claimant] wore [Redacted] and wore [Redacted]. "Worked near the 2 giant silos." No external exposure accrued, all uranium bioassay were less than the MDA.

Table 13. Examination of 22 Unmonitored Claimants in the 1990–1994 Period with Occupations with the Potential for Thorium Exposure

Ref #	Job Title	Emp. Start	Emp. End	Relevant Information
10	Ironworker	[Redact]/1994	[Redact]/1994	CATI Job Duties: Water treatment plant - welding, grinding and bolting steel together. "[Claimant] was told they were working next to one building which was supposed to be the dirtiest building on the plant site." No external exposure accrued, all uranium bioassay were less than the MDA.
11	Laborer/Maso n	[Redact]/1955	[Redact]/1996	Survivor CATI Job Duties: Worked all over site. Dug holes, did brick work on silos, masonry repairs. External monitoring ended in 1991 with a total of 16 mrem assigned (shallow and deep) from 1990 to 1991. Only bioassay in period was in response to a UO3 incident in 1988.
12	[Redacted] Engineer	[Redact]/1991	[Redact]/2003	CATI Job Duties: TACOS Trailers, Security, Administration, Lab , Work Trailers by Waste Pits and Silos, cell containment areas, perimeter of production areas where things were being torn down and dug up, services building… had to walk around the site and into different areas in order to do the job. Was not assigned a film badge.
13	Ironworker	[Redact]/1989	[Redact]/1990	CATI Job Duties: Ironworker. Used a torch and welded structural steel. Wore a respirator "daily" No external dose was accrued during period, uranium bioassay was less than the MDA.
14	Laundry / painter	[Redact]/1985	[Redact]/2001	CATI Job Duties: Work all over site. Sometimes wore a respirator when "fully dressed out." In laundry - separated, washed, dried, and put clothes in bins. As i[Redacted] - went into contaminated areas, handled uranium cores using gloves. As painter - did motors, industrial painting, office work on weekends, airless spraying of roofs, hand painting or rollers, stenciled numbers on railroad cars. External film badging ends in 1992, no external dose accrued. All uranium bioassay results were below the MDA. Was monitored in both the MIVRML (June 1987) and IVEC facility (November 1989) - both results were non-detectable.
15	Welder/Iron worker	[Redact]/1988	[Redact]/1990	CATI Job Duties: All over site. Welding hand rails around pits, decking, misc. duties, erecting building. External badging was sporadic. Only monitored during June for 1990 (no dose accrued). Uranium bioassay results are less than the MDA.
16	Pipefitter	[Redact]/1991	[Redact]/1991	Had several other brief employment periods at Fernald prior to this period. CATI Job Duties: Dismantling Plants 5 and 7 (this may have occurred during 1989 when claimant was monitored). Not all jobs required [claimant] to be around radioactive materials. No external monitoring during this period (1991).
17	sheetmetal worker	[Redact]/1994	[Redact]/2001	CATI Job Duties: worked in heating/air conditioning. He would put duct work in any building as needed. He put grills and diffusers in rooms as the work progressed. He is not sure of the potential for radiation exposure. No one ever told him if he was working in radiation areas. Claimant had baseline fecal samples for Th-228, Th-230, Th-232 prior to employment start date. No external dosimetry is available; claimant stated they were badged in CATI. Records indicate claimant was terminated in May 1994. DOL records indicate he worked building a new office building "outside the fenced area"

Table 13. Examination of 22 Unmonitored Claimants in the 1990–1994 Period with Occupations with the Potential for Thorium Exposure

Ref #	Job Title	Emp. Start	Emp. End	Relevant Information
18	Electrician	[Redact]/1994	[Redact]/1994	CATI Job Duties: All over the site. Claimant notes he was probably exposed to radiation 40-50% of the time. "at the Thorium Building they had concrete barriers that were four feet thick and twelve feet high. [Redacted]. He entered the area, drilled the holes, and set the pole; he was not wearing any form of protection." Worked intermittently after 1994 as well, has several IVEC counts beginning in 1996. Claimant not monitored for external radiation during 1994.
19	Cable splicer ([Redacted])	[Redact]/1980	[Redact]/1990	From CATI: "[Redacted]." From CATI: "Some weeks he'd be out there 8 hours per day, and other days he would be there for a few hours a day." Claimant was not monitored for external or internal exposure.
20	[Redacted]/ Heavy Equipment Operator	[Redact]/1988	[Redact]/1990	CATI was declined. TLD Issue forms indicate claimant was issued temporary access to Plant 5 as an ironworker during 1990, no external dose accrued.
21	Laborer, Transportation; Motor Vehicle Operator; Locomotive/ Switchman	[Redact]/1993	[Redact]/2006	CATI Job Duties: "[Claimant] worked in the Thorium Overpack site where she remotely operated a device that would move drums around. [Redacted] had to dress out and enter the building to get an electric forklift, went over to the actual boxes they loaded the drums in (overpacks), [Redacted] put a lid on the boxes and set them in an area for the Chemical Operators to clean, then the Rad Techs came in to survey them, if they were clean they were sent out to a driver on the "clean" area on process side and then they were sent to an area to be readied to ship offsite. [Redacted]... In the Thorium Overpack [Redacted]. [Redacted]... [Redacted] always wore a full-face respirator in the Thorium Overpack area... [Redacted] had lapel monitoring done when [Redacted] was in Thorium Overpack when [Redacted] was dressed out in double sets of anti-contamination clothing." Claimant has numerous breathing zone samples for isotopic thorium from April 1996 -April 1997. External monitoring from start of employment.
22	On Site [Redacted] and Millwright	[Redact]/1988 [Redact]/1990	[Redact]/1990 [Redact]/1991	Radiation exposure investigation from May to June 1989 indicated: "worked in vicinity of thorium, but not close to the area" no other information is available including why the radiation exposure investigation took place. 10 mrem external dose was assigned (beta and gamma). Separate incident investigation a couple of months later indicates claimant wore a full face respirator.

8.0 CHARACTERIZATION AND ANALYSIS OF BREATHING ZONE SAMPLING (1995–2006)

As stated in NIOSH 2014a and summarized in Section 2, no coworker model is being proposed for the post-1994 period. Instead, the BZ results available in Fernald's electronic radiation monitoring database (known as the HIS_20), as well as relevant in vivo monitoring, will be used to reconstruct thorium exposures to individual claimants. This issue was initially discussed during the September 2014 Work Group meeting; for a transcription of the relevant discussions, refer to Attachment 2. In addition to BZ samples specifically labelled as thorium, NIOSH 2012a states:

> *In addition to isotopic thorium results in HIS-20, a review conducted in August 2013 indicated five "custom" nuclides identified as: BL-13, BL-65, CELL 8, KS-65 and RT-210.*

No direct reference was provided as to what study was conducted and how it reached its conclusions.

Observation 6: NIOSH should cite the aforementioned review and/or provide additional discussion of the underlying evidence that BL-13, BL-65, Cell 8, KS-65 and RT-210 are representative of thorium material.

Nonetheless, the thorium-related BZ samples analyzed in this section were assumed to be Th-232, Th-228, BL-13, BL-65, CELL 8, KS-65 and RT-210.[10] A breakdown of each sample type by year is shown in Table 14, and the sum of thorium BZ samples is plotted in Figure 1. Figure 2 plots the number of monitored workers per year from 1995–2006.

Table 14. Breakdown of Thorium Breathing Zone Samples by Year

Year	BL-13	BL-65	Cell 8	KS-65	Th-228	Th-232	RT-210	Total Thorium Samples
1993						5		5
1994						51		51
1995					10	1,636		1,646
1996		749			7	3,905		4,661
1997		1,346			2	910		2,258
1998		214			9	123		346
1999		688				158		846
2000		223			5	227		455
2001		418				51	57	526
2002		620			8	860		1,488
2003	85	1,002			3	2,625	240	3,955
2004	839			1,776	5	682	31	3,333
2005			2	11,625	3	40	154	11,824
2006				9633	6	9	7	9,652

[10] NIOSH 2014a also lists thorium-230 as an isotope of interest. However, thorium-230 is part of the uranium decay chain, not part of the thorium decay chain, and was therefore not considered in this report.

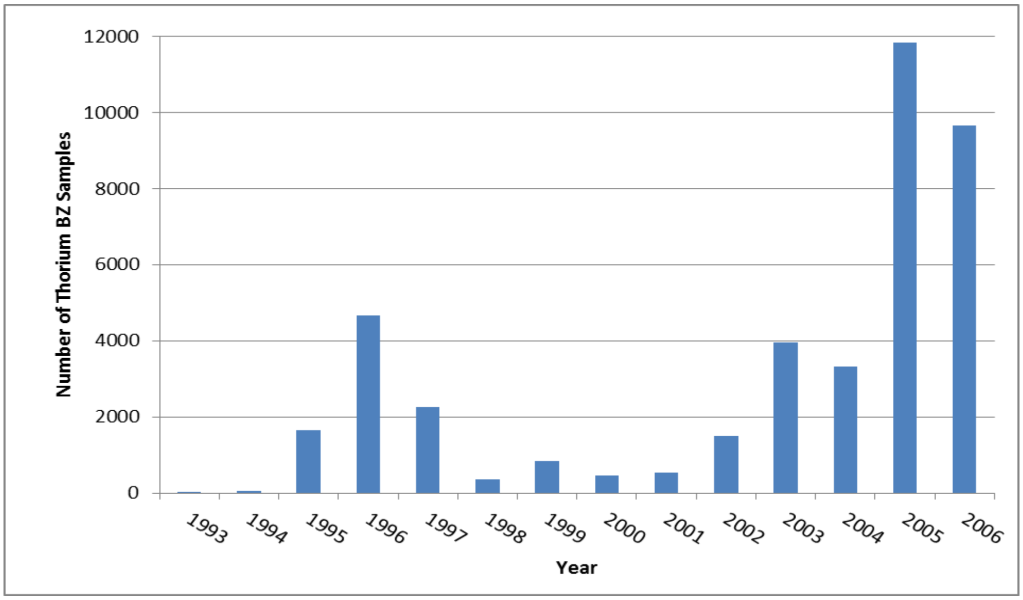

Figure 1. Total Number of Thorium Breathing Zone Samples by Year (1993–2006)

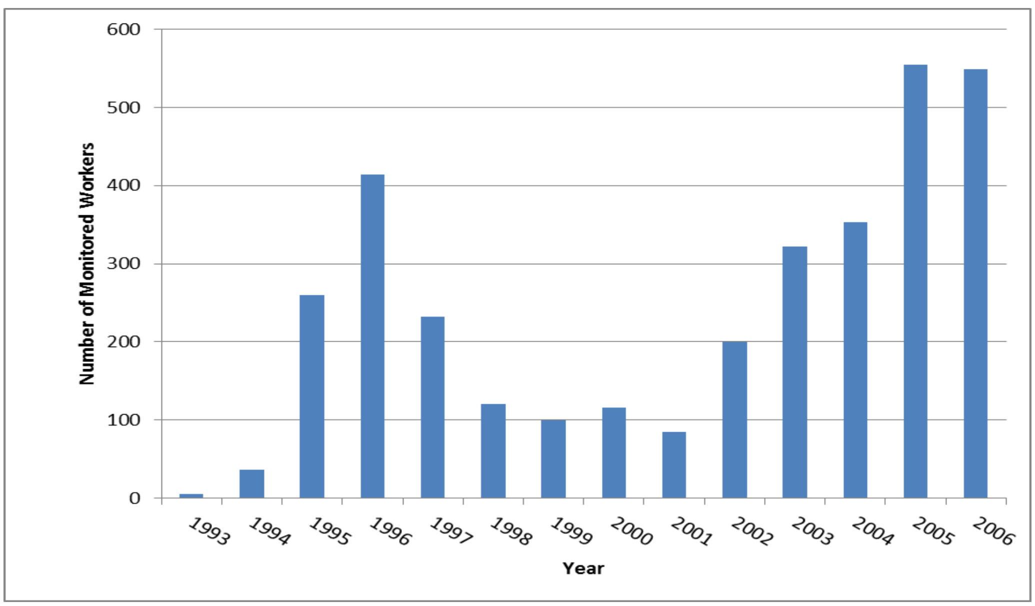

Figure 2. Total Number of Monitored Workers by Year (1993–2006)

As can be seen in Table 14 and Figure 1, very few samples exist in 1993 and 1994; however, the number of thorium BZ samples increases substantially in 1995. For most years, the thorium BZ samples were labelled “BL-65” or “Th-232.” Starting in 2004, samples labelled “KS-65” dominate the available data. Figure 2, which plots the number of monitored workers, generally mirrors the total number of samples observed in any given year.

Table 15 shows the average, median, 95th percentile, and maximum number of samples per worker per year. As seen, the maximum number of samples per worker in any given year was 200. In the period of interest, 8 of the 12 years had a maximum number of samples per worker that was less than 100. The 95th percentile number of samples was less than 100 for all years. The average number of samples was generally less than 10 with the exception of 1996, 2003, 2005, and 2006. The median number of samples per worker was always less than 10.

Table 15. Number of Samples per Monitored Worker per Year

Year	Total Workers	Average	Median	95th Percentile	Max
1993	5	1.0	1	1.0	1
1994	36	1.4	1	3.3	4
1995	260	6.3	2	31.0	68
1996	414	11.3	4	39.7	91
1997	232	9.7	2	49.5	108
1998	121	2.9	2	8.0	42
1999	100	8.5	2	42.0	76
2000	116	3.9	1	16.0	34
2001	85	6.2	2	33.2	41
2002	200	7.4	2	33.1	52
2003	353	12.3	2	61.9	200
2004	322	9.4	4	36.4	70
2005	555	21.3	6	91.0	171
2006	549	17.6	9	60.0	147

Attachment A of NIOSH 2014a provides an extensive list of thorium-related activities that took place from 1995 through 2006. It is likely that workers who were involved in such activities would perform thorium-related work until each individual project, such as thorium overpacking, was complete.

As noted in Section 7, SC&A identified a claimant who was involved in the thorium overpacking project. The CATI Report for that individual stated the following:

> [Claimant] *worked in the Thorium Overpack site where* [redacted] *remotely operated a device that would move drums around.* [Redacted] *had to dress out and enter the building to get an electric forklift, went over to the actual boxes they loaded the drums in (overpacks),* [redacted] *put a lid on the boxes and set them in an area for the Chemical Operators to clean, then the Rad Techs came in to survey them, if they were clean they were sent out to a driver on the "clean" area on process side and then they were sent to an area to be readied to ship offsite.* [Redacted]*... In the Thorium Overpack she had to wear double sets of cloth coveralls.* [Redacted] *had to wear a cloth hood...* [Redacted] *always wore a full-face respirator in the Thorium Overpack area...* [Redacted] *had lapel monitoring done when* [redacted] *was in Thorium Overpack when* [redacted] *was dressed out in double sets of anti-contamination clothing.*

Based on the worker's monitoring record, it is likely that this activity took place from May 1996 to April 1997. The BZ samples for that worker are shown in Table 16. As shown in the table, the worker has 58 BZ results that span from May 9, 1996, to April 30, 1997, which comports with the claimant's statements that they were involved in overpacking for "one year." However, it is also evident from the BZ records that samples were not taken on a daily basis or necessarily a consistent schedule.

Table 16. Breathing Zone Results for Worker Involved in Thorium Overpack Project

BZ_DATE	NUCLIDE	SOL_ CLASS	RESPIRATOR _TYPE	DAC_ HRS_ PF	MDI_ DAC_ HRS	RESP_ WORN _FLAG	DAC_ HRS_ NOPF	LOCATION	NEW_ AIR_ CONC
05/09/1996	BL-65	W	PAPR	0	0.003	Y	0.000	BLDG 65	0
05/20/1996	BL-65	W	PAPR	0	0.004	Y	0.000	BLDG 65	0
05/28/1996	BL-65	W	PAPR	0	0.003	Y	0.000	BLDG 65	0
05/31/1996	TH-232	W	None	1.154	4.317	N	1.154	BLDG 64	0
06/03/1996	BL-65	W	None	0.139	0.671	N	0.139	BLDG 64	0
06/06/1996	BL-65	W	PAPR	0.002	0.003	Y	2.000	BLDG 64	0
06/12/1996	BL-65	W	None	-0.229	1.142	N	-0.229	BLDG 64	0
06/17/1996	BL-65	W	None	0.197	0.974	N	0.197	BLDG 64	0
06/18/1996	BL-65	W	PAPR	0.001	0.003	Y	1.000	BLDG 65	0
06/20/1996	BL-65	W	None	-0.552	1.543	N	-0.552	BLDG 64	0
06/24/1996	BL-65	W	None	-0.541	1.52	N	-0.541	BLDG 64	0
06/27/1996	BL-65	W	PAPR	0.007	0.003	Y	7.000	BLDG 65	0.007
07/02/1996	BL-65	W	PAPR	0	0.003	Y	0.000	BLDG 65	0
07/10/1996	BL-65	W	PAPR	0.01	0.003	Y	10.000	BLDG 65	0.01
07/22/1996	BL-65	W	PAPR	0.004	0.003	Y	4.000	BLDG 65	0.004
07/31/1996	BL-65	W	PAPR	0.016	0.004	Y	16.000	BLDG 65	0.016
08/14/1996	BL-65	W	PAPR	0.001	0.003	Y	1.000	BLDG 65	0
08/21/1996	BL-65	W	PAPR	0.016	0.004	Y	16.000	BLDG 65	0.016
09/03/1996	BL-65	W	PAPR	0.014	0.004	Y	14.000	BLDG 65	0.014
09/12/1996	BL-65	W	PAPR	0.043	0.004	Y	43.000	BLDG 65	0.043
09/24/1996	BL-65	W	PAPR	0.03	0.003	Y	30.000	BLDG 65	0.03
09/27/1996	BL-65	W	PAPR	0.035	0.003	Y	35.000	BLDG 65	0.035
10/03/1996	BL-65	W	PAPR	0.098	0.003	Y	98.000	BLDG 65	0.098
10/15/1996	BL-65	W	PAPR	0.061	0.004	Y	61.000	BLDG 65	0.061
10/17/1996	BL-65	W	PAPR	0.048	0.002	Y	48.000	BLDG 65	0.048
10/29/1996	BL-65	W	PAPR	0.037	0.002	Y	37.000	BLDG 65	0.037
11/07/1996	BL-65	W	PAPR	0.005	0.003	Y	5.000	BLDG 65	0.005
11/20/1996	BL-65	W	PAPR	0.054	0.003	Y	54.000	BLDG 65	0.054
11/27/1996	BL-65	W	PAPR	0.066	0.002	Y	65.900	BLDG 65	0.066
12/03/1996	BL-65	W	PAPR	0.086	0.002	Y	86.000	BLDG 65	0.086
12/12/1996	BL-65	W	PAPR	0.036	0.003	Y	36.000	BLDG 65	0.036
01/08/1997	BL-65	W	PAPR	0	0.004	Y	0.000	BLDG 65	0
01/10/1997	BL-65	W	PAPR	0.134	0.003	Y	134.000	BLDG 65	0.134
01/29/1997	BL-65	W	PAPR COMBO	0.011	0.003	Y	11.477	BLDG 65	0.011
02/04/1997	BL-65	W	None	0	2.55	N	0.000	BLDG 64	0
02/07/1997	BL-65	W	PAPR HEPA	0.036	0.003	Y	36.170	BLDG 65	0.036
02/11/1997	BL-65	W	None	0.908	2.384	N	0.908	BLDG 64	0
02/13/1997	BL-65	W	None	0	1.234	N	0.000	BLDG 64	0
02/25/1997	BL-65	W	None	-0.028	0.931	N	-0.028	BLDG 64	0
02/26/1997	BL-65	W	None	0.208	1.457	N	0.208	BLDG 64	0
03/03/1997	BL-65	W	PAPR HEPA	0.003	0.003	Y	2.569	BLDG 65	0
03/06/1997	BL-65	W	None	0.042	1.217	N	0.042	BLDG 64	0
03/10/1997	BL-65	W	None	-0.111	1.059	N	-0.111	BLDG 64	0
03/18/1997	BL-65	W	None	0.826	1.25	N	0.826	BLDG 64	0
03/19/1997	BL-65	W	None	-0.238	1.608	N	-0.238	BLDG 64	0
03/22/1997	BL-65	W	None	0.125	1.118	N	0.125	BLDG 64	0
03/24/1997	BL-65	W	PAPR HEPA	0.048	0.002	Y	48.423	BLDG 65	0.048
03/25/1997	BL-65	W	None	0.042	1.217	N	0.042	BLDG 64	0

Table 16. Breathing Zone Results for Worker Involved in Thorium Overpack Project

BZ_DATE	NUCLIDE	SOL_ CLASS	RESPIRATOR _TYPE	DAC_ HRS_ PF	MDI_ DAC_ HRS	RESP_ WORN _FLAG	DAC_ HRS_ NOPF	LOCATION	NEW_ AIR_ CONC
03/27/1997	BL-65	W	None	-0.041	1.297	N	-0.041	BLDG 64	0
04/08/1997	BL-65	W	None	0.11	1.415	N	0.110	BLDG 64	0
04/09/1997	BL-65	W	None	-0.265	1.726	N	-0.265	BLDG 64	0
04/14/1997	BL-65	W	PAPR HEPA	0.03	0.003	Y	29.923	BLDG 65	0.03
04/17/1997	BL-65	W	None	0.36	1.165	N	0.360	BLDG 64	0
04/21/1997	BL-65	W	None	-0.496	1.334	N	-0.496	BLDG 64	0
04/23/1997	BL-65	W	PAPR HEPA	0.043	0.003	Y	43.480	BLDG 65	0.043
04/25/1996	TH-232	W	PAPR	-0.001	0.009	Y	-1.000	BLDG 65	0
04/29/1997	BL-65	W	None	-0.014	1.125	N	-0.014	BLDG 64	0
04/30/1997	BL-65	W	None	0.281	1.275	N	0.281	BLDG 64	0

Observation 7: It is not immediately clear what the temporal criteria were for collecting and analyzing breathing zone samples; however, it is evident that they were not necessarily collected on a daily basis. One likely possibility is that the breathing zone sample was measured over longer periods of time. However, documentation or other evidence should be provided to sufficiently establish that the breathing zone data are complete and represent comprehensive monitoring for thorium activities.

9.0 EVALUATION OF THORON EXPOSURES AT FERNALD

As outlined in Section 2 of this report and described in NIOSH 2014a, exposures to Rn-220 and associated daughters (also known as thoron) are derived based on characterizing the source term (by weight) of thorium in specific buildings, establishing the release fractions for Rn-220 in stored material as well as materials in process, and finally converting it to exposure using an assumed volume of respirable air in each facility. This derivation also includes an equilibrium factor of 0.02 and an assumed occupancy time.

Table F-5 of NIOSH 2014a gives the summary of thoron exposure estimates for various time periods. The time period that is relevant to this review is 1979–2006 and so the pertinent entries of Table F-5 are reproduced in Table 17.

Table 17. Summary of NIOSH 2014a Thoron Exposure Estimates (1979–2006)

Location & Time Period	Available Thoron Activity	Reduction & Calculation Factors	Eff. Facility Volume-Liters[11]	Rn-220/ Po-216 Activity (pCi/l)	Pb-212/ Bi-212 Activity	WLM Per year
1954–1989 Various Storage Sites	300 metric Tons Th = 2×10^{13} pCi Rn-220 source term in Storage Facilities	RF[12] 1E-4 Feq[13] 2E-2 Focc.[14] 3 mo per yr	1×10^{7}	200	0.53WL	1.55WLM
1972–2006 Final Closure Storage	300 metric tons Th = 2×10^{13} pCi Rn-220 source term in Storage Facilities	RF 1E-4 Feq 2E-2 Focc. 1 mo/yr	1×10^{7}	200	0.53WL	0.53WLM

* For maximization purposes the mixing of the thoron and daughters during the processing of thorium is assumed to be in a 20’ hemispherical volume immediately around the release point, which in turn is assumed to be the process work station and for the short term stored thorium in the process facilities. For long term storage facilities the volume of the storage facilities was used.

In this table, various assumptions are made that are discussed individually:

1. The mass of thorium present in the storage site is assumed equal to 300 metric tons; however, this assumption is not referenced or explained. On the page preceding Table F-5 of NIOSH 2014a, the summary assumptions specify that 450 metric tons is to be used,[15] although no explanation or reference is provided to justify this quantity as well. Table F-2 of NIOSH 2014a provides the thorium storage inventory in 1987, and shows 338 metric tons in Building 68 and 351 metric tons in the Pilot Plant liquid tank. However, it is not evident that the quantities in Table F-2 are representative for the entire

[11] For maximization purposes the mixing of the thoron and daughters during the processing of thorium is assumed to be in a 20’ hemispherical volume immediately around the release point, which in turn is assumed to be the process work station and for the short-term stored thorium in the process facilities. For long-term storage facilities, the volume of the storage facilities was used.

[12] Release Fraction

[13] Equilibrium Factor

[14] Occupancy Factor

[15] NIOSH 2014a, pg. 132: “Long-term DOE storage – 100 to 450 MT in any given storage location, 450 assumed.”

period of interest (1979–2006). In addition, the values provided in Table F-2 appear to contradict other information in NIOSH 2014a, such as the unlabeled table on page 4 of the introduction, which also presents source term inventory for 1987. The total inventory of thorium material in this table is 2062.2 metric tons, in addition to the Plant 8 silo/storage bins and thorium nitrate solution in the Pilot Plant storage tank. The total thorium inventory listed in Table F-2 is only 1,436 metric tons.

2. The release fraction of Rn-220 assumed in NIOSH 2014a was based on few examples and did not provide adequate references to verify its validity. A release fraction of 1×10^{-6} was calculated based on measurements made for the Plant 8 storage silo (Example 3 on page 129 of NIOSH 2014a). In Example 2, a release fraction of the order of 1×10^{-3} was indicated for Building 65 storage facility operations in 1996. However, NIOSH indicated that the calculated release fraction cannot be used quantitatively, because of "many unknowns in this example: ventilation of the building, fraction of the stored material containers that were breached, location of the air sample in relation to leaking drums, etc."

   According to the report, *Radon /Thoron Occupational Monitoring Decision Basis* (Daniels 1997), the areas and practices in which personnel without respiratory protection were likely to have the highest potential exposure to thoron consisted of the Thorium Warehouse, Building 64; (Old) Plant 5 Warehouse, Building 65; Metals Fabricating Plant Thorium Furnace, Building 6; and Pilot Plant Wet Side, Building 13A; Quonset Hut #1, Building 60; and Breech of Containment of Thorium Nitrate Tank, T-2. The release fraction (RF) for the period of interest, 1979–2006, was assumed equal to 1×10^{-4} (as seen in Table F-5 of NIOSH 2014a), although no specific justification of this value is given. This RF is not based on measurements taken in areas with the highest potential for exposure to thoron, nor in areas with low exposure potential.

3. The equilibrium factor adopted in NIOSH 2014a is equal to 0.02. According to Daniels (1997):

   > *…progeny equilibrium varies markedly with ventilation; standard equilibrium factors were not acknowledged. Although equilibrium values of 2% to 10% have been documented at several FEMP locations, more precise studies are warranted to accurately relate ^{220}Rn concentrations to WL* [Working Levels].

   The choice of the equilibrium factor was not based on measurements made in all buildings at representative times, so appears somewhat arbitrary.

4. The occupancy time for the period of 1979–2006 was assumed to be 3 months per year for various storage sites up through 1989. Final closure storage facilities were assumed to be 1 month per year in the period of interest. There appears to be no distinct indication of which storage sites should be assigned occupancy times of 3 months per year versus 1 month per year. Additionally, the justification for the assumed occupancy times is not well established and appears somewhat arbitrary. In order to credibly establish the

occupancy in a given location the work-load of affected personnel at different times and facilities must be considered.

5. The specific activity of thoron in thorium bearing materials at Fernald was considered equal to 6.4×10^4 pCi/g based on exposures ranging from 6 months to 1 year after separation, as well as an equilibrium fraction of Th-228/Th-232=0.65. This assumption is inappropriate to assume for all years in the waste repository. The document, *Technical Basis for the Effective DAC for Th232 Stored in Building 65* (Allen 1995), assumes at least 95% equilibrium:

> *The thorium in building 65 was put in the building in the 1960s and early 1970s. Since the thorium was chemically processed before the 1970s, at least 25 years have past. This would indicate that at least 95% of the equilibrium activity of the daughters has been reached. This equilibrium condition has been verified with analysis of the material in the building (see attachment B).*

Finding 6: The underlying assumptions employed in NIOSH 2014a to reconstruct doses to thoron are not well established or referenced. The assumptions concerning thorium source term inventory, release fraction, equilibrium factor, occupancy time, and specific activity of thoron must be thoroughly defined based on credible documentation and site specific records.

Finding 7: It is necessary that NIOSH evaluate the thoron/thoron daughters' exposures due to Ra-228. Independent of the time assumed after separation, it is necessary to evaluate if workers could have worked in areas where Ra-228 was handled or stored and consider the associated thoron exposures. As stated on page 105 of NIOSH 2014a, Ra-228 has a half–life long enough to permit its presence in the workplace for years independent of the original parent isotope (Th-232).

REFERENCES

ABRWH 2012. *Letter to the Secretary of the Department of Health and Human Services – Advisory Board Recommendation on SEC Petition*. Advisory Board on Radiation Worker Health. May 29, 2012.

ABRWH 2013a. *Transcript of the Work Group on Fernald – 6/17/2013*. Advisory Board on Radiation Worker Health, U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health.

ABRWH 2013b. *Letter to the Secretary of the Department of Health and Human Services – Advisory Board Recommendation on SEC Petition*. Advisory Board on Radiation Worker Health. August 28, 2013.

ABRWH 2014. *Transcript of the Work Group on Fernald – 9/3/2014*. Advisory Board on Radiation Worker Health, U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health.

Allen 1995. *Technical Basis for the Effective DAC for* Th^{232} *Stored in Building 65*. D.E. Allen. Document No. SD-S&H-BAS-3025. Fernald Environmental Restoration Management Corporation (FERMCO) – Safety and Health Division. October 20, 1995.

Bonfer, D.C., 1988. *Thorium – A Search of Available Records at the FMPC.* Document Number: PO(DCB)88-012. Westinghouse Materials Company of Ohio. November 15, 1988.

Daniels 1997. *Radon/Thoron Occupational Monitoring Decision Basis*. R. Doug Daniels – Fluor Daniel Fernald Oversight and Project Integration – Safety and Health. Document No: SD-1015. April 11, 1997.

DOE 1988. *Radiation Protection for Occupational Workers - Order DOE 5480.11*. U.S. Department of Energy. Washington, DC. November 30, 1988.

Labone 2012. *White Paper: Calculation of Chronic Intake IRFs for Th-232 Assuming Shared Kinetics Rev 00.* National Institute for Occupational Safety and Health. February 17, 2012.

Leist 1985. *Assessment of Potential Sales of Thorium Compounds*. Letter from J.R. Leist to R.C. Kispert - National Lead Company of Ohio, Inc. December 16, 1985.

NIOSH 2014a. *Fernald Dose Reconstruction Methodology for the Post Special Exposure Cohort (SEC) Period, 1979–2006 Rev. 02*. National Institute for Occupational Safety and Health. June 23, 2014.

NIOSH 2014b. *1979–1989 Thorium In Vivo Coworker Study for Fernald - A Proposed Attachment for ORAUT-TKBS-0017-5, Rev. 2.* National Institute for Occupational Safety and Health. August 11, 2014.

OCAS 2004. *Estimation of Ingestion Intakes Rev. 00*. OCAS-TIB-009. Office of Compensation Analysis and Support – Technical Information Bulletin. April 13, 2004.

ORAUT 2014a. *Feed Materials Production Center – Occupational Environmental Dose*. ORAUT-TKBS-0017-4 Rev. 02. Oak Ridge Associated Universities Team. March 13, 2014.

ORAUT 2014b. *Analysis of Stratified Coworker Datasets – Rev. 02*. ORAUT-RPRT-0053. Oak Ridge Associated Universities Team. October 8, 2014.

Rixner 1984. *FY-1985 Issue Environmental, Safety and Health Plan.* U.S. Department of Energy – Feed Materials Production Center. October 1, 1984.

SC&A 2012. *Completeness and Adequacy of Thorium In-Vivo Records (1979–1989)*. S. Cohen and Associates, Vienna, Virginia. November 26, 2012.

SC&A 2014. *Memo to the SEC Issues Work Group - Status of Issues Relating to the Development of Coworker Models*. S. Cohen and Associates, Vienna, Virginia. September 5, 2014.

U.S. 2014. *U.S. Code of Federal Regulations – 10CFR835 Appendix A: Derived Air Concentrations (DAC) for Controlling Radiation Exposure to Workers at DOE Facilities*. CFR - Title 10 – Chapter 3 – Part 835 – Appendix A. United States Government. January 1, 2014.

ATTACHMENT 1: ASSESSMENT OF THORIUM INQUIRIES (1977 THROUGH 1985) TAKEN FROM LEIST 1985, ATTACHMENT 3

Inq. No.	Company/Location	Contact Date	Description of Request	Quantity Req'd.	Purity Req'd	Material Shipped	Future Potential
78-P	3 M Co. St. Paul, MN	February 1985	Thorium Nitrate Crystals	2.72 MT	>99.9%	2.09 MT	Program Cancelled
77-P	Magnesium Electron, Inc. Flemington, NJ	November 1984	ThO_2 (Application Unknown)	10–30 MT/Yr.	>98%	Samples	Possible
AP-64.2	Teledyne Cast Products Los Angeles, CA	September 1984	Metal Pellets	Samples	High	None	Unlikely
AP-64.2	NERCO Portland, OR	September 1983	ThO_2 (Ceramic Applications)	Samples	99.99%	None	Unlikely
70-P	Precision Castparts Corp. Portland, OR	August 1983	ThO_2 (ceramics for investment casting)	Up To 20 MT/yr.	99.9%	Samples & 0.23 MT	Possible
AP-64.2	GSD Washington, DC	May 1983	Convert Thorium Nitrate Stockpile to ThO_2	About 3,200 MT	Unknown	NA	Needs DOE Approvals
AP-64.2	Phone Poulenc Freeport, TX	May 1983	Convert Thorium Nitrate By-Product to Sell	Unknown	>99.5%	NA	Needs Capital & Approvals
295-A	EG&G Idaho Falls, ID	December 1982	Thorium Metal (R&D Samples)	NA	99.9%	None	None
289-A	Los Alamos National Lab Los Alamos, NM	July 1982	ThO_2 (R&D Studies with EG&G)	1 MT	99.9%	1.15 MT	Unlikely
AP-64.2	Department of Commerce Washington, DC	June 1982	Convert Thorium Nitrate to Dry Form	54 MT/Yr.	Unknown	NA	Need DOE Approvals
283-A	EG&G Idaho Falls, ID	May 1982	ThO_2 (R&D Studies)	1 MT	99.9%	1 MT	Unlikely
66-P	Battelle Pacific NW Lab Richland, WA	March 1982	ThO_2 (Canadian AECL Program)	0.65 MT	99.9%	None	Unlikely
65-P	Ronson Metals Corp. Newark, NJ	November 1981	Metal or Oxide (Electronics Applications)	27 kg/Yr.	99.5%	None	Unlikely
277-A	Sandia National Lab Albuquerque, NM	October 1981	ThO_2 (R&D Studies)	2 MT	99.9%	2 MT	Unlikely
64-P	General Atomics San Diego, CA	March 1981	ThO_2 (For Public Service of Colorado)	7.5 MT	99.9%	6.764 MT	Possible
AP-64.2	San Jose State U. San Jose, CA	February 1981	Metal Foil	Samples	99.9%	None	None
265-A	Euratom Karlsruhe, W. Germany	February 1981	ThO_2 (Application Unknown)	Unknown	99.9%	None	Unlikely

ATTACHMENT 2: EXCERPTS FROM THE ABRWH TRANSCRIPT REGARDING SELECTION OF WORKERS FOR THORIUM INTERNAL DOSE ASSIGNMENT AND EXPOSURE POTENTIAL POST-1994

Beginning on Page 68 of ABRWH 2014:[16]

R. HINNEFELD: *Yes, I mean, the building was, yes, health and safety building was torn down. The in vivo facility was, actually to a good extent I think it outlived the health and safety building. It was almost sort of a little appendage on it but I think it outlived the health and safety building by a little bit.*

So for individuals then who have in vivo data, and that's a lot of people because anybody who got in vivo'ed in the mobile counter or anybody who got in vivo'ed is going to have an in vivo result.

We intend to use the in vivo data and missed doses and things like that if they are a job category that could have been involved in the repackaging.

And we'd be pretty encompassing about that. You figure almost anybody in operations could have done that, most anybody in maintenance. Transportation could have been involved in it. You could have safety and health people. Might have security people there.

So you've got to be pretty inclusive about the kinds of people that you would include in that. Even though it's only probably a small group of people who actually did the overpacking, we don't want to miss someone who should be included. So we would include in those, those people who might have been involved in some sort of exposure.

And, in fact, this period then extends into the remediation period as well but people who might have been exposed, they will get, if they have in vivo data they will a missed dose. And this goes through '94. I'll explain that in a little bit.

If you don't have in vivo data, then from '79 through '89, which is I guess the mobile period, that's when we have all, for the mobile period we have all the bioassay results that were done because they were kept in log books, in a log book or essentially a book of results. And so all the in vivo results for anybody, regardless of whether they're a claimant or not, we have those.

After 1990 when you go to the FITS system, we only would have the in vivo results for claimants. We don't have the comprehensive list of in vivo data, so the coworker model then is intended to address the years of the mobile monitoring when we have all the in vivo data.

For the years '90 to '94 when we no longer have all the in vivo data, all we have is claimant, you know, data from the claimants, we're proposing to use the control level that was exercised...

[16] Note: Page numbers may not reflect Privacy Act-cleared version of transcript.

Continued on Page 76 of ABRWH 2014.

MR. STIVER: *One kind of overarching question I guess is I see in a lot of these thorium White Papers that have been going on, exchanging over the course of several years now, I guess, you know, your contractor, ORAU, always mentions that this would be applied to thorium workers, you know… A lot of your papers have identified we're going to apply this towards thorium workers and, you know, our research has shown that prior to about 1994 I guess when some of this new information came along, this really job- identifying information is kind of sparse to say the least.*

And so, you know, the two SECs that were based on thorium really give it to everybody because, you know, it's just impossible to say who was, you know, exposed at what time in what building and so forth.

So I see that kind of logic is kind of being carried through in this paper, so I'm just kind of curious. Do you guys have other sources of information you'd be able to find that identify job categories prior to 1994?

MR. HINNEFELD: *Well, I mean, there are --*

MR. STIVER: *Anything new I guess that we haven't looked at before?*

MR. HINNEFELD: *There was a fair amount of thorium work done by subcontract. If you read the paper, there's Project 1, 2 and 3.*

MR. STIVER: *Yes.*

MR. HINNEFELD: *Project 1 was done by IT Corporation, which was removal of the thorium from silos within Plant A. Project, or now it wasn't 2 or 3. It was the neutralization of the UNH. The Pilot Plant was done by Chem-Nuclear. And so, I mean, those are separate, distinct categories of people we know who do that.*

There's some information here about a list of job titles of people who were trained I think for one of the thorium projects, you know, the kinds of people who were involved in that.

But I really, I don't know that we're ever going to find, like, names that we can say this person specifically went in and, at least not with the data available.

MR. STIVER: *So you're saying that the three projects, all three of them used subs for the entire amount of work?*

MR. HINNEFELD: *No, no, no.*

MR. STIVER: *They were separate?*

MR. HINNEFELD: *No, thorium overpack was in-house.*

MR. STIVER: *Project 3 was the --*

MR. HINNEFELD: *Project 3 was in-house.*

MR. STIVER: *Okay.*

MR. HINNEFELD: *Project 1 was bins and silos and I forget what -- Oh, Project 2 was the outside storage. Yes, that was in-house.*

MR. STIVER: *Okay, that was in-house as well.*

MR. HINNEFELD: *Yes.*

MR. BARTON: *Seemed like from your description and reading the paper there's kind of a list of pretty broad job categories. Those would be, at least being proposed to be applied up through 1994 or just for the in vivo period through '89, because it seems like once you get to 1995 you're kind of saying that they're pretty much defined by the fact that they have breathing zone.*

MR. HINNEFELD: *Yes, current breathing zones. From '95 forward they're defined by having breathing zone air sampler for thorium.*

MR. BARTON: *Right. So you're essentially saying there's no coworker model after 1994?*

MR. HINNEFELD: *Correct.*

MR. BARTON: *Right, okay. I guess another question I had about that with the breathing zone specifically and I haven't been able to dive into the references yet but, I mean, when we say that breathing zone is provided for all thorium workers, I mean, are we talking, you know, the main handlers of it?*

But what about, like, you know, sort of ancillary workers that might have been in close vicinity, like a security guard or something like that? I mean, would they have to also been included in the breathing zone?

I mean, is there a possibility that you'd have workers who do have exposure potential but maybe weren't considered thorium workers for the purposes of breathing zone?

MR. HINNEFELD: *Well, by this time, by '94, things were pretty controlled. You know, Fluor had been there a while and they brought a lot of rigor to these things, even more so than Westinghouse.*

MR. BARTON: *So pretty much if you were in the vicinity of a project, you were going to have a breathing --*

MR. HINNEFELD: *A project, you know, a thorium work area would, you know, the thorium area would be defined.*

MR. BARTON: *And anyone entering that --*

MR. HINNEFELD: *And if you're going into this, into the thorium radiological area or the airborne, you know, potential airborne area, everybody had a BZ with them.*

You know, I went in. When I would go in to do an observation, you know, I was some pencil-pushing manager, I wore a BZ. That's what I was. I didn't do any real work.

MR. STIVER: *So you didn't have to worry about, like, janitors and staff?*

MR. HINNEFELD: *If they went in, they wore BZ.*

MR. STIVER: *You're pretty confident that --*

MR. HINNEFELD: *Yes.*

MR. STIVER: *-- anybody who went in that area had --*

MR. HINNEFELD: *You went into that area, you wore a BZ.*

MR. STIVER: *And all that data is captured?*

MR. HINNEFELD: *It is all in HIS-20.*

MR. STIVER: *It seemed like a pretty high bar to set, that we have no unmonitored workers during this period of time.*

MR. HINNEFELD: *I'm pretty sure there are not. I mean, it was controlled. The area was controlled, you know, to the point of having manned, you know, manned patrol and so I'm pretty sure that anybody who went into the thorium area from '95 on had a BZ sampler.*

MR. STIVER: *Now, back to Project 1 and 2, I know that IT did the Project 1 in '89. Were they also doing the D&D of Plant 8 silo, did they also do all of the, do it from start to finish?*

MR. HINNEFELD: *Yes, I believe, IT did that whole thing.*

MR. STIVER: *Okay, all right. Those kind of questions, whether there were somebody else or some of the in-plant workers might have done the D&D but it was all contracted out then?*

MR. HINNEFELD: *Well, I don't really remember. The paper reports that that was all part of Project 1, of the silos, the bins, not Plant 8 itself. You know, Plant 8 was still there when that project was done.*

MR. BARTON: *So I might have heard the answer and it just passed right through one ear and out the other. I'm trying to get a handle on how we're assigning the proposed coworker intakes. Like I said, there's a list of workers that, and one of them is, you know, operations, you know* *what I mean, pretty broad category. It seems like what you're actually saying is that unless you were a secretary or something like that, an administrative position, then you wouldn't even have come close to these sites of operations so it's not appropriate to apply coworker intakes. I mean, is that essentially what we're saying or, I mean.*

MR. HINNEFELD: *Yes. I think it's going to be a pretty wide net because, you know, to avoid excluding people that should be included.*

MR. BARTON: *It almost seems like it would have been better to just go from the other direction and say everybody gets it unless you were clearly an administrative worker, that kind of thing, because I mean --*

MR. HINNEFELD: *Well, I think that's probably, I mean, we put some examples of jobs here that, and the jobs we listed were jobs that were identified I think by the training roster, right?'*

But I think in actuality the approach will be unless this person was clearly administrative or cafeteria worker or, you know, someone who clearly is not going to be in a process area, unless it's somebody like that, they're going to be in.