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National Institute for Occupational Safety and Health

Review of SEC-00250 Evaluation Report Addendum for the Y-12 Site

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
Ac	actinium
ACAL	Administrative Control Action Level
ALARA	as low as reasonably achievable
cm	centimeter
CWT	chest wall thickness
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
dpm/m ³	disintegrations per minute per cubic meter
EE	energy employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ER	evaluation report
FMPC	Feed Materials Production Center
FY	fiscal year
ICRU	International Commission on Radiation Units & Measurements
K-25	Oak Ridge Gaseous Diffusion Plant
keV	kiloelectron volt
LEGe	low-energy germanium
LLW	low-level waste
MDA	minimum detectable activity
MIVRML	Mobile In Vivo Radiation Monitoring Laboratory
NaI	sodium iodide
nCi	nanocurie
NID	nuclide identification
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Claims Tracking System
ORAUT	Oak Ridge Associated Universities Team
ORNL	Oak Ridge National Laboratory
PAV	Plant Action Value
Pb	lead
PCB	polychlorinated biphenyl

Pu	plutonium
R&D	research and development
Ra	radium
RADCON	Radiological Control
RWP	radiological work permit
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document
Th	thorium
Tl	thallium
U	uranium
VAX/VMS	Virtual Address eXtension/Virtual Memory System
X-10	Oak Ridge National Laboratory
Y-12	Y-12 Plant

1 Introduction and Background

Special Exposure Cohort (SEC) Petition SEC-00250 for the Y-12 Plant (Y-12) was received by the National Institute for Occupational Safety and Health (NIOSH) on November 1, 2018, and qualified for evaluation on March 25, 2019. The evaluated class was defined as all employees (including contractors and subcontractors) of the U.S. Department of Energy (DOE) and its predecessor agencies for the period from January 1, 1977, through December 31, 1994. While the original requested petition basis was all internal monitoring, NIOSH qualified the petition based on the feasibility of reconstructing internal doses to thorium based on sufficient activity-based measurements (as opposed to mass-based measurements) available from the Y-12 in vivo monitoring program. As has been found during other SEC investigations (e.g., SEC-00046 for the Feed Materials Production Center), it is not feasible to reconstruct doses with sufficient accuracy based on only mass-based in vivo counting for thorium. Rather, it is necessary to have in vivo measurements of the thorium progeny, lead (Pb)-212 and actinium (Ac)-228, to perform sufficiently accurate dose reconstructions.

NIOSH issued the original evaluation report (ER) for SEC-00250 on July 17, 2019 (NIOSH, 2019). In that evaluation, NIOSH effectively split the evaluated SEC period into three distinct timeframes based on the characteristics of the thorium in vivo monitoring practices and available data, as follows:

1. January 1, 1977–July 31, 1979: NIOSH found it was not feasible to reconstruct doses because there was insufficient activity-based in vivo thorium monitoring to reconstruct doses with sufficient accuracy. While activity-based in vivo sampling was identified for Y-12 during this time, the majority of available data during this period were mass based.
2. August 1, 1979–December 31, 1986: NIOSH found that sufficient activity-based in vivo monitoring existed to reconstruct thorium doses with sufficient accuracy.
3. January 1, 1987–December 31, 1994: NIOSH held the evaluation of this period in reserve pending receipt of additional in vivo data from the Y-12 site.

For the first time period (around 1977–1979), the Advisory Board on Radiation and Worker Health (ABRWH, “Board”) concurred with the NIOSH determination on feasibility and recommended the SEC class be added on September 23, 2019. The second period (around 1979–1986) is still under consideration by the Board and was the subject of SC&A’s 2020 review of SEC-00250 (SC&A, 2020).¹ The third time period, which was held in reserve in NIOSH’s original 2019 ER, is the subject of an addendum to the SEC-00250 ER (NIOSH, 2021). SC&A was tasked with reviewing NIOSH (2021) on December 9, 2021. This report presents the results of SC&A’s review of the SEC-00250 Addendum covering the period 1987–1994.

¹ The applicability of SC&A’s 2020 review findings and observations to the SEC-00250 Addendum are briefly discussed in section 3 of this report.

2 SC&A Review Approach

The SEC-00250 petition qualified on the basis of the feasibility of internal thorium dose reconstruction; thus, thorium doses are the main the focus of SC&A’s review. However, other facets of the radiological control program are also discussed. SC&A structured its review to consider the following facets:

- applicability of prior SC&A findings and observations that formed the basis of its original SEC-00250 review to the Addendum period held in reserve (refer to section 3)
- documentation of thorium-related activities or potential source terms (refer to section 4)
- an overall evaluation of the radiological control program during the period of interest (refer to section 5)
- evaluation of documented communications with former workers for information regarding thorium exposures or other potential SEC-related issues (refer to section 6)
- evaluation and discussion of completeness and representation of the in vivo thorium data (refer to section 7.1)
- review of proposed methods for adequately applying thorium in vivo data at Y-12 as described in DCAS-RPT-008, “Evaluation of the Pb-212 Detection Limit for a Lung Count at the Y-12 Facility from 1992-1995” (NIOSH, 2020b) (refer to section 7.2)

The purpose of these lines of inquiry ultimately relates to the feasibility of constructing a suitable co-exposure model. At the time of this review, SC&A was not able to perform a full review of the claimant population and associated statements or documentation contained in the individual workers’ computer-assisted telephone interview, DOE, or U. S. Department of Labor files during the Addendum period.

3 Applicability of Original SEC-00250 ER Review

This section examines prior SC&A findings and observations documented as part of its original review of SEC-00250 (SC&A, 2020), which covered the years 1979 through 1986. Each finding or observation is repeated here with a brief discussion related to the potential relevance of those findings and observations to the SEC-00250 Addendum period (1987 through 1994). Any additional observations and findings as a result of the Addendum review that are directly related to the original SC&A (2020) review are also included in this section.

3.1 Original SC&A (2020) finding 1

Available documentation only reports the number of quarterly thorium in vivo measurements up through the third quarter of 1981. For this limited time period, the completeness of in vivo thorium data available for dose reconstruction was approximately 95 percent. Direct evaluation of the completeness and availability of thorium in vivo records after this time is not currently possible.

3.1.1 SC&A's recommended disposition of finding 1 for Addendum period

This finding appears to still be relevant, as the total amount of data that should be available for analysis is not known after 1981 and thus the amount of data is not available for the Addendum time period. While periodic health physics reports (discussed in section 5 of this report) gave total in vivo results for uranium, it is not clear that these totals are also representative of the in vivo thorium results. This would continue to pose issues in the Addendum period in establishing the completeness of the available dataset for co-exposure analysis. In its 2020 response, NIOSH acknowledged SC&A's finding 1 and indicated that a full completeness analysis would be performed as part of a future co-exposure modeling effort (NIOSH, 2020a). SC&A recommends this finding remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.2 Original SC&A (2020) finding 2

Information on the annual processing and throughput of thorium materials at the Y-12 plant is currently unavailable to supplement the thorium monitoring completeness evaluation. Evidence suggests that such throughput information was once tabulated in existing documentation. However, it is likely the information was redacted from the original source documentation and thus is not available for analysis at this time.

3.2.1 SC&A recommended disposition of finding 2 for Addendum period

Subsequent to the issuance of SC&A's SEC-00250 ER review, NIOSH captured two sources containing thorium inventory data: Livengood (2019) and Chaffman (2019). The data from Livengood (2019) were included in the SEC-00250 ER Addendum as table 5-3 (NIOSH, 2021). Table 1 summarizes these thorium inventory sources.

Table 1. Summary of thorium inventory data (in kg) from Livengood (2019), Chaffman (2019), and NIOSH (2021)

Description	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Source
Assembled items product	No data	No data		18	18	No data	No data	No data	-16	No data	Chaffman (2019)
Compounds (unirradiated)	250	No data	260	260	260	No data	0	No data	No data	No data	Chaffman (2019)
Dioxides product	8	No data	3	2	2	No data	No data	No data	No data	No data	Chaffman (2019)
Disassembled weapon components	1,108	No data	87	87	87	773	1,233	583	1,732	1,684	Chaffman (2019)
Experimental capsules, elements, pins	0	No data	0	0	0	No data	0	No data	No data	No data	Chaffman (2019)
Fabricated fuel elements & targets product	2,553	No data	2,553	451	2,553	3,054	1,527	1,018	3,053	3,053	Chaffman (2019)
In other R&D usage	58	No data	58	58	48	99	88	1	2	2	Chaffman (2019)
Miscellaneous compounds	13	No data	13	13	17	No data	No data	No data	No data	No data	Chaffman (2019)
Samples & standards	22	No data	22	22	22	43	43	14	43	43	Chaffman (2019)

Description	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Source
Unalloyed formed items product	5	No data	5	5	0	No data	No data	No data	No data	No data	Chaffman (2019)
Unalloyed metal feed	736	No data	No data	No data	No data	No data	No data	No data	No data	No data	Chaffman (2019)
Weapons awaiting disassembly feed	126	No data	603	179	597	No data	296	5	662	13,261	Chaffman (2019)
Grand total	247	No data	198	131	167	694	489	233	687	2,581	Chaffman (2019)
SC&A sum of rows 2–12	4,879	No data	3,604	1,095	3,604	3,969	3,187	1,621	5,476	18,043	Not applicable
NIOSH SEC-0250 ER table 5-3 total	5,437	4,101	4,171	4,185	4,180	4,166	4,888	4,885	5,499	18,066	Livengood (2019), NIOSH (2021)

Based on table 1, it is clear that the two primary references had different estimates of thorium inventory by year with the Livengood (2019) data (which were also presented in the NIOSH SEC-00250 ER) bounding the Chaffman (2019) estimates. It is not clear where the discrepancy arises. However, it may be important to establish general inventory, as it may be useful in evaluating completeness and relative exposure potential for each relevant year.

2024 Observation 1: The thorium inventory estimates presented in table 5-3 of the NIOSH ER Addendum (NIOSH, 2021) appear to disagree with alternate information provided in Chaffman (2019). The source of the discrepancy should be identified to assure that the correct inventory of thorium is reported. However, SC&A notes that the higher estimates of the thorium inventory were reported in NIOSH (2021).

3.3 Original SC&A (2020) finding 3

Analysis of job title or other characteristics of the monitored population is not possible at this time in the uranium urinalysis dataset used in the Y-12 [co-exposure] model. Therefore, neither the evaluation of the representativeness of the dataset, nor the evaluation of the potential need for stratification of the uranium [co-exposure] model, is currently feasible.

3.3.1 SC&A recommended disposition of finding 3 for Addendum period

NIOSH (2020a) acknowledged SC&A's finding and indicates that characterization and potential need for stratification of the monitored population for the purposes of co-exposure development will be performed by NIOSH in future revisions of the uranium co-exposure model. SC&A recommends this finding remain In Progress pending development of future co-exposure models to address unmonitored intakes. SC&A assumes that NIOSH's proposed path forward would also apply to the Addendum period.

3.4 Original SC&A (2020) finding 4

Plutonium-241 is not addressed in the Y-12 SEC-00250 evaluation report, though inability to reconstruct internal exposure to Pu-241 formed part of the basis of SEC-00251, which immediately precedes the SEC-00250 evaluation period.

3.4.1 SC&A recommended disposition of finding 4 for Addendum period

This issue was discussed in the SEC-00251 ER (NIOSH, 2018) and by the Y-12 Work Group at its September 2020 videoconference meeting. NIOSH has determined that an adequate bioassay method for measuring plutonium (Pu)-241 existed at Y-12 at least as early as 1967; therefore, no further infeasibility for Pu-241 was identified. While SC&A acknowledges that a suitable bioassay method likely was available (as documented in ORAUT (2018)), SC&A would note that a suitable exposure method for unmonitored exposures of Pu-241 will likely be required for the years after 1966 at the Y-12 Plant.

3.5 Original SC&A (2020) observation 1

Although SC&A uncovered additional information concerning process departments and areas associated with thorium work, no definitive list was identified to aid in assessing the scope of thorium monitoring at the Y-12 plant. Sought-after documentation might have included those workers actually classified as thorium workers in addition to the department and work area designations. Such information would have aided in evaluating the monitoring program's effectiveness and representativeness.

3.5.1 SC&A recommended disposition of observation 1 for Addendum period

This observation is also relevant for the Addendum period because identifying work activities potentially involving thorium exposures and, more importantly, the workers involved in those activities is important in establishing that the available monitoring data are sufficiently complete and representative of the exposed population. NIOSH (2020a) acknowledged the observation and indicated that evaluation of the thorium-monitoring program will be part of the development of a thorium chest-count co-exposure model. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes. It is important to note that documented communications with former Y-12 workers indicated that thorium workers were not specifically identified and selected for in vivo monitoring (refer to section 6, 2024 observation 11).

3.6 Original SC&A (2020) observation 2

The in vivo monitoring program using the stationary count facilities at the Y-12 Plant employed essentially identical methods and equipment as the Mobile In Vivo Radiation Monitoring Laboratory (MIVRML), which was likewise developed at Y-12. The Board has previously evaluated the adequacy of the MIVRML system at the Fernald site and found it to be a reasonable and scientifically accurate monitoring methodology for use in EEOICPA.

3.6.1 SC&A recommended disposition of observation 2 for Addendum period

This observation is relevant for the part of the Addendum period for which the lung counts of the thorium daughter products (Pb-212 and Ac-228) are present for analysis. This observation would not apply to the period for which only Ac-228 measurements are available. However, as discussed at the September 2020 meeting of the Y-12 Work Group, scientifically acceptable methods are available and have been used in previous SEC discussions of the Fernald site in which the Board found the methods acceptable when both daughter products are present. The

methods used to address the period in which only Ac-228 measurements are available are discussed and evaluated in section 7.2 of this report.

3.7 Original SC&A (2020) observation 3

SC&A's evaluation of the potential for bias in the data identified a negative bias in the Ac-228 data for the years 1981–1986 and Pb-212 for 1981–1984. NIOSH should consider developing adjustment factors to assure any negative bias in the reported results is correctly accounted for in a claimant-favorable manner.

3.7.1 SC&A recommended disposition of observation 3 for Addendum period

This observation is relevant for the part of the Addendum period for which the lung counts of the thorium daughter products (Pb-212 and Ac-228) are present for analysis. NIOSH (2020a) acknowledged SC&A's observation and will provide a formal evaluation of the potential for bias in the data as part of its development of the thorium chest-count co-exposure model. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.8 Original SC&A (2020) observation 4

Evidence suggests additional Pb/Ac in vivo data may be available that were not considered in the SEC-00250 ER due to their in vivo "type" designation. Limited analysis of omitted data discovered for January 1983 suggests the data are comparable to, or in some cases greater than, the current database values under consideration. NIOSH should consider capturing and analyzing any additional data unless sufficient justification exists for omitting such monitoring results.

3.8.1 SC&A recommended disposition of observation 4 for Addendum period

NIOSH (2020a) indicated that attempts to obtain additional data have been requested from the site, but at the time of writing, additional information had not yet been located. NIOSH (2020a) also indicated that a formal analysis that evaluates the completeness of thorium monitoring data will be performed as part of future co-exposure modeling development. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.9 Original SC&A (2020) observation 5

Analysis of available job title information for claimants included in the available thorium in vivo dataset suggests that the monitoring program can be best described as "routine, representative sampling." SC&A did not identify any evidence that the monitoring program systematically excluded workers with higher exposure potential that might preclude the use of such data in [co-exposure] modeling.

3.9.1 SC&A recommended disposition of observation 5 for Addendum period

NIOSH (2020a) indicated that it intends to perform a formal analysis of job title information to determine the representativeness of the monitored population for use in future co-exposure

development. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.10 Original SC&A (2020) observation 6

Analysis of available departmental information included in the thorium in vivo dataset suggests the monitoring program is likely best described as “routine, representative sampling.” SC&A did not identify any evidence that the monitoring program systematically excluded departments with higher exposure potential that might preclude use of such data in [co-exposure] modeling.

3.10.1 SC&A recommended disposition of observation 6 for Addendum period

NIOSH (2020a) indicated that it intends to perform a formal analysis of all relevant information to determine the representativeness of the monitored population for use in future co-exposure development. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.11 Original SC&A (2020) observation 7

Completeness analysis of the uranium data from August 1979 through December 1988 showed that on a quarterly basis, the percentage of available data in comparison to period health physics reports ranged from 75 percent to 121 percent of the reported totals. The average over all evaluated quarters was 98.4 percent. Completeness analysis after this period is not currently feasible.

3.11.1 SC&A recommended disposition of observation 7 for Addendum period

NIOSH (2020a) indicated that it intends to perform a formal analysis of job title information to determine the representativeness of the monitored population for use in future co-exposure development. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.12 Original SC&A (2020) observation 8

The Y-12 [co-exposure] model currently uses uranium urinalysis results in developing unmonitored intakes. Urinalysis was the primary method for monitoring for uranium exposure at Y-12, and it appears to have captured the more highly exposed workers as demonstrated by the number of workers exceeding the plant action value. However, there was a substantial amount of in vivo monitoring as well. Such in vivo monitoring should be discussed in the context of developing [co-exposure models] to assure that the chosen method is claimant favorable.

3.12.1 SC&A recommended disposition of observation 8 for Addendum period

NIOSH (2020a) agreed that a substantial amount of in vivo monitoring exists that could be considered in co-exposure model development. NIOSH indicated that such data would be considered to assure that future uranium co-exposure models are claimant favorable. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.13 Original SC&A (2020) observation 9

Average uranium air concentrations provided for three categories of uranium operations in the quarterly health physics reports indicate that “fabrication” (which is described as machining operations in enriched uranium areas) was consistently bounded by the other two operational categories (both of which are labelled “metal preparation”).

3.13.1 SC&A recommended disposition of observation 9 for Addendum period

NIOSH (2020a) agreed that the potential issue of stratification of co-exposure models should be evaluated during future co-exposure model development. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.14 Original SC&A (2020) observation 10

Evaluation of claimant monitoring records, for workers who are identified only as machinists and who were monitored externally, found that 40–60 percent were also monitored for uranium by year. When considering whether claimant Machinists would theoretically require application of a [co-exposure] model during dose reconstruction, SC&A found that around 51 percent would not require any [co-exposure] assignment, around 24 percent would require partial [co-exposure] assignment, and around 25 percent would require [co-exposure] assignment for all externally monitored years.

3.14.1 SC&A recommended disposition of observation 10 for Addendum period

NIOSH (2020a) agrees that the potential issue of stratification of co-exposure models should be evaluated during future co-exposure model development. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

3.15 Original SC&A (2020) observation 11

SC&A has several open findings and observations for RPRT-0090 pertinent to the ER. These findings are currently under the purview of the Board for consideration.

3.15.1 SC&A recommended disposition of observation 11 for Addendum period

SC&A’s review (SC&A, 2018) of ORAUT-RPRT-0090, revision 00 (ORAUT, 2018; “RPRT-0090”), was discussed by the Oak Ridge National Laboratory (ORNL)/X-10 Work Group on June 30, 2021 (ABRWH, 2021), where it was determined that RPRT-0090 was intended to demonstrate the feasibility to monitor internally for many exotic radionuclides. As SC&A’s pertinent review findings and observations regarding RPRT-0090 (SC&A, 2018, 2020) were generally specific to the application of bioassay methodology and available data in the development of co-exposure modeling, it was determined that those open issues be handled with the development of co-exposure modeling or unmonitored internal dose matrices as applicable to ORNL.

Furthermore, SC&A notes that NIOSH has recently delivered an updated revision of RPRT-0090 in Spring 2023.

3.16 Original SC&A (2020) observation 12

Post-1983 Isotopes Group radioisotope exposures were not addressed in the Y-12 SEC-00250 evaluation report. In particular, the ER does not address residual exposures to contaminated areas and process equipment.

3.16.1 SC&A recommended disposition of observation 12 for Addendum period

Although actual operations of the Isotopes Group may have ceased in 1983, this observation relates to the potential for residual contamination exposures and thus is relevant to the SEC-00250 Addendum period. NIOSH indicated that issues related to the Isotopes Group would be addressed as part of the development of methods to assess unmonitored exposures to exotic radionuclides. SC&A recommends this observation remain In Progress pending development of future co-exposure models to address unmonitored intakes.

4 Documentation of Thorium-Related Activities

SC&A’s approach for documenting thorium-related activities during the 1987–1994 period was twofold. First, SC&A searched through documents publicly available on the Internet, including the site profile and technical information bulletins, then used the references from those documents to search further on the internet for information. Twenty-two documents were found in this manner. Second, SC&A conducted a keyword search in the Y-12 Site Research Database (SRDB) Workgroup folder located on the NIOSH Edge Computing Platform. Keywords included “thorium,” “incident,” and the years after 1986. All documents with these keywords were checked for thorium-related material except for those documents already analyzed and discussed in the SEC ER, which were deemed redundant. A total of 337 of the 5,896 documents in the SRDB folder were deemed relevant for detailed review. Table 2 lists relevant information identified during that detailed review.

Table 2. Summary of thorium related documents during the SEC-00250 Addendum evaluation period (1987–1994)

SRDB number	Year	SC&A comments
003514	1988	Thorium information was found in an environmental report in 1988 as both air emissions and waste at Oak Ridge Reservation. It seems likely the elevated air emissions were related to activities at ORNL, rather than Y-12, such as the uranium/thorium recycling facility located at the Melton Valley complex. However, increased emissions were also attributed to remediation activities, including construction activities in the vicinity of New Hope Pound found on the Y-12 site. Evaluation of general ambient air emissions in the report directly related to the Y-12 site were focused on uranium.

SRDB number	Year	SC&A comments
004095	1989	Some thorium was found in an environmental report in 1989 for stream sediments at ORNL/Y-12. However, in comparison to the derived concentration guide values, SRDB 004095 indicates the measured levels are “not applicable.” The report also discusses the disposal of construction materials that may have contained thorium; however, the report notes that the disposal of these materials was considered nonradioactive due to the application of existing administrative and in-plant controls that prevent the disposal of significant levels of chemical and radioactive waste.
012077	1992	Report discusses environmental thorium in the context of waste storage and stream sampling but appears particularly focused on the K-25 facility. There was no indication of major thorium campaigns at the Y-12 site in this document.
012078	1993	Report evaluates environmental thorium at Y-12/ORNL in the context of vertical composite samples and estimates for ingestion/inhalation doses to offsite members of the public. However, the report does not mention current operational thorium work or other information SC&A found relevant to the SEC-00250 Addendum evaluation.
012079	1993	Report evaluates environmental thorium at Y-12/ORNL in the context of stream sediment sampling but does not discuss any active environmental emissions related to operational thorium activity.
012080	1991	Report evaluates environmental thorium at Y-12/ORNL in the context of stream sediment sampling but does not discuss any active environmental emissions related to operational thorium activity.
012081	1989	Duplicate of SRDB 004095.
012148	1994	Report mentions environmental thorium at Y-12/ORNL in the context of vertical composite samples, estimates for ingestion/inhalation doses to offsite members of the public, etc. but does not mention current operational thorium work or other information relevant to the SEC-00250 evaluation.
012324	2003	This document contains duplicate information to SRDB 59683, which is discussed later in this table.
033662	1993	Overarching report that discusses the amount of thorium buried as LLW at DOE sites including Y-12 and summarizes environmental restoration activities and management. The report notes that the land disposal of LLW at Y-12 was terminated in July 1991. Reported totals generally combine both uranium and thorium into a single category, which does not allow for partitioning of the source term. SC&A did not identify any particular exposure scenarios that would affect the evaluation of the SEC-00250 Addendum period.
033670	1994	Overarching report that discusses the amount of thorium buried as LLW at DOE sites including Y-12. Reported totals generally combine both uranium and thorium into a single category, which does not allow for partitioning of the source term. SC&A did not identify any particular exposure scenarios that would affect the evaluation of the SEC-00250 Addendum period.
033697	1991	Overarching report discusses the amount of thorium buried as LLW at DOE sites including Y-12. Reported totals generally combine both uranium and thorium into a single category, which does not allow for partitioning of the source term. SC&A did not identify any particular exposure scenarios that would affect the evaluation of the SEC-00250 Addendum period.

SRDB number	Year	SC&A comments
033699	1992	Overarching report discusses the amount of thorium buried as LLW at DOE sites including Y-12. Reported totals generally combine both uranium and thorium into a single category, which does not allow for partitioning of the source term. SC&A did not identify any particular exposure scenarios that would affect the evaluation of the SEC-00250 Addendum period.
041375	1992	Document references thorium-232 present in the FMPC pits from residues in earlier processes. Report indicates shipments to customers only go through 1985, with the last reported shipment to Y-12 occurring in 1972. Receipts of thorium from the Y-12 plant are only reported through 1986; however, it is not known if this represents the date of the last thorium shipment received from Y-12.
046680	1990	Urinalysis records include thorium monitoring; however, it is unclear if the individuals are specifically associated with the Y-12 site or the larger Oak Ridge Reservation. The reason for the requested analyses is not provided. All results for Th-232 were reported as less than the MDA.
046795	1991	Urinalysis records include thorium monitoring; however, it is unclear if the individuals are specifically associated with the Y-12 site or the larger Oak Ridge Reservation. The reason for the requested analyses is not provided. All results for Th-232 were reported as less than the MDA.
059683	1995	The "Technical Basis Document for the Internal Dosimetry Program at the Y-12 Plant," Y/DQ-40, states on PDF page 6: "The Y-12 Plant has been primarily a weapons facility and as such the primary radioactive material on site is uranium. Therefore, the largest portion of the <i>in vitro</i> bioassay program focuses on the isotopes of uranium. However, there are also isolated jobs that utilize other radionuclides such as plutonium, americium, thorium , neptunium, technetium, and strontium. Since these isolated jobs are usually of short duration (i.e., 1-2 weeks), baseline and termination bioassay measurements for these radionuclides are all that is required . Based on the nature of the jobs performed on site, Dosimetry Services has work agreements in place with the Y-12 Plant Analytical Services Organization to perform the following analyses: . . . determination of thorium in urine and determination of strontium in urine" [emphasis added]. Refer to SC&A 2024 observation 5 in this section of the report.
078862	1987	Report notes that burial ground C was opened in 1962 for the disposal of beryllium, beryllium oxide, thorium, and solid waste contaminated with these materials. The report also discusses the use of waste oils in land farms for the purpose of biodegradation, which started being sampled for thorium starting in 1979. However, the main focus of the waste oil contamination was concentrated on PCBs.
088811	1990	Report mentions thorium in the context of waste from reactor fuel and mill tailings across the DOE complex including Y-12. The document is a high-level accounting across all DOE sites and does not specifically discuss thorium processing at the Y-12 site.
113914	1997	Bioassay records include one instance of thorium monitoring for an individual in 1997. The reason for the bioassay is not provided, and the sample results were negative for thorium activity. While this is technically outside the Addendum period, it may indicate continued concern over thorium exposures at Y-12.
114153	1999	Bioassay records indicate one monitoring record for Th-232 for an individual worker in 1998; however, the result was negative and no reason was provided for the sample submission. While this is technically outside the Addendum period, it may indicate continued concern over thorium exposures at Y-12.

SRDB number	Year	SC&A comments
122610	1993	<p>“Health and Safety Research Division Progress Report for the Period October 1, 1991 - March 31, 1993”</p> <p>PDF page 18: “At Y-12, the [Measurement Applications and Development] group is currently conducting a radiological characterization of all indoor areas, which is scheduled to be completed at the end of FY 1994.” SC&A was unable to locate the results of this characterization and its potential implications for the SEC-00250 Addendum evaluation. Such an evaluation would be useful in establishing the extent of thorium contamination found within the Y-12 site. Refer to SC&A 2024 observation 2.</p>
124213	1994	Report mentions amount of thorium buried as LLW at DOE sites including Y-12. This report is part of a series of overarching reports identified previously in this table (refer to SRDB 033662, 033670, 033697, and 033699).
137020	2014	Documented explanation of thorium monitoring from a Y-12 internal dosimetrist describing the process for interpreting thorium-monitoring results. In vivo lung counts on workers performed for thorium from 1979 through 1984 can be inferred to represent workers exposed to thorium. Prior to 1989, if in vivo records provide an evaluation of the thorium in vivo result as a percentage of the radiation protection standard, then it can also be inferred the worker had exposure potential to thorium. In addition, if the worker has thorium in vitro bioassay beginning in 1994, the worker was likely exposed to thorium. However, lung count results from 1992 through 2004 should only be considered as screening measurements for the worker population regardless of whether they actually worked with thorium. Refer to SC&A 2024 observation 6.
147342	1994	Report describes a thorium analysis of groundwater in which thorium was below the detection limit for all samples.
147343	1994	Document contains groundwater samples tested for thorium and found to all be below the detection limit.
147344	1995	Thorium tested as a trace metal in groundwater with all results below the detection limit.
147345	1995	Groundwater samples tested for thorium were all at the analytical limit of detection.
163777	1989	Report from 1989 mentions thorium inventory at Y-12 as of 1987; however, the reported totals are the combination of uranium and thorium and do not delineate thorium separately.
163781	1989	Duplicate of SRDB 163777.
165848	1991	Procedure documents a radiochemical method to separate thorium isotopes in potable and industrial water.
166227	1994	Radiological work permit (RWP) dated 1994 described as “Drilling and milling on 4' dia. case of magnesium + 3% Thorium” (PDF p. 2). The attached memo describes safety precautions to be taken, including respirators to be worn during the actual machining of the thorium part. However, it appears that the work permit was modified later in the process to not require respirators after initial air sampling and surface contamination surveys were evaluated from the first 3 days of the operation. Correspondence related to the operation indicates that baseline urinalysis samples should have been taken on the workers but had not been performed. SC&A was unable to cross-reference the workers listed on the sign-in sheet with available in vivo monitoring records for thorium, as only a site-specific badge is provided on the RWP while the in vivo records only indicate a social security number. While out of the evaluated period, Radiological Control (RADCON) assessments were identified for 1998 and 1999. Refer to SC&A 2024 observation 4.

SRDB number	Year	SC&A comments
166229	2000	Thorium smears taken in three distinct areas of Y-12 including the press area of the thorium room (9204-4), the canning room (9201-1), and related to a scrap reclamation operation 9201-5). The smears had instances of both measurable removable and fixed contamination. However, the smears were taken after the evaluated SEC time period during the years 1996–2000. Refer to observation 3.
166232	1994	Contains a summary of a meeting of the Internal Dosimetry Subcommittee at Y-12 and discusses a worker that had an abnormal Th-228 urinalysis result (the result was still below the reported MDA for Th-228). SC&A was unable to locate any followup documentation concerning the individual.
175799	1998	RADCON performed two assessments regarding implementation of the radiological control program that found, in part, “assessments identified deficiencies in the following areas: . . . conduct of operations (e.g., failure to complete required information and document corrections on the RWP sign-in sheets)” (PDF p. 2). However, that same document concluded that impact on worker exposure is minimal. Refer to SC&A 2024 observation 4.
176786	2012	One saw was found contaminated with thorium in 2012. It was determined there was no removable contamination (i.e., only fixed contamination was identified); therefore, the internal exposure potential would be minimal.
184249	1988	Duplicate of SRDB 003514.

Most references to thorium in the time frame of interest were in the form of environmental sampling reports, characterization of low-level waste on site, and other residual contamination found at the Y-12 site. However, at least one notable activity involving thorium was identified that included the drilling and milling of a magnesium-thorium alloy material in 1994 (refer to SRDB 166227). This operation originally required respiratory protection, but after characterization of the radiological environment during the first few days of work, it was determined that respiratory protection was likely unnecessary. However, documentation indicates that the required baseline bioassay samples had not been taken. It is not clear to SC&A if followup samples were taken after the operation ceased. The use of bioassay rather than in vivo monitoring is consistent with a 1995 internal dosimetry technical basis document (refer to SRDB 059683) as well as communications with a Y-12 internal dosimetrist explaining the thorium monitoring program (refer to SRDB 137020).

Additionally, one reference (SRDB 176786) indicated that a saw was discovered to be contaminated with thorium in 2012; however, the contamination was all fixed with no removable component. Finally, technical basis documents covering the internal dosimetry program from 1995 indicate that, given the isolated nature of work specifically involving thorium, baseline and termination bioassays should be provided.

2024 Observation 2: A 1993 Health and Safety report indicated that a project was to be conducted during 1994 to perform a radiological characterization of all indoor areas at the Y-12 site. SC&A was unable to locate the results of the project but notes this would be useful in evaluating the extent of thorium contamination at the site.

2024 Observation 3: Smear surveys from the year 2000 at Y-12, including the press area of the thorium room (9204-4), the canning room (9201-1), and related to a scrap reclamation operation 9201-5), showed both removable and fixed contamination. While these were taken outside of the Addendum period, it is not immediately clear if these represent residual contamination relevant to SEC-00250 exposures.

2024 Observation 4: A radiological work permit dated August 1994 and associated correspondence describe drilling and milling on a 4-foot diameter case of magnesium-thorium and express concern that the workers involved had not submitted baseline urinalysis samples as required. It is not clear to SC&A at this time whether termination urinalysis samples were taken at the end of the operation. As noted in table 2 of this report, an internal assessment in 1998 through the first quarter of 1999 found deficiencies in appropriate completion and correction of RWP sign-in sheets, though it was concluded these had minimal impact on worker doses.

2024 Observation 5: An internal dosimetry technical basis document from 1995 (just after the evaluated period) states that baseline and termination urinalysis samples should be taken for any thorium-specific operations due to their isolated nature. It is not clear to what extent such samples were taken during the Addendum period. However, SC&A did identify a few instances of thorium urinalysis monitoring in 1990 and 1991 (SRDB 046680, 046795, 113914, and 114153).

2024 Observation 6: According to guidance from the 2014 document, “Interpretation of Y-12 Thorium Monitoring Results” (SRDB 137020), lung counts for thorium during the time period of interest are considered screening and were performed whether the individual worked with thorium or not. If a worker has in vitro results beginning in 1994 and on, it can be inferred the worker had exposure potential to thorium.

2024 Observation 7: One saw was found with fixed thorium contamination in 2012, which indicates that residual thorium still existed at the Y-12 facility well after the evaluated SEC period. However, given that no removable component was identified with the contamination, any internal exposure potential would be minimal.

5 Evaluation of Radiological Control Program

During the Addendum evaluation period at the Y-12 Plant, the Radiation Safety Department produced quarterly reports (each titled “Y-12 Plant Health Physics Quarterly Report”) that document and summarize the radiological monitoring and surveillance program during the three prior months. The content of these reports changed over time; however, the main elements included the following:

- number of external dosimeters processed and the percentage of workers exceeding the Radiation Protection Standard guidelines
- internal uranium monitoring measurements (both in vitro and in vivo) and number of individuals exceeding the Administrative Control Action Level (ACAL)
- total number and locations covered by fixed air monitoring stations as well as the number of air samples above the Plant Action Value (PAV)

- number and type of radiation safety audits performed (e.g., x-ray facilities, sources, source facilities, emergency instrumentation)
- number of area surveys categorized by type (e.g., material and equipment, safety work permit, construction, non-special nuclear material, and emergency surveys due to fires/spills/power outages)
- as low as reasonably achievable (ALARA) goals and status of progress made on these goals to date
- special radiological exposure studies (e.g., the study of the extent of shoe contamination among the worker population, characterization of the exposure potential for expectant mothers, etc.)

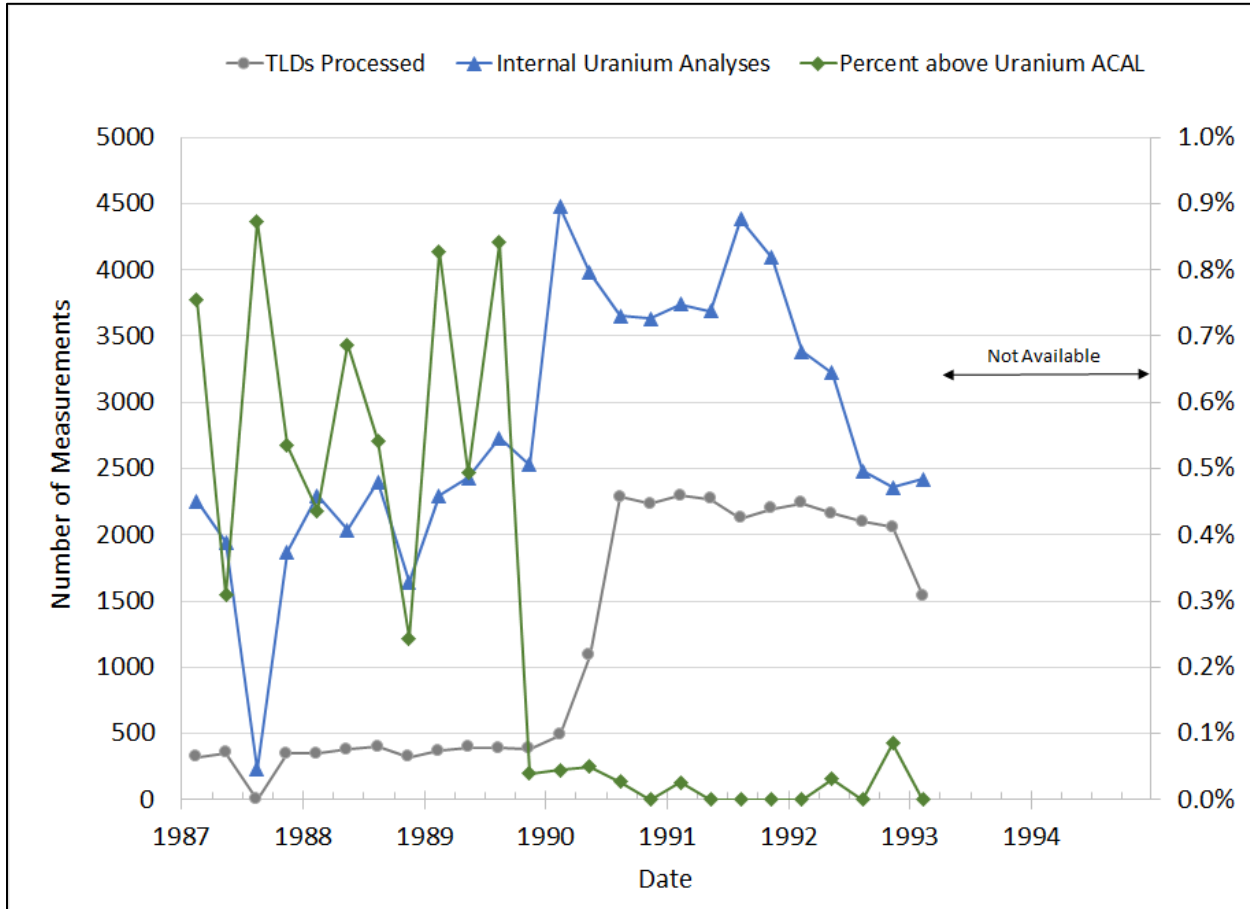
Quarterly reports during the ER Addendum period were available from the first quarter of 1987 through the first quarter of 1993. Based on SC&A's review of these quarterly reports, it is clear that the main focus of the radiological protection program was based on uranium. This is consistent with the main mission of the Y-12 site during the Addendum period. Thorium, or any other exotic radionuclide operations or studies, were not discussed in any of the available quarterly health physics reports. Nonetheless, these reports do provide valuable information regarding the extent of the health physics protection at the Y-12 site during a substantial portion of the Addendum evaluation period.

Figure 1 summarizes the external dosimetry and internal uranium monitoring program. In the early part of the period of interest, the number of dosimeters issued was fewer than 500 per quarter. This number increased by nearly a factor of 4 in early 1990. This increase coincides with the implementation of DOE Order 5480.11 (DOE, 1988), which specified that all workers on an internal dosimetry program must also be monitored externally.

The number of internal uranium analyses included both in vivo (whole-body counting or lung counting) and urinalysis results. The number of internal analyses generally fluctuated between 1,500 and 2,500 by quarter up through 1989, at which time the number increased to over 3,500 for approximately 2 years. After this time, the number of internal analyses decreased back below 2,500. The percentage of uranium analyses that were above the uranium ACAL were all less than 1 percent and decreased to less than 0.1 percent by the fourth quarter of 1989. It should be noted that the proportion of analyses above the ACAL also includes samples that were considered invalid due to suspected contamination. In general, the lower number of analyses that were above the ACAL value generally reflects the increase in the scope of the uranium monitoring program occurring at approximately the same time.

The third quarter of 1987 showed a marked decrease in the number of dosimeters issued and the number of uranium analyses performed. This brief decrease was due to a strike at the Y-12 Plant during this time.

Figure 1. Overview of external and internal monitoring programs, 1987–1994



Regular safety audits were also documented in the quarterly health physics reports through the end of 1989. Similar to the trends observed in the external and internal uranium monitoring coverage, a significant increase in the number of safety audits was observed related to source and source facilities when compared to earlier periods. No specific information was provided to indicate what these safety audits entailed, or what potential radioactive material may have been encountered or specifically checked. Figure 2 presents the number of safety audits by category during each quarterly reporting period.

Figure 2. Number of safety audits conducted per quarter, 1987–1990

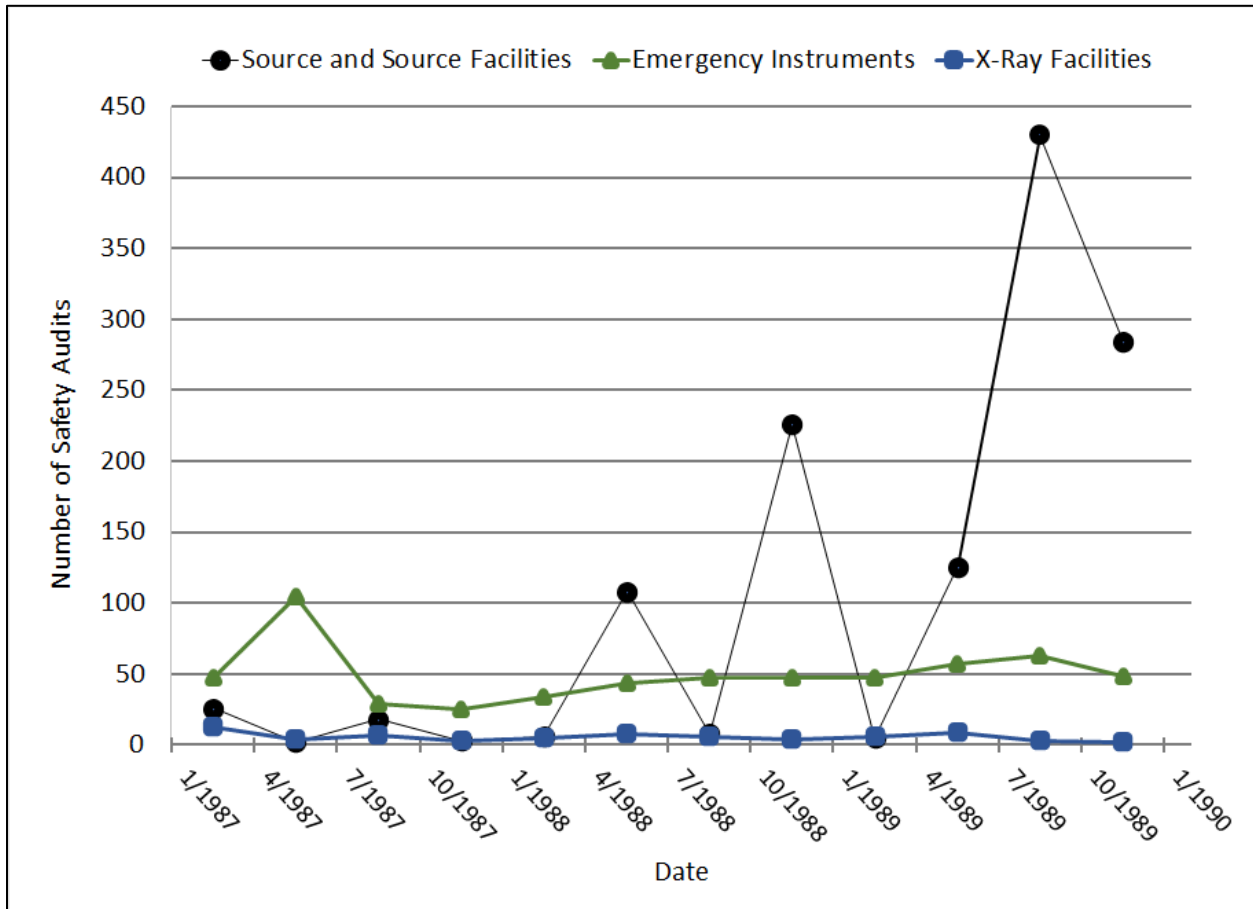
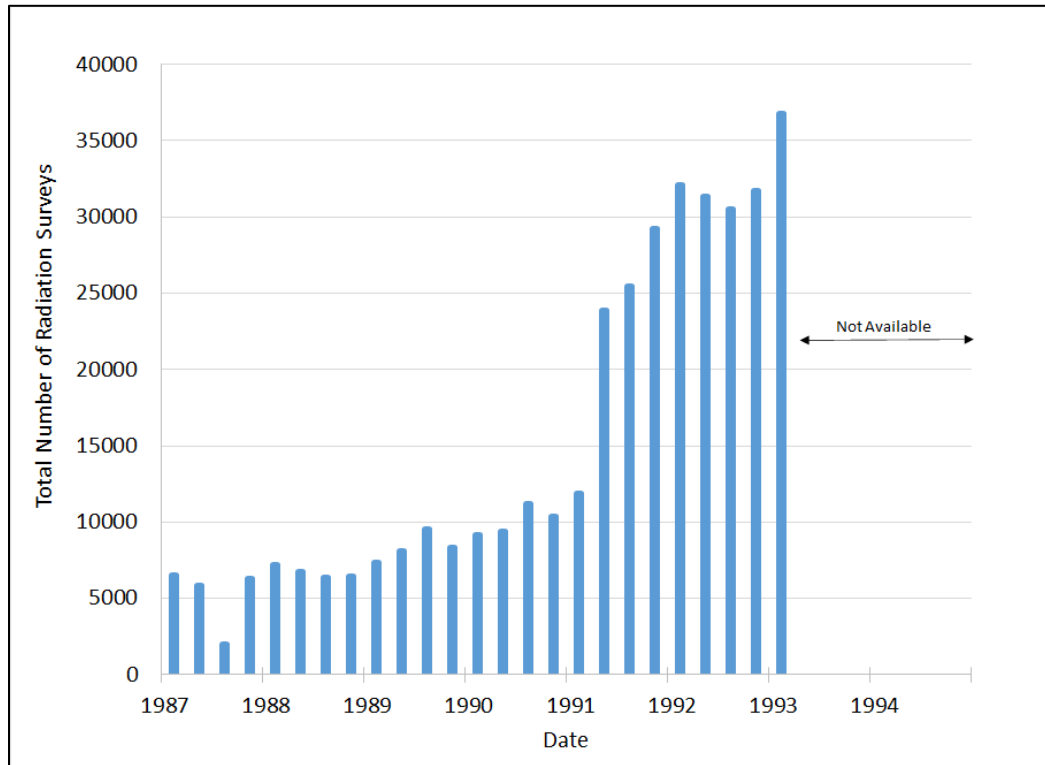


Figure 3 displays the total number of radiation surveys performed by quarter. Notable features of the timeline include the sharp decrease in surveys performed during the third quarter of 1987 (likely due to the worker strike). There is also a steady increase in the number of surveys performed per quarter, with a sharp increase in the second quarter of 1991 when the total number more than doubled and then stayed consistently above 25,000 surveys per quarter.

Figure 3. Total number of radiation surveys performed by quarter, 1987–1994



Additionally, figure 4 shows the percentage of surveys by four major categories: materials and equipment, radiological work permit, construction, and non-special nuclear material. By far the largest percentage (greater than 70 percent throughout the period) was surveys of materials and equipment. Surveys of non-special nuclear material (which likely involved most thorium compounds) constituted roughly 20 percent of the surveys during the early part of the period of interest and steadily declined to less than 1 percent by 1993. Thorium operations or contamination events were not specifically identified in the summaries contained in the quarterly surveys.

Figure 4. Percentage of radiation surveys by type/operation, 1987–1994

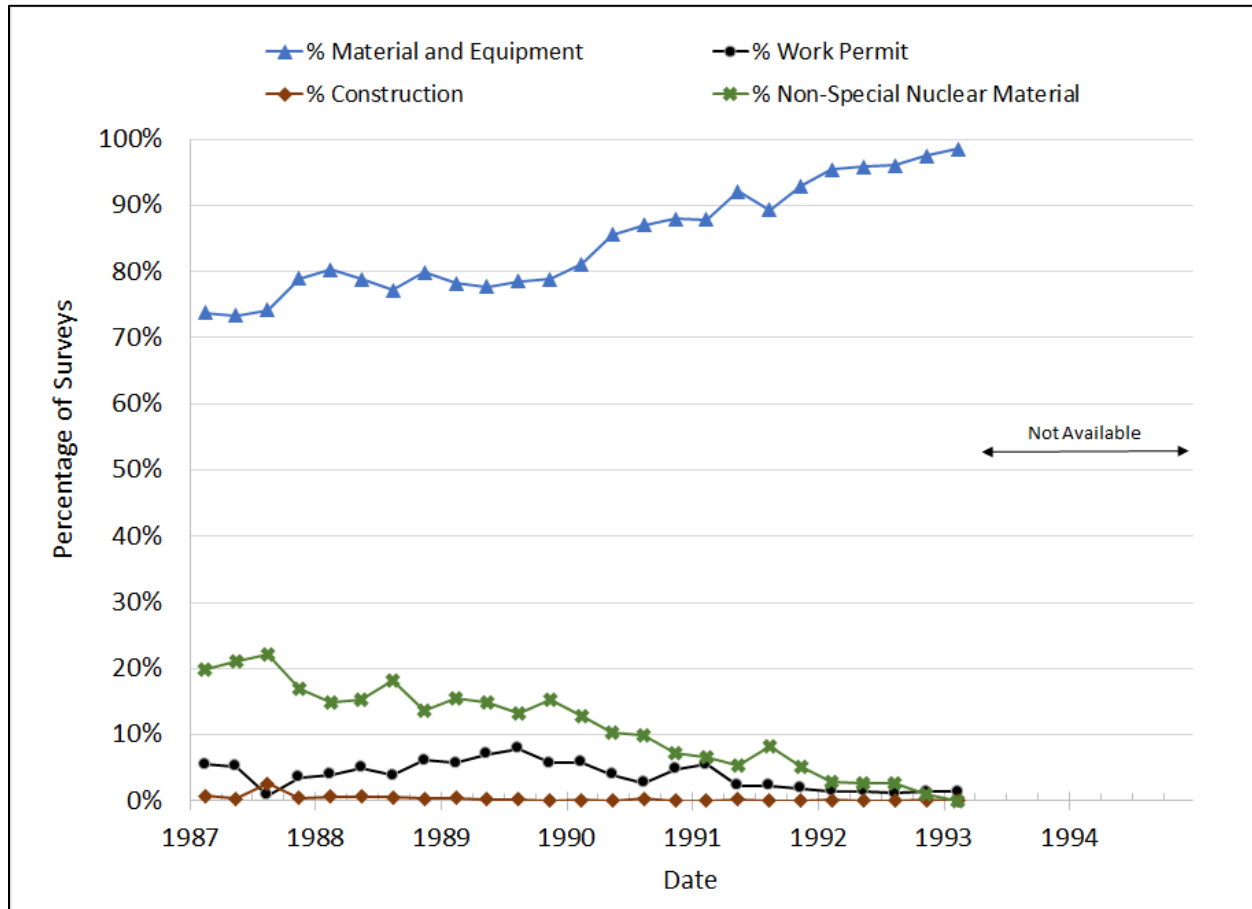


Figure 5 displays the total number of air monitoring stations in use by quarter as well as the number of operating areas covered by the air monitoring program. Similar to trends observed for the internal and external dosimetry program, there was a marked increase in the number of air sampling stations beginning around 1989 along with a modest increase in the number of covered operating areas.

Figure 6 displays the total number of evaluated air samples by quarter as well as the percentage of those samples above the PAV. Generally conforming to the trends observed in the total number of air monitoring stations, the number of evaluated air samples also markedly increased in 1989. Conversely, there was a sharp increase in the percentage of evaluated air samples above the PAV at the end of 1989. However, this did not appear to reflect an actual increase in exposure potential but rather reflected a significant decrease in the actual PAV value itself: The PAV changed from 22 disintegrations per minute per cubic meter (dpm/m³) to 4.4 dpm/m³.

The areas most commonly associated with elevated air sample results were found in the 9212 area and included the following locations: B-1 (wet and dry operations), E-Wing (alligator shear room, basement enclosures, and casting areas), Room 25 incinerator, and special processing rooms (1010, 1021, and 1022). Appendix A lists all noted elevated air contamination areas and a description (when available) of the type of operation or other explanation for the higher-than-

normal results. Thorium was not specifically mentioned in association with any of the areas with elevated airborne concentrations.

Figure 5. Total number of air monitoring stations and covered areas in use by quarter, 1987–1994

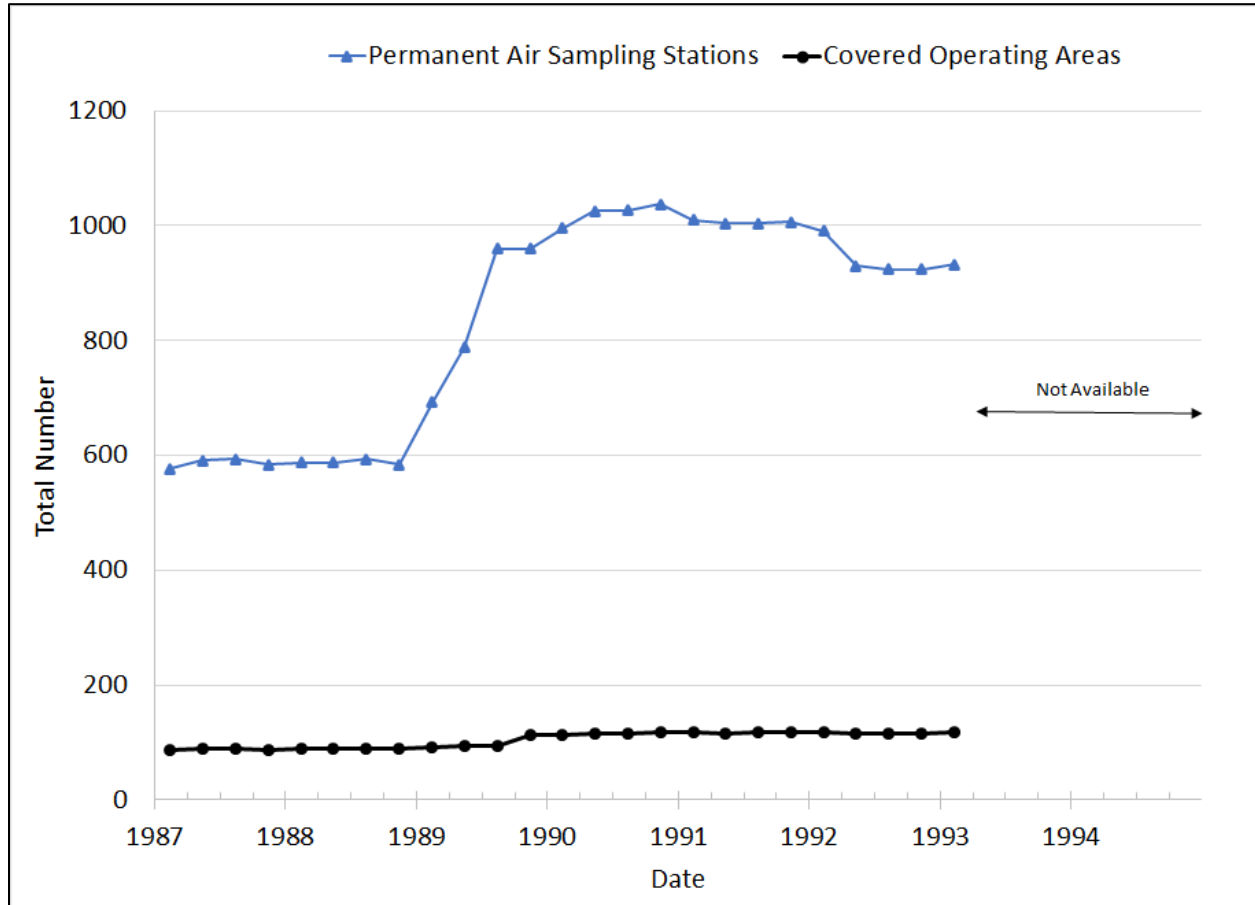
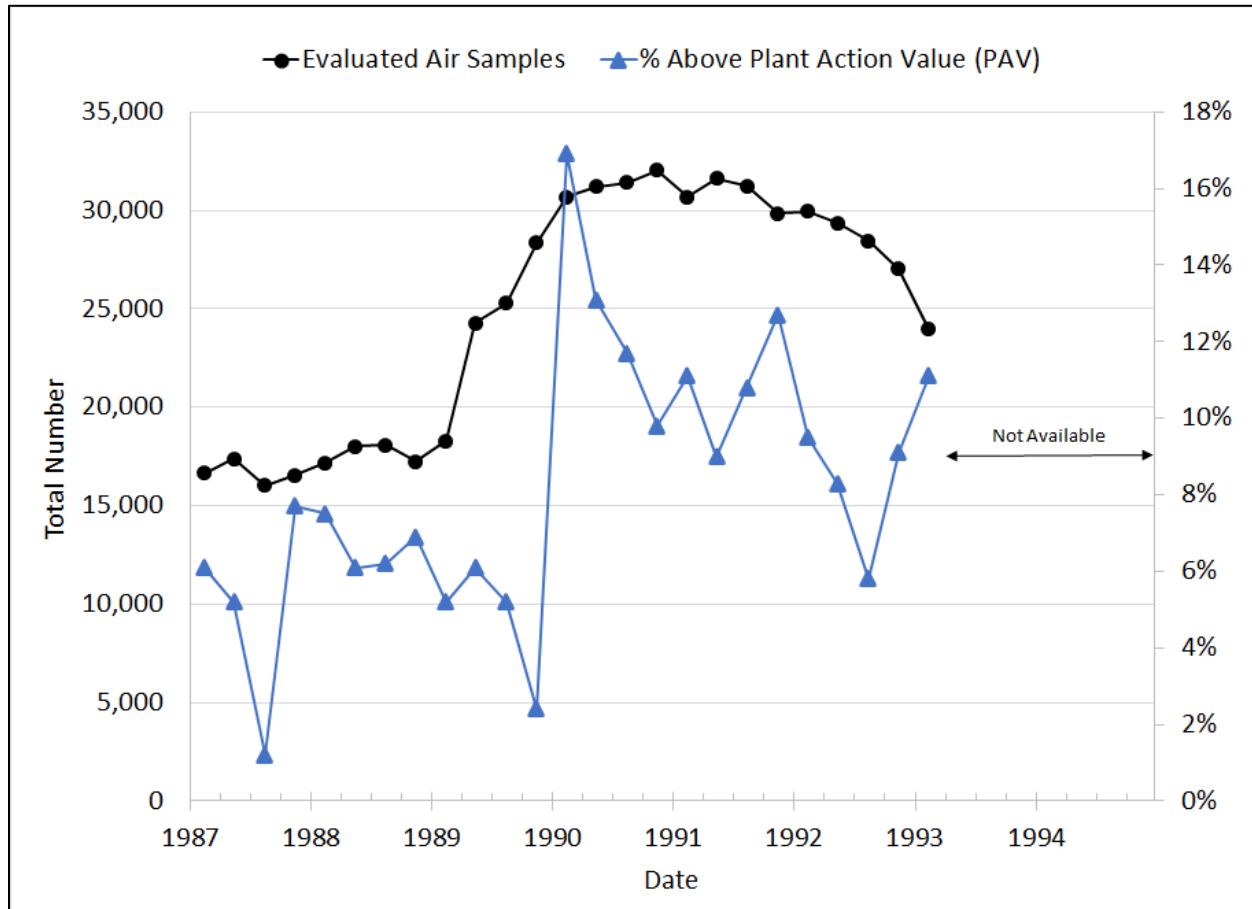


Figure 6. Summary of air sampling results by quarter, 1987–1994



2024 Observation 8: Examination of quarterly health physics reports indicates a significant increase in monitoring coverage in the late 1980s and early 1990s. This is reflected in the increased number of dosimeters issued, internal uranium analyses, permanent air sampling stations, and radiation surveys performed.

2024 Observation 9: Although the quarterly health physics reports provided information on external and internal monitoring for uranium, area surveys, safety audits, and air monitoring results (including the elevated areas and operations), thorium activities were never specifically mentioned in any of these regular reports.

6 Evaluation of Documented Communications for Y-12

NIOSH’s Site Research Database (SRDB) of captured documents for the Y-12 site contains 57 references with “Documented Communication” in the title. SC&A reviewed each of these documents for relevance to the SEC-00250 Addendum period and eliminated 41 of 57 as not containing information directly relevant to the SEC evaluation. For the remaining 16 of 57 that contained relevant information to the SEC-00250 Addendum, SC&A categorized them by the following topics of interest:

- area access controls
- evolution of the radiological control program
- thorium internal monitoring
- thorium operations and/or storage

Table 3 summarizes the relevant information contained in those 16 documented communications. For Privacy Act reasons, each documented communication was given a random alphabetical identifier that has no actual connection to the energy employee (EE).

Table 3. Summary of relevant information contained in documented communications

Case ID	Relevant experience during Addendum time period	Topics of interest	SC&A summary of documented communication
A	Entire period	Radiological Control	Machinists who worked with uranium did not wear respirators due to the presence of engineering controls and the results of air sampling (including breathing zone samples) that indicated respirators were not needed. In general, non-uranium radiological activities were afforded the same level of attention as uranium activities. Specific dates were not given.
B	Entire period	Radiological Control	All workers were monitored appropriately. All new operations required respirators until they were completely evaluated. Non-uranium operations were always evaluated appropriately. Health Physics personnel would always respond to employee requests for additional monitoring checks. All buildings and work areas were surveyed on a regular basis, and cleanup was initiated if necessary.
C	Entire period	Thorium Monitoring	During the lung counter operation in the 1980s, some workers' high results were discarded because the worker was suspected of having external contamination (though it's not clear if this was simply an a priori determination or based on actual survey measurements of the individual). Workers would then be rescheduled for another lung count in 4–6 weeks and restricted from radiological duty until the count was completed successfully. Surveys were regularly performed during the Addendum period.
D	Specifics not documented	Thorium Monitoring, Access Controls	EE participated in the lung count program in the 1980s. During that time, workers had to go through a radiation detector at the guard station before leaving the work area. There were also alpha and beta/gamma probes at the egress to the work area for use by the workers.

Case ID	Relevant experience during Addendum time period	Topics of interest	SC&A summary of documented communication
E	Entire period	Thorium Operations and/or Storage, Radiological Control	Plating and machining of thorium occurred in Alpha 5N (however, no specific dates were given). Access was controlled when the arc melting operation was occurring but believes the major arc melting ceased in 1975. However, arc melting of refurbished parts also occurred 1987–1989. In addition, finishing of components and detector plates for colliders still occurred. EE believes thorium developmental work is still occurring even in the current day, though the primary concern for the Addendum period would be the refurbishment or demolition of areas where thorium was used. Area access control for enriched uranium began around 1980; however, the thorium and depleted uranium areas were still open. After 1994, area controls were in place to restrict access to all of these areas.
F	Early 1990s and on	Thorium Operations and/or Storage, Radiological Control	Positive urine samples for uranium required followup sampling as well as lung counting (however, this may have been in the late 1990s). RWPs were used to determine if you needed to leave a bioassay sample. Arc melting of thorium ended sometime in the 1989 to 1990 timeframe. Thorium activities in the Apha-5 area did not continue, but the EE believes that machining operations may have continued in other areas (potentially the Beta-4 area). There was also a warehouse with crushed thorium parts (potentially 9270-12). To leave a radiological area, workers had to pass through a personal counter monitor and also have the hands and feet surveyed.
G	Entire period	Thorium Operations and/or Storage, Radiological Control	DOE had inquired whether Y-12 could store larger quantities of thorium material, but it was determined there were no viable options. The inventory levels of thorium remained constant. Arc melting operations likely ended in 1988. Controls in the arc melting area and machine shop were stringent (e.g., respirators were required in some areas as far back as the late 1970s). EE believes the Health Physics staff were well-equipped and very capable people. In general, during incidents (such as fires), the workers would often not be allowed to leave and had little protection.
H	Entire period	Thorium Operations and/or Storage, Radiological Control	Thorium overpacking operations would occur in the Alpha-5 area in the early 1980s, but the EE does not recall any active processing occurring. To the EE's knowledge, most arc melting operations involved depleted uranium (does not recall thorium). Radiological control and industrial health practices evolved rapidly starting in the mid-1980s.
I	Up until the late 1980s	Thorium Monitoring, Thorium Operations and/or Storage	Arc melting of thorium occurred from 1983 to 1988; the EE does not recall any other thorium-processing operations. Lung counting for thorium originally involved a large NaI detector, and Pb-212 and Ac-228 results were reported if positive. There was not a specific group of thorium individuals identified for monitoring, but there was exposure potential. However, the EE does not recall any positive thorium exposures.

Case ID	Relevant experience during Addendum time period	Topics of interest	SC&A summary of documented communication
J	Specifics not documented	Thorium Monitoring, Thorium Operations and/or Storage	The EE is not aware of any thorium operations occurring during the Addendum period and does not recall there being a specific group of thorium workers that had been identified for monitoring during the Addendum period.
K	Entire period	Thorium Monitoring, Thorium Operations and/or Storage, Radiological Control	Most of the thorium work occurred in the 1970s, with very little work done in the 1980s through the mid-1990s. However, after this period there may have been dismantling operations. Radiological control improved drastically just prior to 1994 (e.g., better equipment, ventilators, increased monitoring, respirators, etc.). However, there was also a serious change in radiological control polices in the mid-1980s. In the late 1980s, access controls and egress monitoring occurred; however, prior to that time, workers could simply leave their work area without any egress monitoring (e.g., no hand and foot monitors). Single-use respirators were worn for only a single day.
L	All but 1994	Thorium Monitoring, Thorium Operations and/or Storage, Radiological Control	Lung counting could be as frequent as once per month, and a positive lung count would result in restriction from work until the measurements reached acceptable levels. Resampling usually occurred in approximately 1 week. There were special process areas where they were checking for thorium all the time (e.g., 9212), which occurred all the way to 2020. Regarding radiological control, reuse of contaminated respirators was a problem because they were only replaced if they were physically broken. This resulted in the single use policy for respirators (unclear in what time period this occurred). In addition, in the late 1980s the operation of cleaning the respirators was found to not be functional, which may have resulted in extra whole body and lung counting being performed. In the late 1980s, stationary air monitors in use were improperly placed (i.e., the samplers were placed too high in the room to reflect the breathing zones of the workers).
M	Entire period	Thorium Monitoring, Thorium Operations and/or Storage, Radiological Control	Material access areas (i.e., access-controlled areas) were implemented in the late 1970s with the use of guard booths. EE states that while lung counts were performed, they were not performed for all assembly workers. Assembly had its own separate radiological control staff. The EE does not have specific knowledge of thorium operations but that they may have occurred in certain buildings near the West End Gates.

Case ID	Relevant experience during Addendum time period	Topics of interest	SC&A summary of documented communication
N	Entire period	Thorium Monitoring, Thorium Operations and/or Storage, Radiological Control	Thorium was stored in the 9720-3 warehouse until about 1989, where it was being dispositioned and catalogued. The EE does not believe there was constant health physics oversight for these activities. However, in general for these activities, if contamination was found then the health physicists were called in to perform appropriate surveys. Early in the Addendum period, workers were selected for internal monitoring by their area supervisor, though later health physicists made the selection. The EE did not have any knowledge of the arc-melting of thorium.
O	Entire period	Thorium Monitoring, Thorium Operations and/or Storage, Radiological Control	EE believes there were alloys of thorium in use but does not have any knowledge of pure thorium machining. Thorium was processed in the “east machine” and also likely had a press on the 3rd floor of Alpha-5, where the material was stored. An RWP program was instituted in the mid-1980s when material access areas were established to control areas. Contamination would be detected at the boundary control stations. There was a large increase in the radiological control staffing during the 1980s.
P	Specifics not documented	Thorium Operations and/or Storage	EE notes that thorium “grills” were in use in Beta-4 in 1983, and it appears this alloyed material may have been used up through 1990.

It should be noted that it is often difficult to interpret the documented communications, as actual dates can sometimes be unclear to the interviewee or omitted entirely from the interview transcript notes. Nonetheless, some general observations can be made based on the interviews summarized in table 3.

Regarding the radiological control program, unsurprisingly it appears that controls varied by the specific operation. For example, some operations were deemed sufficiently protected by engineering controls and air monitoring stations and did not require respirators (e.g., Case B), while others such as the arc-melting operation appeared to always require respirators (e.g., Case G). Furthermore, access controls depended on the source material operation (refer to Case E). However, it was also indicated that non-uranium operations were given the same attention from the radiological control staff as uranium operations (refer to Cases A and B). While accounts differ, the general consensus was that the radiological control program made significant improvements around the mid-1980s (refer to Cases H, K, and O).

Notably, one interviewee indicated that an RWP program was implemented in the mid-1980s (refer to case O), and another indicated that RWPs were used to determine bioassay requirements (refer to Case F). Additionally, interviewees indicated there was no specific group (or cohort) of thorium workers for monitoring purposes (refer to Cases I and J).

It was generally indicated that arc melting of thorium ended in the late 1980s (refer to Cases E, F, G, and I). Alternate operational activities involving thorium were also indicated by a few interviewees. For example, Case E indicated that continued developmental work with thorium

may have been present throughout the period of interest, and Case F indicated that the machining of parts likely continued past the arc-melting operations. Other former workers indicated that thorium activities were more akin to stewardship of the material, such as dispositioning of contaminated parts, decontamination and decommissioning (D&D) activities, and overpacking of previously utilized material (refer to Cases E, F, H, K, N, and O).

2024 Observation 10: Former workers indicated an RWP program was implemented in the mid-1980s and that the RWPs were used to determine bioassay requirements in at least some instances.

2024 Observation 11: Interviewees indicated that there was no defined group (referred to by the interviewees as a cohort) of thorium workers identified for specific internal thorium-monitoring purposes.

2024 Observation 12: Documented communications with former workers indicated that the thorium arc-melting operations likely ended in the late 1980s. It was generally indicated that the majority of thorium exposure after this time was likely related to stewardship, such as dispositioning of contaminated parts and any decontamination and decommissioning activities in prior thorium areas.

7 Review of Thorium In Vivo Methods for Use in Dose Reconstruction and Co-exposure Model Development

As discussed in section 2, the main focus of the SC&A's SEC-00250 Addendum review was the availability and suitability of data to reconstruct unmonitored or partially monitored thorium exposures using in vivo (specifically, chest counting) measurements in the formulation of a co-exposure model. As noted by NIOSH (2020a) in its response to SC&A's original review of the SEC-00250 ER (SC&A, 2020), the main criteria for co-exposure model development as documented in the NIOSH Implementation Guide No. 6 (DCAS-IG-006): "Criteria for the Evaluation and Use of Co-Exposure Datasets" (NIOSH, 2020c) aren't necessarily fully developed as part of the initial SEC evaluation. Rather, the purpose of the ER is to determine if it is most likely feasible to develop suitable co-exposure models for the relevant exposure pathways.

Nonetheless, it is instructive at this stage to perform some scoping analyses and evaluations to determine if the available monitoring data will meet three of the four main criteria of co-exposure development: completeness, representation, and adequacy.² Data completeness and representation are discussed in section 7.1, while data adequacy is discussed in section 7.2.

7.1 Data completeness and representation

Data completeness refers to the extent to which available datasets are reflective of the full population of monitored workers at the site or whether significant data gaps exist that may have resulted from missing, destroyed, illegible, or otherwise unavailable/unusable records. As noted in SC&A's original review of the SEC-00250 ER (SC&A, 2020) and also discussed in section 3.1 of this report, official tabulations of the number of thorium in vivo measurements are currently unavailable for after 1981. Thus, a direct comparison of the available dataset to the historical monitored population is not possible.

Furthermore, as noted in section 6 of this report, two former workers who were interviewed indicated there was no special cohort of thorium workers selected for monitoring (refer to SC&A 2024 observation 11). Any such identification of workers who handled thorium or were specifically selected for thorium monitoring would help establish the completeness of the dataset by direct examination of the data to verify those workers were appropriately included. However, to date no such list has been identified.

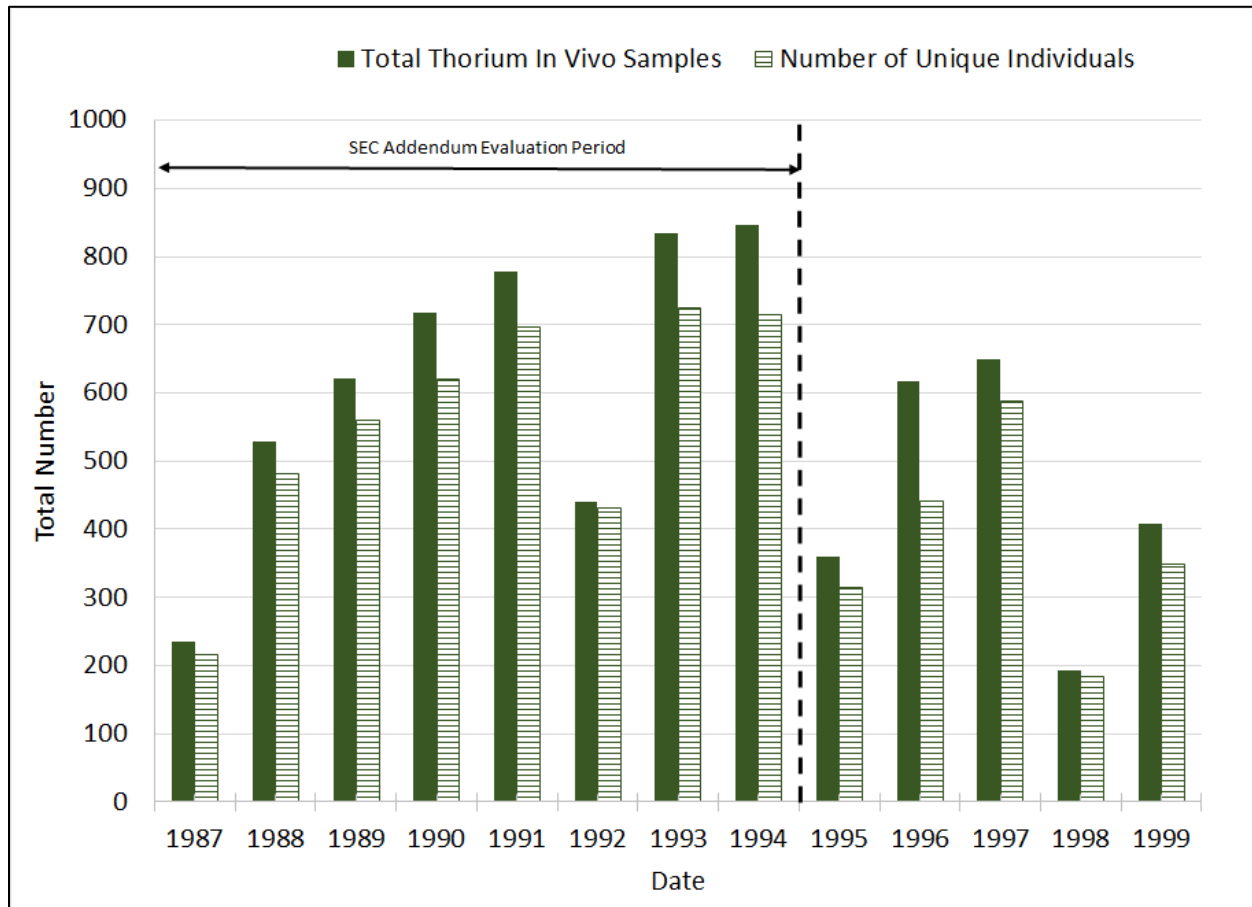
While not as instructive in evaluating data completeness, a simple characterization of the temporal spread is helpful in identifying potential gaps. Figure 7 shows the number of thorium in vivo samples and the number of unique individuals currently comprising part of the NIOSH dataset by year. Although the period 1995–1999 is not part of the SEC-00250 evaluation period, it is included here for reference.

It should be noted that these totals are lower than the summation of those reported in tables 6-3C, 6-3D, and 6-3E of NIOSH (2021). SC&A was unable to locate an electronic database version for

² The fourth criterion, stratification, was not considered by SC&A at this stage of review, as it is typically evaluated after the first three criteria have been sufficiently addressed.

all of the main PDF reference files cited in NIOSH (2021); specifically, SC&A was unable to locate an electronic compilation of SRDB 182925 and 166611. Nonetheless, SC&A was able to locate some of the electronic database files referenced in NIOSH (2021) (SRDB 177978, 177941, and 177942), which are still useful in helping to establish representation.

Figure 7. Overview of electronically compiled thorium in vivo references cited in NIOSH (2021) SEC-00250 evaluation report (1987–1999)



While these database files did not contain job titles, work locations, or general department designations, the social security numbers contained in the database were used to identify EEOICPA claimants for the purposes of characterizing generic job titles.³ SC&A was able to identify 266 individual claimants among the monitored population during the Addendum period only (i.e., post 1994 was not considered). SC&A characterized the listed NOCTS job titles for these individual claims into nine categories as follows:

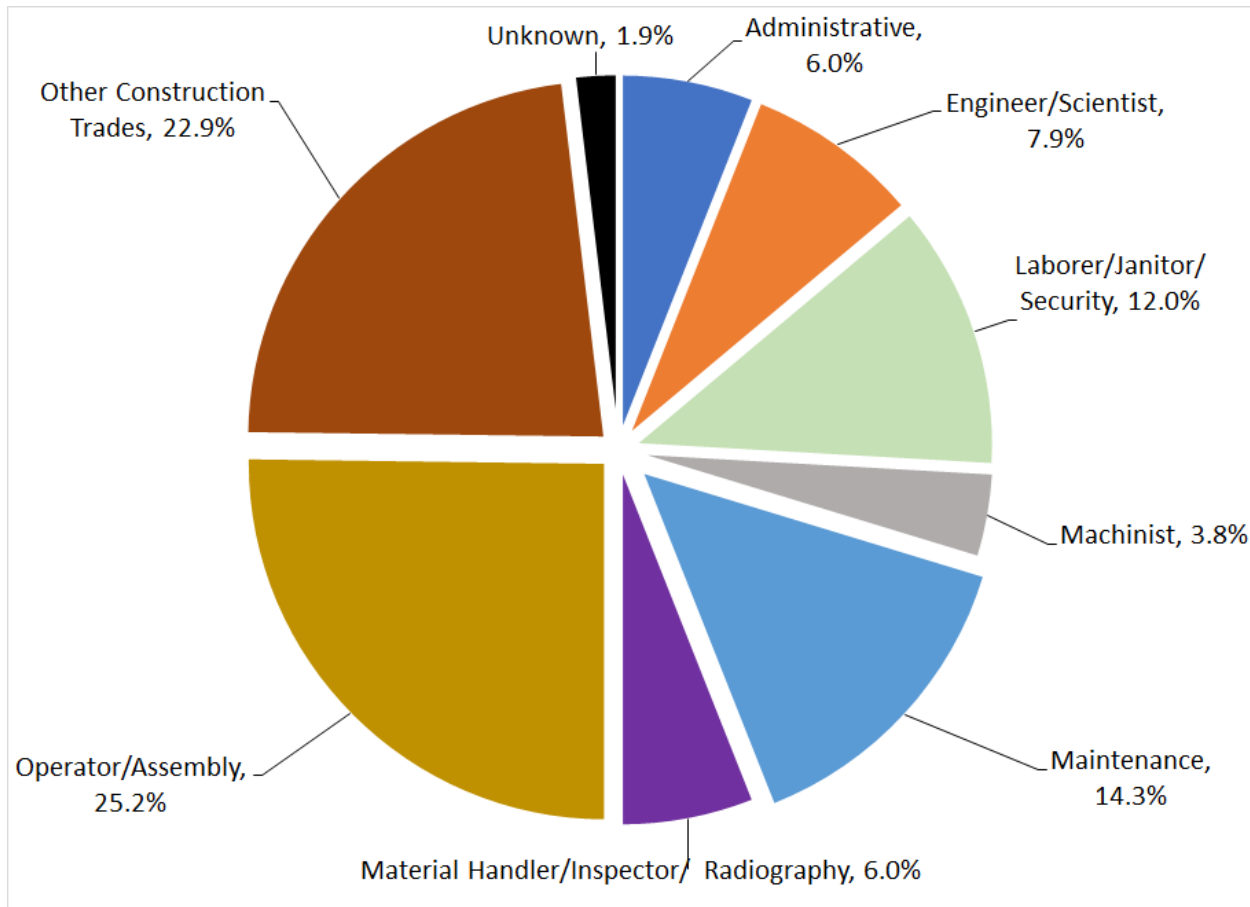
1. **Administrative:** includes clerks, secretaries, and supervisors whom SC&A judged unlikely to have regular exposure in radiological areas compared to other job categories.

³ Although the NIOSH Claims Tracking System (NOCTS) was not available during this review, SC&A was able to use an older compilation of claimants and associated job titles that was used during its review of the original SEC-00250 ER (SC&A, 2020).

2. **Engineer/Scientist:** includes physicists, metallurgists, laboratory technicians, chemists, health physicists, and workers in the “Animal Facility.”
3. **Laborer/Janitor/Security:** also includes the job titles of cleaner, guard, and building services.
4. **Machinist:** specifically delineated due to concerns about the internal monitoring of machinists as discussed by the Board during its August 2019 meeting (ABRWH, 2019).
5. **Maintenance:** includes maintenance mechanics, instrument mechanics, and electrical mechanics (regular electricians were included as part of the “Other Construction Trades” category).
6. **Material Handler/Inspector/Radiography:** also includes the materials inspectors and x-ray technicians.
7. **Operator/Assembly:** includes process operators, component assembly persons, chemical operators, and barrier operators.
8. **Other Construction Trades:** includes welders, surveyors, sheet metal workers, riggers, pipefitters, painters, heavy equipment operators, electricians, carpenters, boilermakers, and general construction job titles.
9. **Unknown:** no specific job title was able to be associated with the claimant.

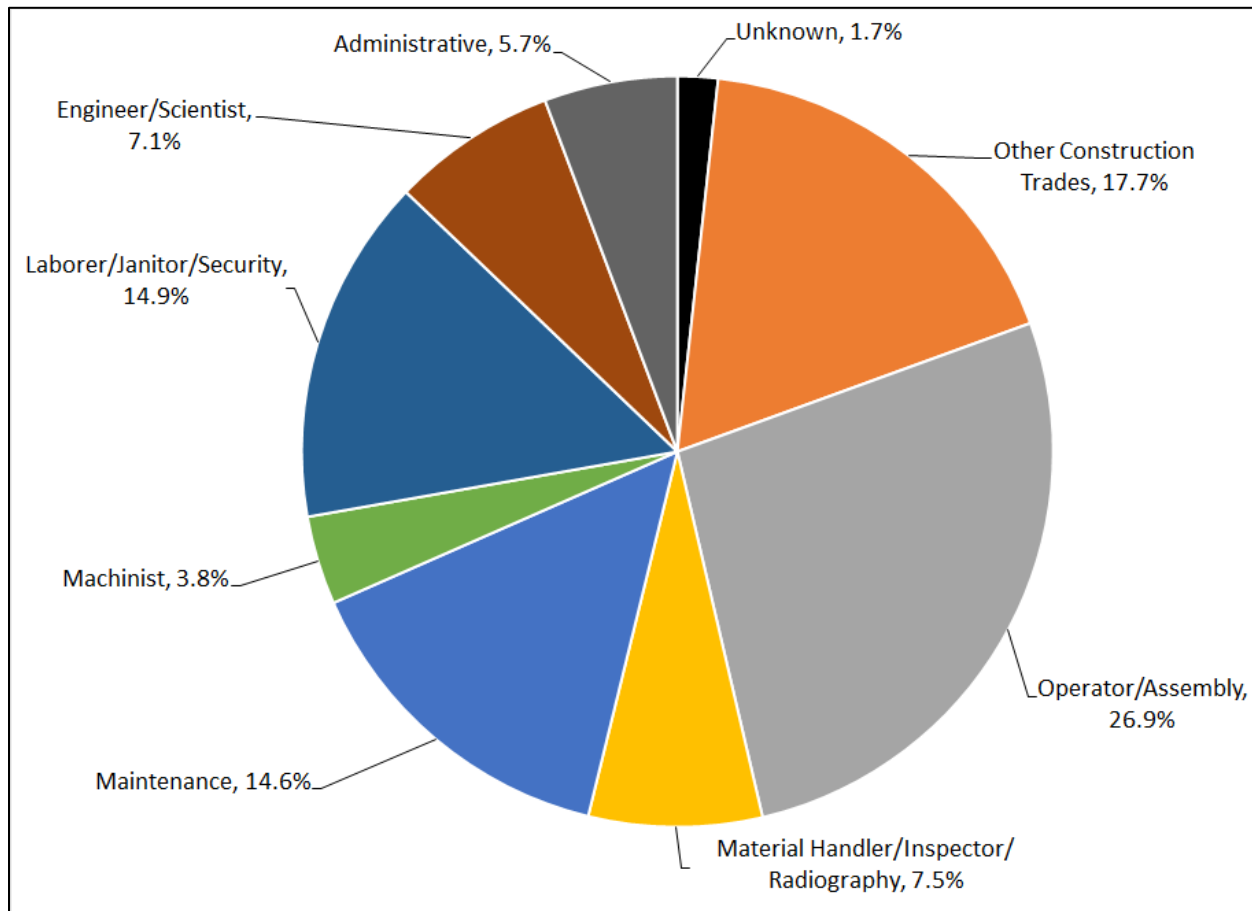
Figure 8 shows the breakdown of monitored claimants by SC&A job category as identified in the subset of thorium in vivo records. As shown in the figure, the identified claimants in partial NIOSH dataset were generally dominated by the “Operator/Assembly” (around 25 percent) and “Other Construction Trades” (around 23 percent) categories. Aside from the “Unknown” category, machinist and administrative-type job categories had the lowest proportion of monitored claimants identified (around 4 and 6 percent, respectively). Interestingly, health physicists (who were included by SC&A as part of the “Engineer/Scientist” category) only included four total identified individuals (around 1.5 percent of the total).

Figure 8. Characterization of job categories by individual monitored worker



Additionally, figure 9 shows a breakdown of job titles by percentage of total thorium samples (rather than by individual). Similar to the analysis by individual, the identified total samples by job type in the partial NIOSH dataset were generally dominated by the “Operator/Assembly” (around 27 percent) and “Other Construction Trades” (around 18 percent) categories. Aside from the “Unknown” category samples, “Machinist” and “Administrative” samples had the lowest proportion of monitored claimants identified (around 4 and 6 percent, respectively). Health physicists, who were included as part of the “Engineer/Scientist” category, only included five total identified samples (<1 percent of the total).

Figure 9. Characterization of job categories by in vivo thorium sample



The breakdowns in figures 8 and 9 suggest to SC&A that the monitoring program is best described as a routine, representative sampling rather than a singular focus on any singular worker category. However, this could also be an artifact of certain groups (e.g., Operator/Assembly) having a higher proportion of EEs in the workforce overall. Nonetheless, the observed routine, representative sampling is consistent with previous SC&A observations made in its original review of the SEC-00250 ER (refer to SC&A (2020) observations 5 and 6, which are discussed in sections 3.9 and 3.10 of this report). This is also consistent with statements made by former workers as discussed in section 6 (refer to 2024 observation 11 of this report), which indicated there was no special identification of “thorium workers” targeted for in vivo chest counting. In addition, this was confirmed by documentation provided by a former Y-12 internal dosimetrist, who indicated in vivo counting for thorium from 1992 through 2004 was for general screening purposes and is not necessarily indicative of work or exposure potential to thorium (refer to SC&A 2024 observation 6).

2024 Observation 13: Evaluation of a limited set of claimants identified within the available thorium dataset indicates that the in vivo monitoring program for thorium is likely reflective of routine, representative sampling rather than a focused sampling of any one particular worker category (e.g., thorium workers). This is consistent with SC&A’s analysis of the earlier portion of the SEC-00250 period (August 1979–December 1986) as well as former worker interview statements.

7.2 Data adequacy and DCAS-RPT-008 methodology

As noted in section 1, in vivo counting data of the thorium progeny can be utilized to perform internal dose reconstructions of Y-12 workers potentially exposed to thorium. The International Commission on Radiation Units & Measurements (ICRU) also states that thorium can be detected in the worker's body by measuring the gamma ray emissions of the thorium (Th)-232 decay chain nuclide Ac-228 (338.32 kiloelectron volts (keV) with 11.4 percent photons emission intensity) or the gamma ray emissions of the Th-228 decay chain nuclides radium (Ra)-224 (240.99 keV with 4.10 percent photons emission intensity), Pb-212 (238.65 keV with 44.6 percent photons emission intensity), and thallium (Tl)-208 (277.35 keV with 6.31 percent photons emission intensity) (ICRU, 2003, pp. 76–77). Pb-212 has the highest photon emission intensity in the Th-228 decay chain and thus higher detection probability in an in vivo lung counting system that features Broad Energy Germanium detectors to collect and analyze lung count spectra (Y-12, 2006).

This section presents methods NIOSH used in DCAS-RPT-008 for applying in vivo data extracted from the Y-12 whole-body count data document to evaluate the Pb-212 detection limit for a lung count at the Y-12 complex discussed in section 7.2.1.

7.2.1 Data adequacy for evaluating Pb-212 detection limits

The whole-body count PDF data file from Y-12 (1989–1995) contains 23,970 pages of in vivo examination reports collected between 1989 and 1995. In DCAS-RPT-008, NIOSH stated that the whole-body count data file provides uncensored minimum detectable activity (MDA) values (or activity values) for Pb-212 prior to 1992 but MDA values for Pb-212 were not reported starting from 1992. This means that no evaluation is necessary prior to 1992 to determine Pb-212 MDA values. To confirm this NIOSH statement in DCAS-RPT-008, SC&A searched the data file (Y-12, 1989–1995) for Pb-212 MDA values. The search confirmed the availability of Pb-212 MDA values prior to 1992. Additionally, the search confirmed that Pb-212 MDA values were not provided starting from 1992.

In DCAS-RPT-008, NIOSH noted that low-energy germanium (LEGe) detectors were used from 1992 for in vivo lung counts for Y-12 personnel. The Y-12 lung counting reports also included spectral data starting from 1992. SC&A searched the whole-body count data file (Y-12, 1989–1995) for gammas within the 238.00 to 238.99 keV energy region for the character string “238” to identify Pb-212 peaks. Table 4 summarizes Pb-212 gamma emission peaks found for Y-12 workers from 1992 to 1995.

Table 4. Summary of Pb-212 gamma emission peaks found for Y-12 workers of various chest wall thicknesses (CWT) in the whole-body count data file (Y-12, 1989–1995)

PDF page number	Year	In vivo energy for Pb-212 (keV)	CWT (cm)	Net counts ***	Background counts
489 *	1993	238.31	3.94	89	1,021
571	1995	238.9	2.65	15	38
617	1993	238.66	2.38	55	46
1034	1992	238.79	2.81	21	33
1122	1992	238.76	4.32	21	39
1536	1993	238.89	3.37	23	30
2777	1994	238.65	4.68	13	45
3758	1994	238.76	2.39	13	36
4944 **	1994	238.79	3.97	8	34
6071	1992	238.93	2.05	2	34
6606 **	1993	238.61	3.09	25	19
6692	1992	238.59	2.97	26	27
6871	1992	238.16	4.68	15	21
7386 **	1993	238.00	2.86	4	18
7404	1994	238.15	4.53	13	38
7549	1993	238.37	4.06	14	30
8629	1993	238.58	3.89	18	22
10135 **	1992	238.73	2.87	21	20
10415 **	1994	238.56	3.72	18	18
10477	1992	238.71	3.64	27	23
10822	1992	238.80	2.62	13	29
10874	1994	238.87	3.64	12	49
12191	1993	238.46	3.89	29	20
12206	1992	238.64	3.97	10	29
14682	1993	238.57	3	22	37
15922	1992	238.52	3.48	13	48
17605	1993	238.46	3.76	30	25
17955	1993	238.89	3.19	19	52
18062 **	1992	238.42	3.29	19	16
18809	1992	238.84	4.85	20	50
20636	1992	238.69	1.50	19	25

* NIOSH excluded Pb-212 background counts on PDF page 489 in DCAS-RPT-008 to calculate MDA.

** PDF page numbers with a double asterisk (also excluded by NIOSH in DCAS-RPT-008) represent Pb-212 peaks found in the in vivo spectral data (“Appendix B,” PDF p. 4944) but not captured in the Y-12 lung counting report (“Appendix C,” PDF p. 4943) in the whole-body count data file (Y-12, 1989–1995). Y-12 lung counting reports were generated using the peak search, nuclide identification (NID), algorithm described in Y-12 (2006), section “Post-NID Peak Search,” in the whole-body count data file Y-12 (1989–1995).

*** Net counts in this table represent peak areas found in the VAX/VMS peak search report (“Appendix B,” Y-12, 1989–1995, PDF p. 4944).

Table 4 reveals that Y-12 in vivo examination reports for 1992–1995 contain sufficient data to estimate the MDA for Pb-212. This means that in vivo counting data for one of the thorium progenies, e.g., Pb-212, can be extracted and utilized to perform internal dose reconstructions of Y-12 workers potentially exposed to Th-232.

SC&A additionally searched the Y-12 lung counting reports for Th-232 MDA values. The search revealed 18 reported Th-232 MDA values in January 1992, 42 in February 1992, 18 in March 1992, 12 in April 1992, 20 in May 1992, 5 in November 1992, and 15 in December 1992. SC&A

found that Th-232 MDA values were only reported for the K-25 in vivo exam center using LEGe detectors. It is not clear why Th-232 MDA values were only reported for the K-25 in vivo exam center. SC&A also searched the Y-12 (1989–1995) file for Ra-224 and Tl-208 MDA values. No MDA values for Ra-224 and Tl-208 were reported.

7.2.2 DCAS-RPT-008 methodology to evaluate Pb-212 MDA

This subsection focuses on the methodology presented in DCAS-RPT-008 for applying the in vivo data in table 4 to evaluate Pb-212 MDA (detection limit) for a lung count at the Y-12 facility. Once Pb-212 peak is identified and quantified, missed dose for Th-232 intake can be determined using the methodology prescribed in ORAUT-OTIB-0076, revision 00, “Guiding Reconstruction of Intakes of Thorium Resulting from Nuclear Weapons Programs” (ORAUT, 2014). For comparison purposes, SC&A also evaluated the methodology presented in DCAS-RPT-008 to compute Pb-212 MDA.

As noted in Section 7.2.1, the in vivo exam center started using an array of LEGe detectors from 1992 to collect and analyze lung count spectra for an in vivo examination of Y-12 workers. LEGe spectral plots covered the energy region of 0–400 keV with an energy calibration of slightly less than 0.1 keV per channel collected in 4,096 data channels. As noted in the 2006 contractor’s report on verification and validation of the Y-12 lung counting system, RCO/TBD-051, revision 1 (Y-12, 2006), americium-241 and europium-152 sources emitting 59.5 keV, 121.8 keV, 244.7 keV, and 344.3 keV gamma peaks are used for calibrating germanium detectors (within the range around 50 keV to around 350 keV) used in the Y-12 lung counting system to detect and quantify isotopes of interest within this energy region. Even though the Y-12 lung counting system’s primary purpose is the detection and quantification of uranium compounds, thorium progeny isotopes can also be detected and quantified.

To estimate the lung burdens of workers potentially exposed to Th-232, an efficiency calibration is required for Ac-228 or Pb-212 with respect to varying CWTs. As stated in RCO/TBD-051 (Y-12, 2006), an efficiency calibration of a lung counting system is performed at various energies of interest for five CWTs ranging from 1.5 to 4.0 centimeters (cm). Next, a continuous exponential fit is obtained for efficiency versus CWT at each energy of interest. The exponential fit function can be used to calculate efficiency for any CWT for an energy of interest.

Using the technique just described, NIOSH in DCAS-RPT-008 extracted net counts, CWTs, and activity data from Y-12 lung counting reports and generated exponential fit functions for efficiency versus CWT at 63.29 keV (Th-234), 92.38 keV (Th-234), 185.71 keV (uranium (U)-235), and 338.32 keV (Ac-228). Equation 1 is a relationship between the detection efficiency for Ac-228 (ϵ_{Ac-228}) in counts/gamma and CWT in cm.

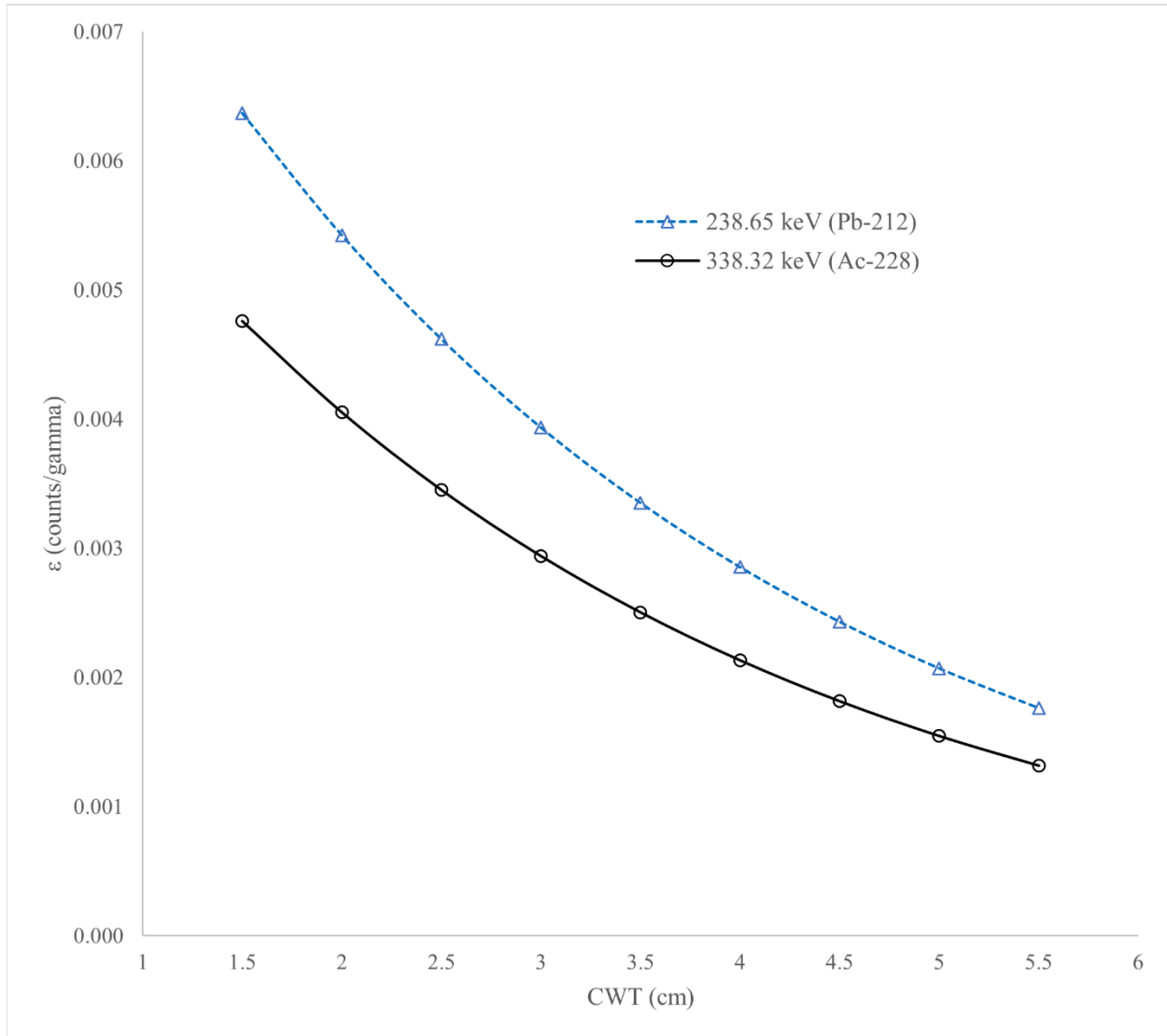
$$\epsilon_{Ac-228} = 0.0077 \times \exp(-0.321 \times CWT) \quad (1)$$

As noted earlier, starting from 1992 no activity data were provided for Pb-212. Therefore, NIOSH derived a relationship between the detection efficiency for Pb-212 (ϵ_{Pb-212}) and CWT by incorporating an efficiency value obtained from an exponential fit function between the U-235 detection efficiency and Ac-228 detection efficiency values at a CWT of 1.5 cm. Note that any CWT could be used to calculate detection efficiencies for U-235 and Ac-228 to derive the ϵ_{Pb-212} versus CWT relationship. Equation 2 is a derived relationship between ϵ_{Pb-212} and CWT.

$$\varepsilon_{\text{Pb-212}} = 0.010307 \times \exp(-0.321 \times \text{CWT}) \quad (2)$$

Figure 10 show detection efficiency versus CWT plots for Ac-228 and Pb-212 computed by SC&A using equations 1 and 2. CWTs between 1.5 and 5.5 cm are used in these calculations. As expected, the detection efficiency for gammas in an LEGe detector is a function of both energy and CWT.

Figure 10. Detection efficiency versus CWT for Th-232 decay chain nuclides



NIOSH used equation 3 to calculate MDA in nanocuries (nCi) for an in vivo exam. The formula is based on the statistical concept derived by Currie (1968). The value 2200 in the formula is the number of disintegrations per minute per nCi of activity.

$$\text{MDA} = \frac{4.66 \times \sigma_{\text{bkg}}}{\varepsilon \times y \times t \times 2200} \quad (3)$$

where:

$$\sigma_{\text{bkg}} = 1.65 \times \sqrt{\text{Background count}}$$

The value 1.65 is the assumption that risks of 5% are acceptable, and that the random errors are normally distributed.

ε is detection efficiency in counts/gamma.

y is photon emission intensity (photon yield) in gamma/disintegration.

t is in vivo counting time.

To customize MDA for Pb-212 ($\text{MDA}_{\text{Pb-212}}$), ε is replaced with the $\varepsilon_{\text{Pb-212}}$ function (equation 2), the Pb-212 photon yield is equal to 0.446, and in vivo counting time is 30 minutes. The modified formula derived from equation 3 for $\text{MDA}_{\text{Pb-212}}$ is shown in equation 4:

$$\text{MDA}_{\text{Pb-212}} = 0.015359 \times \exp(0.321 \times \text{CWT}) \times \sigma_{\text{bkg}} \quad (4)$$

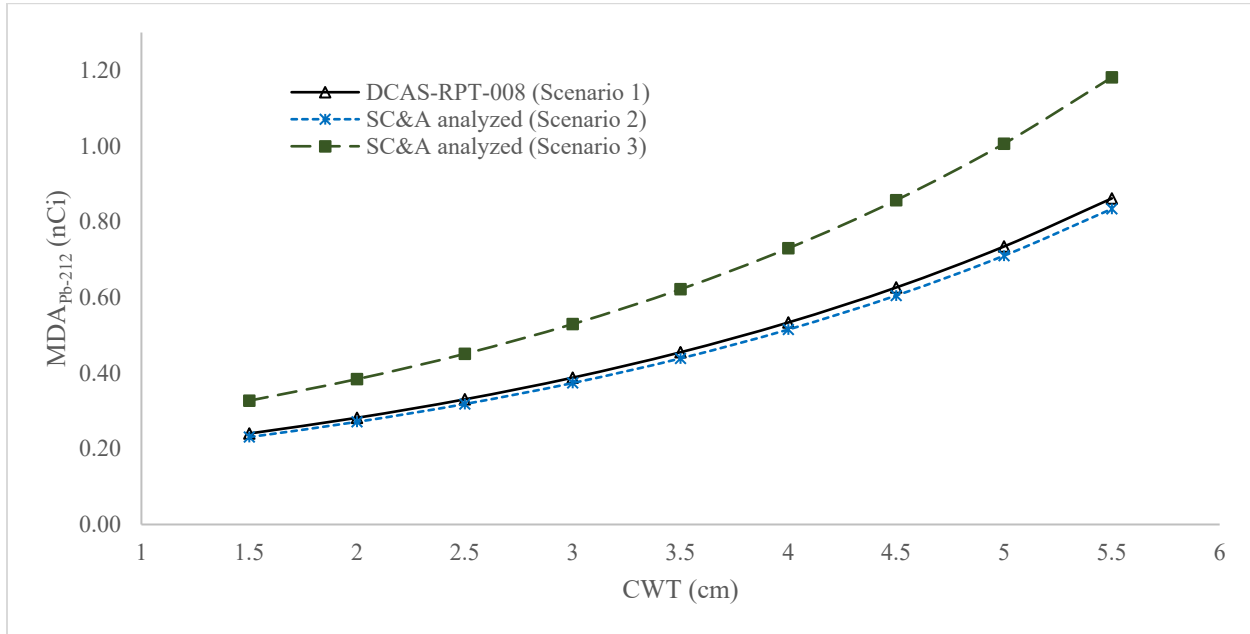
In vivo background counts presented in table 4 are divided into three scenarios for computing $\text{MDA}_{\text{Pb-212}}$ versus CWT using equation 4 as follows:

- **Scenario 1:** NIOSH calculated the mean of in vivo background counts, μ_{bkg} equals 34.42, to determine the standard deviation, $\sigma_{\text{bkg}} = 1.65 \times \sqrt{34.42} \approx 9.70$. The σ_{bkg} value was then used in equation 4 for varying CWTs. The μ_{bkg} value was calculated without the P-212 background count value on PDF page 489 in table 4 and without the Pb-212 background count values on PDF page numbers with double asterisks listed in table 4.
- **Scenario 2:** SC&A calculated the mean of in vivo background counts, μ_{bkg} equals 31.70, to determine the $\sigma_{\text{bkg}} = 1.65 \times \sqrt{31.70} \approx 9.29$. The σ_{bkg} value was then used in equation 4 for varying CWTs. The μ_{bkg} value was calculated without Pb-212 background count value on PDF page 489 in table 4 but included all other Pb-212 background count values listed in table 4.
- **Scenario 3:** SC&A calculated the mean of in vivo background counts, μ_{bkg} equals 63.61, to determine the $\sigma_{\text{bkg}} = 1.65 \times \sqrt{63.61} \approx 13.16$. The σ_{bkg} value was then used in equation 4 for varying CWTs. The μ_{bkg} value was calculated with all Pb-212 background count values listed in table 4.

Figure 11 show $\text{MDA}_{\text{Pb-212}}$ versus CWT plots computed by NIOSH (in DCAS-RPT-008) and SC&A for these three scenarios. The percentage relative differences between scenario 1 and scenario 2 plots underestimated from 3.2 percent to 3.9 percent. The differences are not significant, which indicate that thorium dose reconstruction can also be performed for workers whose Pb-212 peaks were identified in the in vivo spectral data (e.g., PDF page 4944 in the whole-body count data file in which a 238.79 keV Pb-212 peak is also present as shown in appendix B) but not captured in the lung counting report following post-NID peak search (e.g., PDF page 4943 in the whole-body count data file shown in appendix C). As a reminder, the Y-12 lung counting reports were generated after doing post-NID peak search (the peak search algorithm is discussed in RCO/TBD-051). On the other hand, the percentage relative differences between scenario 1 and scenario 3 plots overestimated from 36.1 percent to 37.1 percent. The differences are significant, which indicate that the in vivo measurement for this particular Y-12 lung counting report in Y-12 (1989–1995), PDF page 489, is not a representation of in vivo

measurements collected between 1992 and 1995. Even though no specific reason was provided in DCAS-RPT-008 to exclude the Pb-212 background counts in Y-12 (1989–1995), PDF page 489, SC&A considered this an outlier based on the evaluation presented in the next section.

Figure 11. MDA versus CWT plots for Pb-212 analyzed by NIOSH and SC&A



7.2.3 Alternative methodology to identify outliers and evaluate Pb-212 MDA

In this section, SC&A presents an alternate approach to identify outliers and evaluate MDA_{Pb-212} . This approach relies on extracting CWT and background counts data from the whole-body count data file Y-12 (1989–1995) to generate MDA_{Pb-212} versus CWT data points using equation 4 from DCAS-RPT-008. This means that the mean background value approach used by NIOSH for the population data in which Pb-212 peaks were identified is not used to evaluate MDA_{Pb-212} . Instead MDA_{Pb-212} is individually evaluated for a given CWT and background counts data. These datapoints can then be fitted using an exponential function generated in figures 12, 13, and 14. Based on the R^2 value in figure 14, which is approximately 0.13, the MDA_{Pb-212} evaluated using data on PDF page 489 in the whole-body count data file is considered an outlier. Additionally, the following fitted functions (equations 5 and 6) obtained from figure 12 and figure 13 can also be used to evaluate MDA_{Pb-212} for a given CWT, respectively:

$$MDA_{Pb-212} = 0.01339 \times \exp(0.3337 \times CWT) \quad (5)$$

$$MDA_{Pb-212} = 0.01444 \times \exp(0.3236 \times CWT) \quad (6)$$

The R^2 value for equation 5 is approximately 0.73, whereas the R^2 value for equation 6 is approximately 0.76. An advantage of using one of these equations is that MDA_{Pb-212} can be evaluated with only one dependent variable, i.e., CWT.

Figure 12. MDA_{Pb-212} evaluated using equation 4 for a given CWT and background counts data listed in table 4; CWT and Pb-212 background counts data from PDF page 489 (outlier) in table 4 were excluded

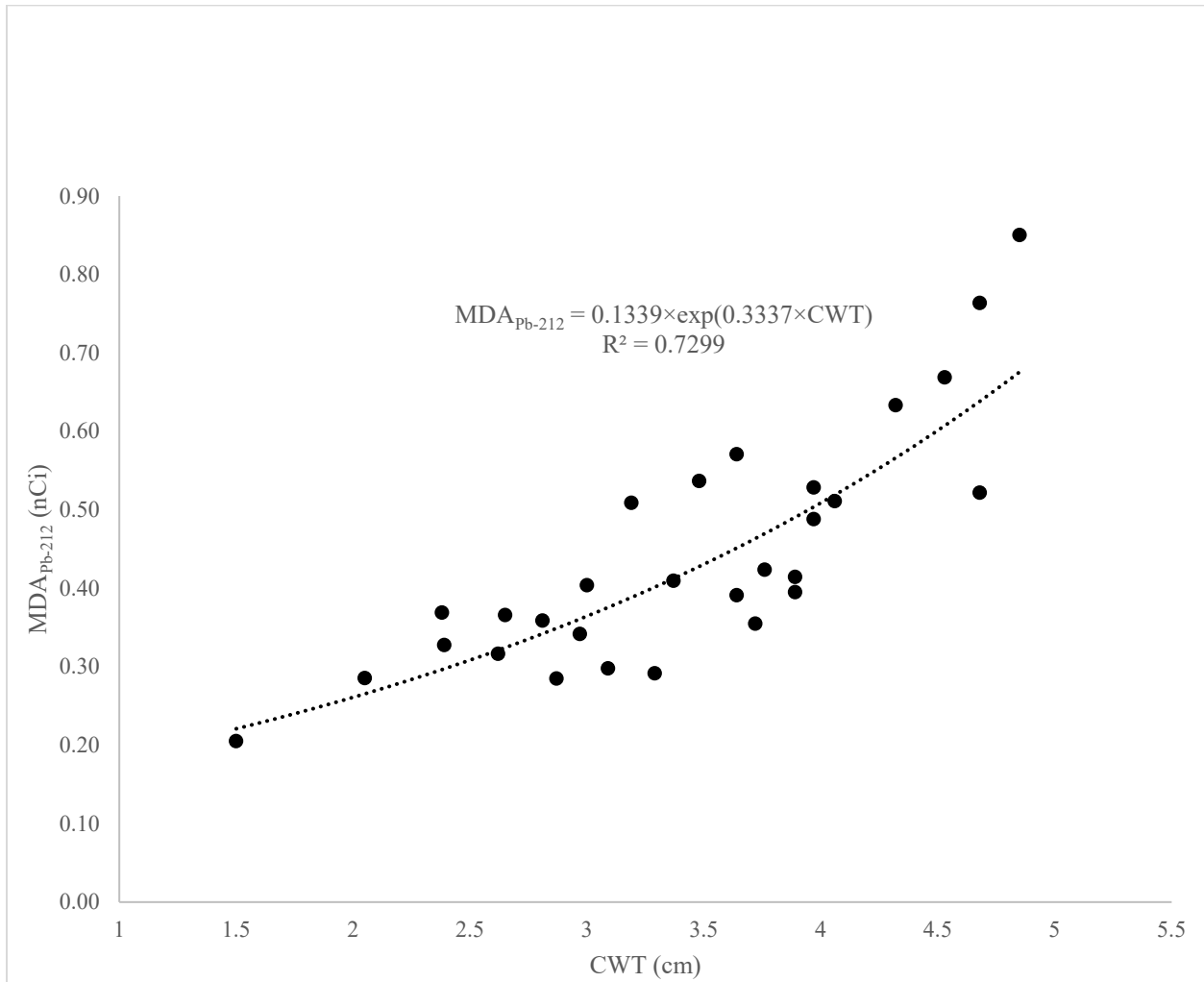


Figure 13. MDA_{Pb-212} evaluated using equation 4 for a given CWT and background counts data listed in table 4; CWT and Pb-212 background counts data from PDF page 489 (outlier) and PDF pages excluded by NIOSH in DCAS-RPT-008 (marked by a double asterisk in table 4) were excluded

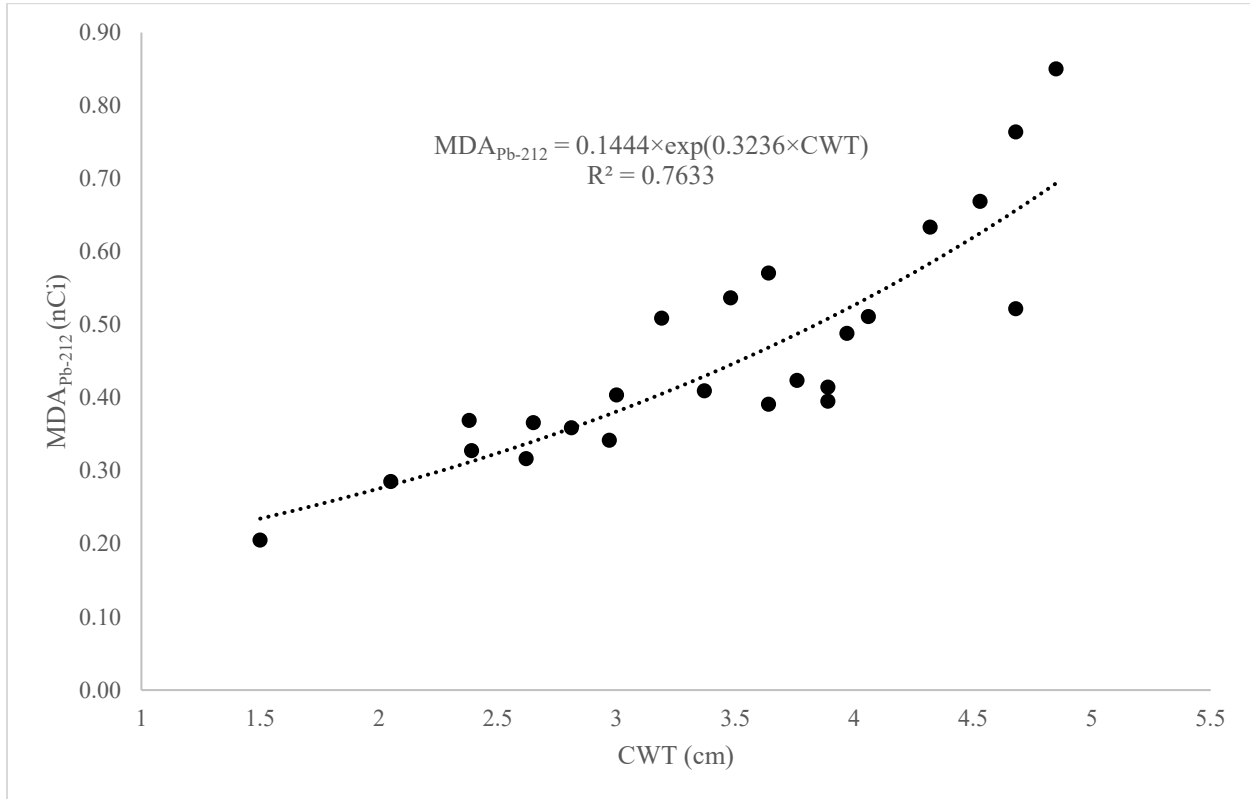


Figure 14. MDA_{Pb-212} evaluated using equation 4 for a given CWT and background counts data listed in table 4; CWT and Pb-212 background counts data from PDF page 489 (outlier) in table 4 were included, identified by a triangle data point

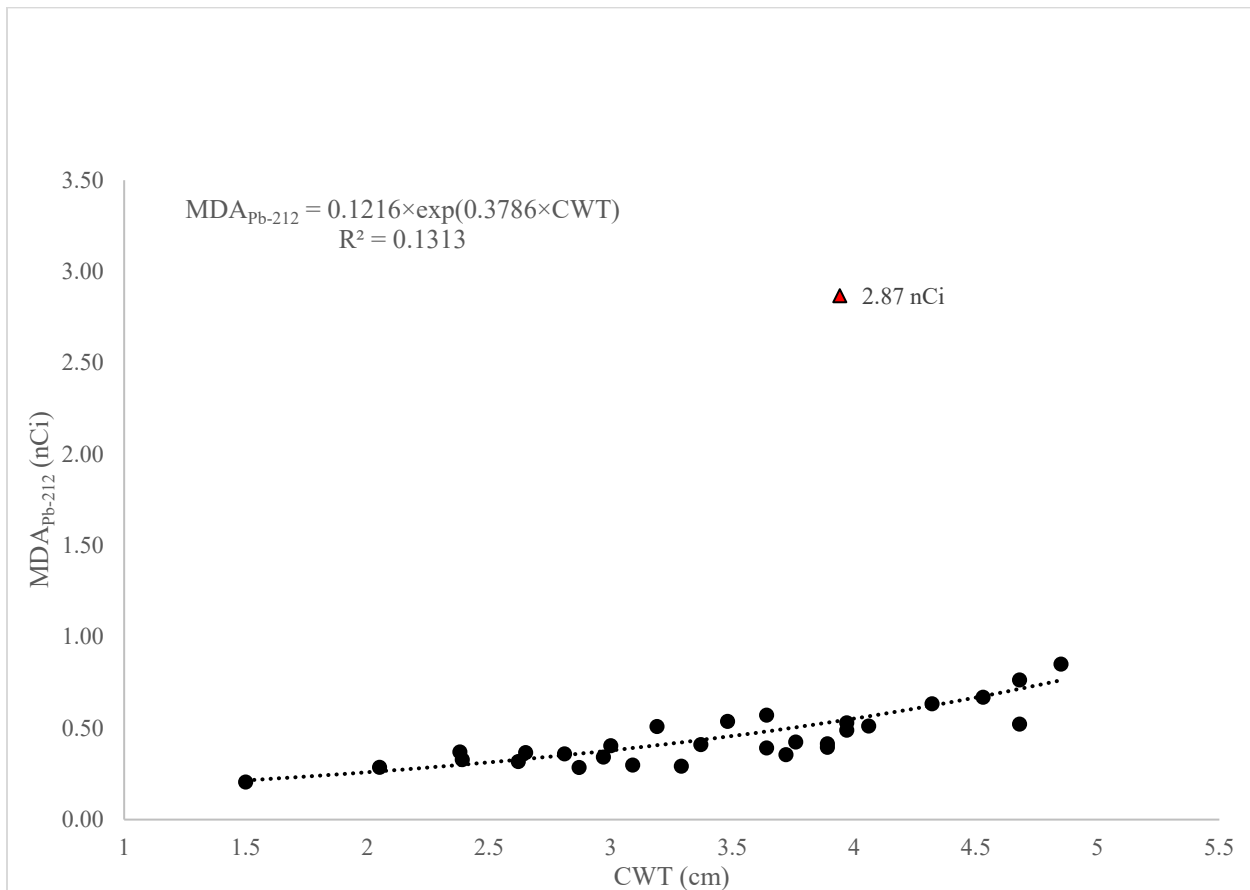
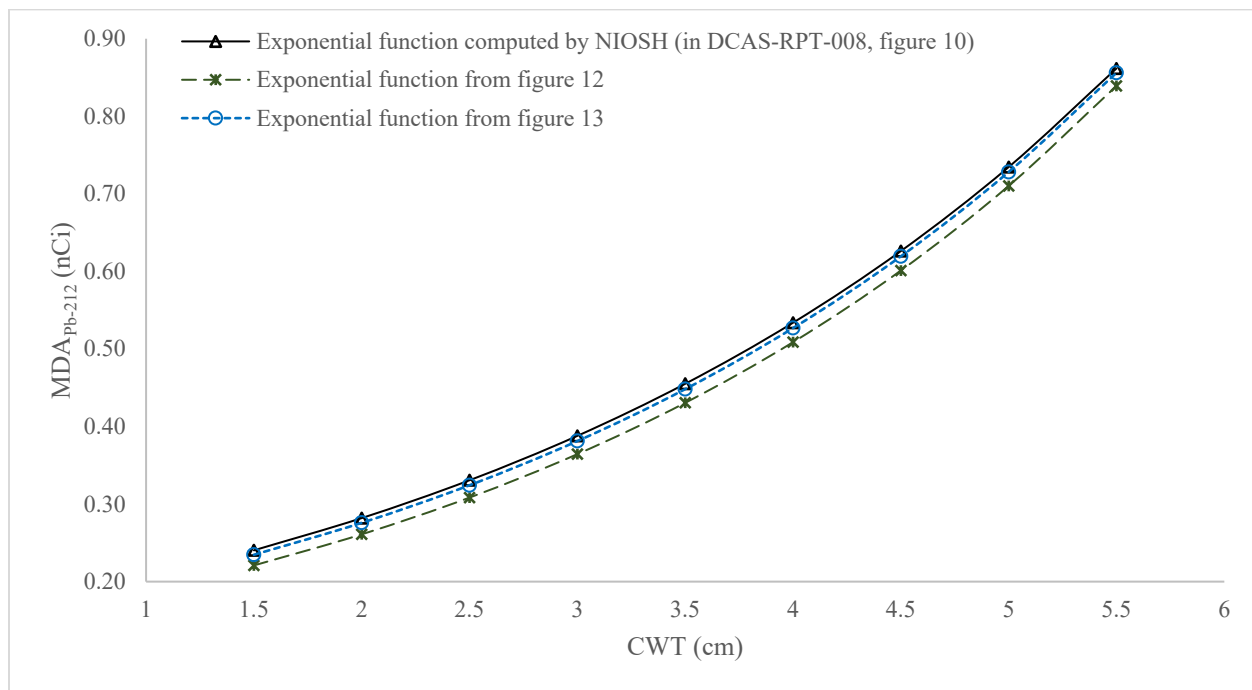


Figure 15 shows a comparison between MDA_{Pb-212} versus CWT plots computed by NIOSH (exponential function used in DCAS-RPT-008, figure 10), with equation 5, and equation 6 used for evaluating MDA_{Pb-212} . All equations are roughly comparable to each other. However, the percentage relative difference between MDA_{Pb-212} evaluated using equation 5 and equation 4 (DCAS-RPT-008) are underestimated up to 8.1 percent. The percentage relative difference between MDA_{Pb-212} evaluated using equation 6 and equation 4 (DCAS-RPT-008) are underestimated up to 2.4 percent.

Figure 15. MDA versus CWT plots generated for Pb-212 using mean background value (DCAS-RPT-008 approach) and individual background values approach that generated exponential functions in figures 12 and 13



The alternative approach that generated equations 5 and 6 is comparable to the exponential function computed by NIOSH (in DCAS-RPT-008, figure 10). Either of these approaches could be used for dose reconstruction. The major advantage of using the alternative approach is that outlier(s) can be easily identified as seen in figure 14. No statistical reasoning was provided in DCAS-RPT-008 to exclude the Pb-212 background counts value from PDF page 489 in the whole-body count data file. It can also be noted that the instrument's sensitivity is also slightly improved for dose reconstruction purposes in the alternative approach. However, the approach is limited to the data (e.g., CWT and background count values for the monitoring time frame) presented in the whole-body count data file (Y-12, 1989–1995).

2024 Observation 14: SC&A identified an alternate approach to evaluating the Pb-212 MDA that may be advantageous in that it can easily identify outliers. SC&A recommends NIOSH consider the use of such a method as a complement to the DCAS-RPT-008 methodology.

8 Summary Conclusions

Based on its review of the Y-12 SEC-00250 ER Addendum (NIOSH, 2021), SC&A identified 14 observations specific to the SEC-00250 Addendum period, which mainly pertain to the ability to appropriately develop appropriate co-exposure estimates for unmonitored or partially monitored workers in accordance with DCAS-IG-006 criteria for the evaluation and use of co-exposure datasets. As NIOSH has committed to development of co-exposure models in accordance with these guidelines, issues raised in SC&A's review are more appropriately classified as observations rather than findings.

As described in section 2 of this report, SC&A's review of the Addendum period focused on the following areas of inquiry:

- applicability of prior SC&A (2020) SEC-00250 ER review findings and observations (section 3)
- documentation of thorium-related activities and/or source terms (section 4)
- evaluation and characterization of the radiological control program (section 5)
- documented communications with former workers (section 6)
- review of the available thorium in vivo data (i.e., completeness and representation) and proposed methods for interpreting and applying these data in dose reconstruction (i.e., adequacy) (section 7)

It is important to note that several of SC&A's findings and observations from its review of the original SEC-00250 ER are applicable to the Addendum period and are directly related to the development of sufficiently accurate co-exposure models. In addition, the original finding 2 from SC&A (2020) produced an additional observation related specifically to the Addendum period regarding apparent discrepancies in source term estimates of thorium. Establishing accurate source term inventory and potential operational activities is useful in evaluating data completeness and representation (2024 observation 1 in section 3.2.1).

Regarding actual operational activities involving thorium during the Addendum period, additional documentation identified an RWP during the Addendum period that involved drilling and milling of a magnesium-thorium alloy in 1994. The documentation associated with the RWP noted that workers had not properly submitted baseline urine samples, and it is not clear whether termination (post-operational) samples were submitted. A late 1990s internal assessment identified deficiencies in documentation associated with RWP sign-in forms but also concluded minimal effect on worker exposures (2024 observation 4, section 4). Additionally, interviews with former workers indicated that an RWP program was implemented during the mid-1980s and that RWPs were used to determine bioassay requirements in some instances (2024 observation 10, section 6).

SC&A found little additional documentation of other thorium-specific operations such as the arc-melting operations that occurred into the 1980s. Documented communications with former workers as related to stewardship and D&D activities (2024 observation 12, section 6). Reports

identified in the SRDB describe a saw that was found to be contaminated with nonremovable/fixed thorium in 2012, which is consistent with residual thorium contamination at the Y-12 site (2024 observation 7, section 4).

The internal dosimetry technical basis document from 1995 indicates that isolated non-uranium operations should be monitored using baseline and termination bioassay samples rather than in vivo monitoring (2024 observation 5, section 4). This internal monitoring practice was echoed by a document submitted by a Y-12 internal dosimetrist who confirmed that the presence of in vitro bioassay for thorium indicates potential exposure to thorium starting at least in 1994 (2024 observation 6, section 4). The Y-12 internal dosimetrist also indicated that beginning in 1992, in vivo results for thorium were for screening only and measurements are included whether the worker was exposed to thorium or not. This was consistent with documented communications with former workers, who indicated that workers who handle thorium were not specifically targeted for internal monitoring (2024 observation 11, section 6). SC&A's evaluation of claimant job titles in the thorium in vivo dataset indicate a cross-section of the Y-12 worker population with a general emphasis on radiation workers (2024 observation 13, section 7.1).

Evaluation of available quarterly health physics reports (refer to section 5) indicates a significant increase in area and personnel monitoring during the late 1980s and early 1990s (2024 observation 8). However, these reports did not provide any relevant information directly related to thorium exposure and/or monitoring practices and results (2024 observation 9).

SC&A's review of the proposed methods to evaluate the Pb-212 MDA in DCAS-RPT-008 found them to be acceptable. However, it should be noted that SC&A also identified an alternate method that has the advantage of the ability to easily identify outliers. NIOSH may want to consider this method as a complement to the DCAS-RPT-008 methodology (2024 observation 14).

In summary, SC&A believes that operational exposure potential to thorium was likely very limited in comparison to the primary uranium missions of the Y-12 site and generally related to residual contamination and remedial and D&D activities. However, isolated operational activities involving thorium did occur and were intended to be monitored via bioassay (at least as early as 1994 and possibly earlier) rather than via in vivo chest counts, which are currently proposed for use in co-exposure modeling. NIOSH should evaluate the existence of thorium bioassay records and any related RWPs that would indicate the need for thorium monitoring via bioassay to ascertain the relevance of those records in relation to any proposed co-exposure intakes based on in vivo records.

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Appendix A: Summary of Locations with Elevated Air Sample Results

Table A-1. Description of elevated air sample occurrence

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
1	152446	1992	9206	Room 100 East Dry Recovery	Unknown	9	2%	1%	Not indicated
2	152468	1990	9206	Room 100 East Dry Recovery	Unknown	11.3	24%	0%	Not indicated
3	152442	1991	9206	Room 100 West	Unknown	9.5	24%	5%	Not indicated
4	152437	1990	9206	Room 101	Unknown	7.3	15%	3%	Not indicated
5	152426	1987	9206	Room 20	Yes	46	46%	0%	Rust construction activities
6	152468	1990	9206	Room 22	Unknown	5.2	7%	2%	Not indicated
7	152427	1988	9206	Room 24 South - Shredder Compactor Area	Yes	23	12%	4%	Elevated counts at compactor and shredder operations
8	152449	1993	9206	Room 25 Incinerator	Unknown	9.4	32%	5%	Not indicated
9	152446	1992	9206	Room 25 Incinerator	Unknown	7.4	25%	6%	Not indicated
10	152447	1992	9206	Room 25 Incinerator	Unknown	11.6	48%	9%	Not indicated
11	152429	1989	9206	Room 25 Incinerator	Yes	58	51%	4%	Elevated activity primarily associated with maintenance operations during inventory
12	152430	1989	9206	Room 25 Incinerator	Yes	33	31%	4%	Elevated activity primarily associated with maintenance operations during inventory
13	153765	1988	9206	Room 25 Incinerator	Yes	56	53%	8%	Start up of new incinerator

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
14	153766	1988	9206	Room 25 Incinerator	Yes	52	48%	6%	Elevated activity due to inventory cleanout. Engineering/Metal Preparation continuing to evaluate.
15	152428	1988	9206	Room 25 Incinerator	Yes	28	44%	1%	Elevated activity primarily during maintenance operation
16	152423	1987	9206	Room 25 Incinerator	Unknown	77	34%	11%	Fire in incinerator filter house 2/5/1987 and construction activity for incinerator replacement. Scheduled completion for construction activity 7/1/1987.
17	152449	1993	9206	Room 27	Unknown	8.7	28%	8%	Not indicated
18	152435	1990	9206	Room 28 Evaporator Extraction	Unknown	8	32%	3%	Not indicated
19	152435	1990	9206	Room 29 Evaporator Denitration	Unknown	22.1	38%	16%	Not indicated
20	152468	1990	9206	Room 29 Evaporator Denitration	Unknown	5.7	26%	2%	Not indicated
21	153765	1988	9206	Room 29 Evaporator Denitration	No	25	17%	3%	Leaking gasket on denitrator
22	152437	1990	9206	Room 30	Unknown	10	12%	3%	Not indicated

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
23	152423	1987	9206	Room 37	Unknown	32	26%	6%	Plugged exhaust line on muffle oven. Exhaust line unplugged.
24	152468	1990	9206	Room 37 Muffle Oven	Unknown	8.8	32%	4%	Not indicated
25	152437	1990	9212	Aux Casting Facility	Unknown	6.6	43%	1%	Not indicated
26	152449	1993	9212	B-1 Dry Operations	Unknown	28	27%	3%	Not indicated
27	152443	1992	9212	B-1 Dry Operations	Unknown	6.1	24%	2%	Not indicated
28	152444	1992	9212	B-1 Dry Operations	Unknown	5.6	22%	2%	Not indicated
29	152447	1992	9212	B-1 Dry Operations	Unknown	9.1	25%	2%	Not indicated
30	153768	1991	9212	B-1 Dry Operations	Unknown	14.9	26%	2%	Not indicated
31	152442	1991	9212	B-1 Dry Operations	Unknown	12.3	31%	5%	Not indicated
32	152435	1990	9212	B-1 Dry Operations	Unknown	21.3	24%	4%	Not indicated
33	152437	1990	9212	B-1 Dry Operations	Unknown	6.2	17%	2%	Not indicated
34	152468	1990	9212	B-1 Dry Operations	Unknown	7.5	15%	2%	Not indicated
35	152428	1988	9212	B-1 Dry Operations	Yes	28	23%	3%	Elevated activity in denitrator operation for maintenance work during inventory

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
36	152423	1987	9212	B-1 Dry Operations	Unknown	62	27%	6%	Increased maintenance of denitrator. Funds have been requested for better containment and ventilation on the denitrator.
37	152449	1993	9212	B-1 Wet Operations	Unknown	13	53%	6%	Not indicated
38	152443	1992	9212	B-1 Wet Operations	Unknown	19.7	60%	10%	Not indicated
39	152444	1992	9212	B-1 Wet Operations	Unknown	29.4	60%	13%	Not indicated
40	152446	1992	9212	B-1 Wet Operations	Unknown	12	38%	6%	Not indicated
41	152447	1992	9212	B-1 Wet Operations	Unknown	14.5	51%	8%	Not indicated
42	152440	1991	9212	B-1 Wet Operations	Unknown	8.2	42%	2%	Not indicated
43	152441	1991	9212	B-1 Wet Operations	Unknown	8.47	33%	2%	Not indicated
44	153768	1991	9212	B-1 Wet Operations	Unknown	28.5	55%	13%	Not indicated
45	152442	1991	9212	B-1 Wet Operations	Unknown	22.4	50%	9%	Not indicated
46	152435	1990	9212	B-1 Wet Operations	Unknown	11.4	59%	4%	Not indicated
47	152437	1990	9212	B-1 Wet Operations	Unknown	8.6	48%	2%	Not indicated
48	152468	1990	9212	B-1 Wet Operations	Unknown	12.7	47%	5%	Not indicated
49	153767	1990	9212	B-1 Wet Operations	Unknown	8.9	55%	2%	Not indicated

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
50	153765	1988	9212	B-1 Wet Operations	No	30	52%	1%	Combination of lack of controls to maintain adequate supply air to area and area decontamination efforts
51	152427	1988	9212	B-1 Wet Operations	No	28	46%	2%	Combination of lack of controls to maintain adequate supply air to area and area decontamination efforts
52	152428	1988	9212	B-1 Wet Operations	No	54	62%	3%	Elevated activity due to lack of ventilation to area. Installed new area exhaust system 12/30/1988, which should reduce air counts.
53	152423	1987	9212	B-1 Wet Operations	Unknown	34	62%	1%	Lack of controls to maintain adequate supply of air to the area. Utility Engineering/Metal Preparation continuing to evaluate.
54	152424	1987	9212	B-1 Wet Operations	No	26	51%	1%	Lack of controls to maintain adequate supply of air to the area. Utility Engineering/Metal Preparation continuing to evaluate.

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
55	152426	1987	9212	B-1 Wet Operations	Yes	49	74%	2%	Combination of lack of controls to maintain adequate supply air to area and area decontamination efforts
56	152444	1992	9212	C-Wing	Unknown	11	15%	3%	Not indicated
57	152440	1991	9212	C-Wing	Unknown	4.6	26%	2%	Not indicated
58	152441	1991	9212	C-Wing	Unknown	3.94	17%	2%	Not indicated
59	153768	1991	9212	C-Wing	Unknown	4.6	9%	1%	Not indicated
60	153767	1990	9212	C-Wing	Unknown	4.9	14%	1%	Not indicated
61	152427	1988	9212	C-Wing	Yes	39	14%	2%	Leaking exhaust line from centrifuge Northwest wall, 1st level
62	152426	1987	9212	C-Wing	Yes	25	23%	3%	Maintenance operations on oxide dissolver and ash leacher
63	152440	1991	9212	D-1 Ext. Packing and Shipping	Unknown	5.8	46%	0%	Not indicated
64	152441	1991	9212	D-1 Ext. Packing and Shipping	Unknown	4.21	21%	1%	Not indicated
65	153767	1990	9212	D-1 Ext. Packing and Shipping	Unknown	5.2	29%	1%	Not indicated
66	152449	1993	9212	E-Wing, Alligator Shear Room	Unknown	5.6	38%	0%	Not indicated
67	152443	1992	9212	E-Wing, Alligator Shear Room	Unknown	6.4	33%	0%	Not indicated
68	152444	1992	9212	E-Wing, Alligator Shear Room	Unknown	7	45%	2%	Not indicated
69	152446	1992	9212	E-Wing, Alligator Shear Room	Unknown	5	13%	2%	Not indicated

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
70	152447	1992	9212	E-Wing, Alligator Shear Room	Unknown	4.5	26%	2%	Not indicated
71	153768	1991	9212	E-Wing, Alligator Shear Room	Unknown	4.7	33%	0%	Not indicated
72	152442	1991	9212	E-Wing, Alligator Shear Room	Unknown	8.1	60%	0%	Not indicated
73	152435	1990	9212	E-Wing, Alligator Shear Room	Unknown	6.4	25%	0%	Not indicated
74	152437	1990	9212	E-Wing, Alligator Shear Room	Unknown	7.2	27%	3%	Not indicated
75	152432	1989	9212	E-Wing, Alligator Shear Room	Yes	24	30%	2%	Due to leaks on alligator shear glovebox. New glovebox is presently being installed.
76	152433	1989	9212	E-Wing, Alligator Shear Room	Yes	267	41%	13%	Due to leaks on alligator shear glovebox. New glovebox is presently being installed.
77	152428	1988	9212	E-Wing, Alligator Shear Room	Yes	40	51%	2%	Elevated activity due to breaking uranium parts, a shear operation
78	152443	1992	9212	E-Wing Basement Enclosures	Unknown	9.4	37%	6%	Not indicated
79	152444	1992	9212	E-Wing Basement Enclosures	Unknown	8.1	39%	5%	Not indicated
80	152447	1992	9212	E-Wing Basement Enclosures	Unknown	20.1	26%	6%	Not indicated
81	152440	1991	9212	E-Wing Basement Enclosures	Unknown	29.6	30%	9%	Not indicated
82	152441	1991	9212	E-Wing Basement Enclosures	Unknown	7.86	24%	5%	Not indicated
83	153768	1991	9212	E-Wing Basement Enclosures	Unknown	82.1	61%	11%	Not indicated

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Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
84	152442	1991	9212	E-Wing Basement Enclosures	Unknown	7.3	47%	1%	Not indicated
85	152435	1990	9212	E-Wing Basement Enclosures	Unknown	65.4	55%	8%	Not indicated
86	152437	1990	9212	E-Wing Basement Enclosures	Unknown	26.1	59%	13%	Not indicated
87	152468	1990	9212	E-Wing Basement Enclosures	Unknown	46.1	32%	8%	Not indicated
88	153767	1990	9212	E-Wing Basement Enclosures	Unknown	10.4	22%	3%	Not indicated
89	152429	1989	9212	E-Wing Basement Enclosures	Yes	24	9%	2%	Elevated activity due to house vacuum bag filter changes during inventory
90	152430	1989	9212	E-Wing Basement Enclosures	Yes	225	18%	11%	Elevated activity due to house vacuum bag filter changes during inventory
91	152427	1988	9212	E-Wing Basement Enclosures	Yes	47	21%	3%	Routine trap and filter changes and bag-filter shakedown during inventory
92	152426	1987	9212	E-Wing Basement Enclosures	Yes	41	15%	2%	The E-1 house vacuum bag filter changes
93	152435	1990	9212	E-Wing Basement Open	Unknown	24	63%	17%	Not indicated
94	152437	1990	9212	E-Wing Basement Open	Unknown	7.7	48%	3%	Not indicated
95	153768	1991	9212	E-Wing Basement Operations	Unknown	4.8	30%	2%	Not indicated
96	152440	1991	9212	E-Wing Casting	Unknown	5	31%	1%	Not indicated
97	152441	1991	9212	E-Wing Casting	Unknown	12.52	30%	2%	Not indicated
98	153768	1991	9212	E-Wing Casting	Unknown	6.2	28%	2%	Not indicated
99	152435	1990	9212	E-Wing Casting	Unknown	5.3	36%	1%	Not indicated

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
100	152437	1990	9212	E-Wing Casting	Unknown	12.1	51%	3%	Not indicated
101	152468	1990	9212	E-Wing Casting	Unknown	7.7	54%	1%	Not indicated
102	153767	1990	9212	E-Wing Casting	Unknown	4.8	31%	1%	Not indicated
103	152443	1992	9212	E-Wing Reduction	Unknown	5.1	46%	0%	Not indicated
104	152442	1991	9212	Furnacing, Milling, Blending Room 1010	Unknown	22.5	66%	12%	Not indicated
105	152429	1989	9212	Furnacing, Milling, Blending Room 1010	Yes	36	29%	1%	Elevated air activity during inventory cleanout of temporary gloveboxes
106	152449	1993	9212	Headhouse Room 26 & 29	Unknown	7.9	28%	2%	Not indicated
107	152435	1990	9212	Headhouse Room 26 & 29	Unknown	11.4	60%	5%	Not indicated
108	152437	1990	9212	Headhouse Room 26 & 29	Unknown	5.2	34%	1%	Not indicated
109	152468	1990	9212	Headhouse Room 26 & 29	Unknown	5.2	31%	1%	Not indicated
110	152444	1992	9212	Receiving and Shipping	Unknown	4.7	38%	0%	Not indicated
111	152443	1992	9212	Receiving and Shipping Room 1004	Unknown	8.5	51%	1%	Not indicated
112	152435	1990	9212	Receiving and Shipping Room 1004	Unknown	4.6	30%	0%	Not indicated
113	152437	1990	9212	Receiving and Shipping Room 1004	Unknown	7.6	45%	1%	Not indicated
114	152442	1991	9212	Receiving and Shipping Room 1009	Unknown	5.3	51%	0%	Not indicated
115	152443	1992	9212	Room 1008	Unknown	6	47%	0%	Not indicated

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
116	152435	1990	9212	Room 1008	Unknown	5.5	48%	0%	Not indicated
117	152468	1990	9212	Room 1008	Unknown	5.5	45%	1%	Not indicated
118	153765	1988	9212	Special Processing Room 1010	Yes	150	45%	7%	Inadequate exhaust on milling and blending hood
119	152435	1990	9212	Special Processing Room 1021	Unknown	8.4	32%	3%	Not indicated
120	152424	1987	9212	Special Processing Room 1021	Yes	23	12%	4%	Combination of filter teardown operation and Rust construction activity
121	152443	1992	9212	Special Processing Room 1022	Unknown	6.2	32%	3%	Not indicated
122	152442	1991	9212	Special Processing Room 1022	Unknown	22.8	56%	13%	Not indicated
123	152442	1991	9212	Special Processing Room 1022	Unknown	10.9	65%	3%	Not indicated
124	152435	1990	9212	Special Processing Room 1022	Unknown	9.7	50%	3%	Not indicated
125	153765	1988	9212	Special Processing Room 1022	No	25	41%	0%	Combination of leaking exhaust line from one of the centrifuges (which has been corrected) and poor hood design for proposed exhaust airflow in centrifuge cleanout hood

Arbitrary reference number	SRDB reference	Year	Area	Location	Respirator protection required?	Area average (dpm/m ³)	% Samples >PAV	% Samples >derived air concentration	Reason/Comments
126	152426	1987	9212	Special Processing Room 1022	Yes	30	27%	3%	Due to acid bath operation in the centrifuge cleanout hood
127	152442	1991	9215	O-Wing	Unknown	13.2	70%	5%	Not indicated
128	153768	1991	9204-4	2nd Floor Disassembly	Unknown	5.7	33%	1%	Not indicated
129	152449	1993	9204-4	Grit Blaster Area	Unknown	9.4	39%	3%	Not indicated
130	152443	1992	9204-4	Grit Blaster Area	Unknown	6	36%	1%	Not indicated
131	152444	1992	9204-4	Grit Blaster Area	Unknown	8.9	39%	5%	Not indicated
132	152447	1992	9204-4	Grit Blaster Area	Unknown	24.8	73%	13%	Not indicated
133	152435	1990	9204-4	Grit Blaster Area	Unknown	10.1	57%	3%	Not indicated
134	152437	1990	9204-4	Grit Blaster Area	Unknown	8.2	55%	0%	Not indicated
135	152443	1992	9401-4	Waste Feed Prep Facility	Unknown	4.7	18%	1%	Not indicated
136	152444	1992	9401-4	Waste Feed Prep Facility	Unknown	5.3	17%	4%	Not indicated
137	152442	1991	9401-4	Waste Feed Prep Facility	Unknown	8	30%	4%	Not indicated
138	152437	1990	9401-4	Waste Feed Prep Facility	Unknown	6.3	22%	6%	Not indicated

Appendix B: Example Whole-Body Count Data File

Figure B-1. PDF page 4944 (VAX/VMS Peak Search Report) in the whole-body count data file (Y-12, 1989–1995)

VAX/VMS Peak Search Report V1.8 Generated 29-APR-1994 14:09:17

Configuration	: DKA300:[USER]408_78_6780_LUNGS.CNF;1									
Analyses by	: PEAK V16.1									
Sample title	: routine									
Sample date	: 22-MAR-1994 10:06:35					Acquisition date : 22-MAR-1994 10:06:35				
Sample ID	:									
Detector name	: LUNGS									
Elapsed live time:	0 00:30:00.00					Detector geometry: LUNGS/TOTAL				
Start energy	: -0.40 keV					Elapsed real time: 0 00:30:00.11 0.0%				
Sensitivity	: 2.58					End energy : 410.84 keV				
Critical level	: No					Gaussian : 5.00				

Pk	It	Energy	Area	Bkgnd	FWHM	Channel	Left	Pw	Cts/Sec	%Err	Fit
1	0	11.21	122	119	0.77	116.70	109	16	6.76E-02	23.7	
2	0	16.10	62	41	0.21	165.42	160	12	3.43E-02	26.4	
3	0	28.92	23	26	0.91	293.09	286	15	1.26E-02	56.2	
4	0	33.60	9	6	0.13	339.72	338	4	5.26E-03	49.5	
5	0	35.33	12	5	0.20	357.00	355	5	6.67E-03	42.8	
6	0	47.46	18	17	0.68	477.78	473	9	1.00E-02	54.4	
7	4	64.69	17	29	0.47	649.44	645	37	9.65E-03	60.1	6.63E-01
8	4	65.11	17	53	0.47	653.54	645	37	9.24E-03	99.9	
9	0	78.92	14	30	0.27	791.10	784	10	7.85E-03	73.0	
10	0	90.94	15	12	0.26	910.91	909	7	8.32E-03	55.8	
11	0	108.61	19	13	0.41	1086.81	1084	7	1.04E-02	44.2	
12	0	143.85	14	28	0.47	1437.79	1433	12	7.78E-03	76.3	
13	0	199.08	9	15	0.29	1987.79	1986	11	5.19E-03	83.7	
14	0	214.77	12	6	0.20	2144.04	2142	8	6.58E-03	46.6	
15	0	238.79	8	34	0.47	2383.26	2364	23	4.43E-03	191.4	
16	0	266.83	9	7	0.24	2662.43	2658	9	5.14E-03	53.9	
17	0	323.35	1	7	0.12	3225.11	3221	6	7.64E-04	262.9	

Appendix C: PDF Page 4943 (Post-NID Peak Search Report in the Y-12 Lung Counting Report Generated) in the Whole-Body Count Data File (Y-12, 1989–1995)

Figure C-1. Energy peaks, peak, and background areas identified using the post-NID peak search algorithm described in RCO/TBD-051 (Y-12, 2006).

```

Y-12 Lung Counting Report generated 22-MAR-1994 10:37:28

                                BUSINESS SENSITIVE

----- Employee Information -----
Employee name   : ██████████      Department:   ██████████
Employee ID num. : ██████████      Chest Wall Thick.  3.97323
----- Count Information -----
Acquisition date : 22-MAR-1994 10:06:35 Elapsed live time: 0 00:30:00.00
Operator initials: TWL                Detector geometry: LUNGS/TOTAL
----- Processing Parameters -----
Sensitivity      : 2.57600           Secondary sens.   : 1.75000
Median Win. Size: 51                 Customer I.D.    : Y940014936

The DOSIMETRIC information which follows is for information purposes only.
This system has been set up to provide an estimate of lung activity only.
All intake/exposure related quantities below should be ignored.

----- Configuration Name -----          ----- Detector Name -----
MCAO:[LONGTW]TOTAL$1                       LUNGS

**** LUNGS **** Post-NID Peak Search Report
It  Energy      Area  Bkgnd  FWHM  Channel  Left  Pw %Err  Fit  Nuclides
0   11.36       833   274   0.30  118.21   95  29  4.5
0   15.86*     31    37   0.80  163.00  157 12 69.6

ICRP-30 Report GE MOUNT; 22-MAR-1994 10:06

Nuclide      Activity 1-Sigma Intake          %ALI  DAC-Hr      H50      HE50      Flag
              (nCi)  % Error (nCi)
----- LUNGS -----
AC-228 < 1.3      0.00 < 4.1      < 150.69 <3.01E+03 <7.52E+04 <4.69E+03
U-235 <0.26      0.00 <0.79      < 0.11 < 2.3  <0.00E+00 < 5.7
U-238 < 4.0      0.00 < 12.      < 1.66 < 33.  < 83.      < 83.
----- No Nuclides Identified -----
-----
Totals: 0.00E+00      0.00E+00      0.00 0.00E+00 0.00E+00 0.00E+00
Comments:

```