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ADVISORY BOARD ON RADIATION AND WORKER HEALTH

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

A FOCUSED REVIEW OF ORAUT-OTIB-0034, REV. 01 *INTERNAL DOSIMETRY COWORKER DATA FOR X-10*

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Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	11/20/2013	Initial issue.

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ABBREVIATIONS AND ACRONYMS

ABRWH or Advisory Board	Advisory Board on Radiation and Worker Health
AWE	Atomic Weapons Employer
BRS	Board Review System
CER	Center for Epidemiologic Research
CFR	*Code of Federal Regulations*
d	day
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EDP	Electronic Data Processing
GSD	geometric standard deviation
hr	hour
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
ml	milliliter
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
ORISE	ORISE Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
OTIB	ORAUT Technical Information Bulletin
PER	Program Evaluation Report
POC	Probability of Causation
SC&A	S. Cohen and Associates (SC&A, Inc.)
TIB	technical information bulletin

1.0 STATEMENT OF PURPOSE

This report presents a "focused" review of *Internal Dosimetry Coworker Data for X-10*, ORAUT-OTIB-0034, Revision 01, dated April 23, 2013 (ORAUT 2013b), by S. Cohen & Associates (SC&A, Inc.) as directed by the Advisory Board on Radiation and Worker Health (Advisory Board) on September 5, 2013.

This focused review of OTIB-0034 principally addresses those changes that were introduced under Revision 01. As such, this review supplements SC&A's previous draft review (SC&A 2007) submitted on October 29, 2007 of OTIB-0034, **Revision 00** (ORAUT 2005), which was issued by NIOSH on December 13, 2005.

2.0 OVERVIEW OF OTIB-0034, REV. 00 AND CURRENT STATUS OF SC&A'S REVIEW COMMENTS/FINDINGS

For Oak Ridge National Laboratory (ORNL) (X-10) workers who may have had occupational internal dose from intakes of radionuclides, but were not monitored or inadequately monitored, the stated purpose of ORAUT-OTIB-0034, Revision 00 (ORAUT 2005), was to provide coworker models for estimating intakes and doses for strontium, uranium, plutonium, and americium during discrete time periods of facility operations.

Radionuclide-specific coworker models were based on urinalysis records for the ORNL site for the period 1951 through 1988. A lognormal distribution for the annual bioassay data for each radionuclide was assumed and the 50th and 84th percentile values were derived. The Integrated Modules for Bioassay Analysis (IMBA) Expert OCAS-Edition computer program along with standard assumptions (e.g., breathing rate, particle size distribution, etc.) were used to fit the bioassay data to a series of inhalation intakes based on solubility type. Each fit was based solely on bioassay data representing that time period.

SC&A's previous review (SC&A 2007) of OTIB-0034, Rev. 00 (ORAUT 2005), identified four findings. These findings were discussed during several Procedures Review Subcommittee meetings held on October 29, 2007; January 20, 2009; March 9 2009; and June 9, 2009. A summary of these findings and their current status is provided below:

- Finding OTIB-0034-01: The procedure is not complete in terms of required data. The document references and uses data and procedures from other documents that need to be known in order to understand the described procedures in OTIB-0034.

  Current Status: Closed.

- Finding OTIB-0034-02. The procedure points out that "a chronic exposure pattern was assumed." This may not be claimant favorable in many cases at ORNL (X-10), considering the fact that numerous buildings exist on the site where exact dates of operations are not known, and the site depended on area health physicists to determine if in-vivo monitoring should be done. Thus, identification of the workers to apply coworker models to is difficult, if not impossible.

  Current Status: Open.

- Finding OTIB-0034-03. For plutonium Type S, the chronic intake for the entire set of years was fitted to the bioassay data for the last 3 years (1986 through 1988) and all the previous years of much higher values were ignored. It appears that the authors have selectively chosen the 50th percentile bioassay results for only the last 3 years and ignored all the previous data that are greatly elevated over these values to derive the inhalation intake model for the Type S Pu-239. This does not provide a claimant-favorable model for reconstruction of doses.

Current Status: In Abeyance. It should be noted that in Revision 01 of OTIB-0034, Table A-11 has been changed to reflect **all** bioassay data for years 1951 through 1988. Therefore, the BRS should be changed from "in abeyance" to "closed."

- Finding OTIB-0034-04: The assumed and predicted intake fits versus the values in the first approximately 5 years are much less, and from about 3,800 days to 7,200 days; the model fit is much higher, indicating that the percentile used for deriving the intake should be greater. This would, in turn, be more claimant favorable.

  Current Status: Open.

3.0 CHANGES INTRODUCED TO OTIB-0034 UNDER REVISION 01

Under Revision 01 of OTIB-0034 (ORAUT 2013b), a total of three major changes were introduced, which are summarized below and are the subject of this focused review.

3.1 INTAKES OF PU-239 TYPE S IN TABLE 5-5 WERE REVISED/EXPANDED TO INCLUDE BIOASSAY DATA FOR ALL YEARS

In Revision 00 of OTIB-0034 (ORAUT 2005), predicted intakes of Type S Pu-239 for the entire 38-year period of 1951 through 1988 were based on a bioassay fit defined by the **last three years** (i.e., 1986, 1987, and 1988), as shown in Figure A-23 of OTIB-0034. This resulted in the inhalation intake rate defined in Table 5-5 of OTIB-0034, Rev. 00 (ORAUT 2005) (reproduced below in Table 1). (Note: This was identified by SC&A as Finding OTIB-0034-03.)

Table 1. Annual Pu-239 Type S Intakes and Rates

Year	Pu-239 Type S Intake Rate, dpm/d	
	50th Percentile	GSD
1951–1988	4.15	5.50

Source: ORAUT-OTIB-0034, Rev. 00, Table 5-5 (ORAUT 2005)

In Revision 01 of OTIB-0034 (ORAUT 2013b), all bioassay data for Pu-239 Type S were fitted for six time periods. For comparison, Table 5-5 of Revision 01 is also reproduced below in Table 2.

Table 2. Pu-239 Type S Intake Periods and Rates (dpm/d)

Year	Pu-239 Type S Intake Rate		
	50th percentile	GSD	95th percentile
1951–1952	1,489	3.00	7,178
1953–1959	159.8	11.06	8,325
1960–1968	159.8	3.00	730
1969–1972	118.5	3.40	886
1973–1984	118.5	3.00	536
1985–1988	36.26	5.46	592

Source: ORAUT-OTIB-0034, Rev. 01, Table 5-5 (ORAUT 2013b)

3.2 THE 95TH PERCENTILE INTAKES WERE ADDED FOR ALL RADIONUCLIDES ASSESSED IN OTIB-0034

In Revision 00 of OTIB-0034 (ORAUT 2005), Tables 5-1 through 5-6 only cited intakes (dpm/d) and corresponding geometric standard deviation (GSD) values for the 50th percentile. For Revision 01, the 95th percentile intakes and GSD values were added to Tables 5-1 through 5-6.

3.3 STATISTICAL SUMMARY TABLES AS CITED IN ATTACHMENT A OF OTIB-0034, REV. 01, WERE EXPANDED

For statistical summary Tables A-1 through A-4 of Attachment A of OTIB-0034, Rev. 01 (ORAUT 2013b) information pertaining to the **annual** total number of personnel assessed by urinalysis for Sr, U, Pu, and Am and the annual total number of bioassay samples used in the statistical analysis for deriving intakes were added.

4.0 SC&A'S REVIEW OF REVISIONS INCORPORATED IN REVISION 01 OF ORAUT-OTIB-0034

Presented below are comments pertaining to each of the three revisions to OTIB-0034 cited in Section 3.0 above.

4.1 REVISION OF PU-239 INTAKES TYPE S

The inclusion of bioassay data for all 38 years for deriving intake rates of Pu-239 Type S addresses concerns raised by SC&A in our review of OTIB-0034, Rev. 00 (SC&A 2007). The expanded use of available bioassay data for the full 38 years not only increased intake rates by as much as a factor of 358 for years 1951 and 1952, but also established significantly higher intake rates for 5 other intake periods, as shown above in Table 2.

SC&A concurs with the revision of Table 5-5, and there is no specific finding with the associated revision. However, SC&A does note that neither the ORNL Site Profile for Occupational Internal Dose, ORAUT-TKBS-0012-5 (ORAUT 2013a), nor ORAUT-OTIB-0034, Revision 01 (ORAUT 2013b) issued April, 23, 2013, mention/address potential exposures to Pu **Type Super S**.

A review of Attachment A of OCAS-PER-012, *Evaluation of Highly Insoluble Plutonium Compounds* (OCAS 2007), identifies X-10 (ORNL) among ". . . sites where Type Super S is to be considered." Thus, if Pu Type SS were to be considered in the OTIB-0034 coworker model for ORNL, intakes would increase by a factor of 4.

Finding #1: ORAUT-OTIB-0034 Fails to Mention/Address Potential Exposure to Pu-239 Type SS in its Coworker Model

4.2 ADDITION OF 95TH PERCENTILE FOR ALL RADIONUCLIDES

For an assumed lognormal distribution of data, the GSD, 50th percentile, and 95th percentile are defined by the following equations:

$$GSD = \frac{84th\ percentile}{50th\ percentile} \quad \text{Eq. 1}$$

or

$$50^{th}\ \text{percentile} = \frac{84th\ percentile}{GSD} \quad \text{Eq. 2}$$

and

$$GSD^{1.65585} = \frac{95th\ percentile}{50th\ percentile} \quad \text{Eq. 3}$$

or

$$95^{th}\ \text{percentile} = (50^{th}\ \text{percentile})(GSD^{1.645}) \quad \text{Eq. 4}$$

By means of Equation 4, SC&A checked every 95th percentile number added to Tables 5-1, 5-2, 5-3, 5-4, 5-5, and 5-6. SC&A duplicated all values except the following three 95th percentile values contained in Table 5-5:

Comparison of 95th Percentile Values (dpm/d) from Table 5-5

Year	NIOSH	SC&A
1951–1952	7,178	9,073
1960–1968	730	973
1973–1984	539	722

Finding #2: Three of the Six Values for the 95th Percentile Intake of Pu-239 Type S in Table 5-5 of ORAUT-OTIB-0034 are Significantly Lower than Values Derived by SC&A and Should Be Reassessed

Of greater concern to SC&A is why the 95th percentile values were added, since OTIB-0034 Rev. 01 offers no guidance for their use, as given by the following statements in Section 5.0, "Assignment of Intakes and Doses:"

> *. . . For each radionuclide, the **50th- and 95th-percentile** intake rates, and the GSDs, are provided in specific tables. **In most cases**, **doses for individuals who were potentially exposed routinely** should be calculated from the **50th-percentile** intake rates by assuming the solubility type that results in the largest probability of causation (POC).*
> . . . [Emphasis added.]

The term "potentially exposed routinely" suggests that the 50th percentile values are appropriate for facility operators, radiation safety personnel, and others who are likely to represent persons with the highest exposure potential.

While guidance in other coworker models also states that ". . . For most cases, individual doses are calculated from the 50th percentile intake rates," subjective and diffuse guidance for assignment of the 95th percentile is provided, as given for the following coworker models:

- ORAUT-OTIB-0061, Rev. 02, *Internal Dosimetry Coworker Data for the Mound Site* (ORAUT 2012b). From Section 5.2:

  > ***There are situations** when the 95th percentile of the coworker distribution and a constant distribution are more appropriate than the 50th percentile and lognormal GSDs. For cases where the 50th-percentile intake rates are **not appropriate**, dose reconstructors should use the 95th-percentile intake rates. The 95th-percentile intakes should be assigned as a constant rather than lognormal distribution.* [Emphasis added.]

- ORAUT-OTIB-0078, Rev. 02, *Internal Dosimetry Coworker Data for the Fernald Environmental Management Project* (ORAUT 2012d). From Section 5.2:

  > *. . . For cases **where there is justification** that the individual may have had larger intakes than the 50th-percentile intake rates, dose reconstructors should use the 95th-percentile intake rates. . .* [Emphasis added.]

In reviewing Section 5.2.3, "Bioassay Programs," of *Oak Ridge National Laboratory – Occupational Internal Dose*, ORAUT-TKBS-0012-5, Rev. 02 (ORAUT 2013a), it is clear that the bioassay data used for the coworker data described in OTIB-0034 Rev. 01 represent a highly heterogeneous worker population (see Table 5-5 of ORAUT 2013a). The degree of heterogeneity representing intake coworker values cited in OTIB-0034 Rev. 01 is further supported by GSD values of up to 10 and greater (see Tables 5-1 and 5-5).

The need to account for heterogeneity in coworker models has been addressed by NIOSH in the past. For example, Section 1.0 of ORAUT-RPRT-0053, *Analysis of Stratified Coworker Datasets* (ORAUT 2012c), states:

> *It is reasonable to postulate that the population of all monitored workers is a conglomeration of a number of smaller subgroups of monitored workers, where the subgroups could receive significantly different average doses. . . . In sampling theory, these relatively homogeneous subgroups are called strata*.
>
> *Breaking a truly heterogeneous population into a number of relatively homogeneous strata is often desirable because the variance of the estimated parameters will be smaller than the variance of the parameters estimated for the whole population of monitored workers and in general the parameter estimates will be more accurate. . . . For example, criteria are needed to identify meaningful strata and assign workers to the appropriate stratum. The term meaningful refers to the assumption that there are groups in the population of monitored workers that have significantly different average doses and that we know how to identify these groups. . . . Thus, it is important to decide if strata constructed from a population of monitored workers are significantly different before constructing coworker models for each stratum*.

In select instances of facility workers with significant differences for exposure potential, NIOSH employed stratification based on job classification, facility-specific operations, and/or time periods. An example of NIOSH's guidance for the assignment of potential intakes based on job classification, location, as well as time periods is given in Table 5-8 of the Site Profile for Ames Laboratory, ORAUT-TKBS-0055, Rev. 02 (ORAUT 2012a).

Consistency and fairness in the adjudication of claims is best achieved by a highly prescriptive process that minimizes the need for subjective interpretation of protocols/guidance issued by NIOSH for use in dose reconstruction. Guidance that is limited to statements such as the following are far too vague for consistent interpretation by dose reconstructors to categorize an **unmonitored worker as eligible for a 95th percentile intake rate**:

> *. . . There are situations when the 95th percentile of a coworker distribution . . .* [is] *more appropriate than the 50th percentile . . .*

or

> *. . . For cases where there is justification that the individual may have had larger intakes than the 50th-percentile intake rates, dose reconstructors should use the 95th-percentile intake rates. . .*

Finding #3: For the X-10 Internal Coworker Model (as well as other internal coworker models), Guidance for the Assignment of the 95th Percentile Intake Values to Unmonitored Workers is Currently Inadequate

4.3 EXPANSION OF STATISTICAL SUMMARY TABLES IN ATTACHMENT A

The inclusion of number of samples and number of employees representing bioassay data for each of the four nuclides provides insight to the data's statistical power. However, SC&A does question whether there is adequate support for the interpretation of the ORISE/CER bioassay data, which contain urinalysis records from the ORNL site from 1951 to 1988. Specifically, SC&A's concern centers around the following statements:

From Section 2.0 of OTIB-0034

> . . . *The database* [ORISE/CER Dosimetry Database] *results are in* ***units of disintegrations per minute (dpm)/24 hours*** . . . [Emphasis added.]

From Section 4.1 of OTIB-0034

> . . . *All results were* ***assumed*** *to be representative of a* ***full day*** *(24 hours) of urinary excretion.* [Emphasis added.]

In an attempt to gain a more complete understanding of the bioassay data used, SC&A reviewed NIOSH's database "tblORNL_Urinalysis_rawData1951-1978." Exhibit 1 shows a representative dataset during 1951. Inspection of Exhibit 1 identifies (1) dpm/sample in Column #5 and (2) dpm/24 hr in Column #6.

Based on the above-cited statement from Section 2.0 of OTIB-0034 Rev. 01 it is uncertain whether the ORISE/CER database contained both the dpm/sample and the dpm/24 hours. If, in fact, the original ORNL data had been recorded as dpm/24 hours, there would be no need for NIOSH to state that ". . . All results were assumed to be representative of a full day (24 hours) of urinary excretion."

Independent of the answer to this question, further inspection of Exhibit 1shows that for all bioassays, the dpm/24-hour activity values are consistently a factor of 10 higher than the dpm/sample values. This relationship would imply a constant sample volume of 140 ml that was analyzed for all nuclides and all personnel monitored.

On the assumption that the ORISE/CER urinalyses data do not consistently reflect the collection of a quantified 24-hour urine volume from which defined aliquots of samples were taken for analysis, these data must be questioned.

Alternatively, if urinalyses were based on **spot samples** (i.e., less than a 24-hour sample), a volume greater than 140 ml would have been collected from which a constant volume of 140 ml per sample would have been analyzed. However, the choice of a 140-ml volume of 1,400 ml/day

for Reference Man had not been formally identified in 1951. A review of earlier scientific texts that reference the 1,400 ml/day excretion volume include ICRP Publication 2 (ICRP 1959), ICRP Publication 23 (ICRP 1975), and the Radiological Health Handbook (PHS 1970), but postdate the earlier years of the ORISE/CER database.

Finding #4 (Conditional): Pending Answers to the Aforementioned Questions, NIOSH's Assumption of ORNL Bioassay Data as Representative of a Full Day (24 hours) of Urinary Excretion is Subject to Question

5.0 SUMMARY CONCLUSIONS

For a substantial number of Department of Energy (DOE)/Atomic Weapons Employer (AWE) facilities, failure to adequately monitor workers has been recognized by NIOSH as a limitation affecting dose reconstruction and the need for developing coworker models in accordance with 42 CFR 82 §82.17.

SC&A's focused review of Revision 01 of ORAUT-OTIB-0034 (ORAUT 2013b) identified a total of four findings. Findings #1 and #2 have a limited potential to alter the reconstruction of doses for unmonitored workers and will likely require minimal discussion/effort for resolution.

Of greater significance and higher potential to affect the reconstruction of dose for unmonitored workers are Findings #3 and #4. For Finding #3, resolution would require prescriptive/ definitive guidance for the assignment of 95th percentile coworker intake values to unmonitored workers; and for the resolution of Finding #4, there is a need for additional information that explains the data shown in Exhibit 1 and supports NIOSH's "assumption" that all bioassay data represented a full day (24 hours) of urinary excretion.

Exhibit 1: Representative Data Set of 1951 Urinalysis Results from the ORNL Database

EmployeeID	Year	Month	GDate	EDP-Code	DPM/Sample	DPM/Sample_Sngl	DPM/24
	1951	1	29-Jan-51	UR0	3.2	3.2	000000032
	1951	4	23-Apr-51	FP0	30	30	000000300
	1951	9	17-Sep-51	UR0	2.3	2.3	000000023
	1951	9	17-Sep-51	FP0	24	24	000000240
	1951	9	17-Sep-51	GU0	0.1	0.1	000000001
	1951	3	05-Mar-51	UR0	0.8	0.8	000000008
	1951	3	05-Mar-51	GU0	0.3	0.3	000000003
	1951	3	05-Mar-51	FP0	52	52	000000520
	1951	12	23-Dec-51	FP0	12	12	000000120
	1951	12	23-Dec-51	UR0	3.2	3.2	000000032
	1951	12	23-Dec-51	GU0	0.1	0.1	000000001
	1951	7	06-Jul-51	FP0	46	46	000000460
	1951	3	12-Mar-51	UR0	6.1	6.1	000000061
	1951	1	02-Jan-51	UR0	4.6	4.6	000000046
	1951	1	29-Jan-51	GU0	0.2	0.2	000000002
	1951	4	20-Apr-51	SR0	2.4	2.4	000000024
	1951	3	12-Mar-51	FP0	44	44	000000440
	1951	4	16-Apr-51	UR0	7.9	7.9	000000079
	1951	4	16-Apr-51	GU0	0.1	0.1	000000001
	1951	4	16-Apr-51	FP0	17	17	000000170
	1951	12	01-Dec-51	UR0	16	16	000000160
	1951	12	01-Dec-51	GU0	0.2	0.2	000000002
	1951	3	12-Mar-51	GU0	0.3	0.3	000000003
	1951	3	16-Mar-51	UR0	7.5	7.5	000000075
	1951	3	16-Mar-51	FP0	51	51	000000510
	1951	5	24-May-51	FP0	100	100	000001000
	1951	1	02-Jan-51	FP0	16	16	000000160
	1951	12	20-Dec-51	SR0	7.3E3	7300	000073000
	1951	1	29-Jan-51	FP0	32	32	000000320
	1951	7	30-Jul-51	FP0	9.6	9.6	000000096
	1951	8	23-Aug-51	GU0	0.1	0.1	000000001
	1951	12	03-Dec-51	GU0	0	0	000000000
	1951	3	12-Mar-51	UR0	2.6	2.6	000000026
	1951	3	12-Mar-51	GU0	0.3	0.3	000000003
	1951	3	12-Mar-51	FP0	40	40	000000400
	1951	9	16-Sep-51	UR0	1.8	1.8	000000018
	1951	9	16-Sep-51	FP0	9.2	9.2	000000092

EXHIBIT #1 (Continued)

EmployeeID	Year	Month	GDate	EDP-Code	DPM/Sample	DPM/Sample_Sngl	DPM/24
	1951	9	16-Sep-51	GU0	0.2	0.2	000000002
	1951	5	25-May-51	FP0	32	32	000000320
	1951	5	25-May-51	UR0	3.3	3.3	000000033
	1951	10	08-Oct-51	FP0	5.4	5.4	000000054
	1951	10	08-Oct-51	UR0	2.2	2.2	000000022
	1951	4	23-Apr-51	UR0	7.4	7.4	000000074
	1951	7	30-Jul-51	GU0	0.2	0.2	000000002
	1951	4	23-Apr-51	GU0	0.1	0.1	000000001
	1951	7	30-Jul-51	UR0	4.9	4.9	000000049
	1951	4	16-Apr-51	FP0	16	16	000000160
	1951	4	16-Apr-51	GU0	0.1	0.1	000000001
	1951	1	30-Jan-51	GU0	0.1	0.1	000000001
	1951	1	30-Jan-51	FP0	54	54	000000540
	1951	1	15-Jan-51	FP0	13	13	000000130
	1951	1	15-Jan-51	GU0	0	0	000000000
	1951	8	06-Aug-51	GU0	0.1	0.1	000000001
	1951	8	06-Aug-51	UR0	1.7	1.7	000000017
	1951	8	06-Aug-51	FP0	9.6	9.6	000000096
	1951	1	15-Jan-51	FP0	10	10	000000100
	1951	1	15-Jan-51	UR0	3.5	3.5	000000035
	1951	5	24-May-51	UR0	2.9	2.9	000000029
	1951	10	08-Oct-51	GU0	0.1	0.1	000000001
	1951	5	18-May-51	GU0	0.1	0.1	000000001
	1951	8	04-Aug-51	FP0	8.0	8	000000080
	1951	7	26-Jul-51	SR0	10	10	000000100
	1951	7	26-Jul-51	GU0	0	0	000000000
	1951	7	26-Jul-51	UR0	3.9	3.9	000000039
	1951	6	07-Jun-51	FP0	41	41	000000410
	1951	4	13-Apr-51	UR0	3.2	3.2	000000032
	1951	10	04-Oct-51	GU0	0.1	0.1	000000001
	1951	10	04-Oct-51	FP0	38	38	000000380
	1951	10	04-Oct-51	UR0	4.8	4.8	000000048
	1951	4	13-Apr-51	FP0	26	26	000000260
	1951	4	13-Apr-51	GU0	0.1	0.1	000000001
	1951	5	11-May-51	GU0	0.2	0.2	000000002
	1951	1	02-Jan-51	GU0	0.5	0.5	000000005
	1951	5	18-May-51	FP0	72	72	000000720
	1951	6	07-Jun-51	GU0	0.3	0.3	000000003
	1951	6	27-Jun-51	FP0	55	55	000000550

EXHIBIT #1 (Continued)

EmployeeID	Year	Month	GDate	EDP-Code	DPM/Sample	DPM/Sample_Sngl	DPM/24
	1951	6	27-Jun-51	GU0	0.1	0.1	000000001
	1951	12	17-Dec-51	FP0	9.2	9.2	000000092
	1951	12	17-Dec-51	GU0	0.1	0.1	000000001
	1951	12	17-Dec-51	UR0	5.2	5.2	000000052
	1951	11	12-Nov-51	GU0	0.1	0.1	000000001
	1951	11	12-Nov-51	UR0	4.7	4.7	000000047
	1951	8	23-Aug-51	UR0	1.8	1.8	000000018
	1951	8	01-Aug-51	GU0	0.3	0.3	000000003
	1951	8	01-Aug-51	SR0	19	19	000000190
	1951	8	01-Aug-51	UR0	2.8	2.8	000000028
	1951	8	23-Aug-51	FP0	70	70	000000700
	1951	5	11-May-51	FP0	16	16	000000160
	1951	7	28-Jul-51	GU0	0.2	0.2	000000002
	1951	5	04-May-51	FP0	30	30	000000300
	1951	5	04-May-51	GU0	0	0	000000000
	1951	6	29-Jun-51	GU0	0.1	0.1	000000001
	1951	6	01-Jun-51	FP0	11	11	000000110
	1951	6	29-Jun-51	UR0	3.7	3.7	000000037
	1951	6	29-Jun-51	FP0	23	23	000000230
	1951	6	01-Jun-51	GU0	0	0	000000000
	1951	4	10-Apr-51	FP0	27	27	000000270
	1951	4	10-Apr-51	GU0	0.2	0.2	000000002
	1951	4	30-Apr-51	FP0	4.8	4.8	000000048
	1951	4	30-Apr-51	GU0	0	0	000000000
	1951	5	28-May-51	FP0	59	59	000000590
	1951	8	04-Aug-51	UR0	1.7	1.7	000000017
	1951	7	28-Jul-51	FP0	7.6	7.6	000000076
	1951	8	04-Aug-51	GU0	0.2	0.2	000000002
	1951	7	28-Jul-51	UR0	1.7	1.7	000000017
	1951	8	16-Aug-51	FP0	40	40	000000400
	1951	8	16-Aug-51	GU0	0	0	000000000
	1951	8	16-Aug-51	UR0	12	12	000000120
	1951	11	08-Nov-51	FP0	0.8	0.8	000000008
	1951	11	08-Nov-51	GU0	0.1	0.1	000000001
	1951	11	08-Nov-51	UR0	1.6	1.6	000000016
	1951	12	06-Dec-51	GU0	0	0	000000000
	1951	12	06-Dec-51	FP0	44	44	000000440
	1951	5	11-May-51	FP0	70	70	000000700
	1951	5	11-May-51	GU0	0.1	0.1	000000001

REFERENCES

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

ICRP 1959. *Permissible Dose for Internal Radiation*. ICRP Publication No. 2. International Commission on Radiological Protection, Pergamon Press, New York.

ICRP 1975. *Reference Man: Anatomical, Physiological and Metabolic Characteristics,* ICRP Publication No. 23. International Commission on Radiological Protection, Pergamon Press, New York.

OCAS 2007. *Evaluation of Highly Insoluble Plutonium Compounds*, OCAS-PER-012, Office of Compensation Analysis and Support, Cincinnati, Ohio. August 7, 2007.

ORAUT 2005. *Internal Dosimetry Coworker Data for X-10*, Rev. 00, ORAUT-OTIB-0034. Oak Ridge Associated Universities Team, Cincinnati, Ohio. December 13, 2005.

ORAUT 2012a. *Site Profile for Ames Laboratory*, Rev. 02, ORAUT-TKBS-0055. Oak Ridge Associated Universities Team, Cincinnati, Ohio. January 3, 2012.

ORAUT 2012b. *Internal Dosimetry Coworker Data for the Mound Site*, Rev. 02, ORAUT-OTIB-0061. Oak Ridge Associated Universities Team, Cincinnati, Ohio. April 13, 2012.

ORAUT 2012c. *Analysis of Stratified Coworker Datasets*, Rev. 01, ORAUT-RPRT-0053. Oak Ridge Associated Universities Team, Cincinnati, Ohio. July 16, 2012.

ORAUT 2012d. *Internal Dosimetry Coworker Data for the Fernald Environmental Management Project*, Rev. 02, ORAUT-OTIB-0078. Oak Ridge Associated Universities Team, Cincinnati, Ohio. December 12, 2012.

ORAUT 2013a. *ORNL Site Profile for Occupational Internal Dose*, Rev. 02, ORAUT-TKBS-0012-5. Oak Ridge Associated Universities Team, Cincinnati, Ohio. February 8, 2013.

ORAUT 2013b. Internal Dosimetry Coworker Data for X-10, Rev. 01, ORAUT-OTIB-0034. Oak Ridge Associated Universities Team, Cincinnati, Ohio. April 23, 2013.

SC&A 2007. *Review of the Third Set of Procedures (45 procedure reviews)*, SC&A-TR-TASK3-0003. S. Cohen & Associates, Vienna, VA. October 29, 2007.

PHS 1970. *Radiological Health Handbook*. U.S. Department of Health, Education, and Welfare, Public Health Service, Rockville, Maryland. 1970.