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**ADVISORY BOARD ON
RADIATION AND WORKER HEALTH**

National Institute for Occupational Safety and Health

REVIEW OF SPECIAL EXPOSURE COHORT EVALUATION REPORT FOR SEC-00217

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Prepared by

William C. Thurber

S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, Virginia   22182

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland   21755

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Task Manager: _____ Date:_____ William C. Thurber	Supersedes: N/A

Project Manager:
 	
_____ Date:_____
John Stiver, CHP
	Peer Reviewer(s):
	
	    John Mauro
	    Steve Marschke
	    John Stiver

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AWE	Atomic Weapons Employer
BZ	breathing zone
d	day
DOE	(U.S.) Department of Energy
DWA	daily weighted average
dpm/d	disintegrations per minute per day
dpm/m^2	disintegrations per minute per square meter
dpm/m^3	disintegrations per minute per cubic meter
ER	Evaluation Report
GA	general area
HASL	Health and Safety Laboratory
hr	hour
λ/sec	lambda per second
m	meter
m^2	square meter
µg/m^2/sec	microgram per square meter per second
µg/m^3	microgram per cubic meter
MAC	maximum allowable air concentration
MED	Manhattan Engineer District
m/s	meters per second
NIOSH	National Institute for Occupational Safety and Health
NRC	(U.S.) Nuclear Regulatory Commission
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
ORISE	Oak Ridge Institute for Science and Education
RESRAD	residual radiation
rpm	revolutions per minute
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort

sec/hr seconds per hour

SRDB site research database

TBD technical basis document

TIB technical information bulletin

WEC Westinghouse Electric Corporation

y year

INTRODUCTION

At the June 9, 2015, teleconference meeting of the Advisory Board on Radiation and Worker Health (ABRWH), the Board tasked SC&A to conduct a review of the Special Exposure Cohort (SEC) Petition Evaluation Report (ER) for Petition SEC-00217, Westinghouse Electric Corporation, New Jersey, issued by the National Institute for Occupational Safety and Health (NIOSH) on April 14, 2015 (NIOSH 2015). The review was to focus on the residual periods only. This report presents SC&A's review as requested by the Board.

NIOSH had previously reviewed Petition SEC-00157 for the Westinghouse New Jersey Plant (NIOSH 2010) and, at that time, proposed in the Petition Evaluation Report dated January 10, 2010, the following addition to the SEC:

All Atomic Weapons Employer employees who worked at Westinghouse Electric Corp., Bloomfield, New Jersey, from August 13, 1942, through December 31, 1949, for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.

The period from August 13, 1942, through December 31, 1949, is referred to here as the 1st operating period.

Although it was noted in the ER for SEC-00157 (NIOSH 2010) that the site "had a residual radiation period of 1950 through July 2006," no approach to reconstructing doses during the residual period was presented.

Subsequently, a petitioner requested that Westinghouse workers be added to the SEC for the period after that proposed under SEC-00157 as follows (NIOSH 2010):

> *All Atomic Weapons Employer employees who worked at any plant production area of Westinghouse Electric Corporation in Bloomfield, New Jersey, from January 1, 1950 through March 1, 2011.*

This petition was qualified by NIOSH on January 8, 2015, and, as noted above, the ER was issued on April 14, 2015 (NIOSH 2015). NIOSH determined that two additional operating periods had occurred during the timeframe under review:

- February 1, 1958, through May 31, 1958 (2nd operating period)
- June 1, 1959, through June 30, 1959 (3rd operating period)

NIOSH also determined that the end date for the residual period should be April 30, 2000, the date that final remediation was completed. Based on these findings, the three residual periods were defined by NIOSH in the SEC-00217 ER:

- January 1, 1950, through January 31, 1958 (1st residual period)
- June 1, 1958, through May 31, 1959 (2nd residual period)
- July 1, 1959, through April 30, 2000 (3rd residual period)

BACKGROUND

Operations at the Westinghouse New Jersey Plant are described in adequate detail in the SEC-00217 ER (NIOSH 2015) and will not be repeated here. However, for the reader's convenience, we have extracted the following summary from NIOSH 2015 (Section 5.1.1):

> *During World War II, WEC was contracted to produce uranium in support of the MED. Operations during this period, from August 1, 1942 through December 31, 1949, are also described in SEC Petition Evaluation Report for Petition SEC-00159 (NIOSH, 2010).*
>
> *WEC developed a photochemical technique to produce uranium metal using uranium oxide or nitrate and potassium fluoride. The process was used to produce limited quantities of uranium. (Under the best weather conditions with good sunlight, the process could produce 1 ton/month.) The green salt produced by the reaction was electrolyzed to yield uranium metal that was subsequently cast into discs, pellets, and ingots (DOE, undated). The contract began on August 1, 1942 (DOE, undated) and was completed on October 15, 1943 (Unspecified, 1942–1943), and would have been capable of producing a total of 14.5 tons of uranium metal. At the end of this contract in 1945, the process equipment was removed (DOE, undated) and the uranium production facility was deactivated. After deactivation, the basement area was used primarily as a research testing laboratory (Westinghouse, 1980, PDF p. 30).*
>
> *WEC also worked with thorium under contract W-7409-ENG-31 for the MED. They produced a total of 200 pounds of thorium metal in the form of bars, tubes, sheets, and wire in early 1945 (Uranium, undated, PDF p. 4).*
>
> *WEC also performed natural uranium machining operations for Fernald during short-term projects under contract from February 1958 through May 1958 and throughout June 1959. During these projects, WEC performed test rollings of uranium tubes on the Assel Mill to evaluate whether this process could be used to elongate hollow fuel rods for eventual use in a nuclear reactor as part of the nuclear weapons production complex (Simmons, 1959, PDF p. 74). The actual machining was scheduled to take one or two days (Kirkman, 1958, PDF p. 6), and the first test was attended by a Health and Safety Laboratory (HASL) representative, May 12 through May 16, 1958 (Ross, 1958). The work was performed on a No.1 Witter mill (also known as an Assel mill) (Simmons, 1958 [sic], PDF p. 100). The first test was unsuccessful because of excessive slippage between the work piece and the roll surfaces. A second rotary-elongation test was conducted on the same mill in June 1959. The actual machining during this second test occurred from June 25 through June 29, 1959, as indicated by the air monitoring dates (Monitoring, 1959). The mill-roll speed was reduced to 43 rpm (128 rpm was used in the previous test) (Steck, 1963).*

NIOSH is not aware of any additional uranium machining operations at WEC after June 30, 1959 (Ansari, 1993, PDF p. 12).

1ST RESIDUAL PERIOD

For the 1st residual period, NIOSH proposed in the SEC-00217 ER to use air sampling data obtained at the beginning of the 2nd operating period, but before any processing of uranium had occurred. At the beginning of the 2nd operating period, air sampling was conducted by the New York Operations Office of the Atomic Energy Commission's (AEC's) Health and Safety Laboratory (HASL). A total of 7 breathing zone (BZ) and 39 general area (GA) air samples were analyzed for gross alpha during the 2nd operating period. Samples taken before any uranium processing on the Assel Mill was done are summarized in Table 1 (NIOSH 2015, Figure 7.1).

Table 1. General Area Gross Alpha Samples Taken at WEC before Any Processing Work was Done during 2nd Operating Period

Sample Description	Number of Samples	Concentration (dpm/m^3)			% MAC^a
		High	Low	Average	
Assel Mill operator's platform	5	5	1	2	0.02
Assel Mill	8	12	2	5	0.07
Argon furnace	2	23	1	12	0.17

a – maximum allowable air concentration (MAC) = 70 dpm/m^3

Based on the HASL sampling, NIOSH selected the highest average concentration of 12 dpm/m^3 as the initial air concentration prior to processing uranium on the Assel Mill. NIOSH assumed that this air concentration was the result of surface contamination during the 1st operating period that was resuspended during the 1st residual period. Using the default depletion constant from ORAUT-OTIB-0070 (ORAUT 2012), NIOSH proposed to extrapolate this air concentration backwards in time to obtain the gross air concentration at the beginning of the 1st residual period.

As described in ORAUT-OTIB-0070, Section 4.1.1 (ORAUT 2012), NIOSH assumed that airborne activity decayed at an exponential rate of 0.00067/day. This average decay rate was obtained from four work sites examined by NIOSH. Assuming that the air concentration was 12 dpm/m^3 in 1958, it can be calculated, using the adjustment factors in Table 4-2 for OTIB-0070, that the air concentration at the beginning of the 1st residual period would have been 85 dpm/m^3. However, this approach is <u>not</u> consistent with what is recommended in OTIB-0070. Per Table 5-1 of OTIB-0070, when the post-operational air concentration is known, the recommended approach is to use an:

> *Exponential fit of postoperational data and estimate of operational airborne radioactivity based on ORAUT (2006)[1] or Battelle (2011).*

NIOSH does not recommend simply back-extrapolating the post-operational data using the generic decay constant of 0.00067/day.

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[1] This document is no longer available.

In its supplemental review of TBD-6000 (Battelle 2011), SC&A noted that, at the Hanford Melt Plant (Adley et al. 1952):

- The removal rate at equilibrium of uranium oxide particles deposited on surfaces was estimated to be 0.035/day. This rate is considerably higher than the removal rate of 0.00067/day developed in ORAUT-OTIB-0070 (ORAUT 2012). The calculations presented here support the position that the OTIB-0070 approach regarding time to reach equilibrium is claimant favorable.

That conclusion was premised on the fact, while the net removal rate could be higher than the value of 0.00067/day, higher rates would result in earlier depletion of contamination and, consequently, lower doses. However, the conclusion regarding claimant-favorability is predicated on using the decay rate to project <u>future</u> air concentrations. In the case of SEC-00217, we believe that, for the first time in dose reconstruction, the decay rate is being used to project backwards in time to predict a previous concentration. In the reverse mode, if the decay rate is higher than the generic value of 0.00067/day, then the derived initial concentration would be higher. While the forward mode appears to be claimant-favorable, the reverse mode does not.

Based on the Adley et al. (1952) data, it can be assumed that there may be some sites where the decay constant for reduction of particles resuspended in the air is higher than for the four sites examined in OTIB-0070. While the OTIB-0070 approach is acceptable when using air concentrations at the cessation of operations to estimate future air concentrations in a claimant-favorable manner (because the OTIB-0070 decay rates are low), the reverse is not true. Using the OTIB-0070 decay constant of 0.00067/day and the air concentration at the end of the residual period to calculate air concentrations at the beginning of the residual period will not be claimant-favorable if the decay constant is higher than that developed in OTIB-0070.

Finding 1. The procedure for calculating air concentrations during the 1st residual period is not consistent with the guidance provided in ORAUT-OTIB-0070.

No specific guidance is included in Table 5-1 of OTIB-0070 as to how to use TBD-6000 (Battelle 2011). However, two possibilities suggest themselves. One is to use the air concentration data for the appropriate operation from Section 7 of TBD-6000 (Battelle 2011) and assume this is the concentration at the end of the operational period and the beginning of the residual period. For example, from Table 7.3 of Battelle (2011), the geometric mean air concentration for rolling uranium is 3,533 dpm/m^3 (DWA). Using the exponential decay equation (OTIB-0070, Equation 4-1):

$$A(residual\ period) = A(operations) * e^{-\lambda t}$$

and assuming the air concentration in year 1 is 3,533 dpm/m^3 and in year 8 is 12 dpm/m^3, the decay constant (λ) is 0.218/y. However, this approach sets the initial air concentration at an unrealistically high level.

The second approach is to estimate the equilibrium surface concentration as described in Section 3.42 of TBD-6000:

> *Using a 30 day deposition time and a 0.00075 m/s settling rate, a deposition factor of 1944 meters can be calculated. The floor contamination level is then estimated as Floor Concentration (dpm/m^2) = Air Concentration (dpm/m^3) × 1944 meters.*

Using this methodology, the floor concentration at the end of operations would be 6.87E+06 dpm/m^2 (3,533 × 1944). This material would rapidly fall out of the atmosphere at the end of operations. The air concentration at the beginning of the residual period will be the result of resuspending some of this material. For example, based on a resuspension factor of 1E-05/m, the air concentration would be 69 dpm/m^3. While the second approach results in a considerably lower air concentration, we believe that the second approach is based on a more realistic model for the physical processes of deposition and resuspension that would be occurring. At the cessation of operations, the air concentration will drop dramatically, as no new contamination is being generated. The reduction in air concentration over time based on the decay factor cited above is given in Table 2.

Table 2. Decay of Air Concentration with Time during 1st Residual Period

Year	Faction of Initial Concentration Remaining
1950	1.000
1951	0.804
1952	0.647
1953	0.520
1954	0.418
1955	0.336
1956	0.270
1957	0.217
1958	0.175

In the "sample DR" developed by NIOSH for Westinghouse, the estimated air concentration at the beginning of the residual period was 85 dpm/m^3 (Spreadsheet 2015). While this value is not significantly different from the air concentration of 69 dpm/m^3 developed here, we believe that the approach taken here is consistent with the recommendations of OTIB-0070. These air concentrations are compared with those developed by NIOSH in the sample DR prepared for Westinghouse in Table 2. It should be noted that the inhalation intakes presented here are per calendar-day. To convert to dpm/work-day, the values in Table 3 should be multiplied by 365/250.

Although the results in intakes differ only slightly, the approach based on the guidance in Table 5-1 of OTIB-0070 should be used to insure that the relevant guidance documents are correctly employed.

Table 3. Comparison of Residual Period Inhalation Intakes

Year	Air Concentration (dpm/m^3)		Daily Inhalation Intake (dpm/day)	
	SC&A Approach	**NIOSH Approach**	**SC&A Approach**	**NIOSH Approach**
1950	6.87E+01	8.49E+01	4.52E+02	5.58E+02
1951	5.52E+01	6.65E+01	3.63E+02	4.37E+02
1952	4.44E+01	5.21E+01	2.92E+02	3.42E+02
1953	3.57E+01	4.08E+01	2.35E+02	2.68E+02
1954	2.87E+01	3.19E+01	1.89E+02	2.10E+02
1955	2.31E+01	2.50E+01	1.52E+02	1.64E+02
1956	1.86E+01	1.96E+01	1.22E+02	1.29E+02
1957	1.49E+01	1.53E+01	9.81E+01	1.01E+02
1958	1.20E+01	1.20E+01	7.89E+01	7.89E+01

Ingestion Doses

NIOSH states in OCAS-TIB-009 (NIOSH 2004), Section 5, that:

> *The amount of activity ingested on a daily basis can be approximated by assuming it to be 0.2 times the activity per cubic meter of air.* (NIOSH 2004)

The ingested activity is assumed to be equally contributed from two sources:

- Mode 2 – material settling from the air onto food and drink, which is then consumed. This term must be adjusted based on the work schedules, as discussed below.

- Mode 3 – material settling on the surfaces, then transferred to the hands and finally transferred to the mouth.

During operations, airborne dust is generated by some processes such as rolling or machining. The dust falls onto the surface at a rate determined by the air concentration and the terminal settling velocity of the dust particles ($\mu g/m^3 \times m/s = \mu g/m^2/sec$). This surface contamination is removed by various processes until the rate of deposition equals the rate of removal and an equilibrium concentration is reached. The removal rate equals the surface concentration times a removal constant ($\mu g/m^2 \times \lambda/sec$) i.e., air concentration × settling velocity = surface concentration × decay rate. If operations are of sufficient duration (i.e., 30 days per TBD-6000), equilibrium will be reached.

During the residual period, there is no source to replenish contamination removed over time. Both the Mode 2 and Mode 3 ingestion sources are dependent on the level of surface contamination, with the airborne concentration driven by resuspension of residual surface contamination.

OTIB-0070 (Section 3.6) provides the following guidance for calculating ingestion intakes during the residual period:

> *If inhalation intakes are calculated from air concentrations, ingestion intakes are to be considered. The ingestion rate, in terms of disintegrations per minute (dpm)*

for an 8-hour workday, can be estimated by multiplying the air concentration in dpm per cubic meter by a factor of 0.2 (NIOSH 2004).

At the January 22, 2015, meeting of the Uranium Refining AWE Work Group, the use of OCAS-TIB-009 (NIOSH 2004) for estimating ingestion during the residual period was discussed extensively (ABRWH 2015). NIOSH pointed out that the TIB-009 ingestion model used airborne contamination in calculating hand-to-mouth transfer of contamination when, in fact, the proper basis should be surface concentration (ABRWH 2015, p. 58), and that in general:

... since TIB-9 kind falls apart for the residual period, and we actually had contamination measurements as a starting point, it really couldn't be used and reverted back to what Jim used from the NUREG..... (ABRWH 2015, p. 61)

Both of the ingestion modes described above depend on the surface concentration, which decreases with time during the residual period. The Mode 2 ingestion during the residual period is the result of resuspended surface contamination that falls on food and drink, while the Mode 3 ingestion involves transfer of surface contamination to the hands and then to the mouth. The ingestion component from Mode 2 is the airborne concentration, while the ingestion component from Mode 3 is the surface concentration.

In OCAS-TIB-009 (NIOSH 2004), Mode 2 ingestion (i.e., airborne dust settling on a 3-in diameter cup of coffee) is calculated as follows:

Air concentration (A dpm/m^3) $\times$ terminal settling velocity (0.00075 m/s) $\times$ cup area (0.00456 m^2) $\times$ settling time (8, 8.8, or 9.6 hr/day) $\times$ 3,600 sec/hr.

For an 8-hr day, the Mode 2 ingestion rate is 0.0984 A dpm/day. These air concentrations were shown previously in Table 2 based on the SC&A and NIOSH derivational approaches. The Mode 2 ingestion is summarized in Table 4. Note that the intakes are on a work-day basis.

Table 4. Mode 2 Ingestion Intakes during 1st Residual Period (based on 8-hr workday).

Year	Daily Ingestion Intake (dpm/work-day)	
	SC&A Approach	NIOSH Approach
1950	6.76E+00	8.35E+00
1951	5.43E+00	6.54E+00
1952	4.37E+00	5.12E+00
1953	3.51E+00	4.01E+00
1954	2.82E+00	3.14E+00
1955	2.27E+00	2.46E+00
1956	1.83E+00	1.93E+00
1957	1.47E+00	1.51E+00
1958	1.18E+00	1.18E+00

In OCAS-TIB-009 (NIOSH 2004), Mode 3 ingestion (hand-to-mouth transfer) is calculated as follows:

Air concentration (A dpm/m^3) × terminal settling velocity (0.00075 m/s) × hand-to-mouth transfer factor (0.1) × area of hand (0.0155 m^2) × 24 hr/d × 3,600 sec/hr = 0.1 A dpm/d

It is not possible to deduce from this equation what is the implied surface concentration, because the settling time is not explicitly defined. Since, as discussed above, TIB-009 (NIOSH 2004) has been judged not to be appropriate for the calculating ingestion via hand-to-mouth transfer during the residual period, an alternate method is needed. One possibility would be to use the guidance in TBD-6000 (Battelle 2011) coupled with the approach documented in RESRAD-BUILD (Yu et al. 2000). The authors of that document recommend in Table 2.7 a default value of 0.0001 m^2/hr for the receptor indirect ingestion rate.[2] Using this rate and the surface concentration at the beginning of the 1st residual period of 6.78E+06 dpm/m^2 (30 days × 0.00075 m/s × 24 hr/day × 3,600 sec/hr × 3,533 dpm/m^3) per TBD-6000, the daily ingestion from this source during the first year of the residual period is 5,496 dpm/day (6.87E+06 dpm/m^2 × 0.0001 m^2/hr × 8 hr/day). However, as noted in NUREG/CR-5512, Volume 3 (NRC 1999):

> *...the actual amount of contamination ingested will also depend on other factors, including the fraction F, of the total source term that is "loose," and therefore available for ingestion.*

Alternatively, Yu et al. 2000, Section 8.3, gives the removable fraction most likely value as 0.2. On the other hand, NUREG/CR-5512, Volume 3, Section 5.5.1 states:

> *10% of the measured source concentration was assumed to be removable.*

Thus, based on the RESRAD approach, the initial ingestion exposure during the 1st residual period would range from 1,099 to 550 dpm/d.

This value would be reduced in subsequent years based on Table 2. This approach results in substantially higher Mode 3 intakes than would result from using OCAS-TIB-009 (NIOSH 2004), as shown in Table 5, using the mostly likely value of 1,099 dpm/d for receptor indirect ingestion rate. The values in the last column are NIOSH values from Spreadsheet 2015.

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[2] The receptor indirect ingestion rate is defined as: The rate at which an individual ingests deposited dust after it has transferred to hands, foods, or other items at each receptor location.

Table 5. Ingestion Intakes for 1ˢᵗ Residual Period.

Year		Mode 2 ing. dpm/day	Mode 3 ing. dpm/d	Total ing. dpm/d	Total ing. dpm/cal-day	NIOSH DR dpm/cal-day
1950	1.000	6.76E+00	1.10E+03	1.11E+03	7.57E+02	1.16E+01
1951	0.804	5.43E+00	8.84E+02	8.89E+02	6.09E+02	9.11E+00
1952	0.647	4.37E+00	7.10E+02	7.15E+02	4.90E+02	7.13E+00
1953	0.520	3.51E+00	5.71E+02	5.75E+02	3.94E+02	5.58E+00
1954	0.418	2.82E+00	4.59E+02	4.62E+02	3.17E+02	4.37E+00
1955	0.336	2.27E+00	3.69E+02	3.72E+02	2.55E+02	3.42E+00
1956	0.270	1.83E+00	2.97E+02	2.99E+02	2.05E+02	2.68E+00
1957	0.217	1.47E+00	2.39E+02	2.40E+02	1.65E+02	2.10E+00
1958	0.175	1.18E+00	1.92E+02	1.93E+02	1.32E+02	1.64E+00

Finding 2. The guidance provided in OTIB-0070 [ORAUT 2012] *(Section 3.6) for calculating doses during the residual period refers to OCAS-TIB-009 (NIOSH 2004). This guidance should be revised since the TIB-009 approach cannot be used to calculate ingestion intakes from transfer of surface contamination to the hands and then to the mouth. Use of the procedure in TIB-009 understates this source of ingestion. The calculations in the SEC-00217 ER for the 1ˢᵗ residual period should be modified accordingly.*

In SEC-00217, NIOSH states that:

NIOSH concludes that there are methods available in Battelle-TBD-6000 [Battelle 2011]*, OCAS-TIB-009* [NIOSH 2004]*, and ORAUT-OTIB-0070* [ORAUT 2012]*, as well as available air data and operational descriptions, so that internal radiation doses can be completely reconstructed with sufficient accuracy for all AWE employees during the following periods under evaluation:*

- *All employees during the residual radiation period from January 1, 1950 through January 31, 1958*

- *All employees during the residual radiation period from June 1, 1958 through May 31, 1959*

- *All employees during the residual radiation period from July 1, 1959 through April 30, 2000*

Thus, NIOSH concluded that ingestion doses for the all three residual periods can be reconstructed using OCAS-TIB-009 (NIOSH 2004). Using the TBD-6000 (Battelle 2011) methodology, the following assumptions should be made regarding hours worked per week:

- 1950 – 48 hours (9.6 hr/day)
- 1951–1955 – 44 hours (8.8 hr/day)
- After 1955 – 40 hours (8 hr/day)

We note in the sample DR for WEC (Spreadsheet 2015) that these adjustments are not made. Rather a constant 8 hr/d is assumed. As discussed below, this correction should be applied to the Mode 2 ingestion doses. We recognize that the adjustment is minor, but the logic behind the calculational methodology should be preserved.

Observation 1. Mode 2 ingestion exposures based on OCAS-TIB-009 should be adjusted for the duration of the work-day (i.e., 8, 8.8 or 9.6 hr) based on the dates which the exposures occurred.

2ND RESIDUAL PERIOD

For the 2nd residual period (June 1, 1958, through May 31, 1959), NIOSH assumed that the air concentration remained constant at 12 dpm/m^3. The basis for this assumption is as follows (NIOSH 2015):

> *During the 2nd operational period, an on-site representative from HASL collected 4 general-area, gross-alpha air samples "after all clean-up and decontamination work was done" (see Figure 7.1 above) (Ross, 1958). NIOSH will assume that the average of these 4 samples (12 dpm/m^3) is representative of the air concentration at the start of this residual radiation period. Since the length of this residual radiation period is approximately one year, no source term depletion was applied. NIOSH will apply the air concentration of 12 dpm/m^3 in a constant manner to model activity available for inhalation and ingestion by personnel during this period.*

It should be noted that it is coincidental that the air concentration at the beginning and end of the 2nd operational period was the same (12 dpm/m^3). The basis for the airborne concentration value at the beginning of the 2nd operational period was described in Table 1, while the basis for the concentration at the end of that period is provided in the quotation above.

Although the 2nd operating period was defined as February 1, 1958, through May 31, 1958 (the contract period), actual rolling operations on the Assel mill only occurred from May 12–16, 1958, when six uranium fuel rods were processed. During operations, both BZ and GA air samples were taken by HASL. For four GA samples taken on the Assel mill platform during rolling, the average air concentration was 2,412 dpm/m^3, and for two GA samples taken at the Assel mill during rolling, the average air concentration was 1,544 dpm/m^3. A bounding estimate of the surface concentration can be made by assuming that rolling occurred over four 8-hour work-days for 25% of each work-day. Assuming an average air concentration of about 2,000 dpm/m^3 and 8 hours of deposition, the surface concentration at the end of operations would be 43,200 dpm/m^2 (2,000 dpm/m^3 × 0.00075 m/s × 3,600 sec/hr × 8 hr).[3] If the resuspension factor is 1E-05/m, then the air concentration would be 0.4 dpm/m^3. This calculation is clearly bounding, since cleanup and decontamination were done after 2nd period operations were complete (Ross 1958). Thus, the

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[3] We presume that, since the operations were limited in scope, it is reasonable to assume that deposition should be based on an 8-hr day rather than a 24-hr day.

assumption of 12 dpm/m^3 for the air concentration in the 2nd residual period is reasonable and claimant favorable for inhalation intakes.

With regard to ingestion intakes, the same conceptual issue exists as was discussed for the 1st residual period; i.e., the need to use surface concentration to estimate hand-to-mouth ingestion. Assuming, for discussion, that the surface concentration is 43,200 dpm/m^2, the daily ingestion based on an indirect ingestion rate of 0.0001 m^2/h is 35 dpm/work-day (43,200 dpm/m^2 × 0.0001 m^2/h × 8 hr/work-day). The Mode 2 contribution to ingestion based on an air concentration of 0.4 dpm/m^3 is 0.4 dpm/work day (0.4 dpm/m^3 × 0.00075 m/s × 0.0456 m^2 × 3,600 sec/hr × 8 hr/work-day). The total ingestion intake would be 24 dpm/calendar-day. For comparison, NIOSH developed an estimate of 1.64 dpm/d based on OCAS-TIB-009 (NIOSH 2004) methodology.

Finding 2 is applicable to the 2nd residual period as well.

3RD RESIDUAL PERIOD

For the 3rd residual period (July 1, 1959, through April 30, 2000), NIOSH used air-sampling data from the 3rd operating period. As described by NIOSH (2015, Section 5.2.1.1):

> *The third AWE contract started on June 1, 1958 and ended on June 30, 1959; however, NIOSH found indications that potential uranium machining exposures occurred only during operations from June 25, 1959 through June 29, 1959.*

During the 3rd operational period, HASL collected 27 gross alpha air samples (both BZ and GA). The highest observed value was 5,551 dpm/m^3 for a BZ sample. Based on that sample, NIOSH proposed to calculate the surface concentration for the 5 days over which rolling of uranium was actually conducted. Airborne concentrations resulting from resuspension would be based on a resuspension factor of 1E-05/m. Based on the methodology proposed by NIOSH, SC&A has estimated the initial surface concentration to be 6.00E+05 dpm/m^2 (5,551 dpm/m^3 × 0.00075 m/s × 3,600 sec/hr × 8 hr/day × 5 days) and that the initial airborne concentration would be 6 dpm/m^3. NIOSH further proposes that this concentration be decayed over time, based on the source term depletion factors developed in Table 4-2 of OTIB-0070 (ORAUT 2012).

This approach to developing surface and airborne concentrations is reasonable and should provide an appropriate basis for calculating inhalation intakes during the 3rd residual period. The concerns discussed above regarding use of the OCAS-TIB-009 (NIOSH 2004) methodology for calculating ingestion intakes also apply to the 3rd residual period.

As a sidebar comment, we note in Spreadsheet 2015 (Sheet: Res 6-30-1959 to 4-30-2000) that the initial surface concentration is 10,791,144 dpm/m^2. This is the surface concentration that would be obtained from 30 days of round-the-clock deposition. Such an estimate would be appropriate for an extended production operation, but not for the limited 3rd operational period at Westinghouse. This approach is inconsistent with that documented on page 37 of NIOSH 2015, which states:

The estimate of surface contamination will be made by assuming continuous settling of this airborne radioactive material at a rate of 0.00075 m/s for 5 days.

Observation 2. The deposition time used in the Model DR (Spreadsheet 2015) is not consistent with that proposed on p. 37 of NIOSH 2015.

As described in the SEC-00217 ER, NIOSH proposes to increase the resuspension factor to 1E-04/m for the period from November 1, 1976, through April 30, 2000, to account for the effects of aggressive decontamination activities on resuspension. This adjustment is appropriate, given the known history of the site.

SUMMARY

Based on its review of how NIOSH proposed to address exposures during the residual periods at WEC, SC&A has two findings and two observations:

Observation 1. Mode 2 ingestion exposures based on OCAS-TIB-009 should be adjusted for the duration of the work-day (i.e., 8, 8.8 or 9.6 hr) based on the dates which the exposures occurred.

Observation 2. The deposition time used in the Model DR (Spreadsheet 2015) is not consistent with that proposed on p. 37 of NIOSH 2015.

Finding 1. The procedure for calculating air concentrations during the 1ˢᵗ residual period is not consistent with the guidance provided in ORAUT-OTIB-0070.

Finding 2. The guidance provided in OTIB-0070 (Section 3.6) for calculating doses during the residual period refers to OCAS-TIB-009 (NIOSH 2004). This guidance should be revised, since the OCAS-TIB-009 approach cannot be used to calculate ingestion intakes from transfer of surface contamination to the hands and then to the mouth. Use of the procedure in TIB-009 understates this source of ingestion. The calculations in the SEC-00217 ER for the 1ˢᵗ residual period should be modified accordingly.

Finding 2 is applicable to all three residual periods. Implementation of this finding will require revisions not only to the SEC-00217 ER, but also to OCAS-TIB-009 (NIOSH 2004) and ORAUT-OTIB-0070 (ORAUT 2012).

It is recognized that these corrections will result in small changes to the residual period doses; however, the corrections should be made to ensure that a consistent and scientifically sound calculational methodology is preserved.

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