Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

WHITE PAPER: SUPPLEMENTAL INFORMATION AND RESPONSE TO FINDING 434.1-C.1.1 FOR A WESTINGHOUSE NUCLEAR FUELS DIVISION DOSE RECONSTRUCTION

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Prepared by

U.H. Behling, PhD, MPH

SC&A, Inc.
2200 Wilson Boulevard, Suite 300
Arlington, Virginia, 22201

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TASK MANAGER:	Rose Gogliotti [signature on file]
PROJECT MANAGER:	John Stiver, MS, CHP [signature on file]
DOCUMENT REVIEWER(S):	Rose Gogliotti [signature on file] John Stiver, MS, CHP [signature on file]

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AWE	Atomic Weapons Employer
BZ	breathing zone
DCF	dose conversion factor
DOE	U.S. Department of Energy
dpm	disintegrations per minute
DR	dose reconstruction
EE	energy employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EPA	U.S. Environmental Protection Agency
EU	enriched uranium
FEMP	Fernald Environmental Management Project
ICRP	International Commission on Radiological Protection
keV	kiloelectron volt
LMFBR	Liquid Metal Fast Breeder Reactor
MDA	minimum detectable activity
MeV	mega-electron volt
mrem	millirem
NERVA	Nuclear Engine for Rocket Vehicle Application
NIOSH	National Institute for Occupational Safety and Health
NU	natural uranium
ORAUT	Oak Ridge Associated Universities Team
OTIB	ORAUT technical information bulletin
Pu	plutonium
Ra	radium
SCDRR	Subcommittee for Dose Reconstruction Reviews
SRDB	Site Research Database
Th	thorium
WNFD	Westinghouse Nuclear Fuels Division

1.0 STATEMENT OF PURPOSE

This report provides SC&A's analysis of information submitted by the National Institute for Occupational Safety and Health (NIOSH) on March 31, 2017, pertaining to Finding 434.1-C.1.1 for a dose reconstruction (DR) review of an energy employee (EE) who worked at the Westinghouse Nuclear Fuels Division (WNFD).

2.0 RELEVANT BACKGROUND INFORMATION AND TIMELINE OF EVENTS

- In February 2013, NIOSH completed its DR for the WNFD EE.

- In February 2014, SC&A issued its draft review of the WNFD DR along with five findings (SC&A 2014).

  Finding 434.1-C.1 stated that NIOSH employed an "*unsupported method for determining photon dose during the residual period*." More specifically, this finding cited the absence of information needed for SC&A to duplicate doses derived by NIOSH. Duplication and verification of values used by NIOSH for reconstruction of assigned radiation doses is essential to SC&A's DR review.

- On September 13, 2015, and November 16, 2015, findings for the WNFD DR were discussed with the Subcommittee for Dose Reconstruction Reviews (SCDRR). In its September 13, 2015, response to SC&A's Finding 434.1-C.1.1, NIOSH stated: "*NIOSH agrees that though these calculations were **described** in the DR report, they were **not** directly included in the claim file or detailed in the DR report*" (emphasis added) (BRS 2015).

- On January 30, 2017, Finding 434.1-C.1.1 was again discussed during another SCDRR teleconference. For resolution of the finding, NIOSH agreed to provide the necessary information that would allow SC&A to verify and validate external doses during the residual period.

- On March 31, 2017, NIOSH provided SC&A with the following documents:

  – The WNFD Template, titled *Dose Reconstruction Methodology for Westinghouse Nuclear Fuels Division, Cheswick, PA*, issued February 8, 2013. This document is reproduced herein as Appendix A.

  – The WNFD spreadsheet developed by NIOSH for deriving external deep and shallow doses during the WNFD residual period.

- On April 13, 2017, the SCDRR conducted its most recent teleconference to discuss select DRs and their findings, which included Finding 434.1-C.1.1. Due to time constraints, SC&A had not been able to provide the SCDRR with a written analysis of the recently furnished data prior to the teleconference. As a result, the SCDRR asked SC&A to supplement its oral presentation of these two documents in a formal report. Presented below are summary evaluations that provide the following information:

– An evaluation of forwarded data used by NIOSH for the derivation of external doses during the WNFD residual period

– Remaining concerns and uncertainties pertaining to Finding 434.l1-C.1.1

– Recommendations for the resolution of Finding 434.1-C.1.1

3.0 EVALUATION OF DATA USED BY NIOSH TO DERIVE EXTERNAL DOSES DURING THE WNFD RESIDUAL PERIOD

3.1 GUIDANCE IN THE WNFD TEMPLATE

For the derivation of external dose during the residual period, the WNFD Template (see Appendix A) provides the following guidance that is limited to the statements quoted below:

> <u>*Residual External Dose*</u>
>
> *Though a monitoring program existed at WNFD during the residual period, **continuing operations** that are not covered under the EEOICPA also occurred. Therefore, external dosimetry should only be used to limit residual exposures. Residual exposures are **calculated** based on the **contamination levels** calculated below and applying the dose conversion factors from EPA Federal Guidance Report 12 for **contaminated surfaces and submersion**. These doses are provided in the table below.* [emphasis added]

Year	***OTIB-0070 Adjustment Factor***	***Photon (rem)***	***Electron (rem)***
1973	*1.000*	*0.032*	*0.171*
1974	*0.783*	*0.025*	*0.134*
1975	*0.613*	*0.020*	*0.105*
1976	*0.480*	*0.016*	*0.082*
1977	*0.376*	*0.012*	*0.064*
1978	*0.294*	*0.010*	*0.050*
1979	*0.231*	*0.007*	*0.040*

In behalf of the “derived” photon dose of 0.032 rem/yr and electron dose of 0.171 rem/yr given in the table, NIOSH’s explanation for these numbers is confined to (1) unspecified “contamination levels” and (2) the application of the U.S. Environmental Protection Agency’s (EPA’s_ dose conversion factors (DCFs) for contaminated surfaces and contaminated air submersion cited in Federal Guidance Report 12 (EPA 1993).

SC&A's inability to reproduce and validate the aforementioned photon and electron doses that prompted Finding 434.1-C.1.1 must, therefore, be viewed in context with the limited information provided in the WFND Template.

3.2 EVALUATION OF SPREADSHEET DATA PROVIDED TO SC&A ON MARCH 31, 2017

Reproduced as Figures 1 and 2 are two spreadsheets that in combination provide numerical data that trace the conversion of the specified surface contamination level of 2.83×10^6 dpm/m^2 in 1973 to a deep dose rate of 0.032 rem/yr and a shallow dose rate of 0.171 rem/yr for natural thorium (Nat-Th). (Note: Data are also provided for three other potential source terms: plutonium (Pu) mix 12% 10 year, recycled natural uranium [NU], and recycled 2% enriched uranium [EU].)

3.1.1 Figure 1: External Exposure Doses to Natural Thorium

Shown below the deep dose in Figure 1 is the derivation of the shallow dose of 0.171 rem/yr, which parallels that of the deep dose with the exception of DCF values taken from EPA's Federal Guidance Report 12 that correspond to skin as the target tissue for the shallow dose. For simplicity and convenience to the reader, salient elements in Columns 1 through 10 of Figure 1 are sequentially identified in numbered list items 1 through 10 below the figure.

Figure 1: Spreadsheet Data Obtained from NIOSH Pertaining to External Exposure Doses to Natural Thorium

Surface Activity (dpm/m2)	2.83E+06

Column #1	Column #2	Column #3	Column #4	Column #5	Column #6	Column #7	Column #8	Column #9	Column #10
Deep Dose									
Radionuclide	Surface Activity (dpm/m2)	Resuspension (m-1)	Air Concentration (dpm/m3)	Effective Contaminated DCF (rem/dpm hr m-2)	Effective Submersion DCF (rem/dpm hr m-3)	Effective Contaminated Dose Rate (rem / hr)	Effective Submersion Dose Rate (rem / hr)	Workhours / Year	Effective WB Dose (rem/yr)
Nat-Th	2.83E+06	1.00E-06	2.83	5.73E-12	2.99E-10	1.62E-05	8.47E-10	2000	0.032
Pu Mix 12% 10 yr	2.83E+06	1.00E-06	2.83	4.98E-14	1.45E-12	1.41E-07	4.10E-12	2000	0.000
Recycled NU	2.83E+06	1.00E-06	2.83	1.16E-13	5.22E-12	3.30E-07	1.48E-11	2000	0.001
Recycled 2% EU	2.83E+06	1.00E-06	2.83	7.00E-14	3.08E-12	1.98E-07	8.72E-12	2000	0.000
Shallow Dose									
Radionuclide	Surface Activity (dpm/m2)	Resuspension (m-1)	Air Concentration (dpm/m3)	Skin Contaminated DCF (rem/dpm hr m-2)	Skin Submersion DCF (rem/dpm hr m-3)	Skin Contaminated Dose Rate (rem / hr)	Skin Submersion Dose Rate (rem / hr)	Workhours / Year	Skin Dose (rem/yr)
Nat-Th	2.83E+06	1.00E-06	2.83	3.03E-11	5.00E-10	8.57E-05	1.42E-09	2000	0.171
Pu Mix 12% 10 yr	2.83E+06	1.00E-06	2.83	1.65E-13	2.33E-12	4.67E-07	6.59E-12	2000	0.001
Recycled NU	2.83E+06	1.00E-06	2.83	2.77E-11	1.72E-10	7.84E-05	4.87E-10	2000	0.157
Recycled 2% EU	2.83E+06	1.00E-06	2.83	1.16E-11	7.68E-11	3.29E-05	2.18E-10	2000	0.066

Year	OTIB-070	95th Pecentile	
		Photon (rem)	Electron (rem)
1973	1.000	0.032	0.171
1974	0.783	0.025	0.134
1975	0.613	0.020	0.105
1976	0.480	0.016	0.082
1977	0.376	0.012	0.064
1978	0.294	0.010	0.050
1979	0.231	0.007	0.040

1) NIOSH identified four different potential source terms that could result in external exposure. (Natural thorium, however, resulted in the highest deep dose and shallow dose among the four potential source terms and is highlighted in yellow.)

2) Identifies the assigned surface contamination level of 2.83×10^6 dpm/m^2 for year 1973.

3) A resuspension value of 1×10^{-6} m^{-1} was selected to derive the air contamination level.

4) By means of the assumed resuspension value of 1×10^{-6} m^{-1} times the 2.83×10^6 dpm/m^2, NIOSH calculated the air concentration of 2.83 dpm/m^3.

5) Corresponds to the combined effective DCF for the three isotopes representing natural thorium, as derived in Figure 2, from surface contamination.

6) Corresponds to the combined effective DCF for the three isotopes representing natural thorium, as derived in Figure 2, from Federal Guidance Report 12 for submersion exposure.

7) Represents the effective external dose rate that results from contaminated surface. For example, the derived "effective contaminated" dose rate of 1.62E-05 rem/hr is the product of columns 2 and 5: (2.83×10^6 dpm/m^2) × (5.73×10^{-12}) = 1.62E-05 rem/hr.

8) Represents the effective external dose rate that results from submersion in contaminated air.

9) Work-hours per year during which external exposure is assumed.

10) The effective annual dose of 0.032 rem/yr is the combined effective external dose from surface contamination and submersion in contaminated air.

3.1.2 Figure 2: Isotopic Components Representing Natural Thorium

Figure 2 segregates the source term described in Figure 1 as natural thorium into its isotopic components of thorium-232 (Th-232), Th-228, and radium-228 (Ra-228) and provides the contribution of effective contaminated dose rate and effective submersion dose rate for each radionuclide. Incorporated into isotopic-specific dose rates, however, are the isotopic activity fractions (shown in the upper left-hand side of Figure 2 for natural thorium) of 0.084 for Th-228, 0.0145 for Th-232, and 0.9015 for Ra-228.

However, the assigned isotopic activity fractions of 8.4% for Th-228, 1.45% for Th-232, and 90.15% for Ra-228 appear to represent activity fractions for thorium tailings. For unprocessed natural thorium, Th-232, Th-228, and Ra-228 must reasonably be assumed to exist in secular equilibrium where each of the three radionuclides contribute the identical activity fraction of 0.333.

Therefore, NIOSH's inappropriate assignment of activity fractions for natural thorium for deriving external dose assessment conflicts with the correct natural thorium activity fractions of 0.333 used by NIOSH for deriving internal dose, as shown in the “Internal Dose” section of the WNFD Template (see Appendix A).

Figure 2: Spreadsheet Data Obtained from NIOSH Pertaining to the Isotopic Components Representing Natural Thorium

Natural Thorium

Activity Faction	
Radionuclide	Activity Faction
Th228	0.084
Th232	0.0145
Ra228	0.9015

Radionuclide	Activity Faction	Effective Contaminated DCF (rem/dpm hr m-2)	Effective Submersion DCF (rem/dpm hr m-3)	Effective Contaminated Dose Rate (rem / hr)	Effective Submersion Dose Rate (rem / hr)	DU Contaminated Dose Rate (rem / hr)	DU Submersion Dose Rate (rem / hr)
Th228	8.40E-02	8.43E-12	4.82E-10	7.08E-13	4.05E-11	5.73E-12	2.99E-10
Th232	1.45E-02	3.31E-15	5.23E-14	4.79E-17	7.59E-16		
Ra228	9.02E-01	5.57E-12	2.87E-10	5.02E-12	2.59E-10		

Radionuclide	Activity Faction	Skin Contaminated DCF (rem/dpm hr m-2)	Skin Submersion DCF (rem/dpm hr m-3)	Skin Contaminated Dose Rate (rem / hr)	Skin Submersion Dose Rate (rem / hr)	DU Skin Contaminated Dose Rate (rem / hr)	DU Skin Submersion Dose Rate (rem / hr)
Th228	8.40E-02	5.44E-11	8.83E-10	4.57E-12	7.42E-11	3.03E-11	5.00E-10
Th232	1.45E-02	4.12E-14	2.06E-13	5.97E-16	2.99E-15		
Ra228	9.02E-01	2.85E-11	4.73E-10	2.57E-11	4.26E-10		

4.0 REMAINING CONCERNS AND UNCERTAINTIES

While data in Figures 1 and 2 allowed SC&A to duplicate NIOSH's derived external deep dose of 0.032 rem/yr and shallow dose of 0.171 rem/yr of the residual period, it does not imply their validation. Imbedded in the derivation of external doses are three unexplained or undocumented assumptions and two inconsistencies that require further clarification, as explained below.

4.1 UNDOCUMENTED SURFACE ACTIVITY

Figures 1 and 2 identify the starting surface contamination of 2.83×10^6 dpm/m^2, which quantitatively directly affects the derivation of external doses. However, no information is provided by NIOSH that explains and validates the origin and derivation of the 2.83×10^6 dpm/m^2 contamination level.

4.2 INAPPROPRIATE VALUE FOR RESUSPENSION FACTOR

For the derivation of external submersion doses, NIOSH assigned the resuspension factor of 1.00E-06 m^{-1}. NIOSH's assigned resuspension value of 1.00E-06 m^{-1} is not only inappropriate but also produces a resulting air concentration that is incompatible with air concentrations assumed by NIOSH for the derivation of internal/inhalation uptake values, as explained below.

In the "Residual External Dose" section of the WNFD Template (see Appendix A), NIOSH states the following:

> *Though a monitoring program existed at WNFD during the residual period, **continuing operations** that are **not covered** under the EEOICPA also occurred.* [emphasis added]

This statement implies that (1) there was no decontamination at the WNFD facility after completion of Atomic Weapons Employer (AWE) activities in 1972, and (2) some radiological activities continued that were not covered under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA).

A resuspension factor as low as 1.00E-06 m^{-1} is generally only used to validate a thorough and documented decontamination effort for a facility that complies with standards specified in the U.S. Atomic Energy Commission's (AEC's) Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors* (AEC 1974), and meets the standard for unrestricted use given in Table 1 of the regulatory guide. Acceptable surface contamination levels for natural thorium as well as other nuclides given in Regulatory Guide 1.86, Table 1 are reproduced in Appendix B.

SC&A concludes that conditions during the residual period at WNFD do not meet these criteria. NIOSH's use of a 1.00E-06 m^{-1} resuspension factor for deriving external submersion doses is, therefore, inappropriate.

4.3 INCONSISTENCY OF RESUSPENSION-FACTOR-DERIVED AIR CONCENTRATION

The resuspension factor of 1.00E-06 m^{-1} and its derived submersion air concentration of 2.83 dpm/m^3 of air (i.e., $(2.83\times10^6$ dpm/$m^2) \times (1\times10^{-6}) = 2.83$ dpm/m^3) is incompatible with the corresponding value of 100 dpm/m^3 air concentration used by NIOSH for estimating the daily inhalation of 965.121 dpm (see the "Internal Dose" section of Appendix A).

Based on 1971 and 1972 air sampling data (given in Site Research Database [SRDB] Ref. IDs 65275, 65285, 65298, 65299, 65387, 65388, 65391, 65393, 65394, 65396, 65398, 65399, 65401, 65402, and 65404), NIOSH derived inhalation and ingestion intakes during the residual period at the 95th percentiles for three separate job categories (see the "Internal Dose" section of the WNFD Template in Appendix A). For the highest exposed group, the derived 95th percentile inhalation intake for operators/general laborers corresponds to 965.121 dpm per day during year 1973. (Note: The 15 SRDB Ref. IDs identified by NIOSH are not referenced in the template. The template does not contain a reference list.)

Incorporated in the inhalation intake of 965.121 dpm/day is the assumed breathing rate of 1.2 m^3 of air per hour and an 8-hour workday.

The inhalation of 965.121 dpm/day, therefore, assumes an air concentration of 100 dpm alpha activity per cubic meter of air at the beginning of the WNFD residual period of 1973.

In summary, the concurrent exposure to two air concentrations that differ by a factor of ~35 must clearly be regarded as incompatible, inasmuch as a person cannot be exposed to an air submersion dose defined by 2.83 dpm/m^3 of air while at the same time inhaling air containing 100 dpm/m^3.

4.4 UNDOCUMENTED AIR CONCENTRATION FOR INTERNAL DOSE ASSESSMENT

With regard to NIOSH's assumption of an air concentration of 100 dpm/m^3 for the assignment of inhalation intakes, it must also be noted that no explanation is given for its derivation. A reasonable assumption is that this value reflects air sampling data in the 15 SRDBs cited in the "Internal Dose" section of the WNFD Template (see Appendix A).

4.5 INCONSISTENT ASSIGNMENT OF ISOTOPIC ACTIVITY FRACTIONS

The activity fractions assigned to natural thorium in the derivation of external doses correspond to values that do not represent secular equilibrium but more likely represent thorium tailings.

However, for the assessment of internal doses from inhalation and ingestion of natural thorium, NIOSH assigned activity fractions that represent secular equilibrium among decay-chain members.

Because internal and external exposures to natural thorium are likely concurrent, activity fractions assumed for deriving external and internal dose must, therefore, be the same.

5.0 RECOMMENDATIONS FOR THE RESOLUTION OF FINDING 434.1-C.1.1

Whenever a dose reconstruction is based on a facility-specific template that has not been previously evaluated, SC&A's charter is to include the template in its review of the DR.

On behalf of Finding 434.1-C.1.1, SC&A recommends the following changes for resolution:

1) Provide information/data that validate the surface contamination of 2.83×10^6 dpm/m^2 used to derive external dose.

2) For the derivation of external doses, revise activity fractions for natural thorium that represent a state of secular equilibrium, as was assumed by NIOSH in the derivation of internal exposures.

3) For external submersion dose, replace the resuspension factor of 1.00E-06 m^{-1} with a resuspension factor that realistically reflects an AWE facility that had not been decontaminated and decommissioned but actively continued operations that were not covered under EEOICPA.

   A review of Figure 3-1, Table 3-1, and Figure 3-2 in Revision 01 to ORAUT-OTIB-0070 (NIOSH 2012) suggest more realistic resuspension factors in the range of 5E-05 m^{-1} to 1E-03 m^{-1}.

   Justification for a more realistic resuspension factor is also prompted by the need to establish parity between the air concentration assumed for external submersion dose and the air concentration assumed for internal/inhalation exposure. Thus, if NIOSH had selected the resuspension factor of 3.5E-05 m^{-1}, the resultant air concentration of 99.0 dpm/m^3 (i.e., 99.0 dpm/m^3 = (3.83×10^6 dpm/m^2) × 3.5 E-05 m^{-1}) used to derive external air submersion dose would perfectly match NIOSH's assumed air concentration of 100 dpm/m^3 for assessing inhalation dose.

4) Provide information/data that validate the air concentration of 100 dpm/m^3 and, therefore, the inhalation of 965.121 dpm/day.

6.0 REFERENCES

AEC 1974. *Termination of Operating Licenses for Nuclear Reactors*, Regulatory Guide 1.86, U.S. Atomic Energy Commission. June 1974.

BRS 2015. Subcommittee for Dose Reconstruction Reviews, Board Review System, Set 14-18 Other DCAS Cases, WNFD 434.1-C.1.1. NIOSH finding response added September 13, 2015.

EPA 1993. *External Exposure to Radionuclides in Air, Water, and Soil, Federal Guidance Report No. 12*, EPA-402-R-93-081, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, DC. September 1993.

NIOSH 2012. *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, ORAUT-OTIB-0070, Revision 01, National Institute for Occupational Safety and Health, Cincinnati, Ohio. March 5, 2012.

SC&A 2014. *Audit of the 18th Set of 12 Dose Reconstruction Cases*, Contract No. 200-2009-28555, SC&A, Inc., Vienna, Virginia. February 3, 2014.

APPENDIX A: REPRODUCTION OF THE WNFD DOSE METHODOLOGY TEMPLATE

Dose Reconstruction Methodology for *Westinghouse Nuclear Fuels Division, Cheswick, PA*

February 8, 2013

Facility Description

The Westinghouse Nuclear Fuels Division received shipments of nuclear materials from the AEC nuclear weapons complex in 1971 and 1972. The Cheswick site received a shipment of enriched uranium from the AEC's Fernald plant in 1971. It also received a shipment of plutonium in 1972 from the West Valley facility. This plutonium originated out of Hanford.

Although the Westinghouse facility in Cheswick, PA, conducted substantial work with radioactive materials in other years, this work is not covered under EEOICPA because it was not related to nuclear weapons production. This includes the fabrication of nuclear fuels and reactor subsystems for naval, space, and civilian applications. Among the projects to which the Cheswick facility contributed were the Naval Nuclear Propulsion Program, the Nuclear Engine for Rocket Vehicle Application (NERVA) program, and the Liquid Metal Fast Breeder Reactor (LMFBR) program.

External Dose

<u>Photon Dose</u>

The limit of detection for photons is 0.04 rem for photons, as found in the Technical Information Bulletin: A Standard Complex-Wide Methodology for Overestimating External Doses Measured with Film Badge Dosimeters, (SRDB RefID 29953).

The evaluation of cases under the guidance found in the Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose, (SRDB RefID 19434), will require a 0.05 rem limit of detection for photons.

All photon doses will be assigned as acute dose, in the 30-250 keV photon energy range.

The monitoring program at the Cheswick facility was comprehensive. Dosimetry records exist for the operational period of 1971 to 1972, and are sufficient to perform dose reconstructions, with the adjustment for potential neutron dose discussed below.

<u>Shallow Dose</u>

The limit of detection for electrons is 0.05 rem for electrons, as found in the Technical Information Bulletin: A Standard Complex-Wide Methodology for Overestimating External Doses Measured with Film Badge Dosimeters, (SRDB RefID 29953).

Shallow doses were included in the dosimetry records. Measured shallow doses will be assigned as acute dose, in the <30 keV photon energy range. Blanks in the records will be treated as zeros.

Neutron Dose

As the records indicate that the plutonium originated at the Hanford site, neutron energies were assigned as 90% 0.1 – 2 MeV and 10% 2 – 20 MeV neutrons, with ICRP-60 weighting factors of 1.71 and 0.13, respectively, based on information regarding non-reactor plutonium facilities from the Technical Basis Document for the Hanford Site – Occupational External Dose (SRDB RefID 32074).

Neutron missed doses are assigned based on a monthly exchange frequency and a claimant-favorable limit of detection of 100 mrem. The limit of detection is based on the known neutron detection limits for the relevant era major DOE sites, such as the Savannah River Site, as found in the Technical Basis Document for the Savannah River Site (SRDB RefID 20176).

On-Site Ambient Dose

The dosimetry records include reports for several control dosimeters (SRDB RefID 59671), all of which were less than 0.040 rem per badge, below the limit of detection for photons described above. When adjusted to reflect a 2,500 hour work-year, per guidance in Occupational On-Site Ambient Dose Reconstruction for DOE Sites (SRDB RefID 29986), this results in an annual dose of 0.137 rem/year, and should be assigned to all unmonitored workers during operational years (1971-1972). The calculated annual dose should be multiplied by the appropriate exposure (R)-to-organ DCF documented in OCAS-IG-001 for an isotropic exposure geometry (SRDB RefID 29986). An assumption of a normal distribution and 30% standard deviation should be applied.

Medical Dose

No specific information can be found regarding occupational X-ray dose. In the absence of specific information, X-ray doses will be assigned in accordance with the Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures (SRDB RefID 20220). Assuming a pre-employment, annual, and post-employment X-ray will result in one view for each operational year (1971 – 1972). Medical exposure does not apply to the residual period.

Residual External Dose

Though a monitoring program existed at WNFD during the residual period, continuing operations that are not covered under the EEOICPA also occurred. Therefore, external dosimetry should only be used to limit residual exposures. Residual exposures are calculated based on the contamination levels calculated below and applying the dose conversion factors from EPA Federal Guidance Report 12 for contaminated surfaces and submersion. These doses are provided in the table below.

Year	OTIB-0070 Adjustment Factor	Photon (rem)	Electron (rem)
1973	1.000	0.032	0.171
1974	0.783	0.025	0.134
1975	0.613	0.020	0.105
1976	0.480	0.016	0.082
1977	0.376	0.012	0.064
1978	0.294	0.010	0.050
1979	0.231	0.007	0.040

Internal Dose

Bioassay records are available for most individuals involved with fuel production, involving work directly with powder and/or fuel pellets. Records indicate that thorium and plutonium were used on the Westinghouse site. The plutonium originated at the Hanford site and arrived at Cheswick via the West Valley site. Both nuclides were used to experimentation in the laboratories onsite and in the manufacture of mixed oxide fuels, though the thorium found in the fuel appears to have been regarded as more of an impurity. Bulk containers of thorium were stored in a vault in Building 7 on the site and were used primarily for experimentation.

Additionally, a shipment of enriched uranium was received at the site from Fernald. Potential constituents of recycled uranium must be evaluated and will be performed in accordance with the guidance found in the Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Occupational Internal Dose, (SRDB RefID 19485), with an assumption of 2% enrichment.

Radionuclide	2% Enriched Recycled Uranium Ratios
U-234:Alpha	1.000
Pu-239:U-234	0.00246
Np-237:U-234	0.00182
Tc-99:U-234	0.379
Th-228:U-234	2.73E-06
Th-232:U-234	2.73E-06

The plutonium mixture will be evaluated using the guidance found in the Technical Basis Document for the Hanford Site – Occupational Internal Dose, (SRDB RefID 32522), assuming 12%, 10-year-old fuel grade plutonium.

Radionuclide	12%, 10-year-old Fuel Grade Plutonium Ratios
Pu-238:Alpha	0.117
Pu-239:Alpha	0.593
Pu-241:Alpha	14.201
Am-241:Alpha	0.289

Bioassay and air monitoring records are available. The bioassay records indicate monitoring for uranium (natural and enriched) and plutonium. There is no indication of any monitoring for thorium. An addendum to the site health physics manual, dated June 1, 1961, states: "The properties of uranium and thorium are not sufficiently dissimilar to warrant their separate treatment. As far as potential hazard is concerned, both natural uranium and thorium have substantially the same specific activity. Therefore, the handling procedures and techniques for thorium are the same as those used for uranium" (SRDB RefID 40618).

Radionuclide	Natural Thorium Ratios
Th-228:Alpha	0.333
Th-232:Alpha	0.333
Ac-228:Alpha	0.333
Ra-228:Alpha	0.333
Ra-224:Alpha	0.333

No minimum detectable activities (MDAs) were given in the records. In assigning missed internal dose, the reporting value or three times the uncertainty (if the reported value is zero) should be assumed to be the MDA.

Air monitoring results are reported in both units of microCuries/milliliter of air and in dpm/cubic meter. In most cases, the dpm/cubic meter results were more legible in the records. These results are largely from stationary air samples, collected on a daily or weekly basis, at strategic locations around the process areas and the stack. These are considered general area air samples. These results are reported as gross total alpha activity. A daily weighted average was established based on a breathing rate of 9.6 cubic meters per day (SRDB RefID 22735), for 250 working days per year. There are several breathing zone (BZ) air sampling records, listed by the individual. These are included within the individual DOE response files and may be used to calculate intakes in the unexpected absence of bioassay information.

Air sampling data (SRDB RefIDs 65275, 65285, 65298, 65299, 65387, 65388, 65391, 65393, 65394, 65396, 65398, 65399, 65401, 65402, and 65404) were evaluated for the years 1971 and 1972, the operational period for the site. From these data, inhalation and ingestion intakes at the 95^{th} percentiles were determined and are provided in the table below and should be assigned as a constant distribution. Airborne activities during the residual period were reduced in accordance with the Technical Information Bulletin: Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities (SRDB RefID 108851).

Intakes for Unmonitored Operators and General Labor			
Year	OTIB-0070 Adjustment Factor	Inhalation Intake (dpm/d)	Ingestion Intake (dpm/d)
1971 - 1972	1.000	965.121	19.302
1973	1.000	965.121	19.302
1974	0.783	755.690	15.113
1975	0.613	591.619	11.832
1976	0.480	463.258	9.265
1977	0.376	362.885	7.258
1978	0.294	283.746	5.675
1979	0.231	222.943	4.459

Intakes for Unmonitored Supervisors			
Year	OTIB-0070 Adjustment Factor	Inhalation Intake (dpm/d)	Ingestion Intake (dpm/d)
1971 - 1972	1.000	482.561	9.651
1973	1.000	482.561	9.651
1974	0.783	377.845	7.557
1975	0.613	295.810	5.916
1976	0.480	231.629	4.632
1977	0.376	181.443	3.629
1978	0.294	141.873	2.837
1979	0.231	111.472	2.229

Intakes for Unmonitored "Other" Workers			
Year	OTIB-0070 Adjustment Factor	Inhalation Intake (dpm/d)	Ingestion Intake (dpm/d)
1971 - 1972	1.000	48.256	0.965
1973	1.000	48.256	0.965
1974	0.783	37.784	0.756
1975	0.613	29.581	0.592
1976	0.480	23.163	0.463
1977	0.376	18.144	0.363
1978	0.294	14.187	0.284
1979	0.231	11.147	0.223

Intake ratios between the classifications of workers are based on the guidance found in the Technical Basis Document: Site Profiles for Atomic Weapons Employers That Worked Uranium Metals (SRDB RefID 101251). The intakes for operators and general labor are assumed to be the same. Supervisors are assumed to 50% of the operator/ general labor's exposure and all other workers are assumed to be 10% of the supervisor's.

During the operational period (1971-1972), partially-monitored workers, those who have bioassays for uranium and/or plutonium, should be assigned unmonitored exposure in excess of any missed dose calculated from the bioassay data, i.e. subtracting missed intake activity from the 95th percentile intake activity described in the tables above, and assigning the remainder as either uranium, plutonium, or natural thorium (excluding the ones accounted for via bioassay), based on which nuclide provides the most claimant favorable result.

For completely unmonitored workers, unmonitored exposures should be based on the geometric mean intake rate and assigned as either uranium, plutonium, or natural thorium, based on which nuclide provides the most claimant favorable result.

During the residual period (1973-1979), intakes should be based on the tables above. These should be assessed as either uranium, plutonium, or natural thorium, based on which nuclide provides the most claimant favorable result. These intakes should be limited by the worker's bioassay data if they would result in higher excretions then detected.

APPENDIX B: TABLE 1 FROM REGULATORY GUIDE 1.86

Table 1. Acceptable Surface Contamination Levels

NUCLIDE [a]	AVERAGE [b c]	MAXIMUM [b d]	REMOVABLE [b e]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, PA-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm/100 cm^2	3000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5000 dpm β-γ/100 cm^2	15,000 dpm β-γ/100 cm^2	1000 dpm β-γ/100 cm^2

[a] Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.
[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[c] Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.
[d] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filters or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

Source: Reproduced from AEC 1974, page 1.86-5.