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Savannah River Site Decontamination Facility Attendant Whole Body-to-Extremity Dose Relationships

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☒ New ☐ Total Rewrite ☐ Revision

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
12/02/2025	00	New document to describe a method for estimation of right and left extremity dose from recorded whole body dose for Decontamination Facility Attendants in the Savannah River Site 772-F facility. Incorporates formal internal and NIOSH review comments. Training is not required. Initiated by Delis G. Maldonado and authored by Zachariah C. Tribbett.

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ACRONYMS AND ABBREVIATIONS

AWE	Atomic Weapons Employer
cpm	counts per minute
cm	centimeter
DCF	dose conversion factor
DFA	Decontamination Facility Attendant
DOE	U.S. Department of Energy
dpm	disintegrations per minute
gal	gallon
GM	geometric mean
GSD	geometric standard deviation
HP	Health Physics (department)
Hp(10)	personal dose equivalent at 10 millimeters depth in tissue
hr	hour
in.	inch
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron-volt, 1,000 electron-volts
mR	milliroentgen
mrad	millirad
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
ORAUT	ORAU Team
oz	ounce
POC	probability of causation
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TIB	technical information bulletin
TLD	thermoluminescent dosimeter
U.S.C.	*United States Code*
§	section or sections

1.0 INTRODUCTION

Technical information bulletins (TIBs) are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s), such as changing scientific understanding of operations, processes, or procedures involving radioactive materials. TIBs may be used to assist NIOSH staff in the completion of individual dose reconstructions.

In this document the word "facility" is used to refer to an area, building, or group of buildings that served a specific purpose at a U.S. Department of Energy (DOE) or Atomic Weapons Employer (AWE) facility. It does not mean, nor should it be equated to, an "AWE facility" or a "DOE facility." The terms AWE and DOE facility are defined in 42 *United States Code* (U.S.C.) § 7384l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000, respectively.

1.1 PURPOSE

This document describes a method the Oak Ridge Associated Universities (ORAU) Team (ORAUT) can use to estimate extremity dose for Decontamination Facility Attendants (DFA) who: (1) worked in an area with known nonuniform exposures to different areas of the body outside of the torso, (2) wore (or are assumed to have worn) a whole body dosimeter underneath a lead apron, (3) were not provided extremity monitoring or are missing extremity monitoring data during all or parts of the period being reviewed, and (4) developed a cancer on a portion of the body not covered by the lead apron. This is accomplished by using the worker's whole body dose results with developed quantile regression equations to estimate extremity dose. This method can be used to estimate extremity dose when detailed, worker-specific extremity dose data are missing or incomplete. It requires the worker-specific whole body cycle dose measurements of the period of interest, which are in the exposure records in the claim file.

1.2 APPLICABILITY

This method can be applicable to Savannah River Site (SRS) claims when the *Employee's Work History* section of the U.S. Department of Labor occupational history questionnaire includes:

1. *Specific Location* of "772-F" or "772-1F";

2. *Position/Title* of "Laboratory Technician" or "Lab Technician"; and

3. *Description of Work Duties* that describes work with and/or decontamination of "doorstops," more generically described as shielded lead containers or "lead pigs."

While most claims have included some or all the information above, descriptions of the work vary from claim to claim. Therefore, work descriptions in the initial documentation, the computer-assisted telephone interview, correspondence, or follow-up documentation that indicate work as a DFA or with the previously mentioned doorstops should be considered as potential claims requiring application of this method.

Discretion should be used by the dose reconstructor in determining if a claim requires the application of this method. Even if a claim meets the work criteria listed above, there must be missing or incomplete extremity data in the worker's exposure history to justify use of the method. Reconstructions for workers with complete monitoring data do not need application of this method.

This method can be used with worker records in both the film and thermoluminescent dosimeter (TLD) eras. The estimated doses can be assigned for any area of the body outside of the torso that is not covered by the lead apron. The ORAU Team assessed the data used and found no associated neutron dose. Therefore, the potential for neutron exposure appears low. If neutron dose assignment is needed, dose reconstructors should contact the Principal External Dosimetry Scientist for guidance. Attachment A contains application example evaluations.

2.0 DESCRIPTION OF WORK LOCATIONS

The activities discussed in this document occurred in the 772-F building in F-Area. The 772-F building was one of many unique facilities designed to support the separations processes. While physically located in F-Area, it supported both F- and H-Areas. Construction was completed in 1953, and the building was turned over to operations in 1954. It was directly west of 221-F Canyon and was originally referred to as the Control Laboratory (see Figure 2-1). It was more commonly referred to later as the Analytical Control Laboratory or the Analytical Laboratory. Building 772-1F was built in 1985 and served as an annex to 772-F [Reed et al. 2013]. Operations ended in 2021, and both buildings are currently scheduled for decommissioning [ORAUT 2024].

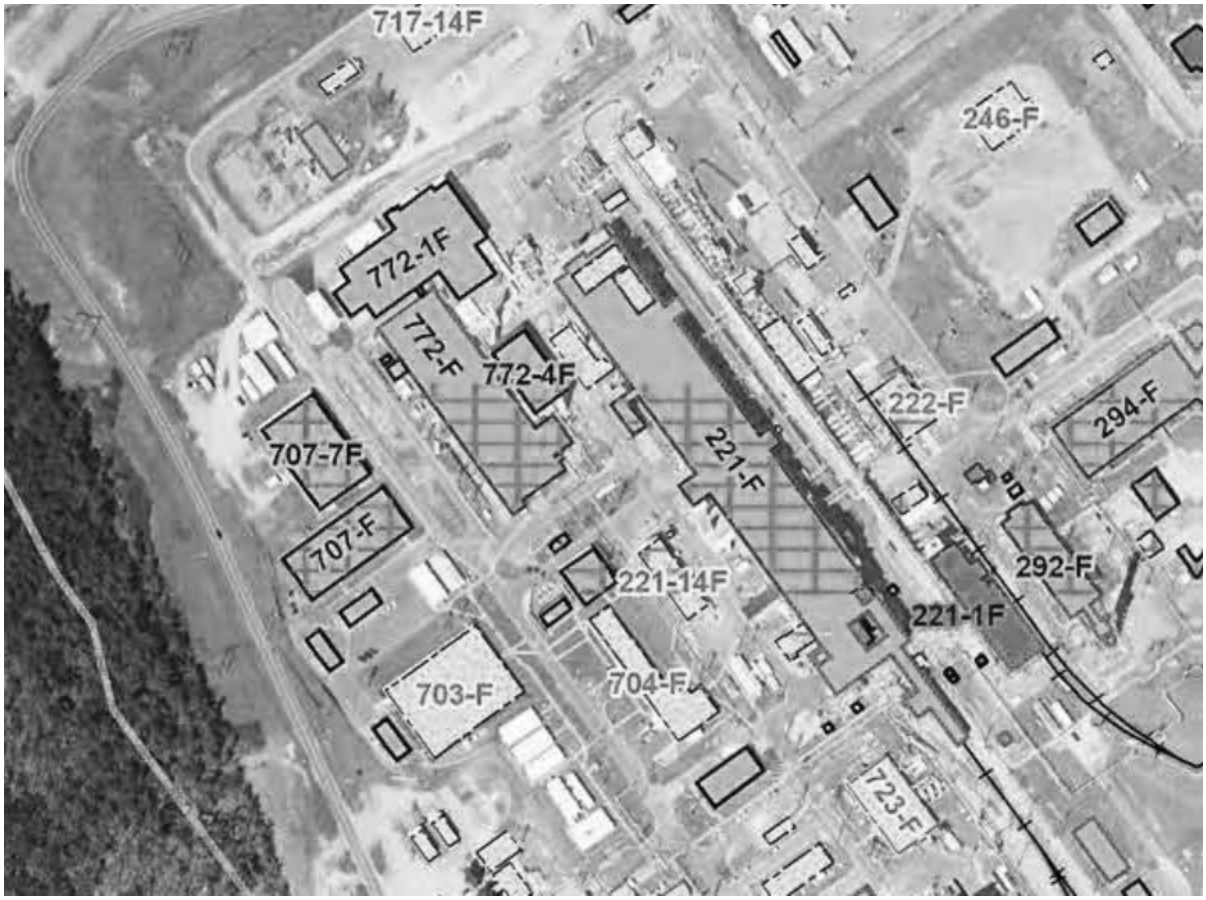

Figure 2-1. Portion of F-Area containing 772-F, 772-1F, and 221-F [adapted from SRNS 2009, p. 114].

From the beginning, Building 772-F was paired both functionally and physically with 221-F. The two buildings were attached by a ground-level covered causeway that was often referred to as the “tunnel.” The purpose of the laboratory was to ensure the purity of the uranium and plutonium that came out of H- and F-Area processes, respectively. Tritium was not normally dealt with in the laboratory. Samples were taken directly from F- and H-Area processes to determine exactly what was

in the solutions at any given time. This sampling allowed for timely process feedback. The sample size was normally 1 fluid oz and was placed in a glass vial. The vial was then placed in a “doorstop,” which was a special shielding container made of stainless steel, lead, or depleted uranium. Doorstops were all similar in size, 5.5-in. outside diameter, 6.75 in. tall, and the upper section was hollow to provide a pocket for the sample vial, a doorstop cover and a plunger [Durant and Perkins 1983]. A second type of container known as a “warm sample container” could also be used. The activity of the sample would determine which type of container was employed. These containers were transported through the tunnel to 772-F in specially designed sampling carts. Samples from H-Area were transferred to the laboratory by truck [Reed et al. 2013]. Figures 2-2 and 2-3 show examples of a doorstop sample holder and a warm sample carrier. The radionuclides of concern included uranium, plutonium, and fission products [La Bone 1996].

Figure 2-2. Doorstop sample container [Reed et al. 2013, p. 117].

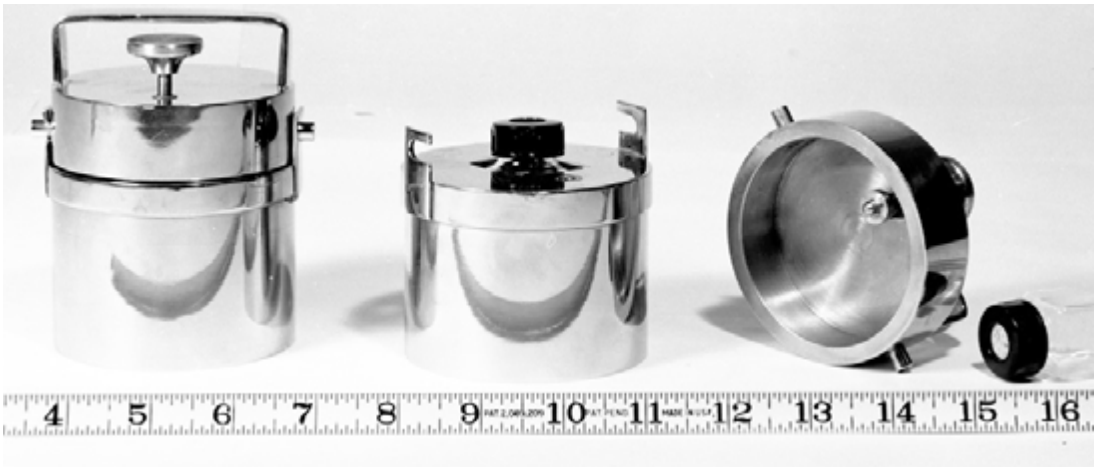

Figure 2-3. Warm sample containers [Reed et al. 2013, p. 117].

Several areas were involved in the movement and analysis of samples and doorstops once received into the laboratory. Figure 2-4 shows a floor map of the laboratory areas through which a doorstop and its sample would move. Table 2-1 includes room numbers, names, and descriptions of notable work areas [Durant and Pritchard 1986].

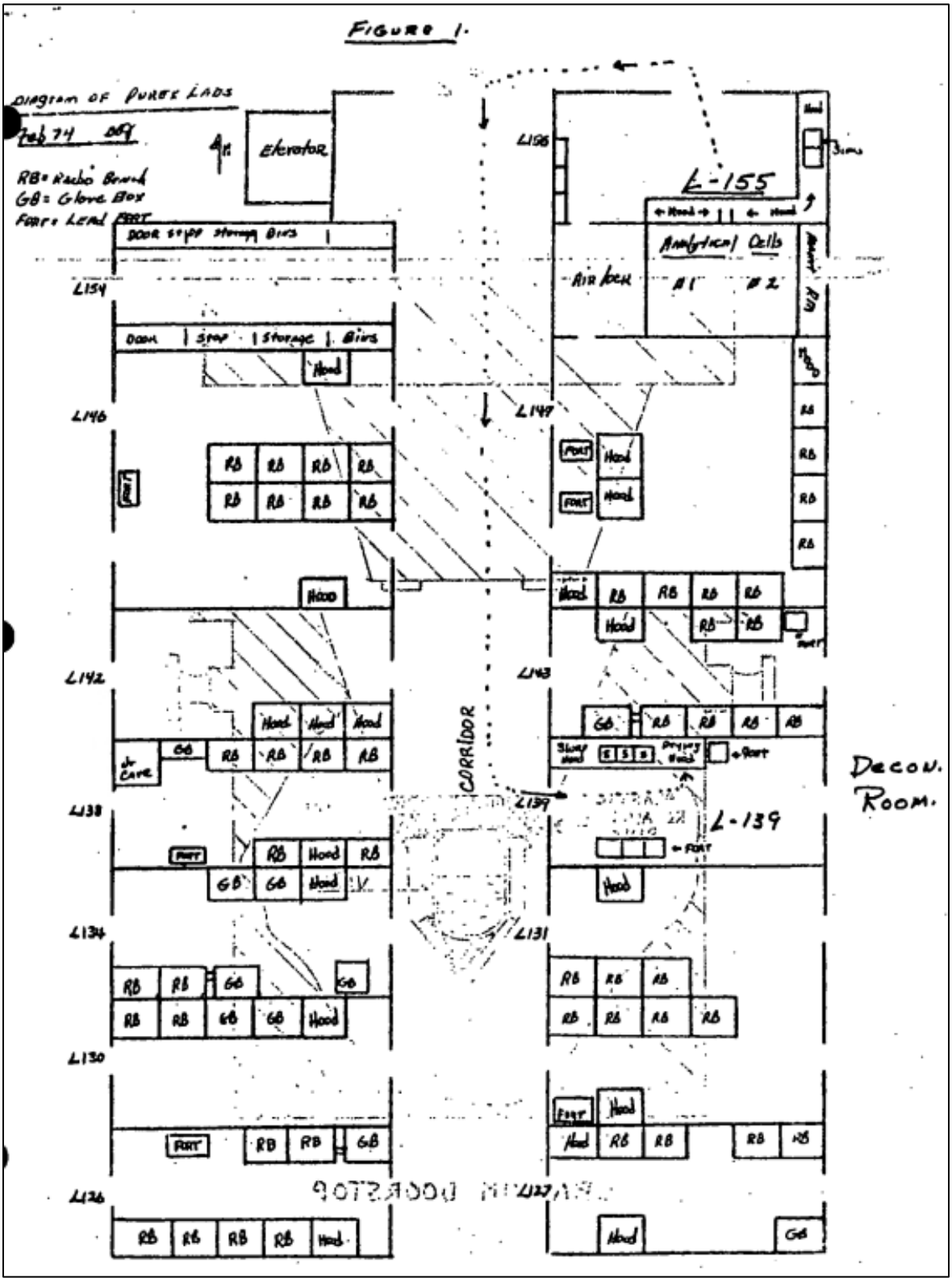

Figure 2-4. Work areas within 772-F [DuPont 1974–1983, p. 70]. Attachment B contains an extended description.

Table 2-1. Doorstop work locations in Building 772-F.[a]

Room	Name	Description
A-158	Sample Receiving Area	Located at the Building 772-F end of the tunnel that connects the laboratory building to Building 221-F. Samples were delivered on carts directly from F-Canyon or via the sample truck from H-Canyon and other locations.
139	Sample Disposal and Decontamination	Used for disposal of samples after analyses were completed and for the decontamination of sample containers and small equipment.
147	Analytical Cell Area	Used for the analysis of uranium in plutonium solution and for support of the analytical cell operations.
154	Changeover and Sample Storage	Used for sample changeover and storage. Changeover involved removal of vials from doorstops and their transfer to snuff boxes (shielded sample containers).
155	Cell Introduction Room	Used for the receipt of samples to be transferred to the intermediate level cells.

a. Source: Durant and Pritchard [1986].

3.0 DESCRIPTION OF DOORSTOP WORK

Detailed procedures for work involving doorstops are in DPSOP 90-1 Radiation Control Procedures, specifically in codes 215.1, 221.0, 226.0, and 232.2 [DuPont 1983a,b, 1984, 1985]. The information below is a summary of the work described in these procedures and is supported by descriptions of work practices in signed statements by former SRS employees who worked as DFAs or as support staff for the work [Scope of DFA 2018]. These procedures might not encompass the entirety of the work performed by DFAs, but they do highlight the manual nature of the tasks and the high activity and high exposure potentials present during the processes. This is demonstrated, in part, through the inclusion of the following administrative control limits for contamination and exposure rates in procedures that required monitoring.

- If smearable contamination levels exceeded 1,000 cpm beta/gamma or 500 dpm alpha, workers were instructed to notify supervision and Health Physics (HP). If levels did not exceed these values, the work was allowed to proceed.

- If beta/gamma levels exceeded 500 mrad/hr or 100 mR/hr at 5 cm, workers were to request HP coverage. If levels did not exceed these values, the work was allowed to proceed with self-monitoring.

- When monitoring a doorstop containing a sample, if the reading was greater than 1,000 mrad/hr at the top of the open doorstop, workers were instructed to contact supervision. If levels did not exceed these values, the work was allowed to proceed.

These general limits are in addition to other task-specific administrative control levels within a procedure. The procedures do not go into detail about next steps if the result of the monitoring required notifications to supervision or HP. Therefore, the procedures in the next section are summarized as if levels did not exceed the administrative control limits and work was allowed to proceed.

Certain procedures specifically call for workers to wear a special lead apron and laboratory coat, while others mention the use of respiratory protection and surgical gloves. It is noteworthy to add that the procedures are descriptive as to which hand workers should be using to perform certain tasks. Multiple samples and doorstops were handled by workers in a shift.

3.1 DOORSTOP TRANSPORTATION AND WARM SAMPLE TRANSFER

Samples transported to 772-F from F- or H-Area were received in the Sample Receiving Area (A-158) and then transported to the appropriate room in the laboratory (Room 155 or Room 154). After performing required monitoring, doorstop samples were then taken to intermediate cells as described in Section 3.2, or the sample vial was transferred to a warm sample carrier as determined by laboratory supervision [DuPont 1983a].

If the sample was to be transferred to a warm sample carrier, it was taken to Room 154 where the work was performed in front of an exhaust vent. DFAs would tilt the doorstop so the top was shielding their bodies and perform required monitoring. The top was then removed with one hand and held over the doorstop while a retaining ring was removed using 12-in. tongs and placed into a waste container. Before removing the sample from the doorstop, the vial was inspected for cracks and leakage. If any signs of cracks or leakage were found, workers were instructed to contact supervision. Using the tongs, the sample vial was transferred to the warm sample carrier. The doorstop top was then replaced [DuPont 1983a].

Once in the warm sample containers, the samples were monitored for beta/gamma activity and a “Radiation Danger” tag was attached to the sample tag with the radiation levels noted. Workers then used both hands to transfer the warm sample carriers to a sample router cart. Smears were taken on the doorstops and carts. The doorstops and carts were then transferred to Room 155 or Room 139 for cleaning [DuPont 1983a].

3.2 INTRODUCTION OF DOORSTOPS TO INTERMEDIATE CELLS

Doorstops to be transferred to intermediate cells were taken to Room 155. Using hoists, the doorstop was lifted from the sample cart to the loading hood. It was inspected for signs of damage before going into the hood. If a doorstop was damaged, procedures called for special handling and contacting of supervision. Once lifted, but before going into the hood, a plastic bag covering the doorstop was removed. The doorstop was then moved into position in the transfer port entry system. The doorstop was rotated to loosen the retaining ring. The cell operator in Room 147 would verify the vessel code and log number and then instruct the DFA as to which cell to direct the doorstop. The DFA would then remove the doorstop lid and use a pushrod to push the doorstop into the transfer port. Turning a wheel control, the doorstop was manually delivered to the desired cell. The cell operator in Room 147 would then remove the sample and smear the doorstop for contamination. Once actions by the cell operator were complete, the DFA would rotate the doorstop back to the loading side and use the pushrod to pull the doorstop back into position to remove with the hoist. The doorstop would then be transferred to the decontamination hood and sink. This procedure was repeated for all samples that needed to be transferred into the intermediate cells [DuPont 1985].

3.3 DECONTAMINATION OF DOORSTOPS

After removal from the transfer hood, the doorstop was transported with the hoist to the decontamination sink. The doorstop top was removed manually using both hands or by using the hoist to lift the top. The top was then washed with cleaning agents and scrubbed with a brush. Once finished, the top was moved to a drying board. Next the doorstop was filled with water and cleaning agents, and a brush was used to scrub it. A device called a “slurper jet” was used to remove the liquid from the doorstop. The doorstop was rinsed thoroughly with hot water. After the initial cleaning, the doorstop was monitored for beta/gamma activity. If the reading was greater than 100 mrad/hr at 2 in., the cleaning process was repeated until desired levels were achieved. If the reading was less than 100 mrad/hr at 2 in., the doorstop was transferred to the drying hood. Doorstops and tops were allowed to dry and then checked for smearable contamination. If the doorstop exceeded administrative control levels, the cleaning cycle was repeated. If the doorstop measurements did not

exceed the control levels, the doorstop and top were transferred from the drying hood to a doorstop cart. Multiple doorstops might have been cleaned at once. Any doorstop that was sealed in plastic bags with radiation tags, or was over the limits for self-monitoring, required HP and lab supervision to be present. Additional procedures can be found for a scenario in which the doorstop contained a broken or stuck vial. Those procedures required HP supervision throughout the process [DuPont 1983b, 1984].

3.4 REMOVAL OF SOLID WASTE FROM CELLS

As a result of analytical operations performed with the samples, high-level beta/gamma waste accumulated in the cells. A 0.5-gal ice cream carton with a plastic bag inside was placed into the cell to collect waste during the work. Any solid waste generated was placed into this container. The waste containers were monitored frequently, and procedures instructed workers to notify HP and supervision if readings at the face of the entry port exceeded 500 mrad/hr or 100 mR/hr. The waste container was to be removed if levels exceeded 500 mrad/hr or 1,000 mR/hr at the face of the glove port, or when the container was full. The bag was taped shut inside the cell by the cell operator using the glovebox gloves. DFAs would then remove the containers from the cell, place them in a larger cardboard box, and transport the solid waste generated by these processes via cart to a high-level beta/gamma dumpster. The transport cart was shielded on the sides but did not have a lid. A similar process and container were followed for solid waste generated during the decontamination process [DuPont 1983c; Scope of DFA 2018].

3.5 DECONTAMINATION FACILITY ATTENDANT POSITIONING DURING WORK

Figure 3-1 was provided in claim documentation to show the positioning of a DFA worker in relation to the doorstop [DFA worker 2016]. The image shows the exposure potential of the head and extremities to the sample activity in the chamber. The highest exposure potential was present during portions of the work where the doorstop lid was removed (i.e., loading into the intermediate cells and during decontamination) or when transporting waste. Shielding provided during various portions of the work by the doorstop container and/or by the TLD being worn underneath the lead apron prevent use of the recorded whole body dose as an accurate representation of the dose to other portions of the body.

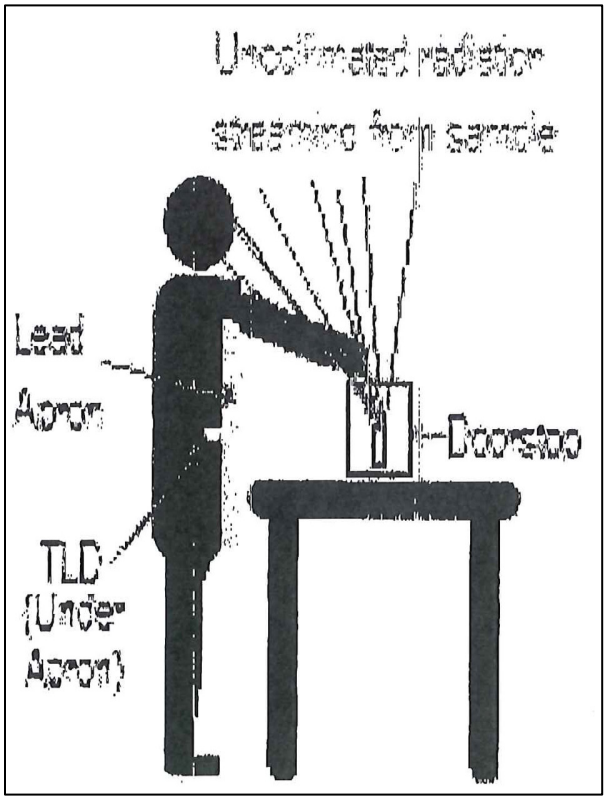

Figure 3-1. Diagram of possible DFA workstation setup [DFA worker 2016, p. 3]. Attachment B contains an extended description.

4.0 WHOLE BODY DOSE-TO-EXTREMITY DOSE METHOD

4.1 DESCRIPTION

The following method can be used for best-estimate dose reconstructions where the worker has whole body cycle data but is missing extremity data for some or all the monitoring cycles during the period when they performed work with doorstops in 772-F.

4.2 ANALYSIS

Using whole body and extremity cycle data from workers in the 772-F laboratory, the following quantile regression equations were created to estimate right and left extremity dose from whole body shallow or deep dose, or average extremity dose if right or left cannot be easily determined [ORAUT 2025a,b]. For periods that require adjustment (pre-1987), whole body deep dose and shallow dose data used to generate the quantile regression equations have been corrected using the appropriate *Hp(10)* correction factors [ORAUT 2005; NIOSH 2007a]. These corrections allow use of the quantile regression equations for both the film and TLD eras.

4.2.1 Estimating Left Extremity Dose from Deep Dose

Figure 4-1 shows the 50th- and 95th-percentile extremity dose to the left hand versus deep dose.

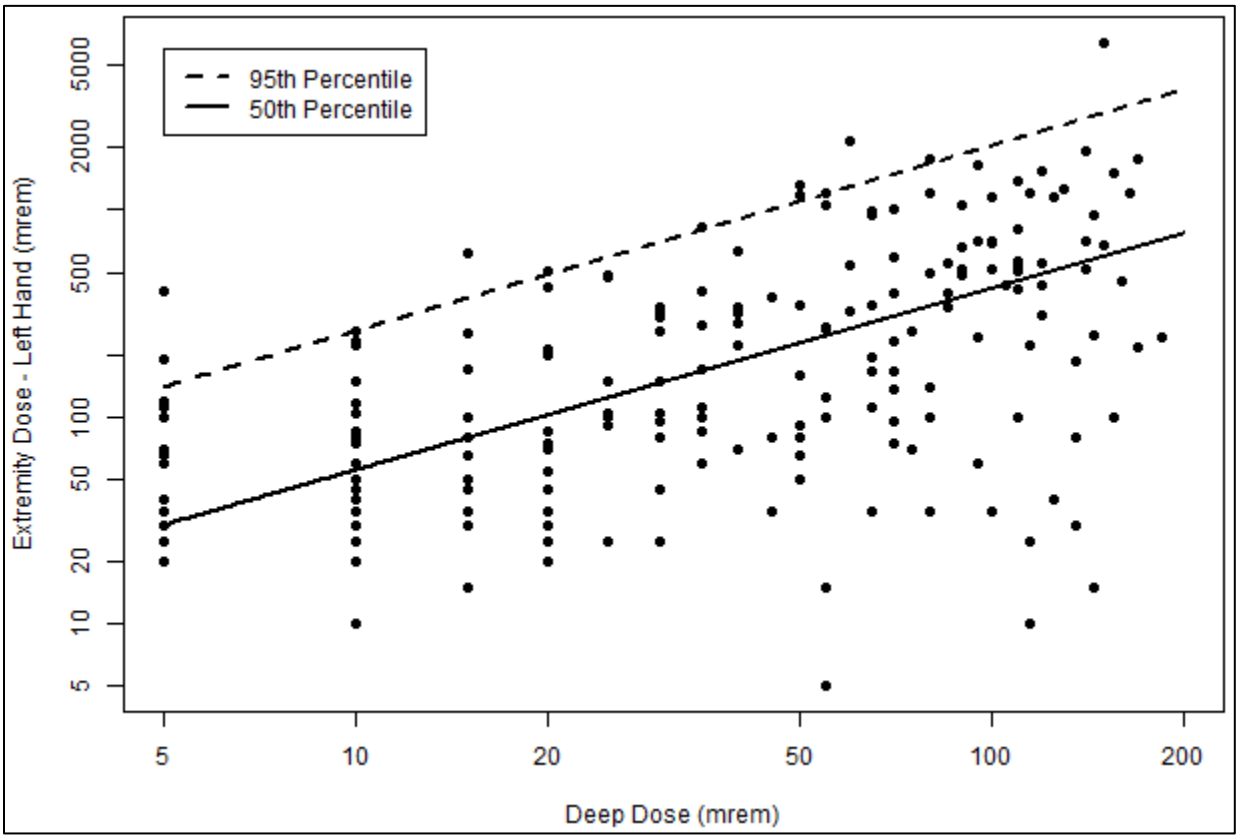

Figure 4-1. Extremity dose left hand 50th and 95th percentile versus deep dose. Attachment B contains an extended description.

Given deep dose, the predicted value of 50th-percentile left-hand dose is:[1]

$$\widehat{H}_{LH,50} = \exp[2.0379 + 0.8471 \log(H_{deep})] \quad (4\text{-}1)$$

Given deep dose, the predicted value of 95th-percentile left-hand dose is:

$$\widehat{H}_{LH,95} = \exp[3.5354 + 0.8652 \log(H_{deep})] \quad (4\text{-}2)$$

[1] In this document, "log" refers to the natural logarithm.

4.2.2 Estimating Left Extremity Dose from Shallow Dose

Figure 4-2 shows the 50th- and 95th-percentile extremity dose to the left hand versus shallow dose.

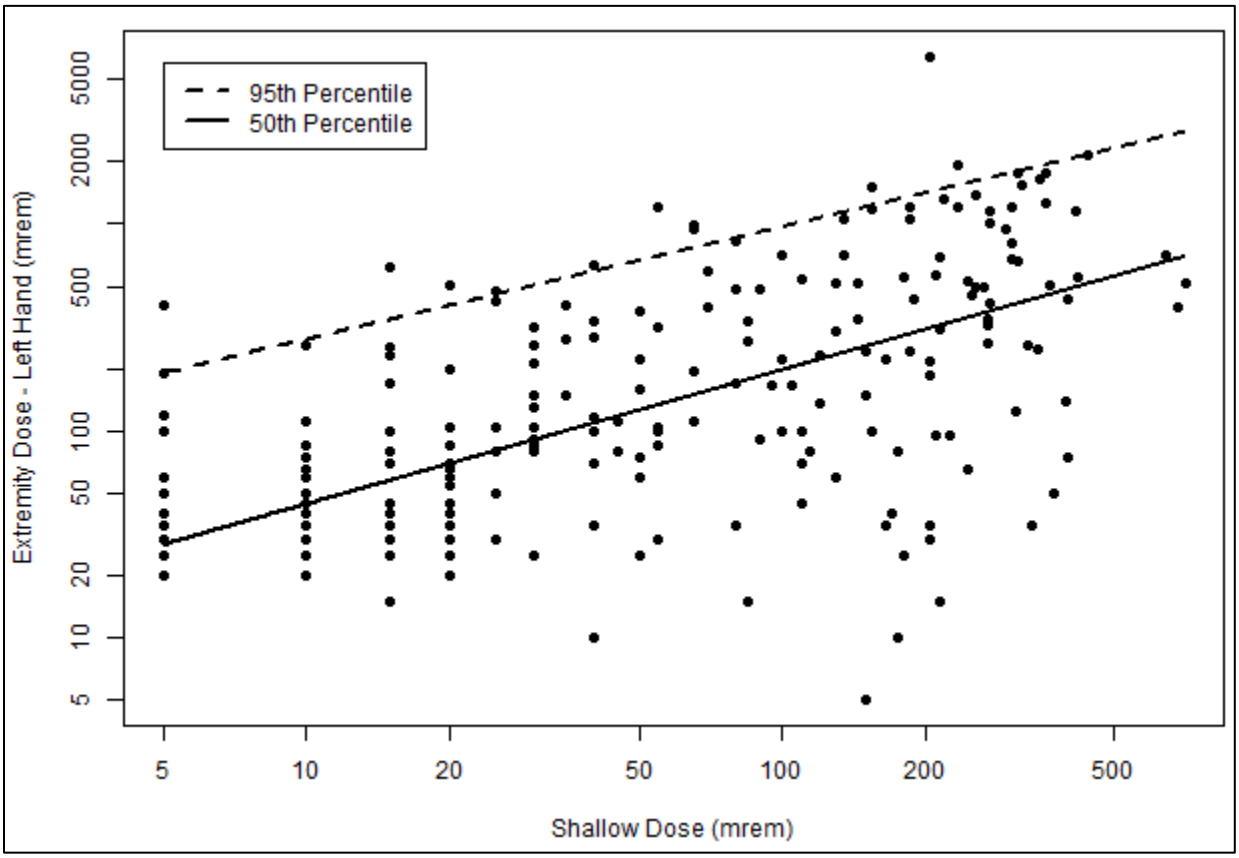

Figure 4-2. Extremity dose left hand 50th and 95th percentile versus shallow dose. Attachment B contains an extended description.

Given shallow dose, the predicted value of 50th-percentile left-hand dose is:

$$\widehat{H}_{\mathrm{LH},50} = \exp[2.2059 + 0.6628 \log(H_{\mathrm{shallow}})] \quad (4\text{-}3)$$

Given shallow dose, the predicted value of 95th-percentile left-hand dose is:

$$\widehat{H}_{\mathrm{LH},95} = \exp[4.3122 + 0.5429 \log(H_{\mathrm{shallow}})] \quad (4\text{-}4)$$

4.2.3 Estimating Right Extremity Dose from Deep Dose

Figure 4-3 shows the 50th- and 95th-percentile extremity dose to the right hand versus deep dose.

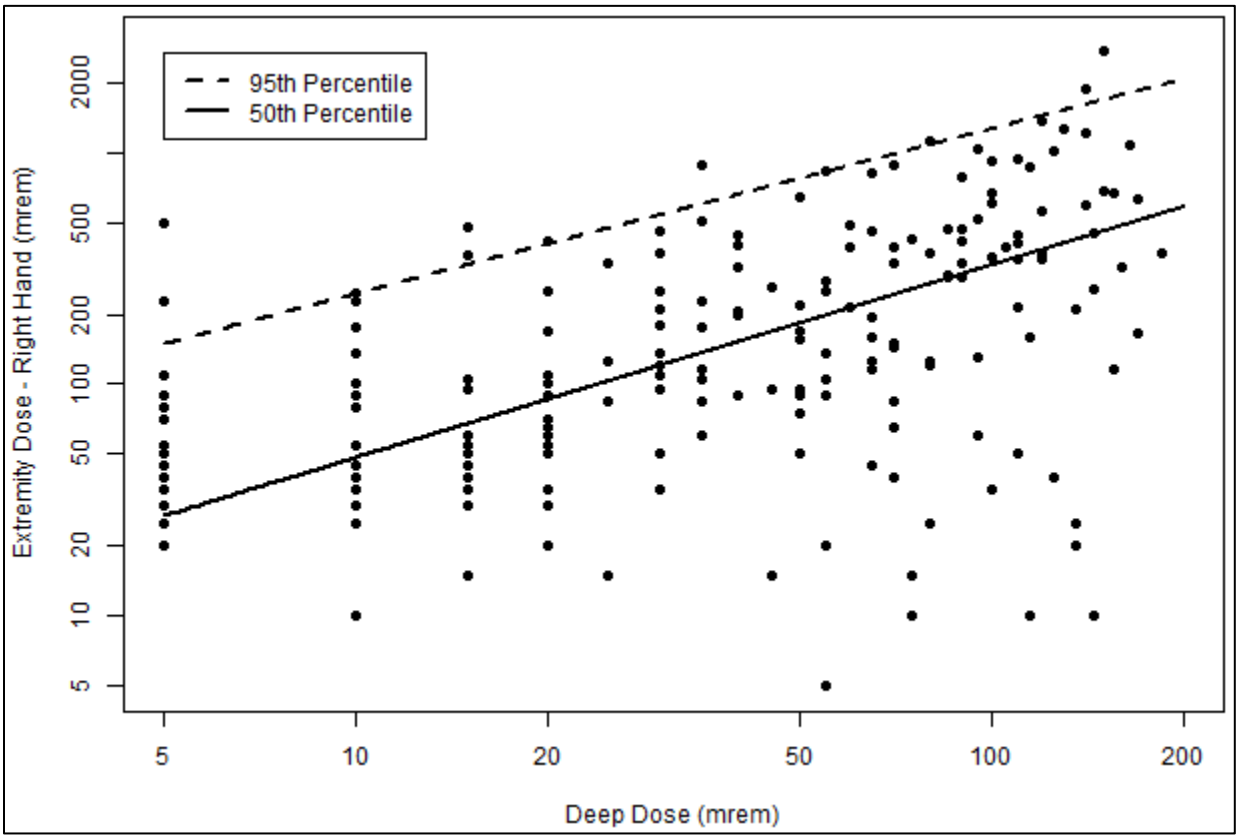

Figure 4-3. Extremity dose right hand 50th and 95th percentile versus deep dose. Attachment B contains an extended description.

Given deep dose, the predicted value of 50th-percentile right-hand dose is:

$$\widehat{H}_{RH,50} = \exp[1.9132 + 0.8223 \log(H_{deep})] \quad (4\text{-}5)$$

Given deep dose, the predicted value of 95th-percentile right-hand dose is:

$$\widehat{H}_{RH,95} = \exp[3.9753 + 0.6627 \log(H_{deep})] \quad (4\text{-}6)$$

4.2.4 Estimating Right Extremity Dose from Shallow Dose

Figure 4-4 shows the 50th- and 95th-percentile extremity dose to the right hand versus shallow dose.

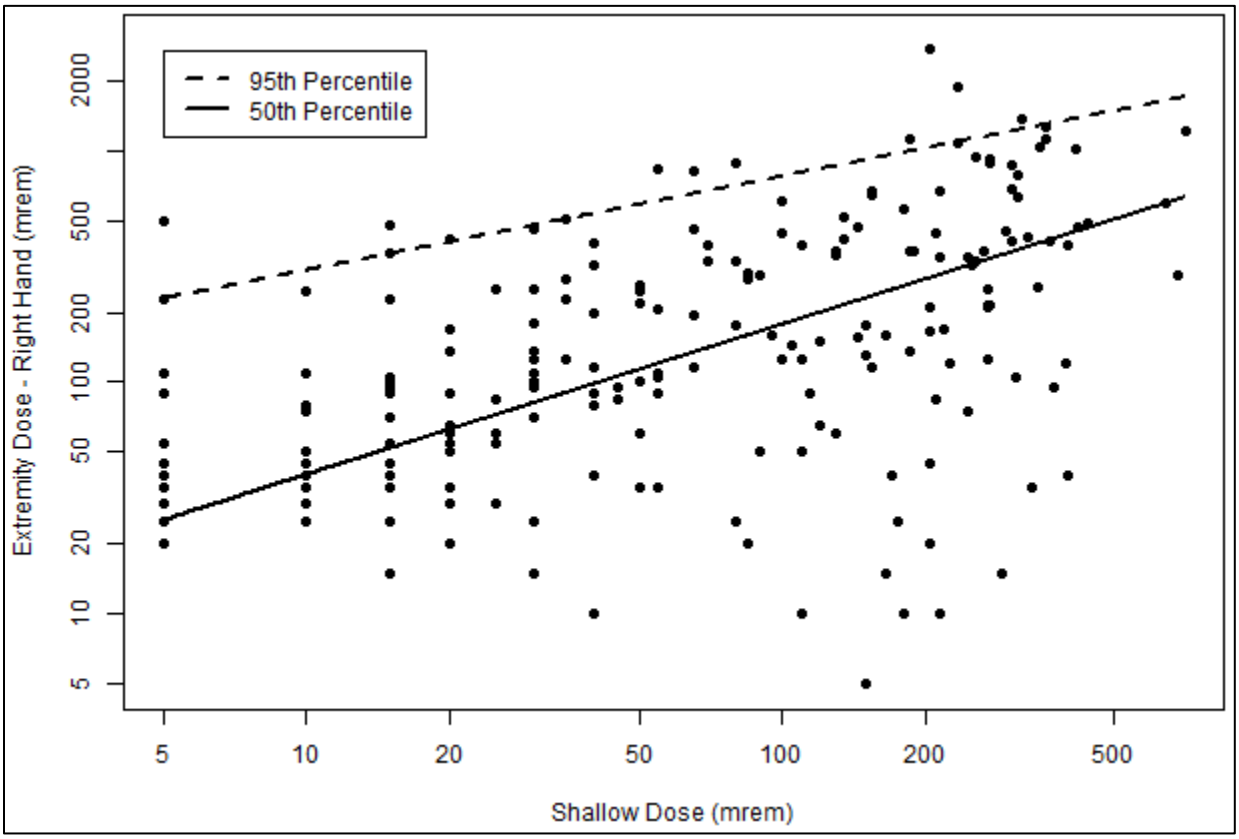

Figure 4-4. Extremity dose right hand 50th and 95th percentile versus shallow dose. Attachment B contains an extended description.

Given shallow dose, the predicted value of 50th-percentile right-hand dose is:

$$\widehat{H}_{RH,50} = \exp[2.2444 + 0.6273 \log(H_{shallow})] \quad (4\text{-}7)$$

Given shallow dose, the predicted value of 95th-percentile right-hand dose is:

$$\widehat{H}_{RH,95} = \exp[4.6987 + 0.4292 \log(H_{shallow})] \quad (4\text{-}8)$$

4.2.5 Estimating Average Extremity Dose from Deep Dose

Figure 4-5 shows the 50th- and 95th-percentile average extremity dose versus deep dose.

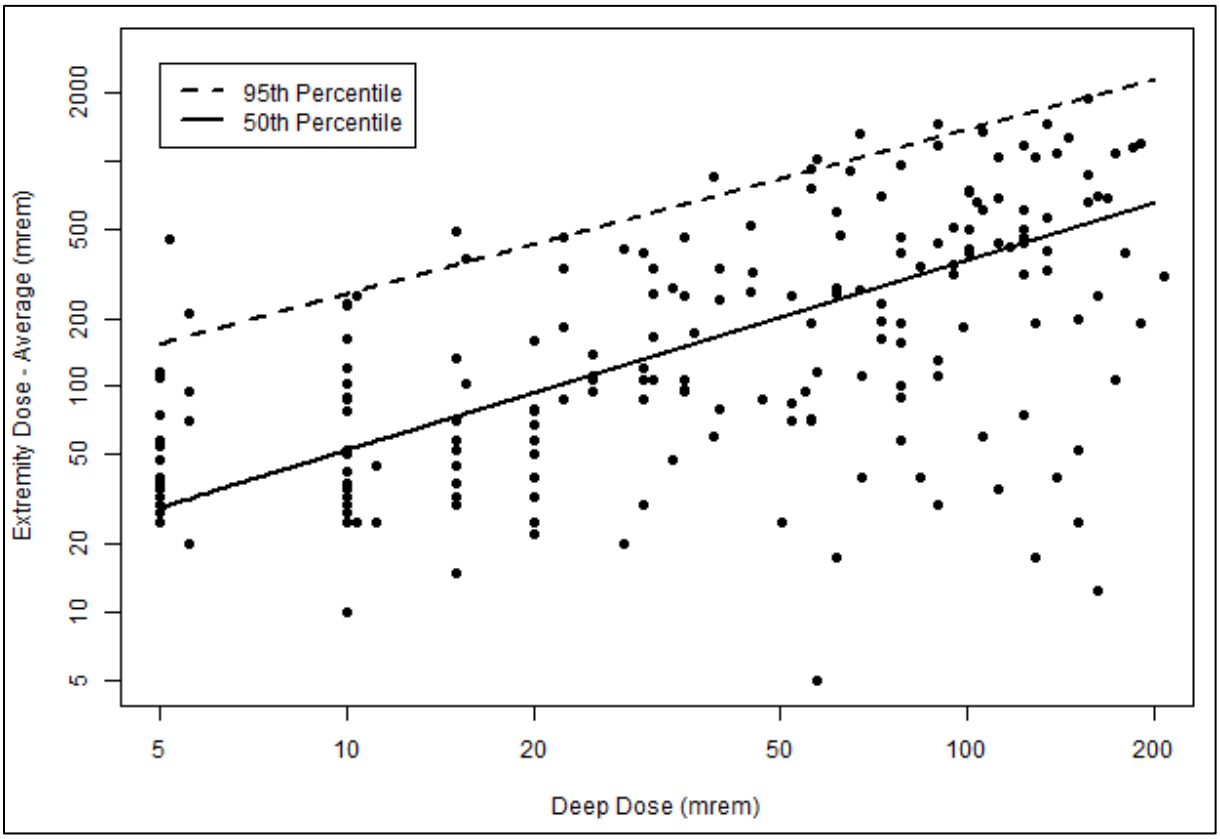

Figure 4-5. Average extremity dose 50th and 95th percentile versus deep dose. Attachment B contains an extended description.

Given deep dose, the predicted value of 50th-percentile average extremity dose is:

$$\widehat{H}_{\text{avg},50} = \exp[2.0204 + 0.8396 \log(H_{\text{deep}})] \quad (4\text{-}9)$$

Given deep dose, the predicted value of 95th-percentile average extremity dose is:

$$\widehat{H}_{\text{avg},95} = \exp[3.8699 + 0.7276 \log(H_{\text{deep}})] \quad (4\text{-}10)$$

4.2.6 Estimating Average Extremity Dose from Shallow Dose

Figure 4-6 shows the 50th- and 95th-percentile average extremity dose versus shallow dose.

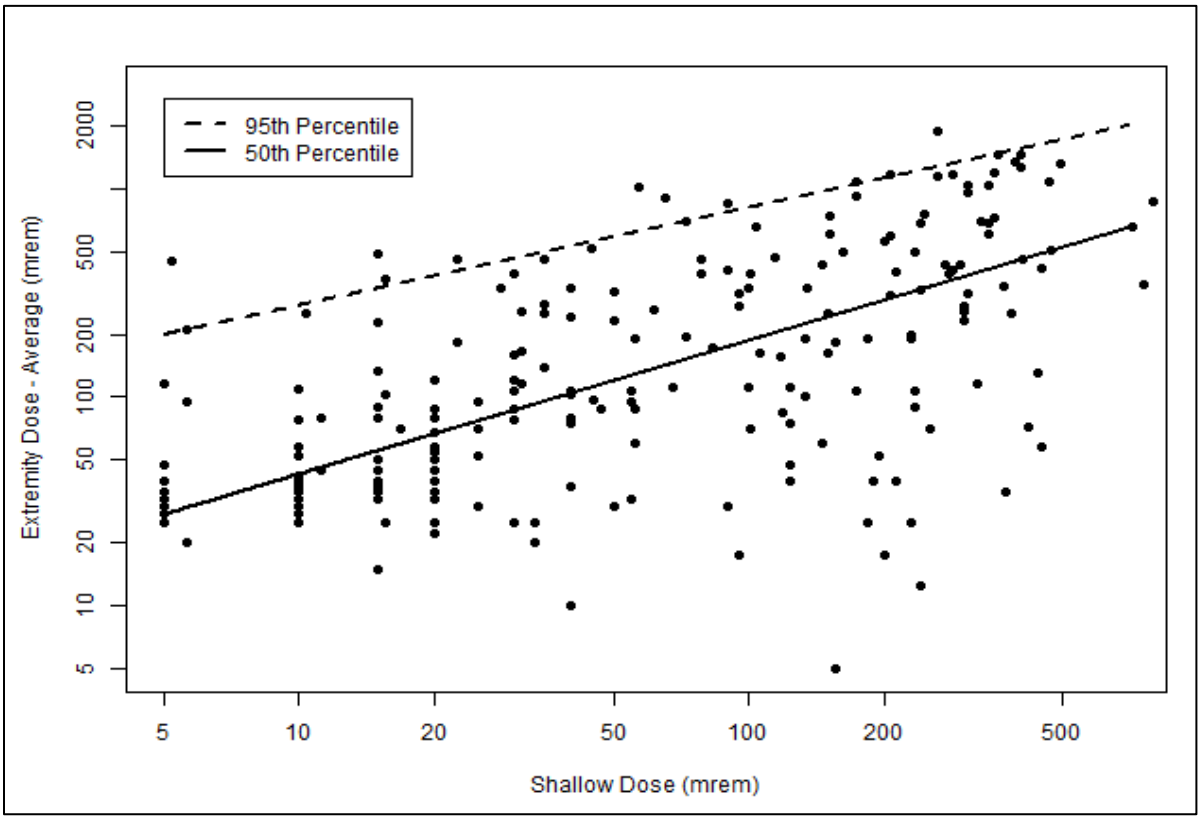

Figure 4-6. Average extremity dose 50th and 95th percentile versus shallow dose. Attachment B contains an extended description.

Given shallow dose, the predicted value of 50th-percentile average extremity dose is:

$$\widehat{H}_{\text{avg},50} = \exp[2.2864 + 0.6386 \log(H_{\text{shallow}})] \quad (4\text{-}11)$$

Given shallow dose, the predicted value of 95th-percentile average extremity dose is:

$$\widehat{H}_{\text{avg},95} = \exp[4.5437 + 0.4666 \log(H_{\text{shallow}})] \quad (4\text{-}12)$$

4.3 APPLICATION OF METHOD

Use the quantile regression equations above to estimate missing extremity cycle data from the worker's whole body deep and shallow cycle data. When performing dose reconstructions, the guidance in the following sections should be applied. If a claim contains multiple cancers, the dose reconstructor should evaluate each cancer individually based on the side on which the cancer is located. If the cancer is on the left side of the body, models presented for left-hand dose should be used. If the cancer is on the right side of the body, models presented for right-hand dose should be used. If the cancer is in the middle of the body, or if the cancer location cannot be determined, the average extremity model should be used.

1. Based on cancer location, determine whether to use the left-hand model (Equations 4-1 through 4-4), the right-hand model (Equations 4-5 through 4-8), or the average extremity model (Equations 4-9 through 4-12).

2. For each cycle, for periods requiring adjustment, correct the whole body deep dose and shallow dose data using the appropriate *Hp(10)* correction factors [ORAUT 2005; NIOSH 2007a]. Then determine the predicted 50th- and 95th-percentile dose using the equations selected in step 1.

3. For each cycle, using the slice method, determine the geometric mean (GM) and geometric standard deviation (GSD) of a lognormal distribution that has the 50th and 95th percentiles determined in step 2 [ORAUT 2025a].

4. Using Monte Carlo analysis, sum the cycle lognormal distributions determined in step 3 for each year. The Monte Carlo calculation should also include any additional correction factors or dose conversion factors (DCFs).

5. For each year, determine which distribution available in Interactive RadioEpidemiological Program (IREP) fits the annual sum from step 4 best.

An example evaluation is shown in Section A.1.

5.0 SUMMARY

Using the methods outlined in this document, right and left extremity cycle doses can be estimated from whole body deep and shallow cycle doses for 772-F DFA workers who were not provided extremity monitoring or whose records are missing some or all cycle extremity data for the period in which they performed this work. The estimated extremity doses can then be used for dose reconstruction purposes as outlined in Section 4.3 and Attachment A.

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ATTACHMENT A
APPLICATION EXAMPLE EVALUATIONS

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ATTACHMENT A
APPLICATION EXAMPLE EVALUATIONS (continued)

A.1 EXAMPLE EVALUATION

The measured doses for a DFA worker with thyroid cancer are in Table A-1. Because the worker has thyroid cancer, and the cancer location cannot easily be determined to be on the left or right, the average extremity dose model should be used. All calculations in this attachment are in ORAUT [2025b].

Following the steps in Section 4.3, steps 2 (predicted doses) and 3 (lognormal parameters) values are also in Table A-1. Performing Monte Carlo analysis (step 4) and determining which distribution in IREP fits the annual sums best (step 5) results in annual dose distributions for 1986 and 1987. The annual dose distributions and details about correction factors and DCFs are in Table A-2.

NOTE: In an actual claim, shallow dose would not be included in the probability of causation (POC) calculation to the thyroid. In this example the shallow dose calculation is included, up to the point of annual dose distributions in Table A-2, to demonstrate the shallow dose equations. Only the deep dose IREP lines are used for the thyroid POC calculation.

ATTACHMENT A
APPLICATION EXAMPLE EVALUATIONS (continued)

Table A-1. Measured doses (mrem), predicted doses (mrem) for average extremity, and lognormal parameters (GM in rem) for a worker with thyroid cancer.[a,b]

Year	Cycle	Deep	Shallow	Deep adjusted[c]	Shallow adjusted[c]	$H_{LH,50}$ deep	$H_{LH,95}$ deep	$H_{LH,50}$ shallow	$H_{LH,95}$ shallow	Deep GM	Deep GSD	Shallow GM	Shallow GSD
1986	1	10	0	10.39	0.00	53.83	263.25	N/A	N/A	0.05	2.62	N/A	N/A
1986	2	20	0	20.78	0.00	96.33	435.91	N/A	N/A	0.10	2.50	N/A	N/A
1986	3	40	80	41.56	83.12	172.38	721.81	165.54	739.67	0.17	2.39	0.17	2.48
1986	4	40	75	41.56	77.93	172.38	721.81	158.85	717.73	0.17	2.39	0.16	2.50
1986	5	75	190	77.93	197.41	292.21	1,140.41	287.60	1,107.45	0.29	2.29	0.29	2.27
1986	6	20	35	20.78	36.37	96.33	435.91	97.64	502.94	0.10	2.50	0.10	2.71
1986	7	55	135	57.15	140.27	225.22	910.03	231.21	944.21	0.23	2.34	0.23	2.35
1986	8	30	80	31.17	83.12	135.39	585.49	165.54	739.67	0.14	2.44	0.17	2.48
1986	9	25	25	25.98	25.98	116.17	512.75	78.76	429.87	0.12	2.47	0.08	2.81
1986	10	35	65	36.37	67.54	154.10	654.98	144.98	671.37	0.15	2.41	0.14	2.54
1986	11	20	15	20.78	15.59	96.33	435.91	56.84	338.70	0.10	2.50	0.06	2.96
1986	12	35	65	36.37	67.54	154.10	654.98	144.98	671.37	0.15	2.41	0.14	2.54
1987	1	50	65	50.00	65.00	201.33	825.75	141.48	659.49	0.20	2.36	0.14	2.55
1987	2	55	125	55.00	125.00	218.10	885.04	214.81	894.79	0.22	2.34	0.21	2.38
1987	3	15	30	15.00	30.00	73.26	343.87	86.35	459.76	0.07	2.56	0.09	2.76
1987	4	0	0	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	5	0	0	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987	6	0	30	0.00	30.00	N/A	N/A	86.35	459.76	N/A	N/A	0.09	2.76

a. Source: ORAUT [2025b].
b. N/A – not applicable. Measured doses of zero cannot be evaluated using the equations in Section 4.2.
c. When required, values have been adjusted using the appropriate *Hp(10)* correction factors [ORAUT 2005; NIOSH 2007a].

Table A-2. Annual dose distributions for average extremity dose.[a]

Year	Radiation type	Distribution	GM (rem)	GSD	Shift (rem)
1986	Shallow - photons E <30 keV	Lognormal	1.948	1.480	0.21903
1987	Shallow - photons E <30 keV	Lognormal	0.669	1.762	0.035219
1986	Deep - photons E <30 keV[b,c]	Lognormal	0.317	1.424	0.042952
1987	Deep - photons E <30 keV[b,c]	Lognormal	0.085	1.803	0.0035336
1986	Deep - photons E = 30–250 keV[b,d]	Lognormal	1.585	1.417	0.18036
1987	Deep - photons E = 30–250 keV[b,d]	Lognormal	0.415	1.819	0.019755

a. Source: ORAUT [2025b].
b. For deep dose, assume 25% is <30 keV and 75% is 30–250 keV [NIOSH 2007a, p. 3].
c. For deep dose <30 keV, the DCF is a constant 0.586 [NIOSH 2007b, pp. 37–38].
d. For deep dose 30–250 keV, the DCF is triangular: min. = 0.818, mode = 1.017, max. = 1.042 [NIOSH 2007b, p. 62].

ATTACHMENT B
EXTENDED DESCRIPTIONS OF FIGURES

This attachment contains extended descriptions for figures and equations that exceed the character limit for inline alt text. These descriptions are provided to enhance accessibility for screen reader users.

Figure 2-4
Hand-drawn floor layout of the portion of Building 772-F where doorstop work occurred. The left column contains in descending order Rooms 154, 146, 142, 138, 134, 130, and 126. The middle column is the central corridor. The right column contains in descending order Rooms 155, 147, 143, 139, 131, and 127. Analytical cells Number 1 and Number 2 are shown between Rooms 155 and 147 and Room 139 is denoted as the decontamination room.

Figure 3-1
Diagram showing a DFA working with a doorstop sample holder. Attendant is wearing a lead apron with a TLD underneath. From the open doorstop, lines radiating vertically and towards the head of the person denote uncollimated radiation streaming from the sample.

Figure 4-1
The x-axis is log-scaled, labeled “Deep Dose (mrem),” and ranges from 5 to 200. The y-axis is log-scaled, labeled “Extremity Dose – Left Hand (mrem),” and ranges from 5 to 5,000. A solid line represents the slope and intercept in Equation 4-1 and is the 50th percentile. A dashed line represents the slope and intercept in Equation 4-2 and is the 95th percentile. Points fall in a rough cone shape, increasing left to right.

Figure 4-2
The x-axis is log-scaled, labeled “Shallow Dose (mrem),” and ranges from 5 to 700. The y-axis is log-scaled, labeled “Extremity Dose – Left Hand (mrem),” and ranges from 5 to 5,000. A solid line represents the slope and intercept in Equation 4-3 and is the 50th percentile. A dashed line represents the slope and intercept in Equation 4-4 and is the 95th percentile. Points fall in a rough cone shape, increasing left to right.

Figure 4-3
The x-axis is log-scaled, labeled “Deep Dose (mrem),” and ranges from 5 to 200. The y-axis is log-scaled, labeled “Extremity Dose – Right Hand (mrem),” and ranges from 5 to 2,000. A solid line represents the slope and intercept in Equation 4-5 and is the 50th percentile. A dashed line represents the slope and intercept in Equation 4-6 and is the 95th percentile. Points fall in a rough cone shape, increasing left to right.

Figure 4-4
The x-axis is log-scaled, labeled “Shallow Dose (mrem),” and ranges from 5 to 700. The y-axis is log-scaled, labeled “Extremity Dose – Right Hand (mrem),” and ranges from 5 to 2,000. A solid line represents the slope and intercept in Equation 4-7 and is the 50th percentile. A dashed line represents the slope and intercept in Equation 4-8 and is the 95th percentile. Points fall in a rough cone shape, increasing left to right.

Figure 4-5
The x-axis is log-scaled, labeled “Deep Dose (mrem),” and ranges from 5 to 200. The y-axis is log-scaled, labeled “Extremity Dose – Average (mrem),” and ranges from 5 to 2,000. A solid line represents the slope and intercept in Equation 4-9 and is the 50th percentile. A dashed line represents the slope and intercept in Equation 4-10 and is the 95th percentile. Points fall in a rough cone shape, increasing left to right.

ATTACHMENT B
EXTENDED DESCRIPTIONS OF FIGURES (continued)

Figure 4-6
The x-axis is log-scaled, labeled “Shallow Dose (mrem),” and ranges from 5 to 200. The y-axis is log-scaled, labeled “Extremity Dose – Average (mrem),” and ranges from 5 to 2,000. A solid line represents the slope and intercept in Equation 4-11 and is the 50th percentile. A dashed line represents the slope and intercept in Equation 4-12 and is the 95th percentile. Points fall in a rough cone shape, increasing left to right.