DOE Review Release 08/01/2014

Parameters to Consider When Processing Claims for Construction Trade Workers	ORAUT-OTIB-0052	Rev. 02
	Effective Date:	07/24/2014
	Supersedes:	Revision 01

Subject Expert(s): Melton H. Chew, Robert L. Morris, and Eugene W. Potter

Document Owner Approval:	Signature on File Matthew H. Smith, Document Owner	Approval Date:	07/09/2014
Concurrence:	Signature on File John M. Byrne, Objective 1 Manager	Concurrence Date:	07/09/2014
Concurrence:	Signature on File Edward F. Maher, Objective 3 Manager	Concurrence Date:	07/09/2014
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	07/09/2014
Approval:	Signature on File James W. Neton, Associate Director for Science	Approval Date:	07/24/2014

☐ New ☐ Total Rewrite ☒ Revision ☐ Page Change

FOR DOCUMENTS MARKED AS A TOTAL REWRITE, REVISION, OR PAGE CHANGE, REPLACE THE PRIOR REVISION AND DISCARD / DESTROY ALL COPIES OF THE PRIOR REVISION.

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
08/31/2006	00	First approved issue. New document to describe the parameters to consider when processing claims for CTWs. Incorporates formal internal review comments and comments from the Worker Outreach meetings with the Hanford PACE Local (Steelworkers and Guards) on 05/22/2005 and the Central Washington Building and Construction Trades Council on 01/15/2005. Revised to incorporate additional NIOSH comments. There is an increase in assigned dose and a PER is required. Training required: As determined by the Task Manager. Initiated by Melton H. Chew and John A. Devanney.
01/16/2007	00 PC-1	Sections 8.2, 8.3, and 8.4 on pages 32 and 33 revised in order to provide consistent guidance for dose reconstruction. No sections were deleted. Incorporates internal formal review comments. No changes were needed as a result of NIOSH formal review. This revision does not result in an increase of dose and no PER is required. Training required: As determined by the Task Manager. Initiated by John M. Byrne. Approval: Signature on File 12/19/2006 John M. Byrne, Document Owner Signature on File 12/18/2006 Edward F. Maher, Task 5 Manager Signature on File 01/11/2007 Kate Kimpan, Project Director Brant A. Ulsh Signature on File for 01/16/2007 James W. Neton, Associate Director for Science
02/17/2011	01	The Advisory Board tasked SC&A to review OTIB-0052 Rev 00 PC-1. A draft report and sixteen findings were produced. Eight findings were closed after discussion in the Procedures Review Working Group, three were transferred to another Working Group, and five (“in abeyance”) are closed by this revision. These changes clarify the basis for certain assumptions and provide cautions regarding the limitations of the available data. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Melton H. Chew and Matthew H. Smith.
07/24/2014	02	Revised to add language to Purpose, Scope, Section 7.0, and Section 8.0 to clarify applicability of the document to construction trade workers who could have worked for prime M&O contractors at DOE sites. Incorporates formal internal and NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by Matthew H. Smith.

TABLE OF CONTENTS

SECTION **TITLE** **PAGE**

LIST OF TABLES

TABLE **TITLE** **PAGE**

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
AMW	all monitored workers
CER	Center for Epidemiologic Research (database)
CTW	construction trade worker
d	day
DOE	U.S. Department of Energy
dpm	disintegrations per minute
GSD	geometric standard deviation
HPAREH	Health Protection Annual Radiation Exposure History (database)
INL	Idaho National Laboratory
M&O	Management and Operations
mL	milliliter
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
PUREX	plutonium-uranium extraction
REMS	Radiation Exposure Monitoring System (database)
REX	Radiological Exposure (database)
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TBD	technical basis document
TIB	Technical Information Bulletin
U.S.C.	United States Code
yr	year
§	section or sections

EXECUTIVE SUMMARY

This document provides guidance for performing dose reconstructions for unmonitored construction trade workers (CTWs).

An investigation of the U.S. Department of Energy (DOE) complex was conducted to determine the ratio of the external and internal annual doses received by CTWs to those received by all other monitored workers (AMWs). In general, it was found that for the DOE complex the internal and external annual doses received by the CTWs were usually bounded by those received by the AMWs. Examination of the individual DOE sites indicated that in some instances, at some sites, the external annual doses received by the CTWs exceeded those of AMWs. In these instances, the observed ratios of CTW-to-AMW external doses were further examined. This resulted in the development of a favorable to claimant adjustment factor of 1.4, which will be applied by dose reconstructors to all unmonitored CTWs throughout the DOE complex. Guidance is provided for dose reconstructors on the use of this adjustment factor.

Examination of the individual DOE sites for internal dose indicated that only the Hanford Site required adjustment. For the Hanford Site, the intake rates in the Hanford coworker study should be multiplied by a factor of 2. Guidance is provided for dose reconstructors on the determination of internal dose.

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). TIBs may be used to assist NIOSH staff in the completion of individual dose reconstructions.

In this document, the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy (DOE) facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. § 7384l(5) and (12)].

This document presents information that compares doses received by monitored CTWs to doses received by AMWs. For the purposes of this document CTWs may include, but are not limited to, laborers, mechanics, masons, carpenters, electricians, painters, pipefitters, insulators, boilermakers, sheet-metal workers, operating engineers, and iron workers.

For the initial comparison on CTW and AMW doses, five DOE sites were selected to represent the DOE complex as a whole. These sites [Rocky Flats Plant, Savannah River Site (SRS), Y-12, K-25, and Oak Ridge National Laboratory (ORNL)] represent the full spectrum of work (plutonium and uranium processing, reactor operations, weapons production, and research laboratory operations) associated with DOE facilities. Using external dosimetry data from these sites, an investigation and comparison was made to determine the relationship between the annual external doses received by CTWs and those received by AMWs at the 95th percentile. The annual external doses for CTWs are represented by more than 200,000 histories, while those for AMWs are represented by more than 1,000,000 histories. The investigation showed that for 1943 to 2005 the annual external doses to CTWs were typically bounded by the doses to AMWs. In a more detailed comparison, seven individual DOE sites were examined to determine if, at any time, the external dose to CTWs exceeded that to AMWs. There were instances where external doses to CTWs exceeded those to AMWs. This document presents the data that support the use of an adjustment factor to account for instances when CTWs received higher doses.

As part of the more detailed comparison mentioned above, six of the DOE sites were analyzed to determine if, at any time, the bioassay results for CTWs exceeded those of AMWs. It was concluded that no adjustment factors were needed for internal dose with the exception of the Hanford Site (see Section 8.4).

For new facility construction, most CTWs were unmonitored because no radioactive material would be installed until after the facility was commissioned. However, modifications or major maintenance of existing facilities could have involved exposure to radioactive materials and would require monitoring of some CTWs.

Radiation safety regulations [e.g., U.S. Atomic Energy Commission (AEC) Manual-0524 (AEC 1968)] dating back to the 1950s required all personnel working in a radiation area to wear a gamma-measuring film badge. At some sites, such as the Nevada Test Site, all personnel entering the site were required to wear a gamma-measuring film badge in conjunction with their security badge (DOE 1961). As a consequence, all persons, including CTWs, working in a radiation area were routinely monitored for exposure to external radiation. In most instances, CTWs were not routinely included in the bioassay program of the site. However, CTWs were included in the bioassay program if they were suspected of having experienced a radioactive material intake.

While safety regulations and facility-specific radiation protection practices required monitoring of radiation workers, it is recognized that under some circumstances some CTWs at a facility might not have been fully covered or monitored by the radiation protection programs at a site, regardless of whether they were employed by the management and operations (M&O) contractor or a construction subcontractor. The reasons for partial or altered monitoring of CTWs varied from facility to facility on a site, but it was not uncommon to have minimal or alternative monitoring in place during the construction of new facilities that were separate from existing facilities. Further, there are instances in which a CTW's dose records might be incomplete or unavailable. In such cases, the ability to perform a dose reconstruction for that CTW is limited by a lack of claimant-specific information and data, so the claimant is categorized as an unmonitored CTW. During the development of this TIB, there was a consistent effort to identify CTWs who were monitored regardless of whether they were employed by the M&O contractor or a subcontractor. This document provides the basis and guidance for performing dose reconstructions for unmonitored CTWs.

Although there are limitations and conditions on the data sets used in this TIB, it is possible to separate and compare the external and internal doses received by CTWs and AMWs at a site. These comparisons are provided graphically in this TIB. From these comparisons, which are presented for sites that had differing missions, operations, facilities, and radioactive source terms, the relationship between doses received by CTWs and AMWs becomes evident. Specifically, the comparisons demonstrate that, with some important exceptions and conditions, the doses received by the monitored CTWs were typically bounded by the doses received by AMWs on the same site. To account for instances in which unmonitored CTWs might have received higher doses than other monitored workers, the need for an adjustment factor was identified. The adjustment factor provides a dose reconstruction method that is favorable to claimants who have been categorized as unmonitored CTWs.

2.0 PURPOSE

This document provides guidance for performing dose reconstructions for unmonitored CTWs. For the purpose of this document, unmonitored CTWs are defined as workers who worked on site at any time in the site's history and might have been employed by the M&O contractor at any DOE site. These unmonitored CTWs may include, but are not limited to, laborers, mechanics, masons, carpenters, electricians, painters, pipefitters, insulators, boilermakers, sheet-metal workers, operating engineers, and ironworkers who were employed by subcontractors or worked directly for the M&O contractor at any DOE site. These workers might have been brought on site by subcontractors to do construction work, but might not have been covered under the site's radiological protection program. It should be noted that, in some instances, the prime contractor is not necessarily the M&O contractor. For example, in the late 1980s at the Hanford Site, the M&O contractor in the 100 Area was Westinghouse Hanford Company while the prime contractor was Kaiser Engineering Hanford.

3.0 SCOPE

The guidance in this TIB is limited to dose reconstruction for unmonitored CTWs who:

1. Were employed by subcontractors or worked directly for the prime M&O contractor at any DOE site. These workers might have been brought on site by subcontractors or the prime M&O contractor to do construction work, but might not have been covered under the site's radiological protection program.

2. Worked at any time in the site's history.

3. Do not have a complete exposure history such as that for external exposure; had no external monitoring at all or there were gaps of at least a year in their external monitoring or for internal

exposure; had no internal monitoring at all; or the monitoring they had was inadequate to bound their potential exposure.

3.1 LIMITATIONS AND EXCEPTIONS

Analysis and recommendations in this document are based on data that were readily available, and abundant enough to enable statistically significant comparisons. As a consequence, there could be unusual cases in which the recommendations of this document do not apply. Intakes of less common radionuclides, those other than uranium or plutonium, are not assessed. Refer to the site technical basis document (TBD) for information about less common radionuclides [1].

External dose to SRS pipefitters who were unmonitored and employed for a limited duration between 1972 and 1974 or between 1990 and 1998 might be underestimated slightly. See ORAUT-OTIB-0020 (ORAUT 2011a) for additional guidance.

4.0 SOURCES OF DATA

Many sources of data were used to develop this document. These included databases, such as the Comprehensive Epidemiologic Data Resource, the Center for Epidemiologic Research (CER), the Radiation Exposure Monitoring System (REMS), and the SRS Health Protection Annual Radiation Exposure History (HPAREH), as well as annual reports based on U.S. Atomic Energy Commission (AEC) Form 190 (e.g., Helmberg 1974).

The quality, usability, and accessibility of the data varied, making a standardized comparison among sites difficult. For example, some data are available in a modern database as official records while others are available only as summaries in centralized compilations. Some data have rigorously characterized parametric descriptions, while others are described only by a mean value. At some sites, the AMW group includes the CTWs. At others, it does not. Some site comparisons are made using data that have been corrected for external missed dose, while others are made without that correction. The analysis method was appropriately adapted to the differences in data, but in all cases the comparisons are consistent for each site. The outcome of a specific comparison might have been affected by these differences, but only negligibly in the context of the threshold for adjustment described in Section 4.2 [2].

During the review and query of the databases, there was a consistent effort to identify all CTWs regardless of whether they were employed by the M&O contractor or a subcontractor.

Because the source and degree of data specificity varied among the DOE sites, a brief description of the source and treatment of data associated with each site is provided.

4.1 GENERAL DESCRIPTION OF EXTERNAL DOSE DATA

External dose data represent the most widely available dosimetry data for radiation workers. Very large and well-defined external dosimetry databases exist for most DOE facilities. A number of the databases cover or contain data from the entire history of a site.

Data for penetrating dose are contained in various databases, some of which have more detail than others. Data for AMWs and CTWs are reported for SRS, Y-12, ORNL, K-25, Hanford Site, Idaho National Laboratory (INL), and Rocky Flats Plant. However, only the arithmetic mean of the annual external dose is available for INL and Hanford.

4.2 GENERAL DESCRIPTION OF THE ADJUSTMENT FACTOR

The need for an adjustment factor is considered when the annual external penetrating dose for CTWs exceeds that for AMWs. If the observed ratio of the annual external penetrating dose for CTWs to that of AMWs is less than 1.2, the observed ratios were not included in the site-specific tables. The value of 1.2 is based on the characteristics of the dosimeter systems and their ability to measure dose (NRC 1989).

The adjustment factor addresses instances in which the annual external penetrating dose for CTWs exceeded that for AMWs. Because data from all sites in the DOE complex were not readily available for analysis and inclusion in this TIB, a prescribed DOE complex-wide adjustment factor is developed and described in Section 7.1.

4.3 GENERAL DESCRIPTION OF BIOASSAY DATA USED FOR INTERNAL DOSE

Bioassay data are available to cover the majority of large DOE sites. Bioassay programs are typically based on the need to monitor individuals or groups who had a recognized potential for intake of radioactive material. As a consequence, bioassay sampling programs or internal dose monitoring practices are more highly focused and applied more selectively to a smaller group of workers than external monitoring programs. In most instances, CTWs were not included in the routine bioassay program of the site. However, CTWs were regularly included in the bioassay program if they were suspected of having experienced a radioactive material intake.

4.4 GENERAL DESCRIPTION OF NONPENETRATING DOSE DATA

Nonpenetrating dose data for CTWs and AMWs were available only for the SRS and Rocky Flats Plant.

5.0 <u>COMPARISON OF CTW AND AMW DOSES</u>

Five major DOE sites (SRS, Rocky Flats, Y-12, K-25, and ORNL) were selected to represent the DOE complex in an investigation to determine the relationship between the external annual doses received by CTWs and AMWs at the 95th percentile. These sites were selected because they represent a spectrum of DOE sites where major construction activities took place. More than 215,000 histories for CTWs and more than 1,000,000 histories for AMWs were examined. Figure 5-1 is a composite graph of the sites and shows the annual external penetrating dose for the period from 1943 through 2005. With the exception of 1955, Figure 5-1 shows that the external annual dose received by CTWs is well bounded by that received by AMWs. In 1955, the external annual dose received by CTWs exceeded that received by AMWs by approximately 20%. Based on this observation, seven sites were examined individually to determine if, at any time, the external or internal dose to CTWs exceeded the dose to AMWs. The seven sites included SRS, Rocky Flats, Y-12, K-25, ORNL, INL, and Hanford. Hanford and INL were not included with the initial five DOE sites because the dosimetry data available for them addressed only the mean of the external dose as opposed to the 95th percentile.

As indicated in Figure 5-1, doses to CTWs occasionally exceeded doses to AMWs in the 1980s and later. A review of the data used in the figure indicated that these exceedances are an artifact caused by a large number of AMWs with no measured dose. The large number of AMWs with no measured dose led to a smaller value for the 95th-percentile annual dose, making the 95th-percentile annual dose for CTWs comparatively larger.

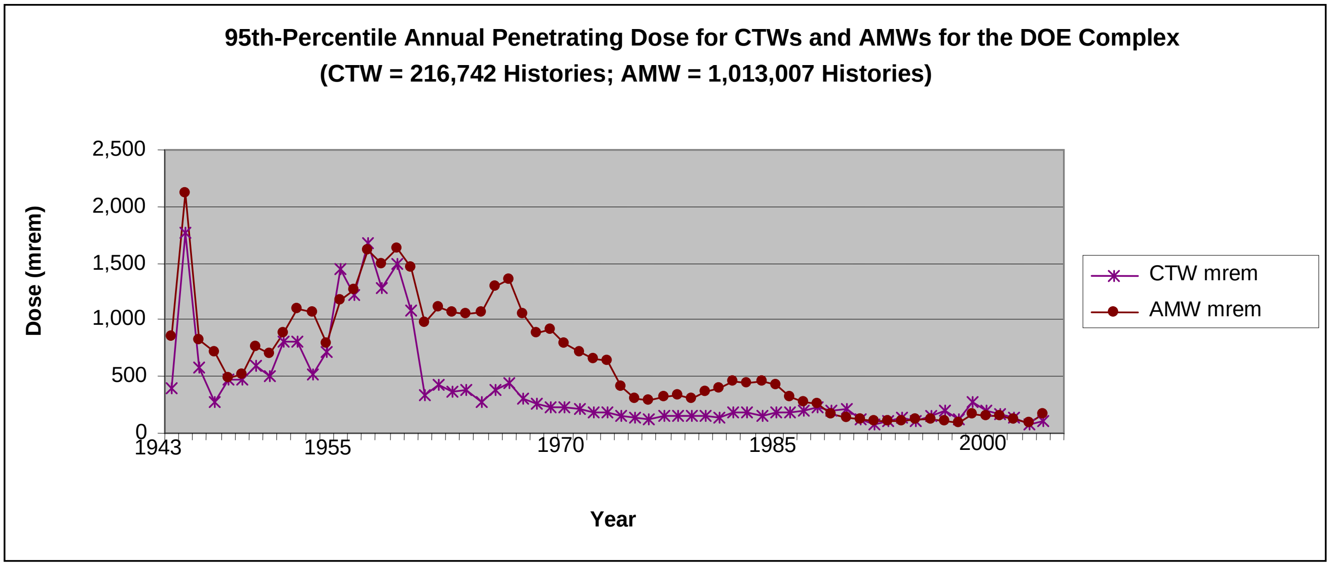

Figure 5-1. 95th-percentile annual penetrating dose for CTWs and AMWs for the DOE complex.

5.1 SRS PENETRATING DOSE COMPARISON

Information for the period from 1953 through 1999 concerning penetrating doses for SRS CTWs is contained in the onsite personnel dosimetry database, HPAREH. The dosimetry data for the SRS CTWs in the HPAREH database are identified as Payroll 4 (ROLL 4). This information is subdivided to identify specific construction trades. However, some trades were not represented or represented only a few individuals. As a consequence, conclusions for the period from 1953 through 1999 are based only from ROLL 4 data as a whole.

Dosimetry data include annual deep doses (i.e., external photon radiation) and annual shallow doses (i.e., penetrating photons plus nonpenetrating radiation). Summary statistics in this document do not extend after 1999 because, at the time the information supporting this document was collected, sufficient data beyond that year were not available. Figure 5-2 shows the 95th-percentile penetrating dose for SRS.

The usefulness of data from other sources besides HPAREH was evaluated. The Fayerweather database contains some data before 1960 that are not in HPAREH. S. Cohen & Associates compared reconstructed doses using the HPAREH and Fayerweather data and concluded that the average and 95th-percentile doses are higher when the HPAREH data are used (SC&A 2007). This provides some assurance that the workers in the Fayerweather database are adequately represented by those in the HPAREH database and the analysis is favorable to the CTW claimant [3].

Table 5-1 lists the observed ratios that are greater than 1.2 for CTWs and AMWs at SRS.

5.2 SRS INTERNAL DOSE COMPARISON

For the SRS, during the development of this OTIB, no coworker study has been published. During the development of this TIB, bioassay data were not available electronically before about 1990 and were stored both on and off the site in paper files and on microfiche. A random sample of records stored on the site was obtained for workers with a nonzero external dose recorded in the HPAREH database.

Equal number of records for CTWs and other workers were requested for individuals employed from 1955 through 2000. CTWs were identified as ROLL 4 in the HPAREH database.

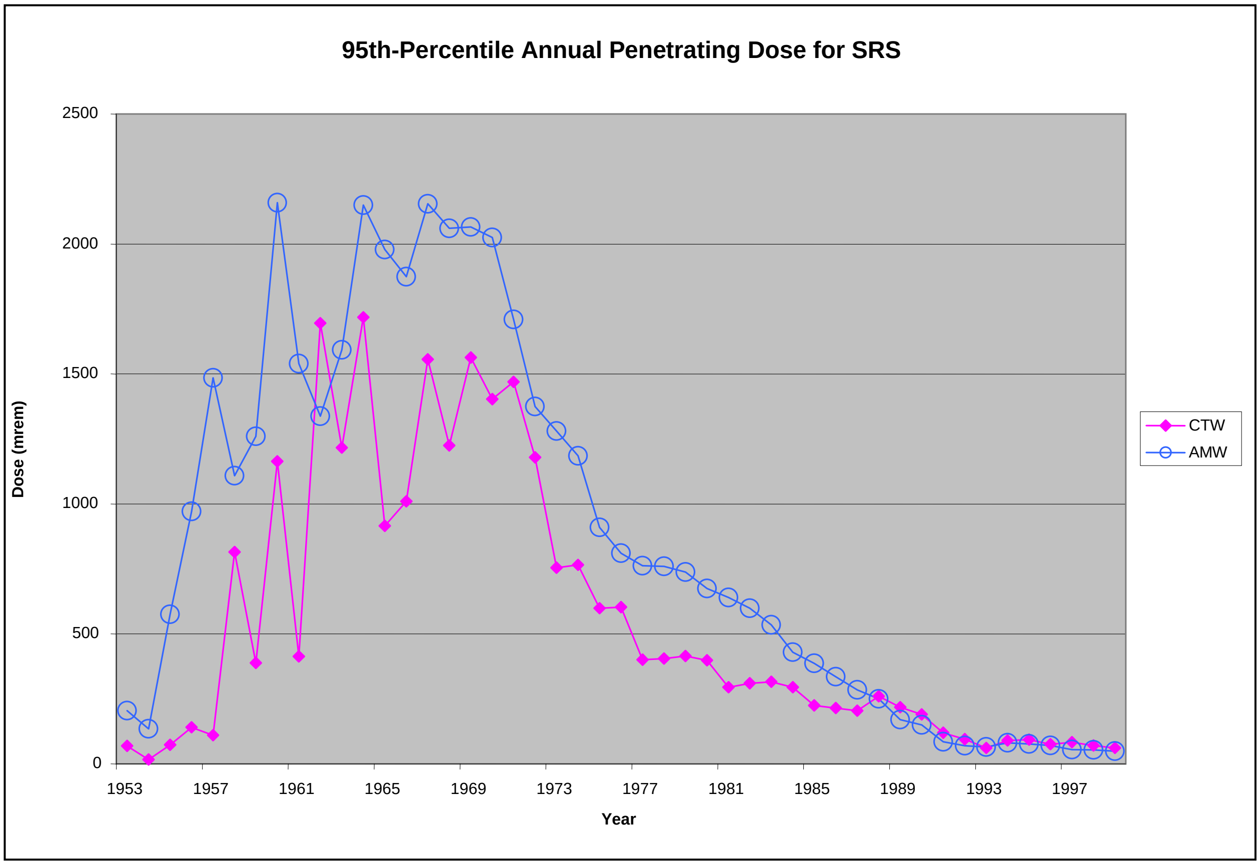

Figure 5-2. 95th-percentile penetrating dose for SRS.

Table 5-1. Observed ratios for SRS.

Year	CTWs			AMWs			Observed ratios (CTWs/AMWs)
	Number monitored	Number with measurable dose	95th-percentile dose (mrem)	Number monitored	Number with measurable dose	95th-percentile dose (mrem)	
1962	259	236	1,696	3,371	3,101	1,337	1.3
1989	2,408	1,818	218	15,517	8,749	170	1.3
1990	2,440	1,567	190	18,494	8,503	150	1.3
1991	2,202	1,104	120	18,630	6,468	85	1.4
1992	1,902	792	95	17,780	5,016	70	1.4
1997	949	317	83	11,344	2,410	55	1.5
1998	870	280	71	10,750	2,210	54	1.3
1999	785	240	62	10,365	2,159	49	1.3

This sampling produced a data set containing approximately 1,830 plutonium-in-urine measurements, one-third of which represented CTWs. According to ORAUT (2005a), before 1981 (1988 for special samples), the total activity from alpha-emitting isotopes was used to report the amount of plutonium in urine, whereas ^{238}Pu and $^{239+240}$Pu results were reported separately from 1981 to the present. Because this comparison is of the relative activities in the samples, no adjustments were made. All results were normalized to 1,400-mL sample size. Results for employees with multiple bioassay samples in the same year following a significant intake were removed prior to plotting. This was done so as not to bias the results for more typical workers. However, results less than 10 dpm/1,400 mL were retained even if there were other samples collected in the same year. Results for three non-CTWs and one CTW were removed using this method.

For non-CTWs, 93% of the results were below the reporting level, while for CTWs, 97% of the results were below the reporting level. Only results greater than the reporting level are plotted in Figure 5-3. Due to the limited amount of data greater than the reporting level in any given period, no attempt was

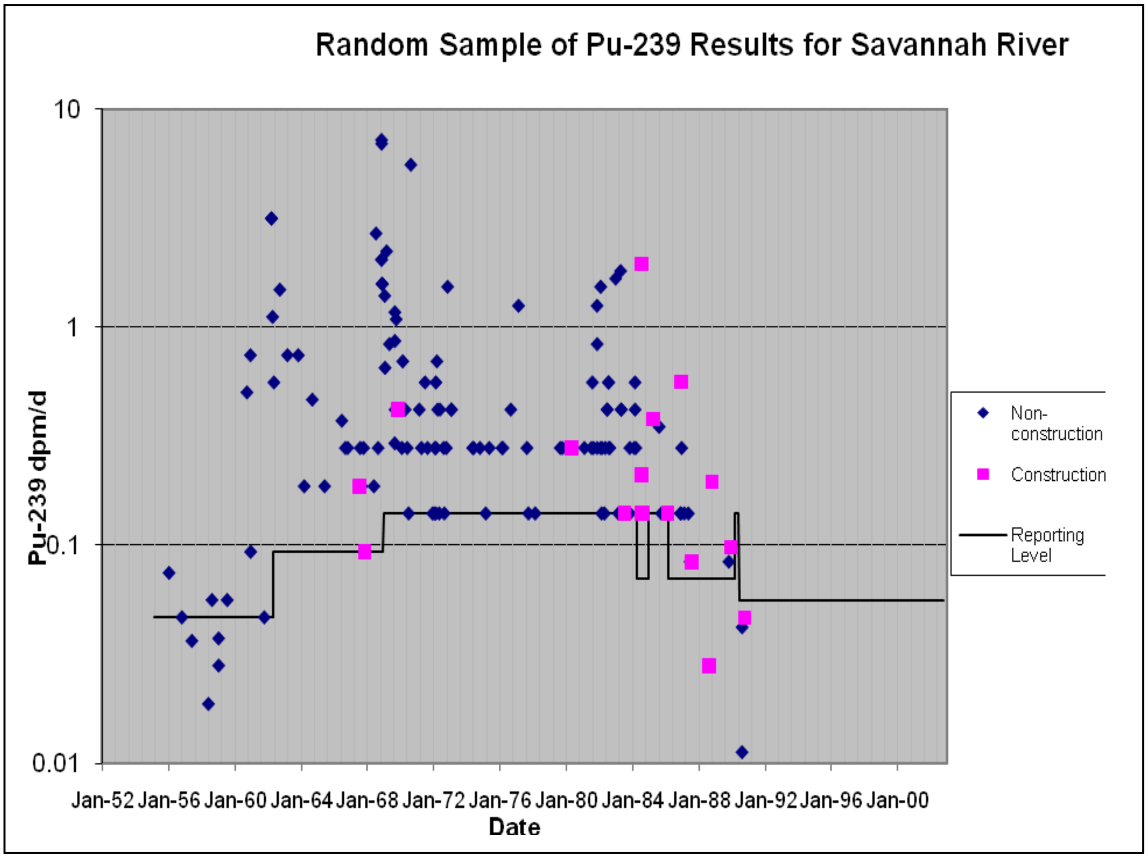

Figure 5-3. Results of bioassay samples above the reporting level for randomly selected CTWs and non-CTWs at SRS.

made to calculate 50th-percentile values. Figure 5-3 includes the typical reporting level estimated by a visual inspection of the various periods for comparison. This plot shows that non-CTWs were more likely to have results above the reporting level and more likely to have higher results than CTWs.

5.3 SRS NONPENETRATING DOSE COMPARISON

As mentioned in Section 5.1, information for the period from 1953 through 1999 on nonpenetrating doses for SRS AMWs and CTWs is contained in the onsite personnel dosimetry database, HPAREH. The dosimetry data for the SRS CTWs are identified as Payroll 4 (ROLL 4) in the database.

The results for the 95th-percentile annual nonpenetrating doses appear in Figure 5-4. As is evident, the annual nonpenetrating dose received by the monitored CTWs is adequately bounded by the dose received by AMWs at the SRS.

5.4 ROCKY FLATS PLANT PENETRATING DOSE COMPARISON

Construction worker data for the Rocky Flats Plant was obtained from the HIS-20 (TM CANBERRA) database. This database was the Plant's last dosimetry data tracking system and contains dosimeter results from the entire Plant history. The CTW data set consisted of workers with the company names "Kaiser-Hill Company, L.L.C." (if the department field contained "construct"), "Kaiser-Hill RFETS\10389" (if the department field contained "construct"), "Swinerton & Walberg Company," and

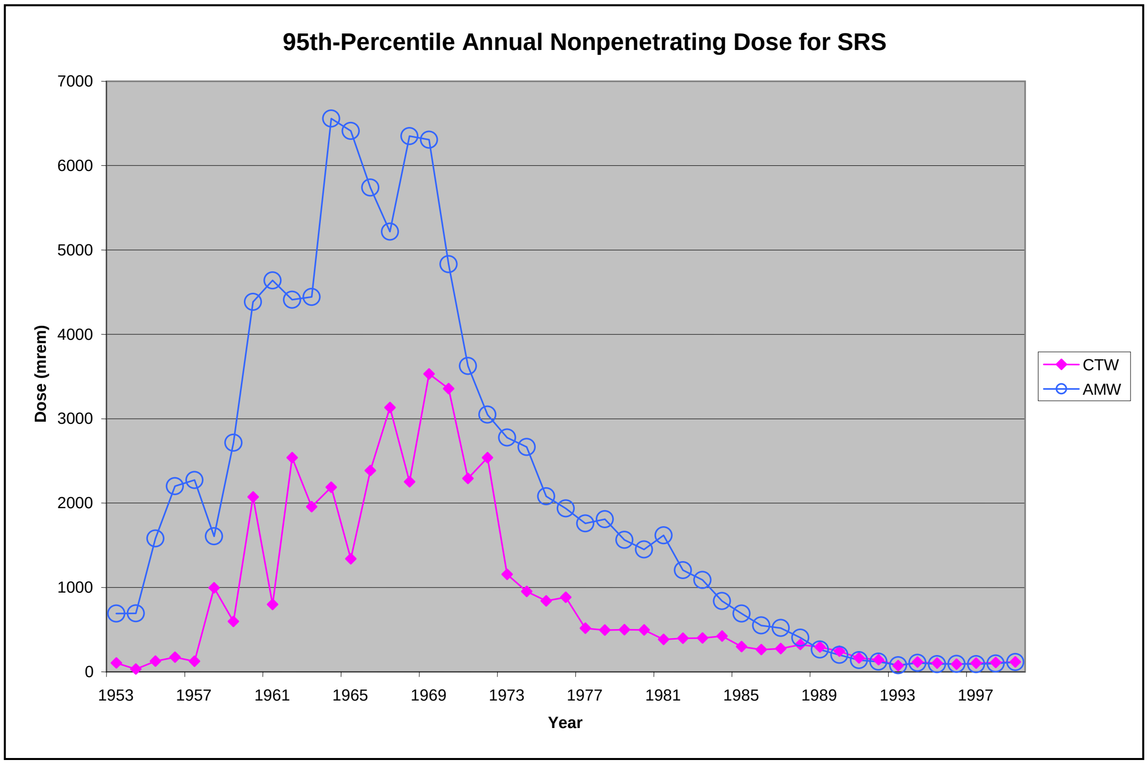

Figure 5-4. 95th-percentile nonpenetrating dose for SRS.

"J. A. Jones Construction\3893." The latter two companies were the construction contractors for most of the Plant's history.

Figure 5-5 shows the annual penetrating doses for monitored CTWs and AMWs for the period 1955 through 2005.

Table 5-2 lists the observed ratios that are greater than 1.2 for CTWs and AMWs at Rocky Flats.

Table 5-2. Observed ratios for Rocky Flats.

Year	CTWs			AMWs			Observed ratios (CTWs/ AMWs)
	Number monitored	Number with measurable dose	95th-percentile dose (mrem)	Number monitored	Number with measurable dose	95th-percentile dose (mrem)	
1991	386	340	755	5,641	4,951	337	2.2
1994	147	96	242	4,839	3,198	179	1.4
1995	138	88	455	4,130	2,502	200	2.3
1996	109	95	393	3,454	2,761	274	1.4
1998	265	218	592	3,470	2,036	275	2.2
1999	197	151	359	3,655	2,138	192	1.9
2000	175	110	278	3,576	1,256	164	1.7
2001	185	108	202	3,443	1,518	160	1.3

5.5 ROCKY FLATS PLANT INTERNAL DOSE COMPARISON

CTW data for Rocky Flats internal dose comparison was obtained from the HIS-20 database. Two sets of data containing urine results for the entire history of the Plant were drawn from the database. The first data set consisted of workers with the company names "EG&G Rocky Flats Plant" and "Kaiser-Hill Company, L.L.C." (if the department field did not contain "construct"), "Kaiser-Hill

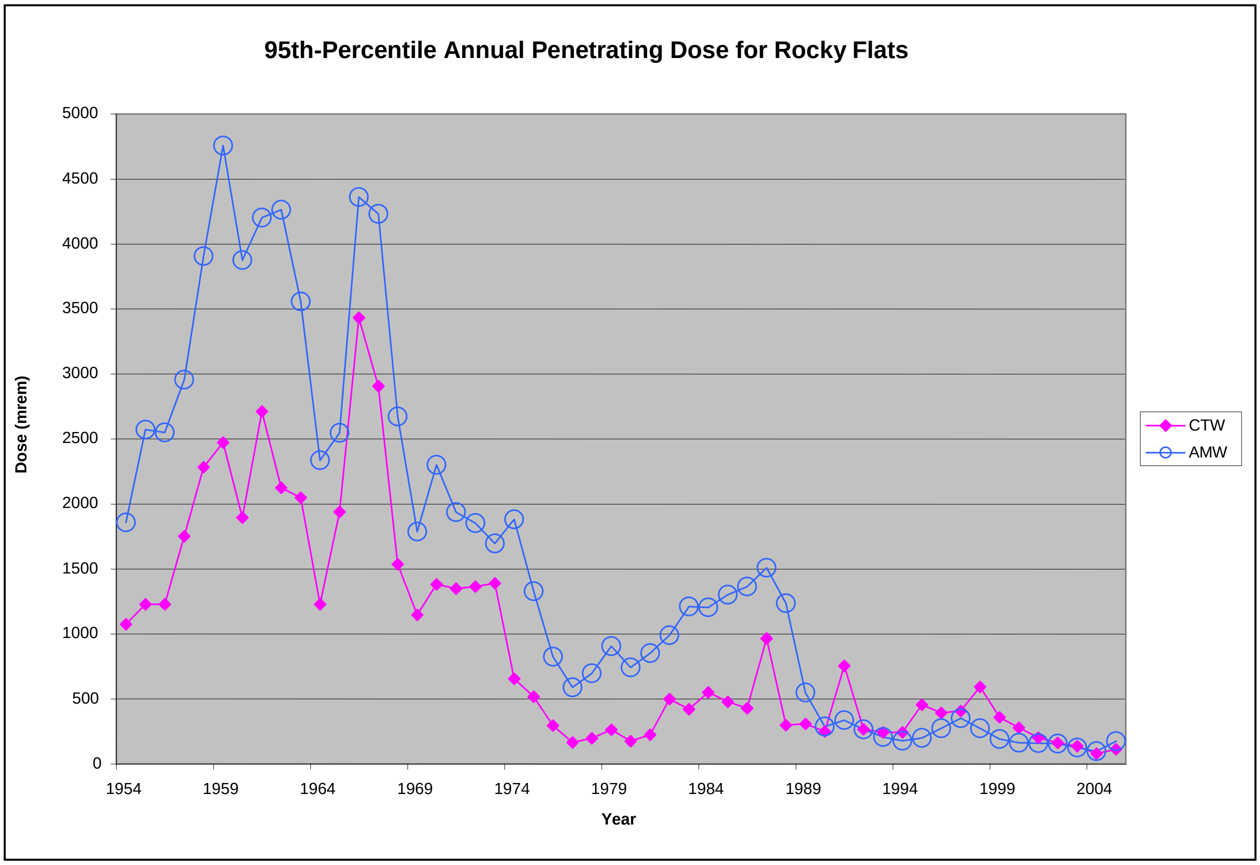

Figure 5-5. 95th-percentile penetrating dose for Rocky Flats.

RFETS\10389" (if the department field did not contain "construct"), "Safe Sites of Colorado, L.L.C.," and "Rocky Mt Remediation Srv\10528." This set was selected to represent AMWs.

The second data set consisted of workers with the company names "Kaiser-Hill Company, L.L.C." (if the department field contained "construct"), "Kaiser-Hill RFETS\10389" (if the department field contained "construct"), "Swinerton & Walberg Company," and "J. A. Jones Construction\3893." The latter two companies were the construction contractors for most of the site's history. This second data set was used to represent CTWs. A number of smaller companies could have been added, but the number of urine results would not have increased significantly.

The data set included only results that were identified in the database as "P," "Pu239," or "Pu-239." The results included the activity of all plutonium alphas in the early years, and only ^{239}Pu and ^{240}Pu activity after analysis by alpha spectroscopy was initiated [see ORAUT (2007) for details]. For the period from 1953 through 2005, 129,225 results were collected for AMWs and 5,571 results were collected for CTWs.

The Rocky Flats data were analyzed by applying the basic techniques discussed in ORAUT (2005b) for coworker studies. The data were assumed to be lognormally distributed. Results for highly exposed workers who were followed-up with multiple samples in 1 year were removed from the population so as not to bias the results for more typical workers. However, not all high results were removed. This resulted in multiple individuals having their results removed from the AMW data set, but only one individual's results were removed from the CTW data set. The data were analyzed annually for AMWs, while the data for CTWs were grouped in intervals of every 5 years to include enough data for statistical analysis. Each group was examined, and duplicate and invalid results were eliminated. Negative and zero results were replaced by a uniform (linear) distribution ending at the minimum detectable activity value in ORAUT (2007). The results were assumed to represent 24-hour samples or were normalized to 24-hour samples by volume in years where volumes were recorded in the database. The results were sorted and ranked using the midpoint of the rank. A linear regression analysis of the rank versus the natural log of the result was performed and plotted. The R^2 value of the regression and the plot were inspected to ensure that an adequate fit to the data had been obtained. From the regression, the values for the 50th- and the 84th-percentiles of the distributions were calculated and are shown in Figures 5-6 and 5-7, respectively. As shown in these figures, the results for plutonium in the urine of the CTWs are comparable to results for AMWs who were monitored routinely at Rocky Flats.

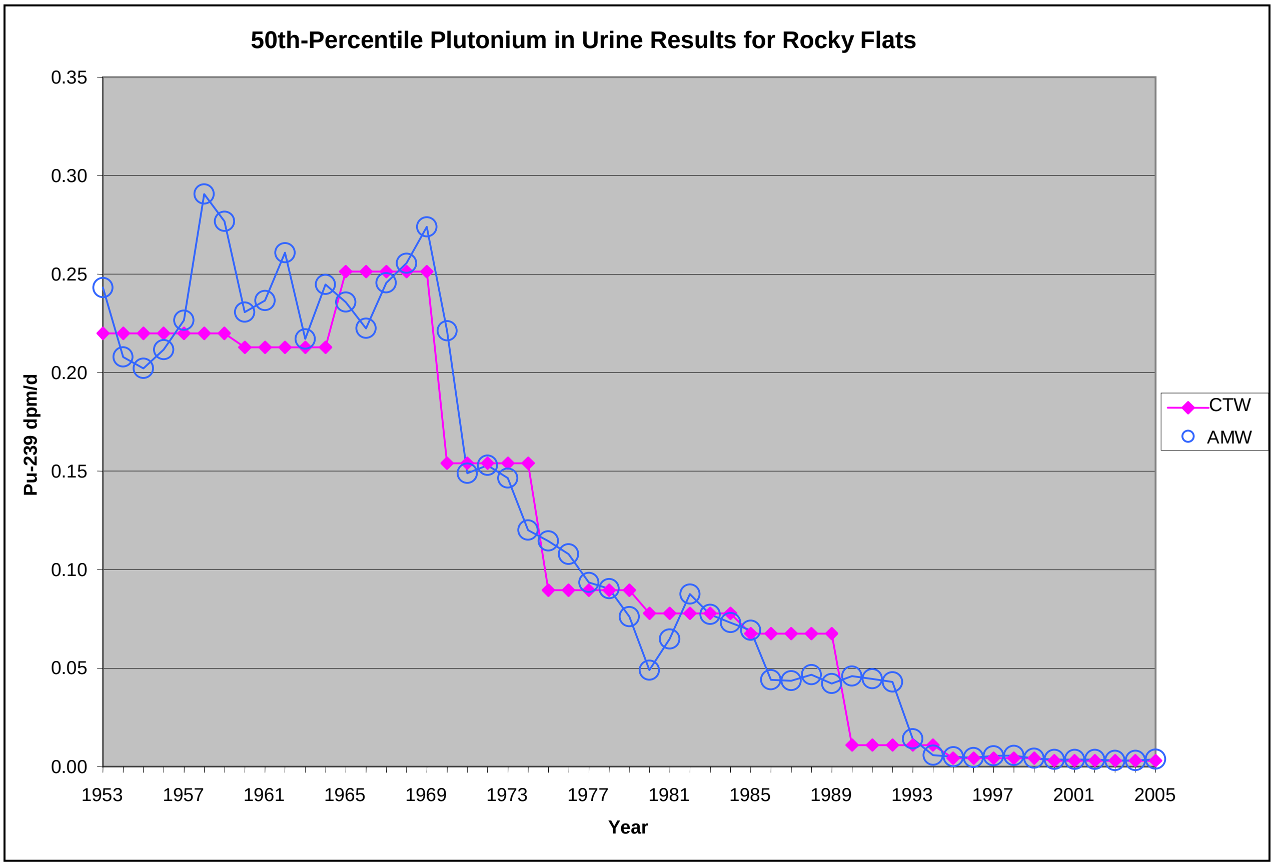

Figure 5-6. 50th-percentile plutonium in urine for Rocky Flats.

5.6 ROCKY FLATS PLANT NONPENETRATING DOSE COMPARISON

CTW and AMW data for Rocky Flats were obtained from the HIS-20 database using the criteria discussed in Section 5.4.

The results for the 95th-percentile annual nonpenetrating doses appear in Figure 5-8 and show that at the 95th percentile, the annual nonpenetrating dose received by the monitored CTWs at the Rocky Flats Plant is adequately bounded by the dose received by AMWs at the Rocky Flats Plant.

5.7 Y-12 PENETRATING DOSE COMPARISON

External dose data for the Oak Ridge Y-12 are from the Oak Ridge Institute for Science and Education (ORISE) CER database. The records in this database include external radiation exposure measurement results pertinent to the health and safety monitoring of employees and contract employees of DOE and its predecessor organizations. Data on CTWs were obtained using a query designed to extract job titles associated with construction work. Data on any worker with a job title

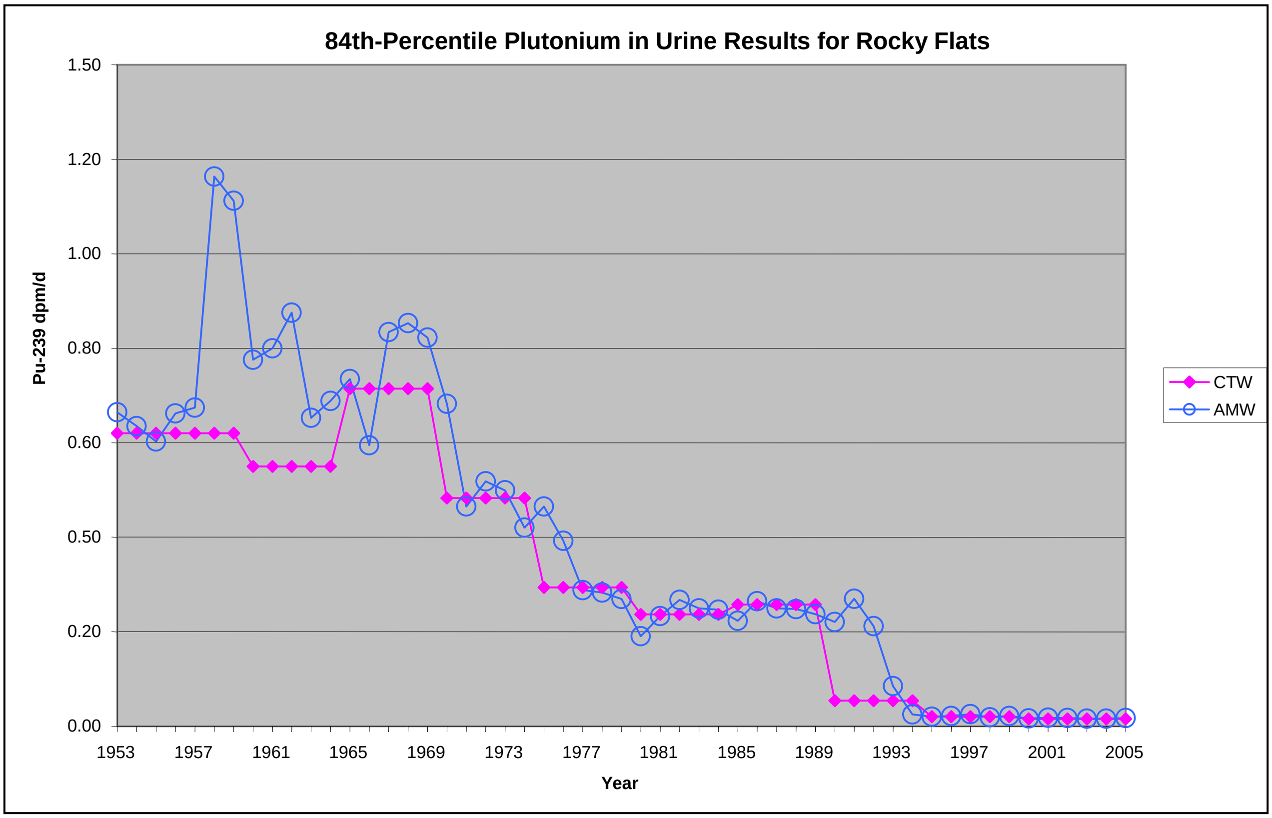

Figure 5-7. 84th-percentile plutonium in urine for Rocky Flats.

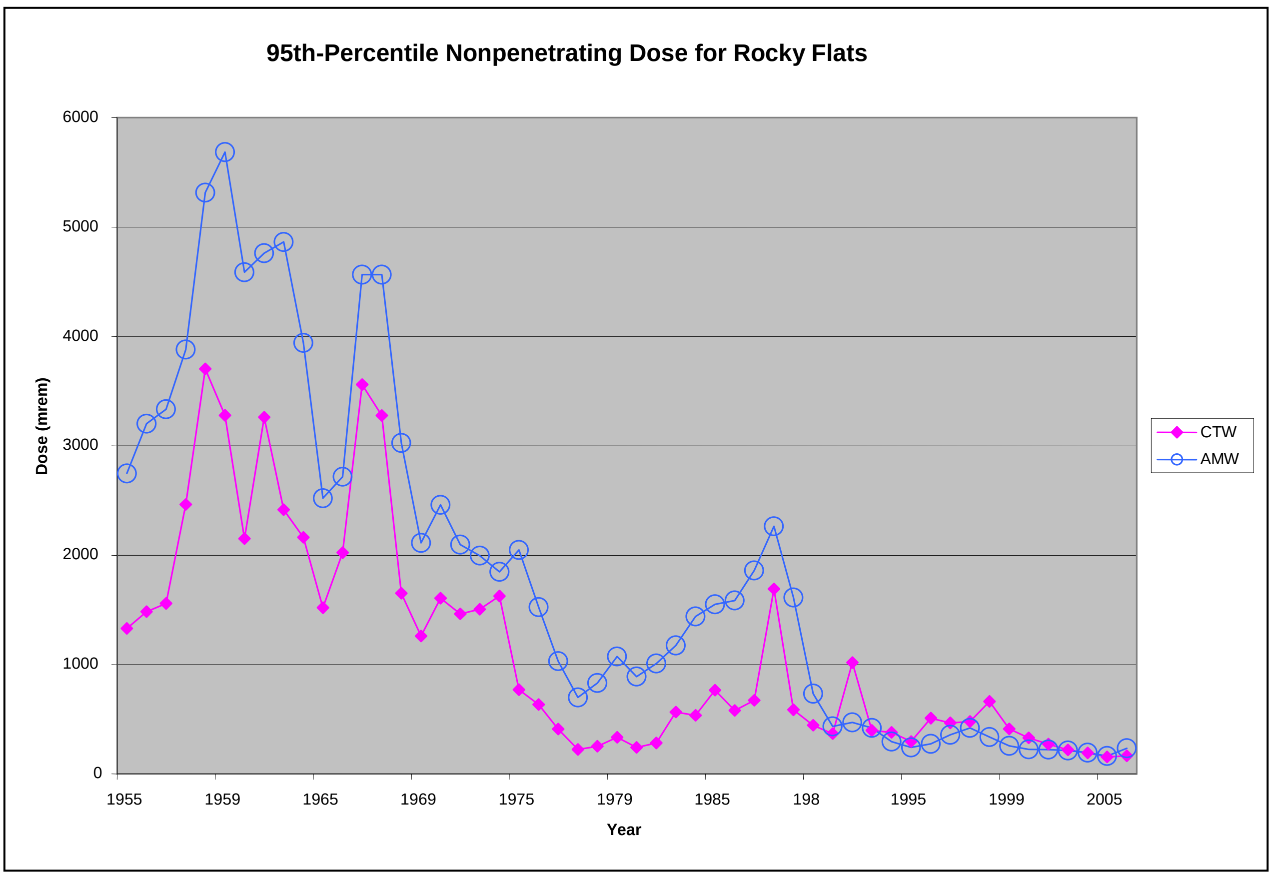

Figure 5-8. 95th-percentile nonpenetrating dose for Rocky Flats.

that included any of the following words or portions of words were included in the CTW data set: craft, carp, equip, heavy, plumb, pipef, millw, ship, skill, laborer, black, linem, boil, brick, tile, metal w, metal, crane, paint, mason, sheet, maint, truck, weld, rigger, or iron.

Figure 5-9 shows the data for 95th-percentile penetrating dose for monitored CTWs and AMWs for the period from 1950 through 1988. As shown in Figure 5-9, the 95th-percentile annual penetrating dose received by the monitored CTWs at Y-12 is adequately bounded by the doses received by AMWs at Y-12.

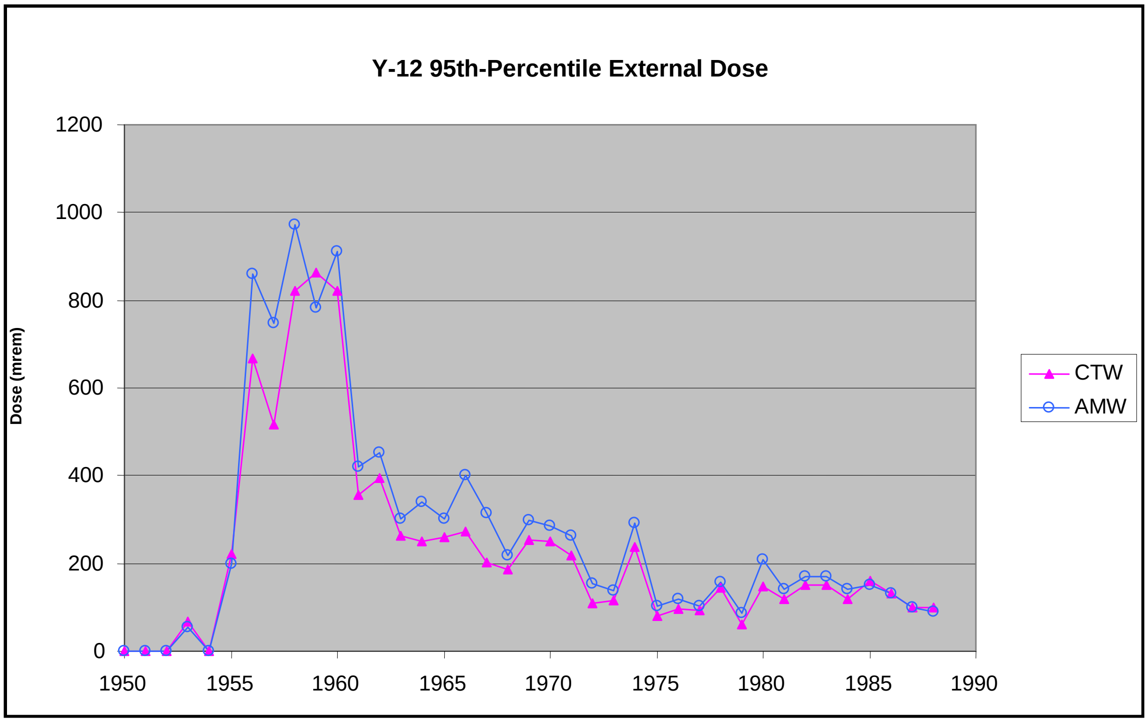

Figure 5-9. 95th-percentile penetrating dose for Y-12.

5.8 Y-12 INTERNAL DOSE COMPARISON

Bioassay results for uranium in urine samples for personnel who worked at Y-12 are from the ORISE CER database. Data on CTWs were obtained using a query designed to extract job titles associated with construction work. (See Section 5.7 for details on the data query.)

Data generated by the query were reviewed to determine if a singular sample result or results associated with unusual incidents was unduly influencing the overall data comparison. Such data are characterized as outliers and these results were removed from the data set to improve the value of the data comparison.

The 50th and 84th percentiles of these bioassay results are shown by year in Figures 5-10 and 5-11, respectively. In general, there is good agreement between the sample results for CTWs and AMWs.

5.9 K-25 PENETRATING DOSE COMPARISON

External dose data for K-25 are taken from the ORISE CER database. The records in this database include external radiation exposure measurement results pertinent to the health and safety monitoring of employees and contract employees of DOE and its predecessor organizations. Data on CTWs were obtained using a query designed to extract job titles associated with construction work. (See Section 5.7 for details on the data query.)

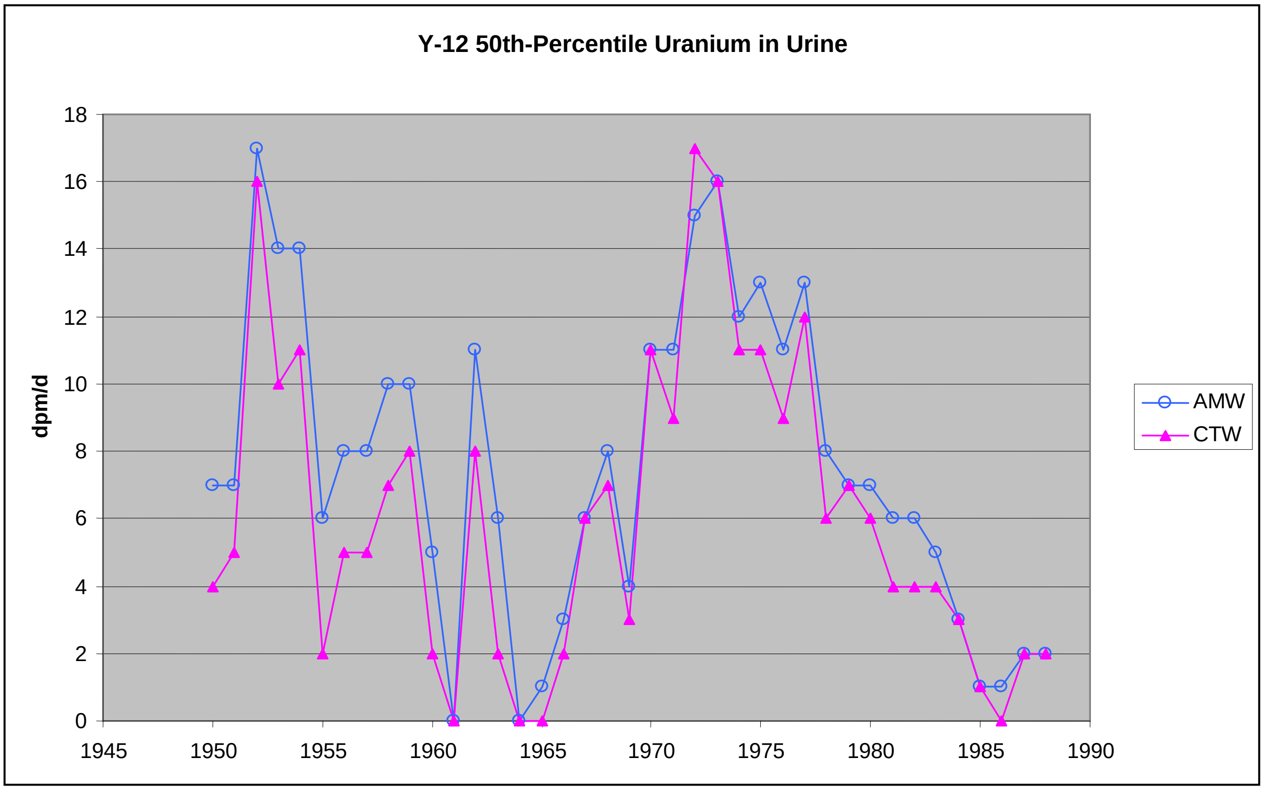

Figure 5-10. 50th-percentile uranium in urine for Y-12.

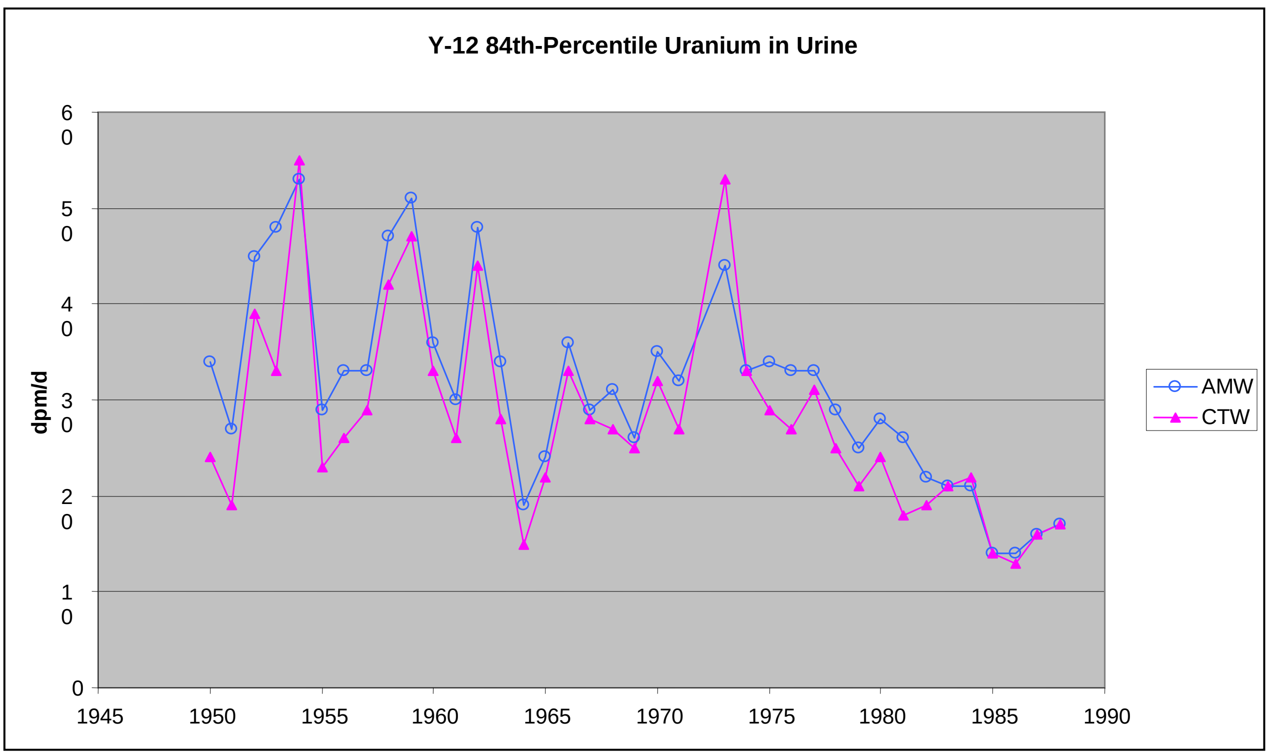

Figure 5-11. 84th-percentile uranium in urine for Y-12.

Figure 5-12 shows the data for the 95th-percentile penetrating dose for both monitored CTWs and AMWs for the period beginning in 1943 and ending in 1988. Figure 5-12 shows that the annual penetrating dose received by the monitored CTWs at K-25 is adequately bounded by the doses received by AMWs at K-25.

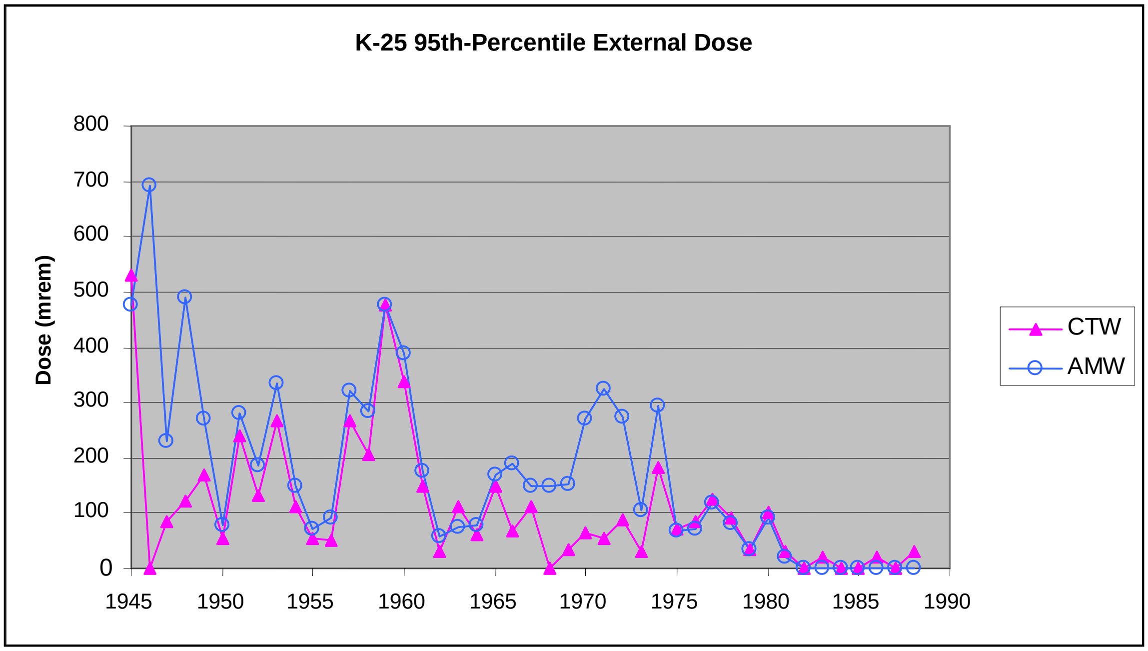

Figure 5-12. 95th-percentile penetrating dose for K-25.

5.10 K-25 INTERNAL DOSE COMPARISON

Bioassay results for uranium in urine samples for personnel who worked at K-25 are from the ORISE CER database. Data on CTWs were obtained using a query designed to extract job titles associated with construction work. (See Section 5.7 for details on the data query.)

The 50th and 84th percentile of these bioassay results are shown in Figures 5-13 and 5-14, respectively. In general, there is good agreement between the sample results for CTWs and AMWs.

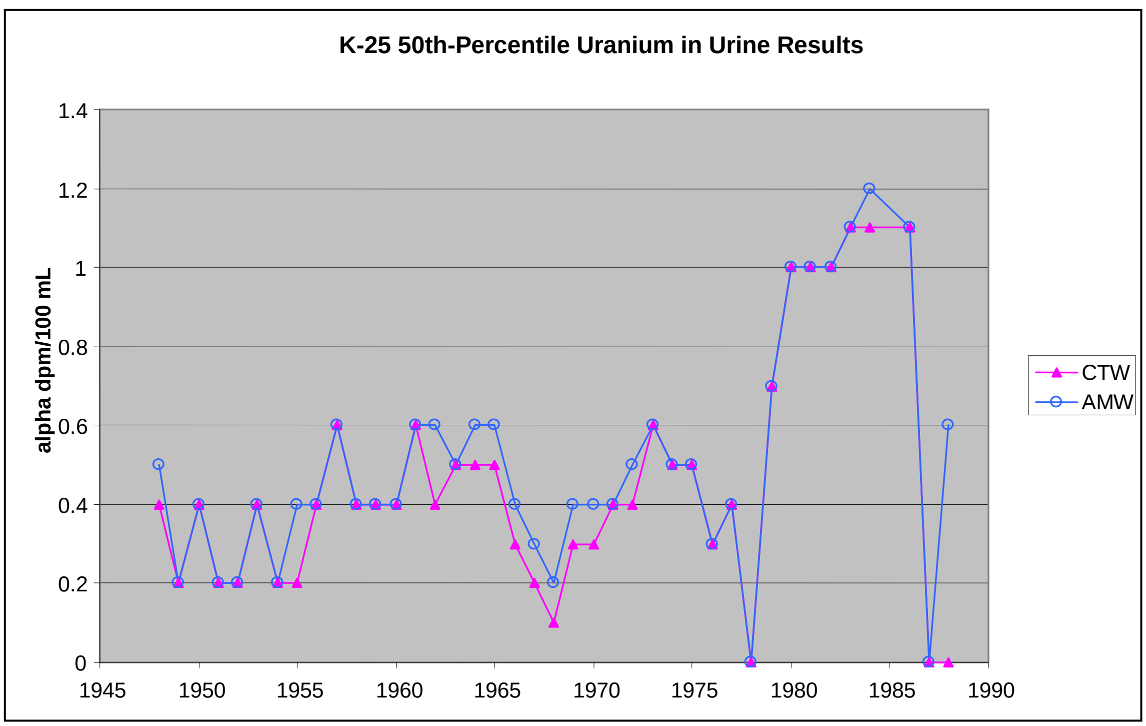

Figure 5-13. 50th-percentile uranium in urine for K-25.

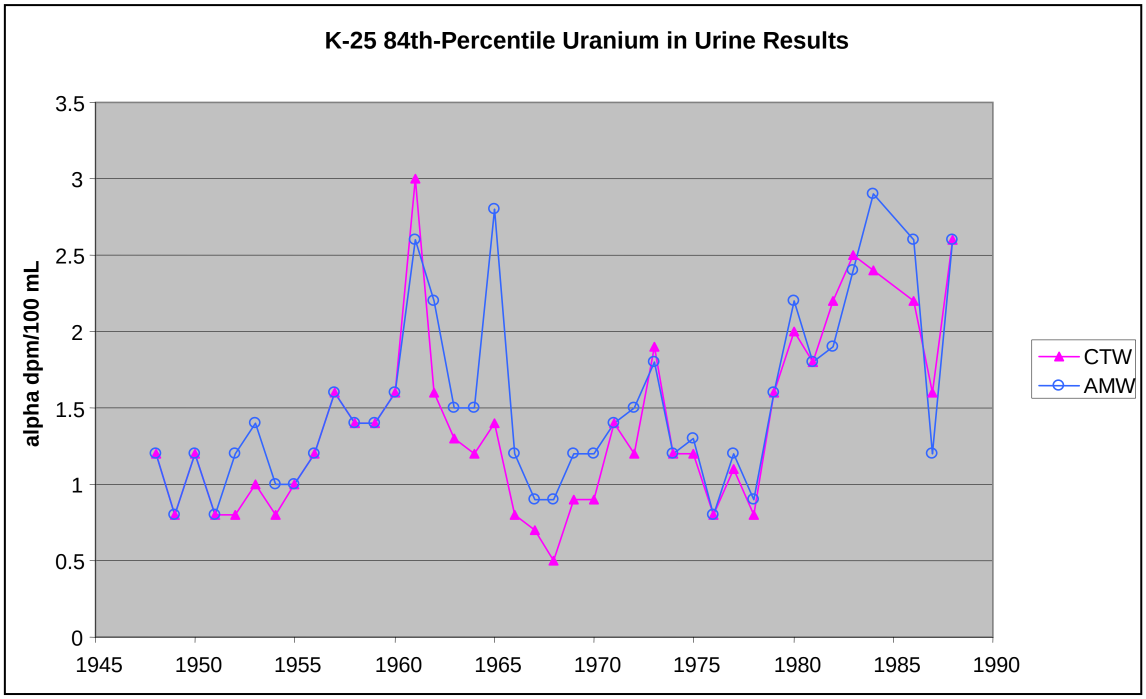

Figure 5-14. 84th-percentile uranium in urine for K-25.

5.11 ORNL PENETRATING DOSE COMPARISON

External dose data for ORNL are from the ORISE CER database. The records in this database include external radiation exposure measurement results pertinent to the health and safety monitoring of employees and contract employees of DOE and its predecessor organizations. Data on CTWs were obtained using a query designed to extract job titles associated with construction work. (See Section 5.7 for details on the data query.)

Figure 5-15 shows the 95th-percentile annual penetrating dose for monitored CTWs and AMWs at the ORNL for the period from 1943 through 1988.

Table 5-3 lists the observed ratios that are greater than 1.2 for CTWs and AMWs at ORNL.

5.12 ORNL INTERNAL DOSE COMPARISON

Bioassay results for urine samples for personnel who worked at ORNL are from the ORISE CER database. Data on CTWs were obtained using a query designed to extract job titles associated with construction work. (See Section 5.7 for details on the data query.)

From 1951 through 1964, plutonium in urine was measured as gross alpha. From 1965 to 1987, the analysis method became specific for plutonium. The 50th and 84th percentiles of these bioassay results are shown by year in Figures 5-16 and 5-17, respectively.

Uranium in urine was also measured at ORNL. Figures 5-18 and 5-19 show the results of the median and 84th percentile for this analysis, respectively.

In general, there is good agreement between the CTW and AMW data for both plutonium and uranium at the 50th and 84th percentile.

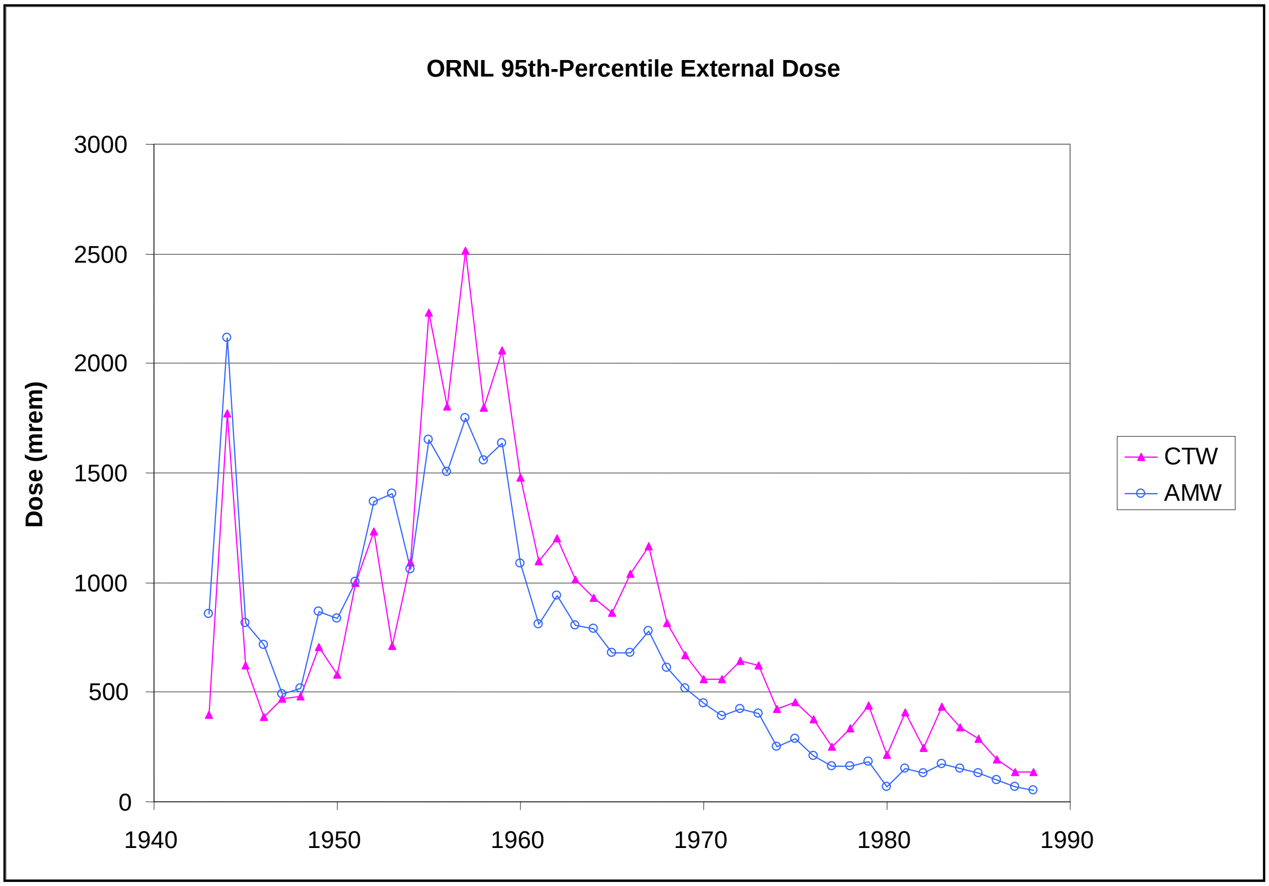

Figure 5-15. 95th-percentile penetrating dose for ORNL.

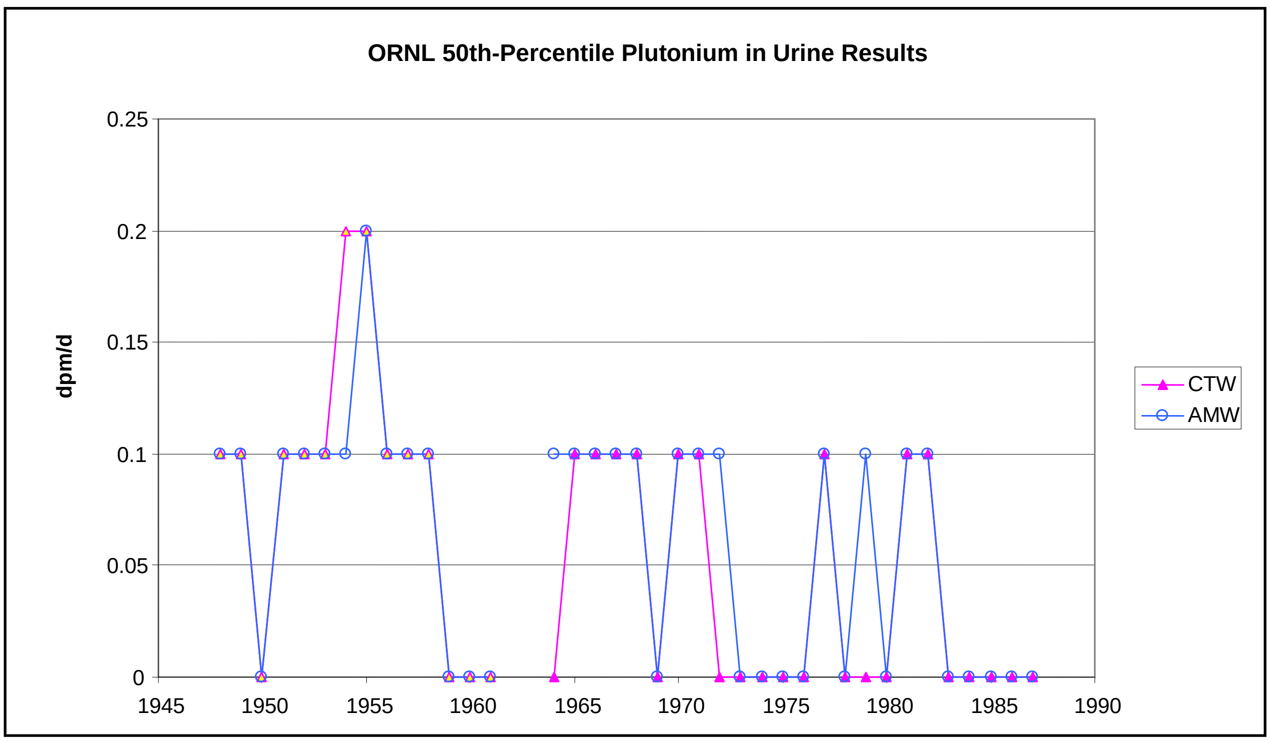

Figure 5-16. 50th-percentile plutonium in urine for ORNL.

Table 5-3. Observed ratios for ORNL.

Year	CTWs			AMWs			Observed ratios (CTWs/AMWs)
	Number monitored	Number with measurable dose	95th-percentile dose (mrem)	Number monitored	Number with measurable dose	95th-percentile dose (mrem)	
1955	604	470	2,231	3,931	2,193	1,650	1.4
1957	623	608	2,515	4,277	3,734	1,750	1.4
1959	704	696	2,058	4,698	4,350	1,636	1.3
1960	682	618	1,480	4,793	3,427	1,087	1.4
1961	695	627	1,096	4,779	3,785	810	1.4
1962	722	696	1,200	4,953	4,591	940	1.3
1963	750	681	1,015	5,174	4,243	803	1.3
1965	817	551	864	5,646	2,930	680	1.3
1966	822	582	1,040	5,972	2,765	680	1.5
1967	878	585	1,163	6,252	2,657	780	1.5
1968	852	542	814	5,981	2,303	610	1.3
1969	808	403	670	5,809	1,754	516	1.3
1971	725	318	558	5,154	1,428	390	1.4
1972	691	289	645	5,097	1,203	422	1.5
1973	661	315	620	4,984	1,336	400	1.6
1974	739	363	421	5,407	1,611	250	1.7
1975	767	283	457	5,788	1,129	290	1.6
1976	784	268	378	6,123	1,169	210	1.8
1977	804	228	250	6,434	1,042	160	1.6
1978	798	206	333	6,660	899	160	2.1
1979	776	209	440	6,357	915	182	2.4
1980	754	130	214	6,480	635	70	3.1
1981	723	170	409	6,313	606	150	2.7
1982	667	119	247	5,782	480	130	1.9
1983	608	146	436	5,562	489	170	2.6
1984	602	144	339	5,610	522	150	2.3
1985	585	139	288	5,641	502	130	2.2
1986	514	94	193	4,998	430	100	1.9
1987	482	92	138	4,894	382	70	2.0
1988	484	91	134	5,102	372	50	2.7

5.13 INL PENETRATING DOSE COMPARISON

Penetrating doses for INL are presented in Figure 5-20 for the period beginning in 1974 and ending in 2005. Radiation exposure data prior to 1974 was not available. However, in *Occupational Radiation Exposure History of Idaho Field Office Operations at the INEL*, Horan and Braun (1993) discuss CTW exposures during the early period: "[Construction personnel] exposures were negligible during the first decade and were almost all below 0.5 rem/yr thereafter."

Data in Schubauer-Berigan et al. (2005) were considered for comparison but rejected because they include data on civilian employees of the Naval Reactor Facilities who are not covered by the *Energy Employees Occupational Illness Compensation Program Act of 2000*. Also confounding those data is the fact that service workers are grouped with CTW, a practice that is inconsistent with the definition of CTW in this document [4].

Table 5-4 lists the observed ratios that are greater than 1.2 for CTWs and AMWs at INL.

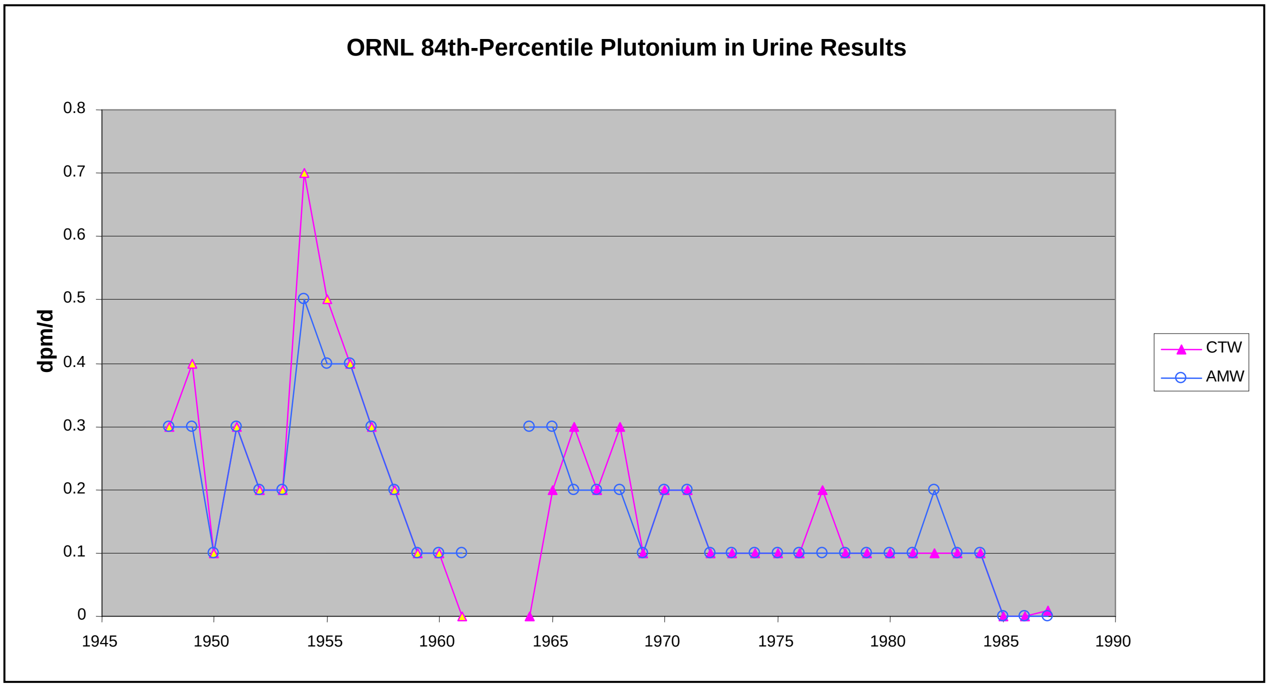

Figure 5-17. 84th-percentile plutonium in urine for ORNL.

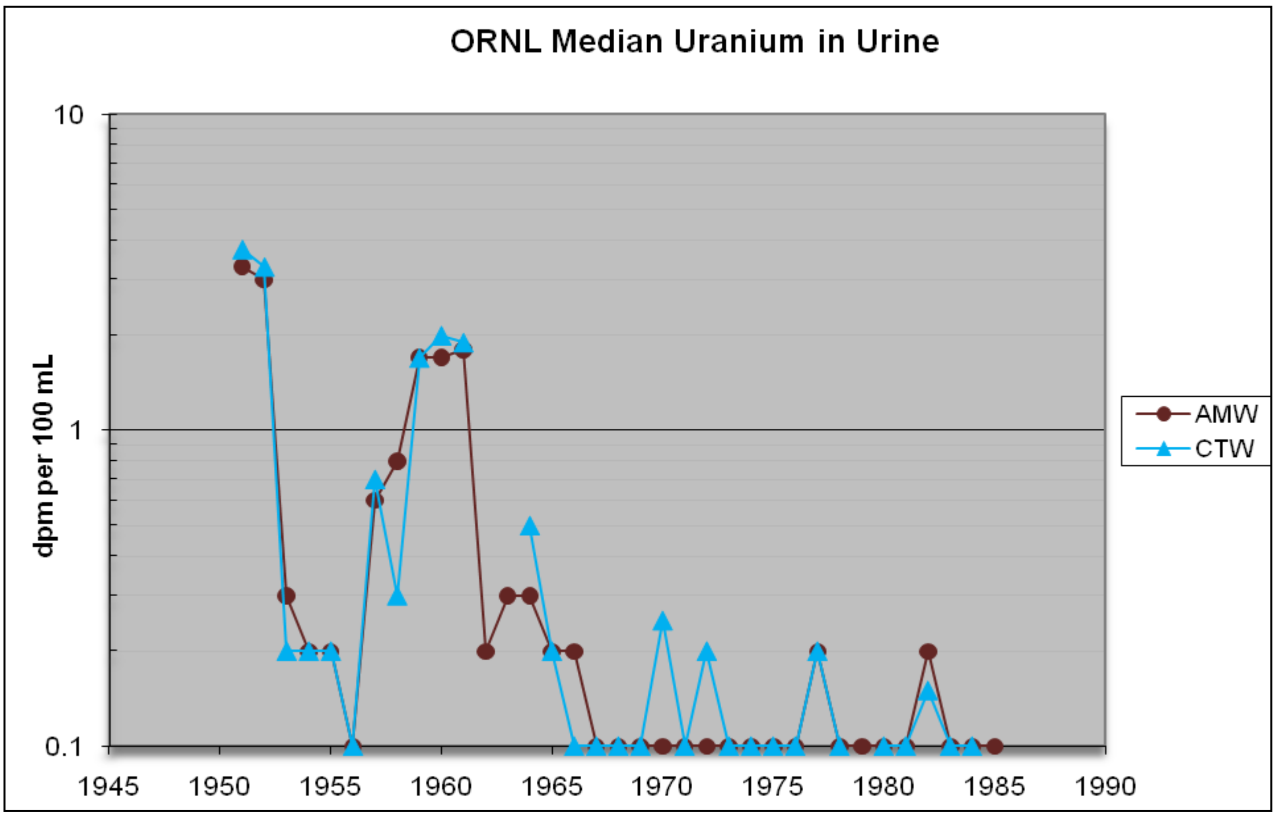

Figure 5-18. 50th-percentile uranium in urine for ORNL.

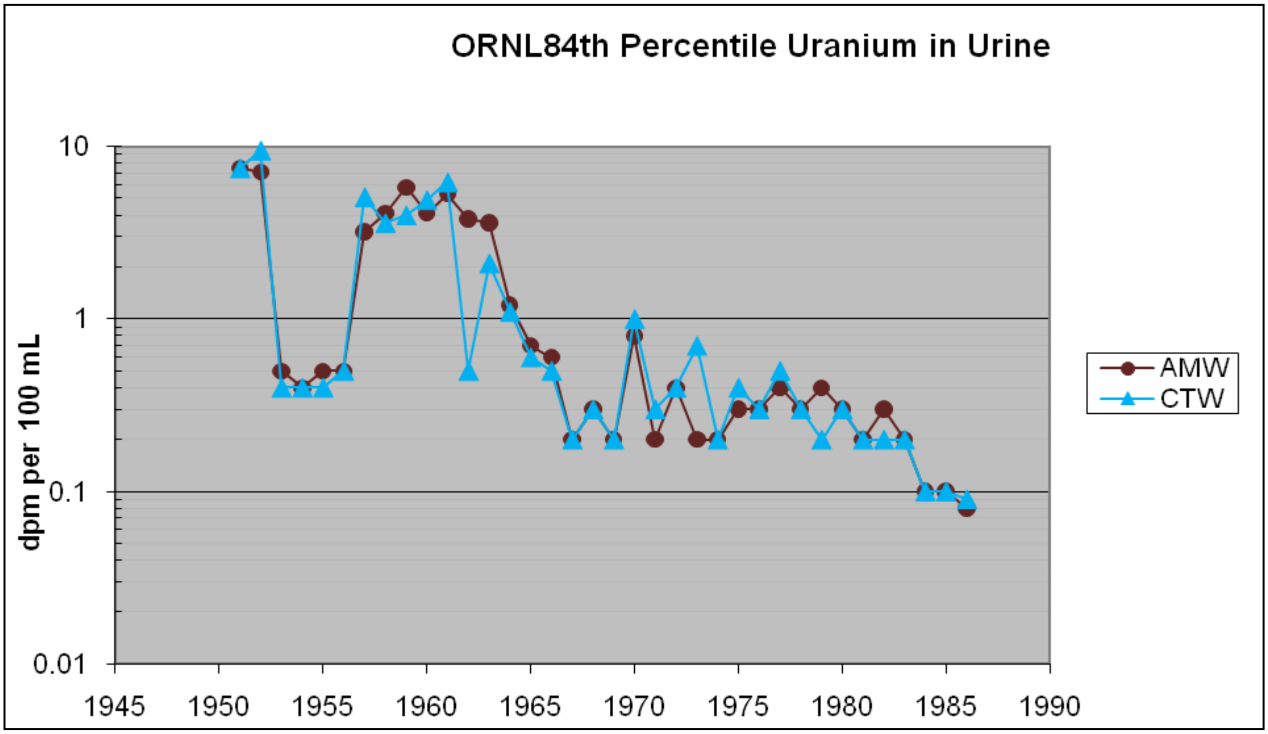

Figure 5-19. 84th-percentile uranium in urine for ORNL.

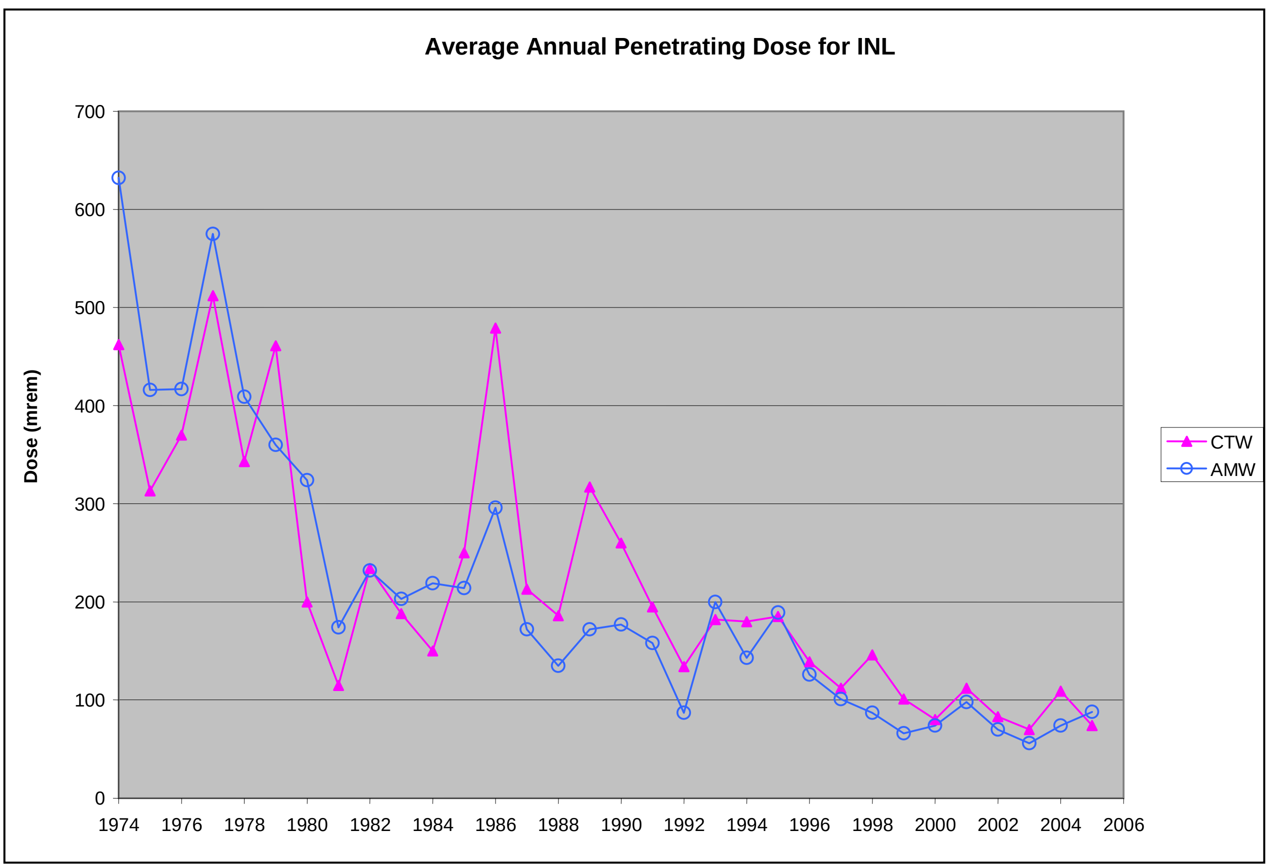

Figure 5-20. Mean value for penetrating dose for INL.

Table 5-4. Observed ratios for INL.

Year	CTWs			AMWs			Observed ratios (CTWs/AMWs)
	Number monitored	Number with measurable dose	Average dose (mrem)	Number monitored	Number with measurable dose	Average dose (mrem)	
1979	953	396	461	5,097	2,407	360	1.3
1986	1,321	536	479	5,956	1,994	296	1.6
1988	463	311	186	4,813	1,751	135	1.4
1989	416	263	317	5,385	1,829	172	1.8
1990	430	223	260	6,033	1,960	177	1.5
1992	427	157	134	5,889	1,007	87	1.5
1994	418	211	180	6,006	1,659	143	1.3
1998	384	104	146	5,075	743	87	1.7
1999	565	95	101	8,885	729	66	1.5
2003	422	155	70	4,682	1,141	56	1.3
2004	428	186	109	3,853	1,471	74	1.5

5.14 INL INTERNAL AND NONPENETRATING DOSE COMPARISON

Data for internal exposures for workers at the INL were not available in a validated electronic format [5]. However, the Horan and Braun (1993) report briefly discusses nonpenetrating and internal exposures, and indicates that they were traditionally negligible:

> *Non-penetrating radiation exposure to the skin from soft X-rays or Beta particles were also not included along with irradiation by internally deposited radionuclides since historically they have been extremely rare events and as a result a very minor contributor to the effective dose.*

No comparison of CTW and AMW internal dose or nonpenetrating dose is presented. Nevertheless, general guidance for internal dose reconstruction developed in this document applies to unmonitored CTWs at INL [6].

6.0 HANFORD SITE

Hanford was the first facility to generate and separate special nuclear material for weapons production. As such, Hanford can be viewed as a type of research and development facility where chemical separation processes were one-of-a-kind experimental prototypes. As the research/information base grew and new chemical processes were developed, contaminated facilities were retrofitted or replaced to accommodate the new processes. It is postulated that this practice was responsible for elevated doses to CTWs. As a consequence, adjustment factors are developed to augment the dose to the CTWs during specific periods.

6.1 HANFORD SITE PENETRATING DOSE COMPARISON

The data were extracted from various sources including a scientific paper (Keene 1960), a series of annual reports based on AEC Form 190 and a series of letter reports (Foster et al. 1959-1973), the annual summary reports of radiation exposures (DOE 1978, 1980a,b, 1982, 1983, 1984a,b, 1985, 1986, 1987, 1989, 1990; ERDA 1975, 1976; Smith et al. 1993), the REMS database (DOE 2006), and a Hanford coworker study of external dose (ORAUT 2010).

The data from Keene (1960) for the period from 1944 through 1959 consist of the 14 job categories that have the highest accumulated dose for that period. Five of the job categories are assumed to represent CTWs. The number of workers, the average service in years, and the average dose are provided for each job category. From these data, average doses per year are calculated for CTWs and AMWs.

From 1960 through 1972, the data come from letters, required by AEC Order, summarizing the site annual dose data (Foster et. al. 1959–1973) [7]. The reports generally present the annual dose in ranges (0 to 1 rem, 1 to 2 rem, etc.). In those instances, the value of the midpoint of each range was used to calculate the average dose.

No annual report was located for 1973. From 1974 through 1990 the data were extracted from the *Annual Report, Radiation Exposures for DOE and DOE Contractor Employees* (DOE 1978, 1980a,b, 1982, 1983, 1984a,b, 1985, 1986, 1987, 1989, 1990; ERDA 1975, 1976; Smith et al. 1993) [8].

For the period from 1991 through 2005, the doses for CTWs and AMWs are determined using the REMS database (DOE 2006). The annual collective penetrating dose is determined by subtracting the collective committed effective dose equivalent (if any) from the collective total effective dose equivalent (person-mrem). The average penetrating dose is determined by dividing the annual dose by the number of workers with measured dose. For CTWs, the annual dose is determined by summing the annual doses for the REMS Construction and Laborer labor categories. The workers in the Laborers category are segregated by the reporting organizations. The annual doses reported by the organizations that are not the M&O contractor are summed and added to the annual dose for the Construction category. Doses in the range less than 100 mrem are not included; this eliminates most visitors and administrative personnel from the REMS data. The average annual dose for CTWs is determined by dividing the annual dose for the Laborers and Construction categories by the number of workers in those categories with measurable dose. For AMWs, the average annual dose is determined by summing the annual doses in the REMS All category (management, scientists, service, etc.) and dividing that sum by the sum of workers who had measured dose in the All category.

Electronic access to the Radiological Exposure (REX) database was not available when this bulletin was drafted. However, the data in REMS was derived from the data in REX and is judged to adequately represent the ratio of CTW and AMW doses [9].

Penetrating doses for monitored CTWs and AMWs are shown in Figure 6-1. Table 6-1 lists the observed ratios that are greater than 1.2 for CTWs and AMWs at Hanford. As indicated in the figure and table, the doses for the CTWs and AMWs are comparable with two exceptions: the periods from 1968 through 1981 and from 1985 through 1988. These periods generally coincide with the increased work activity associated with the shutdown of the production reactors from 1968 through 1981 and the restart of the PUREX [plutonium-uranium extraction] Plant from 1985 through 1988. Due to the nature and period for this work, it is unlikely that unmonitored CTWs were involved. Therefore, these data points were not considered as representative and meaningful for the purposes of this TIB.

6.2 HANFORD SITE INTERNAL DOSE COMPARISON

An internal dosimetry coworker study that includes both CTWs and AMWs has been published for the Hanford Site (ORAUT 2012). The database used to develop the study had limited descriptive information for workers such that data for CTWs cannot be identified before 1965. For the period from 1965 through 1978, plutonium data for CTWs is identified by a company-field in the database. These data were processed in accordance with ORAUT (2012) to develop data sets for CTWs. For the period from 1965 through 1975, the data sets were analyzed annually rather than quarterly due to their small size. For the period from 1975 through 1978, the data sets were grouped and analyzed together. [See ORAUT (2012) for additional details.]

For the period from 1978 through 1989, the plutonium data for CTWs are very limited and appear to consist mainly of special samples following incidents. If it was appropriate, duplicates and data for

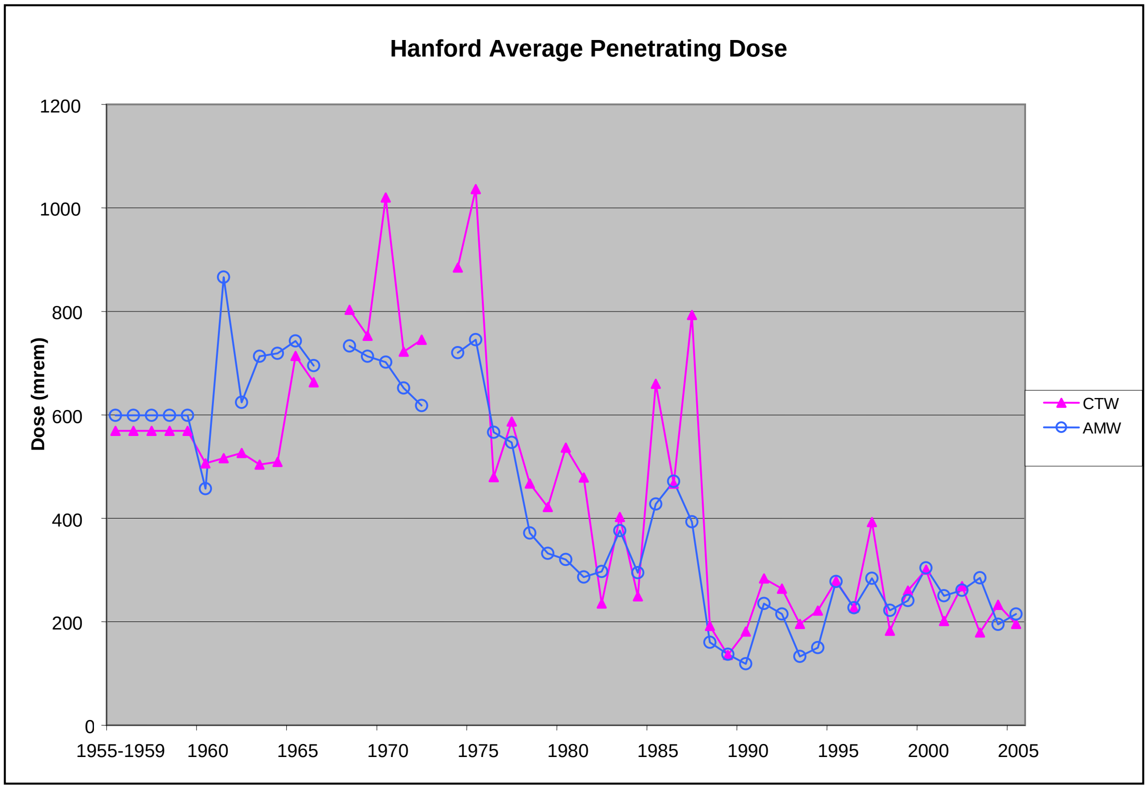

Figure 6-1. Average annual penetrating dose for Hanford.

Table 6-1. Observed ratios and average penetrating dose for CTWs and AMWs at Hanford.

	CTWs			AMWs		
Year	Number monitored	Number with measurable dose	Average dose (mrem)	Number with measurable dose	Average dose (mrem)	Observed ratios (CTWs/AMWs)
1970	1,365	1,158	1,020	10,053	702	1.5
1975	408	402	1,036	3,578	745	1.4
1978	1,917	1,864	467	6,882	372	1.3
1979	1,915	1,770	422	7,517	332	1.3
1980	1,585	1,437	537	6,917	320	1.7
1981	1,542	1,386	479	7,182	286	1.7
1985	1,642	808	660	5,954	427	1.5
1987	1,804	1,225	793	6,697	393	2.0
1990	934	428	181	3,753	119	1.5
1993	1,351	556	196	3,147	133	1.5
1994	1,696	567	222	3,166	150	1.5
1997	1,022	366	393	2,058	284	1.4

Sources: 1960–1973 from various Hanford letter reports (Foster at al. 1959–1973).
1975–1990 from DOE annual dose reports (DOE 1978, 1980a,b, 1982, 1983, 1984a,b, 1985, 1986, 1987, 1989, 1990; ERDA 1975, 1976; Smith et al. 1993)
1991–2005 from the DOE REMS database (DOE 2006)

highly exposed individuals were removed because these data are not truly representative of CTWs as a group. However, no attempt was made to remove all special (follow-up) results. This approach for reviewing and qualifying the data recognized that small intakes were essentially a part of routine operations. As in ORAUT (2012), results with volumes less than 400 mL were not used in the statistics.

The results were assumed to be lognormally distributed and were analyzed using the basic techniques for coworker studies described in ORAUT-OTIB-0019, *Analysis of Coworker Data for Internal Dose Assignment* (ORAUT 2005b). The resultant 50th- and 84th-percentile values were multiplied by 0.835 to convert total plutonium alpha to ^{239}Pu activity, assuming 10-year-aged fuel-grade plutonium. This conversion was necessary to make the results directly comparable to the values in ORAUT (2012).

The Hanford data forms included a field to enter the reason for the bioassay ("reason code"). Unfortunately, this field was not used consistently over the years in question; in addition, it was not reported in the Hanford coworker study. It appears that a high percentage of special bioassay samples might have biased the data for the years in which the data for CTWs are higher than the data for AMWs. The maximum difference between the CTW data and the AMW data was about a factor of 2 but, as evident in Figures 6-2 and 6-3, the difference varied from year to year. It appears that applying a factor of 2 to the intake rates in the Hanford coworker study is favorable to CTW claimants.

The results of the analysis and the data from ORAUT (2012) appear in Figures 6-2 and 6-3.

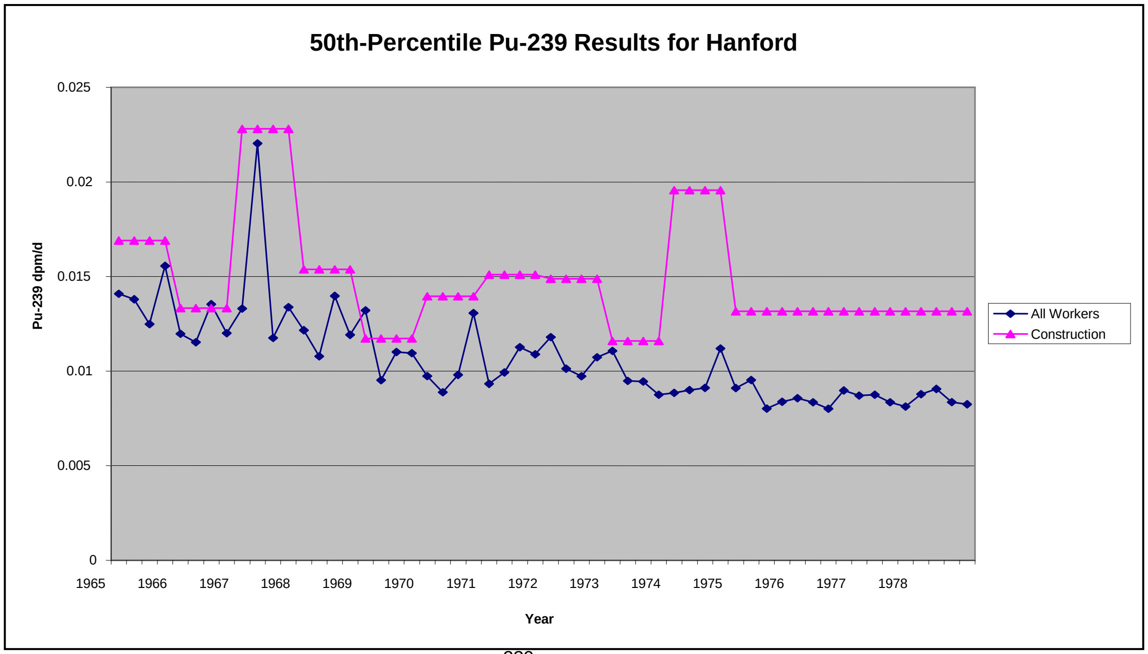

Figure 6-2. 50th-percentile results for ^{239}Pu in urine for Hanford.

6.3 PRESCRIBED EXTERNAL ADJUSTMENT FACTOR FOR ALL DOE FACILITIES

Due to limitations on the availability and specificity of CTW and AMW data from other DOE sites, this TIB presents a limited analysis and comparison of CTW and AMW data. To reconcile this limited data analysis with the site-specific comparisons that indicate that external doses to CTWs occasionally exceeded doses to AMWs, a prescribed adjustment factor is needed for dose reconstructions for unmonitored CTWs.

7.0 <u>CONCLUSIONS</u>

Comparisons between the doses received by CTWs and AMWs have shown that, with some exceptions and conditions, the doses received by the monitored CTWs were usually bounded by the doses received by AMWs on the same site.

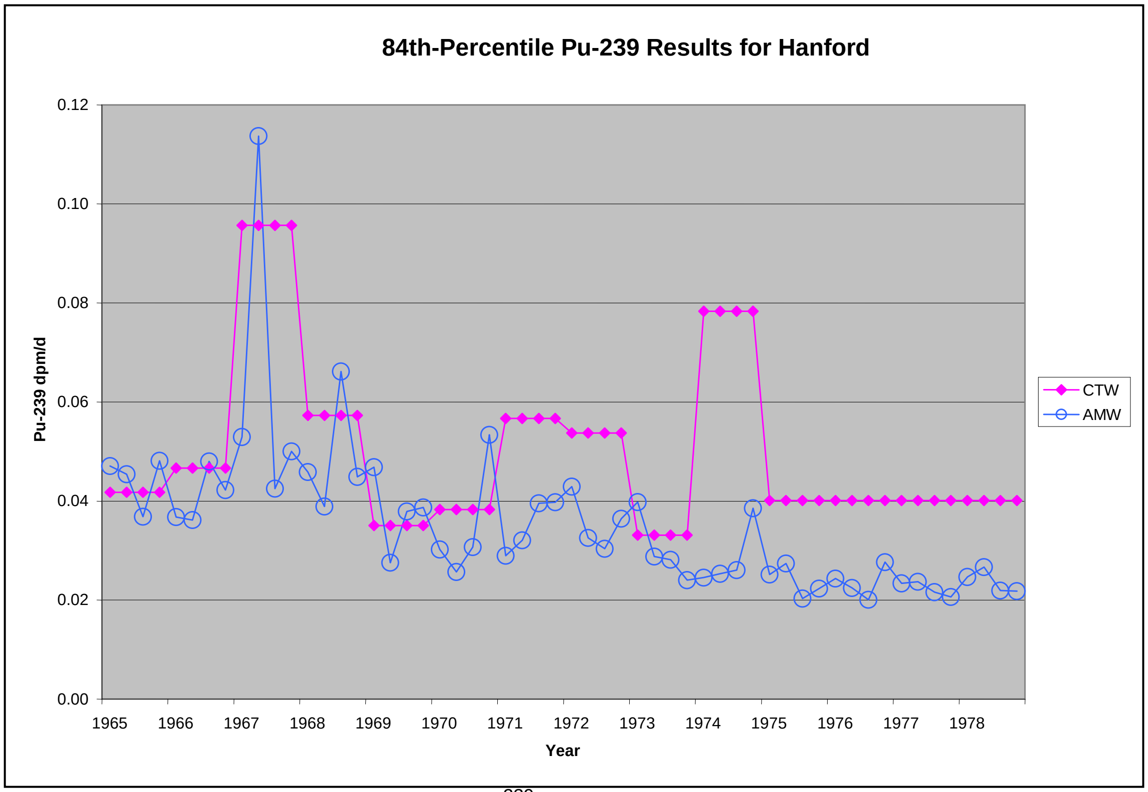

Figure 6-3. 84th-percentile results for ^{239}Pu in urine for Hanford.

This relationship between the doses received by CTWs and AMWs can be combined with the premise that the nature of the construction work (carpentry, masonry, pipefitting, etc.) performed by unmonitored CTWs was not significantly different (from a radiation protection perspective) from the construction work activities performed by monitored CTWs. Doses to monitored CTWs can, therefore, serve as an acceptable surrogate for doses to unmonitored CTWs.

An analysis of the specific DOE sites identified specific years that CTW doses exceeded AMW doses. To address these instances, an adjustment factor is needed. The factor is applicable to unmonitored CTWs who were employed by subcontractors or worked directly for the prime M&O contractor at any DOE site. These workers might have been brought on site by subcontractors or the prime M&O contractor to do construction work, but might not have been covered under the site's radiological protection program.

More accurate dose reconstructions are possible at sites with abundant dosimetry data. At sites for which data are lacking, dose reconstruction methods tend to produce higher bounding doses and to be more favorable to the claimant. Application of the guidance in this document along with the site-specific guidance available in TBDs results in dose reconstructions that are favorable to the unmonitored CTW claimant [10].

The prescribed external dose adjustment factor was based on consideration of the relative magnitude and trend in CTW and AMW doses shown in Figure 5-1, specifically:

- CTW doses occasionally exceeded AMW doses during the late 1980s and 1990s. However, this reflects work in the DOE complex when radiation protection programs were well established and nearly all potentially exposed workers were monitored. Further, these occasional exceedances have been identified as artifacts caused by a large number of AMWs with no measurable dose.

- CTW doses were significantly lower than AMW doses for an extended period that started in 1961. This indicates that the adjustment factor should be based on instances where CTW doses exceeded AMW doses before 1961.
- The values for pre-1961 adjustment factors range from 1.3 to 1.4.
- The maximum value of 1.4 was selected as the prescribed favorable to claimant external dose adjustment factor (i.e., dose multiplier) for all DOE facilities for all years.

8.0 LIMITATIONS AND APPLICATIONS

8.1 LIMITATIONS

The conclusions and adjustment factors in this document are limited to dose reconstructions for unmonitored CTWs at sites with applicable coworker data or an acceptable method for dose reconstruction for unmonitored workers. The adjustment factor is applicable to unmonitored CTWs who were employed by subcontractors or worked directly for the prime M&O contractor at any DOE site. These workers might have been brought on site by subcontractors or the prime M&O contractor to do construction work, but might not have been covered under the site's radiological protection program.

8.2 GUIDANCE ON THE DETERMINATION OF PENETRATING DOSE FOR UNMONITORED CONSTRUCTION TRADE WORKERS

Use the guidance in ORAUT-OTIB-0020 (ORAUT 2011a) to assign a penetrating dose that is favorable to unmonitored CTWs. Apply an adjustment factor of 1.4 to the appropriate percentile of the measured coworker data for the site, plus the assigned coworker missed dose, to determine the total assigned penetrating dose that is favorable to unmonitored CTWs.

8.3 GUIDANCE ON THE DETERMINATION OF NONPENETRATING DOSE FOR UNMONITORED CONSTRUCTION TRADE WORKERS

Based on the comparison from SRS and Rocky Flats Plant, the annual nonpenetrating doses in the other coworker studies can be used to assign annual nonpenetrating doses to those CTWs whose dose history is unavailable or incomplete.

Due to a lack of data, it was not possible to provide a comparison of nonpenetrating doses from Hanford. Dose reconstructors should not apply any adjustment factors for nonpenetrating dose.

8.4 GUIDANCE ON THE DETERMINATION OF INTERNAL DOSE

For Hanford dose reconstructions covered by this TIB, the intake rates in the Hanford coworker document should be multiplied by a factor of 2.

If coworker studies are available for other sites, assign a lognormal distribution with the dose equal to the 50th-percentile dose and assign the associated geometric standard deviation (GSD) to account for the possible variation in actual dose. The minimum value assigned to the GSD of a coworker data set is 3.

8.5 GUIDANCE ON THE DETERMINATION OF OCCUPATIONAL MEDICAL DOSE

Dose reconstructors should review the claim file for X-ray records.

If there are X-ray records in the file, the dose reconstructor should use the TBD for the site where the worker performed the work to assign X-ray dose. For example, a worker who worked for Atkinson/ Jones at Hanford could have X-ray records in his/her file. The X-ray dose should be assigned from the Hanford TBD organ dose tables. The dose from any X-rays in the records that appear to have been taken off site at a non-covered facility should NOT be included in dose reconstruction (ORAUT 2011b).

For sites with an indication of "X-ray records do not exist" and there are in fact no-X-ray records in the file or for sites that are not currently including X-ray records, such as Y-12 and INL, the dose reconstructor should use the TBD for the site where the worker performed the work to assign the frequency and dose or X-ray procedures that are clearly not a result of work-related injury.

9.0 ATTRIBUTIONS AND ANNOTATIONS

Where appropriate in this document, bracketed callouts have been inserted to indicate information, conclusions, and recommendations provided to assist in the process of worker dose reconstruction. These callouts are listed here in the Attributions and Annotations section, with information to identify the source and justification for each associated item. Conventional References, which are provided in the next section of this document, link data, quotations, and other information to documents available for review on the Project's Site Research Database (SRDB).

[1] Chew, Melton H. Oak Ridge Associated Universities (ORAU) Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-05.

[2] Chew, Melton H, and Morris. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close findings OTIB-0052-13 and OTIB-0052-14.

[3] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-08.

[4] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-10.

[5] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-11.

[6] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-11.

[7] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-12.

[8] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-12.

[9] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-12.

[10] Chew, Melton H. ORAU Team. Health Physicist, and Morris, Robert L. ORAU Team. Health Physicist. September 2010.
This change was made as a result of the July 21, 2008 Advisory Board Work Group on Procedures meeting to close finding OTIB-0052-11.

REFERENCES

AEC (U.S. Atomic Energy Commission), 1968, "Chapter 0524, Standards for Radiation Protection," *AEC Manual*, 0524-01, Washington, D.C., November 8. [SRDB Ref ID: 10668]

DOE (U.S. Department of Energy), 1961, TITLE, NTSO-0524, Nevada Test Site Office, Las Vegas, Nevada, June 26. [SRDB Ref ID: 132771]

DOE (U.S. Department of Energy), 1978, *Ninth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1976*, DOE/EV-0066/9, Washington, D.C., April. [SRDB Ref ID: 26903]

DOE (U.S. Department of Energy), 1980a, *Tenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1977*, DOE/EV-0066/10, Washington, D.C., March. [SRDB Ref ID: 26902]

DOE (U.S. Department of Energy), 1980b, *Twelfth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1979*, DOE/EV-0066/12, Assistant Secretary for Environment, Washington, D.C., December. [SRDB Ref ID: 16121]

DOE (U.S. Department of Energy), 1982, *Thirteenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1980*, DOE/EP-0040, Washington, D.C., February. [SRDB Ref ID: 26888]

DOE (U.S. Department of Energy), 1983, *Fourteenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1981*, DOE/EP-0040/1, Washington, D.C., March. [SRDB Ref ID: 26890]

DOE (U.S. Department of Energy), 1984a, *Fifteenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1982*, DOE/EP-0040/2, Washington, D.C., February. [SRDB Ref ID: 26892]

DOE (U.S. Department of Energy), 1984b, *Sixteenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1983*, DOE/PE-0072, Washington, D.C., October. [SRDB Ref ID: 26895]

DOE (U.S. Department of Energy), 1985, *Seventeenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1984*, DOE/EH-0011, Washington, D.C., December. [SRDB Ref ID: 26896]

DOE (U.S. Department of Energy), 1986, *Eighteenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1985*, DOE/EH-0036, Washington, D.C., December. [SRDB Ref ID: 26897]

DOE (U.S. Department of Energy), 1987, *Nineteenth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1986*, DOE/EH-0069, Washington, D.C., December. [SRDB Ref ID: 26898]

DOE (U.S. Department of Energy), 1989, *Twentieth Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1987*, DOE/EH-0128, Washington, D.C., October. [SRDB Ref ID: 26899]

DOE (U.S. Department of Energy), 1990, *Twenty-First Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1988*, DOE/EH – 0171P, Washington, D.C., December. [SRDB Ref ID: 26900]

DOE (U.S. Department of Energy), 2006, *The United States Department of Energy's Web Page for Information on Radiation Exposure Monitoring Systems*. http://www.eh.doe.gov/rems/, accessed 1986-2005.

ERDA (U.S. Energy Research and Development Administration), 1975, *Seventh Annual Report, Radiation Exposures for AEC and AEC Contractor Employees – 1974*, ERDA-76/119, Washington, D.C. [SRDB Ref ID: 26905]

ERDA (U.S. Energy Research and Development Administration), 1976, *Eighth Annual Report, Radiation Exposures for ERDA and ERDA Contractor Employees – 1975*, ERDA-77-29, Washington, D.C. [SRDB Ref ID: 26904]

Foster, R. F., A. R. Keene, K. R. Heid, C. M. Unruh, and H. V. Larson, 1959–1973, "Hanford Annual Radiation Summary Letter Reports". [SRDB Ref ID: 26116]

Helmberg, R. L., 1974, untitled letter to Contracting Officer (U.S. Atomic Energy Commission, Burlington AEC Plant) with attachment “Summary of Whole-Body Radiation Exposures to External Penetrating Radiation Accumulated During the Year” (AEC Form 190), Mason & Hangar-Silas Mason Company, Burlington, Iowa, February 12. [SRDB Ref ID: 828, p. 2]

Horan, J. R. and J. B. Braun, 1993, *Occupational Radiation Exposure History of Idaho Field Office Operations at the INEL*, EGG-CS-11143, EG&G Idaho, Idaho National Engineering Laboratory, Idaho Falls, Idaho, October. [SRDB Ref ID: 1023]

Keene, A. R., 1960, *Analysis of the Distribution of Externally Received Radiation at Hanford, 1944-1959,* HW-SA-1933, General Electric Company, Richland, Washington. [SRDB Ref ID: 24381]

Schubauer-Berigan, M. K., G. V. Macievic, D. F. Utterback, C-Y. Tseng, and J. T. Flora, 2005, *An Epidemiologic Study of Mortality and Radiation-Related Risk of Cancer Among Workers at the Idaho National Engineering and Environmental Laboratory, a U.S. Department of Energy Facility*, 2005-131, National Institute for Occupational Safety and Health, January. [SRDB Ref ID: 33197]

NRC (National Research Council), 1989, *Film Badge Dosimetry in Atmospheric Nuclear Tests*, National Academy of Sciences, National Academy Press, Washington D.C. [SRDB Ref ID: 1905]

ORAUT (Oak Ridge Associated Universities Team), 2005a, *Savannah River Site*, ORAUT-TKBS-0003, Rev. 03, Oak Ridge, Tennessee, April 5.

ORAUT (Oak Ridge Associated Universities Team), 2005b, *Analysis of Coworker Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 01, Oak Ridge, Tennessee, October 7.

ORAUT (Oak Ridge Associated Universities Team), 2007, *Rocky Flats Plant – Occupational Internal Dose*, ORAUT-TKBS-0011-5, Rev. 02, Oak Ridge, Tennessee, August 17.

ORAUT (Oak Ridge Associated Universities Team), 2010, *Hanford Site – Occupational External Dose*, ORAUT-TKBS-0006-6 Rev. 04, Oak Ridge, Tennessee, January 7.

ORAUT (Oak Ridge Associated Universities Team), 2011a, *Use of Coworker Dosimetry Data for External Dose,* ORAUT-OTIB-0020, Rev. 03, Oak Ridge, Tennessee, November 14.

ORAUT (Oak Ridge Associated Universities Team), 2011b, *Guidance on Assigning Occupational X-Ray Dose Under EEOICPA for X-Rays Administered Off Site,* ORAUT-OTIB-0079, Rev. 00, Oak Ridge, Tennessee, January 3.

ORAUT (Oak Ridge Associated Universities Team), 2012, *Hanford Site – Occupational Internal Dose*, ORAUT-TKBS-0006-5 Rev. 05, Oak Ridge, Tennessee, November 5.

SC&A (S. Cohen & Associates) 2007, Review of ORAUT-OTIB-0052, *Parameters to Consider when Processing Claims for Construction Trade Workers*, SCA-TR-TASK3-0004, DRAFT July 30. [SRDB Ref ID: 88584]

Smith, M. H., T. E. Hui, W. H. Millet, and V. A. Scholes, 1993, *Twenty-third Annual Report, Radiation Exposures for DOE and DOE Contractor Employees – 1990*, DOE/EH-0287P, Pacific Northwest Laboratory, Richland, Washington, March. [SRDB Ref ID: 22395]

Watkins, J. P., D. L. Cragle, E. L. Frome, J. L. Reagan, C. W. West, D. J. Crawford-Brown, and W. G. Tankersley, 1997, “Collection, Validation, and Treatment of Data for a Mortality Study of Nuclear Industry Workers,” *Applied Occupational and Environmental Hygiene*, volume 12, number 3, pp. 195–205.