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Internal Coworker Dosimetry Data for the Savannah River Site	ORAUT-OTIB-0081	Rev. 03
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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
02/08/2013	00	New technical information bulletin to provide internal coworker data for the Savannah River Site. Incorporates formal internal and NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by Matthew Arno.
04/01/2013	01	Revision initiated to correct the values provided in Tables 5-6, Type S uranium intake rates for 1968 through 2007, 5-10, changed end date from 2006 to 2007, A-3, plutonium bioassay data for 1955 through 2007, and A-8, neptunium bioassay data for 1991 through 2007. Incorporates formal internal review comments. No changes were made as a result of formal NIOSH review. No sections were deleted. Training required: As determined by the Objective Manager. Initiated by Matthew G. Arno.
12/16/2013	02	Revision initiated to add dose reconstruction guidance for radionuclide assignment in response to an ABRWH request. Text added in Section 5.0 and a new Table 5-1 added. Intake rates for Cm and Cf added for the pre-1995 time period. Incorporates formal internal and NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by Matthew G. Arno.
11/22/2016	03	Revision initiated to address the coworker study Implementation Guide requirements for americium, thorium, and tritium. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Matthew G. Arno.

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ACRONYMS AND ABBREVIATIONS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AQL	acceptance quality level
CPF	Californium Processing Facility
cpm	counts per minute
CTW	construction trade worker
d	day
D&D	decontamination and decommissioning
DCAS	Division of Compensation Analysis and Support
DDCP	dibutyl N,N-diethylcarbamylphosphonate
DOE	U.S. Department of Energy
dpm	disintegrations per minute
DTPA	diethylene triamine pentaacetic acid
DWPF	Defense Waste Processing Facility
E&I	electrician and instrument
ETF	Effluent Treatment Facility
EU	enriched uranium
FP	fission product
g	gram
GM	geometric mean
GSD	geometric standard deviation
HDEHP	bis-(2-ethylhexyl) phosphoric acid-toluene
HLC	high-level cave
HP	health physics
HPRED	Health Protection Radiation Exposure Database
hr	hour
HTO	tritiated water vapor
IA	induced activity
ID	identification (number)
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
L	liter
LIP	lost in process
LTPD	lot tolerance percent defective
MDA	minimum detectable amount or activity
MFP	mixed fission product
MFPG	mixed fission product-gamma
mL	milliliter
nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH-Division of Compensation Analysis and Support Claims Tracking System

NP	neptunium (analysis)
NU	natural uranium
OPOS	one person – one sample
ORAU	Oak Ridge Associated Universities
pCi	picocurie
PEF	$^{238}PuO_2$ Experimental Facility
PRID	payroll ID
PSF	Plutonium Storage Facility
PuFF	$^{238}PuO_2$ Fuel Form Facility
PUREX	plutonium-uranium extraction
QA	quality assurance
RBOF	Receiving Basin for Off-Site Fuel
REAC/TS	Radiation Emergency Assistance Center/Training Site
RRF	Resin Regeneration Facility
SEC	Special Exposure Cohort
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
SWDF	Solid Waste Disposal Facility
TIB	technical information bulletin
TIOA	triisooctylamine
TWOPOS	time-weighted one person – one sample
U.S.C.	United States Code
WBC	whole-body count
yr	year
α	producer’s risk (ORAU Team risk)
β	consumer’s risk (DCAS risk)
µCi	microcurie
µm	micrometer
§	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). 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)].

ORAUT-OTIB-0019, *Analysis of Coworker Bioassay Data for Internal Dose Assignment* (ORAUT 2005a), describes the general process NIOSH uses to analyze bioassay data for the assignment of doses to individuals based on coworker results. ORAUT-PLAN-0014, *Coworker Data Exposure Profile Development* (ORAUT 2004a), describes the approach and processes to develop reasonable exposure profiles based on available dosimetric information for workers at DOE sites. *Interim Guidance Criteria for the Evaluation and Use of Coworker Datasets* (NIOSH 2015) provides the criteria to evaluate the adequacy and completeness of coworker data. In the sections below, the data and evaluations required by the guidance are provided for each evaluated radionuclide.

Bioassay data in the NIOSH-Division of Compensation Analysis and Support Claims Tracking System (NOCTS) for Savannah River Site (SRS) employees was used to develop a representative database of coworker bioassay data using the guidance of ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling* (ORAUT 2016a), and NIOSH (2015).

A statistical analysis of the data was performed according to ORAUT-OTIB-0019 (ORAUT 2005a) and ORAUT-RPRT-0053, *Analysis of Stratified Coworker Datasets* (ORAUT 2014b). The results were entered in the Integrated Modules for Bioassay Analysis (IMBA) computer software to obtain intake rates for the assignment of dose distributions.

2.0 PURPOSE

Some employees at DOE sites were not monitored for potential intakes of radioactive material, or the records of such monitoring are incomplete or unavailable. In such cases, data from monitored coworkers can be used to assign an internal dose to address potential intakes of radioactive material. The purpose of this TIB is to provide monitored coworker information for calculating and assigning occupational internal doses to employees at SRS for whom no or insufficient monitoring records exist.

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 6.0.

3.0 GENERAL METHODS

This section provides information on the general selection characteristics of the data and methods of analysis. More detailed radionuclide-specific information is provided in Section 4.0.

3.1 DATA SOURCES

There are two basic data sources for the coworker study. The first is NOCTS bioassay data from energy employees who worked at SRS. The second is data from laboratory logbooks for americium and neptunium. For these radionuclides, there is insufficient NOCTS bioassay data available to perform a coworker study. The NOCTS sources are discussed in this section and the logbook data sources are discussed in the radionuclide-specific discussions below.

For each data source, the data entry process was subjected to quality assurance checks in accordance with ORAUT 2016b. This report describes a sampling plan that computes "transcription" error rates, which quantify the degree to which an electronic dataset agrees with the original hardcopy records. The sampling plan is used to select a representative sample of the data and to estimate the transcription error rates. Statistical sampling techniques in which a comparison of the electronic dataset to the original data is performed after the transcription is complete is used to confirm that the specified unacceptable error rates have not been exceeded and to generate error rate confidence intervals. Sampling plans for "critical" fields are created with an unacceptable error rate of 1% or higher, while plans for "all" fields have an unacceptable error rate of 5% or higher. Critical fields are those fields containing an analytical result or that are used to identify and individual (payroll identification number).

3.1.1 Completeness of Claims Tracking System Data

For the period before availability of the HPRED data (before 1991), NOCTS data was used as the best available compilation of data in a usable form (i.e., electronic spreadsheet or database). This dataset contained 260,412 tritium bioassay results and 260,607 non-tritium bioassay results for samples submitted by 1,520 workers between 1954 and 1990. NOCTS data is not complete. However, the NOCTS data is assumed to be a random sampling that can be considered a representative database of coworker bioassay data based on the analysis in ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling* (ORAUT 2016a). This analysis demonstrated that, for three evaluated cases, claimant datasets can be considered to be random samples of the complete dataset and that the justification provided the basis for applying this assumption to other sites and datasets.

3.2 STRATIFICATION

Two classifications of workers were evaluated: construction trade workers (CTWs) and non-construction trade workers (nonCTWs). CTWs at SRS, also referred to as building trades workers, fit into two categories. The first consists of workers hired by the site prime contractor tending to stay in mostly permanent employment, while the second consists of workers brought in temporarily and often for short periods to perform specific tasks. Many of the workers in the second category have repeat temporary employment at either SRS or other DOE sites. From the onset of construction at SRS through 1989, workers in the first category were employed by DuPont while workers in the second category were employed by subcontractors such as B.F. Shaw Company, Miller-Dunn Electric Company, and North Brothers Company. CTWs in the first category were assigned to DuPont Roll number 2. Workers in the second category were assigned to Roll 4 and some to Roll 5 and were assigned a two-digit craft code. For example, craft code 20 was "boilermaker" (DuPont 1954). In 1989, Bechtel Savannah River took over construction duties at SRS. Bechtel tended to use CTWs hired through subcontracted companies rather than direct hire.

3.2.1 Worker Classification Background

At SRS, CTWs were deployed temporarily but frequently for short periods to perform specific tasks usually pertaining to facility construction and modification, system maintenance, and decontamination. These types of jobs were performed by workers in both categories. Workers from both categories worked around the site, while production and operation staff normally worked at fixed locations. While workers assigned to Roll 2 were employed directly by DuPont Construction and Bechtel Savannah River, workers in Rolls 4 and 5, or subcontractors, were employed at SRS for periods ranging from a few days to years. One electrician (NOCTS Claim redacted) worked lengthy periods between 1958 and 1975, while another (NOCTS Claim redacted) worked varying periods from 1955 through 1966. Workers from each of the rolls were assigned to do jobs. Some tasks, such as painting, were mostly performed by workers in Roll 4 and some in Roll 5, while others such as instrument maintenance were mostly performed by workers in Roll 2. Maintenance and decontamination type tasks shared common exposure profiles where workers, in some of the jobs, could be exposed to higher levels of radiation from surface and/or airborne contamination.

Bingham et al. (1997) stated that DOE in Congressional testimony said it is likely that the greatest risks to workers on its sites involve mainly the construction workers, including those who are involved in decommissioning, dismantling of facilities, and in maintenance or repair activities. According to SRS procedures, Health Physics (HP) provided the same level of job planning and monitoring to these tasks as it did with operation and production tasks (DuPont 1959–1971, DuPont undated a). HP surveyed and collected air monitoring samples in all areas where release of contamination was possible. NIOSH has collected air monitoring data for areas where known CTW work was performed. Examples of personal monitoring include monitoring of a job by a CTW on Roll 4, subsequent monitoring on CTW contamination in a job in H Area in 1972 (DuPont 1972), and monitoring of two CTW workers on Roll 2 contaminated in a similar job in F Area in 1974 (DuPont 1974). Two Roll 2 CTW workers were exposed to high concentrations of airborne curium contamination while working in Savannah River Laboratory in 1978 (DuPont undated c). In 1979, a Roll 4 CTW received an intake of radioactive material while removing a hood at Savannah River Laboratory (DuPont undated c). These examples and others show that CTW workers in Rolls 2, 4, and 5 were subjected to similar potential paths of radiation exposure and that both were monitored. External dose and bioassay data received from the Department of Energy (DOE) for former SRS workers also support both of those.

Therefore, permanent workers in Roll 2 who performed maintenance or decontamination tasks should be included in the same cohort as workers who performed such type of tasks from Roll 4 or 5. Including both groups is supported by work previously done within the DOE complex. In *Surveillance of Former Construction Workers at Oak Ridge Reservation*, the authors identified two categories of CTWs very similar to the two categories at SRS but included workers from both categories in one CTW population for surveillance and evaluation (Bingham et al. 1997). In *Savannah River Building Trades Medical Screening Program: A Needs Assessment*, the authors' intended population was "building and CTWs who have been employed mainly by subcontractors at DOE sites" but included workers that had mostly permanent employment with the construction subcontractors. While that definition does not specifically include building trade workers employed by DuPont Construction, those workers performing building and construction trades should be included because the report's goal was those "mainly" employed by subcontractors. Lastly, the website for the DOE-funded Building Trades National Screening Program states this as the criteria for being included as a CTW (CPWR 2016):

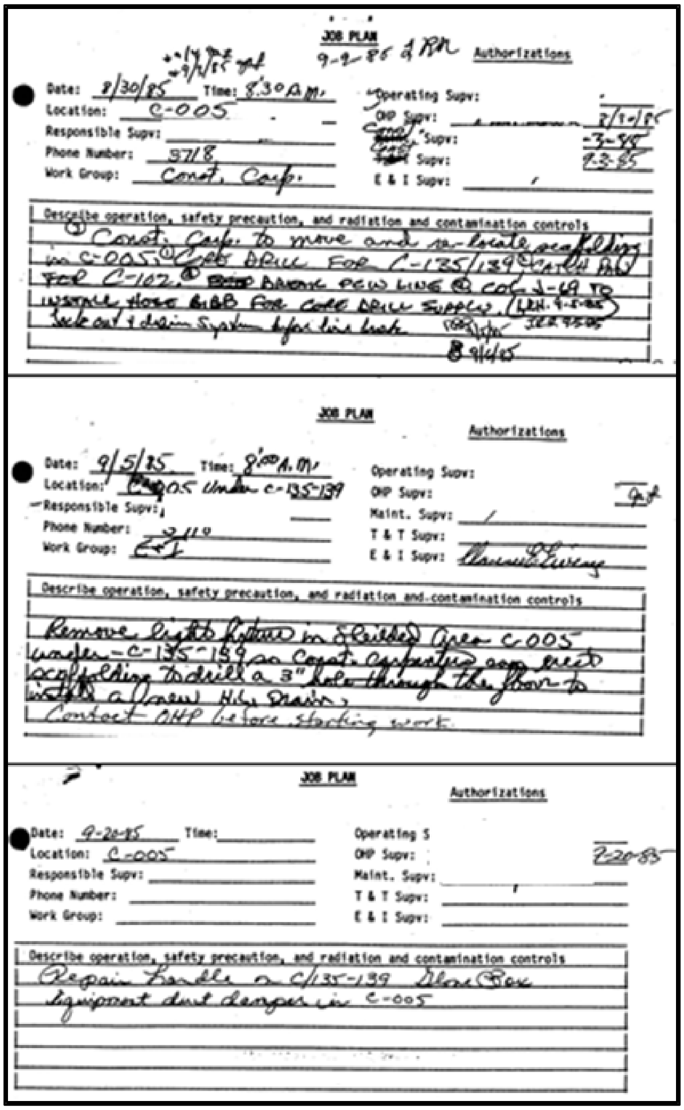
> *You performed construction work (for either the prime contractor or subcontractors) at any time in the past at any of the following: Atomic Energy Commission (AEC) or Department of Energy (DOE) sites associated with the research or production of nuclear weapons.*

The population of CTWs at SRS includes people that worked for the prime and subcontracted construction contractors. A previous SRS employee of DuPont made the following statement in a worker outreach meeting in 2008 (NIOSH 2008, p. 13):

> *[Name Redacted] stated that although the site profile accounts for missed dose, he believes that NIOSH cannot account for the missed dose for unmonitored workers who were in and out of the "hot" areas all the time. [Name Redacted] explained that the E&I mechanics were like the construction workers named in the proposed SEC* [Special

> Exposure Cohort] *class in that they did not work in a specific area like the production workers did.*

While the occupation “E&I mechanic” was cited by the former worker, other prime contractor craftspeople worked across the site performing maintenance type tasks. Portions of three job plans for a set of connected work in Building 773-A Rooms C-135/C-139 are shown in Figure 3-1. Work was performed by construction carpenters, E&I mechanics, and maintenance mechanics, which supports the premise that both DuPont and subcontracted CTWs performed similar work for short periods across SRS. Additional examples are shown in Attachment D.



JOB PLAN

9-9-85 [illegible]

Authorizations

Date: 8/30/85 Time: 8:30 A.M.
Location: C-005
Responsible Supv:
Phone Number: 5718
Work Group: Const. Carp.

Operating Supv:
OHP Supv: 9/10/85
Const. Supv: 9-3-85
Const. Supv: 9-3-85
E & I Supv:

Describe operation, safety precaution, and radiation and contamination controls
① Const. Carp. to move and re-locate scaffolding in C-005. ② Core drill for C-135/139 ③ Catch pan for C-102. ④ Break PCW line @ col. J-69 to install hose bibb for core drill supply. (LEH 9-5-85)
Lock out & drain system before line break [illegible] 9-5-85
9/6/85

JOB PLAN

Authorizations

Date: 9/5/85 Time: 8:00 A.M.
Location: C-005 Under C-135-139
Responsible Supv:
Phone Number: 2110
Work Group: E&I

Operating Supv:
OHP Supv:
Maint. Supv:
T & T Supv:
E & I Supv:

Describe operation, safety precaution, and radiation and contamination controls
Remove light fixture in Shielded Area C-005 under C-135-139 so Const. carpenters can erect scaffolding to drill a 3" hole through the floor to install a new HL Drain.
Contact OHP before starting work.

JOB PLAN

Authorizations

Date: 9-20-85 Time:
Location: C-005
Responsible Supv:
Phone Number:
Work Group:

Operating S
OHP Supv: 9-20-85
Maint. Supv:
T & T Supv:
E & I Supv:

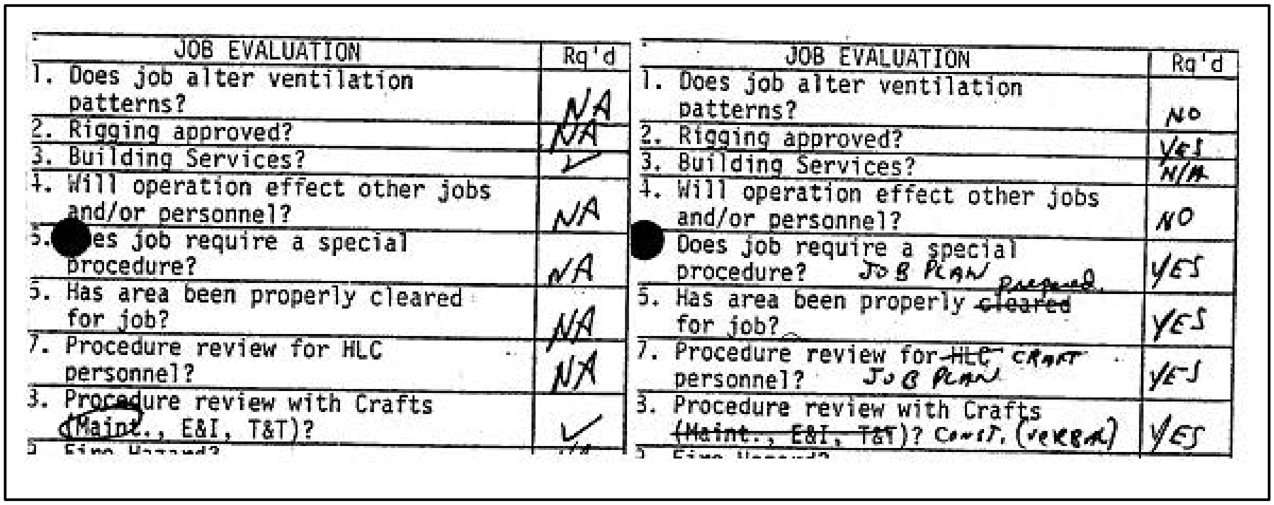
Describe operation, safety precaution, and radiation and contamination controls
Repair handle on C/135-139 Glove Box
Equipment dust damper in C-005

Figure 3-1. Job Plans.

SRS HP treated construction and DuPont Roll 2 crafts the same by procedure for job evaluation as evidenced in Figure 3-2. As stated, workers in the CTW population would perform frequent tasks of generally short duration that could nevertheless present a potential for external and internal radiation exposure. Bingham et al. (1997) provided the following set of workers for the Oak Ridge study.

- Carpenters
- Ironworkers
- Electricians

- Painters
- Asbestos Workers or Insulators
- Pipefitters or Steamfitters
- Cement Masons
- Laborers
- Bricklayers
- Boilermakers
- Mechanics or Millwrights
- Operating Engineers or Heavy Equipment Operators
- Sheet Metal Workers
- Roofers
- Truck Drivers



JOB EVALUATION	Rq'd
1. Does job alter ventilation patterns?	NA
2. Rigging approved?	NA
3. Building Services?	✓
4. Will operation effect other jobs and/or personnel?	NA
5. [illegible]es job require a special procedure?	NA
5. Has area been properly cleared for job?	NA
7. Procedure review for HLC personnel?	NA
3. Procedure review with Crafts (Maint., E&I, T&T)?	✓

JOB EVALUATION	Rq'd
1. Does job alter ventilation patterns?	NO
2. Rigging approved?	YES
3. Building Services?	N/A
4. Will operation effect other jobs and/or personnel?	NO
Does job require a special procedure? JOB PLAN Prepared	YES
5. Has area been properly ~~cleared~~ for job?	YES
7. Procedure review for ~~HLC~~ CRAFT personnel? JOB PLAN	YES
3. Procedure review with Crafts ~~(Maint., E&I, T&T)~~? CONST. (VERBAL)	YES

Figure 3-2. Procedure review with Crafts, DuPont, and Construction.

For SRS, the Center to Protect Workers' Rights compiled the following list in Bingham et al. (1997). It identified the same list, although laborers, roofers, and truck drivers were identified by their unions. Truck drivers meet the criteria of a CTW at Savannah River Site. They frequently hauled radioactive wastes to the tank farms, to the burial grounds or to the burning pits. Workers with the job title E&I Mechanic went to areas of the site to perform installation, maintenance, and repair of control and measurement equipment; they had a similar exposure profile to that of electricians and mechanics.

Table 3-1 lists the job titles from SRS that should be included in CTW data population. This list includes all the occupations in the list of construction worker trades in ORAUT-OTIB-0052, *Parameters to Consider When Processing Claims for Construction Trade Workers* (ORAUT 2014c). SRS payroll number and craft code (DuPont 1954) are included.

3.2.2 **Worker Classification Methodology**

The determination of whether an individual is a CTW is based on the person's payroll identification (ID) number prefix and their occupation. The payroll ID prefix is the primary designator, but the occupation title is used to exclude or include some occupations where the payroll ID prefix would otherwise erroneously indicate the person is or is not a CTW. The method consists of using the payroll ID number associated with the bioassay data for which a CTW determination is needed, if available, and an occupation title extrapolated from the datasets for which those occupation titles are available. For this coworker study, workers were considered CTWs if they had a Roll 4 or higher payroll ID prefix, except if their job title was one of the nonCTW job titles in Table 3-2. If no Roll code

Table 3-1. Construction trade crafts with roll and craft codes.

Craft	Roll and craft code
Boilermaker	Roll 4, craft code 20
Carpenter	Roll 2, 4, craft code 6
Concrete Worker (or cement worker or mason)	Roll 4, craft code 8
Construction Worker	Roll 4
Driver	Roll 2, 4, craft code 10
E&I Mechanic	Roll 2
Electrician	Roll 2
Heavy Equipment Operator	Roll 2, 4, craft code 14
Insulator	Roll 2, 4, craft code 31
Ironworker	Roll 2, 4, craft code 21
Laborer	Roll 2, 4, craft code 5
Mechanic	Roll 2
Millwright	Roll 2, 4, craft code 18
Painter	Roll 2, 4, craft code 33
Pipefitter (or plumber)	Roll 2, 4, craft code 26
Rigger (or Laborer)	Roll 2, 4, craft code 5
Roofer	Roll 2, 4
Sheetmetal Worker	Roll 2, 4, craft code 21

Table 3-2. CTW determination job titles.

CTW occupations
Boilermaker
Carpenter
Concrete worker
Construction worker
Driver
E&I Tech
Electrician
Heavy equipment operator
Insulator
Ironworker
Laborer
Maintenance
Mechanic
Painter
Rigger
Sheetmetal worker
Welder

nonCTW occupations
Machinist
Security
Engineer
Clerical
Pilot
Instructor
Manager
Human Resources
Supervisor
Escort
Laundry
HP

nonCTW occupations
Administrative Assistant
Specialist
Assistant
Layout
Reactor Operator
QA
Cafeteria

is available, the person is assumed to be Roll 2 and the designation is made based on the occupation title.

There are two applications of this methodology.

1. Self-contained dataset. A dataset internally containing all the data necessary to make the CTW determination. The datasets that meet this description are the americium and neptunium logbook data and the NOCTS whole-body count (WBC) data. In these cases, the worker's occupation title has been directly obtained from the worker history cards on each bioassay date. The datasets also contain the payroll ID number, which is also verified from the worker history cards. CTW determinations are directly made from this information.

2. Dataset without occupation titles and/or payroll ID numbers. The datasets that meet this description are the NOCTS in vitro data (other than tritium) and the NOCTS tritium data, which is a separate dataset. The NOCTS in vitro data is the source for plutonium, uranium, and strontium plus fission product (FP) bioassay data. In these cases, the following procedure is followed to make the CTW determination.

    - Create a "master" occupation and payroll ID lookup table by merging:

        - Americium logbook data
        - Neptunium logbook data
        - NOCTS WBC data
        - ORAUT-RPRT-0058 in vitro data

    - Determine individual's name from NOCTS based on the claim number for a given bioassay sample (tritium dataset only)

    - For each bioassay result in the dataset (NOCTS in vitro or tritium data), find the bioassay date preceding or closest to it within 5 years for that person in the master lookup table. Base the lookup on the payroll ID number if available or the person's name otherwise.

    - If a preceding or closest bioassay date within 5 years is found:

        - Assign the occupation title (and payroll ID number if needed) from the bioassay date in the master lookup table to the bioassay result.

    - If no preceding or closest bioassay data within 5 years is found (person not listed in the master lookup table):

        - Manually look up the occupation title and payroll ID number (if needed) on the bioassay date from the worker history cards.

- Make the CTW determination based on the payroll ID number and assigned occupation title.

For this revision, the MFP analysis was based on the source NOCTS data rather than the ORAUT-RPRT-0058 in vitro data created specifically for the MFP stratification report (ORAUT 2012b). This is due to changes in how MFPs were evaluated. Therefore, the only future use of this dataset is via its inclusion in the master lookup table described above. Similarly, the neptunium data for the neptunium stratification report (ORAUT 2012a) has no future use.

3.2.3 Worker Classification Quality Assurance

As discussed above, a Master Occupation Table was compiled from four data sources: americium logbook data, neptunium logbook data, NOCTS WBC data, and ORAUT-RPRT-0058 in vitro data. The data entry accuracy for each of these sources was evaluated in accordance with ORAUT-RPRT-0078, *Technical Basis for Sampling Plan* (ORAUT 2016b); the fields containing the payroll ID number and the numerical sample results were evaluated with a maximum 1% allowable error rate. All other fields from the hardcopy records were evaluated with a maximum 5% allowable error rate. Each dataset passed the quality assurance (QA) check, the results of which are summarized in Table 3-3. The details of the results of the evaluation are contained in Attachment E.

Table 3-3. Master Occupation Table data source QA check results.

Data source	1% check results (95% confidence interval)	5% check results (95% confidence interval)
Americium logbook data	0.59% (0.39%–0.86%)	0.69% (0.25%–1.49%)
Neptunium logbook data	0.67% (0.46%–0.95%)	1.53% (0.83%–2.59%)
NOCTS WBC data	0.62% (0.41%–0.89%)	2.17% (1.31%–3.37)
ORAUT-RPRT-0058 in vitro data	0.43% (0.27%–0.67%)	0.12% (0.0042%–0.65%)

3.3 EVALUATION OF MISSED DOSE

For individual dose reconstructions, missed dose is assigned based on results that are less than the minimum detectable activity or amount (MDA) or reporting level of the results and fitted dose is typically separately assigned based on results above this level. For internal dose coworker studies, missed and fitted dose are addressed simultaneously by the use of all bioassay data regardless of whether an entry is above or below the MDA. The actual uncensored <MDA results are used where available, and the techniques used to fit distributions to censored datasets in ORAUT-RPRT-0053 (ORAUT 2014b) are used otherwise. This is consistent with the general guidelines in Section 3.4.2 of ORAUT-OTIB-0060 (ORAUT 2014a).

4.0 RADIONUCLIDE ANALYSES

4.1 AMERICIUM

4.1.1 Data Adequacy

4.1.1.1 Personnel Monitoring

DuPont specified bioassay operating guides, sampling frequencies, and related administrative controls in a *Bioassay Control* procedure. The earliest available version of the procedure is Revision 2 dated January 2, 1968 (DuPont 1968). It indicates an americium sample size of 500 mL was used with a “positive result” level of 1 dpm/250 mL and a resample level of 5 dpm/250 mL. The procedure does not specify americium sampling frequencies. The sample request process indicates that 24-hour composite samples required approval by an HP Senior Supervisor or above, indicating that routine samples were probably not 24-hour samples.

In Revision 3 of the *Bioassay Control* procedure (DuPont 1970), the positive level for total activity from trivalent actinides (americium, curium, and californium) was noted as 0.3 dpm/1.5L and the sample value was used for the resample level. The sample size was reduced to 250 mL. An intake was considered confirmed if the initial bioassay results was >1 dpm/1.5L and a resample was >0.3 dpm/1.5L. The sampling frequencies for various personnel are provided in Attachment A. The process for requesting samples was similar to the previous process, but approval of an HP Senior Supervisor or above was no longer required for 24-hour samples. Additional instructions were provided for collecting samples in the event of suspected inhalations, ingestions, injections, skin contaminations, or whenever airborne contamination exceeded control guides. In 1971, additional guidance for construction division personnel was added but with no specific guidance for trivalent actinides. “Other nuclides,” which would have included the trivalent actinides, were monitored as specified by area HP in the construction job plans (DuPont 1971a).

The periodicity of urine sampling changed throughout the 1970s for various work locations and as a result of the introduction of in vivo counting (DuPont 1971a, 1971b, 1976). The sampling frequencies for various personnel at various times are provided in Attachment A.

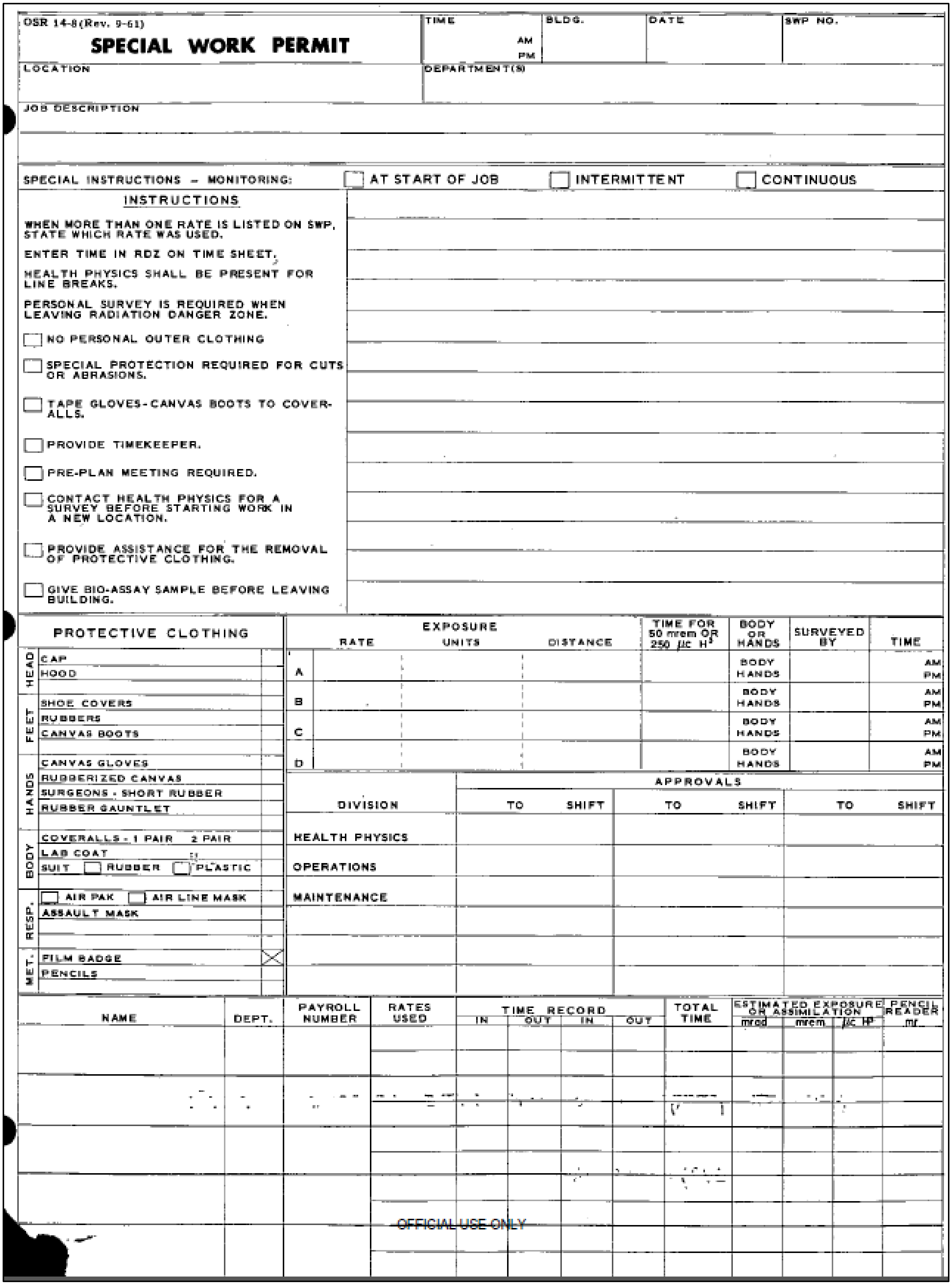
The *1990 Internal Dosimetry Technical Basis Manual* monitoring program for trivalent actinides specified quarterly urine bioassay, an annual chest count, semiannual fecal bioassay, and personal air sampling (WSRC 1990). If monitored by workgroup, the urine bioassay decreased to annually unless a member of the workgroup had a confirmed intake. Trivalent actinide monitoring was required for the F-Area New Special Recovery facility.

4.1.1.2 Applicability to Unmonitored Workers

Records of in vitro bioassay for trivalent actinides show urinalysis data back to about 1963. As discussed above in the description of the sample collection process, there was guidance for whom to sample by 1970, which is consistent with a substantial increase in the number of collected samples in 1969. With additional experience and history, the number of collected samples, both by workers in the monitoring program and frequency of samples decreased as can be seen in Table 4-1. The sampling frequency decreased during this same period as detailed in Tables A-2 through A-8, resulting in some of the decrease in the total number of samples per year. The inference is that the increased sampling during the early 1970s provided the basis for selection of those worker groups, work locations, and job classifications for which trivalent actinide monitoring was needed and for an appropriate sampling frequency. The transition to workgroup monitoring in the 1980s also resulted in a reduction in the number of samples collected.

DuPont workers, which included Roll 2 CTWs, were part of the routine monitoring program in the bioassay control procedures detailed in Section 4.1.1.1. The monitoring program was based on work location with the radionuclides for which monitoring was performed and bioassay frequency was chosen based on the exposure potential in each facility. Construction division workers were not necessarily included in this routine monitoring program. The monitoring program for the construction division was different in that it was job-specific. Area HPs specified the bioassay monitoring for each specific job plan. Those nonCTWs in areas with the potential for exposure, a decision made during job plan review, were thus included in the monitoring program. Figure 4-1 shows a special work permit with a box to check if bioassay is required.

Both of these types of monitoring programs can be considered variations on routine, representative sampling. For workers normally present in an area (i.e., nonCTWs and Roll 2 CTWs), the monitoring is specified on an annual basis in the bioassay control procedures. For workers intermittently present in an area (i.e., some CTWs, the monitoring was based on the job plan). For the duration of the job plan and the duration of the exposure potential, the required monitoring was specified. The key point is that in both instances monitoring was based on exposure potential rather than being driven by



OSR 14-8 (Rev. 9-61)

SPECIAL WORK PERMIT

TIME AM PM	BLDG.	DATE	SWP NO.

LOCATION	DEPARTMENT(S)

JOB DESCRIPTION

SPECIAL INSTRUCTIONS – MONITORING: ☐ AT START OF JOB ☐ INTERMITTENT ☐ CONTINUOUS

INSTRUCTIONS

WHEN MORE THAN ONE RATE IS LISTED ON SWP, STATE WHICH RATE WAS USED.

ENTER TIME IN RDZ ON TIME SHEET.

HEALTH PHYSICS SHALL BE PRESENT FOR LINE BREAKS.

PERSONAL SURVEY IS REQUIRED WHEN LEAVING RADIATION DANGER ZONE.

- ☐ NO PERSONAL OUTER CLOTHING
- ☐ SPECIAL PROTECTION REQUIRED FOR CUTS OR ABRASIONS.
- ☐ TAPE GLOVES-CANVAS BOOTS TO COVERALLS.
- ☐ PROVIDE TIMEKEEPER.
- ☐ PRE-PLAN MEETING REQUIRED.
- ☐ CONTACT HEALTH PHYSICS FOR A SURVEY BEFORE STARTING WORK IN A NEW LOCATION.
- ☐ PROVIDE ASSISTANCE FOR THE REMOVAL OF PROTECTIVE CLOTHING.
- ☐ GIVE BIO-ASSAY SAMPLE BEFORE LEAVING BUILDING.

PROTECTIVE CLOTHING		
HEAD	CAP	
	HOOD	
FEET	SHOE COVERS	
	RUBBERS	
	CANVAS BOOTS	
HANDS	CANVAS GLOVES	
	RUBBERIZED CANVAS	
	SURGEONS - SHORT RUBBER	
	RUBBER GAUNTLET	
BODY	COVERALLS - 1 PAIR 2 PAIR	
	LAB COAT	
	SUIT ☐ RUBBER ☐ PLASTIC	
RESP.	☐ AIR PAK ☐ AIR LINE MASK	
	ASSAULT MASK	
MET.	FILM BADGE	☒
	PENCILS	

	EXPOSURE RATE	UNITS	DISTANCE	TIME FOR 50 mrem OR 250 μc H^3	BODY OR HANDS	SURVEYED BY	TIME
A					BODY HANDS		AM PM
B					BODY HANDS		AM PM
C					BODY HANDS		AM PM
D					BODY HANDS		AM PM

DIVISION	APPROVALS TO	SHIFT	TO	SHIFT	TO	SHIFT
HEALTH PHYSICS						
OPERATIONS						
MAINTENANCE						

NAME	DEPT.	PAYROLL NUMBER	RATES USED	TIME RECORD IN	OUT	IN	OUT	TOTAL TIME	ESTIMATED EXPOSURE OR ASSIMILATION mrad	mrem	μc HP	PENCIL READER mr

~~OFFICIAL USE ONLY~~

Figure 4-1. Special Work Permit.

incidents. In either case, if an incident did occur, incident-driven sampling would have been performed.

SRS also used workgroup monitoring as a representative sampling method to confirm the lack of intakes. The bioassay frequency of individual workers was reduced while still monitoring the entire group. Effectively, it was assumed that a worker's intake potential could be based on the bioassay data for coworkers, very similar to this coworker study. If coworker bioassay data was negative, then it was assumed that there was no intake for all the workers in the workgroup. If an intake (positive bioassay result) was confirmed, then bioassay frequencies for the entire workgroup increased. Indications are that this practice began in the 1980s, which is consistent with the observed decrease in the number of bioassay records available in NOCTS.

4.1.1.3 Bioassay Analysis Techniques

Records showing urinalysis for trivalent actinides date back at least to the mid-1960s, using liquid ion exchange: triisooctylamine (TIOA) followed by di-2-ethylhexyl phosphoric acid (HDEHP), deposition on planchets, and alpha counting. A 10% thenoyl trifluoroacetone in toluene extraction was used to remove solids and reduce alpha self-absorption in the samples. Tracer recoveries were greater than 90% (Butler 1964). The early reporting levels varied from 1 to 3 dpm/1.5 L. In 1964, solid-state surface barrier detectors replaced the previous counting method for using alpha track counting (Butler and Splichal 1965). Samples were usually analyzed in batches of 20, including spikes and blanks, with one blank and two to four spikes in each batch. Multiple counts of a sample (assumed to be separate aliquots) was not common until 1969, when the logbook records also start to record "dpm/disc" values (DuPont 1963–1970).

In about 1970 an extraction method using the bidentate dibutyl N,N-diethylcarbamylphosphonate (DDCP) was developed that allowed sequential separation of plutonium, neptunium, and uranium with TIOA, followed by extraction of thorium, americium, curium, berkelium, californium, and einsteinium with bidentate. (It would also have captured fermium.) The extraction efficiency for americium was 89 ±8% (Butler and Hall 1970). The sensitivity of that method was reported to be 0.02 ±0.01 dpm/250 mL or 0.12 dpm/1.5 L for a 24-hour count. The article states that alpha spectrometry can be used to identify individual radionuclides but the sensitivity appeared to be based on a gross alpha count (Butler and Hall 1970, pp. 3, 4). Samples were analyzed in batches of 20, including spikes and blanks, with one blank and two spikes in each batch (DuPont 1970–1973). In 1971, the reporting level using gross alpha counting on a solid-state detector was listed as 0.3 dpm/1.5 L (Taylor 2000, p. 4). The Butler and Hall article was a report on research and reported the limits obtainable under research conditions. The 0.3 dpm/1.5L reporting level provided by Taylor is assumed to be the actual reporting level in actual practice under production conditions.

In 1990, a change in radiochemical processing (ion exchange resin) resulted in a MDA of 0.15 dpm/L (WSRC 2001, p. 182; Taylor et al 1995, p.79). Alpha spectrometry has been used since 1992 for special samples and since 1995 for routine samples with MDAs of 0.064 dpm/L for ^{241}Am and 0.047 dpm/L for ^{244}Cm and ^{252}Cf (WSRC 2001, p. 58). A review of the recorded data shows that the transition from gross alpha to alpha spectrometry was not clean with a few routine samples having alpha spectrometry in 1993 and 1994. The gross alpha results are listed as "AmCmCf" in the database.

4.1.1.4 Paired Measurements Sample Variance

The americium data from the logbooks contain multiple counts for each sample. Commonly making multiple counts began in 1969 and tapered off in the late 1980s. A review of results significantly greater than the MDA (i.e., greater than 1 dpm/d) was performed to identify results with significant variation in the individual counts. Those with significant variation were investigated further to attempt to determine the reason for this variation. This evaluation is contained in Attachment B. The conclusion of the evaluation is that the occurrence of samples with significant intra-count variation is limited and that inclusion of these samples has an insignificant effect on the overall results.

Data from HPRED does not contain the level of detail necessary to evaluate paired measurements or even to determine if there are paired measurements.

4.1.2 Data Validation

4.1.2.1 Logbook Data Completeness

For the period before availability of the HPRED data (before 1991), data from analytical laboratory logbooks was used (DuPont 1961–1969, 1963–1970, 1969, 1969–1973, 1970–1973, 1973–1978, 1973–1979, 1978–1983, 1979–1980, 1980–1981a,b, 1981–1986, 1986–1989). The quantity of data from the logbooks was compared to annual bioassay summaries (DuPont 1963–1967, DuPont 1965–1971, DuPont 1969–1981) with the number of samples in the logbooks shown as a percentage of the number given in the bioassay summaries. The results of this comparison are shown in Table 4-1. The ability to compare these numbers directly is limited by the fact that the logbooks record the date of sample collection while the summaries indicate the number of analyzed samples and include fecal samples for 1969 and after. On some occasions samples were not analyzed until months after collection. Before 1969, the number of recorded samples in the logbooks exceeds the number in the summaries. Beginning in 1969, on average, about 90% of the number of samples in the summaries are recorded in the logbooks and fecal samples can be assumed to account for at least part of the difference.

Table 4-1. Logbook data completeness estimate.

Year	Bioassay summary # of Am samples	Logbook # of Am samples	% in logbook
1963	11	19	173%
1964	72	75	104%
1965	173	201	116%
1966	295	283	96%
1967	253	298	118%
1968	480	765	159%
1969	1,194	873	73%
1970	2,730	2,150	79%
1971	2,016	1,822	90%
1972	1,820	1,595	88%
1973	1,332	1,266	95%
1974	1,274	1,127	88%
1975	891	848	95%
1976	761	775	102%
1977	593	546	92%
1978	446	430	96%
1979	664	533	80%
1980	387	254	66%
1981	344	343	100%

4.1.2.2 Data Quality

The data entry effort was evaluated in accordance with ORAUT-RPRT-0078 (ORAUT 2016b); the fields with the payroll ID number and the numerical sample results were evaluated with a maximum 1% allowable error rate. The QA check resulted in a point estimate error rate of 0.59% with a 95%

confidence interval of 0.39% to 0.86%. All other fields were evaluated with a maximum 5% allowable error rate. The QA check resulted in a point estimate error rate of 0.69% with a 95% confidence interval of 0.25% to 1.49%. Therefore, the dataset passed the QA check. The details of the results of the evaluation are contained in Attachment E.

4.1.2.3 Data Interpretation

A single americium urine sample was commonly counted multiple times, usually twice but as many as 10 times was noted. The data in the logbooks consisted of one or more count rate results for each urine sample in units of dpm per disc, depending on how many times a sample was counted (this information was not used) and count-specific results in units of net dpm/1.5 L (this information was used). Further, a reported value for each sample, also in units of dpm/1.5 L, was usually provided. The result in dpm/1.5 L for each count of a sample was generally recorded as an uncensored value (i.e., the calculated result was recorded regardless of its value). In contrast, the “reported” values were generally censored (i.e., results less than some level, typically the detection or reporting limit were reported as a less-than result). Some dpm/1.5 L data that were less than zero were reported as zero.

Not all sample records included all this information, and in some instances the count-specific results were censored. If count-specific results were available, the valid results were averaged by the Oak Ridge Associated Universities (ORAU) Team to determine the sample result. This value was generally uncensored. If count-specific results were not available, the reported values were used, many of which were censored.

4.1.2.4 Data Exclusion

Individuals with uptakes of actinides are sometimes treated by chelation to accelerate the excretion of the radionuclides. Bioassay data influenced by chelation treatment is not suitable for use in an internal dose coworker study due to the altered biokinetics during chelation treatment. A listing of individuals who received chelation at SRS was compiled from Site Research Database (SRDB) chelation records from the Radiation Emergency Assistance Center/Training Site (REAC/TS) (see Table A-1). Bioassay data for samples collected within 100 days after receiving chelation treatment were not used. In addition, samples marked as LIP (lost in process), those marked DTPA to indicate chelation, and those that lacked sufficient identifying information (e.g., sample date or worker ID number) were excluded.

Examination of the data revealed occasions during which individuals were involved in incidents that resulted in large intakes and excretions. All results for three individuals were excluded for an entire year due to an ingestion intake, a plutonium wound intake, and an incident that resulted in the highest assigned intake of ^{244}Cm in the history of SRS. These incidents and intakes were characterized by an extremely high number of bioassay results, many of which were orders of magnitude higher than the bioassay data for other individuals and were considered unrepresentative of the potential exposure to an unmonitored worker and were removed. The incidents were:

- One individual was involved in an incident on March 9, 1970. This person’s bioassay data were excluded for the remainder of 1970.

- One individual was involved in an incident on March 16, 1972. This person’s bioassay data were excluded for the remainder of 1972.

- One individual had a plutonium wound intake on May 8, 1986, that affected the americium bioassay results. This person’s bioassay data were excluded for the remainder of 1986.

- Three individuals had false positive results, which were excluded.

The above discussion is a general summary of the method. The detailed statistical analysis instructions are in Attachment F.

4.1.3 Statistical Analysis

Statistical analysis of the americium bioassay data was performed in accordance with the current version of ORAUT-RPRT-0053 (ORAUT 2014b) using the time-weighted one person – one statistic (TWOPOS) method. The data were analyzed on an annual basis except for 1981 to 1982, 1983 to 1984, 1985 to 1986, and 1987 to 1989. These years were merged due to the small amount of CTW data available for those years. Table 4-2 provides the results of the statistical analysis. Box-and-whisker plots of the TWOPOS data are shown in Figures 4-2 and 4-3. Years fit with a binomial distribution are not shown because there is not enough uncensored data to create a box and whisker plot.

Table 4-2. 50th- and 84th-percentile urinary excretions rates of americium, 1964 to 1989 (dpm/d)[a].

Effective bioassay date	nonCTW 50th percentile	nonCTW 84th percentile	nonCTW GSD	nonCTW # of individuals	CTW 50th percentile	CTW 84th percentile	CTW GSD	CTW # of individuals
7/1/1964	0.9676	1.500	1.55	41	N/A	N/A	N/A	N/A
7/1/1965	0.0646	0.459	7.10	124	N/A	N/A	N/A	N/A
7/1/1966	1.3440	2.198	1.64	151	N/A	N/A	N/A	N/A
7/1/1967	1.1763	1.823	1.55	182	1.2433	1.927	1.55	45
7/1/1968	0.4973	1.027	2.06	280	0.4239	1.015	2.39	89
7/1/1969	0.3072	0.782	2.55	286	0.3403	0.792	2.33	94
7/1/1970	0.2603	0.455	1.75	458	0.2363	0.344	1.45	124
7/1/1971	0.1498	0.347	2.32	556	0.1564	0.333	2.13	105
7/1/1972	0.0663	0.219	3.30	540	0.0638	0.171	2.68	112
7/1/1973	0.0308	0.123	3.98	526	0.0383	0.121	3.16	110
7/1/1974	0.0281	0.140	4.99	376	0.0362	0.123	3.40	86
7/1/1975	0.0390	0.151	3.87	377	0.0350	0.147	4.21	95
7/1/1976	0.0336	0.130	3.88	360	0.0351	0.134	3.81	89
7/1/1977	0.0460	0.178	3.87	315	0.0480	0.156	3.25	69
7/1/1978	0.0593	0.248	4.18	160	0.0488	0.237	4.85	53
7/1/1979	0.0624	0.189	3.04	211	0.0487	0.158	3.23	60
7/1/1980	0.0527	0.164	3.12	182	0.0344	0.146	4.23	40
1/1/1982	0.0359	0.151	4.20	425	0.0904	0.482	5.33	47
1/1/1984	0.0351	0.134	3.81	368	0.0557	0.230	4.13	53
1/1/1986	0.0300	0.149	4.95	339	0.0422	0.233	5.51	34
7/1/1988	0.0552	0.219	3.97	369	0.0338	0.203	6.00	23

a. N/A = not applicable.

4.1.4 Intake Modeling

Each result that was used in the intake calculations was assumed to have a normal distribution. A uniform absolute error of 1 was applied to all results, thereby assigning the same weight to each result. The IMBA program requires results to be in units of activity per day; therefore, all urinalysis results were normalized as needed to 24-hour samples using 1,500 mL (the volume of urine assumed by SRS to be excreted in a 24-hour period).

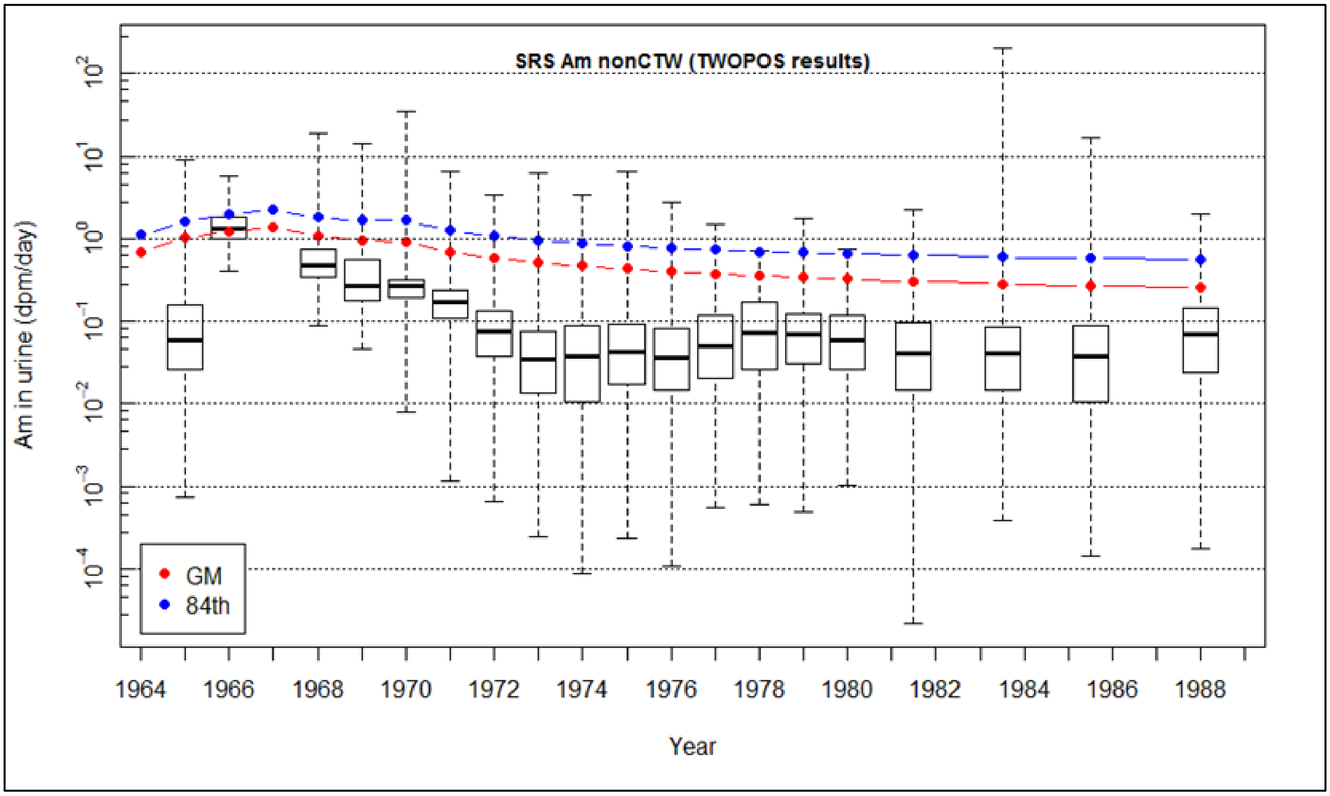


Figure 4-2. nonCTW TWOPOS data box and whisker plot.

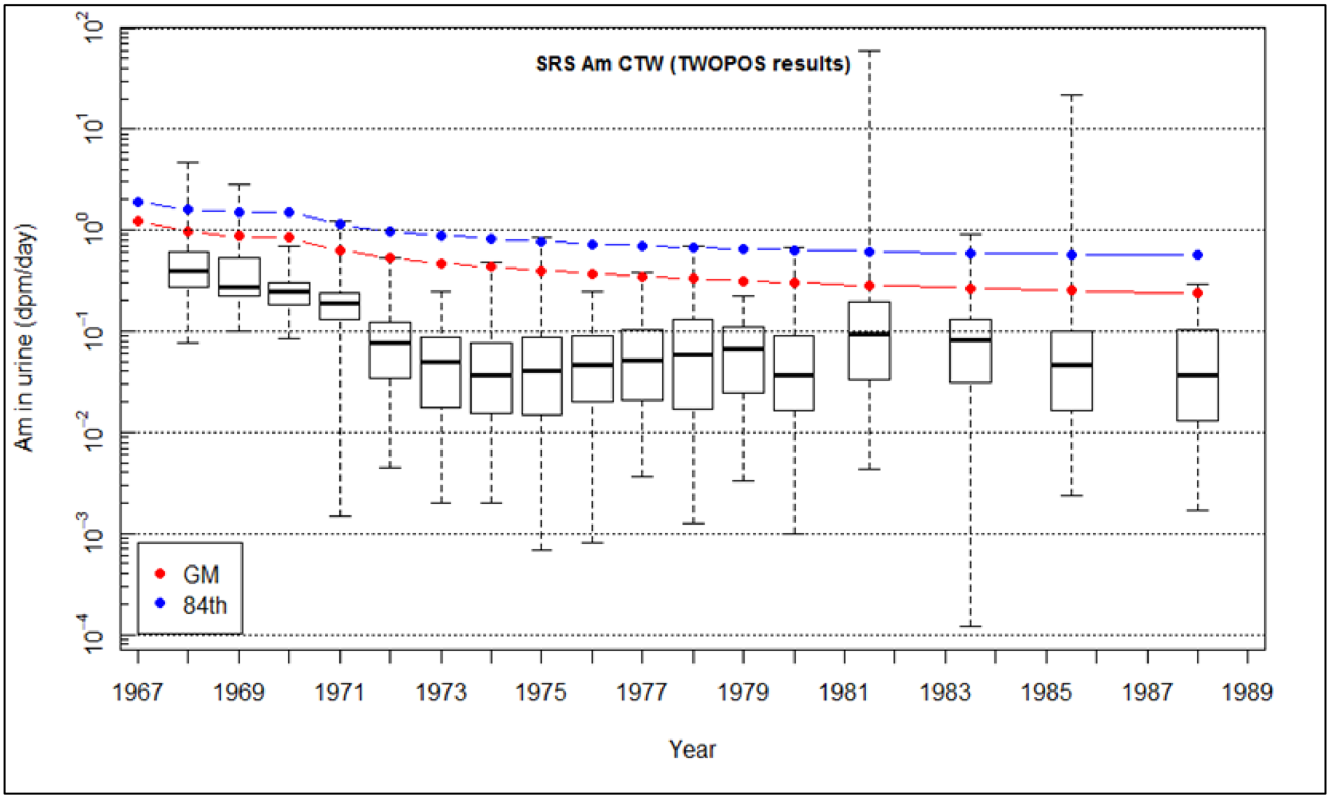


Figure 4-3. CTW TWOPOS data box and whisker plot.

Because of the nature of work at SRS, intakes could have been chronic or acute. However, a series of acute intakes can be approximated as a chronic intake. Therefore, intakes were assumed to be chronic and to occur through inhalation with a default breathing rate of 1.2 m^3/hr and a 5-µm activity median aerodynamic diameter particle size distribution.

IMBA was used to fit the bioassay results to a series of inhalation intakes. Data were fit as a series of chronic intakes. The intake assumptions were based on observed patterns in the bioassay data. Periods with constant chronic intake rates were chosen by the selection of periods in which the bioassay results were similar. A new chronic intake period was started if the data indicated a significant sustained change in the bioassay results. By this method, the years from 1964 through 1989 were divided into multiple chronic intake periods.

Americium intake periods were independently fit using only the bioassay results from the single intake period. This method likely results in an overestimate of intakes for exposures that extend through multiple assumed intake periods. Only the results in the intake period were selected for use in the fitting of each period. Excluded results are shown in light gray or red in the figures in Attachment C; included results are shown in dark gray or blue. The results of the statistical analysis that was used to calculate the intakes are provided for americium in Table 4-2.

Results from 1965 were excluded from the nonCTW intake modeling because they were not consistent with the results for 1964, 1966, and 1967; this is favorable to claimants. CTW intakes for 1964 through 1967 were based on the bioassay data for 1967 only. CTW data is not available before 1967 due to the small amount of CTW bioassay data available for that period. Visual examination of the nonCTW and CTW data shows similar patterns in excretion rates. Therefore, it was judged that 1967 adequately represented the excretion rates for 1964 through 1967 for CTWs.

The solid lines in Figures C-1 to C-12 in Attachment C show the individual fits to the 50th- and 84th-percentile excretion rates for type M materials for nonCTWs and CTWs. Figures C-13 to C-16 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type M intakes for nonCTWs and CTWs. Table C-1 lists the 50th- and 84th-percentile intake rates along with the associated geometric standard deviations (GSDs) from the americium urinalysis.

Figures 4-2 and 4-3 overlay the urinary excretion rates predicted by the intake modeling on the box and whisker plots of the TWOPOS data. As can be seen, the predicted geometric means (GMs) of the excretion rates are favorable to claimants in comparison with the GMs of the TWOPOS data.

4.2 TRITIUM

4.2.1 Data Adequacy

4.2.1.1 Personnel Monitoring

The earliest available version of the *Bioassay Control* procedure is Revision 2 (DuPont 1968), which indicates a tritium sample size of one voiding with a “positive level” of 1 µCi/L and a resample level of 5 µCi/L. The procedure does not specify required tritium sampling frequencies. Revision 3 (DuPont 1970) contains the same information.

In Revision 5 (DuPont 1971b), there was no positive level and the confirmation level was still 5 µCi/L. Most 221-H and H-Area outside facilities workers submitted bioassay samples for tritium analysis twice a year for tritium. Workers in 100 Areas, 105 Building, 232-H, 234-H, 237-H, 238-H, 241-H, and 244-H submitted bioassay samples as specified in “local procedures.” For the construction division, tritium sampling was specified in the Construction Job Plans or in DPSOP 40-1. In Revisions 7 and 8, sampling frequency was still specified in local procedures (DuPont 1976, undated a).

Bioassay control remained unchanged from 1978 through 1985 (DuPont 1985, p. 273) with sampling frequency still controlled by local procedures and construction job plans. The 1990 *Internal Dosimetry Technical Basis Manual* monitoring program for tritium specified monthly urine bioassay (WSRC 1990, p. 235). In the available tritium dataset, there are over 100,000 bioassay results from individuals who submitted more than one sample for tritium analysis on more than one occasion. One third of these samples were collected either daily or weekly, and two-thirds were collected within 7 days. This is illustrated in Figure 4-4.

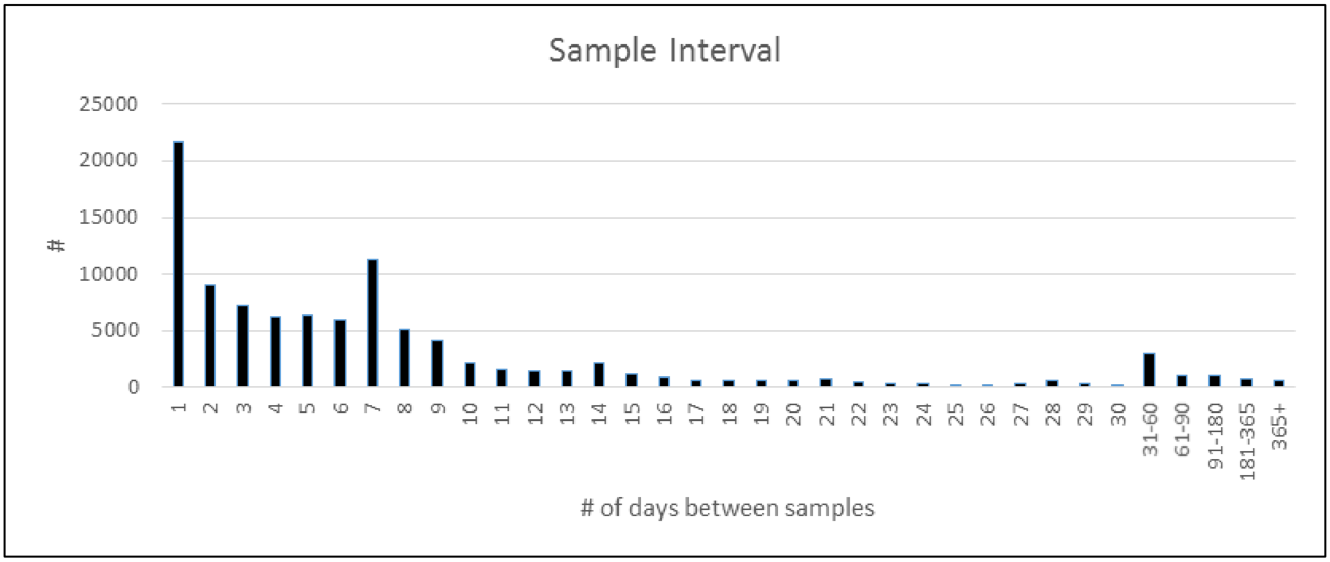


Figure 4-4. Tritium bioassay sample frequency.

4.2.1.2 Applicability to Unmonitored Workers

Records of in vitro bioassay for tritium show urinalysis data back to about 1954. As discussed above in the description of the sample collection process, there was guidance for whom to sample by 1968. Tritium was addressed differently from most other radionuclides in that sampling was more frequent and was controlled at the “local” level rather than in plantwide procedures. By 1976, overall guidance of whom to monitor was in place but with local control still determining precise sampling frequencies. By 1990, facilities with the potential for tritium exposure were using monthly sampling frequencies. Available NOCTS tritium data on the number of monitored individuals trends the same for CTWs and nonCTWs with a peak in the late 1950s and early 1960s after a gradual decline through 1989 with intermittent increases.

DuPont workers, which included Roll 2 CTWs, were part of the routine monitoring program. The monitoring program was based on work location with the radionuclides for which monitoring was performed and bioassay frequency was chosen based on the exposure potential in each facility. Construction division workers were not necessarily included in this routine monitoring program. The monitoring program for the construction division was different in that it was job-specific. Area HPs specified the bioassay monitoring to be performed for each specific job plan. Those nonCTWs in areas with the potential for exposure, a decision made during job plan review, were thus included in the monitoring program. Figure 4-1 shows a special work permit with a box to check if bioassay is required.

Both of these types of monitoring programs can be considered to be variations in routine, representative sampling. For workers normally present in an area (i.e., nonCTWs and Roll 2 CTWs, the monitoring was specified on an annual basis in the bioassay control procedures). For workers intermittently present in an area (i.e., some CTWs), the monitoring was based on the job plan. For the duration of the job plan and the duration of the exposure potential, the required monitoring was specified. The key point is that in both instances monitoring was based on exposure potential rather than being driven by incidents. In either case, if an incident did occur, incident-driven sampling would have been performed.

SRS also used workgroup monitoring as a representative sampling method to confirm the lack of intakes. The bioassay frequency of individual workers was reduced while still monitoring the entire group. Effectively, it was assumed that a worker's intake potential could be based on the bioassay data for coworkers, very similar to this coworker study. If coworker bioassay data was negative, then it was assumed that there was no intake for all the workers in the workgroup. If an intake (positive bioassay result) was confirmed, then bioassay frequencies for the entire workgroup increased. Indications are that this practice began in the 1980s, which is consistent with the observed decrease in the number of bioassay records available in NOCTS.

4.2.1.3 Bioassay Analysis Techniques

From startup until 1958, tritiated water vapor (HTO) in urine was analyzed by passing hydrogen evolved from the urine sample through an ionization chamber; the reported MDA for this method was 1 µCi/L. In 1958, liquid scintillation counting was initiated and remains in use. The reporting level remained at the value of 1 µCi/L until approximately February 1981 when it was reduced to 0.5 µCi/L. Based on review of bioassay results, the switch was not clean with some samples dated in December 1980 and January 1981 reported as <0.5 µCi/L while some samples dated after February 1981 were reported as <1 µCi/L.

The reporting level was reduced again to 0.1 µCi/L in about January 1986. (Again the date is not certain with either value being recorded for a few months before and after.) During the 1980s, although the reporting level of 0.5 µCi/L was generally used, some results below 0.5 are listed directly, (e.g., 0.4 and 0.3). The true MDA was probably well below the reporting level, and these results below the reporting level should be considered as real. Quality control was ensured by daily, weekly, monthly, and quarterly checks of the bioassay measurement process specified in the DPSOL 47-268 procedure (WSRC 1990).

A *History of Personnel Radiation Dosimetry at the Savannah River Site* (Taylor et al. 1995) reports that the MDA consistently improved to the current level of 20,000 pCi/L (or 0.02 µCi/L). This MDA value was stated in the 1990 technical basis manual so was applicable at least that far back (WSRC 1990, p. 396). It should be noted that for current analyses, tritium results of 0.05 µCi/L or less are reported as "<0.1µCi L-1," and results between 0.05 µCi/L and 0.1 µCi/L are reported as "0.1 µCi L-1." Results greater than 0.1 µCi/L are reported as measured (to one significant figure) (WSRC 2001, p. 181).

Tritium analyses are listed as "T" on the employee bioassay cards. Tritium may also be listed as "P-10," especially in the 1950s. Tritium results in the 1990s were listed on the same summary form as external dose monitoring results. They are referred to as sample results with dates and analysis results, but the word "tritium" or any other radionuclide identifier is not mentioned directly.

For tritium results, the denominator used for reporting purposes has always been per liter of urine. (The denominator of 1.5 L was never used for tritium as it was for other radionuclides.)

4.2.2 Data Validation

Tritium data are from NOCTS bioassay data as discussed in Section 3.0. The data entry effort was evaluated in accordance with ORAUT-RPRT-0078 (ORAUT 2016b); all fields were evaluated with a maximum 5% allowable error rate. The QA check resulted in a point estimate error rate of 0.69% with a 95% confidence interval of 0.25% to 1.49%. Therefore, the dataset passed the QA check. The details of the results of the evaluation are contained in Attachment E.

4.2.3 Intake Modeling and Statistical Analysis

Tritium was evaluated differently from the other radionuclides in this coworker study. For other radionuclides, intake rates were determined. For tritium, individual doses were determined and were statistically evaluated. This is akin to the external dosimetry analysis in external dose coworker studies. The protocol in *Technical Information Bulletin: Tritium Calculated and Missed Dose Estimates* (ORAUT 2004b) was used to calculate the dose for each individual with the following rules concerning the elapsed time between consecutive samples:

- If there was a single urine sample in a calendar year and it was a less-than result (less than the MDA or reporting level), that result was excluded from the analysis because it was assumed not to be part of routine monitoring.
- Samples on the same date were ordered from lowest to highest result.
- All dose was assigned as if it occurred on the bioassay date.
- Type 1 calculations were performed for samples separated by 40 or fewer days.
- Type 3 calculations were performed if there were no other samples within 90 days after a sample.
- Type 2 calculations were performed in all other situations.

The doses for a period were then plotted on a lognormal probability plot and the typical parameters (GM and GSD) were determined from a linear regression. Individuals who received less than 0.001 rem at three significant digits (i.e., less than 0.0005 rem), were excluded from the statistical analysis. The plotting positions were calculated with $i/n - 1/(2n)$ convention specified in ORAUT-PROC-0095, *Generating Summary Statistics for Coworker Bioassay Data* (ORAUT 2006). Doses for 1954 to 1990 were calculated from the NOCTS dataset, which is considered a random sample of the complete dataset (ORAUT 2016a). Doses for 1991 to 1995 were calculated from the HPRED dataset, which is considered a complete dataset. Table 4-3 lists the tritium doses and GSDs to be used for each year of potential tritium exposure for CTWs and nonCTWs.

4.3 PLUTONIUM

RESERVED. Evaluation of plutonium will be added in Revision 4 of this document.

4.4 URANIUM

RESERVED. Evaluation of uranium will be added in Revision 4 of this document.

4.5 COBALT-60

RESERVED. Evaluation of ^{60}Co will be added in Revision 4 of this document.

4.6 CESIUM-137

RESERVED. Evaluation of ^{137}Cs will be added in Revision 4 of this document.

Table 4-3. Tritium annual doses (rem) and GSDs.

Year	nonCTW # of individuals	nonCTW 50th-percentile dose	nonCTW GSD	CTW # of individuals	CTW 50th-percentile dose	CTW GSD
1954	89	0.012	1.83	33	0.012	1.89
1955	103	0.013	1.99	57	0.015	2.16
1956	83	0.019	2.67	53	0.016	2.52
1957	166	0.025	2.76	114	0.025	2.56
1958	243	0.035	2.45	157	0.031	2.36
1959	219	0.034	3.04	112	0.038	2.78
1960	231	0.046	3.12	151	0.042	3.07
1961	227	0.050	2.88	142	0.039	3.37
1962	247	0.051	2.84	186	0.041	2.81
1963	239	0.048	2.49	186	0.040	2.74
1964	218	0.060	3.02	158	0.054	2.84
1965	188	0.055	3.38	113	0.043	2.88
1966	182	0.046	2.89	97	0.031	3.13
1967	174	0.049	2.46	79	0.034	3.00
1968	162	0.051	2.77	91	0.030	2.97
1969	160	0.052	2.43	75	0.031	3.24
1970	156	0.042	2.63	68	0.023	3.50
1971	163	0.051	2.30	63	0.028	3.32
1972	214	0.047	2.83	80	0.033	3.33
1973	227	0.045	2.77	83	0.027	3.39
1974	205	0.048	2.65	74	0.031	3.34
1975	188	0.048	2.68	69	0.032	2.97
1976	176	0.047	2.68	69	0.030	3.27
1977	168	0.053	2.40	78	0.026	3.37
1978	170	0.048	2.45	63	0.028	2.97
1979	173	0.047	2.54	59	0.029	2.76
1980	162	0.049	2.21	68	0.024	2.79
1981	166	0.031	2.40	98	0.016	2.74
1982	188	0.027	2.40	99	0.015	2.72
1983	189	0.022	2.41	104	0.016	2.38
1984	183	0.023	2.48	93	0.015	2.75
1985	150	0.025	2.18	63	0.016	2.43
1986	144	0.008	3.33	66	0.006	3.19
1987	132	0.008	3.11	57	0.007	3.13
1988	117	0.008	2.72	47	0.006	3.53
1989	138	0.006	2.81	70	0.004	3.07
1990	136	0.006	2.78	94	0.006	2.58

4.7 NEPTUNIUM

RESERVED. Evaluation of neptunium will be added in Revision 4 of this document.

4.8 THORIUM

By 1990, thorium in urine was quantified by an offsite vendor (WSRC 1990). However, the analytical techniques SRS used for americium before 1990 also captured thorium (NIOSH 2012; Butler and Hall 1970; Taylor et al 1995). Butler (1964) indicates an extraction efficiency of 93% for thorium into 20% HDEHP-toluene. An extraction efficiency of 97% with the TIOA-DDCP technique (Butler and Hall 1970) was reported. DDCP extracts all the alpha-emitting actinides from thorium through einsteinium from the sample. The extraction efficiency for the various actinides is given in Table 4-4. For practical use at SRS, the plutonium, uranium, and neptunium would be stripped first to permit separation of the americium, californium, and curium.

Table 4-4. Extraction efficiencies with DDCP (from Butler and Hall 1970).

Element	Principal Valence	Extracted %
Ca	2	<1
Cs	1	<1
Fe	3	95
Pm	3	99
Ce	3	99
Th	4	97
U	6	82
Np	5	92
Pu	4	98
Am	3	95
Cm	3	95
Bk	3	98
Cf	3	95
Es	3	97

The TIOA-DDCP method provides a simple, accurate method for quantitative determination of actinides. TIOA is used to extract the plutonium, uranium, and neptunium from the sample in an 8N HCl solution. Next, a sequence of nitric acid dissolution steps is performed followed by the use of DDCP to separate the remaining actinides. Toluene is used to return the actinides to the aqueous phase, which is then evaporated to dryness and counted. Separation of the thorium, berkelium, and einsteinium from the americium, curium, and californium was not done because they “are not present in biological samples in sufficient quantities to require separation or routine identification by alpha spectroscopy” (Butler and Hall 1970). However, if present, they would continue with the americium, curium, and californium. This is shown graphically in Figure 4-5. Thorium was also noted as being included in the americium, curium, and californium determination in 1987 (DuPont 1987, p. 60) as shown in Figure 4-6. Therefore, although not originally intended to measure thorium, the analytical technique for americium measurement would also capture any thorium present in the sample and establish an upper bound on the amount of thorium present.

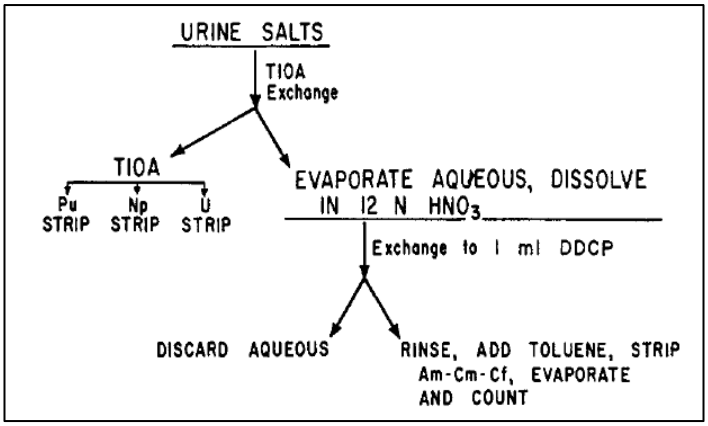
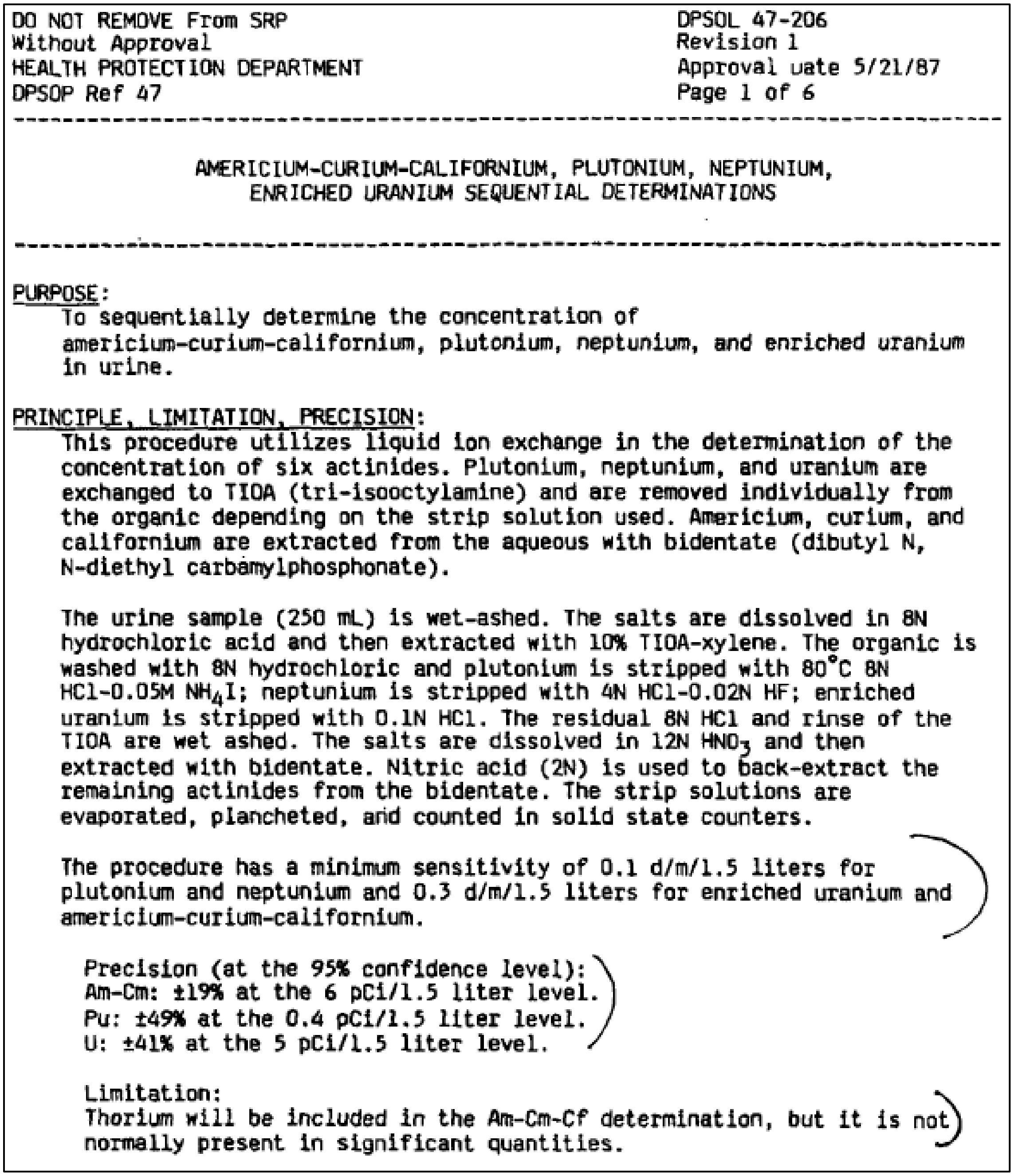


Figure 4-5. TIOA-DDCP sequential stripping process (Butler and Hall 1970).

Therefore, the americium bioassay data discussed above was also used to model thorium intakes for October 1972 through 1989. Separate intake modeling was performed for thorium due to the differing



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AMERICIUM-CURIUM-CALIFORNIUM, PLUTONIUM, NEPTUNIUM, ENRICHED URANIUM SEQUENTIAL DETERMINATIONS

PURPOSE:

To sequentially determine the concentration of americium-curium-californium, plutonium, neptunium, and enriched uranium in urine.

PRINCIPLE, LIMITATION, PRECISION:

This procedure utilizes liquid ion exchange in the determination of the concentration of six actinides. Plutonium, neptunium, and uranium are exchanged to TIOA (tri-isooctylamine) and are removed individually from the organic depending on the strip solution used. Americium, curium, and californium are extracted from the aqueous with bidentate (dibutyl N, N-diethyl carbamylphosphonate).

The urine sample (250 mL) is wet-ashed. The salts are dissolved in 8N hydrochloric acid and then extracted with 10% TIOA-xylene. The organic is washed with 8N hydrochloric and plutonium is stripped with 80°C 8N HCl-0.05M NH_4I; neptunium is stripped with 4N HCl-0.02N HF; enriched uranium is stripped with 0.1N HCl. The residual 8N HCl and rinse of the TIOA are wet ashed. The salts are dissolved in 12N HNO_3 and then extracted with bidentate. Nitric acid (2N) is used to back-extract the remaining actinides from the bidentate. The strip solutions are evaporated, plancheted, and counted in solid state counters.

The procedure has a minimum sensitivity of 0.1 d/m/1.5 liters for plutonium and neptunium and 0.3 d/m/1.5 liters for enriched uranium and americium-curium-californium.

Precision (at the 95% confidence level):
Am-Cm: ±19% at the 6 pCi/1.5 liter level.
Pu: ±49% at the 0.4 pCi/1.5 liter level.
U: ±41% at the 5 pCi/1.5 liter level.

Limitation:
Thorium will be included in the Am-Cm-Cf determination, but it is not normally present in significant quantities.

Figure 4-6. Sample analysis procedure for extracting americium, curium, californium, plutonium, neptunium, and enriched uranium (DuPont 1987).

biokinetics of thorium in comparison with americium. The intake rates start in October 1972 because an SEC covers ^{232}Th exposures before October 1972.

Due to the relatively uniform excretion rates, ^{232}Th was fit as a single intake period for all of 1972 through 1989. The results of the statistical analysis, which were used to calculate the intakes for thorium, are the same as those for americium (Table A-9).

For type M thorium, the solid lines in Figures C-17 to C-20 in Attachment C show the individual fits to the 50th- and 84th-percentile excretion rates for nonCTWs and CTWs. Table C-2 lists the 50th- and 84th-percentile intake rates along with the associated GSDs from the americium urinalysis.

For type S thorium, the solid lines in Figures C-21 to C-25 in Attachment C show the individual fits to the 50th- and 84th-percentile excretion rates for nonCTWs and CTWs. Table C-3 lists the 50th- and 84th-percentile intake rates along with the associated GSDs from the americium urinalysis.

5.0 GUIDANCE FOR DOSE RECONSTRUCTORS ON ASSIGNMENT OF INTAKES AND DOSES

This section describes the derived intake rates and provides guidance for assigning doses. For the calculation of doses to individuals from bioassay data, a minimum GSD of 3 has been used to account for biological variation and uncertainty in the models. It was considered inappropriate to assign a value less than 3 for the coworker data. Therefore, a GSD of at least 3 was assigned for each intake period. The GSDs for different intake periods were conservatively adjusted for consistency between intake periods for calculational efficiency. The 95th-percentile values were based on the adjusted GSD for the intake period. The original GSDs are provided in the Attachment C tables for each element. For input into the Interactive RadioEpidemiological Program (IREP), the 50th percentile of the calculated intake rates should be assigned as a lognormal distribution with the associated GSDs in the tables in this section to the majority of workers for whom coworker intakes are assigned as the default assumption. For cases in which there is justification that the individual could have had intakes larger than the 50th percentile, dose reconstructors should use the 95th-percentile intake rates input into IREP as a constant. The intake rates or dose for the last year listed may be extended to subsequent years as a measure favorable to claimans.

The following sections list the intake rates that should be used for each radionuclide and the period of applicability of each intake rate except for tritium. For tritium, the actual dose that should be used is provided. Coworker intakes should be assigned for radionuclides that could have been present at the worker's location and for which the worker was not monitored. Table 5-1 lists the radionuclides potentially present at various SRS facilities or to which a worker who was assigned to a particular facility might have been exposed. Most radionuclides apply to the entire duration of the facility's existence; a few radionuclides apply to limited periods as noted in the table (ORAUT 2013). The dosimeter codes applicable to various periods are included to assist with determining a worker's work location. The dosimeter codes may be used to help identify an individual's work location. However, the dosimeter codes are guidance only and claimant-specific information (telephone interview statements, incident reports, U.S. Department of Labor claim file information, etc.) supersedes the guidance provided by these dosimeters codes.

If the work location is unknown, then the radionuclides listed for "not identifiable or unknown" (the last line in Table 5-1) should be assigned. This might especially apply to maintenance workers sent from the Central Shops area to a variety of work locations and any other workers who worked in multiple facilities.

5.1 AMERICIUM

Table 5-2 lists the ^{241}Am intakes and associated GSDs to be used for each year of potential americium exposure for nonCTWs and CTWs.

Table 5-1. Radionuclides of concern potentially present at SRS facilities.

Building or facility	Dosimeter codes[a] 1961–1972	Dosimeter codes[a] 1973–1990	Dosimeter codes[a] 1991–2003	Dosimeter codes[a] 2004–present	Radionuclides of concern
Reactors (R, P, L, K, C)	7A, 8A, 9A, 10A, 11A,	1C through 6C, 1K, 1P, 1L, 1R	C01, C02, C03, K01, L01, P01	LLL, NMM, SDD[b]	^{3}H, FP
F-Area unknown facility	1A	1F through 5F, 7F through 9F	F, F01 through F05, F07 through F09	235, CLB, FBL, FCA	Pu, U, Am, Np, FP
F-Area A-Line	1A	See F canyon	See F canyon	FCA	U
221-F B-Line (FB- and JB-Lines)	1A	1F through 5F, 7F through 9F	F, F01 through F05, F07 through F09	FBL	Pu, Am
221-F Canyon	1A	1F through 5F, 7F through 9F	F, F01 through F05, F07 through F09	FBL, FCA,	Pu, U, FP, Np, Th through 1966
F-Area Outside Facilities	1B	9F	F09	FCA	Pu, U, FP
PuFF and PEF (235-F)	1A	5F, 8F	F05, F08	235	Pu, Am, Np, Th
235-F Vaults	1A	2F, 5F, 8F	2F, F05, F08	235	Pu, U, Np, Am, Cm, Th
772-F and 772-1F Laboratories	1A	1A[c]	A01	CLB	Pu, U, FP, Am, ^{3}H, Np
F/H Tank Farms, Effluent Treatment Facility (ETF), Cooling Water and Retention Basins	None	5F, 5H	F05, H05	ETP, FTF	Pu, U, FP, Am, Np
H-Area unknown facility	2A	1H through 6H	H01 through H06	299, HBL, HCA	^{3}H, Pu, U, Am, FP, Np
HB Line Facility	2A	6H	H06	HBL	Pu, FP, Am, Np, U[d]
H-Canyon and A-Line	2A	1H, 2H, 5H, 6H	H, H01, H02, H05, H06	HCA	Pu, U, FP, Np
221-H Area Outside Facilities	2A	9H	H09	HCA	^{3}H, Pu, U, FP, Np
232-H, HANM, HAOM, Tritium complex	None	6F, 4H	F06, H04, T	TEF, TRI	^{3}H
300 M-Area, M Area unknown facility	3A	3M	M03	SDD[b]	Th, Pu, Np, Am, Cm 1964–1965 only
704-U, 704-B	None	1U, 6E, 7G	U, U01, E06, G07	No active codes	FP
723-A, 773-A	5A, 6N	1A, 5A	A01, A02, A05,	SRTC	Pu, Am, Cm, Cf, Th October 1972 and after, U, Np, FP, ^{3}H
735-A and 735-11A	6F	5D	A02, A03, A09, A16, B01	SRTC (apply 773-A intakes)	Environmental radionuclides, Np 1962
776-A	None	1A, 15A	A01, A15	SRTC (apply 773-A intakes)	Pu, Am, Cm, Cf, Th, U Np 1961–1988, FP, ^{3}H
777-M	5B	5B	A33	No active codes	U, FP, Np through 1984
CMX and TNX	5C	5C	T01	No active codes	U

Building or facility	Dosimeter codes[a] 1961–1972	Dosimeter codes[a] 1973–1990	Dosimeter codes[a] 1991–2003	Dosimeter codes[a] 2004–present	Radionuclides of concern
Central shops & Maintenance, Pittsburgh Testing Laboratory	6C, 6H, 6I, 6M, 6N, 6R, 12D, 12E, 12I	5J, 5W, 6B,6W, 7A, 7B, 7G, 7I, 7J, 7K, 7L, 7M, 7N, 7R, 7Q, 7W, 8A through 8C, 8H, through 8M, 8P, 8S, 8T, 1N	A12, A24, A25, A26, A27, A29, A34, J01, through J08, J12 through 41	No active codes	Pu, U, FP, ^{3}H, Am, Cm, Np, Th
D-Area	4A	1D, 4D	D, D01, D04	SDD	^{3}H
E-Area Solid Waste Disposal Facility (SWDF)	12A	12B, 4F, 3G, 8G	B12, G03, F04	SSS	^{3}H, Pu, FP, Np
New Special Recovery and Plutonium Storage Facility (PSF)	None	See H-Area unknown facility	See H-Area unknown facility	MPF	Pu, Am, U
Receiving Basin for Off-Site Fuel (RBOF) and Resin Regeneration Facility (RRF)	See H-Area unknown facility	See H-Area unknown facility	See H-Area unknown facility	RBO	Pu
S-Area Defense Waste Processing Facility (DWPF)	None	1S, 2S, 1W, 2W	S01, S02	SWM	Pu, FP
Waste Certification Facility	None	3G	G03	SSS	^{3}H, Pu, FP
Z-Area	None	2Z	Z02	ZZZ	^{3}H, FP, Pu, Am, Cm, Cf, Np, Th
Not identifiable or unknown[e]	None	7Y, 8D, 8E, 000, missing	R01, Y01, missing	Blank, any code not already listed	Pu, U, FP, ^{3}H, Am, Cm, Cf, Np, Th

a. Any code with an "X" should not be included. These indicate offsite assignment.

b. Code SDD is used both for the reactors and for 300-M area. If no other information about work location is available, the applicable radionuclides for both locations should be assigned.

c. Code 1A is used for both 772 and 773 before 1991. If no other information about work location is available, the applicable radionuclides for both locations should be assigned.

c. Unknown facility radionuclides should only be assigned if no information is available from any source about the worker's work location.

d. Uranium-232/233 should only be assigned for the HB-Line for January 1, 1964, through September 30, 1972.

Table 5-2. Type M ^{241}Am intake rates (dpm/d).

Start	End	nonCTW 50th percentile	nonCTW GSD	nonCTW 95th percentile	CTW 50th percentile	CTW GSD	CTW 95th percentile
1/1/1964	12/31/1967	124.5	3.00	759	110.3	3.00	672
1/1/1968	12/31/1970	39.8	3.00	243	37.91	3.00	231
1/1/1971	12/31/1989	3.126	3.70	26.9	3.338	4.15	34.7

5.2 TRITIUM

Table 5-3 lists the tritium doses and GSDs to be used for each year of potential tritium exposure.

Table 5-3. Tritium annual doses (rem) and GSDs.

Year	nonCTW 50th-percentile dose	nonCTW GSD	nonCTW 95th-percentile dose	CTW 50th-percentile dose	CTW GSD	CTW 95th-percentile dose
1954	0.012	3.00	0.073	0.012	3.00	0.071
1955	0.013	3.00	0.080	0.015	3.00	0.093
1956	0.019	3.00	0.116	0.016	3.00	0.100
1957	0.025	3.00	0.151	0.025	3.00	0.154
1958	0.035	3.00	0.215	0.031	3.00	0.190
1959	0.034	3.02	0.208	0.038	3.00	0.232
1960	0.046	3.18	0.306	0.042	3.06	0.264
1961	0.050	3.00	0.304	0.039	3.36	0.284
1962	0.051	3.00	0.313	0.041	3.00	0.251
1963	0.048	3.00	0.295	0.040	3.00	0.242
1964	0.060	3.01	0.368	0.054	3.00	0.329
1965	0.055	3.37	0.403	0.043	3.00	0.261
1966	0.046	3.00	0.281	0.031	3.12	0.200
1967	0.049	3.00	0.301	0.034	3.00	0.208
1968	0.051	3.00	0.310	0.030	3.00	0.182
1969	0.052	3.00	0.315	0.031	3.24	0.215
1970	0.042	3.00	0.258	0.023	3.49	0.180
1971	0.051	3.00	0.308	0.028	3.32	0.204
1972	0.047	3.00	0.286	0.033	3.33	0.238
1973	0.045	3.00	0.276	0.027	3.50	0.212
1974	0.048	3.00	0.293	0.031	3.33	0.227
1975	0.048	3.00	0.294	0.032	3.00	0.196
1976	0.047	3.00	0.285	0.030	3.26	0.207
1977	0.053	3.00	0.326	0.026	3.37	0.192
1978	0.048	3.00	0.295	0.028	3.00	0.168
1979	0.047	3.00	0.286	0.029	3.00	0.179
1980	0.049	3.00	0.300	0.024	3.00	0.147
1981	0.031	3.00	0.188	0.016	3.00	0.100
1982	0.027	3.00	0.164	0.015	3.00	0.093
1983	0.022	3.00	0.135	0.016	3.00	0.095
1984	0.023	3.00	0.138	0.015	3.00	0.093
1985	0.025	3.00	0.150	0.016	3.00	0.095
1986	0.008	3.32	0.061	0.006	3.17	0.043
1987	0.008	3.08	0.052	0.007	3.12	0.045
1988	0.008	3.00	0.047	0.006	3.52	0.050
1989	0.006	3.00	0.036	0.004	3.07	0.027
1990	0.006	3.00	0.034	0.006	3.00	0.036

5.3 PLUTONIUM

RESERVED

5.4 URANIUM

RESERVED

5.5 COBALT-60

RESERVED

5.6 CESIUM-137

RESERVED

5.7 NEPTUNIUM

RESERVED

5.8 THORIUM

Tables 5-4 and 5-5 list the ^{232}Th intakes and associated GSDs to be used for each year of potential ^{232}Th exposure for nonCTWs and CTWs for solubility types M and S respectively. No ^{232}Th intakes should be assigned for periods before October 1, 1972, because this period is covered under an SEC.

Table 5-4. Type M thorium-232 intake rates (dpm/d).

Start	End	nonCTW 50th percentile	nonCTW GSD	nonCTW 95th percentile	CTW 50th percentile	CTW GSD	CTW 95th percentile
10/1/1972	12/31/1989	4.813	3.86	44.5	5.172	4.35	58.2

Table 5-5. Type S thorium-232 intake rates (dpm/d).

Start	End	nonCTW 50th percentile	nonCTW GSD	nonCTW 95th percentile	CTW 50th percentile	CTW GSD	CTW 95th percentile
10/1/1972	12/31/1989	67.59	3.87	626.2	72.74	4.54	874.8

6.0 CONCLUSIONS

The NIOSH guidance for evaluation and use of coworker datasets requires that data adequacy, completeness, and applicability be determined (NIOSH 2015). This requires determination that the bioassay techniques SRS used were valid, collected data was reliable, and the data can be interpreted. The bioassay analytical techniques discussed above and review of the results provide evidence that the techniques were valid, reliable, and can be interpreted.

The guidance requires that all or a representative sample of the potentially exposed worker population submit samples. The bioassay sample schedules indicate that SRS had a process in place to identify and collect samples from potentially exposed workers with a graded approach commensurate with the exposure potential and that unmonitored workers could be adequately represented by monitored workers.

The stratified statistical analyses established two populations of workers (CTWs and non-CTWs), evaluated the bioassay data from each, and determined intake rates or doses applicable to each for the evaluated range of years. The intake rates or doses in Section 5.0 may be assigned to unmonitored workers to evaluate potential unmonitored internal dose.

7.0 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).

Tom LaBone served as the initial Subject Expert for this document. Mr. LaBone was previously employed at SRS and his work involved management, direction or implementation of radiation protection and/or HP program policies, procedures or practices related to atomic weapons activities at the site. Preparation of this document has been overseen by a Document Owner who is fully responsible for the content, including all findings and conclusions. In all cases where such information or prior studies or writings are included or relied upon by Mr. LaBone, those materials are fully attributed to the source. Mr. LaBone's Disclosure Statement is available at www.oraucoc.org.

[1] Arno, Matthew G. ORAU Team. Principal Health Physicist. January 2009.
This is based on communications with Tom LaBone indicating "<" values were recorded as negative results in the HPRED.

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ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS

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BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-1. SRDB Ref IDs for REAC/TS chelation data.

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ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-2. 1968 bioassay frequencies (samples per year by analysis type) (DuPont 1968).[a]

Category	Description	Pu	FP	EU	U	NP
A	**Minimum potential (except HTO).** Personnel assigned to 232-H, 234-H, 284-F & -H, 704-F & -H, 706-F & -H, 717-F, and 235-F nonprocess sections; patrolmen.	1 ea. 3 yr	1 ea. 3 yr	1 ea. 3 yr	1 ea. 3 yr	1 ea. 3 yr
B	**221-H Fourth level.** Separations senior supervisors and above; all separations technology personnel, control room operators, and secretaries.	1	1	1	N/A	N/A
C	**221-H Regulated areas and H-Area outside facilities.** All personnel assigned to H-Area outside facilities; all utility operators, janitors, power operators, and selected E&I and maintenance mechanics assigned to 221-H regulated areas.	1	2	2[b]	N/A	N/A
D	**221-H maximum potential (canyons).** All auxiliary operators, crane process operators, HP personnel, and selected E&I and maintenance mechanics.	2	2	2[b]	N/A	N/A
E	**B-Line, H Area.** All assigned personnel.	4	1	N/A	N/A	2
F	**235-F.** All personnel assigned to process section of building.	4	1	N/A	N/A	N/A
G	**221-F fourth level.** Separations senior supervisors and above; all separations technology personnel, control room operators, and secretaries.	1	1	N/A	N/A	N/A
H	**221-F regulated areas, 723-F, 643-G and 717-A.** All personnel assigned to 723-F and 634-G; all janitors, power operators, and selected E&I and maintenance mechanics assigned to 221-F regulated areas; all 717-A field crews assigned.	1	2	N/A	N/A	N/A
I	**221-F maximum potential (canyons).** All auxiliary operators, utility operators, crane process operators, HP personnel, and selected E&I and maintenance mechanics.	2	2	N/A	N/A	N/A
J	**JB-Line and B-Line, F Area.** All assigned personnel.	4	1	N/A	N/A	N/A
K	**Outside facilities, F Area.** All assigned personnel.	1	2	N/A	4	N/A
L	**772-F, UO3 section.** All assigned personnel.	1	1	1	4	N/A
M	**772-F (excluding UO_3 section).** All assigned personnel.	4	2	2[b]	1	N/A
N	**313 and 320-M.**	N/A	N/A	N/A	1	N/A
O	**322-M.** All assigned personnel.	N/A	N/A	1	1	N/A
P	**322-M.** Personnel processing samples from field.	N/A	1	1	1	N/A
Q	**321-M.** Machine casting.	N/A	N/A	4	N/A	N/A
R	**321-M.** Service groups.	N/A	N/A	2	N/A	N/A
S	**321-M.** All assigned personnel	N/A	N/A	1	N/A	N/A
T	**100 Areas, 105 Buildings**. Reactor department personnel from C&D crews, purification, and pump room observation; control room and monitor operators; all 100-Area HP, maintenance, and T&T personnel; all E&I, laboratory, and HP personnel assigned to 105 buildings; T&T personnel in central shops; reactor tech personnel as designated by supervision.	(c)	(c)	(c)	(c)	(c)
U	**773-A.** Radiation control and maintenance.	1	1	N/A	1	N/A
V	**773-A.** Area maintenance mechanics.	1	1	1	1	N/A
W	**773-A.** Special group.	(d)	(d)	(d)	(d)	(d)
X	**700 Area.** Shop personnel provide samples as considered advisable by 3/700-Area survey.	(e)	(e)	(e)	(e)	(e)

a. N/A = not applicable.
b. Personnel are sampled for applicable isotope at frequency shown during operation of plutonium-uranium extraction (PUREX) and (HM).
c. IA and FP.
d. IA.
e. As considered advisable by 3/700-Area survey.

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-3. 1970 bioassay frequencies (samples per year by analysis type) (DuPont 1970).[a,b]

Cate-gory	**Description**	**Pu**	**FP**	**EU**	**U**	**Am/ Cm/ Cf**
A	**Minimum potential (except HTO).** Personnel assigned to 232-H, 234-H, 237-H, 238-H, 284-F & -H, 704-F & -H, 706-F & -H, 717-F, and nonprocess sections of other facilities; patrolmen.	1 ea. 3 yr	1 ea. 3 yr	1 ea. 3 yr	1 ea. 3 yr	1 ea. 3 yr
B	**221-F & -H Fourth level.** Separations supervision; all separations technology personnel, control room operators, janitors, and secretaries.	1	1	N/A	N/A	N/A
C	**221-H and H-Area outside facilities.** All operators (except control room and sample aisle), HP personnel, and selected power, E&I and maintenance personnel assigned to 221-H process areas; all personnel assigned to H-Area outside facilities.	1	2	1	N/A	N/A
D	**221-H sample aisle and 772-F.** All sample aisle operators; selected 772-F laboratory personnel.	2	2	2	N/A	2
E	**221-H B-Line, 221-F B-Line, JB-Line & 235-F.** In 235-F all personnel assigned to process sections of building; in other facilities all assigned personnel.	2	2	N/A	N/A	2
F	**221-F, 723-F, and 643-G.** All operators (except control room and sample aisle), HP personnel, and selected power, E&I and maintenance personnel assigned to 221-F process areas; all personnel assigned to 723-F and 643-G.	1	2	N/A	N/A	N/A
G	**221-F sample aisle.** All 221-F sample aisle operators.	2	2	N/A	N/A	N/A
H	**F-Area outside facilities**. All assigned personnel.	1 ea. 3 yr	2	N/A	4[c]	N/A
I	**772-F, UO3 section.** All assigned personnel.	1 ea. 3 yr	1	1	4	N/A
J	**772-F (excluding UO3 section).** All assigned personnel.	2	2	1	1	N/A
K	**313-M.**	N/A	N/A	N/A	4	N/A
L	**322-M.** All assigned personnel.	N/A	N/A	1	4	N/A
M	**322-M** Personnel processing samples from field.	1 ea. 3 yr	1	1	4	N/A
N	**321-M.** All assigned personnel.	1	N/A	4[d]	N/A	N/A
T	**100 Areas, 105 Buildings**. Reactor department personnel from C&D crews, purification, and pump room observation; control room and monitor operators; all 100-Area HP, maintenance, and T&T personnel; all E&I, laboratory, and HP personnel assigned to 105 buildings; T&T personnel in central shops; and selected reactor tech and 400-Area personnel.	N/A	1[e]	N/A	N/A	N/A
U	**773-A.** Reactor engineering group and 777-M assigned personnel.	1 ea. 3 yr	N/A	1	4	N/A
V	**773-A.** Analytical chemistry, high level caves, building services, radiation control, and maintenance personnel.	1 ea. 3 yr	1	N/A	N/A	2
W	**773-A.** Selected clerical and supervisory personnel.	1 ea. 3 yr	N/A	N/A	N/A	1
N/A	700-Area shop personnel provide samples as considered advisable by 3/700 Area HP.	(f)	(f)	(f)	(f)	(f)

a. N/A = not applicable.
b. Neptunium analysis is performed when requested by area HP. Neptunium has never been detected without at least an equal amount of plutonium.
c. Except A-Line where operators are sampled weekly.
d. Except casting area where operators are sampled monthly.
e. Samples also analyzed for induced activity (IA).
f. 700-Area shop personnel provide samples as considered advisable by 3/700-Area HP.

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-4. Early 1971 bioassay frequencies (samples or counts per year by analysis type) (DuPont 1971a).[a,b]

Category	Description	H3 samples	Pu samples	FP samples	EU samples	U samples	Am/Cm/Cf samples	EU counts	Pu/Am/Cm/Cf counts
A	**Minimum potential (except HTO).** Personnel assigned to 284-F & -H, 704-F & -H, 706-F & -H, 717-F, and nonprocess sections of other facilities; patrolmen.	N/A	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A
B	**221-F & -H Fourth level.** Separations supervision; all separations technology personnel, control room operators, janitors, and clerical personnel.	N/A	1	1	N/A	N/A	N/A	N/A	N/A
C	**221-H and H-Area outside facilities.** All operators (except control room and sample aisle), HP personnel, and selected power, E&I and maintenance personnel assigned to 221-H process areas; all personnel assigned to H-Area outside facilities.	2	1	2	1	N/A	N/A	N/A	N/A
D	**221-H sample aisle and 772-F.** All sample aisle operators; selected 772-F laboratory personnel.	N/A	2	2	2	N/A	1	N/A	1
E	**221-H B-Line, 221-F B-Line, JB-Line & 235-F.** All personnel assigned to process sections in building 235-F; and all assigned personnel in other facilities.	N/A	2	2	N/A	N/A	N/A	N/A	1
F	**221-F, 723-F, and 643-G.** All operators (except control room and sample aisle), HP personnel, and selected power, E&I and maintenance personnel assigned to 221-F process areas; all personnel assigned to 723-F and 643-G.	N/A	1	2	N/A	N/A	N/A	N/A	N/A
G	**221-F sample aisle.** All 221-F sample aisle operators.	N/A	2	2	N/A	N/A	2	N/A	1[c]
H	**F-Area outside facilities**. All assigned personnel.	N/A	1 ea. 3 yr	2	N/A	4[d]	N/A	N/A	N/A
J	**772-F (excluding UO_3 section).** All assigned personnel.	N/A	2	2	1	1	N/A	N/A	N/A
K	**313-M.** All assigned personnel.	N/A	N/A	N/A	N/A	4	N/A	N/A	N/A
L	**322-M.** All assigned personnel. **320-M.** All laboratory and selected radioactive material personnel. **773-A.** Reactor engineering group and 777-M assigned personnel.	N/A	1 ea. 3 yr	N/A	1	4	N/A	N/A	N/A
M	**322-M** Personnel processing samples from field. **772-F, UO3 section.** All assigned personnel.	N/A	1 ea. 3 yr	1	1	4	N/A	N/A	N/A
N	**321-M.** All assigned personnel.	N/A	1	N/A	4[e]	N/A	N/A	2[f]	N/A
T	**100 Areas, 105 Buildings**. Reactor department personnel from C&D crews, purification, and pump room observation; control room and monitor operators; all 100-Area HP, maintenance, and T&T personnel; all E&I personnel assigned to 105 buildings; T&T personnel in central shops; and selected reactor tech and 400-Area personnel.	(g)	N/A	1[h]	N/A	N/A	N/A	N/A	N/A
V	**773-A.** Analytical chemistry, high level caves, building services, radiation control, and maintenance personnel.	N/A	1 ea. 3 yr	1	N/A	N/A	2	N/A	1
W	**773-A.** Selected clerical and supervisory personnel	N/A	1 ea. 3 yr	N/A	N/A	N/A	1	N/A	N/A

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Cate-gory	Description	H3 samples	Pu samples	FP samples	EU samples	U samples	Am/Cm/Cf samples	EU counts	Pu/Am/ Cm/Cf counts
X	**232-H, 234-H, 237-H, & 238-H.** All assigned personnel. **241-H & 244-H.** Selected personnel.	(g)	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A
N/A	700 Area shop personnel provide samples as considered advisable by HP.	(i)	(i)	(i)	(i)	(i)	(i)	(i)	(i)

a. N/A = not applicable.
b. Neptunium analysis is performed when requested by area HP. Neptunium has never been detected without at least an equal amount of plutonium.
c. Selected personnel.
d. Except A-Line where operators are sampled weekly.
e. Except casting area where operators are sampled monthly.
f. Only personnel assigned to casting areas.
g. Samples also analyzed for IA.
h. Sample frequency established by local procedures.
i. 700 Area shop personnel provide samples as considered advisable by HP.

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-5. Late 1971 bioassay frequencies (samples per year or counts per year by analysis type) (DuPont 1971b) .[a,b]

Cate-gory	Description	H3 samples	Pu samples	FP samples	EU samples	U samples	Am/Cm/Cf samples	EU counts	Pu/Am/ Cm/Cf counts
A	**Minimum potential (except HTO).** Personnel assigned to 284-F & -H, 704-F & -H, 706-F & -H, 717-F, and nonprocess sections of other facilities; patrolmen.	N/A	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A
B	**221-F & -H Fourth level.** Separations supervision; all separations technology personnel, control room operators, janitors, and clerical personnel.	N/A	1	1	N/A	N/A	N/A	N/A	N/A
C	**221-H and H-Area outside facilities.** All operators (except control room and sample aisle), HP personnel, and selected power, E&I and maintenance personnel assigned to 221-H process areas; all personnel assigned to H-Area outside facilities.	2	1	2	1	N/A	N/A	N/A	N/A
D	**221-H sample aisle.** All 221-H sample aisle operators; selected 772-F laboratory personnel.	N/A	2	2	2	N/A		N/A	1
E	**221-F Sample aisle.** All 221-F sample aisle operators; selected 772-F personnel.	N/A	2	2	N/A	N/A	2	N/A	
F	**221-F, 723-F, and 643-G.** All operators (except control room and sample aisle), HP personnel, and selected power, E&I and maintenance personnel assigned to 221-F process areas; all personnel assigned to 723-F and 643-G.	N/A	1	2	N/A	N/A	N/A	N/A	
G	**221-H B-Line, 221-F B-Line, JB-Line, 235-Fe.** All personnel assigned to process sections in building 235-F, and all assigned personnel in other facilities.	N/A	2	2	N/A	N/A	N/A	N/A	1
H	**F-Area outside facilities**. All assigned personnel.	N/A	1 ea. 3 yr	2	N/A	4[c]	N/A	N/A	N/A
J	**772-F (excluding UO_3 section).** All assigned personnel.	N/A	2	2	1	1	N/A	N/A	1[d]
K	**313-M.** All assigned personnel.	N/A	N/A	N/A	N/A	4	N/A	N/A	N/A
L	**322-M.** All assigned personnel, including personnel processing samples from field. **320-M.** All laboratory and selected RADIOACTIVE MATERIAL personnel. **773-A.** Reactor engineering group and 777-M assigned personnel.	N/A	1 ea. 3 yr	N/A	1	4	N/A	N/A	N/A
M	**322-M** Personnel processing samples from field. **772-F, UO_3 section.** All assigned personnel.	N/A	1 ea. 3 yr	1	1	4	N/A	N/A	N/A
N	**321-M.** All assigned personnel.	N/A	1	N/A	4[e]	N/A	N/A	2[f]	N/A
T	**100 Areas, 105 Buildings**. Reactor department personnel from C&D crews, purification, and pump room observation; control room and monitor operators; all 100-Area HP, maintenance, and T&T personnel; all E&I personnel assigned to 105 buildings; T&T personnel in central shops; and selected reactor tech and 400-Area personnel.	(g)	N/A	1[h]	N/A	N/A	N/A	N/A	N/A

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Category	Description	H3 samples	Pu samples	FP samples	EU samples	U samples	Am/Cm/Cf samples	EU counts	Pu/Am/Cm/Cf counts
V	**773-A.** Analytical chemistry, high level caves, building services, radiation control, and maintenance personnel.	N/A	1 ea. 3 yr	1	N/A	N/A	2	N/A	1[d]
W	**773-A.** Selected clerical, supervisory personnel, and selected 100-Area personnel.	N/A	1 ea. 3 yr	N/A	N/A	N/A	1	N/A	N/A
X	**232-H, 234-H, 237-H, & 238-H.** All assigned personnel. **241-H & 244-H.** Selected personnel.	(g)	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A
N/A	**700 Area.** Shop personnel provide samples as considered advisable by HP.	(i)	(i)	(i)	(i)	(i)	(i)	(i)	(i)

a. N/A = not applicable.
b. Neptunium analysis is performed when requested by area HP. Neptunium has never been detected without at least an equal amount of plutonium.
c. Except A-Line where operators are sampled weekly.
d. Selected personnel.
e. Except casting area where operators are sampled monthly.
f. Only personnel assigned to casting areas.
g. Sample frequency established by local procedures.
h. Samples also analyzed for IA.
i. 700 Area shop personnel provide samples as considered advisable by HP.

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-6. 1976 bioassay frequencies (samples per year or counts per year by analysis type) (DuPont 1976).[a]

Personnel work assignment	**Pu samples**	**Eu samples**	**U samples**	**IA/ FP samples**	**Am/ Cm/ Cf samples**	**Sr samples**	**H3 samples**	**FP samples**	**Days counts**	**Shift counts**
Minimum Potential. Personnel working in tritium facilities, 200-FH facilities not mentioned below, 723-A (EED), and 305-M. Selected 100-Area and 773-A personnel.	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	(b)	N/A	1 ea. 3 yr[c]	1 ea. 3 yr
221-FH. All operators, Sep Tech, HP, and 4th level personnel; E&I, Maintenance. Clerical, and Service Department personnel assigned to process areas. **241-FH, 211-FH, 723-F, A-Line, 643-G & 244-H.** All assigned personnel. **772-F & 235-F.** Personnel assigned to nonprocess areas. **Patrol & T&T**. All personnel assigned to 200-FH Areas. **773-A.** Selected clerical and supervisory personnel. 100-Areas. Selected personnel.	1	(d)	(e)	N/A	(f)	(g)	N/A	N/A	1	2
221-HB Line, 221-FB Line, JB-Line. All assigned personnel. **235-F.** Personnel assigned to process areas. **772-F.** Personnel assigned to process areas. **773-A.** Selected ACD, SEC, SCD, NMD, HLC, Radiation Control, Building Services, and Maintenance personnel.	4	(d)	N/A	N/A	(f)	N/A	N/A	(c)	1[h]	2
313-M. All assigned personnel.	N/A	N/A	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
322-M & 772-F (UO_3 Section). All assigned personnel. **320-M.** All laboratory and selected radioactive material personnel. **773-A.** Reactor Engineering and 777-M personnel.	1 ea. 3 yr	1	4	N/A	N/A	N/A	N/A	N/A	(i)	(i)
321-M. All assigned personnel except those in Casting Area.	1	4	N/A	N/A	N/A	N/A	N/A	N/A	1 ea. 3 yr	1
Reactor Department personnel from CH purification and pumproom observation; control room and monitor operators; all 100-Area HP, maintenance, and T&T personnel; E&I and service personnel assigned to 105 buildings; T&T personnel in central shops and 618-G; selected reactor tech, project and 400-Area personnel.	1[c]	N/A	N/A	N/A	N/A	N/A	(b)	N/A	1[j]	1[j]
321-M. All personnel assigned to Casting Area.	1	12	N/A	N/A	N/A	N/A	N/A	N/A	2	2

a. N/A = not applicable.
b. Sample frequency established in local procedures.
c. Selected personnel.
d. Selected personnel in 221-H, 211-H, and 772-F sampled for enriched uranium (EU) four times a year.
e. A-Line assigned personnel in F-Area sampled weekly; samples collected after day(s) of rest and before exposure.
f. Selected personnel in 221-F, 211-F, and 773-A sampled for Am-Cm once a year.
g. Selected personnel assigned to waste management work sampled for Sr once a year.
h. All B-Line and JB-Line personnel and 772-F laboratory attendants counted twice a year.
i. 322-M personnel processing 200-Area samples and 772-F (UO3 Section) personnel counted once a year.
j. Selected day and all shift personnel; urine sample not required if in-vivo count scheduled.

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-7. 1985 bioassay frequencies (samples per year or counts per year by analysis type) (DuPont 1985)[a,b].

Personnel work assignment	Pu samples	EU samples	NU samples	FP/IA samples	Am/ Cm/ Cf samples	Np samples	Sr samples	In-vivo counts[c]
100-400 Areas. Selected day personnel and all shift Reactor Department CH, purification, pump observation room, and monitor operators.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1
100-400 Areas. Reactor control room operators, HP, Maintenance, T&T, E&I, and service personnel assigned to 105 Building, T&T personnel in Central Shops and 618-G; selected Reactor Tech, Project, and selected 400-Area personnel.	1 ea. 3 yr	N/A	N/A	1	N/A	N/A	N/A	N/A
100-400 Areas. Maximum potential. Selected personnel.	1	N/A	N/A	N/A	N/A	N/A	N/A	1
100-400 Areas. Other personnel assigned to 105 Building. Selected 400 Area personnel.	N/A	N/A	N/A	1	N/A	N/A	N/A	N/A
200 Area. Personnel working in tritium facilities or 200-FH facilities not mentioned below.	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A	1
211-FH, 723-F, 643-G, A-Line, 241-FN, 244-H. All Separations operators; Sep. Tech, HP, and other 4th level personnel; E&I, Maintenance, clerical, and service department personnel assigned to process areas.	1	N/A	N/A	N/A	N/A	N/A	N/A	1
235-F, 772-F. Selected personnel.	1	N/A	N/A	N/A	N/A	N/A	N/A	1
221-F. Selected personnel.	1	N/A	N/A	N/A	1	N/A	N/A	1
221-H. Selected personnel.	1	4	N/A	N/A	N/A	N/A	N/A	1
643-G. Selected personnel assigned to waste management work.	1	N/A	N/A	N/A	N/A	N/A	1	1
221-FB-Line, JB-Line. All assigned personnel.	2	N/A	N/A	N/A	N/A	N/A	N/A	1
235-**F**. Personnel assigned to process areas.	2	N/A	N/A	N/A	N/A	1	N/A	1
772-F. Personnel assigned to laboratories in the PUREX and Pu sections.	2	1	N/A	N/A	N/A	N/A	N/A	1
221-F. Selected personnel.	2	N/A	N/A	N/A	2	N/A	N/A	1
221-H, 772-F. Selected personnel.	2	4	N/A	N/A	N/A	N/A	N/A	1
221-HB-Line. All assigned personnel.	4	N/A	N/A	N/A	N/A	N/A	N/A	2
300 Areas, 313-M. All assigned personnel.	N/A	N/A	4	N/A	N/A	N/A	N/A	1
322-M. UO_3 Sections and other selected personnel.	1	1	4	N/A	N/A	N/A	N/A	1
322-M. All other assigned personnel.	1 ea. 3 yr	1	4	N/A	N/A	N/A	N/A	1
320-M. All laboratory and selected radioactive material personnel.	N/A	1	4	N/A	N/A	N/A	N/A	1
321-M. All personnel assigned to charge prep, casting, and machining areas.	1	12	N/A	N/A	N/A	N/A	N/A	2
321-M. All other assigned personnel.	1	4	N/A	N/A	N/A	N/A	N/A	1
773-A. Minimum potential.	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A	1
773-A. Selected ACD, SED, SCD, NMD, HLC, Radiation Control, Building Services, and Maintenance personnel.	2	N/A	N/A	N/A	N/A	N/A	N/A	1
773-A. Reactor Engineering and 777-M personnel.	1 ea. 3 yr	1	4	N/A	N/A	N/A	N/A	1

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Personnel work assignment	Pu samples	EU samples	NU samples	FP/IA samples	Am/ Cm/ Cf samples	Np samples	Sr samples	In-vivo counts[c]
773-A. Selected clerical and supervisory personnel.	1	N/A	N/A	N/A	N/A	N/A	N/A	1
773-A. Maximum potential. Selected personnel.	2	2	4	N/A	2	N/A	N/A	1

a. N/A = not applicable.
b. This 1985 procedure indicates it is a duplicate of a 1978 procedure, so these frequencies apply for at least the 1978 to 1985 period.
c. The count frequency for shift employees is twice a year unless they only receive triennial plutonium urine bioassay.

ATTACHMENT A
BIOASSAY DATA TYPES AND STATISTICAL ANALYSIS RESULTS (continued)

Table A-8. 1989 bioassay frequencies (samples per year or counts per year by analysis type)[a] (DuPont undated a).

Personnel Work Assignment	Pu samples	EU samples	NU samples	Am/Cm/ Cf samples	Np samples	Sr samples	In-vivo counts
100-400 Areas, All reactor area departments and construction. Selected day personnel and all shift Reactor Department CH, purification, pump observation room, and monitor operators. Maintenance, T&T, E&I, and service personnel assigned to 105 building, T&T personnel in Central Shops and 618-G; selected Reactor Tech, Project, and selected 400-Area personnel.	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A
100-400 Areas, All reactor area departments and construction. HP, selected CH.	1	N/A	N/A	N/A	N/A	N/A	1
211-H. Selected personnel.	1	4	N/A	N/A	N/A	N/A	1
643-G. Selected personnel assigned to waste management work.	N/A	4	N/A	N/A	N/A	1	1
FB-Line. Operators and first line supervisors. SWE mechanics.	4	N/A	N/A	N/A	N/A	N/A	1
FB-Line. Other assigned personnel.	N/A	4	N/A	N/A	N/A	N/A	1
HB-Line. Operators.	4	N/A	N/A	N/A	1	N/A	1
HB-Line. Other assigned personnel.	1	N/A	N/A	N/A	1	N/A	1
235-F. Operators.	4	N/A	N/A	N/A	1	N/A	1
235-F. Other assigned personnel.	1	N/A	N/A	N/A	1	N/A	1
A-Line (F). All assigned personnel.	1	N/A	12	N/A	N/A	N/A	1
772-F. Personnel assigned to laboratories in the PUREX and Pu sections.	2	1	N/A	N/A	N/A	N/A	1
221-F. Selected personnel.	1	N/A	N/A	N/A	N/A	N/A	1
221-H. Selected personnel.	2	4	N/A	N/A	N/A	N/A	1
313-M. All assigned personnel.	N/A	N/A	4	N/A	N/A	N/A	
322-M. All assigned personnel.	1	4	4	N/A	N/A	N/A	1
320-M. All laboratory and selected radioactive material personnel.	N/A	4	4	N/A	N/A	N/A	1
321-M. All personnel assigned to charge prep, casting, and machining, and assembly weld areas.	1	12	N/A	N/A	N/A	N/A	1
773-A. Minimum potential.	1 ea. 3 yr	N/A	N/A	N/A	N/A	N/A	N/A
773-A. Selected ACD, SED, SCD, NMD, HLC, Radiation Control, Building Services, and Maintenance personnel.	2	N/A	N/A	1	N/A	N/A	1
773-A. Reactor Engineering and 777-M personnel.	1 ea. 3 yr	1	4	N/A	N/A	N/A	N/A
773-A. Selected clerical and supervisory personnel.	1	N/A	N/A	N/A	N/A	N/A	1
773-A. Maximum potential. Selected personnel.	2	2	4	2	N/A	N/A	1
221-S. All assigned personnel.	1	N/A	N/A	N/A	N/A	1	1
250-S. All assigned personnel.	1	N/A	N/A	N/A	N/A	1	1
210-Z. All assigned personnel.	1	N/A	N/A	N/A	N/A	1	1
247-F. Personnel who perform work in process core.	N/A	12	N/A	N/A	N/A	N/A	1
247-F. Personnel who do not perform work in process core.	N/A	4	N/A	N/A	N/A	N/A	1

a. N/A = not applicable.

ATTACHMENT B
EVALUATION OF HIGH-VARIABILITY AMERICIUM DATA

An SC&A memorandum of February 24, 2014, to the Savannah River Site Work Group contains an examination of raw trivalent actinide (americium, curium, and californium) urinalysis data that were used to calculate thorium intakes for the SRS internal dose coworker study (SC&A 2014). The examination focused on results greater than the MDA that exhibited a large variability between multiple counts of the same sample, or where the reported result was inconsistent with the individual sample counts. Individual urine samples might be counted anywhere from 1 to 10 times, with 2 or 4 times being common. Large variability occurs when the results of these repeat counts of the same sample are widely different. An inconsistent reported result occurs when the reported result does not match the average of the individual counts of the sample. The examination consisted of the compilation of >MDA results, highlighting of results with inconsistency or large variability, and identification of workers who were chelated. This attachment provides further evaluation of those results to determine the potential significance of the highlighted results as well as evaluation of the removal of chelated individuals. For the highlighted results, only the inconsistent and high-variability results greater than 1 dpm/d were evaluated further.

During the preparation of the response to SC&A's findings, ORAUT-RPRT-0053 was revised to alter the OPOS analysis method to the TWOPOS method (ORAUT 2014b). An additional change with the TWOPOS method is to consider all negative (in the numeric sense of being less than zero rather than less than the MDA) sample results as "<0" censored results. The impact of the high-variability and inconsistent results and removal of the chelated individuals were evaluated using the TWOPOS method.[1]

Chelation accelerates the removal of actinides from the body by chemically binding with the actinide, which produces a chemical compound more readily eliminated through urine or feces (or both). This chemical process perturbs the normal bodily excretion of actinides and can also result in heterogeneity of the actinide concentration in the urine. SRS commonly analyzed small aliquots of urine samples using a sample volume of 5 or 10 mL. When a small aliquot is taken from a urine sample, this heterogeneity can result in markedly different radionuclide concentrations in comparison with a different aliquot from the same urine sample.

Results Greater than 3 dpm/1.5L

SC&A found 220 results greater than 3 dpm/1.5L. These 220 samples were from 35 different individuals. Twenty-one of those individuals had received DTPA. Of these 220 results, 28 results had high variability between the dpm/1.5L values. An additional 20 results had inconsistent results between the reported and dpm/1.5L values.

Of the 28 results with high variability, 17 were from one person who had already been excluded from the coworker study; therefore, the variability in those data is not relevant. Urinalysis results influenced by administration of DTPA have been removed from this revision of the coworker study. Therefore, the data from any other individuals whose urinalysis results were influenced by administration of DTPA do not need any further evaluation because they are excluded.

After exclusion of urinalysis results influenced by administration of DTPA, 21 samples greater than 3 dpm/1.5L remained. Of these, only five individuals not receiving DTPA had highlighted results. Two individuals had one sample each exhibiting high variability, two individuals had one sample each with an inconsistent result, and one individual had two samples with inconsistent results, one of which was a typographical error. These individuals had a total of 21 results >3 dpm/1.5L.

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[1] This evaluation was conducted before stratification of the coworker data into CTW and non-CTW strata.

ATTACHMENT B
EVALUATION OF HIGH-VARIABILITY AMERICIUM DATA (continued)

A broad-scale view of the trends in variability of all the trivalent actinide bioassay data without chelation can be seen in Figure B-1. This figure plots the coefficient of variation in the count-specific results for each sample as a function of sample result. Figure B-2 is a smaller scale view of the same data focusing on results less than 5 dpm/d. The trend line is the 95th percentile of the coefficient of variation, meaning only 5% of the sample results are above this line. The trend line behaves as expected, with higher values for very small results and decreasing as a function of increasing sample results. There are a few results that can be perceived to be high outliers, but most of these results have straightforward reasons for the high variability and will most likely be excluded in the next revision of the coworker study.

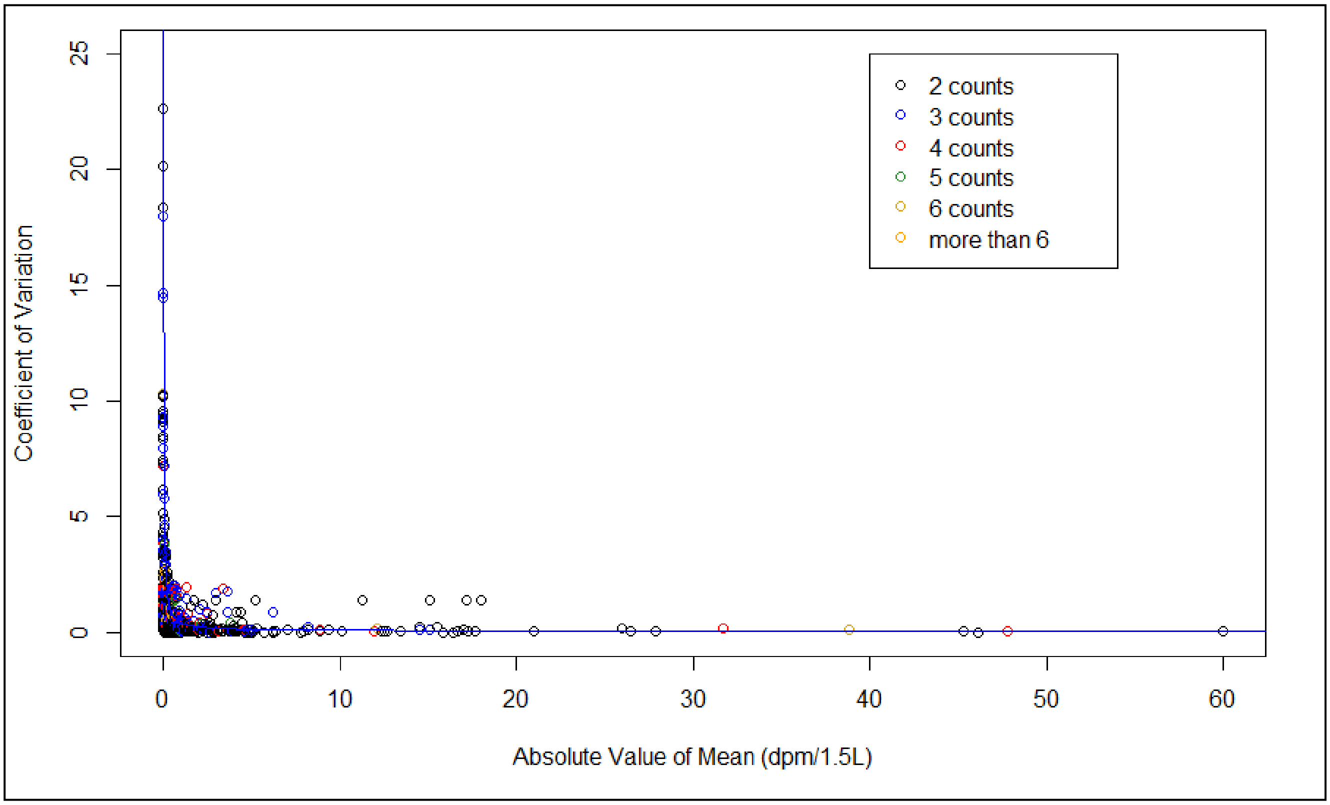


Figure B-1. Coefficient of variation of count-specific results.

Results Between 1 and 3 dpm/1.5L

SC&A found 116 results between 1 and 3 dpm/1.5L from 49 different individuals. Twenty-one of the individuals received DTPA. Of the 116 results, 29 had high variability between the dpm/1.5L values. An additional five results had inconsistent results between the reported and dpm/1.5L values.

Of the 29 results with high variability, 14 were from one person who had already been excluded from the coworker study because the high americium results were from a plutonium wound intake; therefore, the variability in those data is not relevant. Urinalysis results influenced by administration of DTPA have been removed from this revision of the coworker study. Therefore, the data from any other individuals whose urinalysis results were influenced by administration of DTPA do not need any further evaluation because they are excluded.

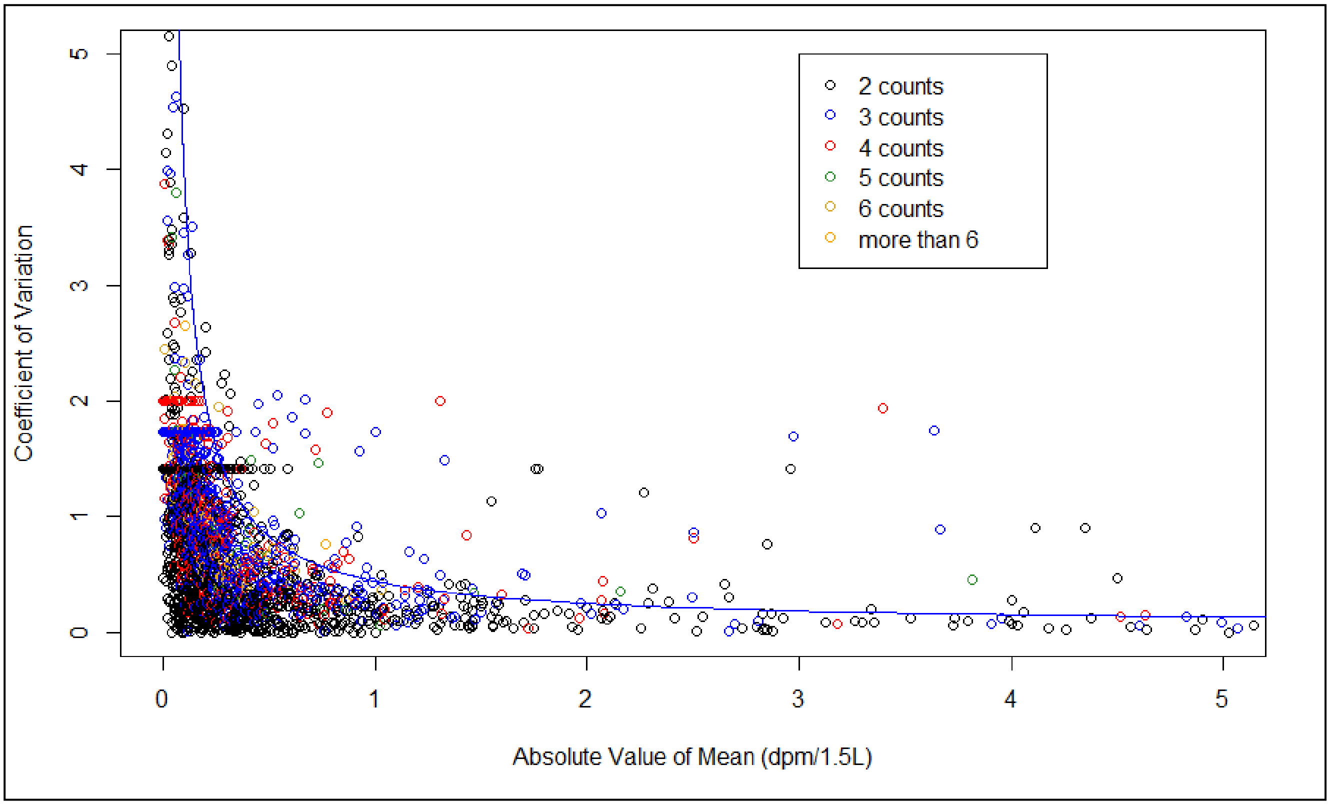


Figure B-2. Coefficient of variation of count-specific results, small scale.

After exclusion of urinalysis results influenced by administration of DTPA, 31 sample results between 1 and 3 dpm/1.5L remained. Of these, only three individuals not receiving DTPA had highlighted results. All three individuals had one result with high variability. These individuals had a total of four results between 1 and 3 dpm/1.5L. Only one had a result greater than 3 dpm/1.5L, and that result was not highlighted.

Conclusions

Table B-1 summarizes the data SC&A reviewed that was greater than 1 dpm/d and the portion that had high variability. Only 4 of 52 samples >1 dpm/d unaffected by chelation had high variability. Two of those were characterized as highly variable due to issues with data entry rather than with the site's bioassay program. This means that, of the samples used in the coworker study, less than 4% had high variability as defined by SC&A due to potential issues with the site's bioassay program. This low percentage of individual disc variability and uncertainty is subsumed under the statistical analysis of all the samples collectively. All of the uncertainties discussed by SC&A are much less than the minimum GSD of 3.0 used for coworker study intakes. Therefore, the conclusion is that aliquot variability has an insignificant effect on the overall results and the data can be used as is.

ATTACHMENT B
EVALUATION OF HIGH-VARIABILITY AMERICIUM DATA (continued)

Table B-1. Summary of data >1 dpm/d.

Sample type	**Total # of samples**	**# of samples with high variability**[a]
All samples >3 dpm/d	220	28
Samples > 3dpm/d w/o chelation	21	2
All samples between 1 and 3 dpm/d	116	29[b]
Samples between 1 and 3 dpm/d w/o chelation	31	0

a. Excluding high variability due to data entry issues.
b. 14 of these 29 samples are from one person.

ATTACHMENT C
COWORKER DATA FIGURES

LIST OF TABLES

LIST OF FIGURES

ATTACHMENT C
COWORKER DATA FIGURES (continued)

ATTACHMENT C
COWORKER DATA FIGURES (continued)

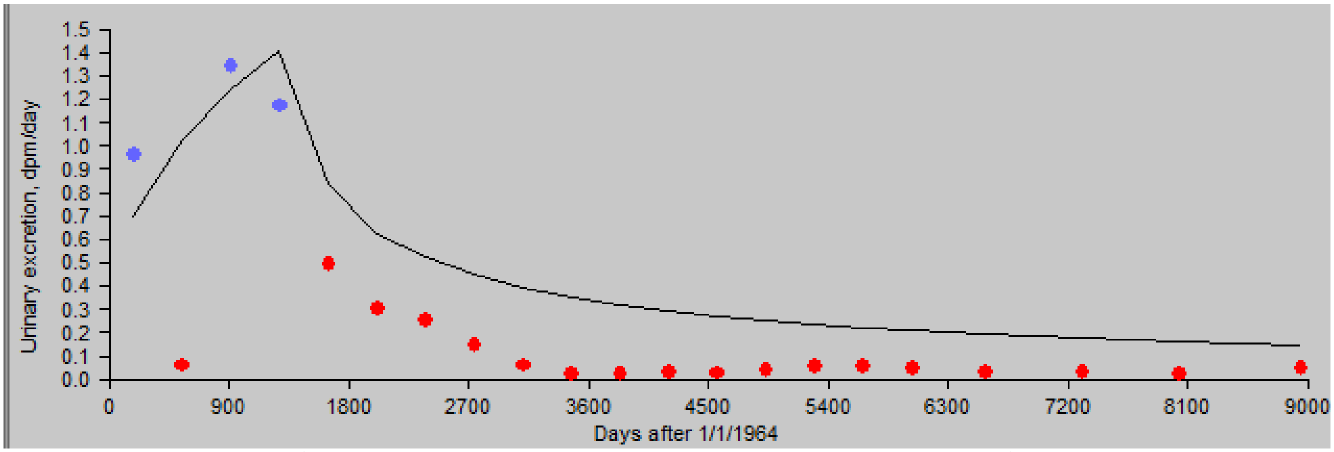


Figure C-1. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 50th percentile, 1964 to 1967, type M.

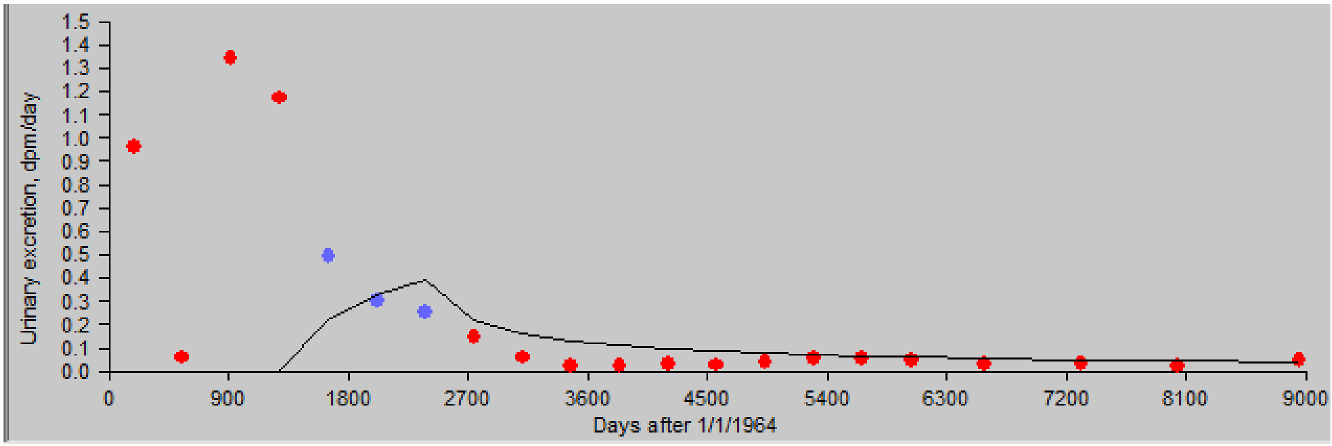


Figure C-2. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 50th percentile, 1968 to 1970, type M.

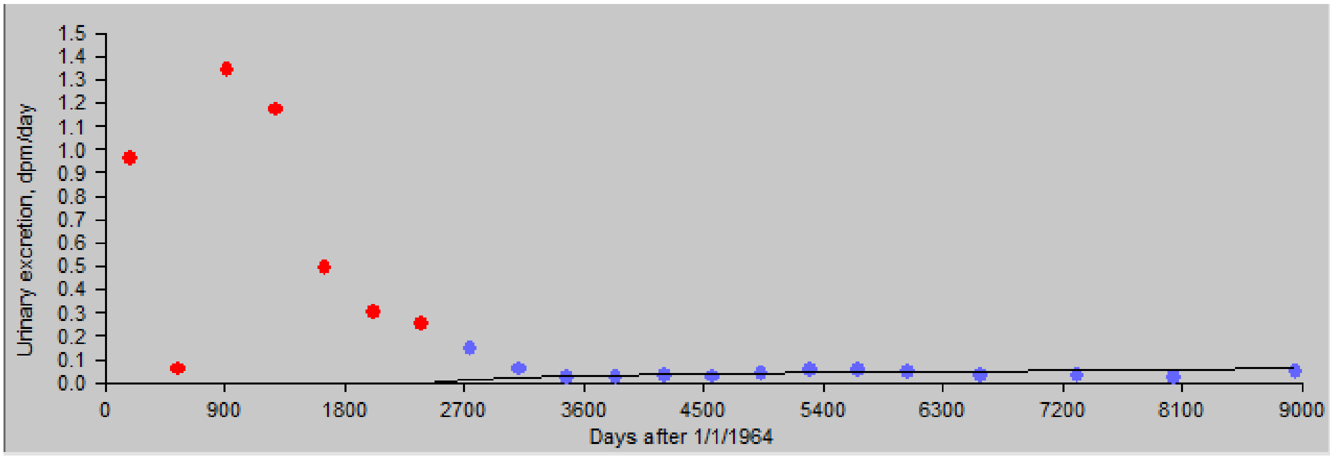


Figure C-3. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 50th percentile, 1971 to 1989, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

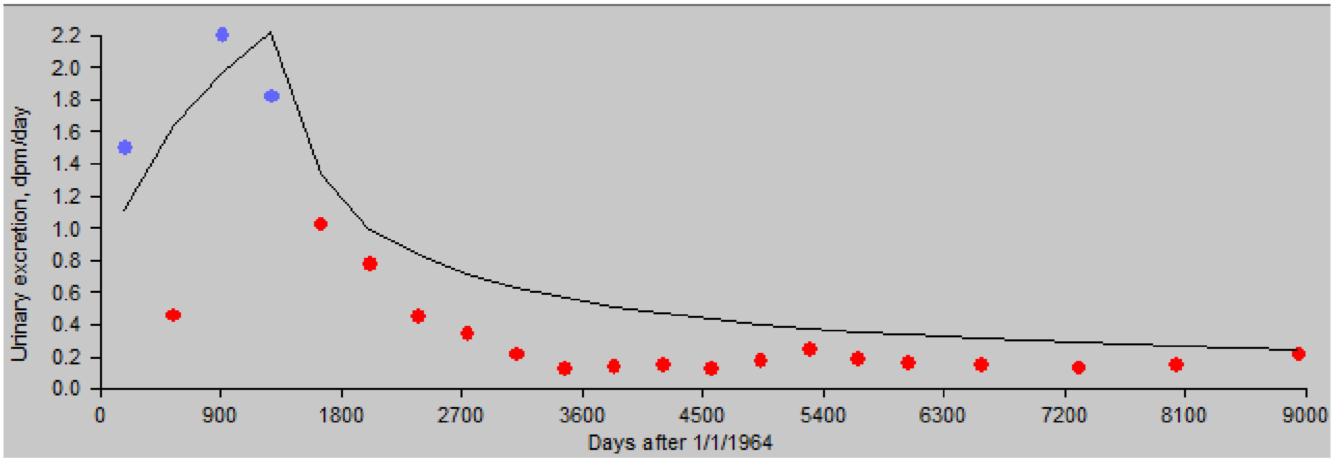


Figure C-4. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 84th percentile, 1964 to 1967, type M.

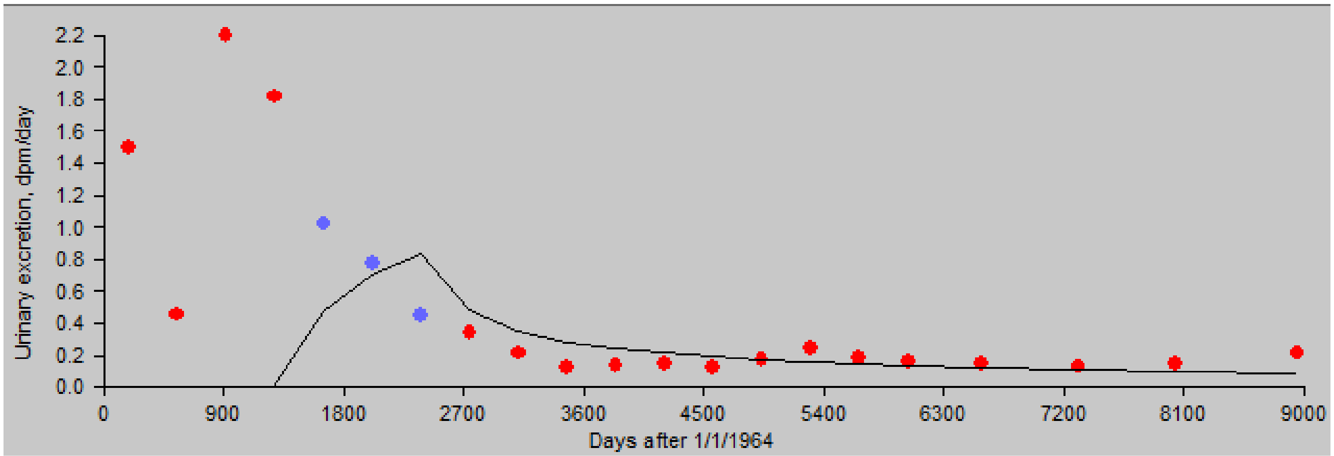


Figure C-5. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 84th percentile, 1968 to 1970, type M.

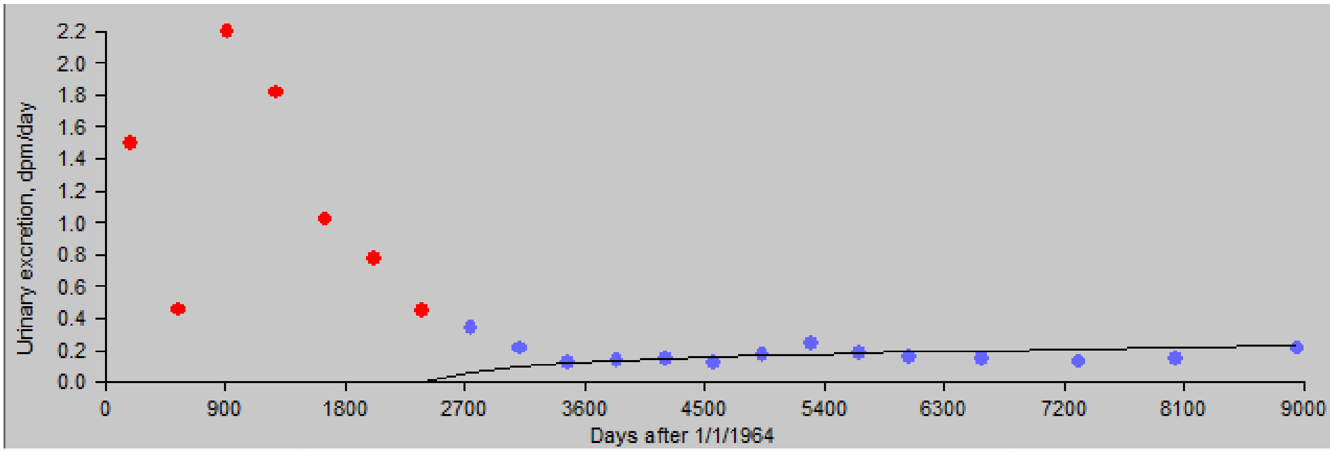


Figure C-6. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 84th percentile, 1971 to 1989, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

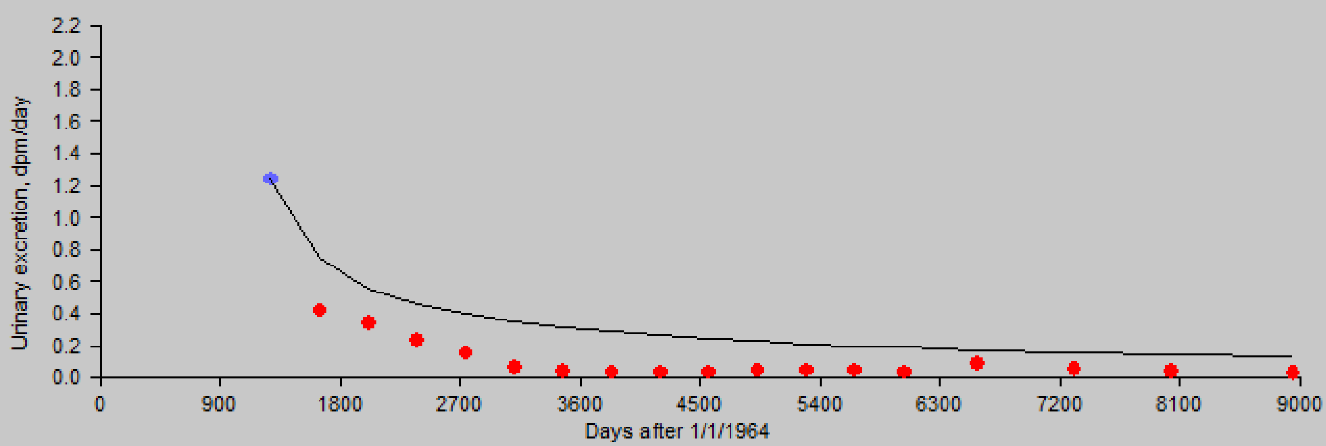


Figure C-7. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 50th percentile, 1964 to 1967, type M.

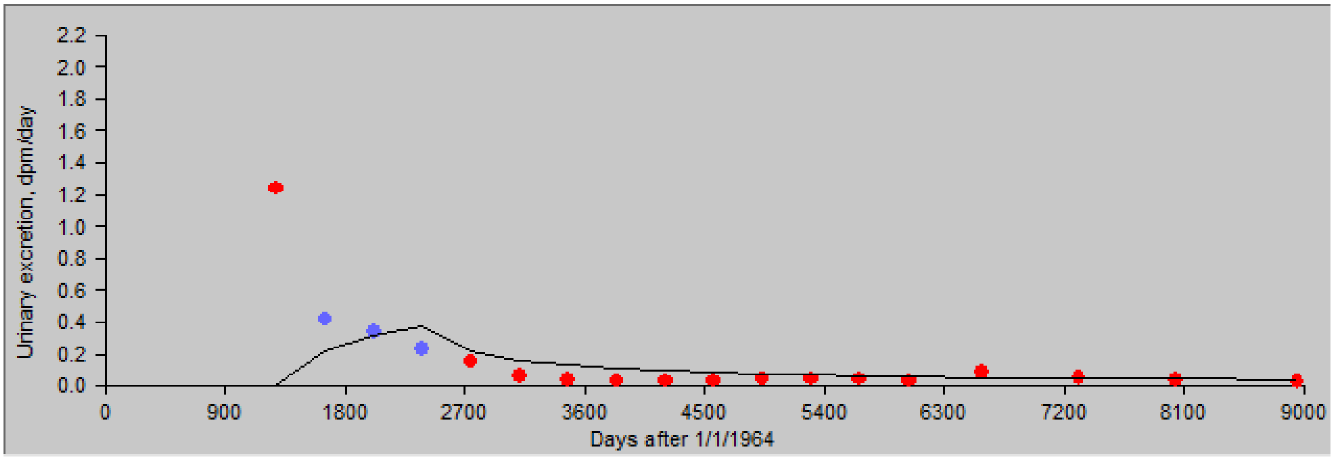


Figure C-8. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 50th percentile, 1968 to 1970, type M.

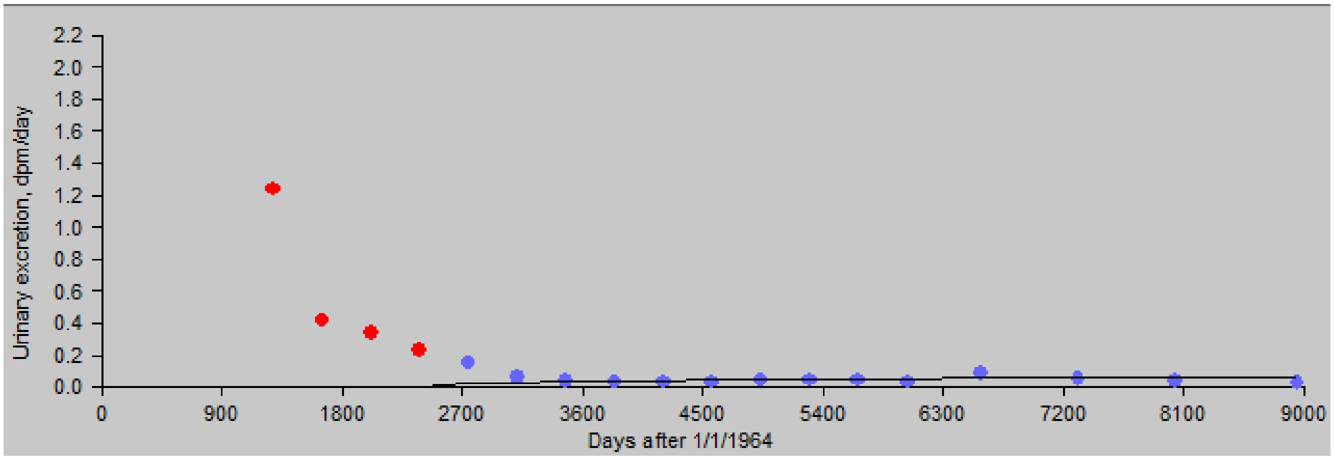


Figure C-9. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 50th percentile, 1971 to 1989, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

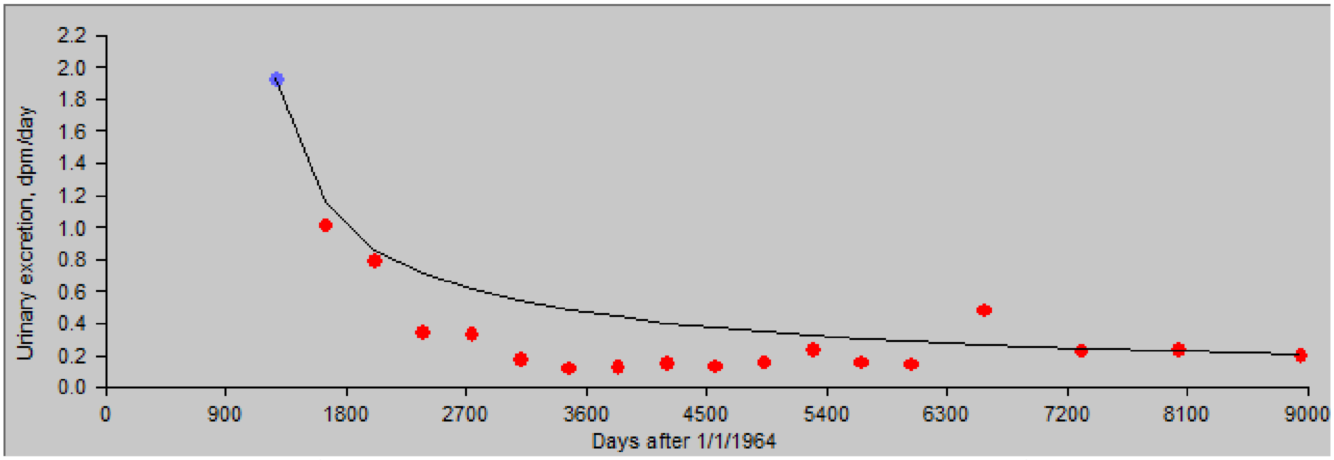


Figure C-10. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 84th percentile, 1964 to 1967, type M.

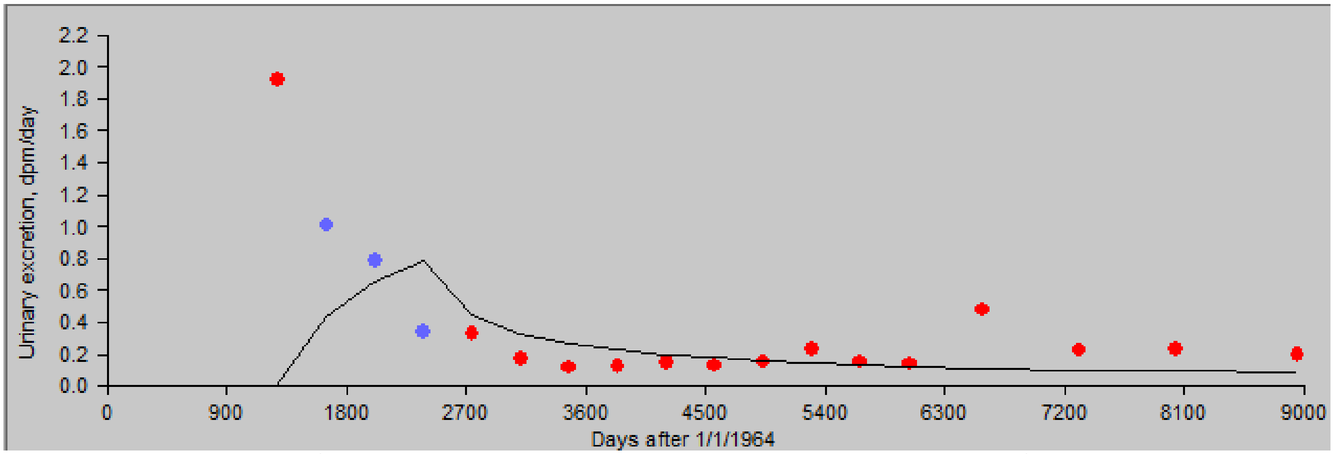


Figure C-11. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 84th percentile, 1968 to 1970, type M.

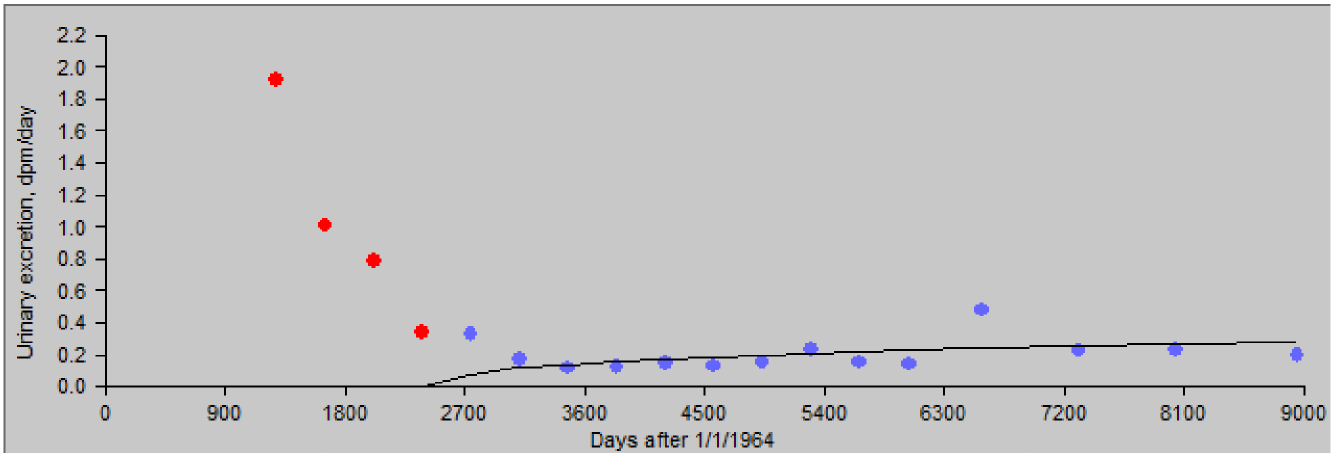


Figure C-12. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 84th percentile, 1971 to 1989, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

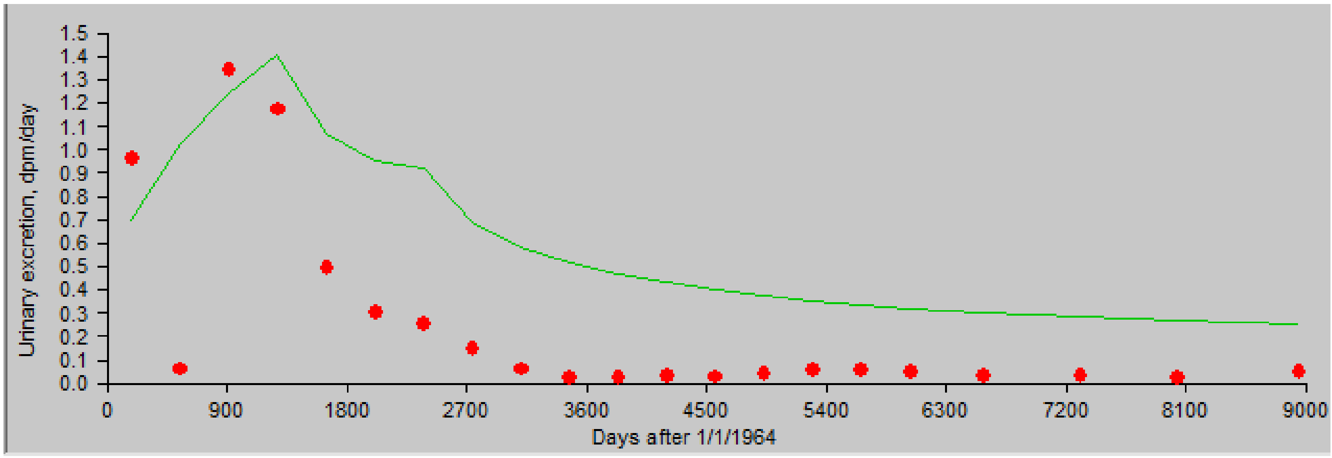


Figure C-13. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 50th percentile, all years, type M.

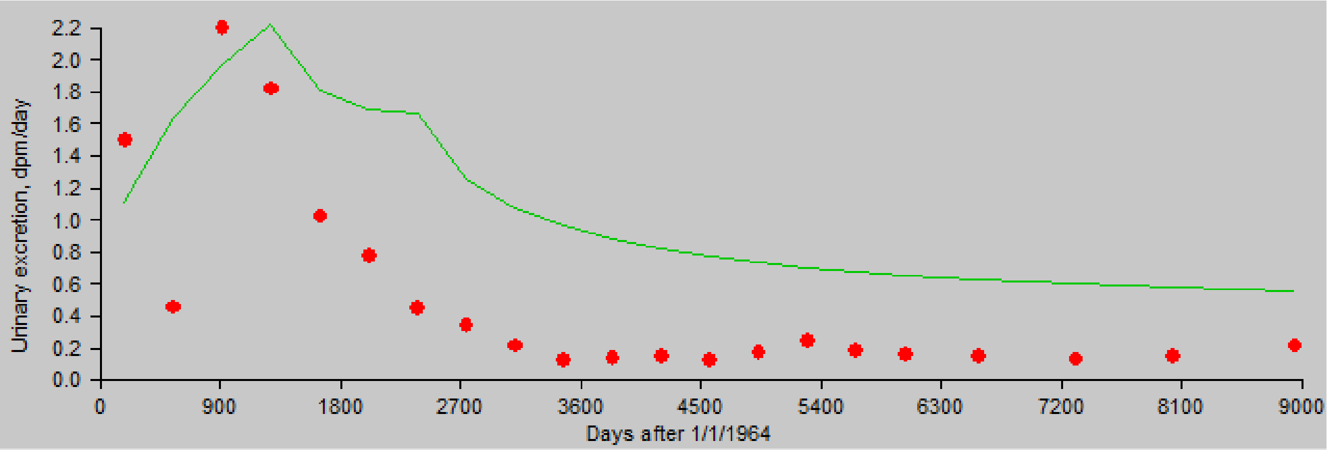


Figure C-14. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), nonCTW 84th percentile, all years, type M.

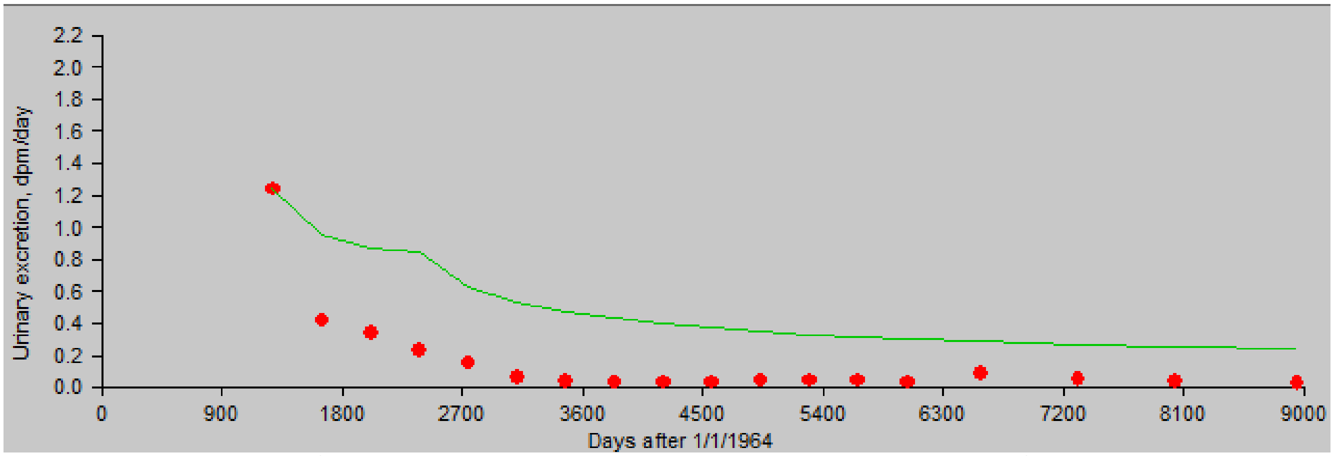


Figure C-15. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 50th percentile, all years, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

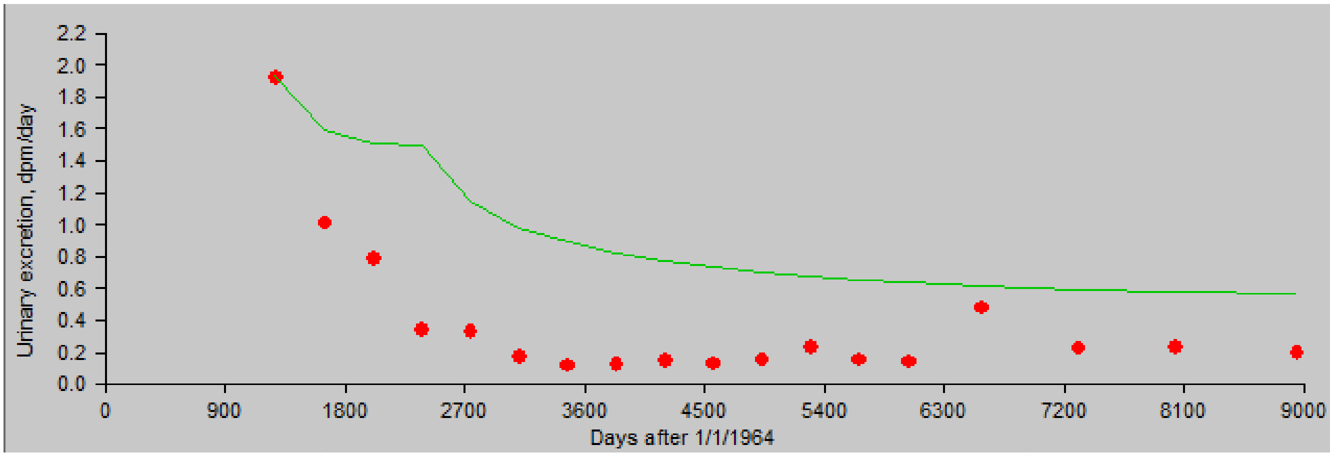


Figure C-16. Predicted ^{241}Am bioassay results calculated using IMBA-derived ^{241}Am intake rates (line) compared with measured bioassay results (dots), CTW 84th percentile, all years, type M.

Table C-1. Summary of ^{241}Am intake rates (dpm/d) and dates.

nonCTW

Start	End	50th percentile	84th percentile	GSD	Adj GSD	95th percentile
01/01/1964	12/31/1967	124.5	197.5	1.59	3.00	759
01/01/1968	12/31/1970	39.8	84.2	2.12	3.00	243
01/01/1971	12/31/1989	3.126	11.58	3.70	3.70	26.9

CTW

Start	End	50th percentile	84th percentile	GSD	Adj GSD	95th percentile
01/01/1964	12/31/1967	110.3	171	1.55	3.00	672
01/01/1968	12/31/1970	37.91	78.69	2.08	3.00	231
01/01/1971	12/31/1989	3.338	13.85	4.15	4.15	34.7

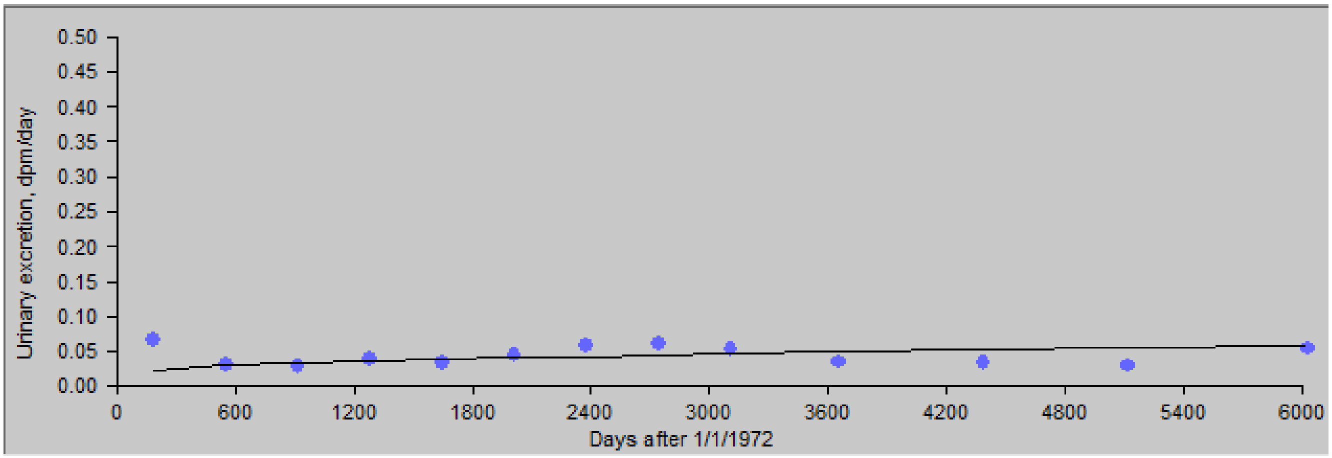


Figure C-17. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 50th percentile, nonCTW 1972 to 1989, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

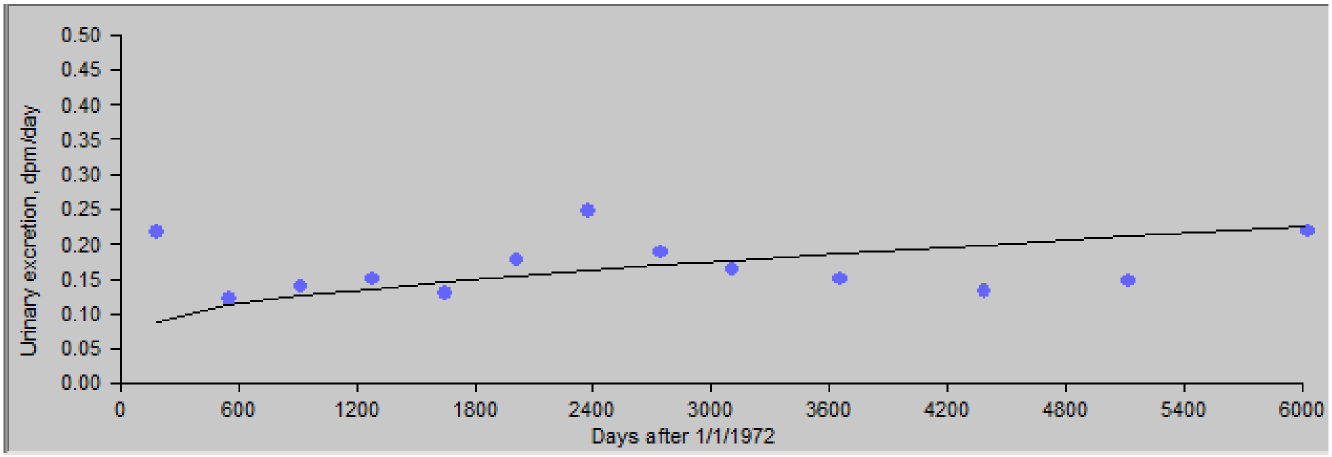


Figure C-18. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 84th percentile, nonCTW 1972 to 1989, type M.

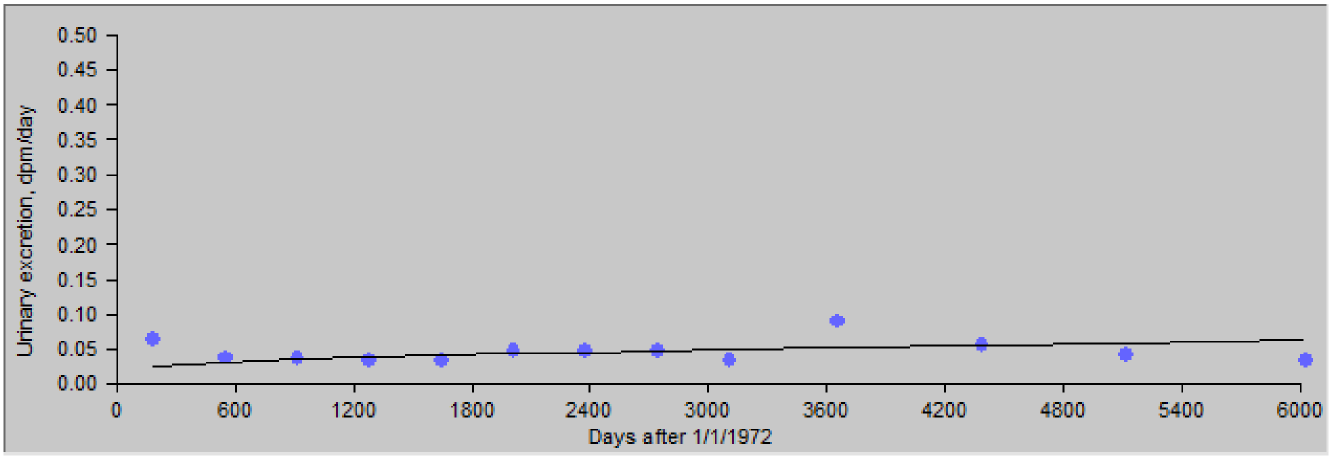


Figure C-19. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 50th percentile, CTW 1972 to 1989, type M.

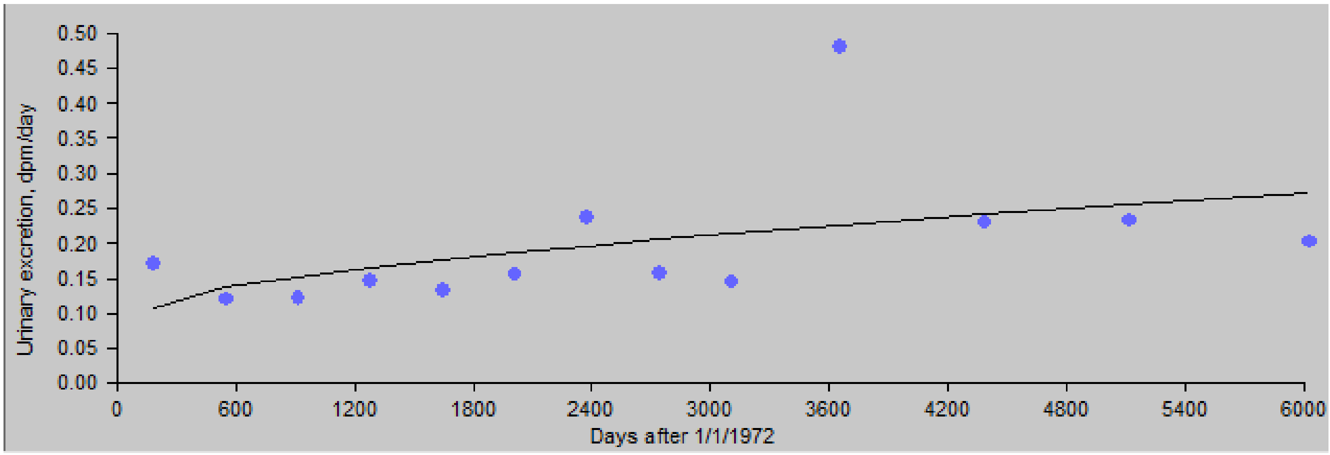


Figure C-20. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 84th percentile, CTW 1972 to 1989, type M.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

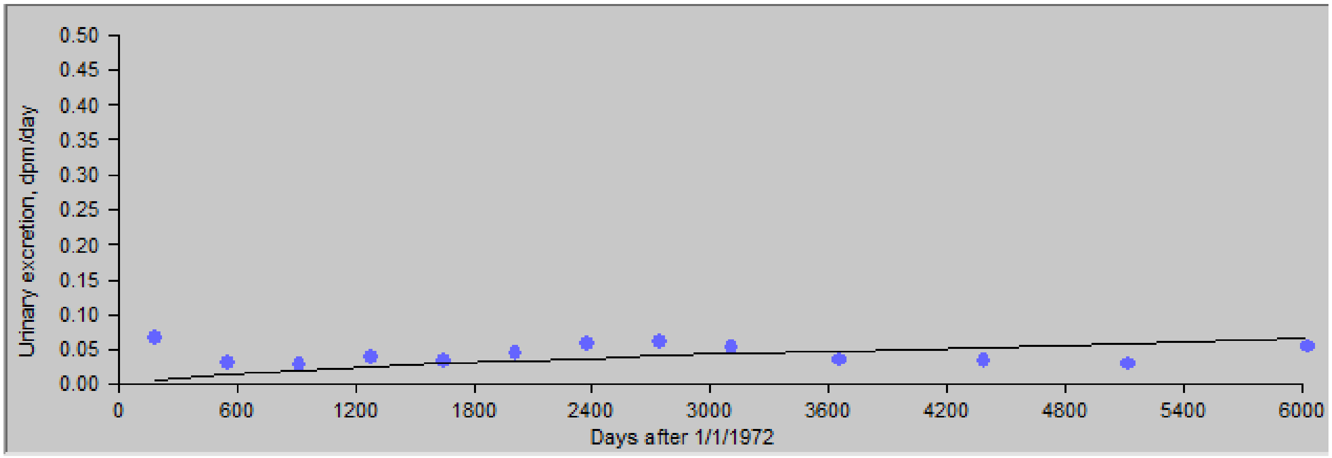


Figure C-21. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 50th percentile, nonCTW 1972 to 1989, type S.

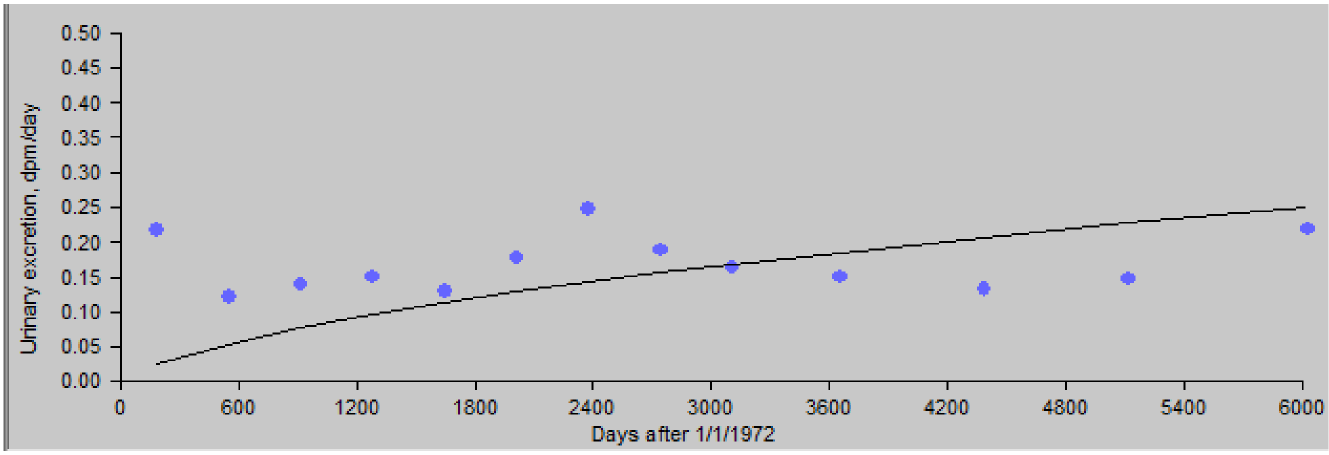


Figure C-22. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 84th percentile, nonCTW 1972 to 1989, type S.

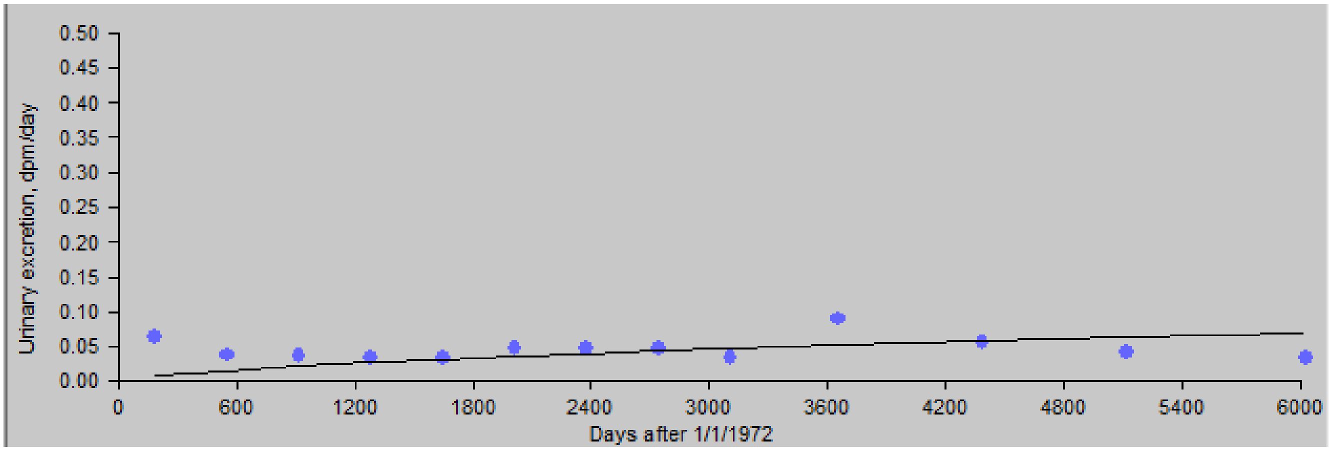


Figure C-23. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 50th percentile, CTW 1972 to 1989, type S.

ATTACHMENT C
COWORKER DATA FIGURES (continued)

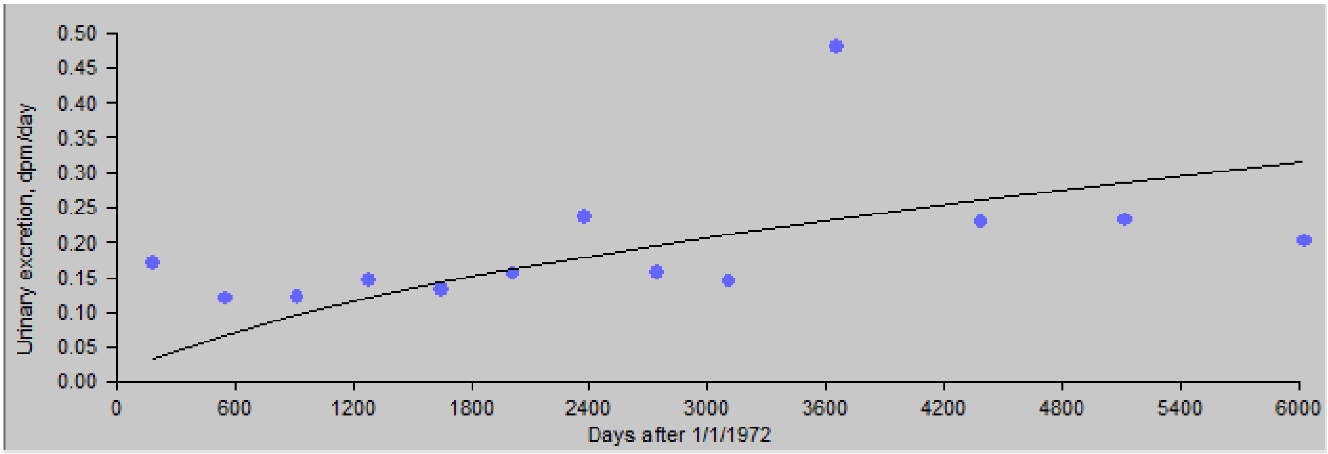


Figure C-24. Predicted ^{232}Th bioassay results calculated using IMBA-derived ^{232}Th intake rates (line) compared with measured bioassay results (dots), 84th percentile, CTW 1972 to 1989, type S.

Table C-2. Summary of type M ^{232}Th intake rates (dpm/d) and dates.

nonCTW

Start	End	50th percentile	84th percentile	GSD	Adj GSD	95th percentile
1/1/1972	12/31/1989	4.813	18.6	3.86	3.86	44.5

CTW

Start	End	50th percentile	84th percentile	GSD	Adj GSD	95th percentile
1/1/1972	12/31/1989	5.172	22.52	4.35	4.35	58.2

Table C-3. Summary of type S ^{232}Th intake rates (dpm/d) and dates.

nonCTW

Start	End	50th percentile	84th percentile	GSD	Adj GSD	95th percentile
1/1/1972	12/31/1989	67.59	261.6	3.87	3.87	626.2

CTW

Start	End	50th percentile	84th percentile	GSD	Adj GSD	95th percentile
1/1/1972	12/31/1989	72.74	329.9	4.54	4.54	874.8

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES

LIST OF FIGURES

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)

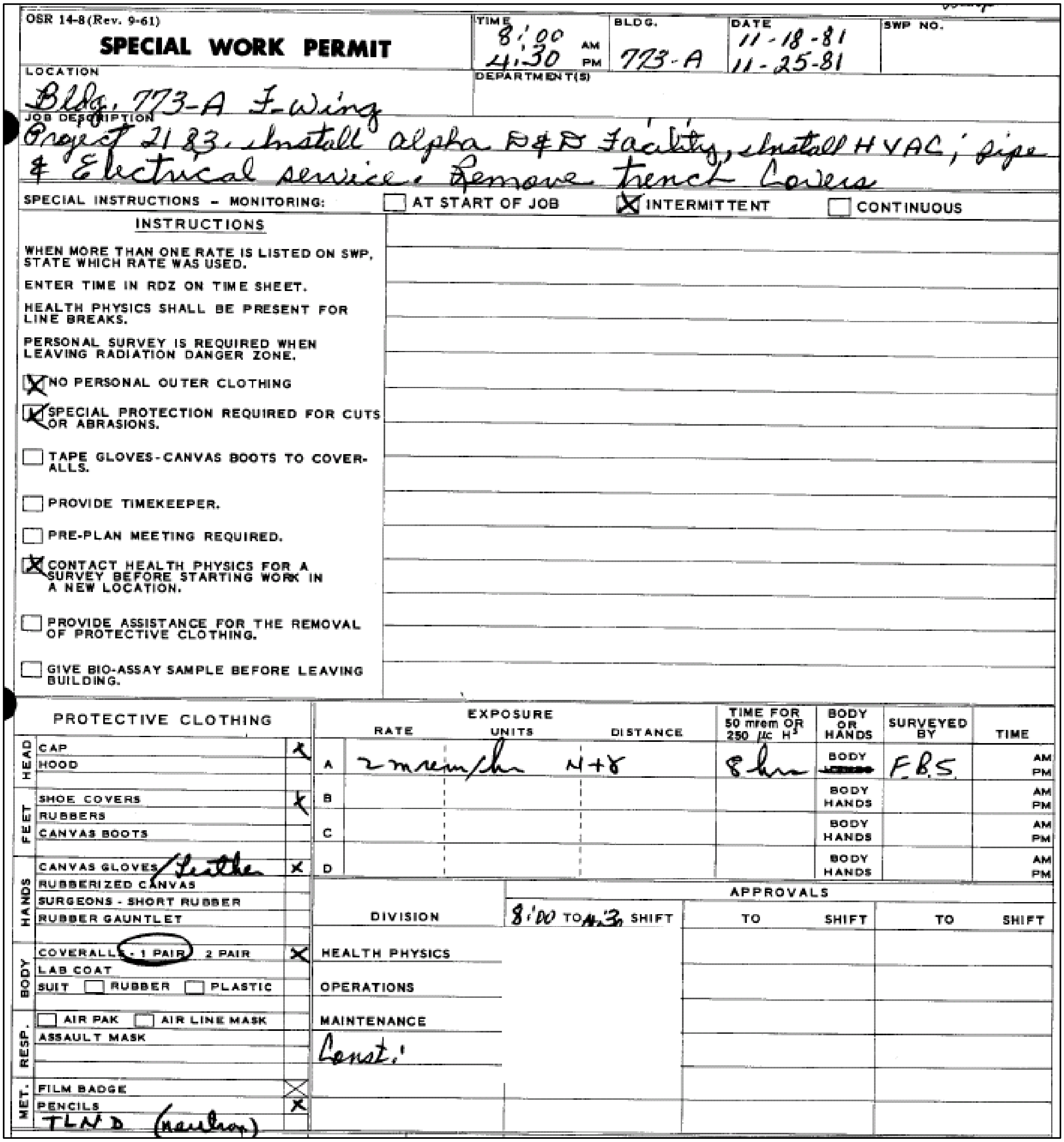
Work tasks performed on the installation of the Alpha Decontamination and Decommissioning (D&D) facility on November 18 and 19, 1981, by Construction and Maintenance are shown in Figure D-1.

Work tasks performed with the modification of Cells 10 and 11 from late January 1982 through early February 1982 by Construction and Maintenance are shown in Figure D-2. Both groups poured cement in performance of respective tasks.

A job plan describing work performed by Maintenance to prepare for work to be done by Construction is shown in Figure D-3.

Work tasks performed with the modification of the Californium Processing Facility (CPF) in April 1984 Construction and Maintenance and E&I are shown in Figure D-4.

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)



OSR 14-8 (Rev. 9-61)

SPECIAL WORK PERMIT

TIME: 8:00 AM 4:30 PM

BLDG.: 773-A

DATE: 11-18-81 11-25-81

SWP NO.:

LOCATION: Bldg. 773-A F-Wing

DEPARTMENT(S):

JOB DESCRIPTION: Project 2183. Install alpha D&D Facility, Install HVAC; pipe & Electrical service. Remove trench Covers

SPECIAL INSTRUCTIONS – MONITORING: ☐ AT START OF JOB ☒ INTERMITTENT ☐ CONTINUOUS

INSTRUCTIONS

WHEN MORE THAN ONE RATE IS LISTED ON SWP, STATE WHICH RATE WAS USED.

ENTER TIME IN RDZ ON TIME SHEET.

HEALTH PHYSICS SHALL BE PRESENT FOR LINE BREAKS.

PERSONAL SURVEY IS REQUIRED WHEN LEAVING RADIATION DANGER ZONE.

- ☒ NO PERSONAL OUTER CLOTHING
- ☒ SPECIAL PROTECTION REQUIRED FOR CUTS OR ABRASIONS.
- ☐ TAPE GLOVES-CANVAS BOOTS TO COVERALLS.
- ☐ PROVIDE TIMEKEEPER.
- ☐ PRE-PLAN MEETING REQUIRED.
- ☒ CONTACT HEALTH PHYSICS FOR A SURVEY BEFORE STARTING WORK IN A NEW LOCATION.
- ☐ PROVIDE ASSISTANCE FOR THE REMOVAL OF PROTECTIVE CLOTHING.
- ☐ GIVE BIO-ASSAY SAMPLE BEFORE LEAVING BUILDING.

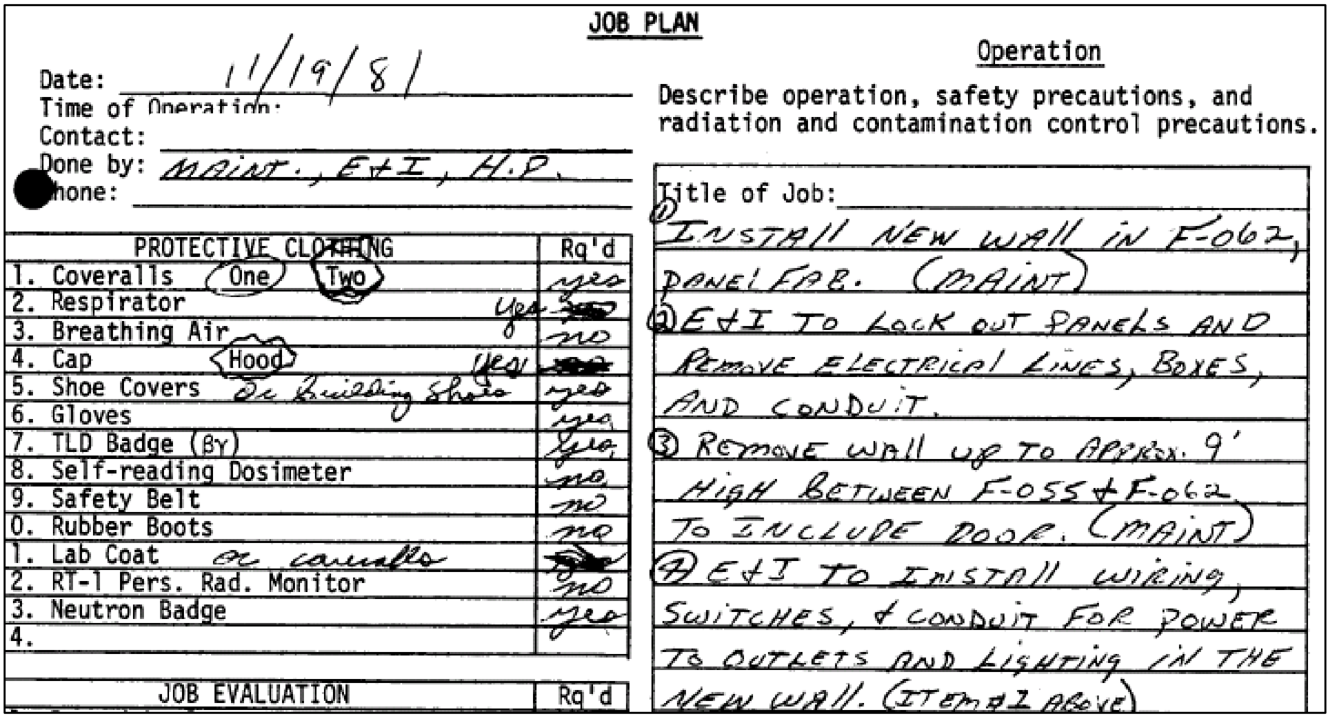
PROTECTIVE CLOTHING		
HEAD	CAP	X
	HOOD	
FEET	SHOE COVERS	X
	RUBBERS	
	CANVAS BOOTS	
HANDS	CANVAS GLOVES/Leather	X
	RUBBERIZED CANVAS	
	SURGEONS - SHORT RUBBER	
	RUBBER GAUNTLET	
BODY	COVERALLS [✓ - 1 PAIR] 2 PAIR	X
	LAB COAT	
	SUIT ☐ RUBBER ☐ PLASTIC	
RESP.	☐ AIR PAK ☐ AIR LINE MASK	
	ASSAULT MASK	
MET.	FILM BADGE	☒
	PENCILS	X
	TLND (neutron)	

	EXPOSURE RATE	UNITS	DISTANCE	TIME FOR 50 mrem OR 250 μc H³	BODY OR HANDS	SURVEYED BY	TIME
A	2 mrem/hr	N+8		8 hrs	BODY ~~HANDS~~	F.B.S.	AM PM
B					BODY HANDS		AM PM
C					BODY HANDS		AM PM
D					BODY HANDS		AM PM

DIVISION	APPROVALS 8:00 TO 4:30 SHIFT	TO SHIFT	TO SHIFT
HEALTH PHYSICS			
OPERATIONS			
MAINTENANCE			
Const.			

Figure D-1a. Work tasks performed on the installation of the Alpha D&D facility on November 18 and 19, 1981 (DuPont 1981).

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)



JOB PLAN

Date: 11/19/81
Time of Operation:
Contact:
Done by: MAINT., E+I, H.P.
Phone:

PROTECTIVE CLOTHING	Rq'd
1. Coveralls [✓ One] [✓ Two]	yes
2. Respirator Yes	~~no~~
3. Breathing Air	no
4. Cap [✓ Hood] Yes	~~no~~
5. Shoe Covers Or Building Shoes	yes
6. Gloves	yes
7. TLD Badge (βγ)	yes
8. Self-reading Dosimeter	no
9. Safety Belt	no
0. Rubber Boots	no
1. Lab Coat or coveralls	~~[illegible]~~
2. RT-1 Pers. Rad. Monitor	no
3. Neutron Badge	yes
4.	

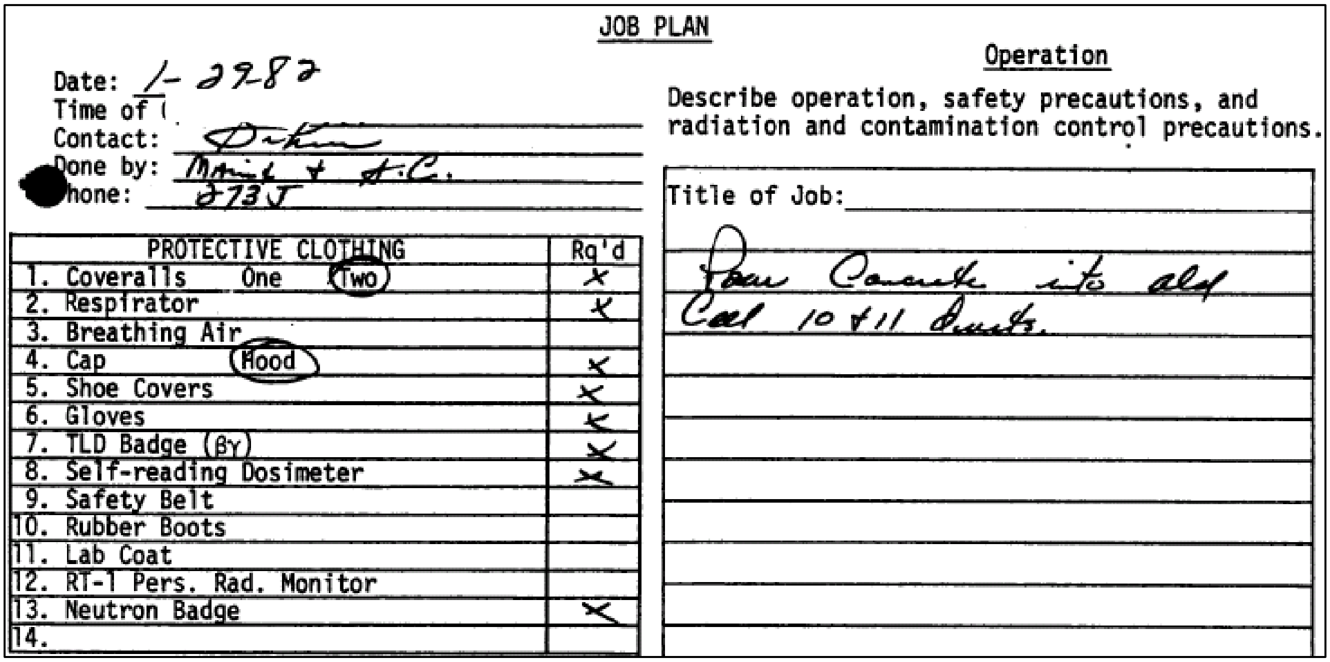
JOB EVALUATION	Rq'd

Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

Title of Job:
① INSTALL NEW WALL IN F-062, PANEL FAB. (MAINT)
② E+I TO LOCK OUT PANELS AND REMOVE ELECTRICAL LINES, BOXES, AND CONDUIT.
③ REMOVE WALL UP TO APPROX. 9' HIGH BETWEEN F-055 + F-062 TO INCLUDE DOOR. (MAINT)
④ E+I TO INSTALL WIRING, SWITCHES, + CONDUIT FOR POWER TO OUTLETS AND LIGHTING IN THE NEW WALL. (ITEM #1 ABOVE)

Figure D-1b. Work tasks performed on the installation of the Alpha D&D facility on November 18 and 19, 1981, continued (DuPont 1981).



JOB PLAN

Date: 1-29-82
Time of (
Contact: [illegible]
Done by: Maint + A.C.
Phone: 273J

PROTECTIVE CLOTHING	Rq'd
1. Coveralls One [✓ Two]	x
2. Respirator	x
3. Breathing Air	
4. Cap [✓ Hood]	x
5. Shoe Covers	x
6. Gloves	x
7. TLD Badge (βγ)	x
8. Self-reading Dosimeter	x
9. Safety Belt	
10. Rubber Boots	
11. Lab Coat	
12. RT-1 Pers. Rad. Monitor	
13. Neutron Badge	x
14.	

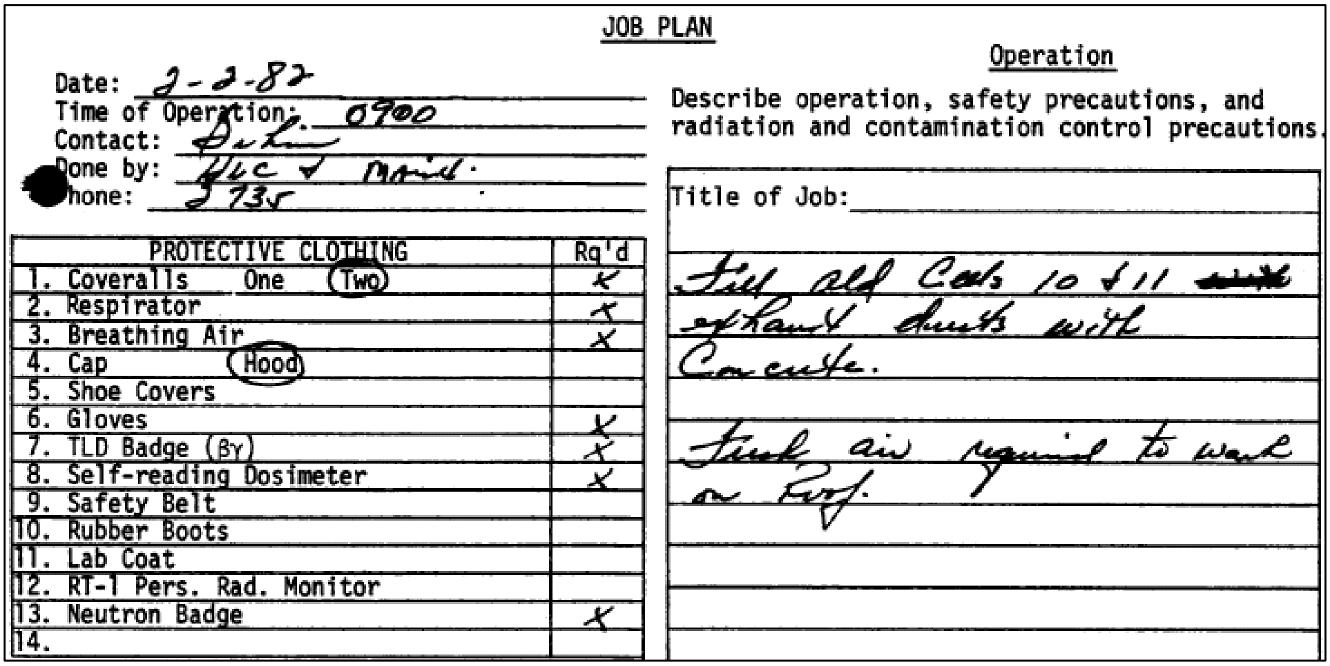
Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

Title of Job:
Pour Concrete into old Cell 10 + 11 Ducts.

Figure D-2a. Work tasks performed with the modification of Cells 10 and 11 from late January 1982 through early February 1982 (DuPont 1982).

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)



JOB PLAN

Date: 2-2-82
Time of Operation: 0900
Contact: [illegible]
Done by: Elec & Maint.
Phone: 2735

PROTECTIVE CLOTHING	Rq'd
1. Coveralls One [✓ Two]	X
2. Respirator	X
3. Breathing Air	X
4. Cap [✓ Hood]	
5. Shoe Covers	
6. Gloves	X
7. TLD Badge (βγ)	X
8. Self-reading Dosimeter	X
9. Safety Belt	
10. Rubber Boots	
11. Lab Coat	
12. RT-1 Pers. Rad. Monitor	
13. Neutron Badge	X
14.	

Operation

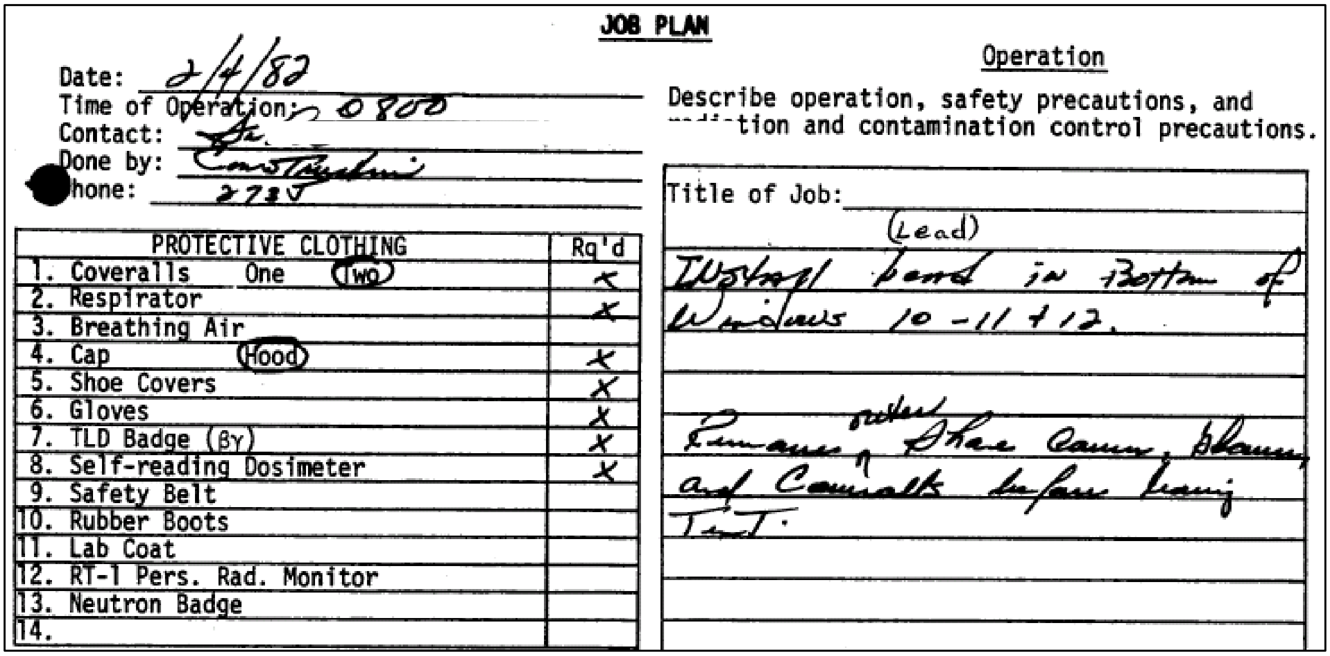
Describe operation, safety precautions, and radiation and contamination control precautions.

Title of Job:

Fill old Cells 10 & 11 exhaust ducts with Concrete.

Fresh air required to work on Roof.

Figure D-2b. Work tasks performed with the modification of Cells 10 and 11 from late January 1982 through early February 1982, continued (DuPont 1982).



JOB PLAN

Date: 2/4/82
Time of Operation: 0800
Contact: [illegible]
Done by: Construction
Phone: 2735

PROTECTIVE CLOTHING	Rq'd
1. Coveralls One [✓ Two]	X
2. Respirator	X
3. Breathing Air	
4. Cap [✓ Hood]	X
5. Shoe Covers	X
6. Gloves	X
7. TLD Badge (βγ)	X
8. Self-reading Dosimeter	X
9. Safety Belt	
10. Rubber Boots	
11. Lab Coat	
12. RT-1 Pers. Rad. Monitor	
13. Neutron Badge	
14.	

Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

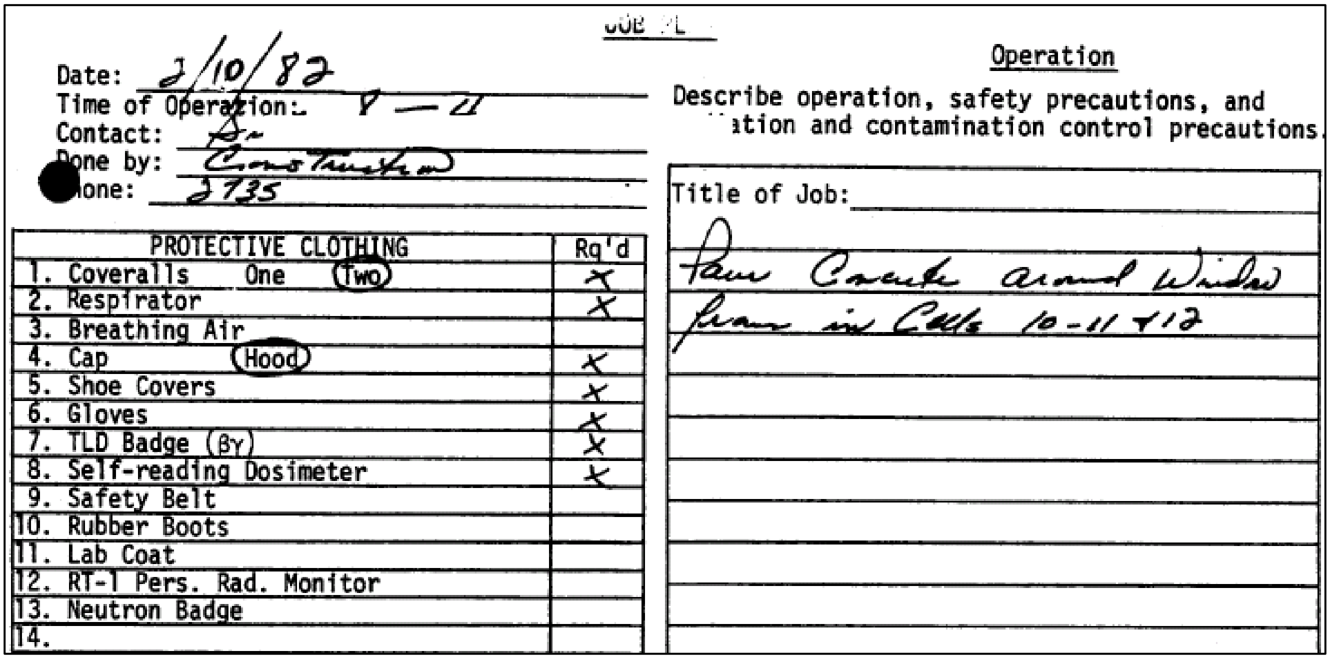
Title of Job:

(Lead)
Install band in Bottom of Windows 10-11 & 12.

rubber
Remove Shoe Covers, Gloves and Coveralls before leaving Tent.

Figure D-2c. Work tasks performed with the modification of Cells 10 and 11 from late January 1982 through early February 1982, continued (DuPont 1982).

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)



JOB PL

Date: 2/10/82
Time of Operation: 8 — 11
Contact:
Done by: Construction
[illegible]one: 2735

PROTECTIVE CLOTHING	Rq'd
1. Coveralls One [✓ Two]	X
2. Respirator	X
3. Breathing Air	
4. Cap [✓ Hood]	X
5. Shoe Covers	X
6. Gloves	X
7. TLD Badge (βγ)	X
8. Self-reading Dosimeter	X
9. Safety Belt	
10. Rubber Boots	
11. Lab Coat	
12. RT-1 Pers. Rad. Monitor	
13. Neutron Badge	
14.	

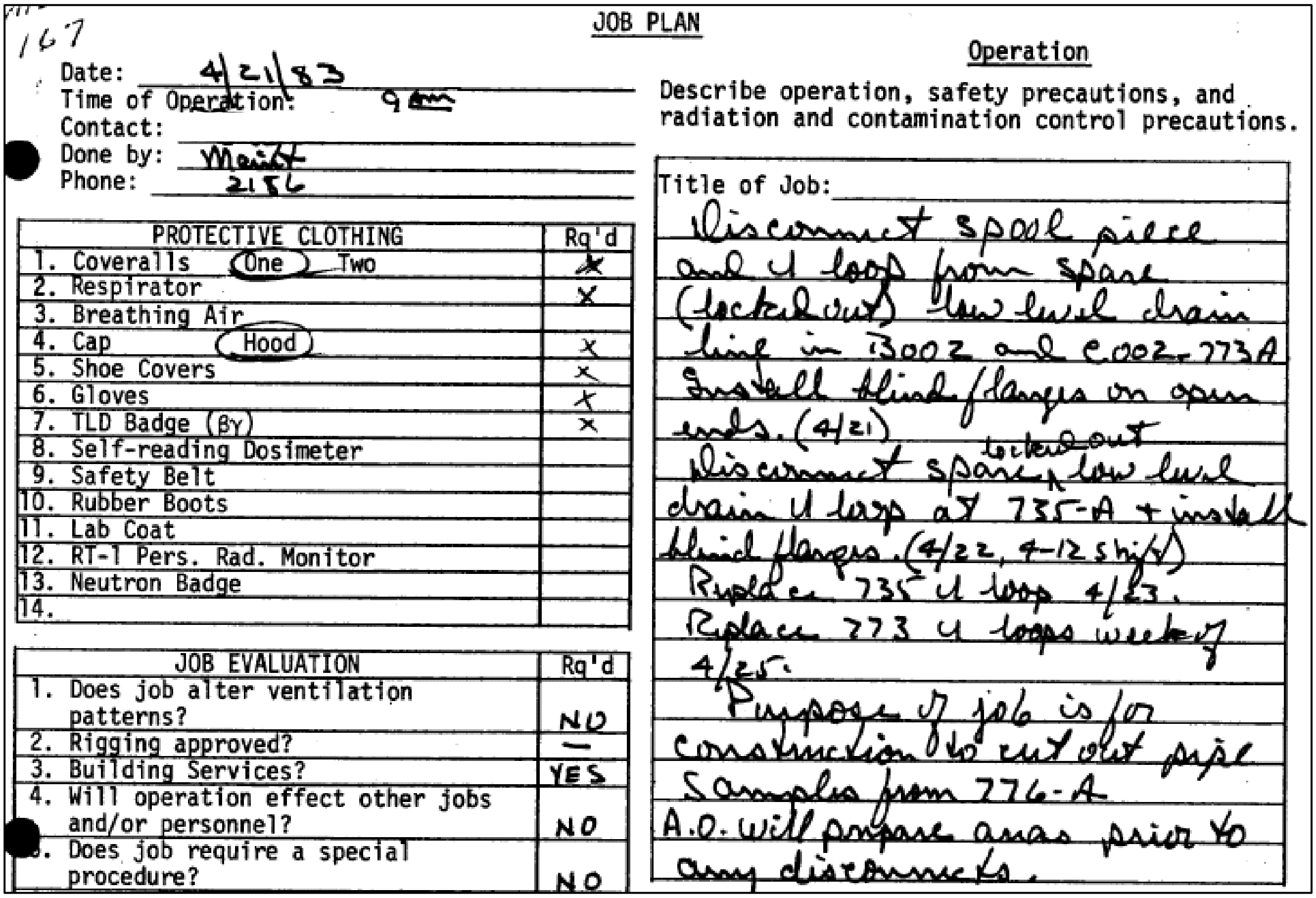
Operation

Describe operation, safety precautions, and ation and contamination control precautions.

Title of Job: Pour Concrete around Window frame in Cells 10-11 + 12

Figure D-2d. Work tasks performed with the modification of Cells 10 and 11 from late January 1982 through early February 1982, continued (DuPont 1982).

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)



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JOB PLAN

Date: 4/21/83
Time of Operation: 9 am
Contact:
Done by: Maint
Phone: 2156

PROTECTIVE CLOTHING	Rq'd
1. Coveralls [✓ One] Two	X
2. Respirator	X
3. Breathing Air	
4. Cap [✓ Hood]	X
5. Shoe Covers	X
6. Gloves	X
7. TLD Badge (βγ)	X
8. Self-reading Dosimeter	
9. Safety Belt	
10. Rubber Boots	
11. Lab Coat	
12. RT-1 Pers. Rad. Monitor	
13. Neutron Badge	
14.	

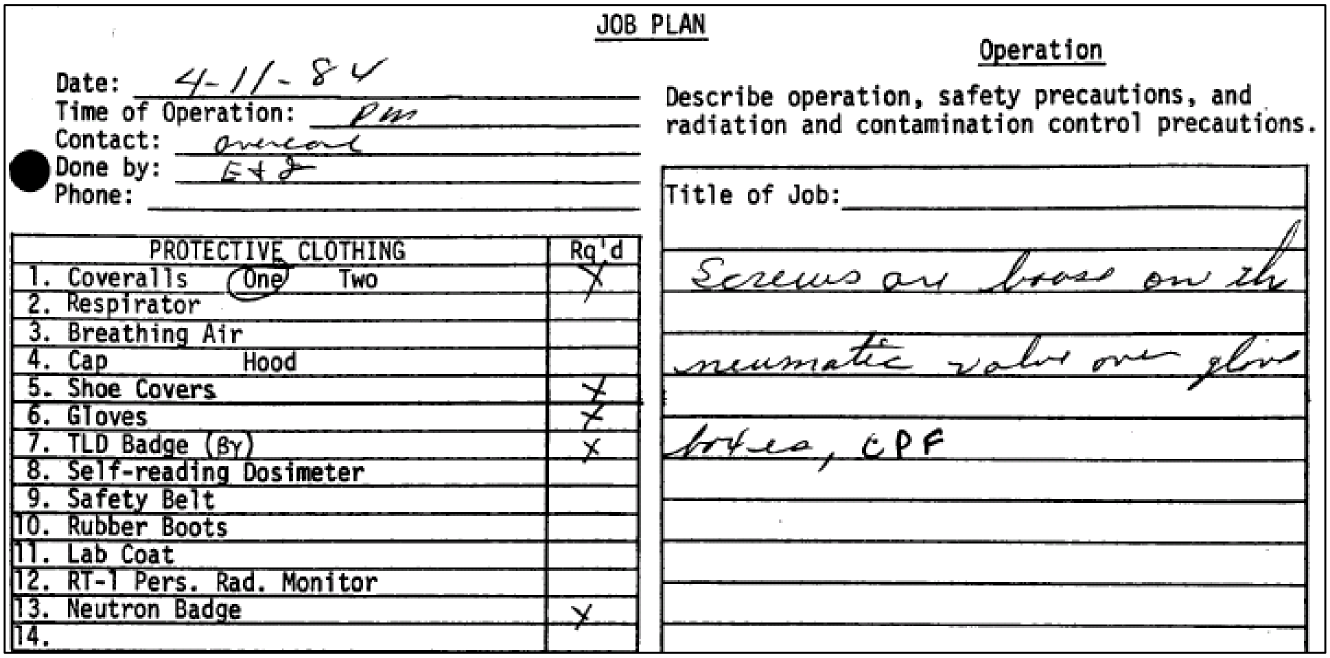
JOB EVALUATION	Rq'd
1. Does job alter ventilation patterns?	NO
2. Rigging approved?	—
3. Building Services?	YES
4. Will operation effect other jobs and/or personnel?	NO
5. Does job require a special procedure?	NO

Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

Title of Job:
Disconnect spool piece
and U loop from spare
(locked out) low level drain
line in B002 and C002-773A
Install blind flanges on open
ends. (4/21)
Disconnect spare, locked out low level
drain U loop at 735-A + install
blind flanges. (4/22, 4-12 shift)
Replace 735 U loop 4/23.
Replace 773 U loops week of
4/25.
Purpose of job is for
construction to cut out pipe
Samples from 776-A
A.O. will prepare areas prior to
any disconnects.

Figure D-3. Job plan describing work performed by Maintenance to prepare for work to be done by Construction (DuPont 1983).



JOB PLAN

Date: 4-11-84
Time of Operation: pm
Contact: overcoat
Done by: E+I
Phone:

PROTECTIVE CLOTHING	Rq'd
1. Coveralls [✓ One] Two	X
2. Respirator	
3. Breathing Air	
4. Cap Hood	
5. Shoe Covers	X
6. Gloves	X
7. TLD Badge (βγ)	X
8. Self-reading Dosimeter	
9. Safety Belt	
10. Rubber Boots	
11. Lab Coat	
12. RT-1 Pers. Rad. Monitor	
13. Neutron Badge	X
14.	

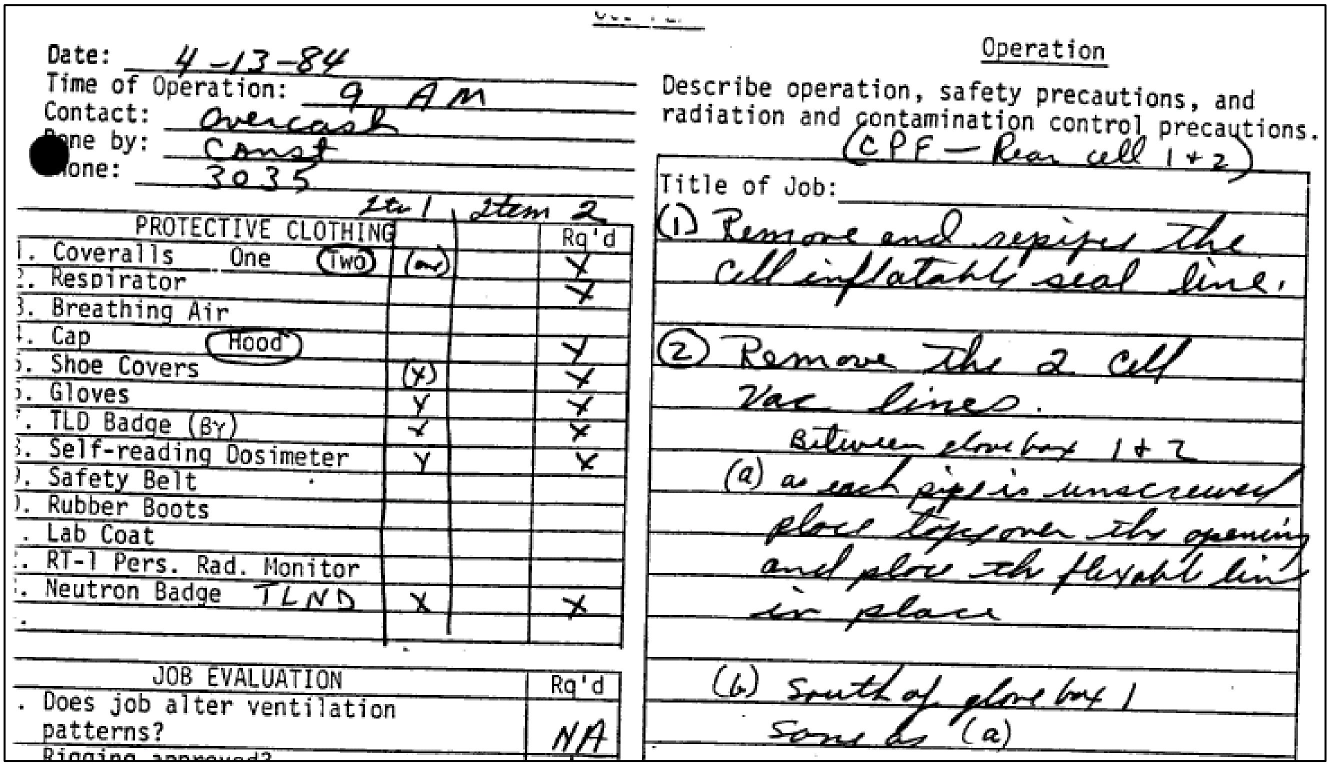
Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

Title of Job:
Screws are loose on the
neumatic valve over glove
boxes, CPF

Figure D-4a. Work tasks performed with the modification of the CPF in April 1984 (DuPont 1984).

ATTACHMENT D
HIGH-LEVEL CAVE JOB PLAN EXAMPLES (continued)



Date: 4-13-84
Time of Operation: 9 AM
Contact: Overcash
[illegible]ne by: Const
[illegible]one: 3035

PROTECTIVE CLOTHING	Ite 1	Item 2	Rq'd
1. Coveralls One [✓ Two]	(on)		X
2. Respirator			X
3. Breathing Air			
4. Cap [✓ Hood]			Y
5. Shoe Covers	(X)		X
6. Gloves	Y		X
7. TLD Badge (βγ)	✓		X
8. Self-reading Dosimeter	Y		X
9. Safety Belt			
0. Rubber Boots			
. Lab Coat			
2. RT-1 Pers. Rad. Monitor			
3. Neutron Badge TLND	X		X
.			

JOB EVALUATION	Rq'd
. Does job alter ventilation patterns?	NA

Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

(CPF — Rear cell 1 + 2)

Title of Job:

① Remove and repipe the cell inflatable seal line.

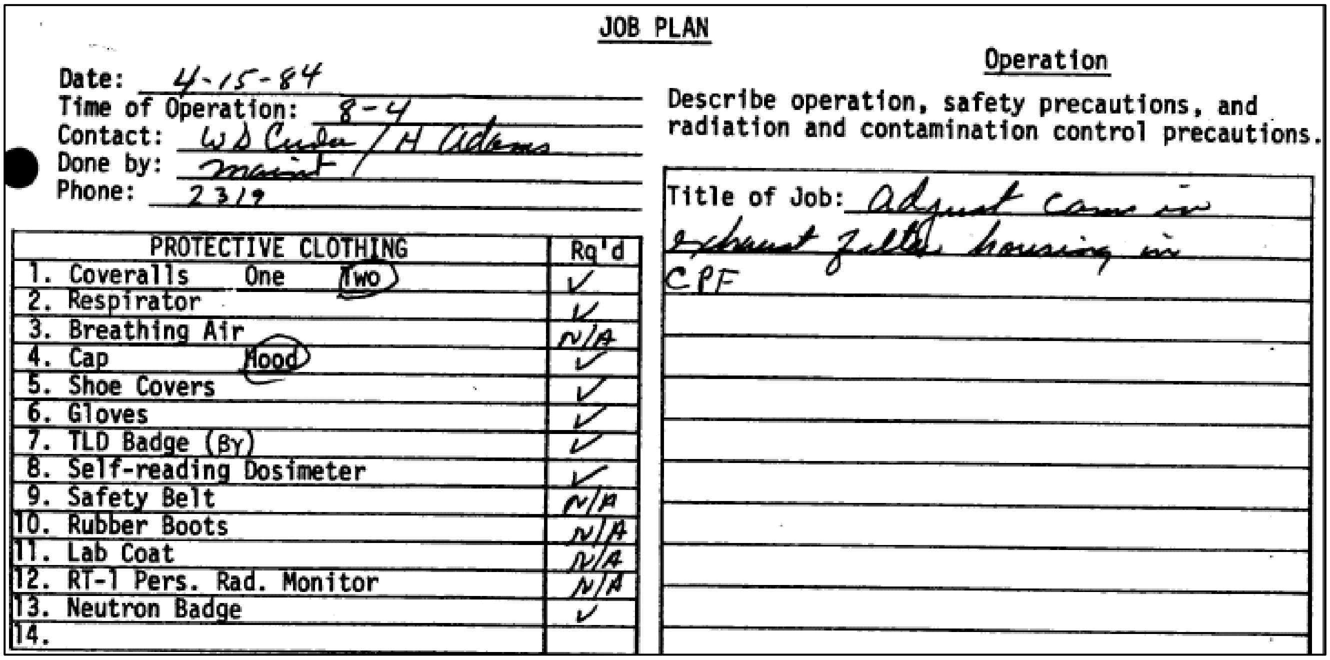
② Remove the 2 cell vac lines.

Between glove box 1 + 2

(a) as each pipe is unscrewed place tape over the opening and place the flexible line in place

(b) South of glove box 1
Same as (a)

Figure D-4b. Work tasks performed with the modification of the CPF in April 1984, continued (DuPont 1984).



JOB PLAN

Date: 4-15-84
Time of Operation: 8-4
Contact: WD Cuda / H Adams
Done by: maint /
Phone: 2319

PROTECTIVE CLOTHING	Rq'd
1. Coveralls One [✓ Two]	✓
2. Respirator	✓
3. Breathing Air	N/A
4. Cap [✓ Hood]	✓
5. Shoe Covers	✓
6. Gloves	✓
7. TLD Badge (βγ)	✓
8. Self-reading Dosimeter	✓
9. Safety Belt	N/A
10. Rubber Boots	N/A
11. Lab Coat	N/A
12. RT-1 Pers. Rad. Monitor	N/A
13. Neutron Badge	✓
14.	

Operation

Describe operation, safety precautions, and radiation and contamination control precautions.

Title of Job: Adjust cam in exhaust filter housing in CPF

Figure D-4c. Work tasks performed with the modification of the CPF in April 1984, continued (DuPont 1984).

ATTACHMENT E
QUALITY ASSURANCE REPORTS

SRS Am QA Report

June 16, 2016

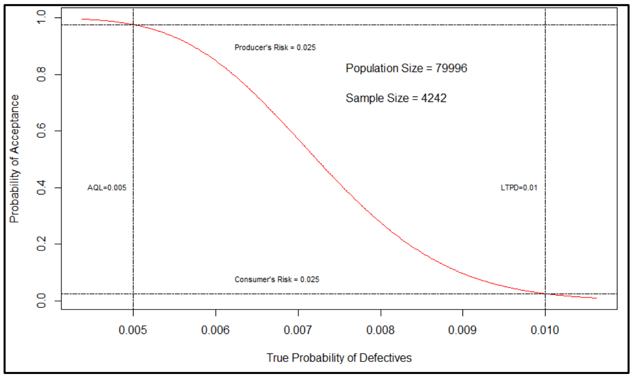
Critical Fields Plan

Fields

Payroll ID#
Pu dpm/1.5L (12 columns) (nonblank)
Pu Report (nonblank)
EU dpm/1.5L (10 columns) (nonblank)
EU Report (nonblank)
Am dpm/1.5L (10 columns) (nonblank)
Am Report (nonblank)
Np dpm/1.5L (10 columns) (nonblank)
Np Report (nonblank)

Sampling Plan

N = 79,996
AQL = 0.5%
LTPD = 1%
α = 0.025 (producer's risk or ORAU Team risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 4,242



Results

25 errors / 4,242 checked = 0.59%

We are at least 95% confident that the critical field transcription error rate is between 0.39% and 0.86%.

Evaluation

The critical field interval is entirely below 1%. There is no issue with the critical field transcription error rate in this SRS americium dataset.

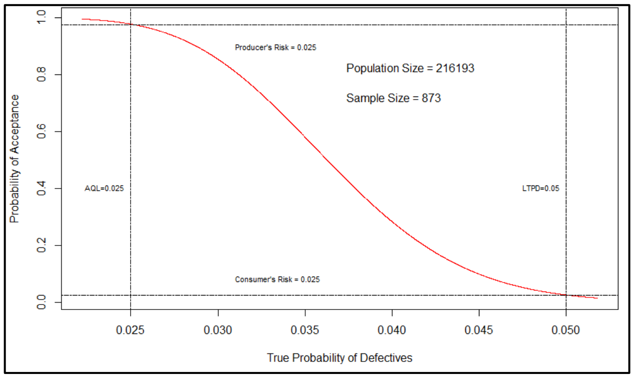
All Fields Plan

Fields

Critical Fields
Employee Last Name
Employee First Initial
Employee Middle Initial
Volume
Area
Occupation Title
Bottle Date
Remarks (nonblank)

Sampling Plan

N = 216,193
AQL = 2.5%
LTPD = 5%
α = 0.025 (producer's risk or ORAU Team risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 873



Results

6 errors / 873 checked = 0.69%

We are at least 95% confident that the all field transcription error rate is between 0.25% and 1.49%.

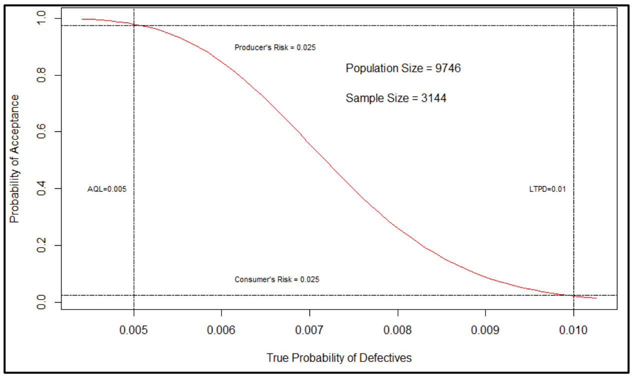
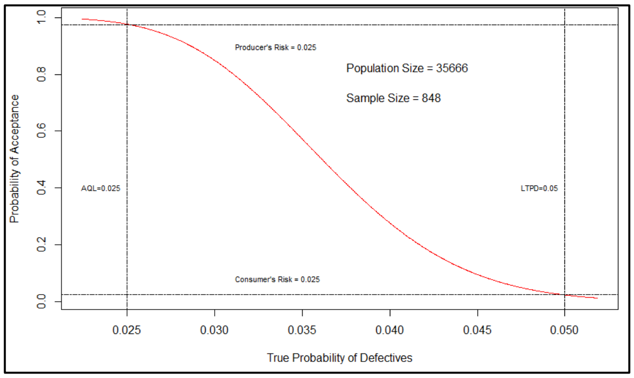
Evaluation

The all field interval is entirely below 5%. There is no issue with the all field transcription error rate in this SRS americium dataset.

ATTACHMENT E
QUALITY ASSURANCE REPORTS (continued)

SRS Np Logbooks QA Report

May 25, 2016

Critical Fields Plan	All Fields Plan
Fields	Fields
Payroll ID # Pu results (nonblank) Pu units (nonblank) Np results (nonblank) Np units (nonblank)	Critical fields Area Employee Last Name Employee First Initial Employee Middle Initial Occupation Title Bottle Date Received Date Comment (nonblank)
Sampling Plan	Sampling Plan
N = 9,746 AQL = 0.5% LTPD = 1% α = 0.025 (producer's risk or ORAU Team risk) β = 0.025 (consumer's risk or DCAS risk) n = 3,144	N = 35,666 AQL = 2.5% LTPD = 5% α = 0.025 (producer's risk or ORAU Team risk) β = 0.025 (consumer's risk or DCAS risk) n = 848
	
Results	Results
21 errors / 3144 checked = 0.67% We are at least 95% confident that the critical field transcription error rate is between 0.46% and 0.95%.	13 errors / 848 checked = 1.53% We are at least 95% confident that the all field transcription error rate is between 0.83% and 2.59%.
Evaluation	Evaluation
The critical field interval is entirely below 1%. The all field interval is entirely below 5%. There are no issues with the transcription error rates in this SRS tritium dataset. Note: Of the 21 critical errors, ten were payroll ID prefix issues. Six of the payroll ID prefix issues had to do with the presence or absence of a "0-" prefix.	The all field interval is entirely below 5%. There are no issues with the transcription error rates in this SRS tritium dataset.

ATTACHMENT E
QUALITY ASSURANCE REPORTS (continued)

SRS NOCTS WBC QA Report

June 3, 2016

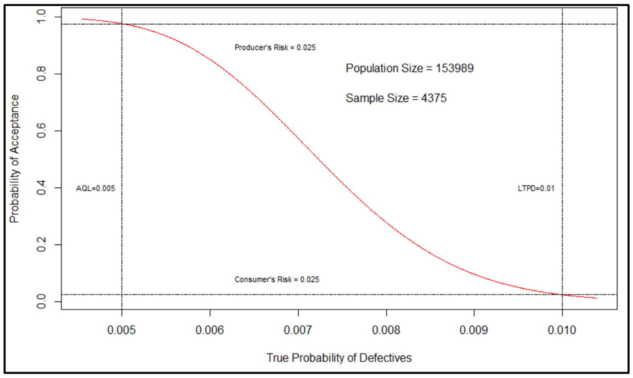
Critical Fields Plan

Fields

PR
Form Type (nonblank)
Nuclide
gross counts (nonblank)
bkg counts (nonblank)
net counts (nonblank)
NET c/m (nonblank)
DIFF counts (nonblank)
Result (nCi) (nonblank)
MDA @95%CL (counts) (nonblank)
MDA @95%CL (nCi) (nonblank)
Lung Burden (nCi) (nonblank)

Sampling Plan

N = 153,989
AQL = 0.5%
LTPD = 1%
α = 0.025 (producer's risk or ORAU Team risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 4,375



Results

535 errors / 4375 checked = 12.23%

We are at least 95% confident that the critical field transcription error rate is between 11.29% and 13.22%.

Not counting payroll prefix issues as errors:

pt. est. = 1.37% interval: (1.05% , 1.76%)

Counting errors in columns other than payroll ID and payroll ID errors that impact CTW determination:

pt. est. = 0.62% interval: (0.41% , 0.89%)

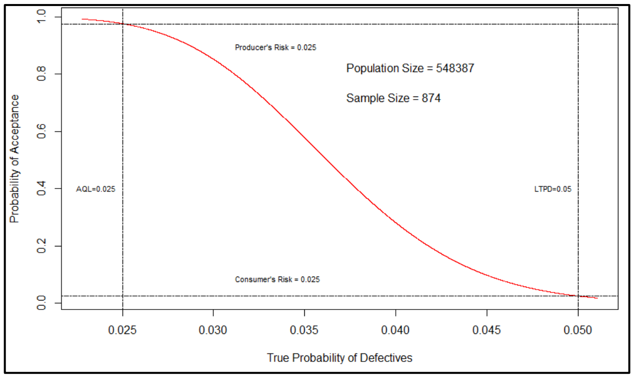
All Fields Plan

Fields

Critical Fields
Last name
Fist Name
Middle Name
Occupation Title
Position Title
Date
Dept
Location
Type (WBC or CC)
Reason
Detector
Comments (nonblank)

Sampling Plan

N = 548,387
AQL = 2.5%
LTPD = 5%
α = 0.025 (producer's risk or ORAU Team risk)
β = 0.025 (consumer's risk or DCAS risk)
n = 874



Results

45 errors / 874 checked = 5.15%

We are at least 95% confident that the all field transcription error rate is between 3.78% and 6.83%.

Not counting payroll prefix issues as errors:

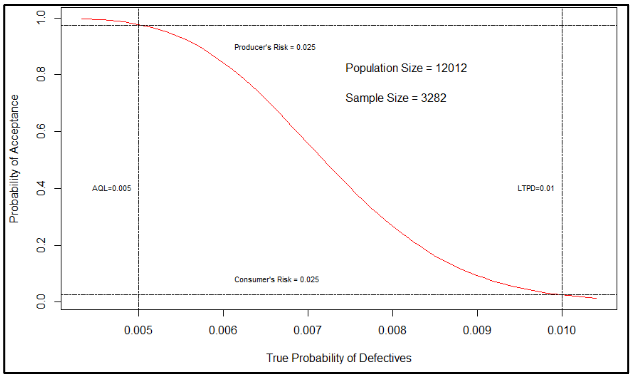
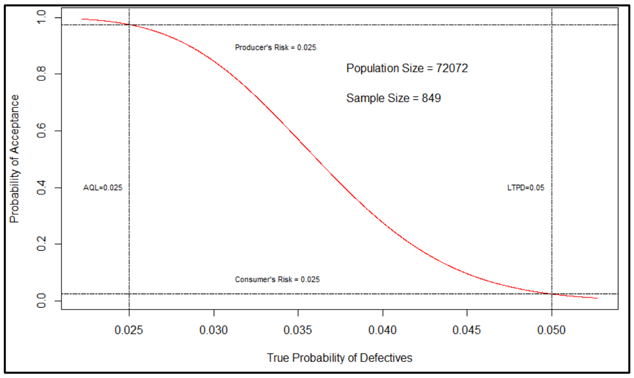
pt. est. = 2.17% interval: (1.31% , 3.37%)

ATTACHMENT E
QUALITY ASSURANCE REPORTS (continued)

Critical Fields Plan	All Fields Plan
Critical Fields Evaluation Payroll ID issues comprise the majority of the transcription errors, 523 of the 535 errors identified, although PRID fields were less than 25% of the total number of critical fields sampled. There were 12 non-payroll ID errors out of 3373 non-payroll ID critical fields sampled for a non-payroll ID error rate point estimate of 0.4%. There were 523 payroll ID errors out of 1002 payroll ID critical fields sampled for an error rate point estimate of 52%. 475 of the 523 were payroll ID prefix issues that have no impact on the data usage for an error rate point estimate of 47%. Examples of prefix issues that have no impact on the data usage are using “0-,” “1-,” “T-,” or no prefix interchangeably; presence of a prefix when there was not a prefix on the source data and vice versa (although present in other locations and accurate); and substitution of craft codes for a roll code of 4-, 5-, or 6- or vice versa. Of the 48 remaining (523-475) payroll ID errors, only 15 of the errors affected usage of the data for CTW determination or for proper identification of the person. Most of the errors were either simple transposition errors already caught in subsequent data cleanup or instances where a worker was promoted from operator, laboratory technician, or similar job to a salaried position with no change in CTW status. However, there is still sufficient information to properly identify the person by claim #, name, or corrected payroll ID number. These types of errors, while errors, do not affect the subsequent usage of the data. CTW status is unchanged, and the usage of the data for calculation of bioassay statistics is not affected. Therefore, the set of all errors can be refined to the subset of errors that affect data usage. There are 27 such errors, the 12 non-payroll ID errors and the 15 payroll ID errors that affect CTW determination or proper identification of the person. The error rate for this subset of errors is 0.62% with a confidence interval of 0.41% to 0.89%, below the desired 1% error rate acceptance criteria.	All Fields Evaluation As with the critical fields, payroll ID prefix issues that have no impact on the data usage comprised the majority of the all fields errors, 26 of 45 errors. Although the overall error rate is above the desired acceptance rate of 5%, excluding these payroll ID prefix errors reduces the error rate to 2.17% with a confidence interval of 1.31% to 3.37%, below the desired 5% error rate acceptance criteria. Since this error rate is below the desired acceptance criteria, no further evaluation of the significance of the non-payroll ID prefix errors was performed.

ATTACHMENT E
QUALITY ASSURANCE REPORTS (continued)

SRS MFPG QA Report
June 6, 2016

Critical Fields Plan	**All Fields Plan**
Fields	Fields
PR	PR Date Last name Fist Name Middle Name Occupation Title
Sampling Plan	Sampling Plan
N = 12,012 AQL = 0.5% LTPD = 1% α = 0.025 (producer's risk or ORAU Team risk) β = 0.025 (consumer's risk or DCAS risk) n = 3,282	N = 72,072 AQL = 2.5% LTPD = 5% α = 0.025 (producer's risk or ORAU Team risk) β = 0.025 (consumer's risk or DCAS risk) n = 849
	
Results	Results
1980 errors / 3282 checked = 60.33%	89 errors / 849 checked = 10.48%
We are at least 95% confident that the critical field transcription error rate is between 58.88% and 61.75%.	We are at least 95% confident that the all field transcription error rate is between 8.52% and 12.73%.
Not counting payroll prefix issues as errors:	*Not counting payroll prefix issues as errors:*
pt. est. = 1.34% interval: (1.03% , 1.72%)	pt. est. = 0.12% interval: (0.0042% , 0.65%)
Counting errors in columns other than payroll ID and payroll ID errors that affect CTW determination and person identification:	
pt. est. = 0.43% interval: (0.27% , 0.67%)	

ATTACHMENT E
QUALITY ASSURANCE REPORTS (continued)

Critical Fields Plan	All Fields Plan
Critical Fields Evaluation Payroll ID prefix issues comprise the majority of the transcription errors, 1936 of the 1980 errors identified. The 1936 payroll ID prefix errors have no impact on the data usage and have an error rate point estimate of 59%. Examples of prefix issues that have no impact on the data usage are using “0-,” “1-,” “T-,” or no prefix interchangeably; presence of a prefix when there was not a prefix on the source data and vice versa (although present in other locations and accurate); and substitution of craft codes for a roll code of 4-, 5-, or 6- or vice versa. Of the 44 remaining (1980 to 1936) payroll ID errors, only 14 of the errors affected usage of the data for CTW determination or for proper identification of the person. Most of the errors were either simple transposition errors already caught in subsequent data cleanup or were instances where a worker was promoted from operator, laboratory technician, or similar job to a salaried position with no change in CTW status. However, there is still sufficient information to properly identify the person by claim #, name, or corrected payroll ID number. These types of errors, while errors, do not affect the subsequent usage of the data. CTW status is unchanged, and the usage of the data for calculation of bioassay statistics is not affected. Therefore, the set of all errors can be refined to the subset of errors that affect data usage. There are 14 such errors. The error rate for this subset of errors is 0.43% with a confidence interval of 0.27% to 0.67%, below the desired 1% error rate acceptance criteria.	All Fields Evaluation As with the critical fields, payroll ID prefix issues that have no impact on the data usage comprised the majority of the all fields errors, 88 of 89 errors. Although the overall error rate is above the desired acceptance rate of 5%, excluding these payroll ID prefix errors leaves only a single error and reduces the error rate to 0.12 % with a confidence interval of 0.0042% to 0.65%, below the desired 5% error rate acceptance criteria.

ATTACHMENT E
QUALITY ASSURANCE REPORTS (continued)

SRS Tritium CTW QA Report
July 14, 2016

QA of tritium data CTW determination. The CTW determinations based on the Master Occupation Table and the CTW Designation Instructions were checked against the worker history cards (or claimant interviews or personnel dosimetry quarterly reports).

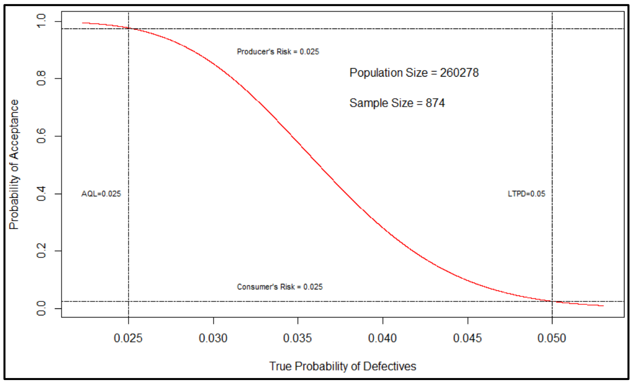
All Fields Plan

Fields

Rev3CTW

Sampling Plan

N = 260,278
AQL = 2.5%
LTPD = 5%
α = 0.025 (producer’s risk or ORAUT risk)
β = 0.025 (consumer’s risk or DCAS risk)
n = 874



Results

6 errors / 874 checked = 0.69%

Evaluation

There is a 95% confidence that the classification error rate between CTW determination and the worker history cards is between 0.25% and 1.49%.

The CTW determination and worker history cards classification error rate interval is entirely below 5%. There is no issue with the classification error rate.

Note: Five of the errors were the CTW determination algorithm calling the person a CTW when the worker history cards said they were not; one was the algorithm calling the person a non-CTW when they were.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016

SOURCE DATA AND GENERAL INSTRUCTIONS

Source Data

- “O:/Coworker Data/Working Files/SRS/Coworker Study/SRS NOCTS Tritium_052710_postQA.mdb” using the “QC copy of SRS NOCTS Tritium_052710” table (**NOCTS H3 data**)

- “O:\Coworker Data\Working Files\SRS\Coworker Study\SRS Np logbook DE/Compiled_SRS Np Logbook_WHC_07202011r0 Mike.xlsx” (**Np data**)

- “O:/Coworker Data/Working Files/SRS/Coworker Study/OTIB-0081 Rev 03/Tritium CTW Data/Np QA/Np logbook data corrections 2016-05-31 Rev1.xlsx” (**Np corrections**)

- “O:\Coworker Data\Working Files\SRS\Coworker Study\SRS_WBC_WHC from OPOS 14\SRS_WBC_WHC_FINAL_Compiled_101811r1 Mike Rev 1.xlsx” **(WBC data)**

- “O:\Coworker Data\Working Files\SRS\Coworker Study\coworker study re-do\MFP&G review 32916\ Reviewed MFP&G Data for Board_032916.xlsx” **(MFPG WHC data)**

- “O:\Coworker Data\Working Files\SRS\Coworker Study\OTIB-0081 Rev 03\Am CTW Data\CTW review_051616\ Reviewed_Am Final Compiled_SRS WHC_06302011r2Ready Updated rev 4_062416.xlsx” **(Am data)**

- “O:\Coworker Data\Working Files\SRS\Coworker Study\OTIB-0081 Rev 03\Tritium CTW Data\CTW Update_07816\Compiled CTW Master update part 1 with names_071516.xlsx” **(CTW Master Update Part 1)** Note: repeat for successive parts as needed.

- “O:\Coworker Data\Working Files\SRS\Coworker Study\OTIB-0081 Rev 03\Tritium CTW Data\NOCTS WBC QA\WBC data corrections 2016-06-22.xlsx **(WBC corrections)**

- “O:\Coworker Data\Working Files\SRS\Coworker Study\OTIB-0081 Rev 03\Tritium CTW Data\Am QA\Am logbook data corrections 2016-08-01.xlsx **(Am corrections)**

- “O:\Coworker Data\Working Files\SRS\Coworker Study\OTIB-0081 Rev 03\Tritium CTW Data\MFPG QA\MFP&G data corrections 2016-06-22.xlsx **(MFPG corrections)**

- “O:/Coworker Data/Working Files/SRS/Coworker Study/Chelation Spreadsheets/SRS Chelation Data_Payroll ID’s added_082514.xlsx” **(Chelation Data)**

- “O:/Coworker Data/Working Files/SRS/Coworker Study/OTIB-0081 Rev 03/Tritium CTW V&V/NioshClaims_With_Names.csv” **(SRS NOCTS Names)**

- “O:/Coworker Data/Working Files/SRS/Coworker Study/OTIB-0081 Rev 03/Tritium CTW V&V/SRS SSNs.csv” **(SRS NOCTS SSNs)**

- “O:\Coworker Data\Working Files\SRS\Coworker Study\OTIB-0081 Rev 03\Tritium CTW Data\H-3 QA\Tritium data corrections 2016-07-12.xlsx **(NOCTS H3 corrections)**

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

Instructions

- For each applicable data source, make corrections as listed in the associated corrections file.
    - Replace individual cell contents based on cell contents in the corrections file
    - If a cell in the corrections file contains “blank”, then delete that cell’s contents in the source data file.
    - If the corrections file comments column contains the word “exclude,” then do not use that line for the statistical analysis
- Correct the “Np data” with the “Np corrections” file.
    - Identify lines by the unique ID column
- Correct the “WBC data” with the “WBC corrections” file.
    - Identify lines by the “Unique # for Rick” column
- Correct the “Am data” with the “Am corrections” file.
    - Identify lines by the unique ID column.
- Correct the “MFPG data” with the “MFPG corrections” file.
    - Identify lines by the unique ID column
- Correct the “NOCTS In-vitro data” with the “NOCTS In-vitro corrections” file.
- Correct the “NOCTS H3 data” with the “NOCTS H3 corrections” file.
    - Identify lines by the unique ID column,

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

MASTER OCCUPATION TABLE INSTRUCTIONS

1. Merge the following files into one master occupation table (CTW Master).

    - Np data
    - WBC data
    - MFPG WHC data
    - Am data
    - CTW Master Update Part 1

The following table lists the mapping of column identifiers from each of the source files to the CTW Master table. If a cell in a listed column of the source file is blank (blank or no characters other than “space”) and there is a second column identified in parentheses, use the value from the cell in that column instead. For the first and middle name initials, import only the first character of the name from the source files that provide the full first and middle name.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

Table F-1. CTW Master Table Cross Reference.

Master	Np data	WBC data	MFPG WHC data	Am data	CTW Master Updates
PRID	Corrected PRID (Payroll ID#)	Corrected PR # (PR)	Corrected PR # (PR)	Changed Payroll ID# (Payroll ID#)	PRID
Last Name	Corrected Last Name (Employee Last Name)	Corrected last name (Last name)	Last name	Corrected Last Name (Employee Last Name)	Last Name
First Initial	Corrected FI (Employee First Initial)	Fist name	Fist Name	Corrected First Initial (Employee First Initial)	First Initial
Middle Initial	Corrected MI (Employee Middle Initial)	Corrected middle name (Middle Name)	Middle Name	Corrected Middle Initial (Employee Middle Initial)	Middle Initial
SSN	Not used	Not used	Not used	Not used	SSN
Occupation Title	Corrected Occupation Title (Occupation Title)	Corrected Occupation (Occupation Title)	Corrected Occupation Title (Occupation Title)	Changed Occupation Title (Occupation Title)	Corrected Occupation Title (Occupation Title)
Date	Bottle Date (Received Date)	Date	Date	Bottle Date	Date
NIOSH ID	Not used	Claim	Claim #	NIOSH ID	NIOSH ID
SRDB Ref ID	SRDB Ref ID	Not used	Not used	SRDB Ref ID	SRDB Ref ID
CTW	Not used	Not used	Not used	Not used	CTW
WkHxFile	Link to EDAR & WkHx Images	Link to EDAR & WkHx Images	Link to EDAR & WkHx Images	Link to EDAR & WkHx Images	EDAR.file
WkHxPage	Page[a]	Page[b]	Page[c]	Page[d]	Page[e]

a. Page in column 18.
b. Page in column 14.
c. Page in column 23.
d. Page in column 19.
e. Page in column 15.

2. Remove duplicate lines.

3. Use the first/middle/last name information (corrected and original) to assign NIOSH ID numbers to CTW Master table rows without a NIOSH ID number where possible. (Do not overwrite claim numbers found in the original files.)

4. For each row with a NIOSH ID number and no SSN, look up the SSN in the SRS NOCTS SSNs file and add to the CTW Master Table where possible.

5. For all rows where the PRID prefix = “3-“, set CTW = Null.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

6. For all rows where:

   [the (PRID prefix >= “4-”,
   Or any title listed in Table 2]

Table F-2. CTW Occupation Titles.

Title
* maintenance man
boilermaker
carpenter
concrete
concrete worker
construction
construction worker
ctw
driver
e&i tech
electrician
heavy equipment operator
insulator
iron worker
ironworker
laborer
machinist
maintenance
maintenance mechanic
maintenance mechanic a
mechanic
painter
pipe fitter
pipefitter
plumber
rigger
roll 5
sheetmetal
sheetmetal worker
welder

and Occupation Title ≠ “CATI - Machinist”
and Occupation Title ≠ “Machinist”
and Occupation Title ≠ “Security”
and Occupation Title ≠ “Engineer”
and Occupation Title ≠ “Clerical”
and Occupation Title ≠ “Pilot”
and Occupation Title ≠ “Instructor”
and Occupation Title ≠ “Manager”
and Occupation Title ≠ “Human Resources”
and Occupation Title ≠ “Supervisor”
and Occupation Title ≠ “Escort”
and Occupation Title ≠ “Laundry”

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

and Occupation Title ≠ “Health Physics"
and Occupation Title ≠ “Administrative Assistant”
and Occupation Title ≠ “Specialist”
and Occupation Title ≠ “Assistant”
and Occupation Title ≠ “Layout”
and Occupation Title ≠ “Reactor Operator”
and Occupation Title ≠ “QA”
and Occupation Title ≠ “Cafeteria”

set CTW = ‘Y’. Otherwise, set CTW = ‘N’.

Ignore capitalization differences.

7. If the PRID is a SSN, ignore the PRID field for CTW determination.

8. Overwrite CTW results for the following claims and dates as follows:

   a. Claim 20529, for all dates, CTW=”N”.
   b. Claim 23342, for all dates, CTW=”N”.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

CTW DESIGNATION INSTRUCTIONS

1. For each radionuclide data set used for the coworker study, create a new column of data labeled “Rev 3 CTW.”

2. For each line of data in the data set, look up the CTW designation in the CTW Master file for that person and date.

   a. Match the person based on the following fields given in preference order:

      i. NIOSH ID
      ii. PRID
      iii. Last name and /First/Middle initial

   b. Find the CTW designation date for that person in the following priority order:

      i. Same date
      ii. Most closely preceding date
      iii. Most closely following date (if within 5 years)

   c. Use the CTW designation on that date to update the data set. (NOTE: There should be exact date matches for all dates in the Am data, Np data, and WBC data files)

   d. If the person or a suitable CTW designation date cannot be found in the CTW Master file, mark the CTW designation as “NULL.”

3. Generate a list of all records where the Rev 3 CTW designation is NULL.

4. Manually determine the PRID and occupation for each NULL record and generate a CTW Master Update file with the new information.

5. Update the CTW Master table to include the data in the newly generated CTW Master Update file.

6. Repeat Steps 2-5 until no records have a Rev 3 CTW designation of NULL.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

RADIONUCLIDE INSTRUCTIONS

Tritium

NOCTS H3 Data:

- MDA values:
  - Use the result "<X" values where available if "X" is >0,
  - Otherwise use generic MDAs of:
    - 1 µCi/L through 1980,
    - 0.5 µCi/L for 1981 through 1985
    - 0.1 µCi/L for 1986 and after.
  - For reported positive, nonzero values less than the generic MDA, use the reported value as the MDA.
- Use the "Date" (column D) as the date of sample collection.
- Use the Claim # field as the individual identifier.
- Data set exclusions and revisions:
  - ID 16098: Change result to "<0.5"
  - Exclude ID 35923 (blank result)
  - Exclude ID 175849 (blank result)
  - Change all "<0.05" and "< 0.05" results to "<0.5"
  - Exclude all data from Claim # 16856 (not an SRS worker)
- For each sample date, determine the individual's CTW designation as described above.
  - Look up the individual name using the SRS NOCTS Names file as needed to assist with CTW determination.
- Calculate annual doses for each claimant in accordance with OTIB-0011 with the following assumptions:
  - Evaluate each individual's CTW and nonCTW data, designated using the CTW designations determined in the previous step, separately and treat as two different workers.
  - If there is more than 90 days between samples, use a Type 3 analysis under the assumption that the person is not routinely monitored.
  - If there is a single non-detect urine sample in a calendar year, exclude the result because this is assumed to not be part of routine monitoring.
  - Order samples on the same date from lowest to highest.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

  - Assign all dose as if it occurred on the bioassay date.

- Statistical analysis:

  - Evaluate CTW and non-CTW strata separately for 1954 through 1990.

  - Sum dose for each individual for each year. Exclude from the statistical analysis any individual with an annual dose of less than 0.001 rem at three significant digits, i.e., less than 0.0005 rem.

  - Calculate GM and GSD values for the total annual doses using RPRT-53 methodology.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

Americium

Am logbook data:

- If the Changed Payroll ID field is blank, use the Payroll ID field instead.
- Do not use records:
    - With “LIP” in the “report” field
    - With the following anywhere in the “remarks” field
        - “LIP”
        - “Am do not report”
        - “DTPA”
        - “Am DNR”
        - “Do not report”
        - “DO NOT USE”
        - “Lost”
        - 0.383; Am LIP; Probable Contamination
        - Am – LIP
        - Am DNR
        - Am DNR (Note that there is an extra space after the R in the spreadsheet)
        - Am LIP
        - Am LIP low recovery-Hi Am Blank
        - Am LIP low recovery-Hi Am Blank ,Am=.460
        - Am LIP low recovery-Hi Am Blank, Am=.200
        - Am LIP low recovery-Hi Am Blank, Am=.255
        - Am LIP low recovery-Hi Am Blank, Am=.285
        - Am LIP low recovery-Hi Am Blank, Am=.310
        - Am LIP low recovery-Hi Am Blank, Am=.315
        - Am LIP low recovery-Hi Am Blank, Am=.370
        - Am LIP low recovery-Hi Am Blank, Am=.388
        - Am LIP low recovery-Hi Am Blank, Am=.395
        - Am LIP low recovery-Hi Am Blank, Am=.420
        - Am LIP low recovery-Hi Am Blank, Am=.493
        - Am LIP low recovery-Hi Am Blank, Am=.527
        - Am LIP low recovery-Hi Am Blank, Am=.903
        - Am LIP low recovery-Hi Am Blank, Am=1.440
        - Broken flask sample LIP
        - Do not report
        - Do not report #6 until rerun and found valid
        - Do Not Report Am
        - DO NOT USE, Spike
        - DO NOT USE, Spike -.-010
        - DTPA Program
        - Flask broken - sample lost
        - LIP for Am and Pu
        - LIP for Am; Pu ok
        - LIP. Do Not Report note at bottom of page 23.
        - Lost in Process

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

- o Not used
- o Pu LIP low recovery; Am LIP
- o Pu OK, Re-run AM DO NOT USE for Am
- o Pu OK, Re-run AM DO NOT USE for Am, .150
- o Pu ok; Am LIP see note at bottom of page and note low recoveries.
- o Rerun #7 (Am) lost

- o For Remarks Column comment “1st dpm/disc LIP ; flash broke” which is Unique ID 15640, don’t use the blank dpm/1.5L (1) result; but use the results in the dpm/1.5L (2) and dpm/1.5L (3) column

- o For Remarks Column comment “Am #1 lost; 2nd rinse onto planchet” which is Unique ID # 17920, don’t use the dpm/1.5L (1) result; but use the dpm/1.5L (2) result.

- o Except for the following which are still used:

    - “Pu LIP” (unless “Am LIP” is also in the remarks)
    - “Pu report data LIP”
    - “EU LIP”
    - “LIP (EU)”
    - “Unique ID # 17259 dpm/1.5L (1) even though there is a comment stating 2nd rerun lost.

– Individual “dpm/1.5L” values with a value of “LIP” (other “dpm/1.5L” values for that record are still used).

– If the “report” and all “dpm/1.5L” fields are blank

– Data exclusions:

- o Changed Payroll ID A, incident on March 9, 1970, exclude all results for 1970.

- o Changed Payroll ID B, exclude result on May 1, 1981, false positive.

- o Changed Payroll ID C, exclude result on April 27, 1966, false positive.

- o Changed Payroll ID D, exclude result on October 19, 1976, false positive.

- o Changed Payroll ID E, ingestion intake on March 16, 1972, exclude all results for 1972.

- o Changed Payroll ID F, Pu wound intake on May 8, 1986, exclude all results for 1986.

– With a type of “DTPA” or similar

– With no bottle date.

ATTACHMENT F
SRS COWORKER STUDY STATISTICAL ANALYSIS INSTRUCTIONS, REVISION 15, AUGUST 1, 2016 (continued)

  - With no “Changed Payroll ID#” or “Payroll ID”

  - Within 100 days after receiving chelation as indicated in the Chelation Data spreadsheet. Disregard PRID prefixes for matching bioassay results to the Chelation Data spreadsheet.

  - With a value given as a percentage in any of the report or individual dpm/1.5L values.

- Average all reported “dpm/1.5L” values to determine the result to use

  - If all “dpm/1.5L” values are blank, use the “report” value.

- Use the following censoring levels for negative/zero values:

  - 1963-1965: 2 dpm/1.5L
  - 1966-1967: 3 dpm/1.5L
  - 1968: 1 dpm/1.5L
  - 1969-1989: 0.3 dpm/1.5L

- Perform the statistical analysis in accordance with the TWOPOS method in the latest version of RPRT-0053 as follows:

  - Evaluate two strata; 1) CTW for 1967-1989 and 2) nonCTW for 1964-1989

  - For both strata, evaluate individual years except 1981-82, 1983-84, 1985-86, and 1987-89. Merge grouped years.