Draft

REVIEW OF SPECIAL EXPOSURE COHORT ISSUES FOR THE HANFORD SITE FOR THE PERIOD JULY 1, 1972, TO DECEMBER 31, 1990

Volume II – Appendices

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APPENDIX A: INTERNAL DOSE DATA COMPLETENESS REVIEW

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A.1 OBJECTIVE

The purpose of this report is to examine the internal monitoring records contained in the Radiological Exposure Database (REX) for adequacy and suitability in constructing the coworker model presented in Appendix C of the Hanford site internal dose TBD. Specifically, this report will seek to identify monitoring practices, exposure potential, and potential gaps as they pertain to worker job categories, as well as periods of production and exposure potential during the SEC period. Radionuclides that are considered 'exotic' or 'special,' in that they were only used during specific campaign periods, and/or site locations will also be discussed, though in less depth than the more common contaminants.

A.2 DESCRIPTION OF REX DATABASE

The REX Database is made up of a series of smaller database files that contain a wide variety of information, including employment history, external/internal monitoring, lists of Hanford contractors/subcontractors, general worker information (addresses, passport information, etc.), and lists of incidents occurring at the site. For the purposes of this study, five of the REX database files will need to be analyzed and are described in Table A-1.

Table A-1. Description of REX Database Files Used in Completeness Study

Database Name	Description
REX_WORK_HIST	Identifies workers by a 'REX ID,' which allows for the tracking of individual workers across the different database files. Also contains employment start and end dates.
INV_RESULT	Lists in-vivo counting samples by REX ID and date, and assigns a tracking number to each in-vivo sample, which can be used to obtain the results of the count in 'INV_ISO_RESULT' described in the next row.
INV_ISO_RESULT	Uses the tracking number from 'INV_RESULT' and provides the radionuclides and results of the in-vivo sample.
EXC_RESULT	Contains the urinalysis data for workers listed by REX ID.
DOS_SUM_RESULTS	Contains external monitoring results, which are not part of this analysis; however, the database also contains job title information that can be linked to the internal database files by REX ID.

A.3 METHODOLOGY AND APPROACH

The REX Database files were broken down to track the monitoring practices as they relate to overall coverage of the workforce, monitoring by job title, exposure potential by job title, and area of work. Specific radionuclides were selected for analysis based on the amount of data available in the database (i.e., exotic radionuclides and other contaminants with relatively few samples were not included in the main analysis, but are discussed in Section A-7). Radionuclides selected for analysis include americium, cesium, miscellaneous fission products (mainly Sr-90), iodine, plutonium, thorium, and uranium.

One of the goals of this analysis is to gain information as to what groups of workers may have been monitored more consistently than others, whether that pertains to their job title or their

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specific area of work. The exposure potential of different job titles was also analyzed based on the magnitude of results for specific jobs. Unfortunately, a worker's specific job title and work location are not universally known for every worker and time period contained in the database. For example, a worker may have several different employment periods specified in 'REX_WORK_HIST;' however, only one of those employment periods contains a job title designation. Similarly, a worker may have several different bioassay samples during their employment, but only a handful ever specified the area of work when the sample was taken.

Because taking this information at face value (i.e., only considering worker employment periods with a job title specified or only bioassay samples that specify a work area) would severely limit the amount of data available for analysis, an approximate approach was developed, so that as much data as possible could be included. To this end, it has been assumed that if a worker is identified with a specific job title, they held that job title throughout their SEC employment. Similarly, if a worker is identified with a specific area of work, it is assumed they spent their entire employment at that location. These assumptions will result in some degree of "double counting," in which the monitoring records of a worker who held multiple job titles, or that is identified with multiple work areas, would count towards the totals of both categories (whether job title, work location, or both). For further discussion on the possible implications of this approach, as well as additional information on how the data were analyzed, please refer to Attachments 1 and 2 (for job title and work location, respectively).

A.4 STRUCTURE OF INDIVIDUAL RADIONUCLIDE SECTIONS

Each individual radionuclide section (found in Sections A-6.1–A-6.6) that presents the results of the completeness study can be separated into four categories of tables:

(1) Overall monitoring coverage by year for the entire worker population (for both in-vivo and in-vitro monitoring as available).

(2) Monitoring coverage by year for the 20 job categories most likely to have been monitored during their SEC employment.

(3) Identification of areas and time periods of potential internal exposure to the given radionuclide (based on information describing particular campaigns and area-specific projects), as well as the actual monitoring coverage by year and by area for the site (areas selected were the 100, 200, 300, 400, and 700 Areas, as well as the 100-N Reactor area and 200 Area Tank Farms).

(4) Identification of the most common job title among monitored workers for the areas and time periods identified as having internal exposure potential (as described above under category 3).

Category 1 tables will consist of one or two tables (depending on whether both in-vitro and in-vivo data exist for the given nuclide) that show the percentage of the overall workforce that was monitored for the given radionuclide by year, as well as the median and/or average bioassay

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result for that year.[1] The workforce for each year was identified by their employment periods listed in 'REX_WORK_HIST.' Category 1 tables also include the number of samples per worker employed in a given year, in addition to the number of samples per worker monitored in that year. Note that this analysis does not distinguish between routine samples and those associated with incidents. NIOSH has taken this into account to some extent in its coworker analysis (see main report).

Category 2 consists of two tables. One table lists, in order, the job categories most likely to be monitored for the specific radionuclide during their employment, but does not necessarily indicate they are the worker category with the highest percentage of workers monitored in any specific year. Nor does this category indicate what the most common job title is among monitored workers. As an example, the analysis may indicate that 'Job A' consists of 100 workers of which 70% were monitored during their career, while 'Job B' consists of 1,000 workers of which 30% were monitored during their career. While 'Job A' is the category of worker most likely to be monitored, it is not the most common job title among monitored workers (70 monitored workers for 'Job A' versus 300 monitored workers for 'Job B'). The second table compares the employment monitoring practices shown in the first table against the median, average, and maximum bioassay result for that job category during the SEC period. Specific characterizing of the magnitude of bioassay results by year for all job categories identified is presented in Attachment 3.

Category 3 consists of two tables. The first table presents information on site operations in the context of the areas/buildings (including the period of operation) where internal exposure was possible. The second table shows the percentage of workers monitored for each site area and year, and highlights the areas and years where internal exposure potential has been identified.

Category 4 consists of a single table that lists the most common job category among monitored workers (i.e., 'Job B' described previously) for each year and area of interest for internal exposure potential.

A.5 SUMMARY OF FINDINGS

Table A-2 contains a summary of the completeness analysis for each of the major radionuclide groups. Table A-2 is structured into the analysis categories described in Section A-4. It is important to note that the values given under category 1 (% of workers monitored per year and # of samples per monitored worker per year) represent average values over the entire SEC period, and that these values will vary from year to year, as shown in Section A-6.

Some general findings of the completeness analysis presented in Section A-6 are as follows:

Finding A-1: For the main radionuclides analyzed (Am, Cs, MFP, Pu, and U), workers associated with the 200 Tank Farms were the most likely to be monitored during their employment.

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[1] Because of the large variation in material and solubility types handled in different areas of the site and by different job types, we chose not to do the comparative analysis of the in-vitro samples for uranium and plutonium.

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Finding A-2: ‘Radiation monitors,’ ‘electricians,’ ‘operators,’ ‘pipefitters,’ and ‘science technicians’ were consistently among the five job titles most likely to be monitored during their SEC employment.

Finding A-3: In general, the most commonly monitored job title by area and year are ‘managers and administrators’ (100, 100-N, 200, and 300 Areas), ‘operators’ (200, 200 Tank Farms, and 300 Area), and ‘scientists’ (300 Area).

Finding A-4: In-vivo records analysis for americium, cesium, mixed fission products, and uranium monitoring showed a significant decrease in worker sampling in 1975 (generally less than 1% of the worker population was monitored). Other significant decreases in worker monitoring include 1974 (iodine), 1976–1977 (mixed fission products), and 1985 (cesium). Thorium-232 was sparsely monitored throughout the period, and there are very few data points overall. No significant decreases in worker monitoring were identified for plutonium.

Finding A-5: Section A-7 presents radionuclides not included in the main analysis because of the sparse available records; these include thorium, iodine, polonium, neptunium, radium, curium, californium/berkelium, and ‘total actinides.’ Polonium, curium, and ‘total actinides’ were mostly periodic sampling, while radium and neptunium were likely incident related.[2]

Observation A-1: Based on a review of the radionuclide-specific records in the Site Research Database (SRDB), SC&A found that contamination incidents generally tended to be followed up by urinalysis and/or in-vivo counting of the individuals involved, even if the initial nasal smears indicated no intake potential. However, it should be borne in mind that SC&A did not attempt to correlate these hardcopy incident records with individual personnel files. See also the discussion of Matrix Items 21 and 22 regarding missing or destroyed records in the main section of this report.

[2] It is assumed that samples designated as ‘special’ via their respective ‘reason codes’ were incident-related.

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Table A-2. Summary of Data Completeness Study by Analysis Category (as described in Section A-4)

Radionuclide	Category 1			Category 2	Category 3		Category 4
	Monitoring Type	**Average % of Workers Monitored by Year**	**Average # of Samples per Monitored Worker per Year**	**Job Types Most Likely to be Monitored During Employment**	**Areas and Years of Potential Exposure**	**% of Workers Monitored During Employment for Area of Concern**	**Most Common Job Type Among Monitored Workers by Area of Concern**
Americium	In Vitro	0.21%	3.58	Rad. Monitors, Electricians, Operators, Pipefitters, Science Techs	200 Area (1972–1990)	38.65%	Mngr. and Admin., Operators
	In Vivo	7.62%	1.10		200 Tank Farms (1972–1990)	55.49%	Operators
					300 Area (1972–1988)	42.40%	Scientists
Cesium	In Vivo	24.76%	1.11	Electricians, Rad. Monitors, Firefighters, Operators, Pipefitters	200 Area (1972–1990)	91.71%	Mngr. and Admin.
					200 Tank Farms (1972–1990)	99.41%	Operators
					300 Area (1972–1988)	84.98%	Scientists, Mngr. and Admin
Miscellaneous Fission Products	In Vitro	3.57%	1.43	Rad. Monitors, Operators, Science Techs, Pipefitters, Electricians	100-N Area (1972-1987)	26.42%	Mngr. and Admin.
	In Vivo	2.07%	1.80		200 Area (1972–1990)	37.30%	Operators
					200 Tank Farms (1972–1990)	81.60%	Operators
					300 Area (1972–1990)	22.16%	Technicians, Mngr. and Admin
Plutonium	In Vitro	10.82%	1.75	Rad. Monitors, Operators, Handler/ Laborer, Pipefitters, Electricians	200 Area (1972–1990)	47.83%	Mngr. and Admin.
	In Vivo	0.05%	2.53		200 Tank Farms (1972–1990)	69.14%	Operators
					300 Area (1972–1990)	39.66%	Mngr. and Admin.
					400 Area (1980–1990)	54.06%	Mngr. and Admin.
Uranium	In Vitro	1.36%	1.89	Rad. Monitors, Electricians, Operators, Pipefitters, Science Techs.	100 Area (1972–1977)	23.30%	Engineers
	In Vivo	7.28%	1.08		100-N Area (1972–1987)	22.93%	Mngr. and Admin., Engineers, Operators
					200 Area (1972–1990)	39.01%	Mngr. and Admin., Operators
					300 Area (1972–1990)	42.92%	Scientists, Operators
					400 Area (1980–1990)	54.64%	Mngr. and Admin.

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A.6 INDIVIDUAL RADIONUCLIDE ANALYSIS RESULTS

This section presents the results for each of the radionuclides that were considered for completeness analysis (americium, cesium, other miscellaneous fission products, plutonium, and uranium). As described in Section A-4, the analysis aims to gain insight into the monitoring coverage and practices for the worker population as a whole by occupation and by site area (particularly areas with identified internal exposure potential).

Note that all in-vitro results below MDA are set to zero for convenience and clarity [since there were conflicts between some of the MDAs in the REX database and the TBD (see main report)]. The median and average values of in-vitro results include all below MDA values counted as zero and all above MDA values. For in-vivo results, the REX database already lists the value as half the MDA. Hence, these values that are already in the REX database were used in computations for in-vivo average and media values.

A.6.1 Americium

Tables A-3 and A-4 summarize the site-wide practice of americium monitoring for in-vitro sampling (Table A-3) and in-vivo sampling (Table A-4). Each table shows the percentage of workers monitored by the given method, the average number of samples per worker employed at the site in each year, the average number of samples per monitored worker per year, and the median/average sample result. As seen in Table A-3, the practice of in-vitro monitoring for americium was for only a very small percentage of the worker population; however, the workers who were monitored via this method were often sampled more than once in a year. In 1976, monitored workers averaged over 15 samples per year; however, this appears to be the result of a major incident involving the explosion of an ion exchange column in Building 242-Z, which resulted in significant americium contamination. This is reflected in the sample results for that year as the magnitude of in-vitro sampling was several orders of magnitude higher than other years.

Table A-4 shows that the practice of in-vivo monitoring covered a larger portion of the worker population, but was still generally less than 10%. In general, workers that were monitored via in vivo for americium were only counted once per year. The sample results by year indicate higher exposures earlier in the SEC period and generally decreased over time. However, this is also coupled with an increase in the percentage of the workforce that was monitored, so it is likely the observed decrease in exposures is the result of the monitoring coverage expanding to workers with lower exposure potential.

Table A-5 shows the percentage of workers monitored for americium (either in vitro or in vivo) by year and by job category, as identified in the REX database.[3] The job categories presented in Table A-5 are ranked by the percentage of the workers in a given category that were monitored at some point during their SEC employment. For example, the second job category presented (Ranked 2nd) is 'Radiation Monitors/Technicians,' which covers 417 workers, of which 78.2%

[3] Refer to Attachment 1 for more information on how job title information was derived and interpreted from the REX database.

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were monitored for americium during their SEC employment. It is important to note that the ranking is not indicative of what percentage of workers was monitored in any given year, but rather over their entire SEC employment. As an example, 19.5% of 'Radiation Monitors/ Technicians' (Ranked 2nd overall) were monitored in 1974; however, in this particular year, the job category with the highest percentage of workers monitored was 'Technicians' (Ranked 17th overall) at 38.3%. Table A-6 compares the career-monitoring percentage against the magnitude of observed in-vivo results by job category. As seen in the table, job categories such as operators and science technicians had a high percentage of workers monitored in their career, and also had above average in-vivo results. These job categories also had the highest observed results in the database. The only job title that had above average results and was not contained in the top 20 job categories was security guards; only ~12% of the security guards were monitored for americium during their employment.

Also observed in the table is that very few of the top 20 job categories had median results above the 'all worker' median. This is not of particular concern, however, as the majority of in-vivo results were less than the individual samples' MDA. This would explain the relatively small variability between the median results shown (generally between .06 and .09 nCi).

Table A-3. Americium In-Vitro Overview

Year	Percentage of Workers Monitored In Vitro for Americium			Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year	Median Am-241 Sample Result (µCi/l) Urinalysis	Median Am-241 Sample Result, Fecal (µCi/g)
	Am	Am-241	Combined In-Vitro Samples				
1972	–	0.11%	0.11%	0.002	2.11	0.00E+00	1.67E-07
1973	–	0.20%	0.20%	0.011	5.61	0.00E+00	4.34E-09
1974	–	0.16%	0.16%	0.007	4.41	2.13E-07	0.00E+00
1975	–	0.13%	0.13%	0.004	2.93	NA	NA
1976	–	0.41%	0.41%	0.063	15.32	9.29E-01	6.39E-05
1977	0.16%	0.15%	0.28%	0.018	6.43	NA	NA
1978	–	0.14%	0.14%	0.007	1.19	5.45E-03	NA
1979	–	0.13%	0.13%	0.007	1.67	NA	NA
1980	–	0.17%	0.17%	0.015	7.85	1.52E-06	6.32E-08
1981	0.01%	0.10%	0.11%	0.004	2.00	0.00E+00	5.53E-07
1982	0.04%	0.12%	0.14%	0.009	5.71	2.03E-06	5.09E-07
1983	0.06%	0.10%	0.16%	0.003	1.56	0.00E+00	1.49E-06
1984	–	0.38%	0.38%	0.006	1.45	0.00E+00	1.70E-08
1985	–	0.36%	0.36%	0.008	2.08	1.55E-08	4.42E-08
1986	–	0.53%	0.53%	0.009	1.66	0.00E+00	6.60E-08
1987	–	0.34%	0.34%	0.005	1.56	0.00E+00	0.00E+00
1988	–	0.15%	0.15%	0.002	1.54	0.00E+00	0.00E+00
1989	–	0.06%	0.06%	0.001	1.70	1.20E-08	NA
1990	–	0.09%	0.09%	0.001	1.33	0.00E+00	NA

Dashes (-) indicate 0.00% in percentage of workers monitored
NA indicates data could not be analyzed for magnitude

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Table A-4. Americium In-Vivo Overview

Year	Percentage of Workers Monitored In-Vivo for Americium			Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year	Average Am-241 In-Vivo Result (nCi)	Median Am-241 In-Vivo Result (nCi)
	Am-241	Am-242	Combined In-Vivo Samples				
1972	2.53%	–	2.53%	0.027	1.05	4.65E-01	2.95E-01
1973	4.95%	–	4.95%	0.057	1.15	5.58E-01	2.65E-01
1974	5.75%	–	5.75%	0.066	1.14	8.18E-01	3.20E-01
1975	0.16%	–	0.16%	0.002	1.00	7.48E+00†	1.40E-01
1976	5.90%	–	5.90%	0.063	1.07	4.10E-01	1.30E-01
1977	5.70%	–	5.70%	0.060	1.05	1.76E-01	1.30E-01
1978	7.63%	–	7.63%	0.085	1.11	1.61E-01	1.25E-01
1979	8.41%	–	8.41%	0.094	1.12	1.55E-01	1.25E-01
1980	9.16%	–	9.16%	0.100	1.09	1.99E-01	1.30E-01
1981	9.50%	–	9.50%	0.104	1.10	1.57E-01	1.25E-01
1982	9.09%	–	9.09%	0.099	1.09	1.56E-01	1.30E-01
1983	8.05%	–	8.05%	0.085	1.06	1.56E-01	1.25E-01
1984	8.17%	–	8.17%	0.092	1.12	1.25E-01	8.00E-02
1985	8.29%	–	8.29%	0.093	1.12	4.26E-01	8.00E-02
1986	8.68%	0.01%	8.68%	0.104	1.20	2.67E-01	8.30E-02
1987	8.28%	–	8.28%	0.092	1.11	1.55E-01	8.45E-02
1988	9.42%	–	9.42%	0.103	1.10	1.41E-01	8.60E-02
1989	11.38%	–	11.38%	0.123	1.08	1.71E-01	7.50E-02
1990	13.78%	–	13.78%	0.160	1.16	1.01E-01	6.65E-02

† This value is driven by an unusually high result (1.3E+02 nCi in January of 1975); the sample result was blank, but listed an extremely high MDA (2.6E+02 nCi). The worker was a Westinghouse employee with an unknown job title. The sample is labeled as a termination sample. If this value is excluded, the average drops to 2.7E-01 nCi in 1975.

Dashes (-) indicate 0.00%

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Table A-5. Percentage of Workers Identified by Job Title Who Were Monitored for Americium by Year (1972–1981)

Rank	Job Description	Total Number of Workers Identified	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	Misc Precision/Production	[redacted]	–	–	–	–	–	–	–	–	–	–
2	Radiation Monitors/ Technicians	417	3.2%	28.1%	19.5%	4.4%	26.9%	25.4%	53.2%	50.0%	57.5%	56.0%
3	Electricians	374	2.0%	16.7%	8.8%	0.0%	12.6%	14.7%	15.8%	19.2%	22.4%	24.7%
4	Operators Plant/ System/Utility	1003	6.7%	6.1%	11.0%	2.0%	6.5%	7.8%	15.0%	16.4%	16.6%	13.3%
5	Pipefitters	364	5.0%	8.5%	4.7%	0.0%	7.2%	12.6%	17.3%	12.9%	16.9%	19.3%
6	Science Technicians	394	0.0%	13.0%	16.7%	0.0%	21.6%	15.9%	18.2%	28.7%	30.2%	34.7%
7	Sheet Metal Workers	80	0.0%	0.0%	5.9%	0.0%	0.0%	9.1%	11.1%	29.2%	17.4%	12.9%
8	Painters	88	0.0%	13.6%	0.0%	0.0%	7.4%	6.1%	3.0%	5.9%	12.2%	7.6%
9	Equipment Operator	128	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.9%	0.0%	0.0%
10	Misc Repair/Construction	476	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.4%	2.4%	0.0%	4.4%
11	Carpenters	101	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	0.0%	0.0%	5.1%	4.8%
12	Welders and Solderers	47	0.0%	0.0%	0.0%	0.0%	16.7%	7.1%	10.5%	26.1%	6.7%	11.1%
13	Health Physicists	59	0.0%	20.0%	14.3%	0.0%	15.4%	7.1%	13.3%	33.3%	30.0%	30.0%
14	Handlers/Laborers/Helpers	200	0.0%	0.0%	0.0%	0.0%	7.1%	6.9%	5.0%	6.1%	15.4%	13.8%
15	Miners/Drillers	[redacted]	–	–	–	–	–	–	–	–	0.0%	0.0%
16	Misc Technicians	653	5.3%	5.3%	4.0%	0.0%	10.1%	8.6%	13.6%	13.3%	21.3%	22.0%
17	Technicians	446	14.7%	22.5%	38.3%	0.0%	36.9%	31.0%	38.6%	32.5%	28.2%	31.4%
18	Machinists	98	0.0%	0.0%	3.3%	0.0%	14.3%	11.6%	16.0%	11.5%	15.5%	18.2%
19	Truck Drivers	200	0.0%	0.0%	0.0%	0.0%	0.0%	5.7%	2.3%	3.9%	3.8%	6.2%
20	Mechanics/Repairers	324	3.5%	7.9%	3.9%	0.0%	11.5%	8.7%	14.4%	10.9%	15.7%	15.0%

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-5. Percentage of Workers Identified by Job Title Who Were Monitored for Americium by Year (1982–1990)

(continued)

Rank	Job Description	Total Number of Workers Identified	1982	1983	1984	1985	1986	1987	1988	1989	1990	All SEC Employed Years
1	Misc Precision/Production	[redacted]	–	–	–	–	–	–	–	–	100.0%	**100.0%**
2	Radiation Monitors/ Technicians	417	58.6%	40.0%	31.2%	33.6%	33.2%	35.2%	43.1%	66.1%	68.0%	**78.2%**
3	Electricians	374	22.0%	18.6%	13.5%	16.7%	19.4%	20.9%	31.7%	53.6%	69.8%	**70.9%**
4	Operators Plant/ System/Utility	1003	14.4%	18.1%	22.8%	30.5%	39.2%	38.0%	38.2%	40.9%	46.2%	**65.6%**
5	Pipefitters	364	19.7%	18.6%	17.2%	18.2%	18.1%	18.1%	25.1%	50.9%	65.3%	**65.4%**
6	Science Technicians	394	18.0%	34.3%	35.8%	38.3%	33.2%	36.9%	35.5%	38.2%	46.9%	**63.7%**
7	Sheet Metal Workers	80	11.8%	8.9%	13.7%	15.4%	28.3%	7.9%	31.3%	36.5%	52.5%	**58.8%**
8	Painters	88	13.0%	6.2%	6.0%	6.7%	7.5%	7.9%	19.7%	28.8%	61.2%	**52.3%**
9	Equipment Operator	128	7.1%	2.9%	3.0%	4.0%	8.6%	7.5%	10.0%	27.6%	52.4%	**48.4%**
10	Misc Repair/Construction	476	1.1%	1.4%	2.3%	3.0%	2.6%	2.8%	23.1%	30.7%	64.0%	**48.1%**
11	Carpenters	101	4.6%	5.4%	4.8%	4.1%	7.8%	5.6%	21.1%	26.6%	56.9%	**46.5%**
12	Welders and Solderers	47	11.9%	14.3%	11.1%	13.0%	13.0%	10.9%	13.0%	16.7%	43.2%	**44.7%**
13	Health Physicists	59	27.3%	11.5%	9.1%	11.4%	4.6%	4.7%	10.4%	25.6%	25.0%	**44.1%**
14	Handlers/Laborers/Helpers	200	12.3%	10.4%	9.5%	10.6%	6.3%	7.4%	22.8%	16.8%	38.3%	**40.0%**
15	Miners/Drillers	[redacted]	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	66.7%	66.7%	**40.0%**
16	Misc Technicians	653	22.5%	18.0%	17.2%	14.8%	15.8%	15.8%	17.6%	20.2%	25.7%	**37.4%**
17	Technicians	446	35.3%	29.7%	27.0%	28.5%	23.2%	20.2%	14.1%	18.1%	17.7%	**35.9%**
18	Machinists	98	14.3%	12.4%	9.0%	11.0%	9.7%	12.5%	13.7%	10.3%	16.5%	**34.7%**
19	Truck Drivers	200	8.2%	6.3%	5.6%	7.1%	5.3%	6.5%	5.3%	11.3%	32.0%	**34.0%**
20	Mechanics/Repairers	324	17.1%	15.4%	15.2%	13.1%	17.6%	14.2%	14.7%	19.4%	25.2%	**33.6%**

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-6. Overview of Americium In-Vivo Results (nCi) for the Job Titles Most Likely to be Monitored During Employment

Am-241 In Vitro	Average	Median	Max	Greater Than All Worker Average	Greater than All Worker Median	Percent Monitored During Career	Number of Workers Identified
Misc Precision/Production	6.05E-02	6.05E-02	6.45E-02			100.00%	[redacted]
Radiation Monitors/Technicians	1.04E-01	9.00E-02	4.90E+00			78.20%	417
Electricians	9.82E-02	8.70E-02	7.10E-01			70.90%	374
Operators Plant/ System/Utility	4.73E-01	8.40E-02	1.26E+02	Y		65.60%	1003
Pipefitters	1.04E-01	8.85E-02	4.66E-01			65.40%	364
Science Technicians	4.74E-01	8.75E-02	1.30E+01	Y		63.70%	394
Sheet Metal Workers	8.88E-02	8.50E-02	1.85E-01			58.80%	80
Painters	9.30E-02	8.20E-02	3.20E-01			52.30%	88
Equipment Operator	8.19E-02	7.68E-02	1.90E-01			48.40%	128
Misc Repair/Construction	8.41E-02	7.85E-02	6.80E-01			48.10%	476
Carpenters	8.31E-02	7.93E-02	1.80E-01			46.50%	101
Welders and Solderers	1.08E-01	9.50E-02	2.78E-01			44.70%	47
Health Physicists	1.13E-01	1.10E-01	1.95E-01		Y	44.10%	59
Handlers/Laborers/Helpers	9.57E-02	9.15E-02	1.85E-01			40.00%	200
Miners/Drillers	7.29E-02	6.13E-02	1.18E-01			40.00%	[redacted]
Misc Technicians	1.02E-01	9.20E-02	7.35E-01			37.40%	653
Technicians	1.33E-01	1.00E-01	1.50E+00			35.90%	446
Machinists	1.17E-01	1.05E-01	9.50E-01		Y	34.70%	98
Truck Drivers	9.37E-02	8.50E-02	2.05E-01			34.00%	200
Mechanics/Repairers	1.13E-01	9.40E-02	2.20E+00			33.60%	324
All Workers	2.01E-01	1.00E-01					

Table A-7 shows the specific areas/buildings and periods of operation at the site, where the potential for internal americium exposure existed. As shown, the internal exposure potential was confined to the 200 Area, 200 Area Tank Farms, and 300 Area.

Table A-8 breaks down the monitoring coverage by area and year for the major areas of interest for the site.[4] As shown in Table A-8, the percentage of workers in the 200 Area, 200 Tank Farms, and 300 Area were higher than the percentage monitored in the 100 Area, 100 N Reactor Area, 700 Area and the worker population as a whole. However, from 1979–1985, the 400 Area had the highest percentage of workers monitored for americium, although no known campaigns or activities have been identified that would warrant the increase in monitoring.

Table A-9 further parses the data to identify workers in which information exists to identify both the location and job title in order to find the most common job title among monitored workers for a given location and year. As an example, the first entry in Table A-9 shows that 24 workers have been identified by job title in the 200 Area for 1972,[5] and the most common job title

[4] Please refer to Attachment 2 for more information on how work location information was derived and interpreted from the REX database.

[5] As noted in Attachments 1 and 2, it was not plausible to determine whether the worker was in a specific area with a given job title on a year-by-year basis. Instead, it was assumed that if the worker held a specific job title and was identified as working in a given area at some point during their SEC employment that this job title and location applies to their entire employment. Please refer to Attachments 1 and 2 for further discussion of the implications of this approach.

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monitored was a tie between ‘operators’ and ‘mngr. and admin,’ which represented 50% of the identified workers monitored ([redacted] workers for each category). As shown in the table, the most commonly monitored job category for the 200 Area was generally ‘operators’ and ‘mngr. and admin’ for almost all years. These two job categories were also commonly monitored in the 300 Area; however, the title of ‘Scientist’ was also common from the beginning of the SEC until about 1983. It is worth noting that operators and scientists were also workers with some of the highest exposure potential, as was shown in Table A-6 previously.

Table A-7. Locations and Operational Periods of Potential Americium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
200	T Plant (221T)	1972–End of SEC	Not Yet Established	T Plant was mainly involved in decontamination activities during the SEC period; however, the internal dose TBD indicates americium recovery in the T Plant, but does not indicate a date.
	PUREX (S Plant A Plant, 202A)	1983–End of SEC	Yes – Mainly associated with contamination incidents	- Internal TBD indicates that there was americium recovery performed in the S Plant, but no dates were provided. - 2 contamination incidents identified (April 1982, February 1986).
	UO3 (224U, 224UA)	1984–End of SEC	Yes – Due to large quantities of uranium processed	17 reactor startups in SEC period (generally last 8 days – specific dates not currently known).
	225B Waste Encapsulation Facility	1974–End of SEC	Limited – Facility was remotely operated.	
	232-Z	1972–1973	Yes – Inhalation, Absorption and Injection Potential	- TBD states exposure potential mainly limited to contamination incidents. - Ref 55191 shows 2 inhalation incidents and calculated intakes from Jan 1974.
	2345Z RMA	1972–1984	Yes – Mainly due to contamination incidents	Mainly limited to contamination incidents per TBD.
	2345Z RMC	1972–1989	Yes – Mainly due to contamination incidents	Mainly limited to contamination incidents per TBD.
	2345Z Storage Vault	1972–End of SEC	Yes – Mainly due to contamination incidents	Mainly limited to contamination incidents per TBD.
	236-Z	1972–1976	Yes – Mainly due to contamination incidents	Ref 4892 noted a puncture incident in 1985 that deposited 1.5 MPBB of americium.
	242-Z	1972–1977	Yes – Mainly from contamination incidents	- ER states the facility was specifically for americium recovery. - Ref 55191 shows intake from injury incident in 1973. Ref 4892, 35872 and 8707 document an explosion involving americium in 1976 resulting in significant contamination and internal deposition.

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Table A-7. Locations and Operational Periods of Potential Americium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
200 Tank Farms	Waste Tanks	1972–End of SEC	Limited – Respiratory protection used	Unplanned release incidents from 1972–1985 are described in Ref 60801 pp. 73–79.
300	333	1972–1988	Yes	
	303 (A-G, J, K, M)	1972–1983 (A-G, J, K) 1984–1987 (M)	Yes	
	306	1972–1984	Yes	
	325	1973–1976, Possibly 1982–1984	Not Yet Established	Ref 66625 indicates the 325-A and B cells were considered for use to separate Am and Pm; the document presents cost estimates for 1982–1984 (it is not clear whether this campaign was ever undertaken); site description TBD mentions americium purification being undertaken from 1973–1976.
	3708	Early 1970s	Not Yet Established	Site description TBD mentions that the north end of this building was used for canning experiments of americium and curium; Ref 13724 indicates these pressed powder targets were clad in aluminum and irradiated in other production reactors to produce special isotopes for medical and science applications.
	324	Possibly 1982–1984	Not Yet Established	Ref 66625 indicates that the A cell of the 324 Building was under consideration for Pm-Am separation and purification for the years 1982–1984; it is not clear if this activity ever was undertaken.

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Table A-8. Combined Americium Monitoring Location Data

Year	Percentage of Workers Monitored for Americium (In Vitro + In Vivo)							
	All Workers	100 Area	100N Area	200 Area	200 Tank Farms	300 Area	400 Area	700 Area
1972	2.57%	2.13%	2.00%	***5.76%***	***13.16%***	***7.12%***	4.00%	0.37%
1973	4.97%	4.71%	4.38%	***9.75%***	***6.82%***	***17.29%***	9.25%	0.96%
1974	5.75%	5.95%	5.56%	***8.13%***	***7.41%***	***19.28%***	5.06%	0.53%
1975	0.27%	0.23%	0.26%	***0.78%***	***1.39%***	***0.60%***	0.34%	0.24%
1976	6.00%	4.08%	3.82%	***6.92%***	***3.13%***	***19.50%***	5.41%	1.67%
1977	5.85%	5.17%	5.22%	***7.04%***	***3.20%***	***17.76%***	9.47%	1.24%
1978	7.62%	5.80%	5.62%	***11.03%***	***12.32%***	***21.14%***	18.20%	2.44%
1979	8.41%	6.40%	5.85%	***12.68%***	***11.98%***	***19.22%***	29.55%	1.09%
1980	9.16%	5.14%	4.65%	***12.66%***	***13.95%***	***23.00%***	28.23%	2.61%
1981	9.50%	6.05%	5.39%	***12.96%***	***12.00%***	***23.97%***	30.95%	1.88%
1982	9.07%	3.72%	3.00%	***10.55%***	***13.60%***	***25.35%***	39.92%	1.33%
1983	8.08%	3.01%	2.09%	***11.00%***	***17.28%***	***20.98%***	28.60%	1.38%
1984	8.25%	3.77%	3.00%	***11.51%***	***17.18%***	***20.36%***	26.86%	0.91%
1985	8.24%	4.55%	3.63%	***12.38%***	***21.12%***	***20.02%***	22.85%	1.30%
1986	8.69%	6.36%	5.57%	***14.51%***	***28.06%***	***19.29%***	18.85%	0.95%
1987	8.28%	5.06%	4.27%	***14.72%***	***25.87%***	***18.08%***	19.22%	0.96%
1988	9.45%	10.70%	10.20%	***18.36%***	***24.84%***	***16.96%***	18.80%	1.86%
1989	11.36%	15.03%	14.61%	***22.58%***	***23.96%***	18.44%	17.18%	1.95%
1990	13.82%	23.12%	23.08%	***29.60%***	***32.09%***	19.77%	16.75%	1.93%
All Years:	15.18%	22.80%	22.36%	38.65%	55.49%	42.40%	54.70%	6.29%

Bold and italicized values indicate internal exposure potential, dashes (-) indicate 0.00%

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Table A-9. Most Commonly Monitored Job Title for Areas with Potential Americium Exposure

Year	200 Area			200 Area Tank Farms			300 Area		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title
1972	24	TIE: Mngr. and Admin., Operators	50.0% Combined	[redacted]	Operators	60.0%	48	Technicians	18.8%
1973	70	Mngr. and Admin.	18.6%	[redacted]	Mngr. and Admin.	33.3%	139	Scientists	22.3%
1974	56	Mngr. and Admin.	23.2%	[redacted]	Mngr. and Admin.	50.0%	184	Scientists	20.1%
1975	[redacted]	Operators	60.0%	[redacted]	Operators	100.0%	[redacted]	Misc Professionals	42.9%
1976	84	Mngr. and Admin.	21.4%	[redacted]	Operators	66.7%	262	Scientists	17.9%
1977	107	Mngr. and Admin.	22.4%	[redacted]	Operators	75.0%	271	Scientists	14.4%
1978	219	Mngr. and Admin.	23.3%	17	Operators	52.9%	379	Scientists	14.0%
1979	287	Mngr. and Admin.	20.6%	20	Operators	55.0%	391	Scientists	16.9%
1980	325	Mngr. and Admin.	20.9%	24	Operators	54.2%	498	Scientists	15.1%
1981	379	Mngr. and Admin.	21.4%	23	Operators	47.8%	555	Scientists	13.7%
1982	345	Mngr. and Admin.	16.5%	30	Operators	63.3%	591	Mngr. and Admin.	13.0%
1983	448	Operators	22.1%	47	Operators	68.1%	570	Scientists	12.1%
1984	528	Operators	24.1%	50	Operators	70.0%	590	Mngr. and Admin.	11.4%
1985	631	Operators	27.3%	64	Operators	65.6%	635	TIE: Managers and Admin., Operators	22.4% Combined
1986	782	Operators	30.1%	87	Operators	64.4%	653	Operators	13.5%
1987	830	Operators	29.4%	82	Operators	67.1%	661	Operators	12.6%
1988	1044	Operators	23.6%	78	Operators	57.7%	627	Operators	11.0%
1989	1278	Operators	21.0%	75	Operators	54.7%	No exposure potential identified		
1990	1767	Operators	19.4%	103	Technicians	21.4%			

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A.6.2 Cesium

Table A-10 displays the overview of cesium in-vivo monitoring,[6] including the percentage of workers monitored, the number of samples per worker per year, the number of samples per monitored worker, and the average in-vivo result. The percentage of workers monitored by year generally varied between 10%–50%, with low points in 1975 (0.02%), 1984 (2.61%), and 1985 (0.29%). It is not clear why these 3 years had such a significant decrease in monitoring. The sample results taken during these years do not show a significant difference with surrounding years, though the data that could be analyzed by result was limited to just two samples for 1975. Monitored workers were generally counted once per year.

Table A-10. Cesium-137 In-Vivo Overview

Year	Percentage of Workers Monitored In Vivo for Cesium-137	Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year	Average Cs-137 In-Vivo Result (nCi)
1972	11.80%	0.122	1.03	4.49E+00
1973	20.80%	0.229	1.10	4.42E+00
1974	19.44%	0.219	1.13	1.97E+00
1975	0.02%	0.000	1.00	3.30E-01
1976	15.88%	0.171	1.08	1.71E+00
1977	18.82%	0.201	1.07	1.93E+00
1978	21.75%	0.239	1.10	1.87E+00
1979	26.15%	0.294	1.13	1.49E+00
1980	28.24%	0.306	1.08	1.87E+00
1981	33.15%	0.365	1.10	9.47E-01
1982	35.67%	0.405	1.13	8.04E-01
1983	33.10%	0.374	1.13	6.38E-01
1984	2.61%	0.032	1.22	1.63E+00
1985	0.29%	0.004	1.27	1.88E+00
1986	19.63%	0.213	1.08	1.33E+00
1987	39.20%	0.440	1.12	1.56E+00
1988	39.77%	0.435	1.11	1.52E+00
1989	50.78%	0.562	1.09	1.52E+00
1990	53.26%	0.631	1.13	1.53E+00

Table A-11 shows the monitoring coverage by job category for workers who can be identified by job title in the REX database.[7] Among the major job categories (i.e., categories with more than 50 identified workers), the job titles most likely to have been monitored for cesium during their career were electricians, radiation monitors, firefighters, plant operators, pipefitters, and security guards.

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[6] There was also a very small amount of Cs in-vitro data; because it appears to be non-routine and likely incident-specific, it was included under 'miscellaneous fission products' in Section 6.3.

[7] Refer to Attachment 1 for more information on how job title information was derived and interpreted from the REX database.

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Table A-12 displays an overview of the magnitude of in-vivo results for the top 20 job types listed in Table A-10. As shown, many of the job types that were identified as having a higher percentage of workers monitored during employment also had median and average values above the 'all worker' values.

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Table A-11. Percentage of Workers Identified by Job Title Who Were Monitored for Cesium by Year (1972–1981)

Rank	Job Description	Total Number of Workers Identified	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	Misc Precision/Production	[redacted]	–	–	–	–	–	–	–	–	–	–
2	Miscellaneous Transport	28	0.00%	0.00%	0.00%	0.00%	16.67%	0.00%	0.00%	0.00%	11.11%	22.22%
3	Sales	[redacted]	–	–	–	–	–	–	–	–	–	0.00%
4	Electricians	374	6.12%	20.83%	28.07%	0.00%	27.59%	53.92%	41.73%	51.92%	58.79%	67.06%
5	Radiation Monitors/ Technicians	417	32.26%	50.00%	34.15%	0.00%	38.46%	55.93%	72.15%	69.79%	80.83%	73.13%
6	Firefighters	104	0.00%	0.00%	6.67%	0.00%	0.00%	5.56%	23.68%	76.92%	50.00%	70.69%
7	Operators Plant/ System/Utility	1003	19.10%	24.49%	26.27%	0.00%	14.67%	51.08%	50.56%	57.59%	67.05%	69.16%
8	Pipefitters	364	23.33%	35.59%	30.59%	0.00%	27.84%	39.86%	53.09%	59.41%	73.26%	73.80%
9	Security Guards	531	14.29%	15.87%	16.67%	0.00%	13.40%	8.77%	7.48%	13.33%	14.92%	21.00%
10	Welders and Solderers	47	0.00%	0.00%	16.67%	0.00%	41.67%	21.43%	42.11%	52.17%	73.33%	77.78%
11	Painters	88	12.50%	22.73%	15.38%	0.00%	22.22%	30.30%	39.39%	41.18%	48.78%	69.81%
12	Truck Drivers	200	0.00%	9.52%	10.00%	0.00%	4.44%	17.14%	15.12%	37.25%	37.74%	46.90%
13	Carpenters	101	0.00%	22.22%	0.00%	0.00%	19.05%	19.23%	24.32%	55.26%	43.59%	66.67%
14	Equipment Operator	128	11.76%	0.00%	0.00%	0.00%	0.00%	33.33%	30.00%	46.34%	48.78%	72.34%
15	Sheet Metal Workers	80	11.11%	12.50%	35.29%	0.00%	23.53%	36.36%	22.22%	50.00%	60.87%	61.29%
16	Handlers/Laborers/Helpers	200	0.00%	8.33%	0.00%	0.00%	14.29%	20.69%	15.00%	34.69%	42.31%	53.45%
17	Misc Repair/Construction	476	7.89%	13.95%	10.17%	0.00%	19.72%	36.27%	31.43%	47.56%	38.82%	65.63%
18	Health Physicists	59	0.00%	20.00%	28.57%	0.00%	23.08%	28.57%	33.33%	38.89%	45.00%	55.00%
19	Masons	21	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	100.00%	50.00%	50.00%	50.00%
20	Janitors	204	14.29%	55.56%	38.46%	0.00%	21.74%	15.15%	19.23%	15.00%	25.71%	36.05%

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-11. Percentage of Workers Identified by Job Title Who Were Monitored for Cesium by Year (1982–1990)

Rank	Job Description	Total Number of Workers Identified	1982	1983	1984	1985	1986	1987	1988	1989	1990	All SEC Employed Years
1	Misc Precision/Production	[redacted]	–	–	–	–	–	–	–	–	100.00%	**100.00%**
2	Miscellaneous Transport	28	25.00%	52.38%	0.00%	0.00%	65.38%	92.59%	96.15%	92.00%	95.45%	**100.00%**
3	Sales	[redacted]	0.00%	–	0.00%	0.00%	0.00%	0.00%	–	100.00%	–	**100.00%**
4	Electricians	374	69.78%	50.00%	1.74%	0.33%	25.57%	69.85%	84.62%	93.08%	94.97%	**98.66%**
5	Radiation Monitors/ Technicians	417	86.21%	76.67%	5.37%	0.00%	37.40%	83.22%	86.15%	94.50%	97.25%	**98.32%**
6	Firefighters	104	25.42%	7.94%	0.00%	0.00%	3.85%	27.06%	44.32%	88.76%	91.30%	**98.08%**
7	Operators Plant/ System/Utility	1003	76.35%	73.20%	4.48%	1.18%	38.60%	85.13%	81.69%	88.93%	92.68%	**97.91%**
8	Pipefitters	364	72.34%	68.37%	12.45%	1.78%	32.29%	73.72%	85.37%	93.53%	94.02%	**96.70%**
9	Security Guards	531	15.31%	23.14%	0.73%	0.00%	5.71%	20.44%	47.62%	82.05%	83.86%	**96.23%**
10	Welders and Solderers	47	76.19%	66.67%	8.89%	2.17%	19.57%	76.09%	73.91%	80.95%	91.89%	**95.74%**
11	Painters	88	50.00%	53.85%	4.48%	0.00%	27.50%	67.11%	89.47%	84.93%	94.03%	**95.45%**
12	Truck Drivers	200	40.98%	35.92%	3.11%	0.00%	27.06%	56.52%	62.63%	76.27%	84.02%	**95.00%**
13	Carpenters	101	56.82%	46.43%	3.17%	0.00%	27.27%	65.56%	72.63%	82.28%	95.83%	**94.06%**
14	Equipment Operator	128	67.86%	51.47%	1.49%	0.00%	34.57%	56.07%	71.00%	83.67%	92.23%	**93.75%**
15	Sheet Metal Workers	80	47.06%	60.00%	3.92%	0.00%	47.17%	61.90%	89.06%	78.85%	93.22%	**93.75%**
16	Handlers/Laborers/Helpers	200	47.37%	42.86%	4.05%	2.13%	32.14%	62.22%	77.93%	77.18%	87.94%	**93.00%**
17	Misc Repair/Construction	476	47.46%	44.76%	10.19%	1.14%	25.74%	58.82%	77.69%	84.79%	88.36%	**92.86%**
18	Health Physicists	59	40.91%	34.62%	0.00%	0.00%	34.09%	74.42%	75.00%	76.74%	89.58%	**89.83%**
19	Masons	21	100.00%	33.33%	0.00%	0.00%	10.00%	30.00%	60.00%	60.00%	60.00%	**85.71%**
20	Janitors	204	38.71%	35.19%	1.61%	0.00%	23.03%	36.65%	36.81%	66.23%	70.73%	**85.29%**

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-12. Overview of Cesium In-Vivo Results (nCi) for the Job Titles Most Likely to be Monitored During Employment

Cs-137 In Vivo	Average	Median	Max	Greater Than All Worker Average	Greater than All Worker Median	Percent Monitored During Career	Number of Workers Identified
Misc Precision/Production	7.10E+00	7.10E+00	9.40E+00	Y	Y	**100.00%**	[redacted]
Miscellaneous Transport	1.50E+00	1.50E+00	1.50E+00			**100.00%**	28
Sales	3.53E+00	3.53E+00	3.70E+00	Y	Y	**100.00%**	[redacted]
Electricians	1.18E+00	1.50E+00	1.40E+01			**98.66%**	374
Radiation Monitors/Technicians	1.23E+00	1.50E+00	6.80E+00			**98.32%**	417
Firefighters	5.55E+00	5.40E+00	6.90E+00	Y	Y	**98.08%**	104
Operators Plant/ System/Utility	1.22E+00	1.50E+00	2.30E+01			**97.91%**	1003
Pipefitters	2.10E+00	1.50E+00	9.90E+01	Y		**96.70%**	364
Security Guards	1.50E+00	1.50E+00	1.50E+00			**96.23%**	531
Welders and Solderers	2.20E+01	1.30E+01	2.60E+02	Y	Y	**95.74%**	47
Painters	1.50E+00	1.50E+00	1.50E+00			**95.45%**	88
Truck Drivers	3.83E+00	3.80E+00	4.70E+00	Y	Y	**95.00%**	200
Carpenters	2.47E+00	2.50E+00	2.60E+00	Y	Y	**94.06%**	101
Equipment Operator	2.69E+00	2.30E+00	2.70E+01	Y	Y	**93.75%**	128
Sheet Metal Workers	1.78E+00	1.70E+00	2.20E+00	Y	Y	**93.75%**	80
Handlers/Laborers/Helpers	2.73E+00	2.70E+00	2.90E+00	Y	Y	**93.00%**	200
Misc Repair/Construction	1.27E+00	1.50E+00	2.60E+00			**92.86%**	476
Health Physicists	8.43E+00	8.30E+00	1.10E+01	Y	Y	**89.83%**	59
Masons	1.50E+00	1.50E+00	1.50E+00			**85.71%**	21
Janitors	3.06E+00	3.10E+00	3.30E+00	Y	Y	**85.29%**	204
All Workers	1.52E+00	1.50E+00					

Table A-13 shows the locations in which exposure to cesium would have occurred during the SEC period. As shown in the table, the majority of cesium-related operations occurred in the 200 Area, 300 Area, and 200 Tank Farms. B Plant (in the 200 Area) was specifically involved in separating Cs-137 from high-level wastes generated at the PUREX plant, though documentation indicates the facility was remotely operated, so internal exposure would likely be limited to contamination incidents and maintenance activities.

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Table A-13. Locations and Operational Periods of Potential Cesium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
200	T Plant (221T)	1972–End of SEC	Not Yet Established	T Plant was mainly involved in decontamination activities during the SEC period.
	PUREX (A Plant, 202A)	1983–End of SEC	Yes – Mainly associated with contamination incidents	
	UO3 (224U, 224UA)	1984–End of SEC	Yes – Due to large quantities of uranium processed	17 reactor startups in SEC period (generally last 8 days – specific dates not currently known).
	225B Waste Encapsulation Facility	1974–End of SEC	Limited – Facility was remotely operated.	
	222S	1972–End of SEC	Not Yet Established	
	209E, 222T	1972–1986	Not Yet Established	
	222B	1972–1975	Not Yet Established	
	242 Evaporator	1972–End of SEC	Not Yet Established	
	Z-9 Trench	1972–1978	Not Yet Established	
	241-Z	1972–1973	Not Yet Established	
	B Plant (221B)	1972–1983 (per TBD)	Limited – Remotely Operated	Large-scale separation campaigns described in PUREX History document, but only to 1978, not 1983 per the TBD (Ref 14586, pg. 14).
200 Tank Farms	Waste Tanks	1972–End of SEC	Limited – Respiratory protection used	Unplanned release incidents from 1972–1985 are described in Ref 60801, pp. 73–79.
300	308, 320, 324, 325, 326, 329, 331	1972–End of SEC	Not Yet Established	Incident involving inhalation by a technician in 1978 (Ref 67891, pg. 120) and during a cleanup operation (Ref 67891, pg. 335).
	318	1983-End of SEC	Not Yet Established	
	321	1972–1988	Not Yet Established	
	327	1972–1987	Not Yet Established	
	3730	1972–1981	Not Yet Established	
	3745	1972–1983	Not Yet Established	
	340 Waste Complex	1972–End of SEC	Not Yet Established	

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Table A-14 breaks down the monitoring coverage by area for workers who could be identified with a specific site location in the REX database. As shown, the Tank Farms generally had the largest portion of its workforce monitored starting in 1977; prior to that, the 300 Area had the highest percentage monitored. Aside from the Tank Farms, monitoring coverage was usually highest in the 100 Area, though there has not been a significant internal exposure potential identified for this area.

Table A-14. Cesium-137 In-Vivo Location Data

Year	Percentage of Workers Monitored In Vivo for Cesium-137							
	All Workers	100 Area	100N Area	200 Area	200 Tank Farms	300 Area	400 Area	700 Area
1972	11.69%	16.13%	16.80%	***11.52%***	***15.79%***	***21.46%***	10.67%	5.15%
1973	20.76%	33.77%	33.76%	***17.82%***	***13.64%***	***37.12%***	17.92%	10.54%
1974	19.37%	33.47%	34.50%	***16.70%***	***14.81%***	***36.67%***	18.14%	8.73%
1975	0.02%	0.12%	0.13%	–	–	***0.07%***	–	–
1976	15.83%	31.94%	32.52%	***14.11%***	***6.25%***	***32.36%***	12.11%	8.54%
1977	18.72%	35.75%	35.96%	***30.71%***	***59.20%***	***33.25%***	16.87%	5.86%
1978	21.66%	37.34%	37.88%	***31.94%***	***54.35%***	***36.58%***	27.22%	9.28%
1979	26.00%	46.83%	46.90%	***40.23%***	***62.28%***	***38.00%***	40.15%	7.87%
1980	28.10%	48.38%	48.29%	***42.70%***	***72.67%***	***47.80%***	45.15%	11.17%
1981	32.99%	51.30%	51.81%	***49.15%***	***76.00%***	***51.27%***	56.28%	12.34%
1982	35.49%	64.40%	65.26%	***56.97%***	***82.02%***	***55.91%***	62.35%	18.23%
1983	33.06%	58.65%	59.13%	***51.20%***	***72.06%***	***49.96%***	55.19%	18.91%
1984	2.60%	10.43%	10.93%	***2.77%***	***4.81%***	***3.00%***	2.30%	1.75%
1985	0.29%	0.71%	0.74%	***0.48%***	***1.32%***	***0.24%***	–	0.08%
1986	19.57%	38.08%	38.92%	***27.85%***	***37.10%***	***26.09%***	27.56%	18.10%
1987	38.81%	75.21%	75.86%	***57.67%***	***89.27%***	***53.93%***	55.94%	22.71%
1988	39.07%	76.07%	76.99%	***59.46%***	***89.17%***	***56.42%***	59.44%	18.73%
1989	49.79%	80.47%	81.00%	***80.60%***	***95.53%***	***66.54%***	73.43%	29.38%
1990	50.08%	80.79%	81.38%	***82.87%***	***96.26%***	***66.21%***	73.91%	27.53%
All Years:	48.67%	90.91%	91.30%	91.71%	99.41%	84.98%	91.11%	56.95%

Bold and italicized values indicate internal exposure potential, dashes (-) indicate 0.00%

Table A-15 displays the most common job title among monitored workers for the areas of interest for cesium. Managers and administrators dominated the 200 Area for most years and the 300 Area for the later years (scientists were the most commonly monitored job title in the early years of the 300 Area). 'Operators' were the most common job title for the 200 Tank Farms.

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Table A-15. Most Commonly Monitored Job Title for Areas with Potential Cesium Exposure

Year	200 Area			200 Area Tank Farms			300 Area		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title
1972	72	Mngr. and Admin.	23.6%	[redacted]	Operators	50.0%	151	Technicians	15.9%
1973	143	Engineers	22.4%	[redacted]	Mngr. and Admin.	40.0%	308	Scientists	18.8%
1974	151	Mngr. and Admin.	27.8%	[redacted]	Mngr. and Admin.	50.0%	367	Scientists	17.2%
1975	0	N/A	N/A	0	N/A	N/A	[redacted]	Misc. Prof.	100.0%
1976	192	Mngr. and Admin.	25.5%	[redacted]	Operators	50.0%	442	Scientists	19.0%
1977	514	Mngr. and Admin.	22.0%	69	Operators	47.8%	533	Scientists	15.9%
1978	659	Mngr. and Admin.	24.3%	73	Operators	53.4%	677	Scientists	15.1%
1979	942	Mngr. and Admin.	21.3%	97	Operators	46.4%	775	Scientists	15.9%
1980	1122	Mngr. and Admin.	23.6%	118	Operators	48.3%	1032	Scientists	14.4%
1981	1473	Mngr. and Admin.	22.5%	144	Operators	48.6%	1213	Mngr. and Admin.	14.7%
1982	1786	Mngr. and Admin.	24.6%	180	Operators	46.1%	1320	Mngr. and Admin.	15.3%
1983	1989	Mngr. and Admin.	24.3%	192	Operators	51.0%	1339	Mngr. and Admin.	15.3%
1984	131	Mngr. and Admin.	36.6%	14	Mngr. and Admin.	64.3%	88	Mngr. and Admin.	18.2%
1985	21	Mngr. and Admin.	42.9%	[redacted]	Electricians	25.0%	[redacted]	Mngr. and Admin.	33.3%
1986	1465	Mngr. and Admin.	23.2%	113	Operators	47.8%	838	Mngr. and Admin.	15.9%
1987	3188	Mngr. and Admin.	20.8%	280	Operators	45.4%	1835	Mngr. and Admin.	14.6%
1988	3380	Mngr. and Admin.	20.4%	280	Operators	45.4%	1948	Mngr. and Admin.	13.8%
1989	4564	Mngr. and Admin.	23.3%	299	Operators	42.1%	2242	Mngr. and Admin.	15.8%
1990	4947	Mngr. and Admin.	22.2%	309	Operators	40.5%	2293	Mngr. and Admin.	15.8%

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A.6.3 Miscellaneous Fission Products

Tables A-16 and A-17 display the in-vitro and in-vivo monitoring coverage for the most commonly sampled fission products present in the REX database. As the tables show, monitoring for specific fission products was not a routine occurrence and is likely related to specific campaigns or incidents. The only fission product that has data for each year of the SEC (aside from cesium-137 in-vivo monitoring covered in the previous section) was in-vitro monitoring for strontium, which generally ranged from a fraction of a percent (1972–1977) to well under 10% of the worker population. In-vivo monitoring for fission products shows a gap from 1975–1976.

Documentation indicates that five internal exposures due to Eu-154 occurred in 1973, which explains why in-vivo monitoring is unusually high for this radionuclide in that year (Ref 59156). There was also an incident in 1974 (Ref 68214) involving Ce-144 contamination in Building 325, which contaminated at least six workers (five of six workers submitted urinalysis samples the following day). A suspected Ru-106 intake occurred in Building 325 in 1974; no monitoring was found in response to this incident (Ref 68262). A potential Pm-147 internal exposure occurred in 1975 in the 325 Building when a worker encountered contamination from a faulty valve system (Ref 68236); Pm was separated in the 325 Building of the 300 Area from 1972–1978 (Ref 66625). A technician in the 325 Building in 1978 was involved in an inhalation incident of Sr-90; this year coincides with a general increase in in-vitro strontium monitoring for the general worker population and also one of the highest average in-vitro results of the years shown (Ref 67891, pg. 120).

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Table A-16. Miscellaneous Fission Product In-Vitro Overview

Year	Percentage of Workers Monitored In Vitro for Miscellaneous Fission Products										Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year	Median Sr-90 Bioassay Result (µCi/l)
	Sr	Cs	Pm	Co	Eu	Ce	Nb	Ru	MFP†	Combined In-Vitro Samples			
1972	0.69%	0.01%	0.01%	–	0.01%	0.01%	–	–	–	0.73%	0.012	1.63	7.63E-04
1973	0.82%	0.02%	–	–	0.09%	0.01%	–	–	–	0.92%	0.026	2.80	1.12E-06
1974	0.80%	–	0.01%	0.01%	0.05%	0.06%	0.01%	0.01%	–	0.86%	0.013	1.47	6.59E-07
1975	0.90%	0.18%	0.04%	–	0.01%	–	–	–	–	0.91%	0.013	1.47	NA
1976	0.25%	0.01%	0.09%	–	–	–	–	–	–	0.26%	0.005	1.91	5.11E-07
1977	0.66%	–	0.09%	–	–	–	–	–	–	0.68%	0.008	1.24	NA
1978	2.53%	0.01%	0.11%	–	0.01%	–	–	–	–	2.58%	0.034	1.32	4.85E-05
1979	4.08%	0.08%	0.08%	–	–	0.01%	–	–	0.01%	4.10%	0.057	1.40	NA
1980	4.04%	0.04%	0.02%	–	–	–	–	–	0.01%	4.05%	0.059	1.46	NA
1981	4.46%	0.11%	0.01%	0.13%	0.05%	0.01%	0.02%	0.01%	–	4.49%	0.074	1.64	2.27E-06
1982	3.22%	0.08%	–	0.07%	–	0.04%	0.03%	0.03%	0.20%	3.24%	0.051	1.58	8.02E-05
1983	2.65%	0.04%	–	0.04%	0.01%	0.01%	0.02%	0.01%	–	2.70%	0.035	1.30	1.50E-05
1984	4.37%	0.04%	–	0.01%	0.01%	0.01%	–	0.01%	–	4.37%	0.054	1.23	3.32E-07
1985	4.48%	0.01%	0.02%	–	–	0.01%	–	–	–	4.49%	0.052	1.16	2.13E-06
1986	4.80%	0.03%	–	0.01%	0.01%	0.01%	0.01%	0.01%	–	4.80%	0.056	1.16	6.13E-06
1987	5.22%	–	–	–	–	–	–	–	–	5.22%	0.058	1.11	2.30E-07
1988	7.40%	0.01%	–	–	–	–	–	–	–	7.40%	0.083	1.12	5.05E-07
1989	8.12%	–	–	–	–	–	–	–	–	8.12%	0.094	1.15	2.54E-08
1990	7.90%	–	–	–	–	–	–	–	–	7.90%	0.084	1.07	3.53E-07

† Designated as Mixed Fission Products
Dashes indicate no data could be identified for that year and sampling type
NA indicates data could be not analyzed for result magnitude

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Table A-17. Miscellaneous Fission Product In-Vivo Overview

Year	Percentage of Workers Monitored In Vivo for Miscellaneous Fission Products										Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year
	FP*	Sr	Eu	Sb	Ru	Fe	Zr	Ce	Nb	Combined In-Vivo Samples		
1972	0.14%	0.05%	0.01%	0.09%	0.14%	0.02%	0.19%	–	–	0.62%	0.007	1.12
1973	0.21%	14.08%	0.15%	0.21%	0.25%	0.14%	0.92%	0.07%	0.01%	14.92%	0.177	1.19
1974	–	18.23%	–	–	–	–	–	–	–	18.23%	0.201	1.10
1975	–	–	–	–	–	–	–	–	–	–	–	–
1976	–	–	–	–	–	–	–	–	–	–	–	–
1977	0.01%	–	0.01%	0.01%	0.01%	–	0.05%	–	–	0.09%	0.001	1.08
1978	0.01%	0.02%	0.01%	–	0.01%	0.01%	0.02%	–	0.02%	0.07%	0.001	1.67
1979	–	0.01%	0.01%	–	0.07%	–	0.08%	–	0.08%	0.10%	0.003	2.94
1980	–	–	0.01%	–	–	0.01%	0.06%	–	0.06%	0.09%	0.002	1.67
1981	–	0.02%	0.04%	–	–	–	–	–	–	0.06%	0.001	2.00
1982	–	0.01%	0.01%	–	–	0.01%	–	–	–	0.03%	0.000	1.50
1983	–	0.02%	0.02%	–	–	0.01%	0.01%	0.01%	–	0.06%	0.001	1.10
1984	–	–	0.02%	0.01%	–	–	–	–	–	0.03%	0.001	1.80
1985	–	–	0.08%	–	0.02%	–	–	0.04%	–	0.12%	0.002	2.00
1986	–	–	0.12%	0.02%	–	0.01%	–	0.21%	–	0.29%	0.005	1.78
1987	–	0.01%	0.19%	0.02%	–	–	–	0.08%	–	0.25%	0.006	2.43
1988	–	–	0.06%	–	0.02%	–	–	0.02%	–	0.10%	0.003	2.81
1989	–	–	0.02%	–	–	–	–	–	–	0.02%	0.001	2.75
1990	–	–	0.05%	0.02%	–	–	0.01%	0.01%	–	0.07%	0.001	1.67

* Designated as "Fission Products"
Dashes indicate no data could be identified for that year and sampling type

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Table A-18. Percentage of Workers Identified by Job Title Who Were Monitored for Fission Products by Year (1972–1981)

Rank	Description	Total Number of Workers	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	Radiation Monitors/ Technicians	417	3.23%	40.63%	31.71%	4.35%	5.77%	5.08%	16.46%	32.29%	27.50%	29.85%
2	Operators Plant/System/Utility	1003	8.99%	23.47%	26.27%	6.67%	0.00%	5.63%	18.35%	33.44%	33.52%	33.41%
3	Science Technicians	394	5.88%	18.52%	26.67%	5.97%	1.35%	3.66%	27.27%	33.66%	33.02%	37.19%
4	Pipefitters	364	5.00%	33.90%	29.41%	3.77%	0.00%	0.70%	9.88%	12.35%	17.44%	18.18%
5	Electricians	374	0.00%	20.83%	28.07%	1.23%	1.15%	3.92%	8.66%	10.26%	7.88%	8.24%
6	Handlers/Laborers/Helpers	200	0.00%	8.33%	0.00%	0.00%	0.00%	0.00%	2.50%	2.04%	3.85%	1.72%
7	Welders and Solderers	47	0.00%	0.00%	16.67%	0.00%	0.00%	0.00%	5.26%	4.35%	6.67%	8.33%
8	Misc Repair/Construction	476	0.00%	6.98%	10.17%	0.00%	0.00%	1.96%	2.14%	2.44%	3.95%	5.63%
9	Painters	88	0.00%	18.18%	15.38%	0.00%	0.00%	0.00%	3.03%	5.88%	0.00%	1.89%
10	Sheet Metal Workers	80	0.00%	12.50%	35.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.45%
11	Carpenters	101	0.00%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.38%
12	Health Physicists	59	0.00%	20.00%	14.29%	0.00%	0.00%	0.00%	13.33%	22.22%	15.00%	10.00%
13	Miners/Drillers	[redacted]	–	–	–	–	–	–	–	–	0.00%	0.00%
14	Equipment Operator	128	0.00%	5.26%	0.00%	5.26%	0.00%	0.00%	13.33%	9.76%	7.32%	10.64%
15	Misc Technicians	653	1.75%	13.33%	16.16%	1.80%	0.00%	1.23%	10.19%	10.04%	9.89%	8.78%
16	Mechanics/Repairers	324	3.45%	18.42%	19.23%	3.28%	0.00%	0.00%	5.04%	6.25%	7.62%	8.18%
17	Machinists	98	0.00%	9.52%	16.67%	0.00%	0.00%	0.00%	0.00%	3.85%	3.45%	3.03%
18	Truck Drivers	200	0.00%	4.76%	6.67%	0.00%	0.00%	0.00%	1.16%	2.94%	2.83%	0.88%
19	Technicians	446	2.67%	31.25%	59.57%	7.84%	7.21%	6.20%	6.21%	6.49%	2.35%	1.78%
20	Scientists	1535	0.00%	26.81%	33.14%	1.08%	1.18%	1.62%	3.19%	4.13%	3.12%	2.56%

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-18. Percentage of Workers Identified by Job Title Who Were Monitored for Fission Products by Year (1982–1990)

(continued)

Rank	Job Description	Total Number of Workers	1982	1983	1984	1985	1986	1987	1988	1989	1990	All SEC Years
1	Radiation Monitors/ Technicians	417	20.69%	16.11%	23.90%	27.43%	33.97%	30.20%	37.54%	46.18%	40.50%	**70.98%**
2	Operators Plant/ System/Utility	1003	25.65%	17.81%	26.29%	32.19%	32.36%	34.29%	32.29%	37.86%	34.03%	**63.31%**
3	Science Technicians	394	16.41%	17.47%	27.37%	29.03%	26.00%	35.04%	29.43%	27.08%	30.61%	**57.11%**
4	Pipefitters	364	10.64%	9.77%	12.02%	11.03%	12.50%	15.36%	25.67%	31.03%	30.28%	**56.59%**
5	Electricians	374	5.49%	7.02%	9.03%	11.71%	10.03%	13.23%	21.60%	33.22%	35.23%	**55.35%**
6	Handlers/Laborers/Helpers	200	0.00%	2.60%	1.35%	1.06%	1.79%	1.48%	30.34%	26.85%	38.30%	**55.00%**
7	Welders and Solderers	47	4.76%	2.38%	4.44%	8.70%	10.87%	10.87%	17.39%	14.29%	18.92%	**51.06%**
8	Misc Repair/Construction	476	3.39%	5.71%	8.80%	6.06%	8.25%	7.84%	31.23%	37.86%	32.36%	**50.21%**
9	Painters	88	3.70%	1.54%	1.49%	0.00%	3.75%	1.32%	26.32%	20.55%	31.34%	**47.73%**
10	Sheet Metal Workers	80	5.88%	4.44%	3.92%	7.69%	9.43%	0.00%	26.56%	21.15%	25.42%	**47.50%**
11	Carpenters	101	2.27%	0.00%	1.59%	0.00%	1.30%	1.11%	22.11%	27.85%	38.89%	**44.55%**
12	Health Physicists	59	9.09%	11.54%	9.09%	14.29%	15.91%	18.60%	25.00%	27.91%	20.83%	**42.37%**
13	Miners/Drillers	[redacted]	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	33.33%	33.33%	**40.00%**
14	Equipment Operator	128	7.14%	10.29%	11.94%	17.33%	14.81%	19.63%	25.00%	30.61%	30.10%	**39.84%**
15	Misc Technicians	653	4.23%	3.78%	7.69%	6.64%	7.05%	7.81%	13.42%	14.77%	12.48%	**24.50%**
16	Mechanics/Repairers	324	6.31%	3.86%	7.77%	5.86%	9.15%	5.79%	9.87%	8.65%	9.09%	**24.38%**
17	Machinists	98	1.30%	3.37%	3.37%	0.00%	1.08%	2.08%	0.00%	1.15%	3.80%	**22.45%**
18	Truck Drivers	200	0.00%	2.11%	1.24%	1.78%	2.94%	6.52%	6.32%	7.34%	11.24%	**20.50%**
19	Technicians	446	0.58%	2.01%	2.21%	2.34%	2.26%	1.83%	1.44%	2.59%	2.18%	**19.96%**
20	Scientists	1535	1.06%	1.19%	2.20%	1.40%	2.14%	2.37%	2.62%	3.98%	4.30%	**18.37%**

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Table A-18 shows the monitoring coverage by job category for the fission products presented in Tables A-16 and A-17.[8] Similar to other radionuclides analyzed, the job titles most likely to be monitored during their career were ‘radiation monitors,’ ‘operators,’ ‘pipefitters,’ ‘electricians,’ and ‘handlers/laborers.’

Table A-19 shows an overview of bioassay results for the top 20 job titles most likely to have been monitored for fission products during employment. As the table shows, the top two job titles (radiation monitors and operators) had the highest maximum values observed among the top 20 job titles.

Table A-20 shows the areas and periods of concern for fission products, which include the 200 and 300 Areas, as well as the 200 Area Tank Farms, as the primary locations for exposure potential. In addition, the 100 N Reactor Area is also a location of concern for fission products due to the reactor operations.

Table A-19. Overview of Strontium-90 In-Vitro Results (µCi/l) for the Job Titles Most Likely to be Monitored During Employment

Sr-90 In Vivo	Average	Median	Max	Greater Than All Worker Average	Greater than All Worker Median	Percent Monitored During Career	Number of Workers Identified
Radiation Monitors/ Technicians	7.71E-07	0.00E+00	2.56E-04			**70.98%**	417
Operators Plant/ System/Utility	3.41E-06	0.00E+00	5.23E-03			**63.31%**	1003
Science Technicians	0.00E+00	0.00E+00	0.00E+00			**57.11%**	394
Pipefitters	0.00E+00	0.00E+00	0.00E+00			**56.59%**	364
Electricians	3.63E-07	0.00E+00	2.25E-05			**55.35%**	374
Handlers/Laborers/Helpers	0.00E+00	0.00E+00	0.00E+00			**55.00%**	200
Welders and Solderers	3.34E-05	2.11E-05	2.90E-04	Y	Y	**51.06%**	47
Misc Repair/Construction	5.71E-07	0.00E+00	6.06E-05			**50.21%**	476
Painters	0.00E+00	0.00E+00	0.00E+00			**47.73%**	88
Sheet Metal Workers	0.00E+00	0.00E+00	0.00E+00			**47.50%**	80
Carpenters	1.18E-07	0.00E+00	2.85E-06			**44.55%**	101
Health Physicists	2.36E-05	0.00E+00	2.62E-04	Y		**42.37%**	59
Miners/Drillers	0.00E+00	0.00E+00	0.00E+00			**40.00%**	[redacted]
Equipment Operator	0.00E+00	0.00E+00	0.00E+00			**39.84%**	128
Misc Technicians	0.00E+00	0.00E+00	0.00E+00			**24.50%**	653
Mechanics/Repairers	0.00E+00	0.00E+00	0.00E+00			**24.38%**	324
Machinists	0.00E+00	0.00E+00	0.00E+00			**22.45%**	98
Truck Drivers	0.00E+00	0.00E+00	0.00E+00			**20.50%**	200
Technicians	4.28E-07	0.00E+00	1.28E-05			**19.96%**	446
Scientists	0.00E+00	0.00E+00	0.00E+00			**18.37%**	1535
All Workers	1.29E-05	0.00E+00					

[8] Refer to Attachment 1 for more information on how job title information was derived and interpreted from the REX database.

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Table A-20. Locations and Operational Periods of Potential Fission Product Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
100 N	N Reactor	1972–1987	Not Yet Established – See incident description	Accidental release of irradiated fuel elements in 1977 during a maintenance activity (Ref 26722).
200[9]	T Plant (221T)	1972–End of SEC	Not Yet Established	T Plant was mainly involved in decontamination activities during the SEC period.
	PUREX (A Plant, 202A)	1983–End of SEC	Yes – Mainly associated with contamination incidents	
	UO3 (224U, 224UA)	1984–End of SEC	Yes – Due to large quantities of uranium processed	17 reactor startups in SEC period (generally last 8 days – specific dates not currently known).
	225B Waste Encapsulation Facility	1974–End of SEC	Limited – Facility was remotely operated	
	222S	1972–End of SEC	Not Yet Established	
	209E, 222T	1972–1986	Not Yet Established	
	222B	1972–1975	Not Yet Established	
	242 Evaporator	1972–End of SEC	Not Yet Established	
	Z-9 Trench	1972–1978	Not Yet Established	
	241-Z	1972–1973	Not Yet Established	
	B Plant (221B)	1972–1983 (per TBD)	Limited – Remotely Operated	- B Plant was involved in strontium extraction. - Contamination incident was identified in 1974 when beta/gamma was discovered at numerous locations where an individual worked, including 221B (Ref 73668). - In the early 1980s, a concentrator tube failed, releasing MFP to the atmosphere (Ref 60801).
200 Tank Farms	Waste Tanks	1972–End of SEC	Limited – Respiratory protection used for most operations (see additional comments)	Contamination incident was identified in 1974 when beta/gamma was discovered at numerous locations where an individual worked, including the Tank Farms – no respiratory protection used (Ref 73668). Unplanned release incidents from 1972–1985 are described in Ref 60801, pp. 73–79.

[9] A list and brief description of unplanned releases of fission products is provided in Ref 60801, pp. 302–376.

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Table A-20. Locations and Operational Periods of Potential Fission Product Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
300	308, 320, 324, 325, 326, 329, 331	1972–End of SEC	Incidents Identified	Strontium intake incident in 1978 (Ref 67891, pg. 120) and again during a cleanup operation (Ref 67891, pg. 335). Spread of beta-gamma emitters in Bldg. 324 during load out operation in 1979; exposure levels were at 450 rad/hr (Ref 67867, pg. 105)
	318	1983–End of SEC	Not Yet Established	
	321	1972–1988	Not Yet Established	
	327	1972–1987	Not Yet Established	
	3730	1972–1981	Not Yet Established	
	3745	1972–1983	Not Yet Established	
	340 Waste Complex	1972–End of SEC	Not Yet Established	

Table A-21 shows the monitoring coverage by area for workers who could be identified with a specific location in the REX database. As shown, monitoring was concentrated on the 200 Area and specifically the 200 Area Tank Farms. Much of the fission product monitoring (in terms of the percentage of the workforce monitored) occurred in 1973 and 1974 before dropping off significantly for the 3 years following. The exception to this trend is the Tank Farms, which showed increased monitoring starting in 1978, compared to the prior period.

Table A-21. Miscellaneous Fission Product Location Data

Year	Percentage of Workers Monitored for Fission Products (In Vitro + In Vivo)							
	All Workers	100 Area	100N Area	200 Area	200 Tank Farms	300 Area	400 Area	700 Area
1972	1.30%	3.55%	***3.80%***	***3.49%***	***13.16%***	***0.71%***	1.33%	–
1973	15.50%	24.19%	***23.91%***	***15.72%***	***18.18%***	***26.48%***	12.72%	7.03%
1974	18.70%	31.48%	***32.75%***	***17.74%***	***24.07%***	***35.92%***	16.88%	7.67%
1975	0.91%	0.70%	***0.51%***	***2.99%***	***6.94%***	***1.68%***	0.34%	0.24%
1976	0.26%	0.21%	***0.23%***	***0.06%***	–	***1.28%***	–	0.21%
1977	0.77%	0.75%	***0.73%***	***2.57%***	***3.20%***	***1.26%***	0.62%	–
1978	2.62%	1.89%	***1.92%***	***11.41%***	***25.36%***	***2.04%***	1.24%	0.76%
1979	4.10%	4.08%	***3.79%***	***17.01%***	***51.50%***	***2.02%***	1.52%	0.54%
1980	4.10%	5.20%	***4.65%***	***15.79%***	***49.42%***	***1.68%***	0.75%	0.50%
1981	4.51%	5.53%	***5.22%***	***16.02%***	***46.50%***	***1.78%***	1.23%	0.35%
1982	3.23%	3.05%	***2.90%***	***10.19%***	***32.02%***	***1.11%***	1.19%	0.11%
1983	2.73%	1.70%	***1.32%***	***8.43%***	***30.15%***	***1.06%***	1.09%	0.18%
1984	4.39%	2.38%	***1.78%***	***13.40%***	***31.62%***	***1.59%***	1.94%	0.42%
1985	4.59%	4.06%	***3.32%***	***13.08%***	***36.96%***	***1.44%***	1.98%	0.31%
1986	4.99%	7.29%	***6.74%***	***12.78%***	***36.45%***	***2.30%***	2.37%	0.51%
1987	5.41%	6.50%	***5.86%***	***14.49%***	***38.49%***	***1.91%***	2.48%	0.37%

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Table A-21. Miscellaneous Fission Product Location Data

Year	Percentage of Workers Monitored for Fission Products (In Vitro + In Vivo)							
	All Workers	**100 Area**	**100N Area**	**200 Area**	**200 Tank Farms**	**300 Area**	**400 Area**	**700 Area**
1988	7.46%	12.58%	12.44%	***18.50%***	***39.81%***	***5.98%***	5.33%	2.25%
1989	8.14%	14.15%	14.13%	***19.84%***	***43.77%***	***5.73%***	4.61%	3.18%
1990	7.92%	13.66%	13.52%	***19.99%***	***38.32%***	***5.02%***	5.64%	2.39%
All Years:	13.57%	26.65%	26.42%	37.30%	81.60%	22.16%	14.50%	8.03%

Bold and italicized values indicate internal exposure potential, dashes (-) indicate 0.00%

Table A-22 shows the most common job title among monitored workers in the areas and periods of interest. Beginning in 1978, the monitored workers in the 200 Area and 200 Area Tank farms were most commonly 'operators.' As with other radionuclide classes analyzed, 'managers and administrators' was often the most common job title among monitored workers. The job category 'technicians' was also prominent during the early part of the SEC period for the 300 Area.

Table A-22. Most Commonly Monitored Job Title for Areas with Potential Fission Product Exposure

Year	200 Area			200 Area Tank Farms		
	# Monitored Workers Identified by Job Title	**Most Commonly Monitored Job Title**	**% Identified with Most Common Job Title**	**# Monitored Workers Identified by Job Title**	**Most Commonly Monitored Job Title**	**% Identified with Most Common Job Title**
1972	22	Mngr. and Admin	31.8%	[redacted]	Mngr. and Admin	40.0%
1973	120	TIE: Engineers, Mngr. and Admin	40.0%	[redacted]	Operators	42.9%
1974	155	Mngr. and Admin	31.0%	13	Mngr. and Admin	53.8%
1975	30	Mngr. and Admin	36.7%	[redacted]	Mngr. and Admin	60.0%
1976	[redacted]	Mngr. and Admin	100.0%	0	N/A	N/A
1977	43	Operators	30.2%	[redacted]	Electricians	25.0%
1978	218	Operators	22.0%	32	Operators	53.1%
1979	373	Operators	27.6%	79	Operators	55.7%
1980	390	Operators	29.0%	79	Operators	53.2%
1981	454	Operators	29.1%	86	Operators	55.8%
1982	314	Operators	38.5%	69	Operators	60.9%
1983	329	Operators	34.0%	79	Operators	64.6%
1984	577	Operators	30.7%	89	Operators	55.1%
1985	649	Operators	31.6%	110	Operators	60.0%
1986	678	Operators	30.2%	110	Operators	56.4%
1987	805	Operators	29.1%	119	Operators	55.5%
1988	1051	Operators	21.6%	125	Operators	49.6%
1989	1123	Operators	21.7%	137	Operators	48.9%
1990	1193	Operators	21.6%	123	Operators	41.5%

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Table A-22. Most Commonly Monitored Job Title for Areas with Potential Fission Product Exposure

Year	100-N Area			300 Area		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title
1972	[redacted]	Operators	50.0%	[redacted]	Technicians	66.7%
1973	74	Engineers	24.3%	230	Scientists	19.6%
1974	115	Mngr. and Admin	30.4%	359	Scientists	18.1%
1975	[redacted]	Mngr. and Admin	100.0%	21	Technicians	33.3%
1976	[redacted]	Mngr. and Admin	100.0%	20	Technicians	35.0%
1977	[redacted]	Electricians	33.3%	21	Technicians	33.3%
1978	19	Mngr. and Admin	15.8%	40	Technicians	22.5%
1979	39	Mngr. and Admin	25.6%	47	Technicians	19.1%
1980	53	Mngr. and Admin	24.5%	39	Mngr. and Admin	15.4%
1981	68	Mngr. and Admin	32.4%	45	Mngr. and Admin	15.6%
1982	32	Mngr. and Admin	31.3%	23	Rad Monitors	21.7%
1983	25	Mngr. and Admin	28.0%	31	Mngr. and Admin	25.8%
1984	40	TIE: Mngr. and Admin, Operators	17.5%	49	Rad Monitors	20.4%
1985	92	Operators	44.6%	48	Mngr. and Admin	25.0%
1986	187	Operators	34.8%	77	Rad Monitors	16.9%
1987	167	Operators	38.3%	70	Mngr. and Admin	14.3%
1988	No Exposure Potential Identified			221	Misc. Repair Construction	17.2%
1989				205	Misc. Repair Construction	23.4%
1990				185	Misc. Repair Construction	13.0%

A.6.4 Plutonium

Tables A-23 and A-24 present the plutonium in-vitro and in-vivo monitoring coverage by year. As seen in the two tables, plutonium monitoring was mainly by in-vitro methods for Pu-239, with a handful of years where this was replaced by a 'Pu Alpha' analysis (1981–1983). The percentage of the worker population monitored for plutonium varied from 7% to as high as 16%; however, it generally averaged around 10%. Monitored workers usually only submitted a sample once per year up until 1984, when the average samples per year jumped to just over two samples per year. As a reminder, this analysis of number of samples per worker does not distinguish between routine samples and those related to incidents.

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Table A-23. Plutonium In-Vitro Overview

Year	Percentage of Workers Monitored In Vitro for Plutonium					Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year
	Pu Alpha	Pu-238	Pu-239	Pu-241	Combined In-Vitro Samples		
1972	8.18%	0.01%	2.92%	–	10.85%	0.15	1.35
1973	–	0.01%	16.34%	–	16.34%	0.27	1.63
1974	–	0.02%	14.94%	–	14.94%	0.22	1.45
1975	–	0.03%	14.95%	–	14.96%	0.19	1.29
1976	–	–	14.41%	0.01%	14.41%	0.17	1.20
1977	–	0.01%	11.97%	–	11.98%	0.14	1.16
1978	–	0.02%	9.24%	–	9.26%	0.11	1.21
1979	–	0.01%	7.10%	–	7.11%	0.09	1.25
1980	0.06%	0.07%	9.59%	–	9.59%	0.13	1.32
1981	7.54%	0.02%	1.99%	–	9.25%	0.11	1.17
1982	8.43%	–	0.01%	–	8.43%	0.11	1.27
1983	6.27%	2.30%	2.55%	–	8.48%	0.12	1.41
1984	–	8.47%	8.47%	0.01%	8.47%	0.23	2.68
1985	–	8.98%	8.99%	0.01%	8.99%	0.22	2.42
1986	–	8.26%	8.27%	0.01%	8.27%	0.20	2.42
1987	–	8.62%	8.62%	–	8.62%	0.20	2.32
1988	–	11.40%	11.40%	–	11.40%	0.30	2.64
1989	–	12.36%	12.36%	0.01%	12.36%	0.33	2.67
1990	–	11.89%	11.89%	–	11.89%	0.28	2.34

Dashes (-) indicate that no data are available for that sampling type and year
NA indicates data could not be analyzed for magnitude

As seen in Table A-24, in-vivo monitoring for plutonium was only for a very small portion of the worker population. For most years, workers monitored for plutonium by in-vivo methods were only counted once or twice per year, with the exception of 1982, in which there was a single worker who was counted 59 times for Pu-238 during a 5-month period following an intake incident.

Table A-25 presents monitoring coverage by job category for those workers who could be identified by work category in the REX Database.[10] 'Radiation monitors,' 'operators,' and 'handlers/laborers/helpers' were the job categories most likely to be monitored for plutonium while employed during the SEC period.

[10] Refer to Attachment 1 for more information on how job title information was derived and interpreted from the REX database.

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Table A-24. Plutonium In-Vivo Overview

Year	Percentage of Workers Monitored In Vivo for Plutonium			Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year
	Pu-238	Pu-239	Combined In-Vivo Samples		
1972	–	0.13%	0.13%	0.003	2.09
1973	0.01%	0.08%	0.09%	0.001	1.25
1974	–	0.07%	0.07%	0.001	1.43
1975	–	0.03%	0.03%	0.000	1.00
1976	–	0.01%	0.01%	0.000	1.00
1977	–	0.02%	0.02%	0.000	1.00
1978	0.01%	0.04%	0.05%	0.000	1.00
1979	0.01%	0.06%	0.06%	0.001	1.40
1980	–	0.04%	0.04%	0.000	1.14
1981	0.01%	0.02%	0.02%	0.001	2.75
1982	0.01%	0.01%	0.02%	0.004	20.33
1983	0.01%	0.02%	0.02%	0.001	2.25
1984	–	0.09%	0.09%	0.002	2.40
1985	0.01%	0.05%	0.05%	0.001	1.33
1986	0.01%	0.14%	0.14%	0.003	1.92
1987	0.01%	0.02%	0.02%	0.000	1.25
1988	–	0.01%	0.01%	0.000	1.00
1989	–	0.01%	0.01%	0.000	1.00
1990	–	–	–	0.000	–

Dashes (-) indicate that no data are available for that sampling type and year

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Table A-25. Percentage of Workers Identified by Job Title Who Were Monitored for Plutonium by Year (1972–1981)

Rank	Description	Total Number of Workers	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	Radiation Monitors/ Technicians	417	48.39%	78.13%	70.73%	58.70%	59.62%	61.02%	58.23%	43.75%	50.83%	50.00%
2	Operators Plant/ System/Utility	1003	23.60%	33.67%	27.12%	32.67%	22.83%	27.27%	18.35%	21.36%	19.48%	23.13%
3	Handlers/Laborers/ Helpers	200	0.00%	0.00%	20.00%	40.00%	14.29%	10.34%	12.50%	2.04%	15.38%	6.90%
4	Pipefitters	364	18.33%	23.73%	16.47%	18.87%	29.90%	21.68%	22.84%	11.18%	16.28%	17.11%
5	Electricians	374	10.20%	37.50%	31.58%	30.86%	28.74%	17.65%	21.26%	8.33%	18.79%	25.88%
6	Science Technicians	394	33.33%	66.67%	75.00%	64.18%	60.81%	65.85%	32.95%	31.68%	25.47%	29.75%
7	Sheet Metal Workers	80	16.67%	25.00%	23.53%	16.67%	11.76%	9.09%	18.52%	8.33%	30.43%	9.68%
8	Carpenters	101	0.00%	33.33%	14.29%	14.29%	0.00%	0.00%	5.41%	0.00%	7.69%	7.14%
9	Welders and Solderers	47	33.33%	0.00%	50.00%	54.55%	33.33%	50.00%	10.53%	13.04%	10.00%	8.33%
10	Painters	88	6.25%	18.18%	15.38%	16.00%	11.11%	6.06%	3.03%	5.88%	7.32%	7.55%
11	Health Physicists	59	60.00%	40.00%	28.57%	30.00%	38.46%	14.29%	13.33%	27.78%	40.00%	20.00%
12	Misc Repair/Construction	476	2.63%	16.28%	8.47%	3.08%	11.27%	5.88%	4.29%	2.44%	1.32%	1.88%
13	Equipment Operator	128	5.88%	21.05%	5.00%	10.53%	9.52%	11.11%	3.33%	7.32%	4.88%	4.26%
14	Miners/Drillers	[redacted]	–	–	–	–	–	–	–	–	0.00%	0.00%
15	Machinists	98	13.64%	14.29%	10.00%	15.63%	8.57%	11.63%	4.00%	3.85%	0.00%	3.03%
16	Misc Technicians	653	19.30%	28.00%	19.19%	18.92%	19.42%	17.79%	14.56%	7.23%	23.08%	20.27%
17	Mechanics/Repairers	324	13.79%	23.68%	25.00%	22.95%	28.74%	18.26%	15.83%	6.25%	16.19%	14.09%
18	Truck Drivers	200	0.00%	9.52%	30.00%	15.38%	22.22%	20.00%	6.98%	0.00%	2.83%	5.31%
19	Engineering Technicians	622	33.78%	49.37%	38.89%	42.37%	36.57%	36.77%	32.14%	25.99%	32.81%	31.31%
20	Technicians	446	33.33%	43.75%	41.49%	42.16%	35.14%	31.01%	28.28%	22.08%	22.35%	20.71%

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-25. Percentage of Workers Identified by Job Title Who Were Monitored for Plutonium by Year (1982–1990)

(continued)

Rank	Description	Total Number of Workers	1982	1983	1984	1985	1986	1987	1988	1989	1990	All SEC Years
1	Radiation Monitors/ Technicians	417	35.17%	33.33%	33.17%	43.81%	34.35%	40.27%	49.85%	64.53%	56.20%	**78.18%**
2	Operators Plant/ System/Utility	1003	18.04%	22.60%	28.11%	29.04%	30.96%	34.17%	41.08%	42.01%	37.05%	**68.10%**
3	Handlers/Laborers/Helpers	200	10.53%	10.39%	5.41%	5.32%	7.14%	7.41%	37.93%	26.17%	48.23%	**66.50%**
4	Pipefitters	364	18.09%	19.53%	16.74%	18.15%	21.18%	18.77%	33.13%	46.98%	52.19%	**66.48%**
5	Electricians	374	19.78%	22.31%	15.28%	21.40%	22.65%	19.38%	31.66%	44.98%	50.67%	**65.24%**
6	Science Technicians	394	28.91%	36.14%	37.37%	36.41%	37.60%	41.24%	38.46%	37.54%	40.23%	**64.47%**
7	Sheet Metal Workers	80	14.71%	11.11%	9.80%	15.38%	13.21%	7.94%	37.50%	30.77%	49.15%	**63.75%**
8	Carpenters	101	6.82%	5.36%	1.59%	4.11%	7.79%	5.56%	37.89%	41.77%	51.39%	**60.40%**
9	Welders and Solderers	47	11.90%	14.29%	8.89%	17.39%	15.22%	17.39%	19.57%	26.19%	32.43%	**57.45%**
10	Painters	88	12.96%	7.69%	7.46%	6.67%	6.25%	7.89%	35.53%	34.25%	46.27%	**54.55%**
11	Health Physicists	59	9.09%	19.23%	18.18%	20.00%	11.36%	13.95%	18.75%	30.23%	16.67%	**52.54%**
12	Misc Repair/Construction	476	1.13%	0.95%	1.85%	4.55%	3.63%	7.00%	31.76%	39.81%	40.00%	**52.10%**
13	Equipment Operator	128	3.57%	8.82%	10.45%	13.33%	13.58%	15.89%	23.00%	26.53%	29.13%	**42.97%**
14	Miners/Drillers	[redacted]	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	40.00%	66.67%	33.33%	**40.00%**
15	Machinists	98	0.00%	1.12%	14.61%	18.68%	19.35%	15.63%	18.95%	14.94%	12.66%	**39.80%**
16	Misc Technicians	653	21.82%	20.06%	18.30%	18.14%	14.94%	15.43%	20.60%	19.96%	20.48%	**39.36%**
17	Mechanics/Repairers	324	14.86%	16.60%	14.84%	15.86%	17.29%	12.54%	17.20%	19.03%	17.83%	**37.35%**
18	Truck Drivers	200	7.38%	7.04%	7.45%	8.88%	7.06%	10.87%	10.53%	9.60%	14.20%	**32.50%**
19	Engineering Technicians	622	31.68%	30.53%	23.75%	24.63%	19.34%	18.90%	19.67%	16.63%	11.55%	**32.15%**
20	Technicians	446	23.12%	24.62%	20.35%	17.19%	15.81%	13.46%	10.63%	14.08%	13.08%	**31.17%**

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-26 shows the site areas and time periods that have the potential for internal plutonium exposure. These locations of interest include the 200 Area, 200 Tank Farms, 300 Area, and 400 Area.

Table A-27 shows the plutonium-monitoring coverage by area and by year for workers who could be identified with a specific area. In general, the areas and years with potential plutonium exposure had a larger percentage of the workforce monitored than those areas with lesser potential. One notable exception to this is the 400 Area in 1978, which had the highest percentage of the workforce monitored in that year (22.86%), though no known plutonium exposure potential has yet been identified with that area and year.

Table A-26. Locations and Operational Periods of Potential Plutonium Exposure

<table>
<tr><th>Area</th><th>Building</th><th>Period of Operation</th><th>Internal Exposure Potential</th><th>Additional Comments</th></tr>
<tr><td rowspan="6">200</td><td>231-Z</td><td>1972–1979[11]</td><td>Yes – Mainly associated with contamination incidents</td><td>- Part of the plutonium isolation facility.
- Documentation indicates a contamination incident in 1972 (Ref 67761), 5 in 1974 (Refs 67777, 68241, 68244, 68247 and 68134), 1 in 1975 (Ref 68132), 1976 (Ref 68251), 2 in 1977 (Ref 67848, pg. 8), 1978 (Ref 67867, p.95), 1979 (Ref 67867, pg. 208).</td></tr>
<tr><td>232-Z</td><td>1972–1973</td><td rowspan="3">Yes – Mainly associated with contamination incidents</td><td rowspan="3">- Part of the plutonium finishing facilities.
- Documents indicate the following number of employees sampled internally by year due to incidence [# identified→ # evaluated]: 1972 (50→), 1973 (36→18), 1974 (4→1), 1975 (5→2), 1976[12] (1→0).
- Chelation therapy documents indicate 2 intakes in 1986 (Ref 73182 and Ref 73185), and another in 1989 (Ref 73199).</td></tr>
<tr><td>2345-Z (RMA, RMC, Storage Vault)</td><td>1972–1984 (RMA)
1972–1989 (RMC)
1972–End of SEC (Storage)</td></tr>
<tr><td>236-Z, 242-Z</td><td>1972–1977, 1986,[13] 1989</td></tr>
<tr><td>T Plant (221T)</td><td>1972–End of SEC</td><td>Not Yet Established</td><td>T Plant was mainly involved in decontamination activities during the SEC period.</td></tr>
<tr><td>PUREX (A Plant, 202A)</td><td>1983–End of SEC</td><td>Yes – Mainly associated with contamination incidents</td><td>Ref 59165 lists contamination and other incidents for PUREX/UO_3 plant from 1972–1981.
Contamination incidents are described in Ref 4967, p. 48, for 1984, 1985, 1987, and 1988.
Other incidents documented through chelation therapy records are identified in 1986 (Ref 73188).</td></tr>
</table>

[11] Though the Hanford TBD indicates the 231-Z facility was closed down in 1977, incident reports were found indicating plutonium contamination incidents in 1978 and 1979.

[12] Only the first quarter radiation control report is available for 1976.

[13] Though the Hanford TBD indicates the 242-Z facility was closed in 1977, documentation indicates intake incidents in 1986 and 1989.

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Table A-26. Locations and Operational Periods of Potential Plutonium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
	UO3 (224U, 224UA)	1984–End of SEC	Yes – Due to large quantities of uranium processed	17 reactor startups in SEC period (generally last 8 days – specific dates not currently known).
	225B Waste Encapsulation Facility	1974–End of SEC	Limited – Facility was remotely operated.	
	222S	1972–End of SEC	Not Yet Established	
	209E, 222T	1972–1986	Not Yet Established	Abnormal Pu airborne concentrations reported in reactor room of 209E in 1978 (Ref 67891, pg. 149).
	222B	1972–1975	Not Yet Established	
	242 Evaporator	1972–End of SEC	Not Yet Established	
	Z-9 Trench	1972–1978	Not Yet Established	
	241-Z	1972–1973	Not Yet Established	
	B Plant (221B)	1972–1983 (per TBD)	Limited – Remotely Operated	Large-scale separations campaigns described in PUREX History document, but only to 1978, not 1983 per the TBD (Ref 14586, pg. 14).
200 Tank Farms	Waste Tanks	1972–End of SEC	Limited – Respiratory protection used	Unplanned release incidents from 1972–1985 are described in Ref 60801, pp. 73–79.
300	333	1972-1988	Yes	
	303 (A-G, J, K, M)	1972–1983 (A–G, J, K) 1984–1987 (M)	Yes	Incident in 1979, when a plutonium oxide storage container ruptured during a transfer at the 303-C storage facility.
	306	1972–1984	Yes	
	308, 320, 324, 325, 326, 329, 331	1972–End of SEC	Not Yet Established	Incident in Bldg. 325 (1982) when a [redacted] dislodged significant contamination with a putty knife and spread it around with brush. Additional contamination incidents in 1974 (Ref 68239), 1975 (Refs 68128, 68157, 68220), 1979 (Ref 67867, pp. 91 and 227). Three incidents in Bldg. 331 in 1974 (Refs 68135, 68137, and 68142), 1 in 1975 (Refs 68129/68160), 1976 (Ref 67773), 1977 (Ref 67848, pg. 187). Other incidents included a contaminated tool shed – internal potential not known (Ref 68223).
	318	1983–End of SEC	Not Yet Established	
	321	1972–1988	Not Yet Established	
	327	1972–1987	Not Yet Established	
	3730	1972–1981	Not Yet Established	
	3745	1972–1983	Not Yet Established	
	340 Waste Complex	1972–End of SEC	Not Yet Established	
	HTR	1972	Not Yet Established	
	TTR	1972–1978	Not Yet Established	
	PRCF	1972–1976	Not Yet Established	

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Table A-26. Locations and Operational Periods of Potential Plutonium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
400	FFTF	1980–End of SEC	Not Yet Established	

Table A-27. Plutonium-Monitoring Location Data

Year	Percentage of Workers Monitored for Plutonium (In Vitro + In Vivo)							
	All Workers	100 Area	100N Area	200 Area	200 Tank Farms	300 Area	400 Area	700 Area
1972	11.36%	7.45%	7.60%	***29.84%***	***36.84%***	***20.75%***	10.67%	4.78%
1973	16.73%	11.69%	10.95%	***42.41%***	***47.73%***	***30.21%***	21.97%	6.39%
1974	15.32%	11.11%	10.53%	***39.84%***	***38.89%***	***27.33%***	18.57%	5.03%
1975	15.39%	9.85%	9.18%	***36.91%***	***38.89%***	***28.49%***	16.21%	5.25%
1976	15.34%	10.89%	10.30%	***35.47%***	***46.88%***	***25.09%***	14.43%	4.79%
1977	12.17%	7.67%	7.14%	***30.71%***	***35.20%***	***21.73%***	15.23%	3.37%
1978	9.25%	8.53%	8.16%	***17.76%***	***13.77%***	***21.10%***	22.86%	2.13%
1979	6.97%	5.34%	4.89%	***18.36%***	***23.35%***	***13.35%***	10.23%	2.17%
1980	9.77%	8.03%	7.49%	***16.38%***	***21.51%***	***21.21%***	***28.99%***	3.10%
1981	8.93%	5.74%	5.33%	***16.26%***	***24.50%***	***19.75%***	***29.72%***	2.94%
1982	8.72%	3.27%	2.81%	***12.82%***	***18.86%***	***19.62%***	***32.11%***	1.44%
1983	9.44%	2.02%	1.51%	***14.58%***	***25.00%***	***18.88%***	***27.05%***	1.75%
1984	8.93%	2.89%	1.89%	***16.94%***	***26.12%***	***14.30%***	***20.14%***	1.41%
1985	10.16%	2.86%	1.71%	***17.84%***	***28.38%***	***15.38%***	***22.42%***	1.69%
1986	9.71%	2.99%	1.86%	***16.92%***	***29.03%***	***14.17%***	***18.60%***	0.81%
1987	10.39%	3.14%	2.04%	***18.67%***	***26.50%***	***12.89%***	***19.64%***	1.18%
1988	12.57%	14.28%	13.98%	***23.90%***	***27.39%***	***15.85%***	***19.90%***	2.80%
1989	13.25%	16.44%	16.13%	***25.76%***	***24.92%***	***17.11%***	***17.94%***	3.91%
1990	12.10%	18.41%	18.34%	***25.05%***	***19.31%***	***14.45%***	***15.54%***	3.32%
All Years:	22.65%	24.88%	24.38%	47.83%	69.14%	39.66%	54.06%	11.83%

Bold and italicized values indicate internal exposure potential

Table A-28 shows the most common job title among monitored workers who could be identified by position for each area and year of interest. ‘Operators’ were the most common job title monitored at the Tank Farms for each year of the SEC, while the remaining areas generally showed that ‘managers’ and ‘administrators’ were the most common job title of those monitored.

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Table A-28. Most Commonly Monitored Job Title for Areas with Potential Plutonium Exposure

Year	200 Area			200 Area Tank Farms		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title
1972	185	Mngr. and Admin	30.3%	14	Operators	50.0%
1973	315	Mngr. and Admin	29.2%	20	Operators	35.0%
1974	360	Mngr. and Admin	25.8%	20	Operators	45.0%
1975	376	Mngr. and Admin	26.3%	27	Operators	74.1%
1976	440	Mngr. and Admin	25.7%	42	Operators	42.9%
1977	493	Mngr. and Admin	27.6%	40	Operators	47.5%
1978	324	Mngr. and Admin	21.9%	18	Operators	38.9%
1979	392	Mngr. and Admin	27.0%	37	Operators	43.2%
1980	411	Mngr. and Admin	26.0%	36	Operators	44.4%
1981	467	Mngr. and Admin	24.4%	47	Operators	53.2%
1982	404	Mngr. and Admin	22.5%	42	Operators	50.0%
1983	588	Mngr. and Admin	22.1%	67	Operators	56.7%
1984	744	Operators	23.8%	75	Operators	61.3%
1985	887	Mngr. and Admin	22.4%	85	Operators	61.2%
1986	906	Operators	23.5%	90	Operators	61.1%
1987	1052	Operators	23.9%	84	Operators	65.5%
1988	1359	Operators	19.8%	86	Operators	54.7%
1989	1459	Operators	18.8%	78	Operators	48.7%
1990	1495	Operators	18.5%	62	Operators	27.4%

Year	300 Area			400 Area		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Highest Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Highest Job Title
1972	153	Scientists	22.9%	No Exposure Potential Identified		
1973	248	Scientists	16.9%			
1974	280	Mngr. and Admin	15.7%			
1975	334	Scientists	18.3%			
1976	338	Mngr. and Admin	18.0%			
1977	338	Mngr. and Admin	17.8%			
1978	382	Mngr. and Admin	15.2%			
1979	265	Mngr. and Admin	16.2%			
1980	451	Mngr. and Admin	15.3%	208	Mngr. and Admin	30.3%
1981	440	Mngr. and Admin	17.3%	226	Mngr. and Admin	30.1%
1982	460	Mngr. and Admin	14.8%	246	Mngr. and Admin	22.8%
1983	527	Mngr. and Admin	12.9%	239	Mngr. and Admin	19.2%
1984	428	Mngr. and Admin	11.9%	195	Mngr. and Admin	21.5%
1985	499	Mngr. and Admin	13.0%	235	Mngr. and Admin	24.7%
1986	499	Mngr. and Admin	12.6%	208	Mngr. and Admin	20.7%
1987	472	Mngr. and Admin	14.4%	232	Mngr. and Admin	21.1%
1988	586	Mngr. and Admin	9.7%	235	Mngr. and Admin	17.0%
1989	615	Rad. Monitor	10.4%	214	Mngr. and Admin	15.0%
1990	534	Rad. Monitor	9.9%	193	Mngr. and Admin	16.1%

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A.6.5 Uranium

Tables A-29 and A-30 show the monitoring coverage for uranium (in-vivo and in-vitro, respectively) by year for the entire worker population. In-vivo monitoring was almost exclusively uranium-235, with workers getting counted once per year. In general, uranium in-vivo results decreased from 1974 to the end of the SEC period; no data could be analyzed for results in 1972 and 1973, due to blank results or the lack of a listed MDA.

The in-vitro monitoring in Table A-29 is generally sparse and covered between 1%–2% of the worker population. Workers who were sampled in vitro for uranium generally submitted 1 sample per year until 1984, when they averaged 2–3 samples per year.

Table A-31 shows the monitoring coverage by job category for workers who could be identified by position in the REX database.[14] Similar to plutonium, 'radiation monitors,' 'operators,' 'electricians,' 'pipefitters,' and 'science technicians' were the job categories most likely to be monitored for uranium while employed during the SEC period.

Table A-32 presents an overview of the in-vivo uranium results for the top 20 job categories shown in Table A-31. As seen in Table A-32, there was not a lot of correlation between the likelihood of being monitored and the magnitude of results, though it is important to note that there was not a lot of variability between average and median values for the various job titles (i.e., they are all very close in magnitude).

Table A-33 shows the site areas and periods of interest for potential internal uranium exposure, which include the 100, 100N, 200, 300, and 400 Areas. There are several incidents identified in the 1970s, though none could be found in the 1980s.

[14] Refer to Attachment 1 for more information on how job title information was derived and interpreted from the REX database.

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Table A-29. Uranium In-Vivo Overview

Year	Percentage of Workers Monitored In Vivo for Uranium				Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year	Average U-235 In-Vivo Result (nCi)
	U-234	U-235	U-238	Combined In-Vivo Samples			
1972	–	0.49%	–	0.49%	0.0051	1.03	NA
1973	–	0.84%	–	0.84%	0.0086	1.03	NA
1974	–	5.74%	–	5.74%	0.0655	1.14	2.10E-01
1975	–	0.04%	–	0.04%	0.0004	1.00	6.50E-02
1976	–	5.90%	–	5.90%	0.0633	1.07	6.61E-02
1977	0.01%	5.65%	–	5.66%	0.0593	1.05	6.51E-02
1978	–	7.61%	–	7.61%	0.0842	1.11	6.26E-02
1979	–	8.40%	0.01%	8.40%	0.0936	1.11	6.24E-02
1980	–	9.15%	–	9.15%	0.0994	1.09	6.23E-02
1981	–	9.48%	0.01%	9.48%	0.1033	1.09	6.29E-02
1982	–	9.09%	0.01%	9.09%	0.0988	1.09	6.30E-02
1983	–	8.05%	0.01%	8.05%	0.0850	1.06	6.31E-02
1984	–	8.15%	–	8.15%	0.0887	1.09	5.42E-02
1985	–	8.29%	–	8.29%	0.0884	1.07	5.35E-02
1986	–	8.63%	–	8.63%	0.0931	1.08	5.74E-02
1987	–	8.25%	–	8.25%	0.0875	1.06	5.73E-02
1988	–	9.41%	–	9.41%	0.0999	1.06	5.80E-02
1989	–	11.36%	–	11.36%	0.1211	1.07	5.02E-02
1990	–	13.78%	–	13.78%	0.1578	1.15	4.03E-02

Dashes (-) indicate that no data are available for that sampling type and year
NA indicates data could not be analyzed for magnitude

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Table A-30. Uranium In-Vitro Overview

Year	Percentage of Workers Monitored In Vitro for Uranium							Average # Samples per Worker per Year	Average # Samples Per Monitored Worker per Year
	U-233	U-234	U-235	U-238	Elemental U	U Nat†	Combined In-Vitro Samples		
1972	–	–	–	–	0.58%	0.15%	0.72%	0.009	1.26
1973	–	–	–	–	–	0.69%	0.69%	0.007	1.05
1974	–	–	–	–	–	1.43%	1.43%	0.020	1.42
1975	–	–	–	–	0.18%	1.20%	1.20%	0.023	1.95
1976	–	–	–	–	0.62%	–	0.62%	0.010	1.53
1977	–	–	–	–	0.96%	0.01%	0.96%	0.011	1.19
1978	–	–	–	–	1.67%	–	1.67%	0.020	1.19
1979	–	–	0.01%	–	1.29%	–	1.29%	0.016	1.24
1980	–	–	–	–	1.41%	–	1.41%	0.016	1.10
1981	–	–	–	–	1.48%	–	1.48%	0.020	1.37
1982	–	–	0.01%	–	1.33%	–	1.33%	0.020	1.49
1983	–	–	–	–	1.09%	–	1.09%	0.011	1.03
1984	–	–	–	–	2.04%	–	2.04%	0.056	2.73
1985	0.02%	–	0.02%	0.02%	2.06%	–	2.09%	0.053	2.52
1986	0.05%	0.01%	0.05%	0.05%	1.47%	–	1.51%	0.045	3.00
1987	0.01%	–	0.01%	0.01%	1.73%	–	1.74%	0.047	2.71
1988	0.02%	–	0.02%	0.02%	1.37%	–	1.38%	0.040	2.91
1989	0.02%	–	0.02%	0.02%	1.48%	–	1.50%	0.046	3.10
1990	–	0.44%	0.44%	0.44%	1.35%	–	1.77%	0.054	3.06

† This urinalysis type is likely also an elemental uranium analysis as spectrometric uranium analyses were not introduced to the Hanford site until 1983.
Dashes (-) indicate that no data are available for that sampling type and year

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Table A-31. Percentage of Workers Identified by Job Title Who Were Monitored for Uranium by Year (1972–1981)

Rank	Description	Total Number of Workers	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	Misc Precision/Production	[redacted]	–	–	–	–	–	–	–	–	–	–
2	Radiation Monitors/ Technicians	417	0.00%	0.00%	19.51%	4.35%	26.92%	25.42%	53.16%	51.04%	57.50%	55.97%
3	Electricians	374	0.00%	4.17%	8.77%	0.00%	12.64%	14.71%	15.75%	19.23%	22.42%	24.71%
4	Operators Plant/System/Utility	1003	13.48%	4.08%	11.86%	2.67%	5.43%	7.36%	14.98%	16.10%	16.33%	13.08%
5	Pipefitters	364	0.00%	0.00%	4.71%	0.94%	7.22%	12.59%	17.28%	12.94%	16.86%	19.79%
6	Science Technicians	394	0.00%	0.00%	16.67%	0.00%	20.27%	15.85%	18.18%	27.72%	30.19%	34.71%
7	Sheet Metal Workers	80	0.00%	0.00%	5.88%	0.00%	0.00%	9.09%	7.41%	29.17%	17.39%	12.90%
8	Painters	88	0.00%	4.55%	0.00%	0.00%	7.41%	6.06%	3.03%	5.88%	12.20%	7.55%
9	Health Physicists	59	0.00%	0.00%	14.29%	0.00%	15.38%	7.14%	13.33%	33.33%	30.00%	30.00%
10	Equipment Operator	128	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.88%	0.00%	0.00%
11	Misc Repair/Construction	476	0.00%	0.00%	0.00%	0.00%	2.82%	0.98%	1.43%	2.44%	0.00%	5.00%
12	Carpenters	101	0.00%	0.00%	0.00%	0.00%	0.00%	3.85%	0.00%	0.00%	5.13%	4.76%
13	Welders And Solderers	47	0.00%	0.00%	0.00%	0.00%	16.67%	7.14%	10.53%	26.09%	6.67%	11.11%
14	Handlers/Laborers/Helpers	200	0.00%	0.00%	0.00%	0.00%	7.14%	6.90%	5.00%	6.12%	15.38%	13.79%
15	Miners/Drillers	[redacted]	–	–	–	–	–	–	–	–	0.00%	0.00%
16	Technicians	446	2.67%	6.25%	39.36%	13.73%	37.84%	31.01%	39.31%	33.77%	28.24%	30.18%
17	Masons	21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	50.00%
18	Misc Technicians	653	1.75%	0.00%	4.04%	0.90%	10.07%	8.59%	13.59%	13.25%	21.25%	21.96%
19	Machinists	98	0.00%	4.76%	3.33%	21.88%	22.86%	13.95%	16.00%	11.54%	15.52%	18.18%
20	Truck Drivers	200	0.00%	0.00%	0.00%	0.00%	0.00%	5.71%	2.33%	3.92%	3.77%	6.19%

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-31. Percentage of Workers Identified by Job Title Who Were Monitored for Uranium by Year (1982–1990)

(continued)

Rank	Description	Total Number of Workers	1982	1983	1984	1985	1986	1987	1988	1989	1990	All SEC Years
1	Misc Precision/ Production	[redacted]	–	–	–	–	–	–	–	–	100.00%	**100.00%**
2	Radiation Monitors/ Technicians	417	58.62%	40.00%	31.22%	34.96%	38.55%	38.93%	45.54%	67.28%	71.07%	**79.14%**
3	Electricians	374	21.98%	18.18%	15.28%	18.06%	19.74%	20.62%	31.66%	53.98%	69.80%	**70.59%**
4	Operators Plant/System/Utility	1003	14.63%	17.96%	27.27%	33.11%	39.75%	38.73%	39.04%	41.13%	46.34%	**66.10%**
5	Pipefitters	364	19.68%	18.60%	18.88%	19.22%	18.06%	18.43%	25.67%	50.86%	65.74%	**65.11%**
6	Science Technicians	394	17.97%	34.34%	35.26%	38.25%	34.80%	38.32%	35.79%	39.69%	48.10%	**64.47%**
7	Sheet Metal Workers	80	11.76%	8.89%	11.76%	15.38%	24.53%	7.94%	31.25%	36.54%	52.54%	**58.75%**
8	Painters	88	12.96%	6.15%	5.97%	9.33%	7.50%	7.89%	19.74%	28.77%	61.19%	**52.27%**
9	Health Physicists	59	27.27%	11.54%	9.09%	14.29%	9.09%	4.65%	10.42%	25.58%	31.25%	**49.15%**
10	Equipment Operator	128	7.14%	2.94%	2.99%	4.00%	8.64%	7.48%	10.00%	27.55%	52.43%	**48.44%**
11	Misc Repair/Construction	476	2.26%	1.43%	2.78%	3.03%	3.30%	2.80%	23.10%	30.74%	64.00%	**48.32%**
12	Carpenters	101	4.55%	5.36%	4.76%	4.11%	7.79%	5.56%	21.05%	26.58%	56.94%	**46.53%**
13	Welders and Solderers	47	11.90%	14.29%	11.11%	13.04%	13.04%	10.87%	13.04%	16.67%	45.95%	**44.68%**
14	Handlers/Laborers/ Helpers	200	12.28%	10.39%	10.81%	10.64%	6.25%	7.41%	22.76%	16.78%	39.01%	**40.00%**
15	Miners/Drillers	[redacted]	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	66.67%	66.67%	**40.00%**
16	Technicians	446	35.26%	30.15%	26.11%	29.69%	24.84%	22.32%	16.09%	19.25%	20.98%	**38.34%**
17	Masons	21	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	20.00%	40.00%	**38.10%**
18	Misc Technicians	653	22.48%	18.31%	18.57%	15.49%	16.39%	15.81%	17.77%	20.36%	25.70%	**37.67%**
19	Machinists	98	14.29%	12.36%	8.99%	10.99%	12.90%	12.50%	13.68%	12.64%	17.72%	**35.71%**
20	Truck Drivers	200	8.20%	6.34%	5.59%	7.10%	5.29%	6.52%	5.79%	11.30%	31.95%	**34.00%**

Dashes (-) indicate that no workers could be identified with that specific job category and year

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Table A-32. Overview of Uranium In Vivo (nCi) for the Job Titles Most Likely to be Monitored During Employment

U-235 In Vivo	Average	Median	Max	Greater Than All Worker Average	Greater than All Worker Median	Percent Monitored During Career	Number of Workers Identified
Misc Precision/Production	3.28E-02	3.28E-02	3.58E-02			**100.00%**	[redacted]
Radiation Monitors/Technicians	5.50E-02	5.50E-02	6.80E-01			**79.14%**	417
Electricians	5.61E-02	5.50E-02	4.37E-01			**70.59%**	374
Operators Plant/ System/Utility	5.32E-02	5.20E-02	2.80E-01			**66.10%**	1003
Pipefitters	5.66E-02	5.50E-02	2.80E-01			**65.11%**	364
Science Technicians	5.13E-02	5.00E-02	2.30E-01			**64.47%**	394
Sheet Metal Workers	5.51E-02	5.50E-02	1.35E-01			**58.75%**	80
Painters	5.18E-02	5.15E-02	1.02E-01			**52.27%**	88
Health Physicists	5.81E-02	5.50E-02	9.00E-02	Y		**49.15%**	59
Equipment Operator	4.99E-02	4.63E-02	1.40E-01			**48.44%**	128
Misc Repair/Construction	5.11E-02	4.69E-02	4.05E-01			**48.32%**	476
Carpenters	5.09E-02	4.92E-02	8.51E-02			**46.53%**	101
Welders and Solderers	6.21E-02	5.50E-02	2.88E-01	Y		**44.68%**	47
Handlers/Laborers/Helpers	5.43E-02	5.50E-02	1.23E-01			**40.00%**	200
Miners/Drillers	6.51E-02	3.60E-02	1.63E-01	Y		**40.00%**	[redacted]
Technicians	5.62E-02	5.50E-02	3.40E-01			**38.34%**	446
Masons	5.26E-02	5.50E-02	6.85E-02			**38.10%**	21
Misc Technicians	5.73E-02	5.50E-02	4.45E-01	Y		**37.67%**	653
Machinists	6.44E-02	6.00E-02	5.50E-01	Y	Y	**35.71%**	98
Truck Drivers	5.44E-02	5.50E-02	1.07E-01			**34.00%**	200
All Data	5.72E-02	5.50E-02					

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Table A-33. Locations and Operational Periods of Potential Uranium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
100	108-F	1972–1977	Not Yet Established	
100 N	N Reactor	1972–1987	Not Yet Established	Accidental release of irradiated fuel elements in 1977 during a maintenance activity (Ref 26722).
200	242-B	1978	See incident comments	Radiation occurrence involved spread of UO_2 in 1978 (Ref 67891, pg. 167).
	231-Z	1976–1977	See additional comments for contamination incidents	Contamination resulting from a faulty glovebox in 1976 (Ref 68261).
	232-Z	1972–1973	Yes – Mainly associated with contamination incidents	Part of the plutonium finishing facilities.
	2345-Z (RMA, RMC, Storage Vault)	1972–1984 (RMA) 1972–1989 (RMC) 1972–End of SEC (Storage)		
	236-Z, 242-Z	1972–1976		
	PUREX	1983–End of SEC	Not Yet Established	
	T Plant (221T)	1972–End of SEC	Not Yet Established	T Plant was mainly involved in decontamination activities during the SEC period.
	PUREX (A Plant, 202A)	1983–End of SEC	Yes – Mainly associated with contamination incidents	Ref 59165 lists contamination and other incidents for PUREX/UO_3 plant from 1972–1981.
	UO3 (224U, 224UA)	1984–End of SEC	Yes – Due to large quantities of uranium processed	17 reactor startups in SEC period (generally last 8 days – specific dates not currently known).
	225B Waste Encapsulation Facility	1974–End of SEC	Limited – Facility was remotely operated	
	222S	1972–End of SEC	Not Yet Established	
	209E, 222T	1972–1986	Not Yet Established	
	222B	1972–1975	Not Yet Established	

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Table A-33. Locations and Operational Periods of Potential Uranium Exposure

Area	Building	Period of Operation	Internal Exposure Potential	Additional Comments
300	314	1979	Incidents identified	Spread of uranium during unmonitored modification of 314 Building in 1979 (Ref 67867, pg. 105).
	3720	1974	Incidents identified	Documented incident in October 1974 involving uranium intakes from unprotected workers handling contaminated pipes (Ref 67775).
	333	1972–1988	Yes	
	303 (A-G, J, K, M)	1972–1983 (A-G, J, K) 1984–1987 (M)	Yes	
	306	1972-1984	Yes	Intake incidents in 1975 (Ref 68217); depleted uranium contamination incident [smears showed 0 cpm (Ref 68221)]; 2 depleted uranium fires in 1976 (Refs 68254, 68255); depleted puncture wound in 1979 (Ref 67867, pg. 215).
	308, 320, 324, 325, 326, 329, 331	1972–End of SEC	Not Yet Established	Alpha contamination incident in 1975 [nasal smears less than MDA (Ref 68220)]; inhalation incident in Bldg. 325 in 1978 (Ref 67891, pg. 167).
	318	1983–End of SEC	Not Yet Established	
	321	1972–1988	Not Yet Established	
	327	1972–1987	Not Yet Established	
	3730	1972–1981	Not Yet Established	
	3745	1972–1983	Not Yet Established	
	340 Waste Complex	1972–End of SEC	Not Yet Established	
	HTR	1972	Not Yet Established	
	TTR	1972–1978	Not Yet Established	
	PRCF	1972–1976	Not Yet Established	
400	FFTF	1980–End of SEC	Not Yet Established	

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Table A-34 shows the monitoring coverage by site area and year for workers who could be identified by their work location in the REX Database. The 300 Area was the location with the highest percentage of workers monitored up until 1980; the 400 Area had the highest percentage of monitored workers from 1980–1986, when the Tank Farm took over as the area with the highest percentage. The 100 and 100 N Reactor Area had relatively low numbers of workers monitored when compared to the other areas of potential exposure.

Table A-34. Uranium Monitoring Location Data

Year	Percentage of Workers Monitored for Uranium (In Vitro + In Vivo)							
	All Workers	100 Area	100N Area	200 Area	200 Tank Farms	300 Area	400 Area	700 Area
1972	0.66%	***0.71%***	***0.80%***	***1.79%***	13.16%	***1.93%***	0.67%	–
1973	0.89%	***1.30%***	***1.09%***	***0.53%***	–	***4.46%***	–	0.32%
1974	6.13%	***6.35%***	***5.99%***	***8.13%***	7.41%	***19.88%***	5.49%	1.06%
1975	1.32%	***1.16%***	***1.28%***	***1.11%***	1.39%	***4.29%***	–	0.48%
1976	6.14%	***4.40%***	***4.17%***	***6.75%***	3.13%	***20.14%***	5.67%	1.88%
1977	5.95%	***5.08%***	***5.12%***	***6.99%***	3.20%	***17.76%***	9.47%	1.24%
1978	7.83%	5.66%	***5.47%***	***10.96%***	12.32%	***21.40%***	18.04%	2.28%
1979	8.72%	6.59%	***5.99%***	***12.68%***	11.98%	***19.37%***	29.67%	0.95%
1980	9.66%	5.08%	***4.58%***	***12.69%***	13.95%	***22.97%***	***28.23%***	2.61%
1981	9.40%	6.10%	***5.44%***	***13.01%***	12.00%	***23.90%***	***30.95%***	2.00%
1982	9.44%	4.08%	***3.39%***	***10.63%***	14.04%	***25.51%***	***40.02%***	1.33%
1983	8.55%	3.22%	***2.32%***	***10.98%***	17.28%	***20.98%***	***28.60%***	1.38%
1984	9.60%	4.82%	***4.08%***	***12.33%***	17.87%	***21.74%***	***27.21%***	1.16%
1985	9.79%	5.46%	***4.59%***	***13.23%***	21.78%	***21.37%***	***22.94%***	1.61%
1986	10.15%	6.56%	***5.76%***	***15.06%***	27.74%	***19.74%***	***18.85%***	0.95%
1987	10.20%	5.15%	***4.37%***	***15.05%***	25.87%	***18.76%***	***19.14%***	1.11%
1988	10.63%	10.94%	10.46%	***18.75%***	24.84%	***17.80%***	***18.97%***	1.94%
1989	12.61%	15.35%	14.87%	***22.85%***	23.96%	***18.94%***	***17.27%***	1.95%
1990	15.69%	23.67%	23.62%	***30.12%***	32.09%	***20.72%***	***16.91%***	2.26%
All Years:	16.83%	23.30%	22.93%	39.01%	55.79%	42.92%	54.64%	6.87%

Bold and italicized values indicate internal exposure potential, dashes (-) indicate 0.00%

Table A-35 shows the most common job title among monitored workers for the areas of interest. The most common job title showed some significant variation by site area and year; however, 'managers and administrators,' 'scientists,' 'engineers' (in the early years), and 'operators' (in the later years) were often the most common.

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Table A-35. Most Commonly Monitored Job Title for Areas with Potential Uranium Exposure

Year	100 Area			100 N Area			200 Area		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title
1972	[redacted]	TIE: Mngr. and Admin, Misc Technicians	100.0%	[redacted]	TIE: Mngr. and Admin, Misc Technicians	100.0%	10	Operators	90.0%
1973	[redacted]	TIE: Engineers, Mngr. and Admin	66.7%	[redacted]	TIE: Admin/Clerk, Engineer, Electrician, Mngr. and Admin	100.0%	[redacted]	Engineers	60.0%
1974	26	Engineers	30.8%	23	Engineers	34.8%	56	Mngr. and Admin	23.2%
1975	[redacted]	Engineers	50.0%	[redacted]	Engineers	50.0%	13	Engineers	30.8%
1976	28	Engineers	14.3%	25	Engineers	16.0%	83	Mngr. and Admin	21.7%
1977	47	Engineers, Mngr. and Admin	38.2%	42	Mngr. and Admin	21.4%	106	Mngr. and Admin	22.6%
1978	No Exposure Potential Identified			51	Mngr. and Admin	25.5%	217	Mngr. and Admin	23.5%
1979				63	Mngr. and Admin	30.2%	286	Mngr. and Admin	21.0%
1980				55	Mngr. and Admin	29.1%	324	Mngr. and Admin	21.0%
1981				74	Mngr. and Admin	29.7%	381	Mngr. and Admin	21.8%
1982				53	Mngr. and Admin	17.0%	347	Mngr. and Admin	16.7%
1983				48	Mngr. and Admin	14.6%	448	Operators	21.9%
1984				98	Operators	41.8%	564	Operators	24.8%
1985				129	Operators	44.2%	676	Operators	27.2%
1986				167	Operators	41.9%	811	Operators	29.1%
1987				129	Operators	46.5%	850	Operators	29.3%
1988				No Exposure Potential Identified			1066	Operators	23.6%
1989							1293	Operators	21.0%
1990							1798	Operators	19.1%

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Table A-35. Most Commonly Monitored Job Title for Areas with Potential Plutonium Exposure

(continued)

Year	300 Area			400 Area		
	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title	# Monitored Workers Identified by Job Title	Most Commonly Monitored Job Title	% Identified with Most Common Job Title
1972	[redacted]	TIE: Operators, Technicians	50.0%	No Exposure Potential Identified		
1973	30	Scientists	20.0%			
1974	191	Scientists	19.4%			
1975	47	Technicians	23.4%			
1976	272	Scientists	17.3%			
1977	271	Scientists	14.8%			
1978	382	Scientists	13.9%			
1979	393	Scientists	17.0%			
1980	499	Scientists	15.0%	196	Mngr. and Admin	24.0%
1981	554	Scientists	13.7%	238	Mngr. and Admin	26.1%
1982	595	Mngr. and Admin	12.9%	301	Mngr. and Admin	24.3%
1983	570	Scientists	12.1%	236	Mngr. and Admin	19.9%
1984	626	Mngr. and Admin	11.8%	251	Mngr. and Admin	21.1%
1985	679	Operators	12.5%	231	Mngr. and Admin	24.7%
1986	669	Operators	13.6%	209	Mngr. and Admin	21.1%
1987	686	Operators	12.4%	225	Mngr. and Admin	23.1%
1988	658	Operators	11.2%	224	Mngr. and Admin	17.0%
1989	680	Rad Monitors	9.7%	206	Electricians	16.5%
1990	766	Electricians	9.0%	210	Electricians	13.8%

A.7 DISCUSSION OF ADDITIONAL RADIONUCLIDES

As mentioned in Section A-3, radionuclides were selected for the main analysis based on the amount of data available in the database. However, it is still important to examine the radionuclides with few records to determine why the samples were taken and what implications the samples have on exposure potential to the workforce as a whole. This section will examine the monitoring records for berkelium, californium, curium, iodine, neptunium, polonium, radium, thorium, and samples of 'total actinides.' Table A-36 presents an overview of the available monitoring records for these radionuclides.

As seen in Table A-36, berkelium and californium only had four records each for the same four individuals in March of 1974. Three of the four monitored workers had the same analysis result, although no units are provided. The fourth individual had results that were approximately three times higher than the other three workers. All four samples for each radionuclide were labeled as 'baseline samples.'

Curium had the highest number of samples among the group of radionuclides analyzed in this section (359 in-vitro samples, 1 in-vivo sample). Samples covered most years of the SEC period, with gaps from 1972–1973 and 1979–1980. On average, workers who were monitored for

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curium were sampled 4 times during their employment, though the majority of samples (~57%) were zero, negative, or less than the reported MDA. Eighty-eight percent (88%) of the samples taken were labeled as either a baseline or a periodic sample. Only about 8% of the samples were likely incident-driven (labeled as 'special'), and 4% of the samples were taken for other reasons (either a test sample, sample requested by a contractor, or a re-analysis of a previous sample). The Internal TBD notes that small amounts of curium were processed in the 308 Building at least through 1973. Documentation notes that there was a loss of containment resulting in potential Cm-244 inhalation on two separate occasions in 1978 [one in Building 231-Z and the other location was not reported (Ref 67891, pg. 120)]. This document also notes, a "series of inhalations of Curium-244 has begun at [Bldg.] 331 and is expected to continue for several weeks" (Ref 67891, pg. 336).

In-vivo counting constituted the majority of iodine sampling, and workers were generally counted multiple times during their career. The reasons specified for monitoring varied with less than 20% labeled as 'special' (likely incident samples). Sampling was performed throughout the SEC period, with the exception of 1974–1975. Less than half of the samples taken showed positive results, while the rest were below the limit of detection.

Only 21 samples were found for neptunium, the majority of which appear to be incident-related (62% were labeled as 'special' with only 10% of the samples labeled as 'periodic'). Eight (8) of 13 workers monitored for neptunium were only sampled once, though over 85% of the samples reported a positive result. Records indicate that the PUREX plant was involved in production and dispatching of neptunium in December of 1972 (Ref 68669), though the only samples from this time are from September of that year and are baseline samples. The PUREX plant was shut down at the start of 1973 until sometime in 1983.

Records identified for polonium consisted of 113 samples for 27 individuals (approximately 4.3 samples per monitored worker), with 77% of the samples taken as either a baseline or periodic sample. Almost 95% of the samples reported a positive result for polonium. Monitoring records for polonium stop in 1983.

Monitoring for radium was very scarce (only 23 samples), but appears to be almost entirely incident-driven, with no samples labeled as a baseline; only 17% of samples were periodic, while 70% of the samples were 'special.' All 15 bioassay samples reported positive results, while none of the in-vivo records have a positive result recorded. The majority of samples were taken from 1972–1973 (87%). Records indicate a contamination incident involving two workers in August of 1972 (Ref 67760); this incident is reflected in the monitoring records, with both in-vitro and in-vivo samples taken within a few days of suspected intake.

Similar to radium, there were very few monitoring results for thorium isotopes other than Th-234. Only 35 monitoring results were identified for Th-228 and Th-232, most of which were in-vivo samples. Approximately one-third of the samples yielded positive results and generally workers were only sampled once during their employment. Thorium monitoring does not appear to be incident related (only 3% were designated as 'special' samples), and nearly 40% were labeled as 'periodic' or 'baseline' samples. Many of the remaining samples were labeled as

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‘contractor requested,’ which may reflect limited-scale thorium operations that may have occurred.

Finally, records labeled as ‘total actinides’ comprised 205 records, of which over 97% reported a positive value. Sampling for ‘total actinides’ is mostly periodic and baseline sampling, with only 3% being reported as a ‘special sampling.’ Almost 90% of the sampling occurred between 1980 and 1983.

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Table A-36. Overview of Radionuclides with Infrequent Monitoring Records

Analysis Category	Berkelium	Californium	Curium	Iodine	Neptunium	Polonium	Radium	Thorium-232 related	Total Actinides
Overview of Monitoring Records									
# of In Vitro Records	4	4	359	21	16	113	15	2	205
# of In Vivo Records	0	0	1	263	5	0	8	33	0
Total Records	4	4	360	284	21	113	23	35	205
Years with Monitoring Data	1974	1974	1974–1978, 1981, 1983–1990	1972–1973, 1976–1990	1972, 1981, 1983–1984, 1986–1987, 1989	1972, 1974–1980, 1983	1972–1974, 1982	1972–1973, 1977, 1979, 1981,1983, 1985–1986	1974–1976, 1978–1983
Monitoring Frequency and Sampling Results									
Unique Individuals Monitored	[redacted]	[redacted]	90	134	13	27	12	33	96
Average Samples per Monitored Worker	1	1	4.0	2.12	1.8	4.3	2.1	1.16	2.2
Number of Positive Results	4	4	157	139	18	107	15	12	199
Number of Negative, Zero, or <MDA Results	0	0	203	145	3	6	8	23	6
Rationale for Sampling (% of Total Records)									
Baseline Sampling	100%	100%	12%	30%	19%	12%	0%	17%	2%
Periodic Sampling	0%	0%	76%	11%	10%	65%	17%	20%	83%
Special Sampling	0%	0%	8%	18%	62%	20%	70%	3%	3%
Other Reasons	0%	0%	4%	8%	0%	2%	13%	43%	11%
No Reason Specified	0%	0%	1%	33%	10%	2%	0%	17%	0%

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ATTACHMENT 1: DESCRIPTION OF JOB-SPECIFIC ANALYSIS

Job title designations are available in two of the main database tables in the Hanford REX Database; these tables are entitled 'REX_WORK_HIST' and "DOS_SUM_RESULTS,' respectively, the most useful of which was the table 'REX_WORK_HIST,' which also provides the employment period information for workers in the REX database and occasionally provided job title information via an 'occupation code.' NIOSH provides a companion document to the REX Database entitled, 'REX Data Dictionary Final.doc,' which provides a key to convert the occupation codes to actual job titles. Forty-four (44) distinct job titles and associated codes are identified in the NIOSH document; however, over 3,000 additional occupation codes were found in the database, that were not able to be decoded.

A summary of the 44 distinct job titles that could be decoded is shown in Table A1-1, which includes the number of workers identified for each job title[15] and year. As shown in the table, the practice of entering a worker's job title into the database increased in the later years of the SEC period. In many cases, a worker would have multiple employment period entries in the database, but not every employment period had the occupation code entered (in general, the later employment period was more likely to have the occupation designated than the earlier employment period). The totals presented in Table A1-1 reflect the assumption that if a worker had a job type specified at any point during their SEC employment, that job title applies to all SEC employment periods.

The other REX database table that had the occupation code designated, entitled 'DOS_SUM_RESULTS,' contains external monitoring data for the Hanford workers. The occupation code was identified for only a small fraction of the database entries, and was significantly skewed towards the later years of the SEC period. Of the 984,722 entries in the database, approximately half (471,415) applied to the SEC period (July 1, 1972–December 31, 1990). Of the entries that applied to the SEC period, only 18,143 (or ~4%) had the job title designated and 99.95% of these job title designations were in 1989 or after. The practice of entering the occupation code in this database also appears to coincide with the practice of designating the employee's work location (work location data are further described in Attachment 2).

[15] Table 1 only contains 39 job titles as 5 of the 44 job titles were not found in the 'REX_WORK_HIST' database – these job titles include: Food Service Employees, Forest Workers, Groundskeepers, Misc Agriculture, and Pilots

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Table A1-1. Summary of the Number of Workers Identified by Job Title and Year

Job Title Description	All Years	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Managers and Administrators	4965	808	926	1124	1267	1474	1764	2094	2326	2584	2781	2893	3293	3548	3848	4018	4168	4190	4034	4187
Admin Support and Clerical	3517	276	326	418	480	564	681	852	957	1072	1155	1210	1380	1524	1802	2038	2358	2511	2650	2926
Engineers	2343	322	367	464	517	630	759	882	972	1058	1117	1138	1298	1423	1619	1743	1845	1873	1812	1930
Scientists	1535	257	276	341	371	424	495	564	629	705	743	752	840	910	1002	1121	1224	1259	1230	1327
Misc Professionals	1205	252	281	328	354	402	459	510	549	596	636	653	743	804	874	967	1029	1047	985	1005
Operators Plant/ System/Utility	1003	89	98	118	150	184	231	267	323	349	428	499	668	715	761	785	834	830	795	861
Miscellaneous	953	38	43	46	46	56	64	77	72	73	84	92	97	111	125	149	191	248	497	803
Misc Technicians	653	57	75	99	111	139	163	206	249	273	296	307	344	377	452	482	525	529	501	537
Engineering Technicians	622	74	79	108	118	134	155	168	177	192	198	202	226	240	268	305	344	361	457	502
Security Guards	531	56	63	72	84	97	114	147	165	181	200	196	242	274	356	403	450	462	440	477
Misc Repair/ Construction	476	38	43	59	65	71	102	140	164	152	160	177	210	216	264	303	357	381	309	275
Technicians	446	75	80	94	102	111	129	145	154	170	169	173	199	226	256	310	327	348	348	367
Radiation Monitors/ Technicians	417	31	32	41	46	52	59	79	96	120	134	145	180	205	226	262	298	325	327	363
Science Technicians	394	51	54	60	67	74	82	88	101	106	121	128	166	190	217	250	274	299	325	343
Electricians	374	49	48	57	81	87	102	127	156	165	170	182	242	288	299	309	325	338	289	298
Pipefitters	364	60	59	85	106	97	143	162	170	172	187	188	215	233	281	288	293	335	232	251
Mechanics/Repairers	324	29	38	52	61	87	115	139	192	210	220	222	259	283	290	295	311	314	289	286
Janitors	204	[redacted]	[redacted]	13	15	23	33	52	60	70	86	93	108	124	136	152	161	163	151	164
Handlers/Laborers/ Helpers	200	10	12	10	15	14	29	40	49	52	58	57	77	74	94	112	135	145	149	141
Truck Drivers	200	16	21	30	39	45	70	86	102	106	113	122	142	161	169	170	184	190	177	169
Misc Service	199	36	39	42	49	60	72	84	102	115	122	128	145	156	163	170	173	184	180	171
Equipment Operator	128	17	19	20	19	21	27	30	41	41	47	56	68	67	75	81	107	100	98	103
Firefighters	104	11	13	15	21	30	36	38	39	44	58	59	63	69	71	78	85	88	89	92
Carpenters	101	[redacted]	[redacted]	14	14	21	26	37	38	39	42	44	56	63	73	77	90	95	79	72
Machinists	98	22	21	30	32	35	43	50	52	58	66	77	89	89	91	93	96	95	87	79

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Table A1-1. Summary of the Number of Workers Identified by Job Title and Year

Job Title Description	All Years	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Painters	88	16	22	26	25	27	33	33	34	41	53	54	65	67	75	80	76	76	73	67
Sheet Metal Workers	80	18	16	17	18	17	22	27	24	23	31	34	45	51	52	53	63	64	52	59
Bus Drivers	78	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	13	16	20	29	33	38	48	53	58	64	71	71	68	71
Health Physicists	59	[[redacted]]	[[redacted]]	[[redacted]]	10	13	14	15	18	20	20	22	26	33	35	44	43	48	43	48
Doctors and Nurses	56	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	10	13	16	16	21	23	26	32	38	38	39	46	46
Welders and Solderers	47	[[redacted]]	[[redacted]]	[[redacted]]	11	12	14	19	23	30	36	42	42	45	46	46	46	46	42	37
Machine Setup/Operators	32	10	11	13	14	15	18	20	20	17	19	22	26	26	27	28	28	28	28	27
Miscellaneous Transport	28	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	12	21	24	25	26	27	26	25	22
Masons	21	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	10	10	15	10	10
Health Technicians	11	0	0	0	0	0	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	11
Miners/Drillers	[[redacted]]	0	0	0	0	0	0	0	0	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]
Misc Precision/ Production	[[redacted]]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[[redacted]]
Military	[[redacted]]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[[redacted]]
Sales	[[redacted]]	0	0	0	0	0	0	0	0	0	[[redacted]]	[[redacted]]	0	[[redacted]]	[[redacted]]	[[redacted]]	[[redacted]]	0	[[redacted]]	0

[[redacted]] = Redacted information

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As stated previously, the job title analysis is predicated on the assumption that when a worker was identified with a particular job title, they held that job title throughout their employment at Hanford during the SEC period. Certainly, there are situations where this assumption does not accurately reflect the reality of that worker's employment. Two main examples of this are:

(1) A worker only held the identified job title for a fraction of their employment; however, since other employment periods did not have a job title designated, the identified job title was erroneously applied to the entire employment.

(2) A worker was identified with multiple job titles, so their internal monitoring records are being applied and analyzed for multiple occupations.

The effect of the first case is hard to quantify. Clearly, the effect of extending any identified job title designations to all of a given worker's employment periods will increase the pool of workers available for analysis in each year and job category. One way to analyze the effects of this assumption is to look at the increase in 'worker-years' in each job category, compared to if the assumption was not made; the results of this are shown in Table A1-2. For example, if we uphold the assumption that an individual worker held their same job title for all years of employment during the SEC period, the number of 'worker-years' available for analysis for the 'sales' job category increases 600%. One possible explanation is that the 'sales' job category was not routinely entered into the database until the later years of the SEC period.

Table A1-2. Percent Increase in Worker-Years from Expansion of the Dataset Summed over All Years by Job Category

Job Category	% Increase in Worker-Years	Job Category	% Increase in Worker-Years
Sales	600.00%	Masons	140.54%
Machine Setup/Operators	285.44%	Machinists	138.61%
Misc Repair/Construction	208.50%	Engineering Technicians	137.22%
Welders and Solderers	208.43%	Health Physicists	135.68%
Painters	207.17%	Carpenters	123.13%
Miscellaneous Transport	205.95%	Radiation Monitors/Technicians	108.49%
Pipefitters	200.17%	Science Technicians	98.15%
Engineers	199.60%	Janitors	95.89%
Firefighters	195.56%	Mechanics/Repairers	88.56%
Truck Drivers	189.71%	Miners/Drillers	86.67%
Handlers/Laborers/Helpers	185.43%	Admin Support And Clerical	74.21%
Operators Plant/System/Utility	184.97%	Miscellaneous	73.13%
Equipment Operator	184.11%	Health Technicians	62.22%
Misc Service	179.46%	Misc Professionals	55.81%
Security Guards	172.78%	Technicians	34.67%
Sheet Metal Workers	163.85%	Scientists	33.44%
Misc Technicians	162.36%	Doctors and Nurses	6.52%
Electricians	159.30%	Military	0.00%
Bus Drivers	150.18%	Misc Precision/Production	0.00%
Mngr. and Admin.	145.67%		

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Table A1-3 presents similar data; however, here the analysis looks to see the effect in the number of workers by year for all occupations analyzed. For example, by making the assumption that workers held the same job title throughout their employment resulted in a 404.58% increase in the number of workers available for analysis in 1972. As expected, this effect becomes less pronounced in the later years of the SEC period, as the entering of job title information into the REX database became more commonplace. By 1990, the stated assumption only results in a 6.53% increase in workers available for analysis.

Table A1-3. Percent Increase in Worker-Years from Expansion of the Dataset Summed over All Job Categories by Year

Year	% Increase in Worker-Years
1972	404.58%
1973	383.18%
1974	398.17%
1975	363.34%
1976	379.26%
1977	401.73%
1978	411.92%
1979	405.87%
1980	393.56%
1981	397.77%
1982	381.87%
1983	392.77%
1984	371.19%
1985	358.21%
1986	325.48%
1987	11.94%
1988	6.87%
1989	5.72%
1990	6.53%

Clearly, the effect of expanding the dataset to all employment periods has a significant impact on the majority of job categories, and had a particularly large impact in the earlier years. Therefore, if employment periods for a worker with no job designation do not reflect that worker's occupation in later employment periods, the results of the analysis could have significant bias. However, the reverse could also be true; a worker might have had that same job category their entire career, but parts of that employment would have been ignored if it was not entered as such into the REX Database.

The second instance of concern, where a worker has multiple job titles designated in the REX database, would seemingly bias the results towards those workers who held more than one occupation and had it entered as such in the database. These workers would be accounted for multiple times, and their internal monitoring would be reflected for each job category that they held. To assess the possible impact of this, the worker population was examined to determine how many workers had multiple job titles entered into the database. It was found that the

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maximum number of job titles that any one worker had specified in the REX database was four. Table A1-4 shows the breakdown of the worker population by number of job titles.

Table A1-4. Breakdown of Worker Population by Employees with Multiple Job Titles Specified

Number of Job Titles Designated for an Individual Worker	Percentage of Worker Population *(Total Worker Population of 20,546)*
4	0.01%
3	0.25%
2	5.90%
1	93.84%

As Table A1-4 shows, almost 94% of the worker population had only one job title specified in the REX Database, and only about 0.26% of the workers had 3 or more job titles. Therefore, it does not appear as though the workers holding multiple job titles will have an overly significant impact on the results based on the given assumptions.

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ATTACHMENT 2: DESCRIPTION OF AREA-SPECIFIC ANALYSIS

Location data for Hanford workers can be obtained from the six files in the REX database; characteristics and descriptions of these six files are contained in Table A2-1. The two sources in each file for location data were columns labeled as 'Building (BLDG)' and 'AREA.' The use of the area codes was much less prevalent than the building codes in the REX database, and in almost all cases, the use of an area code was accompanied by a subsequent building code. Therefore, the main task in determining worker location was to identify which building codes were associated with specific areas.

From inspection of the 6 data files described in Table A2-1, over 4,500 different building codes were identified. However, this total includes many codes that are very similar to one another; for instance the codes 'TANKFARM', 'TANK FARM', and 'TNKFRM' all count separately to this total. Several sources were consulted to interpret and convert these building codes to the areas of interest. These sources include two reference data files in the REX databasE- REX_BLDG_FAC_XREF and REX_HAN_FACILITY, as well as the site description portion of the Hanford Technical Basis Document. The six data files themselves could also be used to develop a key when both the building and area were specified in a given entry. In the absence of a specific reference for a building code, reasonable assumptions were made to determine the area where possible. For instance, a building designated as '109N' was assumed to be located in the 100 Area and associated with the N Reactor. Despite these efforts, there are still close to 700 building codes that could not currently be identified with a specific area of the site.

As noted here and elsewhere in the report, an important limitation of the location-specific data is that it is not time period-specific; it is only known that a given worker had evidence of working in a specific location at some point during the SEC period. As an example, if a worker had evidence of working in Area 100, he/she would be included in the 'Area 100' subset of workers for each year he/she was employed at Hanford during the SEC period, whether or not he/she was actually working the entire time in Area 100. Table A2-2 shows how many workers fall into each of the location-specific categories by year, as well as how many total workers were on site in any given year.

The number of workers present at Hanford in any given year was derived from the REX Database file 'REX_WORKER_HIST.SAS.' In-vitro data was obtained from the file 'EXC_RESULT.SAS.' An effort was made to remove irrelevant in-vitro data entries from the database prior to the analysis; for example, entries in which there were no results because the sample was lost. Entries were removed if they were labeled with as 'Employee did not sample,' 'Employee Lost Kit/Can,' 'Insufficient Volume,' 'Lost in Lab/Lost,' 'Cancelled, or other similar labels, which indicated that the entry did not indicate a valid monitoring result. However, database entries were not removed simply if the results were blank; they were only removed if there was an associated label, such as those described previously. In-vivo data were obtained from the two interrelated files 'INV_RESULT.SAS' and 'INV_ISO_RESULT.SAS,' respectively.

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Table A2-1. Description of REX Database Files Containing Location Data

REX Database File Name	# of Total Entries	# of SEC Entries Specifying Location	Description and Comments
DOSE_SUM_ RESULT	984,722	16,440	Contains external dose data, including shallow, deep, neutron, eye, ring, and x-ray doses. The database also specifies the worker's occupation, building, site area and facility type. Facility type refers to the general activities of the worker's building (i.e., weapon production, fuel fabrication, research). The building and area inputs were used to determine work locations; however, only 8 of the 16,440 entries which specified location in the SEC period were prior to 1989.
DOSE_ MASTER	68,088	0	Contains similar information as DOSE_SUM_RESULT; however, the earliest dates of the data file begin in 1999.
INCIDENT	2,530	643	Contains an incident number, worker identifier, incident type code, date, building, area, dose received and any comments. The incident type code and dose received are blank in all entries; comments are only provided for 47 of the 2,530 entries. The distribution of incident dates with the location specified is fairly even throughout the SEC period.
INV_RESULT	282,852	86,248	Contains in-vivo data for workers and includes the following information: worker identifier, date of exam, height/weight, portion of body measured, detector system, count duration, reason for exam, calibration data, in-vivo type, worker building/area, and any comments. Entries with location data specified begin in 1982 and are evenly distributed through the end of the SEC period.
INT_MASTER	3,289	22	Contains internal radionuclide intake data that include, but are not limited to, worker identifier, dates of evaluation and intake, radionuclides considered, and worker's building/area, as well as information related to the reason for the evaluation and any medical dose reduction that was undertaken. Actual values for the intake are not provided. The dates of the 22 entries which specify location are skewed more towards the 1980s, as shown in Figure 5.
ALT_LOC	7,057	2,225	This table is used to identify subcontractor and 'Hanford enterprise company' employees. It contains general information such as a worker identifier, home address, as well as the building and area worked. Unfortunately, this data file does not contain any specific dates so it is impossible to match the building/area designation with the SEC period. Therefore, this database file is of little value to the completeness study.

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Table A2-2. Number of Workers Identified by REX ID in the SEC Period

Year	All Workers	Number of Workers Identified for Each Site Location						
		100 Area	100N Area	200 Area	200 Tank Farms	300 Area	400 Area	700 Area
1972	8494	564	500	1059	38	983	150	272
1973	9051	616	548	1139	44	1099	173	313
1974	10740	756	684	1353	54	1328	237	378
1975	11374	863	784	1536	72	1492	290	419
1976	12164	955	864	1793	96	1718	388	480
1977	14751	1200	1093	2260	125	1988	486	563
1978	16063	1430	1299	2674	138	2299	643	657
1979	16626	1593	1452	3045	167	2524	792	737
1980	16281	1693	1549	3389	172	2730	928	806
1981	16161	1918	1764	3813	200	2916	979	851
1982	15220	2233	2067	4141	228	3069	1012	905
1983	16657	2825	2584	4945	272	3389	1098	1084
1984	16949	2944	2698	5335	291	3532	1132	1203
1985	17826	3498	3223	5774	303	3687	1164	1304
1986	18200	3445	3176	5922	310	3825	1183	1365
1987	18318	3340	3090	6020	317	3816	1212	1356
1988	16542	2934	2725	5686	314	3697	1181	1287
1989	16016	2488	2300	5664	313	3595	1193	1382
1990	16920	2379	2197	5972	321	3702	1242	1504
All Years:	**48549**	**4983**	**4610**	**8287**	**337**	**5186**	**1552**	**1893**

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ATTACHMENT 3: MAGNITUDE OF BIOASSAY RESULTS BY YEAR FOR ALL WORKER TYPES IDENTIFIED

Attachment 3 displays the full results of the magnitude analysis, which characterizes the magnitude of bioassay results for the various types of monitoring by year and job titles analyzed in this report. For most radionuclides analyzed, the median value is given, because this value will be less influenced by outliers and be a more accurate indicator of a given job title's exposure potential. However, in some situations, such as where the majority of samples are designated as below a given MDA, the median is not appropriate, because it shows little variation between the different job categories. In situations where the median shows little to no variability, the average value will be used.

It is important to remember that while all types of bioassay samples can be used in determining the frequency of monitoring, only bioassay samples that can be matched by specific analyte and analysis type can be used when determining the magnitude of bioassay samples. For example, uranium bioassay can be found in a number of forms, both in vivo and in vitro (for example, the in-vitro records contain entries for U-233, U-234, U-235, U-236, U-238, UNAT, Depleted U, Isotopic U, and U Mix). In most cases when this was encountered, a dominant sampling type (sampling type with the most results) was identified and used in this analysis. In cases where the dominant sample type was less clear, multiple sampling types may be presented to give a clearer picture of the exposure potential of different job types. The sample types that were analyzed in this effort are shown in Table A3-1. Table A3-1 also indicates which tables in this attachment contain the desired data.

Table A3-1. Listing of Sample Types Analyzed and Location of Results

Radionuclide	Monitoring Type	Sample Designation	Result Type	Table #
Americium	In Vitro – Urinalysis	Am-241	Median	A3-2
Americium	In Vitro – Fecal	Am-241	Median	A3-3
Cesium	In Vivo	Cs-137	Average	A3-4
Sodium	In Vivo	Na-24	Average	A3-5
Zinc	In Vivo	Zn-65	Average	A3-6
Uranium	In Vivo	U-235	Average	A3-7
Strontium	In Vitro – Urinalysis	Sr-90	Median	A3-8

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Table A3-2. Median Americium In-Vitro Results by Year (Am-241 by Urinalysis in units of µCi/l)

Job Type	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	–	–	–	–	0.00E+00	–	–	–	–	–
Doctors and Nurses	–	–	–	–	0.00E+00	–	–	–	–	–
Electricians	–	–	–	–	–	–	–	–	–	–
Engineering Technicians	–	–	–	–	–	–	0.00E+00	–	–	–
Engineers	–	–	–	–	0.00E+00	–	–	–	–	–
Handlers/Laborers/Helpers	–	–	–	–	–	–	–	–	–	–
Health Physicists	–	–	–	–	0.00E+00	–	–	–	–	–
Janitors	–	–	6.67E-08	–	–	–	–	–	–	0.00E+00
Managers and Administrators	–	–	9.55E-08	–	0.00E+00	–	0.00E+00	–	0.00E+00	0.00E+00
Mechanics/Repairers	–	–	–	–	–	–	–	–	–	–
Misc Professionals	0.00E+00	0.00E+00	–	–	0.00E+00	–	0.00E+00	–	3.33E-07	0.00E+00
Misc Repair/Construction	–	–	–	–	–	–	–	–	–	–
Misc Technicians	–	–	–	–	–	–	–	–	–	0.00E+00
Miscellaneous	–	–	–	–	0.00E+00	–	–	–	–	–
Operators Plant/System/Utility	0.00E+00	0.00E+00	2.11E-07	–	3.93E-07	–	0.00E+00	–	9.57E-06	0.00E+00
Painters	–	–	–	–	–	–	–	–	–	–
Pipefitters	–	–	–	–	–	–	–	–	–	–
Radiation Monitors/Technicians	–	–	–	–	1.87E-06	–	–	–	4.05E-05	0.00E+00
Science Technicians	–	–	–	–	5.66E-06	–	–	–	6.11E-05	0.00E+00
Scientists	–	0.00E+00	3.71E-07	–	1.41E-05	–	0.00E+00	–	–	–
Security Guards	–	–	-	–	1.98E-05	–	-	–	–	–
Technicians	–	0.00E+00	4.30E-07	–	3.98E-05	–	0.00E+00	–	–	–
Unknown	3.00E-05	0.00E+00	1.20E-06	–	1.92E+00	–	6.76E-03	–	2.05E-04	3.37E-07

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Table A3-2. Median Americium In-Vitro Results by Year (Am-241 by Urinalysis in units of µCi/l)

(continued)

Job Type	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	–	0.00E+00	–	0.00E+00	–	0.00E+00	–	–	–
Engineers	–	–	–	–	–	–	–	–	–
Janitors	–	0.00E+00	0.00E+00	0.00E+00	0.00E+00	–	–	–	–
Managers and Administrators	–	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	–	0.00E+00
Mechanics/Repairers	–	–	–	–	–	–	–	0.00E+00	–
Misc Professionals	–	0.00E+00	–	–	–	–	–	–	–
Misc Repair/Construction	–	–	–	–	–	–	–	–	–
Misc Technicians	–	–	–	0.00E+00	–	–	–	–	–
Operators Plant/System/Utility	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Painters	–	–	0.00E+00	–	0.00E+00	0.00E+00	–	–	–
Pipefitters	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Radiation Monitors/Technicians	–	–	–	–	0.00E+00	–	0.00E+00	-	–
Science Technicians	–	–	–	–	0.00E+00	–	–	–	–
Scientists	–	–	–	–	0.00E+00	–	–	–	–
Security Guards	0.00E+00	1.29E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-08	0.00E+00
Sheet Metal Workers	–	–	–	–	–	–	8.50E-09	–	–
Technicians	–	–	–	3.49E-05	0.00E+00	–	–	–	–
Unknown	0.00E+00	1.62E-08	0.00E+00	5.39E-05	0.00E+00	0.00E+00	1.13E-08	1.79E-08	0.00E+00
Admin Support and Clerical	5.32E-07	–	0.00E+00	7.78E-05	0.00E+00	0.00E+00	1.66E-08	2.08E-08	0.00E+00
Engineers	–	2.55E-08	0.00E+00	2.59E-04	0.00E+00	0.00E+00	–	–	5.77E-09
Janitors	7.74E-06	–	–	–	–	1.24E-08	–	–	–
Managers And Administrators	–	–	0.00E+00	2.87E-03	4.29E-08	3.76E-08	3.12E-08	1.29E-06	2.00E-08
Mechanics/Repairers	3.62E-05	8.01E-07	0.00E+00	3.44E-02	8.33E-05	6.28E-06	–	–	–

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Table A3-3. Median Americium In-Vitro Results by Year (Am-241 by Fecal Analysis in units of µCi/g)

Job Type	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	–	1.19E-10	–	–	–	–	–	–	–	–
Engineers	–	1.44E-10	–	–	–	–	–	–	–	–
Janitors	–	–	0.00E+00	–	–	–	–	–	–	–
Managers and Administrators	–	–	0.00E+00	–	0.00E+00	–	–	–	0.00E+00	–
Mechanics/Repairers	–	–	–	–	–	–	–	–	–	–
Misc Professionals	–	–	–	–	–	–	–	–	7.97E-08	0.00E+00
Misc Repair/Construction	–	–	–	–	–	–	–	–	–	–
Misc Technicians	–	–	–	–	–	–	–	–	–	1.11E-06
Operators Plant/System/Utility	–	2.09E-10	–	–	1.19E-07	–	–	–	2.05E-06	–
Painters	–	2.76E-10	–	–	–	–	–	–	–	–
Pipefitters	–	–	–	–	–	–	–	–	–	–
Radiation Monitors/Technicians	–	–	–	–	–	–	–	–	5.04E-06	–
Science Technicians	–	–	–	–	1.02E-06	–	–	–	–	–
Scientists	–	5.66E-10	–	–	–	–	–	–	–	–
Security Guards	–	–	0.00E+00	–	1.11E-05	–	–	–	–	–
Sheet Metal Workers	–	–	–	–	–	–	–	–	–	–
Technicians	–	–	0.00E+00	–	–	–	–	–	–	–
Unknown	1.67E-07	2.09E-07	5.63E-09	–	9.71E-05	–	–	–	–	–

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Table A3–3. Median Americium In–Vitro Results by Year (Am–241 by Fecal Analysis in units of μCi/g)

(continued)

Job Type	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	–	–	–	–	–	–	–	–	–
Engineers	–	–	3.71E-09	–	–	–	–	–	–
Janitors	–	–	–	–	–	–	–	–	–
Managers and Administrators	–	–	1.57E-08	–	0.00E+00	–	–	–	–
Mechanics/Repairers	–	–	–	–	0.00E+00	0.00E+00	–	–	–
Misc Professionals	0.00E+00	–	–	–	–	–	–	–	–
Misc Repair/Construction	–	–	–	2.31E-09	0.00E+00	–	–	–	–
Misc Technicians	–	–	–	–	1.47E-09	–	–	–	–
Operators Plant/System/Utility	0.00E+00	1.49E-06	8.77E-08	4.26E-08	4.07E-09	–	0.00E+00	–	–
Painters	–	–	–	–	–	–	–	–	–
Pipefitters	–	–	–	8.22E-08	4.65E-08	–	–	–	–
Radiation Monitors/Technicians	0.00E+00	–	–	–	–	–	–	–	–
Science Technicians	6.50E-08	–	–	–	–	–	–	–	–
Scientists	–	–	–	–	–	–	–	–	–
Security Guards	3.73E-07	–	–	–	–	0.00E+00	–	–	–
Sheet Metal Workers	–	–	–	2.53E-07	–	–	–	–	–
Technicians	–	–	–	4.75E-07	1.45E-07	–	–	–	–
Unknown	8.39E-06	–	1.03E-06	1.04E-06	4.94E-07	–	–	–	–

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Table A3–4. Average Cesium In–Vivo Results by Year (Cs–137 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	1.7E+00	1.9E+00	1.2E+00	–	1.7E+00	1.4E+00	1.4E+00	1.2E+00	1.1E+00	6.3E-01
Bus Drivers	3.5E+00	2.4E+01	1.9E+00	–	1.1E+00	–	1.8E-01	9.1E-01	7.5E-01	2.3E+00
Carpenters	–	1.5E+00	–	–	1.0E+00	1.0E+00	9.9E-01	1.7E+00	9.4E-01	7.0E-01
Doctors and Nurses	–	2.2E+00	–	–	3.7E+00	–	1.4E+00	–	1.1E+00	3.3E-01
Electricians	2.7E+00	2.5E+00	1.7E+00	–	1.4E+00	2.8E+00	1.1E+00	1.3E+00	1.5E+00	8.2E-01
Engineering Technicians	3.5E+00	2.2E+00	1.3E+00	–	1.4E+00	1.7E+00	1.2E+00	1.3E+00	1.1E+00	8.0E-01
Engineers	4.3E+01	7.5E+00	1.6E+00	–	1.3E+00	1.3E+00	1.2E+00	1.3E+00	1.2E+00	7.6E-01
Equipment Operator	3.7E+00	–	–	–	–	1.9E+00	1.5E+00	1.2E+00	1.4E+00	1.5E+00
Firefighters	–	–	2.3E+00	–	–	2.1E+00	7.7E-01	1.7E+00	1.1E+00	6.0E-01
Handlers/Laborers/Helpers	–	1.2E+00	–	–	1.8E+00	7.5E-01	8.5E-01	1.2E+00	7.4E+00	8.0E-01
Health Physicists	–	–	2.3E+00	–	1.3E+00	1.1E+00	1.2E+00	1.6E+00	1.1E+00	8.9E-01
Health Technicians	–	–	–	–	–	–	3.3E-01	–	3.3E-01	2.0E+00
Janitors	–	2.1E+00	5.3E-01	–	1.5E+00	1.1E+00	7.4E-01	8.9E-01	6.7E-01	5.7E-01
Machine Setup/Operators	2.1E+00	1.7E+00	3.3E-01	–	–	3.3E-01	3.3E-01	–	–	6.4E-01
Machinists	2.8E+00	2.0E+00	1.5E+00	–	1.7E+00	1.4E+00	1.2E+00	1.3E+00	1.0E+00	7.7E-01
Managers and Administrators	2.9E+00	2.5E+00	1.8E+00	–	2.1E+00	2.0E+00	1.5E+00	1.3E+00	4.8E+00	1.6E+00
Masons	–	–	–	–	–	3.7E+00	3.3E-01	1.1E+00	3.3E-01	3.3E-01
Mechanics/Repairers	3.8E+00	2.4E+00	1.8E+00	–	1.2E+00	2.1E+00	1.0E+00	1.2E+00	1.1E+00	7.8E-01
Miners/Drillers	–	–	–	–	–	–	–	–	–	–
Misc Precision/Production	–	–	–	–	–	–	–	–	–	–
Misc Professionals	3.3E+00	2.3E+00	1.5E+00	3.3E-01	1.6E+00	1.4E+00	9.3E-01	1.2E+00	1.1E+00	6.7E-01
Misc Repair/Construction	5.3E+00	2.4E+00	1.5E+00	–	2.0E+00	3.2E+00	2.4E+00	1.5E+00	3.8E+00	9.9E-01
Misc Service	1.7E+00	1.4E+00	1.4E+00	–	6.2E-01	1.4E+00	1.9E+00	1.4E+00	1.3E+00	8.1E-01
Misc Technicians	2.8E+00	2.1E+00	1.4E+00	–	1.5E+00	1.5E+00	1.2E+00	1.0E+00	1.1E+00	6.0E-01
Miscellaneous	4.4E+00	2.4E+00	1.6E+00	–	1.7E+00	1.8E+00	3.6E+00	1.4E+00	1.2E+00	9.6E-01
Miscellaneous Transport	–	–	–	–	1.8E+00	–	–	–	3.3E-01	3.3E-01
Operators Plant/System/Utility	2.7E+00	2.2E+00	3.6E+00	–	2.0E+00	3.1E+00	1.4E+00	2.6E+00	1.6E+00	9.1E-01
Painters	3.3E+00	2.3E+00	1.4E+00	–	1.1E+00	2.7E+00	1.5E+00	1.9E+00	1.1E+00	8.5E-01
Pipefitters	4.8E+00	4.5E+00	2.7E+00	–	1.3E+00	2.0E+00	9.9E-01	1.3E+00	1.7E+00	7.4E-01

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Table A3–4. Average Cesium In–Vivo Results by Year (Cs–137 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Radiation Monitors/Technicians	1.5E+01	1.3E+01	1.4E+00	–	1.1E+00	1.7E+00	1.2E+00	9.9E-01	1.0E+00	6.0E-01
Sales	–	–	–	–	–	–	–	–	–	–
Science Technicians	2.3E+00	2.3E+00	2.6E+00	–	7.9E-01	1.7E+00	1.2E+00	1.5E+00	2.3E+00	7.6E-01
Scientists	2.5E+00	2.9E+01	1.5E+00	–	1.5E+00	1.9E+00	1.2E+00	1.4E+00	1.3E+00	8.4E-01
Security Guards	4.3E+00	1.9E+00	1.1E+00	–	1.4E+00	1.9E+00	1.1E+00	1.5E+00	1.3E+00	7.4E-01
Sheet Metal Workers	3.5E+00	2.7E+00	1.6E+00	–	1.9E+00	1.5E+00	7.4E-01	1.0E+00	1.0E+00	6.7E-01
Technicians	2.2E+00	2.4E+00	1.3E+00	–	1.6E+00	1.4E+00	1.2E+00	1.4E+00	1.1E+00	1.1E+00
Truck Drivers	–	3.0E+00	1.1E+00	–	1.5E+00	1.4E+00	1.1E+00	1.4E+00	1.2E+00	6.2E-01
Unknown	4.6E+00	2.7E+00	2.1E+00	3.3E-01	1.8E+00	1.9E+00	2.3E+00	1.5E+00	1.5E+00	9.2E-01
Welders and Solderers	–	–	1.6E+00	–	1.4E+00	2.4E+00	1.2E+00	1.1E+00	1.5E+00	7.2E-01

Table A3–4. Average Cesium In–Vivo Results by Year (Cs–137 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	5.4E-01	5.7E-01	3.9E-01	4.6E+00	1.1E+00	1.6E+00	1.5E+00	1.5E+00	1.5E+00
Bus Drivers	3.3E-01	3.8E-01	–	–	1.0E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Carpenters	1.7E+00	8.9E-01	2.7E+00	–	1.3E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Doctors and Nurses	3.3E-01	3.3E-01	–	–	–	1.5E+00	1.6E+00	1.5E+00	1.5E+00
Electricians	7.8E-01	6.8E-01	1.8E+00	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Engineering Technicians	6.1E-01	6.3E-01	1.7E+00	8.1E+00	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Engineers	7.3E-01	5.9E-01	2.2E+00	–	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Equipment Operator	7.3E-01	6.3E-01	3.3E-01	–	1.3E+00	1.5E+00	1.7E+00	1.5E+00	1.5E+00
Firefighters	7.5E-01	6.4E-01	–	–	1.5E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Handlers/Laborers/Helpers	4.9E-01	6.4E-01	3.3E-01	–	1.1E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Health Physicists	8.1E-01	7.0E-01	–	–	1.1E+00	1.7E+00	1.5E+00	1.7E+00	1.5E+00
Health Technicians	3.3E-01	3.3E-01	–	–	–	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Janitors	4.9E-01	5.9E-01	3.3E-01	–	1.1E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00

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Table A3–4. Average Cesium In–Vivo Results by Year (Cs–137 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Machine Setup/Operators	3.3E-01	3.3E-01	9.2E-01	–	5.8E-01	1.5E+00	–	1.5E+00	–
Machinists	8.6E-01	6.2E-01	4.5E+00	–	1.4E+00	1.6E+00	1.5E+00	1.5E+00	1.5E+00
Managers and Administrators	6.7E-01	6.0E-01	1.5E+00	1.6E+00	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Masons	7.2E-01	5.4E-01	–	–	1.5E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Mechanics/Repairers	7.2E-01	6.8E-01	5.6E-01	5.7E-01	1.6E+00	1.6E+00	1.5E+00	1.5E+00	1.5E+00
Miners/Drillers	3.3E-01	–	–	–	–	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Misc Precision/Production	–	–	–	–	–	–	–	–	1.5E+00
Misc Professionals	6.7E-01	5.7E-01	2.1E+00	1.1E+00	1.3E+00	1.7E+00	1.5E+00	1.5E+00	1.5E+00
Misc Repair/Construction	6.7E-01	5.3E-01	1.1E+00	6.2E-01	1.2E+00	1.6E+00	1.6E+00	1.5E+00	1.6E+00
Misc Service	5.3E-01	4.6E-01	–	–	1.4E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Misc Technicians	6.3E-01	5.7E-01	5.2E-01	3.3E-01	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Miscellaneous	5.6E-01	4.7E-01	–	–	1.1E+00	1.5E+00	1.6E+00	1.5E+00	1.5E+00
Miscellaneous Transport	2.0E+00	6.8E-01	–	–	1.4E+00	1.5E+00	1.5E+00	1.5E+00	1.4E+00
Operators Plant/System/Utility	1.2E+00	6.4E-01	8.0E-01	3.6E+00	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Painters	6.1E-01	5.0E-01	3.3E-01	–	9.4E-01	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Pipefitters	7.6E-01	7.7E-01	3.7E+00	3.3E-01	1.1E+00	1.6E+00	1.5E+00	1.5E+00	1.5E+00
Radiation Monitors/Technicians	9.5E-01	1.6E+00	1.1E+00	–	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Sales	–	–	–	–	–	–	–	1.5E+00	–
Science Technicians	6.9E-01	5.5E-01	2.4E+00	4.2E-01	1.2E+00	1.5E+00	1.6E+00	1.5E+00	1.5E+00
Scientists	7.4E-01	5.5E-01	3.4E+00	7.7E-01	1.3E+00	1.9E+00	1.5E+00	1.5E+00	1.5E+00
Security Guards	6.3E-01	5.4E-01	3.9E+00	–	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Sheet Metal Workers	4.4E-01	8.8E-01	6.7E-01	–	8.4E+00	1.5E+00	1.5E+00	4.6E+00	1.6E+00
Technicians	7.6E-01	8.6E-01	3.2E+00	3.3E-01	1.4E+00	1.8E+00	1.6E+00	1.5E+00	2.1E+00
Truck Drivers	7.2E-01	5.7E-01	3.3E-01	–	1.1E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Unknown	8.9E-01	6.2E-01	1.0E+00	2.2E+00	1.4E+00	1.5E+00	1.5E+00	1.5E+00	1.5E+00
Welders And Solderers	6.7E-01	4.6E-01	3.3E-01	3.3E-01	1.2E+00	1.5E+00	1.5E+00	1.5E+00	1.6E+00

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Table A3–5. Average Sodium In–Vivo Results by Year (Na–24 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	3.9E-01	3.6E-01	2.0E-01	1.9E-01	2.9E-01	2.2E-01	2.2E-01	2.2E-01	2.2E-01	1.9E-01
Bus Drivers	1.6E-01	1.6E-01	1.6E-01	–	1.6E-01	–	1.6E-01	1.6E-01	1.6E-01	2.1E-01
Carpenters	–	1.6E-01	–	1.6E-01	2.9E-01	1.6E-01	1.7E-01	1.6E-01	2.0E-01	2.2E-01
Doctors and Nurses	–	5.4E-01	–	–	1.6E-01	–	1.6E-01	–	1.6E-01	1.6E-01
Electricians	1.6E-01	3.1E-01	1.9E-01	2.5E-01	2.0E-01	2.6E-01	2.2E-01	2.1E-01	2.0E-01	1.9E-01
Engineering Technicians	4.0E-01	3.4E-01	1.9E-01	1.7E-01	2.1E-01	2.6E-01	2.3E-01	2.3E-01	1.8E-01	2.1E-01
Engineers	3.0E-01	8.8E+00	2.1E-01	2.1E-01	3.0E-01	2.4E-01	2.3E-01	2.3E-01	2.0E-01	2.1E-01
Equipment Operator	2.4E-01	–	–	–	–	1.8E-01	2.6E-01	1.8E-01	1.6E-01	1.7E-01
Firefighters	–	–	1.6E-01	–	–	1.6E-01	2.4E-01	2.3E-01	2.0E-01	2.0E-01
Handlers/Laborers/Helpers	–	4.8E-01	–	1.6E-01	1.6E-01	1.6E-01	2.1E-01	2.7E-01	2.4E-01	2.3E-01
Health Physicists	–	–	5.6E-01	4.5E-01	3.9E-01	6.0E-01	1.6E-01	1.6E-01	2.1E-01	2.1E-01
Health Technicians	–	–	–	–	–	–	1.6E-01	–	3.3E-01	1.6E-01
Janitors	–	2.5E-01	1.6E-01	3.7E-01	1.6E-01	1.6E-01	2.1E-01	1.6E-01	1.7E-01	2.0E-01
Machine Setup/Operators	5.7E-01	2.6E-01	1.6E-01	–	–	2.6E-01	1.6E-01	–	–	1.6E-01
Machinists	1.6E-01	1.6E-01	1.6E-01	2.1E-01	2.0E-01	2.1E-01	1.9E-01	1.6E-01	2.6E-01	1.8E-01
Managers and Administrators	3.2E-01	3.1E-01	2.2E-01	2.0E-01	2.2E-01	2.5E-01	2.0E-01	2.1E-01	2.2E-01	2.0E-01
Masons	–	–	–	–	–	1.6E-01	1.6E-01	4.8E-01	1.6E-01	1.6E-01
Mechanics/Repairers	4.5E-01	2.1E-01	2.1E-01	1.9E-01	2.0E-01	2.7E-01	2.1E-01	2.2E-01	2.2E-01	1.9E-01
Miners/Drillers	–	–	–	–	–	–	–	–	–	–
Misc Professionals	2.9E-01	3.1E-01	1.8E-01	2.0E-01	2.1E-01	2.8E-01	2.0E-01	2.2E-01	2.0E-01	2.1E-01
Misc Repair/Construction	2.2E-01	4.4E-01	1.9E+02	3.6E-01	1.6E-01	2.3E-01	2.1E-01	2.1E-01	1.9E-01	2.1E-01
Misc Service	2.4E-01	2.4E-01	3.4E-01	2.7E-01	2.3E-01	2.5E-01	1.7E-01	2.5E-01	2.1E-01	1.9E-01
Misc Technicians	2.4E-01	3.2E-01	2.0E-01	1.9E-01	1.7E-01	2.4E-01	2.4E-01	2.1E-01	2.0E-01	2.1E-01
Miscellaneous	7.1E-01	3.3E-01	1.9E-01	2.8E-01	2.3E-01	1.6E-01	1.9E-01	2.4E-01	1.6E-01	2.4E-01
Miscellaneous Transport	–	–	–	–	1.6E-01	–	–	–	1.6E-01	2.7E-01
Operators Plant/System/Utility	2.8E-01	3.2E-01	2.3E-01	1.9E-01	2.2E-01	2.3E-01	2.1E-01	2.1E-01	1.9E-01	2.1E-01
Painters	1.6E-01	4.1E-01	2.2E-01	1.6E-01	2.3E-01	1.6E-01	2.0E-01	2.2E-01	2.0E-01	2.0E-01
Pipefitters	4.7E-01	3.0E+01	2.3E-01	1.8E-01	2.3E-01	2.7E+00	2.1E-01	2.1E-01	2.2E-01	1.9E-01
Radiation Monitors/Technicians	3.1E-01	2.9E-01	2.6E-01	2.2E-01	2.8E-01	2.5E-01	1.9E-01	2.0E-01	1.9E-01	1.9E-01

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Table A3–5. Average Sodium In–Vivo Results by Year (Na–24 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Science Technicians	2.7E-01	4.1E-01	1.7E-01	1.7E-01	2.8E-01	2.2E-01	1.6E-01	2.0E-01	2.2E-01	2.1E-01
Scientists	3.4E-01	2.6E-01	2.2E-01	2.0E-01	2.2E-01	2.5E-01	2.2E-01	2.1E-01	1.9E-01	1.9E-01
Security Guards	2.1E-01	4.1E-01	2.3E-01	2.1E-01	3.1E-01	2.9E-01	2.3E-01	2.1E-01	2.1E-01	2.0E-01
Sheet Metal Workers	6.9E-01	1.6E-01	1.6E-01	1.6E-01	1.6E-01	2.0E-01	1.6E-01	2.6E-01	1.6E-01	1.6E-01
Technicians	2.8E-01	3.2E-01	2.7E-01	1.9E-01	2.1E-01	2.5E-01	2.1E-01	3.2E-01	1.9E-01	2.0E-01
Truck Drivers	–	1.1E+00	2.4E-01	2.4E-01	5.7E-01	3.5E-01	2.5E-01	2.3E-01	1.8E-01	1.7E-01
Unknown	1.7E+00	9.0E-01	2.3E-01	1.9E-01	2.2E-01	2.5E-01	2.1E-01	2.1E-01	2.0E-01	2.0E-01
Welders and Solderers	–	–	1.6E-01	2.5E-01	1.9E-01	2.2E-01	1.9E-01	2.6E-01	1.7E-01	2.1E-01

Table A3–5. Average Sodium In–Vivo Results by Year (Na–24 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	2.0E-01	2.2E-01	2.8E-01	–	1.6E-01	–	–	–	–
Bus Drivers	1.6E-01	2.6E-01	–	–	–	–	–	–	–
Carpenters	2.3E-01	2.3E-01	3.6E-01	–	–	–	–	–	–
Doctors and Nurses	1.6E-01	1.6E-01	–	–	–	–	–	–	–
Electricians	2.1E-01	2.0E-01	1.6E-01	1.6E-01	1.6E-01	–	–	–	–
Engineering Technicians	2.0E-01	2.3E-01	4.7E-01	–	1.6E-01	–	–	–	–
Engineers	2.1E-01	2.1E-01	2.7E-01	–	2.2E-01	–	–	–	–
Equipment Operator	1.8E-01	2.0E-01	1.6E-01	–	–	–	–	–	–
Firefighters	2.3E-01	2.0E-01	–	–	–	–	–	–	–
Handlers/Laborers/Helpers	1.8E-01	2.1E-01	1.6E-01	–	–	–	–	–	–
Health Physicists	1.6E-01	2.0E-01	–	–	–	–	–	–	–
Health Technicians	1.6E-01	1.6E-01	–	–	–	–	–	–	–
Janitors	2.2E-01	2.3E-01	1.6E-01	–	–	–	–	–	–
Machine Setup/Operators	2.3E-01	1.6E-01	2.6E-01	–	–	–	–	–	–
Machinists	2.0E-01	2.1E-01	2.9E-01	–	–	–	–	–	–

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Table A3–5. Average Sodium In–Vivo Results by Year (Na–24 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Managers and Administrators	2.0E-01	2.2E-01	2.5E-01	1.6E-01	1.6E-01	–	–	–	–
Masons	2.3E-01	3.4E-01	–	–	–	–	–	–	–
Mechanics/Repairers	2.0E-01	2.2E-01	2.4E-01	2.9E-01	1.6E-01	–	–	–	–
Miners/Drillers	1.6E-01	–	–	–	–	–	–	–	–
Misc Professionals	1.9E-01	2.0E-01	1.6E-01	1.6E-01	1.6E-01	–	–	–	–
Misc Repair/Construction	1.8E-01	2.1E-01	1.9E-01	3.3E-01	1.6E-01	–	–	–	–
Misc Service	2.0E-01	1.8E-01	–	–	–	–	–	–	–
Misc Technicians	2.1E-01	2.3E-01	1.6E-01	4.8E-01	1.6E-01	–	–	–	–
Miscellaneous	2.0E-01	2.8E-01	–	–	–	–	–	–	–
Miscellaneous Transport	3.8E-01	2.1E-01	–	–	–	–	–	–	–
Operators Plant/System/Utility	2.1E-01	2.2E-01	2.6E-01	3.8E-01	1.6E-01	–	–	–	–
Painters	2.5E-01	2.1E-01	1.6E-01	–	1.6E-01	–	–	–	–
Pipefitters	2.0E-01	1.9E-01	2.5E-01	2.6E-01	–	–	–	–	–
Radiation Monitors/Technicians	2.1E-01	2.2E-01	3.3E-01	–	1.6E-01	–	–	–	–
Science Technicians	2.0E-01	2.2E-01	5.1E-01	1.6E-01	1.6E-01	–	–	–	–
Scientists	2.2E-01	2.2E-01	1.7E-01	2.9E-01	1.6E-01	–	–	–	–
Security Guards	2.3E-01	2.0E-01	2.4E-01	–	1.6E-01	–	–	–	–
Sheet Metal Workers	2.4E-01	2.2E-01	1.6E-01	–	–	–	–	–	–
Technicians	2.1E-01	1.9E-01	1.6E-01	1.6E-01	–	–	–	–	–
Truck Drivers	1.9E-01	1.9E-01	4.1E-01	–	–	–	–	–	–
Unknown	2.1E-01	2.1E-01	2.4E-01	3.4E-01	1.6E-01	–	–	–	–
Welders and Solderers	2.1E-01	1.9E-01	3.7E-01	1.6E-01	1.6E-01	–	–	–	–

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Table A3-6. Average Zinc In–Vivo Results by Year (Zn–65 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	1.3E+00	1.4E+00	7.3E-01	3.8E-01	1.8E+00	1.5E+00	4.5E-01	5.3E-01	5.0E-01	4.6E-01
Bus Drivers	2.7E+00	3.8E-01	3.8E-01	–	3.8E-01	–	3.8E-01	8.5E-01	3.8E-01	3.8E-01
Carpenters	–	1.7E+00	–	–	8.4E-01	8.2E-01	5.4E-01	5.9E-01	5.0E-01	6.5E-01
Doctors and Nurses	–	3.2E+00	–	–	3.1E+00	–	3.8E-01	–	3.8E-01	3.8E-01
Electricians	1.7E+00	9.4E-01	7.8E-01	5.8E-01	1.2E+00	6.2E+00	6.6E-01	7.5E-01	5.7E-01	5.1E-01
Engineering Technicians	2.7E+00	2.1E+00	7.8E-01	1.3E+00	1.1E+00	2.6E+00	4.8E-01	5.3E-01	5.0E-01	5.1E-01
Engineers	1.9E+00	8.2E+00	9.9E-01	8.3E-01	1.2E+00	1.7E+00	6.3E-01	6.8E-01	6.8E-01	4.8E-01
Equipment Operator	1.8E+00	–	–	–	–	8.2E-01	3.8E-01	3.8E-01	5.8E-01	4.4E-01
Firefighters	–	–	3.8E-01	–	–	2.3E+00	3.8E-01	6.3E-01	6.3E-01	4.2E-01
Handlers/Laborers/Helpers	–	2.1E+00	–	3.8E-01	2.4E+00	6.8E-01	9.8E-01	1.1E+00	6.4E-01	4.8E-01
Health Physicists	–	–	1.0E+00	–	6.2E-01	7.4E-01	3.8E-01	1.2E+00	1.0E+00	4.9E-01
Health Technicians	–	–	–	–	–	–	3.8E-01	–	3.8E-01	3.8E-01
Janitors	–	7.6E-01	7.0E-01	–	3.8E-01	6.6E-01	5.2E-01	3.8E-01	3.8E-01	4.1E-01
Machine Setup/Operators	1.7E+00	1.6E+00	8.6E-01	–	–	7.4E-01	3.8E-01	–	–	3.8E-01
Machinists	2.2E+00	1.7E+00	6.7E-01	1.3E+00	1.5E+00	9.1E-01	4.6E-01	3.8E-01	4.8E-01	4.3E-01
Managers And Administrators	2.4E+00	1.4E+00	8.8E-01	5.6E-01	3.2E+01	1.7E+00	7.9E-01	7.0E-01	6.4E-01	5.0E-01
Masons	–	–	–	–	–	3.8E-01	3.8E-01	1.3E+00	3.8E-01	3.8E-01
Mechanics/Repairers	3.5E+00	7.3E-01	1.6E+00	3.8E-01	1.5E+00	1.3E+00	6.4E-01	7.6E-01	5.4E-01	5.4E-01
Miners/Drillers	–	–	–	–	–	–	–	–	–	–
Misc Professionals	2.8E+00	1.2E+00	6.5E-01	6.7E-01	1.3E+00	9.7E-01	4.4E-01	5.4E-01	5.3E-01	4.4E-01
Misc Repair/Construction	1.7E+00	9.2E-01	2.4E+00	–	6.7E-01	2.1E+00	1.4E+00	1.0E+00	1.7E+00	7.6E-01
Misc Service	2.4E+00	1.6E+00	3.8E-01	3.8E-01	2.3E+00	8.7E-01	6.0E-01	6.4E-01	7.7E-01	6.4E-01
Misc Technicians	1.1E+00	1.5E+00	6.9E-01	7.5E-01	1.2E+00	9.2E-01	5.0E-01	5.4E-01	5.6E-01	4.5E-01
Miscellaneous	3.8E-01	1.5E+00	1.9E+00	3.8E-01	1.4E+00	1.1E+00	3.8E-01	7.2E-01	6.9E-01	3.8E-01
Miscellaneous Transport	–	–	–	–	3.8E+00	–	–	–	3.8E-01	3.8E-01
Operators Plant/System/Utility	1.2E+00	1.3E+00	1.3E+00	9.4E-01	4.1E+00	1.9E+00	6.4E-01	6.6E-01	7.1E-01	5.2E-01
Painters	1.6E+00	1.3E+00	5.1E-01	1.0E+00	8.7E-01	1.8E+00	1.4E+00	1.2E+00	4.8E-01	6.3E-01
Pipefitters	2.5E+00	3.0E+00	1.1E+00	5.8E-01	2.5E+00	1.4E+00	7.2E-01	8.4E-01	1.0E+00	7.1E-01
Radiation Monitors/Technicians	1.7E+00	1.4E+00	9.5E-01	5.7E-01	1.1E+00	1.2E+00	5.0E-01	4.7E-01	5.6E-01	4.9E-01

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Table A3-6. Average Zinc In–Vivo Results by Year (Zn–65 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Science Technicians	2.1E+00	1.1E+00	5.1E-01	3.8E-01	7.8E-01	8.6E-01	7.2E-01	6.7E-01	5.9E-01	4.4E-01
Scientists	1.6E+00	3.4E+01	7.0E-01	6.7E-01	1.1E+00	1.2E+00	4.7E-01	6.0E-01	5.4E-01	4.6E-01
Security Guards	2.5E+00	9.5E-01	1.1E+00	8.9E-01	1.1E+00	1.1E+00	9.2E-01	1.1E+00	7.7E-01	4.9E-01
Sheet Metal Workers	2.1E+00	1.1E+00	1.0E+00	–	6.8E-01	2.0E+00	1.6E+00	6.4E-01	9.4E-01	3.8E-01
Technicians	2.0E+00	1.9E+00	8.2E-01	9.8E-01	1.2E+00	9.7E-01	4.5E-01	6.6E-01	5.5E-01	4.4E-01
Truck Drivers	–	1.2E+00	9.2E-01	2.4E+00	1.7E+00	1.2E+00	5.9E-01	8.0E-01	5.6E-01	4.8E-01
Unknown	2.3E+00	1.9E+00	1.1E+00	7.0E-01	1.5E+01	1.7E+00	8.0E-01	7.6E-01	7.1E-01	5.6E-01
Welders and Solderers	–	–	6.3E+00	3.8E-01	6.1E-01	8.5E-01	9.3E-01	4.6E-01	8.4E-01	4.3E-01

Table A3-6. Average Zinc In–Vivo Results by Year (Zn–65 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	4.2E-01	5.0E-01	6.3E-01	–	1.4E+00	–	–	–	–
Bus Drivers	3.8E-01	3.8E-01	–	–	–	–	–	–	–
Carpenters	4.6E-01	4.2E-01	7.2E-01	–	–	–	–	–	–
Doctors and Nurses	3.8E-01	3.8E-01	–	–	–	–	–	–	–
Electricians	4.9E-01	4.7E-01	3.8E-01	3.8E-01	3.8E-01	–	–	–	–
Engineering Technicians	5.3E-01	4.6E-01	3.8E-01	–	3.8E-01	–	–	–	–
Engineers	4.9E-01	4.6E-01	7.1E-01	–	3.8E-01	–	–	–	–
Equipment Operator	5.2E-01	4.3E-01	3.8E-01	–	–	–	–	–	–
Firefighters	4.8E-01	3.8E-01	–	–	–	–	–	–	–
Handlers/Laborers/Helpers	6.1E-01	4.7E-01	1.2E+00	–	–	–	–	–	–
Health Physicists	5.3E-01	3.8E-01	–	–	–	–	–	–	–
Health Technicians	3.8E-01	3.8E-01	–	–	–	–	–	–	–
Janitors	4.5E-01	6.0E-01	3.8E-01	–	–	–	–	–	–
Machine Setup/Operators	3.8E-01	3.8E-01	9.9E-01	–	–	–	–	–	–
Machinists	5.1E-01	5.3E-01	5.2E-01	–	–	–	–	–	–

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Table A3-6. Average Zinc In–Vivo Results by Year (Zn–65 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Managers And Administrators	5.3E-01	4.9E-01	5.8E-01	4.6E-01	4.8E-01	8.7E+00	–	–	–
Masons	3.8E-01	3.8E-01	–	–	–	–	–	–	–
Mechanics/Repairers	5.0E-01	5.9E-01	5.0E-01	3.8E-01	6.4E-01	7.4E+00	–	–	–
Miners/Drillers	3.8E-01	–	–	–	–	–	–	–	–
Misc Professionals	4.7E-01	4.7E-01	3.8E-01	3.8E-01	3.8E-01	3.9E+00	–	–	–
Misc Repair/Construction	6.3E-01	4.9E-01	3.9E-01	3.8E-01	1.9E+00	–	–	–	–
Misc Service	4.3E-01	4.1E-01	–	–	–	–	–	–	–
Misc Technicians	5.1E-01	4.4E-01	4.0E+00	3.8E-01	3.8E-01	–	–	–	–
Miscellaneous	5.3E-01	4.5E-01	–	–	–	–	–	–	–
Miscellaneous Transport	3.8E-01	3.8E-01	–	–	–	–	–	–	–
Operators Plant/System/Utility	5.2E-01	4.8E-01	6.7E-01	4.8E-01	9.2E-01	–	–	–	–
Painters	3.9E-01	5.4E-01	3.8E-01	–	3.8E-01	–	–	–	–
Pipefitters	6.7E-01	4.7E-01	6.9E-01	3.8E-01	–	–	–	–	1.6E+00
Radiation Monitors/Technicians	5.2E-01	4.6E-01	5.0E-01	–	1.5E+00	1.1E+01	–	–	–
Science Technicians	5.4E-01	4.7E-01	3.8E-01	1.7E+00	3.8E-01	–	–	–	–
Scientists	4.9E-01	4.4E-01	4.8E-01	3.8E-01	3.8E-01	–	–	–	–
Security Guards	4.7E-01	4.7E-01	9.3E-01	–	3.8E-01	–	–	–	–
Sheet Metal Workers	5.8E-01	5.3E-01	1.2E+00	–	–	–	–	–	–
Technicians	4.7E-01	5.2E-01	3.8E-01	3.8E-01	–	–	–	–	–
Truck Drivers	4.9E-01	4.7E-01	3.8E-01	–	–	–	–	–	–
Unknown	5.1E-01	5.0E-01	5.1E-01	5.9E-01	1.1E+01	2.0E+01	–	–	2.2E+00
Welders and Solderers	5.0E-01	5.2E-01	3.8E-01	3.8E-01	3.8E-01	–	–	–	–

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Table A3–7. Average Uranium In–Vivo Results by Year (U–235 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	–	–	–	–	9.1E-02	6.8E-02	6.6E-02	6.2E-02	6.2E-02	5.3E-02
Bus Drivers	–	–	–	–	8.0E-02	8.8E-02	7.5E-02	7.5E-02	7.5E-02	7.5E-02
Carpenters	–	–	–	–	–	7.0E-02	–	–	7.3E-02	7.3E-02
Doctors and Nurses	–	–	–	–	4.0E-02	–	6.0E-02	–	4.8E-02	5.5E-02
Electricians	–	–	–	–	6.8E-02	6.0E-02	6.7E-02	6.6E-02	6.5E-02	6.5E-02
Engineering Technicians	–	–	–	–	6.1E-02	6.5E-02	6.5E-02	6.3E-02	6.1E-02	6.2E-02
Engineers	–	–	–	–	6.7E-02	6.7E-02	6.2E-02	6.3E-02	6.1E-02	6.2E-02
Equipment Operator	–	–	–	–	–	–	–	8.5E-02	–	–
Firefighters	–	–	–	–	–	–	5.5E-02	7.4E-02	–	–
Handlers/Laborers/Helpers	–	–	–	–	5.5E-02	6.0E-02	4.5E-02	5.0E-02	6.3E-02	6.0E-02
Health Physicists	–	–	–	–	5.5E-02	–	6.3E-02	6.6E-02	6.9E-02	5.6E-02
Health Technicians	–	–	–	–	–	–	5.0E-02	–	5.0E-02	5.0E-02
Janitors	–	–	–	–	7.0E-02	5.8E-02	7.4E-02	7.0E-02	6.0E-02	6.2E-02
Machine Setup/Operators	–	–	–	–	–	–	7.0E-02	–	–	–
Machinists	–	–	–	–	7.1E-02	6.8E-02	6.7E-02	9.1E-02	6.8E-02	6.8E-02
Managers and Administrators	–	–	2.9E-01	–	6.2E-02	6.3E-02	6.4E-02	6.4E-02	6.6E-02	6.4E-02
Masons	–	–	–	–	–	–	–	–	5.5E-02	6.0E-02
Mechanics/Repairers	–	–	–	–	6.9E-02	7.6E-02	7.4E-02	6.4E-02	6.7E-02	6.4E-02
Miners/Drillers	–	–	–	–	–	–	–	–	–	–
Misc Precision/Production	–	–	–	–	–	–	–	–	–	–
Misc Professionals	–	–	–	–	6.8E-02	6.2E-02	6.1E-02	6.0E-02	6.1E-02	6.1E-02
Misc Repair/Construction	–	–	–	–	–	5.5E-02	6.5E-02	6.5E-02	–	7.2E-02
Misc Service	–	–	–	–	6.0E-02	6.5E-02	5.6E-02	6.2E-02	6.8E-02	6.9E-02
Misc Technicians	–	–	–	–	6.2E-02	5.7E-02	6.7E-02	5.8E-02	6.1E-02	6.8E-02
Miscellaneous	–	–	–	–	6.2E-02	5.0E-02	5.9E-02	5.5E-02	6.0E-02	5.9E-02
Miscellaneous Transport	–	–	–	–	–	–	–	–	–	–
Operators Plant/System/Utility	–	–	1.6E-01	–	7.9E-02	6.1E-02	6.4E-02	6.3E-02	6.0E-02	6.3E-02
Painters	–	–	–	–	5.8E-02	6.5E-02	6.5E-02	7.5E-02	6.5E-02	6.9E-02
Pipefitters	–	–	–	–	6.4E-02	7.8E-02	6.7E-02	6.3E-02	6.4E-02	6.9E-02

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Table A3–7. Average Uranium In–Vivo Results by Year (U–235 in units of nCi)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Radiation Monitors/Technicians	–	–	–	7.0E-02	7.2E-02	6.6E-02	6.4E-02	6.5E-02	6.4E-02	6.4E-02
Science Technicians	–	–	2.2E-01	–	6.1E-02	5.8E-02	5.7E-02	6.1E-02	5.9E-02	6.2E-02
Scientists	–	–	2.5E-01	–	6.4E-02	6.1E-02	6.1E-02	6.2E-02	6.1E-02	6.2E-02
Security Guards	–	–	1.1E-01	–	6.9E-02	5.6E-02	7.7E-02	6.3E-02	6.8E-02	6.4E-02
Sheet Metal Workers	–	–	–	–	–	6.5E-02	7.3E-02	5.9E-02	5.6E-02	6.3E-02
Technicians	–	–	1.4E-01	–	7.0E-02	6.3E-02	6.4E-02	5.9E-02	6.3E-02	6.0E-02
Truck Drivers	–	–	–	–	–	6.4E-02	6.8E-02	6.3E-02	6.9E-02	6.1E-02
Unknown	–	–	2.0E-01	6.0E-02	6.6E-02	6.7E-02	6.2E-02	6.2E-02	6.2E-02	6.2E-02
Welders and Solderers	2.0E-01	–	–	–	6.3E-02	7.5E-02	6.5E-02	6.9E-02	6.5E-02	7.9E-02

Table A3–7. Average Uranium In–Vivo Results by Year (U–235 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	6.2E-02	4.8E-02	4.7E-02	5.4E-02	4.8E-02	5.9E-02	4.5E-02	4.4E-02	6.2E-02
Bus Drivers	8.0E-02	6.0E-02	–	–	–	–	–	4.3E-02	8.0E-02
Carpenters	6.5E-02	5.7E-02	6.0E-02	5.5E-02	5.4E-02	6.2E-02	5.3E-02	4.1E-02	6.5E-02
Doctors and Nurses	6.5E-02	5.0E-02	–	–	–	–	–	–	6.5E-02
Electricians	6.6E-02	5.8E-02	5.4E-02	5.8E-02	5.9E-02	6.1E-02	5.7E-02	4.1E-02	6.6E-02
Engineering Technicians	6.2E-02	5.4E-02	5.3E-02	5.7E-02	5.8E-02	5.7E-02	4.8E-02	4.0E-02	6.2E-02
Engineers	6.2E-02	5.3E-02	5.4E-02	5.7E-02	5.6E-02	5.8E-02	5.0E-02	3.9E-02	6.2E-02
Equipment Operator	5.5E-02	5.5E-02	6.0E-02	6.3E-02	6.0E-02	6.4E-02	5.4E-02	4.0E-02	5.5E-02
Firefighters	–	–	–	6.0E-02	5.8E-02	5.1E-02	–	–	–
Handlers/Laborers/Helpers	6.8E-02	5.4E-02	5.6E-02	6.0E-02	6.2E-02	6.0E-02	6.1E-02	4.1E-02	6.8E-02
Health Physicists	–	7.3E-02	5.3E-02	–	–	5.7E-02	5.4E-02	3.5E-02	–
Health Technicians	–	2.5E-02	–	–	–	–	–	–	–
Janitors	5.8E-02	4.9E-02	5.1E-02	5.6E-02	5.5E-02	5.2E-02	4.2E-02	2.9E-02	5.8E-02
Machine Setup/Operators	–	–	–	–	–	–	–	–	–

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Table A3–7. Average Uranium In–Vivo Results by Year (U–235 in units of nCi) (continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Machinists	7.4E-02	5.9E-02	4.2E-02	5.8E-02	5.1E-02	6.1E-02	5.6E-02	8.5E-02	7.4E-02
Managers and Administrators	6.5E-02	5.6E-02	5.5E-02	5.6E-02	5.8E-02	5.6E-02	4.9E-02	4.1E-02	6.5E-02
Masons	–	–	–	–	–	6.2E-02	5.2E-02	3.7E-02	–
Mechanics/Repairers	6.5E-02	5.4E-02	5.4E-02	5.8E-02	5.9E-02	6.0E-02	5.4E-02	4.1E-02	6.5E-02
Miners/Drillers	–	–	–	–	–	–	1.0E-01	2.9E-02	–
Misc Precision/Production	–	–	–	–	–	–	–	3.3E-02	–
Misc Professionals	6.1E-02	5.2E-02	5.2E-02	1.2E-01	5.6E-02	5.8E-02	4.4E-02	4.4E-02	6.1E-02
Misc Repair/Construction	6.5E-02	5.8E-02	7.0E-02	5.8E-02	5.6E-02	6.4E-02	5.2E-02	4.4E-02	6.5E-02
Misc Service	6.2E-02	5.5E-02	5.1E-02	5.2E-02	5.1E-02	5.2E-02	4.5E-02	3.8E-02	6.2E-02
Misc Technicians	6.4E-02	5.7E-02	5.4E-02	5.7E-02	6.0E-02	6.0E-02	5.8E-02	3.9E-02	6.4E-02
Miscellaneous	6.2E-02	4.8E-02	4.9E-02	5.1E-02	3.7E-02	5.1E-02	4.0E-02	3.5E-02	6.2E-02
Miscellaneous Transport	7.1E-02	–	–	–	–	6.3E-02	–	3.6E-02	7.1E-02
Operators Plant/System/Utility	6.1E-02	5.4E-02	5.3E-02	5.5E-02	5.8E-02	5.7E-02	4.7E-02	3.9E-02	6.1E-02
Painters	6.9E-02	6.4E-02	5.5E-02	5.8E-02	6.0E-02	5.7E-02	5.0E-02	4.1E-02	6.9E-02
Pipefitters	6.4E-02	5.9E-02	6.4E-02	5.6E-02	6.3E-02	6.0E-02	5.2E-02	4.1E-02	6.4E-02
Radiation Monitors/Technicians	6.4E-02	5.4E-02	5.4E-02	5.6E-02	5.9E-02	5.8E-02	5.2E-02	3.8E-02	6.4E-02
Science Technicians	5.8E-02	5.3E-02	4.9E-02	5.0E-02	5.4E-02	5.4E-02	4.7E-02	3.8E-02	5.8E-02
Scientists	6.3E-02	5.5E-02	5.3E-02	5.4E-02	5.7E-02	5.6E-02	4.8E-02	3.8E-02	6.3E-02
Security Guards	8.8E-02	6.7E-02	5.8E-02	5.4E-02	5.1E-02	5.9E-02	4.8E-02	4.0E-02	8.8E-02
Sheet Metal Workers	6.8E-02	5.6E-02	5.2E-02	6.6E-02	5.6E-02	6.2E-02	5.5E-02	4.0E-02	6.8E-02
Technicians	6.9E-02	5.1E-02	5.0E-02	5.2E-02	5.6E-02	5.3E-02	4.4E-02	3.9E-02	6.9E-02
Truck Drivers	6.8E-02	5.7E-02	6.3E-02	6.1E-02	6.2E-02	6.3E-02	5.3E-02	4.3E-02	6.8E-02
Unknown	6.2E-02	5.3E-02	5.3E-02	5.3E-02	5.6E-02	5.6E-02	4.3E-02	3.9E-02	6.2E-02
Welders and Solderers	6.5E-02	6.3E-02	6.1E-02	5.6E-02	6.4E-02	6.4E-02	7.3E-02	4.6E-02	6.5E-02

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Table A3–8. Median Strontium In–Vitro Results by Year (Sr–90 in units of μCi/l)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Admin Support and Clerical	3.00E-06	9.50E-07	–	–	0.00E+00	–	0.00E+00	–	–	0.00E+00
Bus Drivers	–	–	–	–	–	–	9.38E-05	–	–	–
Carpenters	–	–	–	–	–	–	–	–	–	0.00E+00
Electricians	–	0.00E+00	–	–	0.00E+00	–	6.01E-08	–	–	0.00E+00
Engineering Technicians	0.00E+00	0.00E+00	0.00E+00	–	–	–	7.09E-05	–	–	0.00E+00
Engineers	6.55E-06	2.32E-07	–	–	–	–	0.00E+00	–	–	0.00E+00
Equipment Operator	–	0.00E+00	–	–	–	–	0.00E+00	–	–	0.00E+00
Firefighters	–	–	–	–	–	–	–	–	–	–
Handlers/Laborers/Helpers	–	–	–	–	–	–	–	–	–	0.00E+00
Health Physicists	–	–	–	–	–	–	0.00E+00	–	–	0.00E+00
Health Technicians	–	–	–	–	–	–	–	–	–	–
Janitors	–	–	–	–	–	–	–	–	–	–
Machine Setup/Operators	–	–	–	–	–	–	–	–	–	–
Machinists	–	–	–	–	–	–	–	–	–	0.00E+00
Managers and Administrators	0.00E+00	0.00E+00	2.76E-07	–	0.00E+00	–	1.14E-06	–	–	0.00E+00
Masons	–	–	–	–	–	–	–	–	–	–
Mechanics/Repairers	–	–	–	–	–	–	0.00E+00	–	–	0.00E+00
Miners/Drillers	–	–	–	–	–	–	–	–	–	–
Misc Professionals	–	0.00E+00	0.00E+00	–	8.56E-07	–	6.38E-07	–	–	0.00E+00
Misc Repair/Construction	–	–	–	–	–	–	3.02E-04	–	–	4.48E-07
Misc Service	–	–	–	–	–	–	2.30E-06	–	–	0.00E+00
Misc Technicians	0.00E+00	–	0.00E+00	–	–	–	0.00E+00	–	–	0.00E+00
Miscellaneous	–	9.50E-07	–	–	–	–	–	–	–	–
Miscellaneous Transport	–	–	–	–	–	–	–	–	–	0.00E+00
Operators Plant/System/Utility	5.25E-07	2.26E-07	1.51E-06	–	–	–	7.05E-06	–	–	0.00E+00
Painters	–	–	–	–	–	–	0.00E+00	–	–	–
Pipefitters	0.00E+00	0.00E+00	0.00E+00	–	–	–	2.33E-07	–	–	1.66E-05
Radiation Monitors/Technicians	8.90E-03	7.74E-06	0.00E+00	–	0.00E+00	–	2.88E-07	–	–	0.00E+00
Science Technicians	0.00E+00	1.43E-06	2.88E-07	–	0.00E+00	–	1.23E-07	–	–	0.00E+00

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Table A3–8. Median Strontium In–Vitro Results by Year (Sr–90 in units of µCi/l)

Job Title	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Scientists	–	0.00E+00	0.00E+00	–	0.00E+00	–	9.07E-08	–	–	0.00E+00
Security Guards	–	0.00E+00	0.00E+00	–	–	–	0.00E+00	–	–	0.00E+00
Sheet Metal Workers	–	–	–	–	–	–	–	–	–	0.00E+00
Technicians	–	5.97E-07	2.13E-06	–	8.28E-07	–	0.00E+00	–	–	0.00E+00
Truck Drivers	–	–	–	–	–	–	0.00E+00	–	–	–
Unknown	1.37E-07	3.13E-07	5.91E-07	–	7.44E-07	–	1.09E-04	–	–	4.52E-06
Welders and Solderers	–	–	–	–	–	–	0.00E+00	–	–	–

Table A3–8. Median Strontium In–Vitro Results by Year (Sr–90 in units of µCi/l)

(continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Admin Support and Clerical	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bus Drivers	–	–	–	–	–	–	–	–	–
Carpenters	0.00E+00	–	0.00E+00	–	–	–	6.20E-08	0.00E+00	0.00E+00
Electricians	2.10E-07	0.00E+00	0.00E+00	2.82E-08	3.72E-07	2.10E-07	1.35E-07	0.00E+00	1.02E-07
Engineering Technicians	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E-07	1.72E-07	0.00E+00	1.71E-06
Engineers	2.78E-07	0.00E+00	0.00E+00	7.15E-08	3.77E-08	2.74E-07	4.66E-08	0.00E+00	0.00E+00
Equipment Operator	9.16E-07	2.23E-06	9.85E-08	4.16E-07	0.00E+00	1.02E-07	1.16E-06	0.00E+00	1.47E-07
Firefighters	–	0.00E+00	–	–	–	–	0.00E+00	–	–
Handlers/Laborers/Helpers	–	0.00E+00	–	–	0.00E+00	0.00E+00	8.16E-08	0.00E+00	0.00E+00
Health Physicists	0.00E+00	–	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.62E-07	0.00E+00	0.00E+00
Health Technicians	–	0.00E+00	3.28E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Janitors	–	–	0.00E+00	–	0.00E+00	–	–	0.00E+00	–
Machine Setup/Operators	–	–	0.00E+00	–	–	–	–	–	–
Machinists	0.00E+00	0.00E+00	0.00E+00	–	0.00E+00	0.00E+00	–	–	0.00E+00
Managers and Administrators	1.11E-07	2.83E-07	1.61E-07	1.22E-07	7.56E-08	1.66E-07	2.13E-07	0.00E+00	0.00E+00
Masons	–	–	–	–	–	–	–	0.00E+00	–

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Table A3–8. Median Strontium In–Vitro Results by Year (Sr–90 in units of µCi/l)

(continued)

Job Title	1982	1983	1984	1985	1986	1987	1988	1989	1990
Mechanics/Repairers	7.70E-08	3.17E-06	0.00E+00	3.71E-08	1.91E-06	1.18E-07	1.80E-07	2.79E-07	1.51E-07
Miners/Drillers	–	–	–	–	–	–	0.00E+00	0.00E+00	0.00E+00
Misc Professionals	0.00E+00	–	–	–	0.00E+00	0.00E+00	3.13E-07	0.00E+00	0.00E+00
Misc Repair/Construction	0.00E+00	1.64E-04	5.42E-06	1.11E-06	0.00E+00	4.01E-07	3.38E-06	1.02E-07	1.45E-07
Misc Service	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.58E-06
Misc Technicians	0.00E+00	2.76E-07	0.00E+00	3.44E-08	1.40E-07	7.96E-08	2.34E-07	0.00E+00	5.15E-08
Miscellaneous	–	–	–	–	2.79E-06	–	–	0.00E+00	8.80E-07
Miscellaneous Transport	–	–	–	–	–	–	–	0.00E+00	0.00E+00
Operators Plant/System/Utility	2.99E-04	6.61E-08	4.37E-08	6.16E-06	1.95E-05	2.80E-07	2.33E-07	2.34E-08	2.13E-07
Painters	0.00E+00	2.70E-06	0.00E+00	–	2.76E-07	0.00E+00	7.48E-08	0.00E+00	7.00E-06
Pipefitters	0.00E+00	1.46E-05	7.49E-07	6.34E-08	6.36E-07	6.48E-07	1.15E-07	0.00E+00	0.00E+00
Radiation Monitors/Technicians	9.98E-08	1.01E-04	1.01E-07	7.42E-07	6.56E-08	2.61E-07	1.95E-07	9.26E-09	4.61E-07
Science Technicians	0.00E+00	6.83E-08	8.28E-08	3.54E-08	2.56E-08	1.49E-07	2.07E-07	0.00E+00	7.41E-07
Scientists	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.53E-08	2.10E-07	0.00E+00	5.67E-07
Security Guards	0.00E+00	3.77E-05	1.59E-06	0.00E+00	0.00E+00	0.00E+00	7.40E-08	3.25E-08	7.66E-07
Sheet Metal Workers	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	–	1.65E-07	5.94E-07	0.00E+00
Technicians	0.00E+00	3.33E-07	0.00E+00	0.00E+00	0.00E+00	3.03E-07	0.00E+00	0.00E+00	4.38E-07
Truck Drivers	–	0.00E+00	1.99E-06	5.75E-07	0.00E+00	3.24E-07	4.92E-07	0.00E+00	0.00E+00
Unknown	1.86E-05	4.76E-07	2.02E-07	2.74E-07	1.41E-06	1.35E-07	0.00E+00	–	8.80E-07
Welders and Solderers	0.00E+00	1.83E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.53E-08	0.00E+00	0.00E+00

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APPENDIX B: NOVEMBER 2009 UPDATED HANFORD SEC ISSUES MATRIX

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REMAINING HANFORD SEC ISSUES
FOR SEC PETITION SEC-00057-2 and PETITION SEC-00152

Draft Issues Matrix Update

Prepared by SC&A
November 2, 2009

This is an update of the Hanford Special Exposure Cohort (SEC) issues matrix made following the Advisory Board's decision to accept NIOSH's recommendation that all eligible Hanford workers employed until June 30, 1972, be included in the SEC provided they meet the health endangerment requirement of 250 days or more of qualified employment. The NIOSH recommendation was contained in an evaluation report of Petition SEC-00152, which is a new SEC petition. NIOSH has also been evaluating Petition SEC-00057-2, which has the same starting date (October 1, 1943) as SEC-00152.

SC&A was not asked to evaluate SEC-00152. This is an 83.14 petition initiated by NIOSH, because it determined that it did not have sufficient data to estimate certain aspects of Hanford dose to June 30, 1972. During its October 2009 meeting, the Board accepted NIOSH's recommendation regarding expansion of the SEC class to June 30, 1972. The follow-on task for SC&A was to update the SEC issues matrix to indicate which issues relevant to Petition SEC-00057-2 had been fully or partially resolved by the Board's decision regarding SEC-00152, and which issues still remain to be investigated in the context of SEC-00057-2.

The matrix below indicates SC&A's understanding of (1) the issues relating to SEC-00057-2 that were resolved by the Board's decision regarding SEC-00152 and (2) the issues that still remain to be resolved for the July 1, 1972, to December 31, 1990, period.

Disclaimer

This document is made available in accordance with the unanimous desire of the Advisory Board on Radiation and Worker Health (ABRWH) to maintain all possible openness in its deliberations. However, the ABRWH and its contractor, SC&A, caution the reader that at the time of its release, this report is pre-decisional and has not been reviewed by the Board for factual accuracy or applicability within the requirements of 42 CFR 82. This implies that once reviewed by the ABRWH, the Board's position may differ from the report's conclusions. Thus, the reader should be cautioned that this report is for information only and that premature interpretations regarding its conclusions are unwarranted.

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Issue Number and Description	NIOSH ER Position (SC&A Reading)	SC&A Statement	Update by SC&A November 2, 2009, for the Work Group	Work Group Comments
		Start of potential SEC Issues (Preliminary list)		
1. Thorium-232 internal exposure from Sept. 1, 1946, up to December 31, 1959	SEC proposed for Buildings 313, 306, 3722, 3706	Buildings and locations other than the ones listed in the NIOSH ER appear to be involved, for instance, and 303-K, 305 Test Pile, 314, 321, 3307 A and B (change houses with thorium contamination), and Sites 300-33 and 300-26, sites with thorium contaminated soil. The 100 Area was also involved in thorium work; for instance, 105-D and 105-H reactors (there was a slug failure in the latter in 1954). The use of the REDOX facility (202-S) for U-233 separation from irradiated Th-232 slugs was evaluated in 1955. Workers moved within an area without a record being maintained on a day-to-day basis. Many workers were roving workers and/or construction workers.	**Post-1972 SEC SC&A update:** This issue is resolved.	
2. Americium-241 internal exposure, January 1, 1949 to December 31, 1968	SEC proposed for Buildings 231-Z, 242-Z and 234-5Z	Buildings and locations other than the ones listed in the NIOSH ER appear to have been involved. 303-C was used for americium storage. There was Am-241 separation in Building 325. The 216 series cribs and ditches were used for discharge of wastes from the Plutonium Finishing Plant. Workers moved within an area without a record being maintained on a day-to-day basis. Many workers were roving workers and/or construction workers.	**Post-1972 SEC SC&A update:** This issue is resolved.	

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Issue Number and Description	NIOSH ER Position (SC&A Reading)	SC&A Statement	Update by SC&A November 2, 2009, for the Work Group	Work Group Comments
3. Thorium-232 internal exposure from January 1, 1960, onward.	The ER assumes that sufficient Th in-vivo data exist, and that dose reconstruction can be done. OTIB-0039 proposes to estimate Th intakes based on uranium intakes. NIOSH investigating further.	The REX database summary in the ER contains no Th data points until 1969, very few scattered data points from 1970 to 1981, and none after that. Data adequacy not established. Validity of using U intakes for Th intake estimation not established.	**Post-1972 SEC SC&A update:** This item is resolved to June 30, 1972. Data adequacy from 1972 onward remains to be investigated.	
4. HEU – uranium intake estimation	ER does not discuss potential for HEU exposure.	HEU was used at Hanford at various times. Only fluorometric urine data for uranium are available until 1983, preventing an estimation of U isotopic composition. HEU was used in early tritium and U-233 production (1949–1954), for reactor power enhancement (to June 1958), and possibly in the mid-1960s for U-233 production (N reactor). Some R&D uses continued into the 1980s. J and C slugs containing HEU were canned at Hanford. Fluorometric data are generally not adequate to estimate exposure to HEU in a context where most exposure to most workers was to low enriched or natural uranium.	**Post-1972 SEC SC&A update:** Issue is resolved to June 30, 1972. Data adequacy remains to be addressed after that date to 1983, the date up to which uranium fluorometry was the urinalysis method.	
5. Uranium intake estimation prior to 1948	ER considers Hanford U data prior to 1948 unreliable and back-extrapolation of later data to be scientifically inappropriate due to changes in equipment and methods. The ER proposes to use AWE data for this period.	Equivalence of the use of AWE uranium data for the experimental and early production processes has not been demonstrated to be bounding or suitable for Hanford circumstances in an SEC context.	**Post-1972 SEC SC&A update:** This issue is resolved.	

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6. Uranium intake estimation to 1990 for unmonitored workers	The ER proposes using coworker data.	Adequacy of coworker model (Table 6-3 in OTIB-0039) remains to be established in the SEC context.	**Post 1972 SEC SC&A update:** Only the July 1, 1972, to 1990 part of the SEC review remains to be completed for OTIB-0039; the corresponding review of OTIB-0054 for the same period also remains to be completed.	
7. U-233 intakes	The ER proposes using the highest U-233 intake estimate.	Adequacy of U-233 internal monitoring data and data for associated contaminants to determine bounding dose (or a dose estimated with greater accuracy) needs to be examined as a potential SEC issue. The history of U-233 production and separation also needs evaluation in the SEC context.	**Post-1972 SEC SC&A update:** This issue is resolved until June 30, 1972. The last reprocessing campaign for U-233 was in 1971, according to vol. 2 of the TBD (Rev. 1, pg. 12). This remains to be confirmed. Handling and further processing of U-233 after June 30, 1972, remains to be investigated, notably for data adequacy, if there was such handling or processing. Exact final date of potential U-233 exposure also remains to be researched.	

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Issue Number and Description	NIOSH ER Position (SC&A Reading)	SC&A Statement	Update by SC&A November 2, 2009, for the Work Group	Work Group Comments
8. Recycled uranium intake estimation.	The ER does not discuss intakes of contaminants in RU. The TBD has some data, with the earliest dating from 1988.	Exposure to the trace contaminants in RU may be a potential SEC issue starting in 1952, when RU was recovered at Hanford from the high-level waste tanks. The potential ending time would need further study. Adequacy of the RU contaminant table in ORAUT-TKBS-0006-5 (Vol. 5, Rev. 01, Table 5.32.5-2, p. 24)) needs to be examined in light of 42 CFR 83 requirements, and historical data at Hanford indicating higher contaminant levels. Some data indicate higher levels of trace contaminants in the early period than are shown in the TBD table.	**Post-1972 SEC SC&A update:** This issue is resolved to June 1972. SC&A has raised the issue of use of 1988 and 1993 data for earlier periods, which now remains for the 1972–1987 period.	
9. Neptunium-237 intakes, 1958 to 1972	The ER states that, "Plutonium[-238] bioassay was considered sufficient to monitor for neptunium intakes" (p. 41).	The validity of the suggested approach has not been established, especially in the context that Hanford handled separated Np. Only four Np bioassay samples exist for 1972 (REX database summary) and none before that.	**Post-1972 SEC SC&A update:** This issue is resolved up to June 30, 1972. Residual contamination and any processing for the July 1, 1972 to December 31, 1972, remains to be investigated.	
10. Tritium intake estimation from 1949 onwards	The ER states that data are available from 1949 onward and that they are sufficient for coworker dose determination.	The REX database shows no tritium samples until 1982. SC&A awaits the results of NIOSH's data capture efforts on this issue.	**Post-1972 SEC SC&A update:** This issue is resolved until June 30, 1972. Data from July 1, 1972 to 1982 recovered by NIOSH (if any) needs to be reviewed for adequacy. External dose records, which reportedly include tritium exposure (TBD Vol. 5), also need to be reviewed.	

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11. Promethium-147	The ER contains a discussion of processes involving promethium, but has no discussion of dose reconstruction methods.	The REX database has promethium bioassay data from 1966 onward. Promethium processing may have started in 1962, and possibly earlier. Feasibility of dose reconstruction remains to be established, at least to 1966. Adequacy of data needs to be investigated from 1966 onwards. The coworker model does not address pre-1966 exposures or roving worker exposures (for workers not based in Buildings 308 or 325).	**Post-1972 SEC SC&A update:** This issue is resolved until June 30, 1972. A check on the last date of Pm-147 processing is needed.	
12. Sr-90, Cs- 137, MFP intake estimation	Prior to 1965, the approach suggested is use of mixed fission product and Cs-137 data. The ER states mixed fission product urinalysis started in 1947; "erratic until 1948" (p. 39)	• Dose reconstruction feasibility before 1948 is a potential issue. • The REX database summary shows no fission product data prior to 1974. Use of the REX database for the early years needs to be assessed for possible changes in processes and validity of back extrapolation, and for its use in coworker dose estimation. • Sr-90 bioassay data available from 1965 onwards. • Cs-137 whole-body count data available from 1960 onward (according to the ER), but no data points in REX until 1972.	**Post-1972 SEC SC&A update:** This issue is resolved until June 30, 1972. Dose reconstruction method for July 1, 1972, to the end of 1973 needs to be evaluated. Data adequacy from 1974 needs to be checked for adequacy.	
13. Tank Farm alpha contamination	The ER does not explicitly discuss this issue.	Site expert interviews indicate that tank farm exposures, including alpha-emitting radionuclide intakes (such as those from resuspension), may have been missed.	**Post-1972 SEC SC&A update:** This issue would remain as part of the data adequacy check from July 1, 1972, onwards.	

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14. Plutonium intake estimation	The ER has an extensive discussion of data and dose reconstruction approach.	May not be an SEC issue. Frequency of Pu urinalysis fell sharply in the late 1950s. Minimum detection limits were variable (higher in earlier years). Coworker models need to be evaluated from an SEC standpoint (e.g., adequacy of the REX database for coworker models).	**Post-1972 SEC SC&A update:** This issue remains only as part of data adequacy and validity (for lung and whole-body counts) from July 1, 1972, onwards.	
15. Hot particle ingestion	The ER does not discuss this issue	Ingestion of hot particles could be an issue for 1947 and 1948 T and B plant emissions and for 1952–1955 REDOX plant emissions (TBD Vol. 4 Rev. 2, p. 27).	**Post-1972 SEC SC&A update:** This issue is resolved.	
16. Cm-244	The ER states, "However, extraction of curium-244 from high-level waste occurred at the 325 Building sometime in the 1970s. Since the curium and americium procedures were the same, the results would have been reported as curium only, if so requested through the bioassay request system…."	Significant amounts of Cm-244 (65 grams—more than 5,000 curies) appear to have been processed in the 1960s in Building 325 (Gerber, M.S. 1993. *Multiple Missions: The 300 Area in Hanford Site History*, WHC-MR-0440, Westinghouse Hanford Company, Richland, Washington. September 1993, p. 23). Earliest Cm-244 data in the REX database summary in the ER are from 1968 (6 data points), after which there are 8 more in 1974. NIOSH has not presented a DR method for estimating Cm-244 intakes during the campaign that purified 65 grams in the 1960s.	**SC&A update June 15, 2009:** This issue is resolved until June 30, 1972. Data check is needed for July 1, 1972 to 1974.	

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17. Neutron doses to December 31, 1971 (after which TLDs were introduced)	ER proposes to use: • n/p ratios until 1958. • Adjusted NTA film data, to end of 1971 NIOSH is engaged in an extensive neutron-related data capture effort.	Issues: • Validity of n/p ratios for specific time and work location • Adjustment factor accuracy and/or bounding value • Area coverage of neutron monitoring • Construction worker neutron monitoring, since there is a claim in the petition that some construction workers were not monitored for neutrons (OTIB-0052 for construction workers did not address neutron doses)	**Post-1972 SEC SC&A update:** This issue is resolved.	
18. External exposure geometry	The ER does not explicitly discuss this issue.	Site expert evidence indicates significant geometry issues in some circumstances that may prevent film badge or TLD from registering relevant organ dose.	**Post-1972 SEC SC&A update:** This is a site profile issue.	
19. Lack of adequate monitoring: Petitioner issue	The ER discusses this in Section 7.4 and bases dose reconstruction feasibility on coworker models	Coworker model adequacy from the SEC point of view needs to be evaluated in general and specifically in light of petitioner affidavits.	**Post-1972 SEC SC&A update:** An external and internal dose completeness check remains to be done from July 1, 1972, onwards.	
20. Skin contamination	The ER and TBD describe skin dose and extremity dose monitoring and assignment.	Site expert interviews indicate unusual potential for skin exposure in some maintenance work. This needs to be evaluated against available data. TBD discusses hot particle skin dose. Validity of skin dose coefficients in the Hanford external dose TBD (Rev. 3) needs to be investigated. Hot particle skin doses need to be evaluated for 1947–1948 and 1952–1954.	**Post-1972 SEC SC&A update:** Incident reports should be evaluated from July 1, 1972, onwards as part of the SEC investigation. This should be joined with item 22 below.	

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21. Missing records –routine (Petitioner issue)	The ER refers to the coworker model OTIB-0052 for construction workers and general guidance to fill in doses corresponding to missing records.	SEC-specific analysis for Hanford is needed to verify that the approaches specified are bounding doses (or more accurate than bounding doses) for all members of the proposed class.	**Post-1972 SEC SC&A update:** SC&A has received a list of destroyed documents. This issue needs to be joined with issue 22 below.	
22. Missing incident records	The ER does not explicitly address this issue.	DOE files of claimants who have affidavits in the Petition need to be examined. Data completeness for incidents needs to be checked. This also links to potential destruction of records and existence of duplicate records. Specific incidents need to be evaluated, including a criticality in the 1950s.	**Post-1972 SEC SC&A update:** Missing and destroyed records and incident reports remain as a potential SEC issue. SC&A has received a list of destroyed records from DOE and some of these documents appear to have included personnel data. Existence of duplicate records from July 1, 1972, onwards for incident documents indicated as destroyed on the list remains to be established.	
23. REX database adequacy and representativeness for coworker models	The ER acknowledges that the REX database is not complete for early-year data, but that other reports provide the data in question.	Coworker models are based on the REX database. The representativeness of the REX database for estimating coworker doses needs to be examined in the SEC context.	**Post-1972 SEC SC&A update:** Certain data adequacy and completeness issues remain to be investigated from July 1, 1972, onwards. See various internal dose items above. This is linked to the coworker model issue.	
24. Polonium-210	Bismuth was irradiated at Hanford starting in 1945, but separation and processing did not begin till 1968, from which date bioassay data are available.	Verification of no processing of irradiated bismuth target rods before 1968 is needed.	**Post-1972 SEC SC&A update**: This issue is resolved.	

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25. Miscellaneous radionuclides (e.g., Cr-51, Ru-106, Ce-144, Co-60)	The ER relies on the internal dose TBD.	Adequacy of the TBD approach for bounding doses needs to be assessed.	**Post-1972 SEC SC&A update:** This issue is resolved up to July 1, 1972. Whole-body and lung-counting data need to be evaluated for adequacy for those radionuclides still relevant from July 1, 1972, onwards. Mixed fission product data should be reviewed in this context.	
26. Data completeness	The ER cites individual dose records and other sources of data. Principal reliance is on individual dose records for the most part.	Completeness of individual dose records may need investigation.	**Post-1972 SEC SC&A update:** The completeness check has been kept pending due to NIOSH's continued work. A plan from July 1, 1972, onwards that includes data quality and adequacy checks needs to be developed. SC&A has started work on developing such a plan.	

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APPENDIX C: PETITIONER/WORKER INTERVIEW SUMMARY FOR THE HANFORD SITE

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S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document Description: White Paper: Petitioner/Worker Interview Summary – Hanford
	Effective Date: Draft – September 8, 2010
	Revision No. 0 (Draft)
PETITIONER/WORKER INTERVIEW SUMMARY FOR THE HANFORD SITE	Page 2 of 45
Task Manager: ____________________ Date: Arjun Makhijani, PhD	Supersedes: N/A
Project Manager: __________________ Date: John Mauro, PhD, CHP	

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	09/08/2010	Initial issue

PETITIONER/WORKER INTERVIEW SUMMARY FOR THE HANFORD SITE

Interviews were conducted with the petitioners and 38 former and current Hanford workers. Years represented by those interviewed range from 1943 to the present. Interviews for the Hanford Special Exposure Cohort (SEC) began October 15, 2007, and will continue on an as-needed basis throughout the petition review process. Two sets of face-to-face interviews were conducted on October 29–November 1, 2007, and December 17–18, 2008, in Richland, Washington, by Arjun Makhijani and Kathryn Robertson-DeMers of SC&A. Additional interviews were conducted over the telephone or answers provided via e-mail. The purpose of these interviews was to receive clarification on the Hanford petition basis and the petition process, accounts of past radiological control and personnel monitoring practices, and a better understanding of how operations were conducted through time. Interviewees were identified through the petitioners, public meeting transcripts, Hanford Atomic Metal Trades Council (HAMTC), and interviewees.

Those interviewed included the petitioners and former and current Hanford workers. Two members of the Advisory Board, Wanda Munn (former worker) and Josie Beach (current worker), were included in the list of those individuals interviewed. Those providing affidavits or comments at the Hanford outreach meetings were interviewed if clarification of the affidavits or comments was needed. Workers represented operations in the 100, 200, 300, 400, 600 and 1100 Areas of Hanford, including major facilities such as the Plutonium Finishing Plant (234-5Z, 231 Z), the reactors (100B, 100C, 100D, 100DR, 100F, 100H, 100K (East and West), 100N, Fast Flux Test Facility (FFTF), Plutonium Recycle Test Reactor, the separations plants (202-S, 202 A, 221-B, 221-T, 221-U, 222-S, 224-B, 233-S, 242-A, 242-S, 242-T, 224-B, Hot Semi-works), the Tank Farms, the fuel manufacturing facilities (305, 306, 308, 313, 314, 333), and decontamination and decommissioning (D&D) areas, including the dig sites and construction. Some individuals interviewed were designated as Rovers, giving them access to all areas of the site. The categories that were represented by interviewees include the following:

- Chemical Process Operations
- Chemical Technician
- Engineering Development
- Laborer
- Maintenance
- Maintenance and Surveillance
- Material Control
- Nuclear Chemical Operations
- Nuclear Engineering
- Planner/Scheduler
- Production Operations
- Radiation Monitor (RM)/Radiation Control Technician (RCT)/Health Physics Technician (HPT)
- Radiation Time Keeper
- Reactor Operations

- Shipping and Handling
- Special Material Processing
- Subcontractors Support Personnel
- Utility Operations
- Waste Management

SC&A's review of the Hanford SEC Petition and NIOSH's Evaluation Report of that petition is being conducted as part of its technical support to the Advisory Board on Radiation and Worker Health (Advisory Board). SC&A explained that the interviews were being conducted as part of this review. Participants were told the interviews were unclassified and not to disclose classified information. Summaries from each interview set were prepared and provided to the interviewees for review. It was explained that interview notes with names (if authorized by the interviewee) are made available to the Advisory Board. A consolidated version of all interviews may be redacted for Privacy Act reasons by the Department of Health and Human Services (HHS) for the publicly released report.

The information the Hanford workers provided to SC&A has been invaluable in providing us with a better understanding of the Hanford SEC petition and its basis. This is not a verbatim discussion, but a summary of information from multiple interviews with many individuals. The information provided by the interviewees was based entirely on their personal experience at the Hanford Site. It is recognized that site expert and former Hanford workers' recollections and statements may need to be further substantiated; however, they stand as critical operational feedback and reality reference checks. These interview summaries are provided in that context. With the preceding qualifications in mind, this summary has contributed to issues raised in the SEC petition evaluation report.

General Information

Workers mentioned that certain contractors were easier to work for than others. According to workers, UNC, DuPont, and General Electric were good companies to work for. There was an enormous difference in culture in the 400 area and with the Chemistry Section, simply because these were new-technology individuals who were futuristic in their concepts. They were not at all secretive in what they were doing. They saw this as the future of the world in a beneficial way, and did not have an "arms race" mentality. They were eager to share information (within the limits, of course). The rest of the site had been operating for close to 30 years, and the old timers were well entrenched in the 1940s mentality (i.e., a secretive, closed-system concept). It's always difficult for a culture that has been established for that long to change to something new.

There were mixed opinions among workers concerning the effectiveness and openness of the Hanford radiation safety program. Many of the interviewees indicated their management strongly recommended that employees work safely. The site was safety-minded, but there was so much development going on, it was impossible to keep ahead of the changes. One worker quoted from *Legend and Legacy: Fifty Years of Defense Production at the Hanford Site*, Revision 2 (Gerber 1995), related to the protection against the unseen danger:

> *The job of the HI Section was especially difficult because strict MED regulations precluded revealing to most employees even the existence of radioactivity. Additionally, onsite Army Commander Colonel Franklin T. Matthias worried that if the workers became concerned about radioactivity, 'this might be disastrous to the project as it might cause a large number of people to leave.'*

Health Physics was considered pretty qualified by many, and thus workers had no reason to question the monitoring process. Workers from some areas found out about hazards after the fact, and felt they were not provided with information about the hazards of particular jobs. Subcontractor personnel indicated when they found something that was a problem, it was implied they should "do something else if you want this job." They would reassign such workers around the Hanford site or they would be laid off.

It was not uncommon for early Hanford workers to have an 8th grade or lower education. Training was primarily accomplished by learning on the job. With the push to get the first reactors up and operating, employees worked 60 hours per week, 10 hours per day. In earlier years, there were no female Chemical Operators at the Plutonium Finishing Plant (PFP). There were a few female RMs.

To enter the site areas, employees had to show their badge at the gate so they could enter the area. In some parts of the 300 Area, individuals had to punch in on a time clock when they went into the area. This was not a universal requirement. Once the worker passed the guard house and entered the fenced area of the 300 Area, they had access to other buildings, even if they did not work in those buildings. Security didn't control access at the building level. It was surprising how free the access was once you got past the gate. Workers talked about having area permits (200 Area permit, 300 Area permit, etc.), which allowed them into particular areas of Hanford. Individuals who were Q-cleared were constantly being rotated between different areas. For 234-5Z, you had to have a special clearance.

There have been several strikes by organized labor at Hanford. J.A. Jones workers went on strike in 1957. In the early 1970s, the Hanford Site contract was split between just two major contractors. J.A. Jones held the construction for the new projects. Construction trades were hired out of local unions. The General Electric (GE) workers went on strike in 1966 over radiation exposure. GE decided that they would increase the weekly exposure limit, so the workers went on strike. J.A. Jones was the construction contractor at Hanford and they supported the strike. The union was on strike for 3½ months. During this time, management fixed what needed to be fixed at the 100N reactor and took the brunt of the exposure during repairs. A third strike at Hanford occurred in 1976. J.A. Jones likely did the same at this time, because they would not cross the picket line.

Fuel Handling and Fabrication

Uranium metal was first shipped to Hanford in January 1944 for fabrication into fuel. The initial fabrication of fuel for the reactors involved trial and error, until they manufactured a fuel that could stand up in the reactor. Finally, they determined that uranium metal in an aluminum cladding would withstand irradiation in a reactor. Uranium was handled in the form of metal and uranium oxide. Fine chips were formed during machining operations.

In Building 313, the fuel for the single pass reactors (SPRs) was cladded with aluminum, and an end cap was added. The end cap was welded onto the rod. Prior to canning, operators had to prepare the furnace. They used lead to get a better heat sink. The furnace (or crucible) was charged with several inches of Pb. This was brought up to a temperature hot enough that molten aluminum could be added on top of the lead. There had to be more than 8 in of aluminum, because the fuel rods were 8 in long. The aluminum and Pb were not compatible and did not mix. With a special pair of tongs, the slugs were lowered through the aluminum into the lead. The lead was heavier, so it would heat up faster, shortening the required heating time. There was a set time it had to be in the lead to come up to temperature. Then the fuel unit was withdrawn into the aluminum portion to wash the lead off. A container was submerged filled up with aluminum. The slug was inserted into the can. At that time, they added a pre-heated aluminum cap on the end of the fuel. They took the fuel and machined it to a certain length. Then they welded the area between the cap and the can to get a good seal. A salt bath was not used with the SPR aluminum clad fuels.

Conditions in Building 313 were hazardous. Employees worked around molten metal pots. The molten aluminum would squirt back and hit the workers, burning them. If a little water was mixed with the molten metal, it would blow out the furnace and material would go right up the stack. These blow ups did not happen too often. During chip recovery, employees wore white coveralls. While canning, workers wore an asbestos apron, gloves, and spats on the feet. In general, workers handled fuel with gloves, but it was difficult to wear gloves when machining with coolant spraying on the material. A worker had to keep the uranium covered or it would catch fire. None of the injuries were monitored for uranium contamination. The workers were patched up and put back to work.

All the early fuels that were put into the reactor were tested in an autoclave to determine if they would hold up to reactor pressure. If the fuel failed, it would oxidize and form a sludge. This material would settle in a settling basin under the autoclave. With failed fuel, the autoclave had to be washed out with water prior to the next test. When the sludge in the settling basin built up to a predetermined level, operators would enter this area and scoop out the sludge (consistency of mud). They wore coveralls, caps, gloves, and shoes to perform this task. Workers involved do not remember whether the job required respiratory protection. Eventually, the autoclave testing was discontinued and rods were tested with induction coils.

Uranium scrap metal (i.e., croppings) was initially fed into 30-gallon drums for shipment off site, but this practice was halted after a fire in Idaho occurred during transportation. The 30-gallon drums were loaded into a boxcar for shipment. As the boxcar passed over the mountains in Idaho, a fire spontaneously started. The boxcar was burned up and uranium contamination was spread throughout the immediate area. Hanford workers had to travel to the location to clean up the uranium. After this incident, the railroad would not ship any more uranium oxide scrap.

Uranium turnings and fine pieces of scrap would spontaneously combust when it was oxidized. It became quite a storage problem, so they tried to develop a scrap recovery process. The scraps and pieces that could be collected were converted into oxide at the oxide burner from about 1946–1948. After a couple of years, it was discovered that putting uranium pieces under oil would prevent the uranium oxide from catching fire. As a result, there were only a couple of fires per year after the implementation of oil.

In Building 314, there was also an operation to convert scrap uranium metal to oxide. The uranium metal in the form of scrap was heated to about 1,400° F in a furnace for several hours. While it was in the furnace, the uranium would oxidize. After the metal was brought up to temperature, it was fed immediately through an extrusion press. An 8-in rod was reduced to only a few inches (e.g., 2.25 in). On occasion, the material would stall or get stuck in the press. Operators used a hack saw to get it out of the press.

When the uranium would oxidize, it would go airborne. The workers were eating and breathing the uranium. There was so much dust in the area that it would dim the lights. They did not wear respiratory protection at first. After a while, dust masks were provided to the workers. The area was so dusty that oxide would settle on the beams supporting the building. This material would form pyramids on these beams as high as they were wide. In 1971, experimental extrusions of zirconium were conducted in the converted old maintenance building right next to Building 314. Workers were told that the exhaust systems were enough to protect them from any harm.

Uranium billets were extruded into rods, annealed after they were extruded, straightened, machined into fuel pieces, canned, and the leftover chips from machining were taken care of.

N-reactor fuel was manufactured in Building 333. The fuel had an inner and outer element (i.e., fuel within fuel). N-reactor fuel used a protective zirconium copper-silicon sheathing, which enclosed the zirconium uranium billets. The billet was lubricated with water-based graphite and oil sprays, then the fuel with surrounding container was pre-heated at temperatures ranging from 1,180°–1,350° F in a furnace. The uranium was then ready for extrusion. The material was removed from the furnace and placed on a loading arm. The uranium billet was extruded into a rod and it was cut to length. Acid was used to extract the copper silicon layer from the rod. Acid was also used to etch the uranium out on the end, so they could add an end cap. Some uranium would etch faster than others. The unit was braised with braise ring to fill the etching voids. The end caps were then welded and checked. The unit was then heat-treated, so the fuel would relax. Salt baths were used in the fabrication of N-reactor fuel. These baths would make the metal relax. If there was warping that could not be straightened, the fuel was discarded. Staff did some experimentation on the removal of warps in the fuel, and was eventually able to mitigate the warping problem.

The 300 Area processed natural and low-enrichment uranium for reactor fuels. As a result, there was not as much concern about radiation exposure as at other areas of the Hanford site. All kinds of uranium (enriched, recycled, and natural) were handled in the same manner. Hands-on workers would not have known the difference when processing the uranium.

The Special Materials Processing group was involved in thorium compaction, which started in 1972 and continued for about 8 months. Thorium powder was vibrated down into a container until the container was full. A cap was then added. They had a hydrogen furnace where thorium was compacted and cintered, so it would not crumble. The thorium compaction was done in the metal preparation buildings. There were four metal preparation buildings that were used for different purposes. In processing thoria, high levels of radioactive material deposited on the steel beams.

There were some small reactors located in the 300 Area. Building 305 housed a 5-watt reactor, which was used for fuel testing and research and development [R&D]. The entire first load of aluminum-clad fuel manufactured was tested in this reactor to determine how it would tolerate reactor conditions. Subsequently, only some of the fuel was tested. Building 336 had a full-scale sodium reactor mock-up located in the high bay. The operators were trained to use a Closed Loop X-Vessel Machine to refuel the reactor.

Hanford ran special irradiations of samples of all kinds in the early years (e.g., ~1947 to 1950). These were taken back to 3706 Building, where they would conduct analyses of the samples. Research and Development (R&D) activities were active in Buildings 324, 325, 326, and 327 that involved multiple radionuclides. Plutonium targets were made in Building 306. Hanford made Np-237 and sent it down to the Savannah River Site (SRS) for irradiation and recovery. Researchers handled and/or separated all kinds of radionuclides (e.g., fission products). Some were brought from offsite and others were used to make up standards. Yttrium was handled and purified in the 300 area.

In the 1970s, workers observed deep orange plumes coming from the stacks of Building 333. This was where the low extrusion press was located.

Single Pass Reactors (SPRs)

There were a total of eight SPRs at Hanford. These included 105-B, 105-C, 105-D, 105-DR, 105-F, 105-H, 105-KW, and 105-KE. 105-B was the first reactor at Hanford to go critical.

The Reactor Gas System feeds the helium into the reactor when the reactor is operating to redistribute the heat in various sections. Reactor gases are to be distinguished from “noble gases,” which are produced in the fission process. After shutdown, oxygen gets into the reactors. Nitrogen is used to purge the oxygen from the reactor at start-up. Helium is used to purge the nitrogen in the system. The gas building housed the system used to circulate gas through the reactor and dry the moisture from the reactor. Reactors were built with a gas atmosphere to get the heat out of the graphite. There were silica gel towers in Building 115 that were monitored, because they became saturated. These huge tanks were probably about 10-ft high and 8-ft to 12-ft wide. An operator would take the tower off line and put in the drying material, if there was an indication of a plug in the tower. There were three towers on 100B reactor. When a tower became saturated, it would be taken out of service and the gel would be replaced. As the reactor gases circulated through the reactor, they became activated.

When there were pipe leaks in the 107 Retention Basin, this would send out steam from highly irradiated water, causing a release of noble gases into the basin. Gas releases also occurred on the X levels (Experimental Levels) of the reactor. An air sample was taken to determine whether the gas was noble gas or reactor gas. Noble gas deposited on the filter, while reactor gas would pass right through the filter. If the air filter indicated a positive count and the decay time was about 35 minutes, this would indicate the presence of noble gas. The reactor gas would pass right through the filter and no count would be detected.

Reactor and noble gases were monitored by taking open and closed window measurements with a Cutie Pie (CP). With an open window (OW) CP, beta and gamma could be measured. A closed window (CW) CP measured only gamma radiation. These measurements were used to establish requirements for respiratory protection. If the difference between the OW CP measurement and the CW CP measurement was five or more, and the CP needle was wavering back and forth, this indicated there was noble or reactor gas present. A surface correction factor of 4.5 (rounded to 5) was multiplied by the difference between the OW and CW measurements. For example, if the OW was 30 mR/hr and the CW was 25 mR/hour, the exposure attributed to noble gas is (30 - 25) * 5 or 25 mR/hour. The storage basin or front face area was put on mask when the corrected OW reading reached 25 mR. A canvas curtain was rolled down between the reactor and the work area to reduce the gases escaping into the work area.

Shortly after the 100-B reactor started up (~1946–1947), scientists discovered the graphite was growing. 100-B reactor was shut down while 100D reactor experimented with different gases. The far side of the graphite moved over so much at the top that there was a heavy neutron beam coming out of the reactor. They had to close off that passageway. C-clamps were used to hold it and weld it until operations developed a different atmosphere. The gas changed from helium to CO_2 and helium. The combination of CO_2 and helium controlled the growth of the graphite. The 100-B reactor was started up again. GE was responsible for changing the gas system in the reactors. At one point, the graphite in 105-D was thought to be so bad, they built the 105-DR (105-D Replacement) reactor. There were also graphite cracks at 105-F, and there were neutron beams penetrating the cracks at 105-D and 105-F.

In the SPRs, vertical safety rods containing boron were inserted into the reactor from the top. Horizontal Control Rods, also containing boron, provided additional control of the reactor flux. A third safety system was used at the 105-B, 105-D, and 105-F reactors. There were four tanks containing liquid boron adjacent to the reactor. If the other safety systems failed, the liquid was released into thimbles to shut down the reactor. During an inspection in the early 1950s, the thimbles were found to be corroding. Failure of these thimbles would allow liquid to seep into the graphite, so the liquid boron safety system was replaced with the Ball 3X system. The boron ball system served as a backup for the control rod system in the reactors. The boron metal balls were stored in hoppers and could be released into the reactor if necessary. B, D, and F-reactors had 29 ball hoppers (2 inches long by 1.5 inches in diameter).

Aluminum splines (1/2 in x 1/8 in) were used to adjust the flux in particular hot spots of the reactor. The splines had to be pulled out of the front face of the reactor and were dropped into the basin when no longer needed. The splines were attached to the spline puller on the elevator. A barricade was established to limit access to the area. Operators and support staff would get behind the shielding and the splines would be pulled out. Once the splines were removed, they would drop down into the C-elevator pit at the front face of the reactor. Occasionally, work had to be done to repair control rods. During these jobs, there was a potential for neutron and gamma exposure, because individuals were working at the front face of the reactor.

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Operations would exercise the ball hoppers periodically. They used a vacuum to suck the balls out of the reactor. Occasionally, they removed a very radioactive ball (reading up to 1,000 mR/hour). At this point, they would have to back away and rope off the area. Balls would have to be transferred to a cask and removed from the area. Balls that became stuck would sometimes be pulled out with the rod. The RM would use a Totem Pole or Teletechtor (Tele) to locate the ball; the operators would retrieve the ball with a rod and duct tape, and drop it into a lead shield.

A couple of times a year, starting in the 1950s, individuals would have to enter the area under the reactor (i.e., the Ball Room) and shovel up the ¼-in poison balls during outages. They suited up in coveralls, leather gloves, a half-face respirator, and shoe covers. Their task was to enter the room, shovel material into a bucket, and exit the area. Because of the radiation field present in the area, each worker would only be able to shovel 4–5 scoops before they burned out. The balls, along with graphite and boron ball dust, would plug the hoses in this area. Workers would have to bang the hoses on the floor in an attempt to unplug the hose. The Control Room monitored this area remotely, but at one point requested a verification of the readings in this area. The dose rate at 3 feet from the hoses containing the balls read 6,000 R/hour with a Teletechtor. For this operation, they would borrow individuals from the 300 Area, because there were short time limits on entry into this area. These individuals brought their dosimetry with them. Some workers remember wearing a job-specific film badge, as well as their routine film badge, for this task. This was probably the most radioactive part of the reactor.

There was an instrument room on the far side of the reactor next to the X-1 area. If leaks or ruptures were suspected, this instrumentation would indicate this. It was a qualitative indicator of a tube rupture. The system measured the gases from different parts of the reactor. Once a leak was identified, the location had to be pinpointed. Rupture recovery involved the recovery of affected fuel from the reactor and the aluminum tube. As a result of fuel ruptures, contamination was spread to the effluent system and the work area. The fuel swelled up in the aluminum tube so much it could not be pushed out. It had to be pulled out of the reactor from the front face or the graphite would be damaged. It was messy. This involved short-term work by lots of people. Another method to detect possible fuel ruptures was to analyze water samples taken from the A, B, and C levels for high radioactivity levels.

The North and South transfer pits in the basin area were used to facilitate transporting fuel to the 200 Area. The fuel was moved under water by a monorail system and put into a cask. The cask was raised out of the water, surveyed, and loaded into a well car. The well car was able to enter the building for loading.

There were occasions when reactors were modified. Sometime in the 1940s, a crew was asked to jack-hammer a big hole through a reactor (not sure which reactor). They dragged some type of rod (20-ft long) out into the courtyard and put it in some form of leaded container. This was covered with a mound of dirt. Millwrights removed hoppers off the top when the carbon broke and put new carbon blocks in at the reactors.

An effort was made to clean up K-basins in the 1970s. This was a tremendous job involving 100/300 Area workers for about 3 years. The clean-up was done because the basins were

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leaking. They circulated the water, removed the filters, washed down the walls, and did other general clean-up. The basins were cleaned up to the point where the PPE (personal protective equipment) could be downgraded. Around 1983 or 1984, they went to K-West Area and refitted it. DOE decided to remove fuel from 100-N basin and store it at the 100-KW basin. K-East/K-West Area was clean prior to this.

In 1975 in the 100-D area, a crew of subcontractors went in and sampled the biological shield around the reactor. This required drilling in through the wall.

When operators were positioning the fuel in the reactor, they used aluminum spacers to position the fuel in the graphite center. Those spacers become very hot. If they were recoverable, they were taken to the wash pad and cleaned with Turco oxalic acid or nitric acid and used again. If they couldn't be recovered, they were packaged. These packages were put into burial carts and moved to the "hot garbage dump" for burial.

In 1608 Building as a part of a D&D project, workers were asked to remove some old pumps. The work had to shut down in the late fall for the winter and resumed in the spring. The fixed contamination levels detected in the spring in the pits were about half what they were in the late fall when they quit. The 115-D Building was in the process of being torn down in the fall. The contractor attached a hose to a fire hydrant to wet the area and keep the dust down. When they were finished, they did not get the flange tightened enough and the hydrant leaked. There was an underground tunnel that ran from the rear face to the stack area. The water leaked down into the tunnel and pulled tritium out of the walls of the concrete. A water sample was collected and analyzed. The water contained high concentrations of tritium. There was also a second building at 100-D where the rain water had leaked in. This area was also contaminated with tritium. This presence of tritium at 100-D was not discovered until the late 1980s/early 1990s.

Experimental tests were conducted with various fuel elements (which were sometimes called metal) in the reactors. Metals tested included U-235, U-238, and tritium (also referred to as "co-product" or B-metal). These fuel elements would sometimes affect the response of the reactor power levels, and adjustments had to be made to start up the reactor. There were three X levels in the SPRs. Each level had horizontal holes to test the radiation effect on different materials. There was some instrumentation kept here. They used bees wax traps to monitor the effects of neutrons. After irradiation, the test fuel elements were removed from the reactor and taken to the testing area of the storage basin. The fuel element was cut open. When this was done, bubbles of radioactive gas would come up through the water and become airborne. Bubbles were also produced when a fuel element developed a pinhole leak in the aluminum can around the uranium or tritium. When bubbles were observed, the storage basis was put on mask until the gas cleared through the exhaust system.

One RM recalls working on the X-Level of the reactor on his first day. The Irradiation Test Group was pulling a very radioactive sample from the reactor. The sample had to be quickly removed and Pb stacked around it to reduce the exposure. Radiation levels were measured in the room directly below the floor where they worked. There were some experimental irradiations at D-reactor in the late 1940s and early 1950s to support the RaLa project.

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Building 231 had an area where packaged tritium was stored, awaiting transport by a courier. The P-10 facility was highly contaminated with tritium. In the late 1980s/early 1990s, tritium became an issue in the 100-B Area when they started to dismantle the 108-B building. As they were tearing down where the tritium was being processed, the bioassay samples of the D&D workers reached high levels. The RMs could not detect tritium with their portable instruments, because tritium had such a low energy that it could not penetrate the windows of the Geiger Mueller (GM) probes they were using. DOE stopped work on that building for several months, until they got some portable tritium monitoring equipment from Germany.

The 108-F Building was used for animal experiments on fish, dogs, and pigs. There was a fish lab where they diverted process water to expose fish. There was also an outside area used for vegetation experiments. There was also a glass blowing shop, where they made the pipettes for the various labs.

The primary concern in the 100 Areas was external exposure. The real hot areas of the reactor were the wash pad area, the rear face discharge area of the reactor, and the top of the unit in the later years when workers had to vacuum the balls out the reactor. At the power house, the hazards were mainly nitric acid and other chemicals. Reactor Operators and support personnel worked in different areas of the reactor (e.g., top of reactor, face of reactor, storage basin areas). Radiation chambers with alarms were situated throughout the reactor buildings. The alarms would sound if the radiation levels were elevated.

The SPRs were not completely shut down, but were maintained at a subcritical level. The inner rod room had higher neutron dose rates than gamma dose rates during reactor operations. For example, RMs would get neutron readings three to four times higher than the CP readings. Elsewhere in the routinely occupied areas of the reactor, the photon exposure was dominant. Although there was typically no entry into this room while the reactor was up and operating, there were occasions where it did occur. Access was allowed to the outer rod room when the reactor was up.

Neutron surveys were conducted on a monthly basis and when neutron shielding material was disturbed at the reactors. In general, no one was allowed on the top of the unit when the reactor was at full power. Survey dose rates were a combination of photon and neutron dose rates, unless otherwise noted.

Neutrons were detected at the front face of the reactor during operations. Neutron dose rates extended 30 to 40 feet from the elevator on the front face of the reactor into the work area for the SPRs. Depending on the reactor, dose rates ranged 5–10 mR/hour (gamma + neutron) in the front face work area. The Operations group prepared fuels for charging in this area a week prior to charging the reactor (while the reactor was still operating). They were sent to this area with neutron pencils and neutron badges (neutron film badges were not known to be very accurate in detecting neutrons in the 1940s, 1950s, and 1960s).

The older reactors were notorious for neutron beams through stairwells. Individuals knew where to duck to avoid these beams. This was a particular problem at the 100-F Area. These were identified with BF_3 detectors by RMs. Documentation available indicates that they were looking for neutron leaks in the reactors as early as 1947. Neutron leaks from the reactors were located using 14 in x 17 in film. The neutron beams identified were actually crescent-shaped coming out of the reactor.

Several groups may have been interested in neutron energies at the reactors, including the 300 Area Calibration group, the Health Physics group, and the Irradiation Testing group. They may or may not have conducted some studies of neutron energies in the work areas at the reactors.

Alpha contamination was not of concern and was not routinely checked for at the SPRs, although it was possibly present. Skin contamination incidents in the reactor areas were quite common during the operation of the SPRs and N-reactor. One activity which led to several personnel contamination incidents was the charging of the reactor. While charging and discharging the reactor, primary coolant water flowed from the reactor on top of the employees. The water came into the front face. When an operator went into the charge-discharge, they had to channel the water into the relief riser. If they were not careful, the relief riser would overflow and water would fall down on them instead of going into the effluent line. This happened quite often, especially with new people. There were times when primary coolant water splashed in the worker’s face or made its way inside protective clothing.

Some Reactor Operators had measurable Na-24 in their in-vivo counts. When asked what the source of Na-24 was, a former RM thought the source of Na-24 in reactor workers was due to activation of elements in the blood.

100-N Reactor

100-N was a cogeneration plant which produced plutonium for weapons and steam for electricity. The N-reactor fuel cycle varied with targets being irradiated. During the Reagan administration, the N-reactor was shut down for refueling for a period of 7–10 days every 28 days. There was a time when the reactor was run for 83 days straight, because there was a large need for electrical power. This took precedence over the need for plutonium. Twenty-eight full-power days made for optimum weapons-grade plutonium production. The 100-N Area storage basin was different from other reactor storage basins, because it could store fuel cans stacked three high in the basin. When the reactor was shut down, the N-reactor fuel was transferred to the 100-K Area.

Reactor Operators were responsible for the valving of the reactor, charging and discharging of fuel, and maintaining the storage basin. Maintenance, laborers (including subcontractors), RMs, and other support staff were also involved in charging and discharging fuel. Contractors such as J.A. Jones and Kaiser supported fueling and maintenance of the reactors.

To charge the reactor, the operator had to enter the Valve -11 and Valve -12 pipe space. They would turn down the flow to Valve -11, go to the opposite side of the reactor, and turn down the flow to Valve -12. In order to access the pipe space, the operator would have to go in through the bottom and come out through the top. Both of these areas were high radiation areas, so they would run out of allotted dose. Entry into this area did not typically require respiratory protection. The caps on the front and rear face of the reactor were loosened. A tip-off was

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added to the rear face of the reactor. The old fuel was pushed out, while the new fuel was pushed in. The caps were replaced after the reactor was charged.

At 100-N, the protective equipment for charging the reactor included a face shield, British leggings (i.e., rubber boots), a poncho, and rubber gauntlets (i.e., elbow-length gloves). The gauntlets were taped to the raincoat. While charging and discharging the reactor, primary coolant water flowed from the reactor on top of the operators. There were times when primary coolant water splashed in their face or made its way into their sleeves. In the mid-1980s, a requirement for use of full plastic hoods (similar to the MSA hoods used at K-basins now) was implemented for skin contamination control. This reduced the number of skin contaminations at 100-N.

When the cooling water left the N-reactor or its basin, it was sent to a crib or trench. The soil was supposed to keep radionuclides from going to the ground water. The reactor leakage rate was approximately 125 gallons of water per minute. The older of the two cribs became saturated, requiring a new crib to be opened.

When a skin contamination occurred, the workers typically decontaminated themselves. The RM had the workers go to the decontamination shower or sink (e.g., at the zero foot at 100-N) to do this. At times, it would take multiple washings.

According to RadCon procedures, the area was washed three times with soap and water as a first attempt at removal. If this did not work, potassium permanganate and sodium bisulfate were tried. In some cases when this didn't work, the area was covered with a glove or plastic and the contamination was allowed to decay, or the individual was allowed to sweat the contamination off. This approach required approval from the Radiation Monitoring Supervisor or the Analyst.

The D Machining room (off the D-elevator) was where maintenance and decontamination of valves and other reactor parts was done. Operators would decontaminate these items to reduce the exposure others received. These shops were considered hot. The Ball Drier Room (100-N) was an area in the reactor where the Samarium balls were washed and dried. The Gas Drier Room (100-N) contained driers that dried the helium prior to circulating it through the graphite.

The N-reactor was used to produce isotopes for hospitals. Scientists at Battelle would send samples to N-reactor to be irradiated in a special tube. These were irradiated for minutes to days, removed from the reactor, and placed in a pig for transport. Lithium targets were used to produce tritium at the N-reactor. The inner rod had to be separated from the outer rod and sent back to Oak Ridge for tritium recovery. By the time it reached Oak Ridge, much of the tritium had dissipated. Tritium was also produced as a byproduct of water passing through the reactor. There was a tritium monitor in place from 1978–1987 at N-reactor, which could detect tritium in the air at the pick-up chutes. This was the only place where an airborne tritium monitor was used.

The graphite at the top of the 100-N reactor was expanding. As a result, a portion of the graphite was removed from the reactor in approximately 1983. This expanding affected the fuel canals in this area of the reactor, so only the smaller fuel rods could be used.

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If a fuel rupture was detected, the reactor was shut down and cooled down to about 100 degrees and operators would go into Zone 1 to make preparations to discharge the ruptured fuel, normally between 8 to 12 hours after shutdown. This time period was shorter than during normal refueling entry of 3 to 4 days and did not allow the ambient temperatures to cool down. These conditions caused the face shields to fog up, so the tendency of operators was to raise the shield or tip their head so they could see.

As with the SPRs, the primary radiological concern at 100-N reactor was external exposure. Activation products were one source of exposure. Originally, samarium oxide balls were used in the N-reactor. The activation of these balls was producing a lot of radioactive europium, so they were replaced with boron carbide balls to fix this problem. To harden the seats on some of the valves, stellite was added. This became activated, producing a Co-60 source term. Other non-traditional sources of exposure at 100-N included a Cf_{252} source used for conducting irradiation experiments, and painting the Golf Ball (i.e., tank). This held contaminated water, which gave off considerable radiation. The Painters who periodically had to repaint the tank picked up significant dose from this work.

A number of workers expressed concern about receiving higher doses at N-reactor. Larger doses were received during certain reactor activities over short periods of time (e.g., charging and discharging, entry into the Ball Room). For example, one contractor employee received 800 mrem for 3 days. There was a Ball Washer Room where the samarium balls were washed with solution. The radiation exposure was so high that the workers were limited to less than 5 minutes in the area, so they would not exceed their 300 millirem for the week. There were people lined up outside the room to run in and out to complete jobs in this area because of the limited time an individual could be in the area. There was also a potential for internal exposure. One interviewee who worked with the construction contractor reported that he pulled the air breathing equipment off and the contamination got all over him while working at 100-N. If an individual was at a lower exposure level prior to very hot jobs, they were used on these hot jobs. Supervisors did “catch up” on the other guys, because they needed to tap everybody, so that no one would be over the exposure limits.

Alpha contamination was not initially a concern at 100-N; however, this changed when alpha contamination was discovered in a sample of mud at the horse trough area (10–20K dpm). The RMs waited for 3 days for the area to be cleaned up; then when nothing was being done, the DOE Radiation Protection Manager was informed. The following day, J.A. Jones was sent out to cover the area with clean soil. When they performed surveys (around 1986 and 1987) in the transfer area of the storage basin at 100-N, it was common to check contamination with both beta/gamma and alpha survey instruments. If alpha contamination was discovered, entry into the area required respiratory protection. Collection of smears in this area was difficult, as there was a lot of moisture around and RMs were told to take dry smears to prevent alpha shielding. This was in contrast to FFTF, where RMs were told to take wet smears to better pick up Cs-137 contamination.

Fast Flux Test Facility Production and Radionuclides

Westinghouse Hanford came to Hanford in 1970, primarily to design and operate FFTF. The reactor was under construction by the mid-1970s. It had been designed as a larger facility. Political wrangling had reduced the budget and had pushed the design to a smaller physical facility; some aspects of construction had to be scaled down, though the reactor was still the same size. FFTF started up in 1982 and shut down in 1992. It operated for 10 very productive cycles. Westinghouse Hanford remained until they lost the contract in 1996.

The reactor had specific experimental programs designed for testing parameters (e.g., thermal decay tests, reactor safety systems). The mission was to test the fuels, materials, and components to make an inherently safe breeder reactor. FFTF was not a breeder reactor itself. As a result, the fuel change frequency for the reactor varied (both short and long time periods) based on the test. FFTF would run at full power and then turn off the reactor to test the decay constants of the reactor and safety systems. The reactor had reflectors (composed of primarily a nickel alloy) to prevent the neutrons from leaving the reactor. This created a harsh neutron environment in the core. There was some activation of the nickel components in the reactor. FFTF did not use blanket assemblies.

FFTF was designed such that the flux could be shaped any way they wanted it. This meant they were capable of creating unusual radionuclides that could not be produced in water-cooled reactors or in accelerators. FFTF did not produce large quantities of isotopes, though they tried towards the end of the project to convince the DOE that they could be an income-producing aspect of the department's program. Politics indicated that this was not to be the case. The U.S. is [now] lacking in fast neutron facilities, requiring us to get medical isotopes created from fast flux internationally. At one juncture, staff was able to show that there are 22 isotopes that required a fast neutron flux, such as that at FFTF, for production. DOE did not accept this as an adequate justification for keeping FFTF operating. It was shown that with contracts with other countries and U.S. sale of isotopes, FFTF could meet 75% of the operating budget. DOE indicated that the facility had to be fully self-sustaining, though this requirement has not been imposed on any other facility in the DOE during its history.

FFTF supplied several isotopes, especially alpha emitters that were used for a couple of brachytherapy experiments. The push was to identify specified energy alpha emitters that had short half-lives and could deliver a great deal of energy to a very limited area of tissue. Copper-67 was being used in human breast cancer trials. The breast cancer tests were showing a great deal of promise, but this method of treatment had to be shut down, because there was no reliable source of the radionuclide. FFTF produced very small quantities of gadolinium (pCi), which were shipped to a children's hospital. They had a premature infant [preemie] that had a severe malformation. They used the gadolinium to identify the placement of internal organs for this preemie. FFTF had a small office that specialized in making sure that short-lived isotopes could be transported fast enough to still have enough activity to be of use.

There was some experimental separations work associated with the Materials Test Assembly. FFTF took the precursor materials and shaped the isotope that was wanted. This is not what you think of normally. The foil or sample would be removed remotely and sent to the 300 Area for separation in Buildings 324 or 325. FFTF held three international contracts that were voided because of the shutdown order. The tests were extensive radiation tests for a potential fusion facility for the Japanese. There was some production of lithium targets and some interest in producing tritium.

FFTF did not have the kinds of distinctions that organized labor forces on people. There was a dedicated maintenance crew at FFTF. Maintenance and construction workers were unionized, but operators were not. At FFTF, the maintenance, crafts, and clean-up crews were a part of what FFTF did. There was no major division between job types. The employees at FFTF were pretty much a seamless team. Engineers relied on the maintenance people without question, because they knew the equipment. Maintenance relied on their engineers when something needed to be changed.

Separations and Tank Farms

The separations facilities were designed to separate plutonium and uranium. The facilities also separated a lot of fission products. Somewhere in the 1960s, Hanford started up fission product processing. B-Plant was revamped and new equipment for solvent extraction was put in. Strontium (Sr) and Cs heated material in the tanks, causing some waste tanks to boil. They wanted to remove the Sr and Cs from the underground storage tanks to make them safer. Strontium and Cs capsules were produced and are currently stored in Building 225-B.

There were a lot of other radionuclides in the waste (e.g., promethium, neptunium, cesium, strontium, uranium). During the Cold War, there was an effort to recycle uranium from the tanks. This was due to a shortage in uranium supplies. Somewhere it dawned on someone that there were thousands of tons of uranium in the underground storage tanks. After all, practically all of the uranium used for producing plutonium was discarded as byproducts to underground storage in million-gallon tanks. After several years, the uranium solution from early plutonium production settled out and deposited a layer of uranium and assorted fission products on the bottom of the tanks. The process at 241-UR was to remove the liquid above the sludge (solids) and slurry them via high-pressure water streams into a process tank, where acid (nitric) was added to the slurry (a mixture where solids are suspended in a liquid). Once the slurry was acidified, it was transferred to 221-U as a nitrate, where it was purified. This solution was then transferred to 224-U, where it was converted to powder.

All reactors were beginning to run at higher power levels and produced higher neutrons per gram per second of plutonium and higher levels of mixed fission products (MFPs). The high Pu-240 content from fuel-grade plutonium from N-reactor was responsible for the neutron dose rates observed at PUREX. This was especially the case at the mixer dumper and calciner in N-Cell at PUREX. There was also Zr and Nb present in N-Cell in 1985. This may have been because of the fuel being processed or less than adequate removal of fission products in the process. There was about a 200–500 gram hold-up in this area. The plutonium solution known as feed for the calciner was analyzed prior to being shipped to PFP.

Hot Semi-Works was located close to A Tank Farm and down the road from B Plant; it served as the test facility for the PUREX process. There were several hot cells in this building. The

PUREX maintenance group supported this facility. There were pipefitters, a millwright, a supervisor, an RM, and a welder. Instrument and electrical personnel were rotated into this area as needed from PUREX.

The Q-cell at PUREX was used for the production of Np-237. The loadout was monitored with alpha instruments for smearable contamination. Cutie Pies were used to determine gamma readings next to the bottles of Np-237. The N-cell, Q-cell, White Room, L-cell, M-cell (the decontamination cell), and some laboratory areas' alpha contamination were present. Analysis for U-233 took place at the PUREX lab in the late 1960s.

There were several jobs that resulted in external exposure to separations facility operators. The operators working in the processing buildings received the most exposure while sampling in the canyons. This was a routine assignment where operators followed strict written procedures and used specialized equipment designed to offer maximum shielding to the sampling personnel. The operator taking the sample would go to the sample room where the risers were marked at the various sampling points. For this operation, individuals dressed out and wore a mask. Most samples were taken with a Bayonet. The cap was taken off the process pipe and the sampler pushed in to make a seal with the Bayonet. First, you would clear the cup at the bottom of the sampler. The pipette had a riser in it and the sample got sucked up into it. Some samples were put into pigs (heavy shielded containers). Other samples were put into a stainless steel container. When the sampler was full, it was taken to the lab for analysis.

The primary function of 233-S was the final purification and concentration of plutonium. After the REDOX processing, plutonium nitrate was sent to 233-S. The operation was mainly to concentrate the plutonium nitrate down to 8 gallons. There were special runs in the 233-S Building, which occurred maybe once a year. Workers did not know what they were concentrating. The radionuclides used in these runs were referred to by code names, rather than their isotopic names. One special run was made to support the Airline Reactor Program (i.e., nuclear powered bomber on the drawing boards that could fly for months without refueling). This program was eventually scrapped. Neptunium (Np) was also concentrated and sent to the SRS. The Np had been separated from the regular process streams. The product was put into product cans for shipment. At one point, they were running out of product cans, so management directed the operators to overfill the cans. As a result, there were spills of radioactive material, which is one source of the hot floor drains. Taking thief samples for laboratory analysis from these cans caused additional spills and required the operator to come in closer proximity to the product.

All the process equipment was in the highly contaminated greenhouse. Nobody went into the greenhouse normally. One of the ways they controlled the spread of contamination was with the air flow. The air flow went from the cleanest areas toward the hottest areas. Neutrons would be expected in Building 233-S, where the plutonium solution was concentrated. After concentration, the plutonium was shipped to Building 234-5Z.

One of the upgrades to 233-S was the installation of an Anion Exchange Column during 1961–1962. This process worked using the same principles as the common household water softener. When the solution passed through the column loaded with resins, ion exchange grabbed and held impurities in a solution. This improved the process. An interviewee was assigned to operate the Anion Exchange one night. When he relieved the swing shift operator, he noticed that the monitoring instrument on the waste stream indicated a malfunction that was trending near the limit that required shutting down the process. He went to discuss this with his supervisor. Shortly after this, there was what sounded like an explosion that shook the building and blew open the instrument doors on the control panel. A fire occurred in 233-S in 1963 destroying the anion exchange column. The process was shut down and the Fire Department was called in. The next day, the interviewee was the first person sent back into the building to retrieve charts from the recording instruments. Note that there is no special shielding in 233-S other than Plexiglas, and no leaded glass. It was difficult, because there were no lights. For several months, crews worked on cleaning up the mess from the explosion. There was a lot of contamination and dust (i.e., 2 or 3 inches deep on the floor). As a result of the fire, the plutonium nitrate was converted to plutonium oxide.

One method used during the clean-up was to fix the contamination in place by painting. This became a problem during D&D of the facility, because the paint was flaking off and it was a horrible mess to try to clean up. The steam line in 233-S was supposed to be a clean line; however, 17 million disintegrations per minute were detected with an Eberline E600 meter with smart probes. There were areas where smearable alpha contamination was so high it could not be quantified with the alpha meter.

The 222-S Building is the principal laboratory for the Hanford site. Chemical Technicians perform a variety of analyses (e.g., gamma energy analysis, alpha energy analysis, thermogravimetric analysis, Inductively Coupled Plasma-Mass Spectroscopy, Emission Spectrometry, plasma coupling) using various instrumentation. They handled radioactive material (e.g., plutonium, americium, mixed fission products, thorium, neptunium, uranium) in all forms (i.e., gas, solids, liquids). Laboratory workers handled thorium as a liquid. They handled Sr and Cs as powders and liquids in Hot Cells. Several dilutions were made from samples and analyzed in open-faced hoods. A majority of the material handled at the 222-S Laboratory was MFPs. The lab was involved in analyses on mice, crows, snakes, and other animals. They were also responsible for the evaluation of environmental samples. Laboratory personnel also make standards. There were a multitude of standards that were stored in the Standards Lab (Room 1G Section), including plutonium, thorium, strontium, uranium, and cesium standards. Special Nuclear Material (SNM) standards were prepared in this room.

In 1979, 222-S Laboratory analyzed some thorium nitrate for the purpose of disposal. There were some outside underground tanks of thorium nitrate at the east end of U Plant. Thorium in these tanks was left over from the thoria runs conducted in the late 1960s. Samples were collected from the tanks and brought to the 222-S Laboratory. Aliquots of the samples were taken, and destructive analysis was run on the aliquots. The 222-S Laboratory also did Pm-147 analysis in the 1960s and worked on several different types of fission products. There was a shed on the east side of 222-S that was contaminated by Pm-147. There may have been a spill.

The primary contaminated areas at 222-S were in the hoods and the hot cells. Other areas of the lab were generally clean. In the 1940s, the contractor was worried about what the lab workers would be exposed to in the 222-T and 222-B labs. As a result, they would put mice above the

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heads of the workers, but they did not tell the workers why the mice were there. They recalled mice changed out from time to time. Interviewees indicated that documents on this are likely buried.

Some operations at the laboratory took place on a bench top, such as cleaning sample containers. The liquid would be vacuumed by the use of a steam jet out in a hood. If the reading was less than 5 mR/hour, they were manually deconned with solvents like acetone, etc., in the open air and not in a fume hood.

Other facilities mentioned by interviewees included the 242-S Evaporator Facility, which started up in 1972, and the 242-A Evaporator Facility, which started up in 1976. At 242-T Evaporator, they started bringing plutonium in to mix with the material being evaporated. The waste may have come from 234-5Z. This was not done for long, because facility management was told it was not a good idea. After they abandoned the evaporator idea, the waste was sent to the tanks.

Tank Farms

A tank crew consisted of 12–15 individuals, including an RM, two riggers, a crane operator, 3–4 operators, an electrician, and a pipefitter. This crew was responsible for changing jumpers on diversion boxes, as well as cleanup and installation of equipment. The diversion box had several pipes coming off of it, which could direct flow to particular tanks. Jumpers were nozzles with heads that were used to control the flow direction of waste to the tanks. In order to change a jumper, a crane was used to move the heavy blocks off the tank. The old jumpers were removed and the new jumpers put in place. Some of the diversion boxes were on top of the tanks and some were located off by themselves. These nozzles had to be replaced whenever they failed.

Operators sometimes took samples from the Tank Farm liquids using a 4-ounce bottle tied to string with a rock fastened to the bottle for weight, and a mark was made on the string to indicate the depth of the sample. The workers suited up in PPE and a respirator. The bottle was lowered into the tank to the marked area on the string. Once they reached this point, they pulled the bottle out and put it into a plastic bag. Samples were sent to the analytical lab. Both 200W and 200E had their own laboratory. The people working in the labs got a lot of radiation exposure.

Scavenging was the earliest process done on the tanks. Chemicals were added to the tanks and they were sparged. This caused the sludge to precipitate out. Operators pumped the supernatant out and into an open ditch across the street 4-ft deep and 60–100 ft long. On graveyard shift in the 200 East Area, workers were doing a scavenging job. They had installed a pump that had a floating suction on it, so it floated in the liquid above the level of the sludge. They pumped the supernatant. The dose rate on the sludge caused the CP against the line to go off scale. The pump was immediately shut down. The content of the pipe was uncertain. The whole system was back-flushed into the tank.

The Saltwell systems were used to pump all the liquid out of the tanks, except for a small part at the bottom. The liquid seeped into the tank and was pumped out slowly. That left a cake in the tank. The site is now sluicing all the cake out. A lot of the tank content is like peanut butter consistency, sometimes making it difficult to get the stuff out.

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One of the tasks at the Tank Farms was to load out ball-shaped casks for shipment. Workers would hook up polyethylene tubing to the cask and the tank. The waste was jetted out of the tanks, filtered, and put into the cask. At 50 feet, the CP would go off scale. They used a crane to load the cask onto a railcar. One could always tell when they had a train shipping this material. It was so hot that in the winter, all the snow would melt around it for 100 feet. Some of this material was sent to New Mexico and some back east. It was always top secret. Workers did not know exactly what was going on. Although they had to fill the casks, they had no idea what material it contained. Someone was separating whatever they were looking for out of this waste. It was a challenge to remove the polyethylene tubing. It had to be cut after it was flushed out. When they handled the tubing, they used tongs and stayed at least 3 feet away, because of the dose rate. Workers put the tubing in plastic bags and put it in the burial ground. The tubing was disposed of and new tubing used each time. This cask loading was done several times a year.

Tank Farms workers were aware of potential exposure from alpha, beta, and gamma radiation. They were not concerned about the alpha exposure, because the beta and gamma exposures were so much higher. There were various locations at the Tank Farms where the dose rates were very high. For example, when pumps on the tank were damaged, an entry was made into the area to replace the pump. This had to be done somewhat remotely, because the dose rate was too high adjacent to the pump area. To avoid overexposure, workers were not allowed to work very long in these areas. The operators that worked in the Tank Farms and those that ran the cranes and the pumps, lifting material up and putting it into plastic bags, got a lot of radiation—more than those who took the samples. Work on diversion boxes at the Tank Farms resulted in as much radiation as any place. Employees papered the areas around the boxes, and then took the blocks off. Since the area was very radioactive, staff used mirrors to guide the work while maintaining some distance from the source.

Timekeeping was used in the Tank Farm areas where dose rates where particularly high. The RM measured the dose rate (R/hour) and provided this to the timekeeper. The timekeeper had a clipboard with the names of the people on the job. The timekeeper calculated how long the person could be in the area and receive only the allotted daily dose or weekly dose. If they reached the dose limit, they could not go in for the rest of the week. The timekeeper told individuals the number of minutes they were allowed in the areas and notified them when they were to come out. Respiratory protection was required when the diversion boxes were opened.

There was a great deal of public concern about the Tank Farms. Many people have heard, wrongly, that Hanford is the most contaminated place on earth. When the Single Shell Tanks were built, designers did not expect them to remain reliable for 25–30 years. Some of the tanks developed leaks over time; however, the contents of the Single Shell Tanks were moved to Double Shell Tanks. An effort was made to flag fugitive waste areas. There were quite a number of these areas at the Tank Farms.

In 1975 at the 241-T Farm in 200-W, a crew helped a contractor drilling test wells to see if some of those tanks were proven leakers. Near 109 Tank, they got down to 92 feet. An acute exposure was received by one worker from sitting on the 'clam-shell' casing trying to break the sample free from it. He was told some minutes later into this activity that the CP (located about 10–15 feet from the worker) was reading the maximum dose for that instrument at the highest

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scale. Since his instrument was already reading at the maximum dose at this distance, the RM could not survey the sample itself. The RM advised the workers to get the entire sample and 'drill' clam-shell into the 55-gallon lead-lined drum they had about 30 feet from the tent they were working in. The workers were told the sampling was complete after this. After that, they stopped all drilling at the tank farm.

The Tri-City Herald reported that absolutely no tanks had leaked contents into the ground at Hanford, which many interviewees believed to be a complete fabrication. Last summer (2007), the local newspaper shared the fact that the Tank Farm was being covered over with an impermeable layer to keep the site's most serious tank leak from migrating further into the ground, which seemed to support the interviewees' position on this issue. Reflecting on the fabrication that leaks had not occurred at Hanford Tank Farms, it is easy to recognize the danger that fraudulent practices have placed upon the health of workers. The workers involved questioned whether Hanford was being truthful to the workers, since they were not truthful to the public.

Apparently during the well drilling activities with Hatch Drilling, who was subcontracting under J.A. Jones during the 1970s, workers were not made aware of the potential for finding contamination [due to leaking tanks]. Radiation Monitors did not provide continuous coverage during the sampling, and there was no follow-up in terms of bioassay or additional monitoring to the workers' recollection in this situation. The site did not think these workers were at high enough risk to warrant extra monitoring.

When asked what types of materials were buried at the burial grounds, one interviewee replied, "Why not ask me what wasn't buried out there?" Burial goes back all the way. In 1943, the site buried the stuff from the mess halls and construction. At that time, there was an uncontaminated burial ground a mile long and half a mile wide. The original settlers had the burial grounds. Hanford workers buried oil, chemicals, tons and tons of aluminum spacers, and a lot of lead. Contaminated trucks and tractors involved in rupture recovery became impossible to clean up and were buried. Plenty of contaminated clothing was buried. We have radiation boxes that were put in trucks to be thrown into the burial ground. The radiation boxes were cardboard boxes with a radiation sign on the side.

Plutonium Finishing Plant

234-5Z goes by several names, including Z-Plant, Plutonium Finishing Plant, PFP, Dash 6 or the Silver Place. Plutonium came into 234-5Z from 231-Z as a liquid. On the Rubber Glove (RG) line, and later the Remote Mechanical Control (RMC) line, it was siphoned into platinum boats. The material was about the consistency of mud. The material was then put into a furnace to dry the material to powder. Operators periodically checked the material during the drying process. The dried powder was pink in color. This powder was placed into a bomb, along with a sodium-containing compound, and the bomb was bolted shut. The bomb was put into a furnace and the powder was reduced to a metal button. As the process continued, the product was passed down the line from one hood to the next. These operations ended somewhere around 1988 to 1990.

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While Hanford was processing weapons cores, they had an inspection protocol, which required an individual to view the item under a microscope. The dose to the eye could have been high and was dependent on whether the piece was coated or not. This practice began in July 1949 and was continued into the 1950s. They changed the final inspection process in the early 1950s and eventually built a final inspection wing. The new process was less hands-on.

No enriched uranium was handled at PFP. Depleted uranium in the form of powder was analyzed in Room 156, Analytical Lab, from ~1985 to early 1990s. The manager of fabrication would not let uranium in his production areas in PFP. The people who worked with enriched uranium would be those at 231-Z. One interviewee thought he may have worked with thorium in a special room at 234-5Z. There were operations in the PFP complex that involved handling of high-fired plutonium oxide.

The RG line was not well shielded and lead aprons were not worn during the 1950s at 234-5Z. The gloves in this line were not originally lead lined, but were made of rubber. The RG line is so named because rubber gloves were used in this line. Lead-lined gloves were added to some of the hoods later. Workers received exposure up to their shoulders when working in a glovebox. Shielding on the hoods was limited to the structural material of the hood (i.e., stainless steel). With the implementation of the RM line, there was improved shielding. Lead-lined gloves were introduced at the time. The thickness of the gloves varied over time.

Hood #8 of the RG line was the worst of the hoods to work with along the line. This is where the liquid material was reduced to a powder. The radiation levels around this hood were high, including neutron dose rates. The dose rates at each of the hoods, including neutron measurements, were made periodically (i.e., more than once per year) by RMs. Hood #9 was also specifically mentioned as a particularly hazardous hood.

Radiation Monitors were responsible for obtaining dose rate readings for the timekeeping cards. Dose rates were generally taken at the same location each time on the hood face. When timekeeping was used, there was typically an RM there to cover the job. There were only a couple of steps where the neutrons were bad. Early in the oxidation process, there were neutron issues (i.e., Room 228).

Personnel tried to be as safe as possible in those days. Initially, individuals were supposed to rotate through the various stations in the process. The company found it more productive to use the same individual at a particular station. As Operators became experienced with the work, they would cut corners at times.

In the 1940s, Building 231-Z concentrated and processed the plutonium nitrate from the separations facilities. There was an operation where plutonium nitrate cans were emptied back into the system at PFP and cleaned. Workers took scraps of plutonium and burned them back into powder. The Plutonium Recover Facility (PRF) was responsible for pulling the plutonium out of the waste until 1987. Other activities at the PFP complex included washing contaminated clothing [laundry], area decontamination, maintenance, an analytical lab, and other general support.

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The HPT office was located in the old Recuplex area after it had been cleaned up. The company had put up a false ceiling. Contamination existed above this false ceiling, which fell on someone and contaminated them. Things were done differently when the facility was in operation than after it was shut down. Today, they are more prone to post an airborne area and put it on mask than historically.

Decontamination and Decommissioning

The Decontamination and Decommissioning (D&D) of 233-S began in about 1999 or 2000. To work in this facility, workers received a full day's facility-specific training. The primary radiological hazards in Building 233-S were Pu-239, with some Am-241 in some areas. During removal of the pipe trench, there were some discussions about Cm-244 and Np-237. There were no discussions concerning the presence of tritium or thorium. Thorium would be secondary to the plutonium and would not be a concern. The radioactive material in this facility was flighty during D&D, and went all over the place. The Radiological Engineer had some particle size studies completed. The radiological conditions at 233-S were like the side of PFP where they made buttons, and there was oxidized stuff.

Construction laborers in the 300 Area were responsible for digging trenches, tearing out building structures (i.e., floor tiles, ceiling tiles, stucco walls) and equipment, and modifying or adding to existing contaminated equipment. This included laboratory facilities. Sometimes there was residual stuff and salt stains on walls. Much of what they were doing was new work. In about the mid-1970s, they were digging a 3½-ft deep hole. They were told if you find a 10-in long and 2-in round object, contact the HPT immediately. Apparently Hanford use to throw fuel slugs in the surrounding area. The workers appreciated being made aware of this potential hazard, which was not always the case at Hanford. Those involved did not follow up or ask questions, because people that did that ended up in the unemployment lines.

The Hanford structure for decommissioning and excessing material was not the easiest thing to control. Rockwell had the responsibility for excessing and salvaging material. UNC had responsibility for safety during their tenure. This made ensuring safety difficult.

Radiological Control

The RMs in earlier years served as Safety Engineers, which meant they had responsibilities other than taking radiation measurements. The RMs had the authority to shut down jobs for safety reasons, although they were not always successful. In the early years, particularly in the 300 Area, interviewees didn't recall a routine presence by RMs in the area, or routine air sampling. The number of RMs at Hanford increased over time, providing better coverage. For example, at FFTF, it was not uncommon to have step-off pads staffed by at least two RMs in almost any contaminated area that was marked. Most of the RMs operated in specific areas of the site, so they became familiar with the specific equipment in the buildings.

Not all Hanford contractors implemented the same rigor in the radiation safety program. For example, operations at PFP appeared tightly controlled to some workers, whereas Bechtel Hanford, Inc., seemed more lax in the implementation of their RadCon program. Personnel with experience from the Nuclear Navy were brought in starting in the late 1970s. There were a lot of changes made in the RadCon program (e.g., initiation of sign-in sheets for Special Work Permits).

The workers were sometimes cavalier in terms of exposure to others. There was one instance in about 1983 or 1984 where some workers from the 200 Area made a bad decision not to obey the postings. Individuals at the Tank Farm near one of the processing buildings decided not to follow the posting. The area was posted as a contamination area, which was not unusual for Hanford. For some reason, the workers took down the posting for a short period of time. This did not pose an immediate threat. An occurrence report was written related to this. For the most part, the work force was aware that they needed protection.

Compared to dosimetry in the 1950s, by 1990, the site was eons ahead. By the mid-1970s and 1980s, worker monitoring and protection were good. RadCon documented everything in later years, and people wore their dosimetry. The Lead Health Physics Technician was assigned to the desk to maintain logbooks of daily activities. Whenever there was a suspected intake, individuals were sent for a chest count. Individuals were asked to submit urine and/or fecal samples. Radiation monitoring in general improved as time went on. There were better radiation detection instruments, finger rings, etc.

The Neut was the first neutron detection instrument used at Hanford, starting in approximately 1949. A few months later, the BF_3 neutron detector was introduced. That detector was used bare or with paraffin moderators. It could distinguish slow, intermediate, and fast neutrons. The portion of slow, intermediate, and fast neutrons varied depending on the location in the reactor. Health Physics implemented the Snoopy detectors (originally known as the Depanger instrument) in the early 1960s. This unit measured the total neutron dose rates, rather than discriminating by energy.

In the 1950s–1970s, alpha monitoring for smearable contamination was detected by cart Poppies. These units had no visual readout, so the measurements were determined by listening to the frequency of pops the unit made. There were portable sources attached to the cart Poppy on a rotating device, which had various activities (500 dpm, 1,000 dpm, 5,000 dpm, etc.). The RM would memorize how many pops were associated with the different source activities. The Poppy had a minimum detectable activity of about 500 dpm. At this level, the sound was barely detectable. As the activity increased, the number of pops increased. The dial of the cart Poppy would go somewhere between half and full scale with each pop. At an activity of 40,000 dpm, the Poppy would be continuously popping. Radiation monitoring also had portable Poppy meters, where measurements were determined by the number of pops. A source of known activity was placed underneath the probe of the alpha instrument to determine the number of pops for that activity. The number of pops measured in the field was compared to the number of pops obtained from the source to determine the alpha activity. In the mid-1970s, the site obtained portable alpha meters with a visible readout.

Instruments were well maintained throughout the site. If calibrations were done properly, the measurements could be trusted. Many were taken back to the shop and/or to Battelle for calibration, including the Continuous Air Monitors (CAMs). An automatic recall system was put

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in place over the years that indicated which instruments were due for calibration. The calibration was done right in the shop every 1–12 months, depending on the instrument. The frequency was based on the unit's history. Technicians at Battelle claimed the Eberline Alpha CAMs were greater than 10% efficient. Instrument Technicians indicated they were borderline and weren't really that good of an instrument; they measured only gross contamination. In later years, they had all kinds of problems with the alarms from the instruments that were monitoring the air. If an alarm went off, Radiation Monitoring would survey individuals with a GM counter and would find nothing. The beta gamma units were pretty reliable.

There were originally alpha stack monitors on process farms and in process buildings as a part of the Air Quality Unit. The monitors were put on top of the tank or in a small housing in later years.

Engineering controls of various types, including fume hoods, gloveboxes, and ventilation, were used to control radioactivity. There were all kinds of restrictions for preventing plutonium from getting into your body. Mouth pipetting was not allowed in laboratories. Administrative controls, such as limiting time in high radiation areas, were employed to reduce exposure. In order to clearly identify contaminated tools, they were sprayed with purple and orange paint. These were left in the radiation zone.

Different protective clothing was required in different areas. In the separations areas, there were very strict requirements as to how workers dressed. Some jobs only required a lab coat and shoe covers as protective clothing. Some jobs required coveralls and assault masks. Some jobs required air masks or a Self Contained Breathing Apparatus. At the Hot Semi-Works building, workers made hot cell entries. In order to make these entries, they put on plastic suits that looked like space suits. They had air attached to them and a source of cooling. Respiratory protection was worn at 234-5Z when a room became contaminated or when components of the hood (e.g., gloves) were changed. When entries were made into the greenhouse area of 233-S, employees wore a bubble suit with supplied air.

In the 1960s and 1970s in the 200 Area, the smearable contamination criteria on jobs being performed in certain locations were not as clear as they could have been. These levels were used to determine when respiratory protection was required (when the area went on mask). This could be at the discretion of the RM. For example, one RM would require an assault mask at 5,000 dpm/100 cm^2 alpha and another RM would require them at 3,000 dpm/100 cm^2. The smearable limits were different, depending on the building worked in and the RM on the job. For beta/gamma smearable contamination, the RM would put a work location on mask when the removable beta contamination was 3,000 dpm/100 cm^2 at PUREX, but at B-Plant, the RM did not require a mask until the smearable beta/gamma contamination reached 10,000 dpm/100 cm^2. Smearable contamination limits at each building were defined by the local area monitor or supervisor. These could also be different, depending on which RM was monitoring the job. Currently, any detectable alpha smearable contamination would require an area be put on mask and would not have to reach a predetermined level.

The original criteria at the reactor for requiring assault masks for airborne contamination (based on Sr-90) was 1.0E-9 µCi/cc, based on an 8-hour work day. Since the radiation level on the rear face of the reactors would only allow a person to work for 1 or 2 hours, a radiation analyst tried to increase the efficiency of the worker by not having them work in a mask. There was a legal sentence in the regulations that would allow a person to work a short time in a higher airborne concentration level without a mask, as long as it was for an hour or two. This resulted in several (at least 4–6) people receiving a small amount of nasal contamination (200–300 c/m above background). The RMs started to perform nasal irrigation on the maintenance personnel themselves, rather than send them to the nurse (which was a customary practice). As the number of nasal contaminations increased, it became necessary for the RMs to send them to the nurse, due to lack of RM manpower. This overwhelmed the nurse with personnel from B reactor, as they only had one nurse. Eventually, the workers went back to the normal procedure of wearing assault masks when the air sample indicated 1.0E-9 μCi/cc.

When a positive nasal smear was obtained from a worker, the nose was rinsed to flush out the contamination. Nasal irrigation in the 200 Areas was typically done by the RMs. In the case of the reactor areas, nasal smears were collected if contamination was identified around the nose. Facial contamination would occur when individuals were splashed with coolant water. For situations where there was contamination around the mouth or a positive nasal smear, special bioassay sampling was done. This could be urine and/or fecal sampling.

Alpha contamination spreads at PFP usually involved bag ruptures, pinhole leaks in some of the rubber gloves, or other leaks in the hoods. There were 200 or 300 fixed air head samplers and CAMs at the PFP facility. About 50% of these samplers were CAMs. They were changed out weekly by one person who did the job full time. There were air samples collected and analyzed in other 200 Area facilities for beta/gamma and alpha contamination.

In the 1950s, hand and foot counters were introduced in some areas in the 300 Area. If the instrument indicated workers had picked up contamination, they simply went to wash the contamination off. They were not required to call in an RM when their skin became contaminated. There was little concern about skin contamination in the 300 Area where they worked with uranium. When individuals with skin contamination did contact the RM, the RM tried to decontaminate the individual in the field.

Radiation Monitors were required to check hands and feet prior to letting workers exit from radiological areas at the Tank Farms. Tank leaks were sometimes found as a result of these contamination surveys. There were times when contamination was found on PPE. Workers would change into clean PPE and re-enter the area to locate the source of the contamination.

In the 300 Area where they handled uranium, workers did not initially know what a glovebox was. After several years (post-DuPont), gloveboxes and hand and foot monitors were installed. Workers were told what they were doing was safe and did not question the management when they said this. The company provided work shoes, which were changed before workers went home. Some interviewees indicated they took a shower and changed coveralls prior to eating lunch and leaving for the day. Showering and changing shoes prior to lunch was not the norm. Workers were merely told to wash their hands before eating lunch or taking breaks. Many workers wore their coveralls into the lunch rooms. Interviewees indicated it was very possible uranium was tracked into the lunch rooms, because of the contamination in the area and the

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practices of many workers. At the 100-KW reactor, operators had a break room located just off the rear face of the reactor.

Radiation Monitoring was responsible for monitoring protective clothing from the laundry. Their detection equipment at the laundry was not state-of-the-art. They would check clothing and return contaminated clothing to the hampers. The clothes had some defined acceptable level of contamination. In some cases, there was even contamination on the inside of the clothing. Later, the site switched to plastic disposable Anti-C's.

There is a program involved with non-destructive analysis (NDA) of several different kinds of sources. This NDA method involves taking a Sodium Iodide (NaI) or Liquid Nitrogen-cooled Germanium detector to the field and making predetermined measurements of items. This NDA method is a non-invasive procedure that does not require opening up systems or containers. It does not involve the use of radiation-generating devices. They measure radionuclide content (i.e., U-233, U-235, U-238, Pu-238, Pu-239, Pu-240, Np-237, Cm-244, or anything with a gamma) of filters, gloveboxes, waste packages, and unknown containers based on customer requests. NDA is used a lot to look for transuranics in waste packages prior to shipment of waste to the Waste Isolation Pilot Plant (WIPP). Fixed Germanium detectors are required to meet the WIPP and transportation requirements (i.e., 20 nCi/gram). It is a part of the material accountability program. Sodium iodide (NaI) detectors are only used for measurement of Pu above 0.5 grams. NDA was used after an accident in 1991 or 1992 at 222-S, when they removed a glovebox. An analysis of the storage cabinet detected about 0.5 grams of SNM (no particular isotope). Although you can assay for thorium with this method, no customers have requested analysis for thorium.

All incoming and outgoing radioactive shipments passed through the 1100 Area. They were brought to the transportation lot, where they were surveyed. Radiation exposure in this area was limited, but occurred with the receipt and departures of all radioactive material, which included alpha, beta, gamma, and neutron shipments.

Newly hired Separations Operators received a 3-day orientation. They were told not to get plutonium on their skin, or inhale or ingest it. Some individuals trained in the Hot Semi-Works building when they began separations assignments.

External Monitoring

The film badge was described as a piece of dental film with part of it shielded to measure gamma. There was also a portion that measured the beta dose. Interviewees actively handling radioactive material indicated badges were changed on a monthly basis. A change was made to thermoluminescent dosimeters (TLDs), because dosimetry felt these badges were more accurate than the film badges.

There have been several radiation exposure limits implemented at Hanford over time. Workers had to keep track of the daily exposures to ensure they did not exceed established limits. The weekly limit was set at 300 millirem. Supervisors were allowed to take greater than 300 millirem/week up to 5.0 rem per year. Any amount over the 300 millirem/week had to be

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specially approved. Workers at PUREX became concerned and filed a grievance when there was talk of increasing the weekly gamma exposure limit from 300 mR/week to 600 mR/week at PUREX. There was a contaminated tunnel that operations wanted decontaminated. As a result of the grievance, the weekly limit remained at 300 mR/week.

In 1966, the union went on strike for about 6 weeks. Douglas United Nuclear (the contractor at the time) wanted to increase the weekly exposure limit from 300 mR/week to 400–500 mR/week. The reason was that if they raised the exposure limit, they would not have to hire people to keep them under the dose limit. A letter was written to Katherine May [congressional representative] informing her of the situation. Ms. May read the letter into the congressional record. A response was provided to the sender from Katherine May and the Atomic Energy Commission (AEC).

Hanford workers were allowed to receive 3.0 rem per year (administrative limit), while construction workers were allowed to receive 5.0 rem per year, based on the legal limit. The original lifetime limit was calculated as (N - 18) * 5, where N is the individual's age. The lifetime dose limit was changed to 1*N in about 1992 or 1993. When the change occurred, at least one worker was told he had exceeded his lifetime limit (i.e., he was 61 years of age and had received 66 Rem lifetime exposure). As a result, the worker was put on restriction, limiting him to work in areas with low or no dose rates. He was not allowed to enter any zones that required respiratory protection.

Film badges were not initially provided to the fuel fabrication personnel until the 1950s. Workers generally wore their whole-body dosimeters. There were occurrences where workers would take off their badge or wear it inappropriately. People were going to take short cuts and they weren't going to be stopped. There were a number of occasions on the production side of things when workers needed to get the job done, so people would put their badge in their back pockets. This was either with the consent of management and/or on the workers' own initiative. Some workers may not have worn their dosimetry because they were not allowed to work overtime once they reached their radiation exposure limit (i.e., 300 mR/week or 3 Rem/year).

External dose monitoring was pervasive and fairly rigid at FFTF. There were extensive personnel monitoring procedures. Those working with fuel assemblies in the 300 Area had a full complement dosimeter. In the 308 and 306 Buildings, they made Mixed Oxide (MOX) powder. The individuals having access to those facilities were given full-range dosimeters, including Personal Nuclear Accident Dosimeters (PNADs, aka "the death chip"). Most of the individuals working at FFTF were monitored for neutrons.

Personnel monitoring for neutron exposure began in the 1950s, using NTA film badges and neutron pencils. Monitoring primarily focused on those individuals who worked in the 105 Buildings in the 100 Area. The neutron pencils could be distinguished from the gamma pencils (black) by their green color. When the workers checked out a green pencil, they also checked out a neutron film badge. The neutron film badge and green pencils seldom showed any neutron exposure. To track real-time dose, individuals had to sign in and out of the area. Personnel neutron monitoring was not accurate until the implementation of the TLDs in the early

1970s. There was indication from workers at 234-5Z that neutron exposures were underestimated prior to implementation of the TLDs.

Since the film badges had to be sent off to be read, pencil dosimeters and timekeeping were used to supplement film badges or TLDs, providing real-time monitoring. Workers were sent into radiological areas with one pencil, or when entering a high radiation area, a pair of pencils. There were times when pencil dosimeters were used without the film badge or TLD. The reactors and the separations areas used self-reading pencil dosimeters (SRPD) after they were implemented in about 1965. The SRPD results for the cycle were used until the monthly badge reading became available. At that point, the exposure was based on the film badge. At the beginning of a new cycle, the SRPD was used to monitor dose until the next film badge reading became available. Electronic dosimeters with alarms were introduced in some areas.

In the 1980s, when individuals working at the reactors were sent into areas of known neutron exposure, the RMs assigned a total dose (neutron + gamma) by multiplying the gamma pencil value by 3. This number was based on field photon and neutron measurements. This was done to track real-time total dose.

Timekeeping cards were used by workers to track their exposures. The RM was sent into the area to set the dose rate for the job. Some RMs were less thorough than others in setting the dose rate. The workers were responsible for filling out these cards, including the in and out time. When there was indication that an individual received a high exposure, he would be moved to a station with a lower dose rate. Interviewees did not have occasion to compare their estimated doses to their actual doses. No one picked up a monitoring instrument without the RM present.

J.A. Jones, the minor construction contractor, had a Radiation Time Keeper (RTK) (also known as Field Assistant) assigned to support them. In the reactor and separations areas, the minor construction contractor RTK was responsible for timekeeping records for all construction contractors. Sign-in sheets were used to record workers' names, payroll numbers, and the times when they entered and exited the radiological areas. In the SPR reactor rear-face areas, time-keeping machines were used. When an employee reached the daily limit, the individual had to leave the area and the timekeeping machine was re-zeroed. If the dollar amount for a job exceeded a certain level, a minor construction contractor was brought in to complete the job, rather than operations doing it. Being an RTK employee for J.A. Jones required that one traveled to areas throughout the 100, 200, and 300 Areas. This included Building 234-5Z, which handled plutonium and americium.

Dosimeter placement has a big role to play in calculating dose. Ideally, the badge was worn in the middle of the chest, but until the end of the 1960s, people clipped their badges to their collar or around the waist. There were many situations where a higher exposure was received to portions of the body that would not be reflected on the badge. As a result, workers question the accuracy of the whole-body dosimeter to quantify the highest exposure received to a particular location of the body. For example, during the 100K basin clean-up, the lower extremities were being exposed to a greater extent than the whole-body. They were not wearing dosimeters on their lower extremities, so an attempt was made to calculate the amount of exposure workers received. There are no official measurements of the dose workers received to their feet and legs.

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There were workers involved from the 100 and 300 Areas. It would be difficult to calculate dose if the orientation of the individual in the field is unknown. Another example of higher exposure to the lower part of the body is when workers conducted jobs on the underground diversion boxes.

The open-faced hoods were lined up along a wall in one room of the laboratories, and the room on the other side of the wall had other open-faced hoods in the same arrangement. It could turn out that someone was working on the other side of a wall where highly radioactive material was handled without their badge. It was not uncommon for people to have high dose items right behind them. In the T Plant and B Plant, the trenches inside the canyon ran right at your feet. Workers here would have gotten a lot of lower body exposure, particularly when samples were being taken on the Canyon floor.

Dose to the lens of the eye was of concern during some jobs. For example, the PUREX operators had safety glasses on while collecting the sample in a sampling cup. A lot of the time the operators could not see, so they would look over the top. Their whole-body badge would not be in the exposure pathway, whereas their eyes were. It should be noted the REDOX operators took samples in a remotely similar fashion; however, due to building design problems that caused the air in the sample galleries to have higher than allowed concentrations of radiation, the operators wore assault masks, providing the eyes and face with a higher level of shielding from beta radiation.

Much of the work required employees to use their hands, which brought them into closer proximity to the source term. The people who were judged to be at risk of exposure were provided extremity monitoring. For example, individuals handling unusual materials in gloveboxes, working on valves in reactors (particularly 100N), or working in certain areas of the Tank Farms were assigned extremity dosimeters. Extremity monitoring was assigned during special jobs, but was not used routinely until recently. At times in the early years, reactor workers were assigned finger films. Individuals at the Tank Farms could receive about 15 times as much exposure to their hands as to their body.

[Note: SC&A was shown a number of pictures where geometry would affect dose reconstruction. For example, a photograph of someone wearing a finger badge facing outward while handling a source was shown. This individual should be wearing the finger ring on the inside of the hand. A photograph was also shown of three workers wearing their badges on their lapels.]

Back in the 1970s, employees conducted work in high radiation areas, which was 5 R per hour (e.g., inside hot cells). Engineering barriers were required at something more than 5 R/hour to limit worker exposure rate. There were situations where workers' badges were highly exposed or overexposed. When the badge numbers came up high, they asked the worker why.

A number of the couriers responsible for safe and secure transport of nuclear materials had overexposed film. Dosimetry would interview personnel when black badges occurred. One courier indicated the dose was assigned based on what his coworker received. This happened quite often in the 1950s. There were a set of couriers assigned to Hanford, Los Alamos, and Oak Ridge. The couriers were AEC workers.

In-Vivo Counting

Whole-body counts were conducted routinely for workers when they worked around radioactive material. These were conducted annually or by special request. Some received only whole-body counts, while others received both whole-body and chest counts. Several examples are provided below.

Chemical Technician	222-S	Annual Chest and Whole Body
Chemical Technician	234-5Z	Annual Chest and Whole Body
Construction Laborer	Rover	Annual Whole Body
Nuclear Engineer	FFTF	Annual Whole Body
Reactor Operator	100N/100K	Annual Whole Body with Chest Count added later

It is unclear whether the construction trades received routine body counts or if they were only done when an incident occurred. If the whole-body count was positive, individuals would be asked to submit bioassay samples.

The instrumentation used for whole-body counting became more sensitive over time and was able to detect smaller uptakes. For example, there is a manager who worked for PFP for 20 years. His chest count has recently begun to show a positive value for americium. His exposure is attributed to chronic exposure, rather than a discrete incident. In more recent years, routine annual whole-body counts have been discontinued as a cost savings measure for some workers, or as processes shut down.

In-Vitro Counting

Hanford has relied on the whole-body/chest counter to identify potential uptakes at many facilities. If the count was positive, a urine sample was collected. If there was an incident or accident, a bioassay sample was collected. A routine urine sampling program was not in place for all workers and has varied over time and by location. Some individuals were aware of what the urine samples were analyzed for, while others were not. One interviewee recalled that their bioassay samples were analyzed for gross alpha (FFTF). Plutonium bioassay was typical for the 200 Area. Interviewees did not recall submitting routine urine or fecal samples specifically for promethium, thorium, americium, or neptunium.

Urine sample bottles or ice cream cartons (for fecal sampling) were left at the workers' residences periodically. Interviewees indicated they always remember receiving their sampling kits at their residence. Collection of bioassay samples in the 300 Area started very early. Up until 1988, PFP workers were asked to submit routine bioassay, including submittal of fecal samples. Interviewees mentioned they were typically on a strontium and plutonium (at PFP) bioassay program, if they were routinely being monitored. During the K-basin clean-up, no bioassay samples were submitted. Interviewees recalled submitting samples as frequently as monthly. For facilities in the 200 Area, such as REDOX, routine samples were submitted quite frequently. The frequency of sample submittals was reduced over the years.

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There were individuals submitting routine urine samples in the 1970s/1980s in some areas that were really on the fringes of those considered at risk.

Medical

The workers interviewed indicated they received annual physical exams, including a complete blood work up and collection of urine samples.

Incidents/Accidents

Incidents or unusual occurrences are documented in a variety of places. Reports of incidents and accidents involving personnel contamination may be found in the individual health physics file. Other places where incidents of personnel contamination are documented include the following:

(1) The survey report of the RM, including contamination levels and/or dose rates
(2) Progress letters or weekly reports sent to managers summarizing weekly activities
(3) Monthly reports (i.e., summary of weekly reports)

The degree of incidents has ranged from incidental skin contaminations to extensive uptakes of radioactive material. Hanford also had two criticality accidents. Other incidents or unexpected occurrences have included fuel failures, metal fires, open wounds, burns, and explosions.

Many of the incidents that occurred at Hanford were related to Industrial Safety. For instance, individuals would enter underground tanks (i.e., confined spaces) and were overcome by fumes. Another example was a steam valve explosion during a valve replacement that resulted in personnel injuries [no date provided].

Criticality Accidents

Hanford had two criticality accidents. The first was on November 16, 1951, when the poison control rod was pulled out of a solution too fast. The second accident occurred on April 7, 1962, at RECUPLEX (plutonium and uranium recovery area), when a non-critically safe tank, K-9, collected too much plutonium nitrate from the floor of the glovebox. K-9 had a tygon hose attached to it to suction up plutonium nitrate that had leaked from other process vessels. The operators were supposed to turn off the vacuum to the K-9 tank and keep the open end of the tygon hose off the floor. At some point, the vacuum was not turned off and the open end fell to the glovebox floor into a kind of “cup” (this “cup” is like a rounded depression on the floor). This cup caused a collection of plutonium nitrate, which went into the K-9 tank. The plutonium nitrate was from a leaking or overflowing receiver tank. This incident directly involved individuals who received high radiation exposures. A former PFP worker recalls that area was restricted to the 200-W Area for about 1 week; there were no entries into the 234-5Z Building. One of the workers involved in the accident reported that he saw the blue flash and was afraid he would die. There was also a significant incident in one of the tanks at PUREX, which was initially investigated as a potential criticality.

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Plutonium Finishing Plant

There was a massive glovebox explosion involving two Hanford workers at PFP in 1976. The columns in the americium process were on a preventive maintenance program, but the materials were not changed out in the way they were supposed to be, or as frequently as required. The incident was so significant that it made the national papers. The east coast newspapers called out to Hanford and wanted to know how big the crater was.

On April 14, 1954, a [**Operator 1**] and [**Operator 2**] were working to clean the filter boats. In the process of making plutonium oxalate, it was captured in these filter boats. Liquid would go through and oxalate would stay. The plutonium had to be recovered from the boat. Oxide was scraped out of the boats, bagged, and shipped to 231-Z. The boat was put into a glovebox (only one in the room), immersed in a stainless steel can with chemicals, and brought to near boiling temperature of the solution (much higher than the boiling temperature of water).

The [**Operator 1**] had been cleaning the boats while the [**Operator 2**] was intermittently supervising and talking to personnel down the hall in a clean area. This was about 20 feet down the hall from the lab where the work was taking place. After about an hour and a half, the [**Operator 1**] pulled his hands out of the glovebox gloves and found that he was contaminated. The [**Operator 2**] surveyed the area and found the area very contaminated. They called for assistance from the RMs, who entered the room wearing masks and in double anti-contamination clothing. The operators involved in the incident had been working in coveralls, street shoes, and latex gloves without a respirator. The [**Operator 1**] picked up his mask from the Poppy cart and put it on. It was later determined that the mask had alpha contamination of 10^5 dpm. The [**Operator 2**] was also contaminated. The source of the contamination was a hole in one of the gloves. Contamination was spread down the hallway, since the [**Operator 2**] had been up and down the hallway during the job. The activity at the radiation chain (boundary) was 20,000 – 10^5 dpm.

The [**Operator 1**] was escorted back to the Health Physics Instrumentation room, which was also the decontamination area. His coveralls were removed and they scrubbed his face and hair down with some solution. The nasal smear taken by the RMs was positive. Nasal irrigation was done until the activity in [**Operator 1**]'s nose was less than detectable. He was given his street clothes and asked to hang around in the lunch room for the rest of the day. The [**Operator 1**] reported that he submitted daily bioassay samples for the next 2 to 3 weeks, including both urine and fecal samples. About the time they stopped delivering the sample containers, the HP indicated that the bioassay results had dropped down to background levels. The incident was formally documented. When the [**Operator 1**] reviewed the records submitted to NIOSH, there was only one bioassay sample in the record associated with the incident.

While machining, metal turnings were produced and would catch fire at times. The use of carbon tetrafluoride precipitated these fires. The metal would smolder inside the gloveboxes. Operators extinguished the fire by smothering it with a piece of metal. These occurrences did not happen all the time, but they were not uncommon.

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When they tried to change the filters in PFP, it was a contamination risk. This task resulted in a few incidents, including some significant uptakes. In one case, workers were changing a hood filter [date not given]. This filter was designed to remove suspended particulate from the hoods. The filter housing was opened, the old filter removed, and the new filter put in place. This operation was done in a greenhouse (containment tent). Respirators were usually worn for this job, but the workers had removed their respiratory protection that day. When the housing was opened, radioactive material was inhaled. Urine and fecal samples were submitted as a result of the incident. One individual involved indicated he received 18% of the limit for plutonium [presumably the Maximum Permissible Body Burden]. This worker is currently a member of the transuranic registry maintained by Washington State University (WSU).

Another interviewee recalled an incident that occurred at 234-5Z, while he was changing a filter. He stayed over on swing shift to change the High Efficiency Particulate Air (HEPA) filters in a particular area. They had set up a tent around the area. The job also required they wear protective clothing and a mask. The filter wouldn't come loose, so the Millwright kicked the filter. It fell down at the workers' feet and the stuff just disintegrated. The fine particles went right through the mask. Radiation Monitoring was called in to assist. Nasal irrigation was required for at least one of the workers involved. Quite a few urine samples were collected after the incident. As a result, the interviewee received an uptake. At one point, he was part of the transuranic registry, but is no longer involved.

A more recent incident occurred in 1993, when operators were tapping on a vacuum gauge in Plutonium Recovery Facility (PRF). [Redacted] of the [redacted] workers had positive nasal smears. Several individuals received uptakes. More recent incidents such as this are well documented.

Skin contamination incidents were a concern at PFP. Over time, Health Physics Technicians maintained an unofficial set of logbooks at PFP. The contamination control was loose historically and contamination was very common. An interviewee indicated there was entry after entry of skin and facial contamination in the logbooks. According to the log books, there were days when people were exposed to more than 40,000 dpm (i.e., facial nasal smears more than 40,000 dpm). It was a daily occurrence when running campaigns. The Poppy used at the time only had a range from 500–40,000 dpm. Also in the logbooks was information on the criticality incident that occurred. Several examples were provided by interviewees.

- One interviewee was involved in an incident where he punctured the glove in the hood while using a lathe. He indicated that his finger was contaminated, but his skin was not broken. Nasal smears and skin monitoring were performed after this incident.

- There was an incident where a hole developed in one of the lead-lined gloves in the hood space. Contamination was present on the outside of the gloves, which in turn contaminated [redacted]. The contamination was on the coveralls, but did not reach the skin. Since there was a single monitoring point, [redacted] did not realize that [redacted] was contaminated until [redacted] went to the Poppy survey station. No nasal smears were taken following the incident.

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- An employee was crawling on [redacted] knees on one of the upper floors of PFP. There was some loose contamination (>20 dpm/100cm^2) in this area, which caused [redacted] to get crapped up [contaminated]. [Redacted] lost [redacted] coveralls as a result. Although there was smearable contamination all over this area, no respiratory protection was required.

In addition to the incidents mentioned above, PFP had metal fires.

[Note: SC&A has tried to locate the technician logbooks, but has not been successful.]

Fuel Manufacturing and Reactors

There were several fuel ruptures that occurred in the reactor areas (5%–10% during operation of the reactors). Fuel ruptures occurred at N-reactor, but this was not a real common occurrence. For a period of time, there were several ruptures because of weld failures on the fuel end caps. This exposed uranium to water, which caused it to oxidize. The fission products entered the primary coolant system, which was routinely monitored. The monitors indicated if a rupture occurred in the reactor. The reactor was shut down and the operations then attempted to identify the tube where the rupture occurred. After the reactor was cooled down, an RM could survey the rear face of the reactor and identify a general location of the ruptured fuel elements. Operations then removed the fuel and started the reactor back up. As soon as the 300 Area fixed the welding process on the fuel end caps, many such ruptures were eliminated.

When they first started up one of the reactors in the 100-K Area, one of the fuel tubes melted because the cooling water to that area was shut off. The aluminum process tube failed, due to a rag plugging the flow to the process tube. This resulted in cladding of the fuel elements. It took workers quite a while to clean up the tube. This was a source of a lot of radiation. There were approximately 4,300 fuel tubes in each reactor (i.e., 105KW and 105KE), with only one failure.

There were two incidents in the early 1980s, where fuel was pushed out onto the D-elevator and also into the C-elevator pit. The operators and RM involved received very high exposures. As a result of the incident, there were some medical tests conducted on these individuals to make sure they were all right. The fuel was left behind on the elevator so a recovery plan could be developed to collect the fuel on the elevator and in the C-elevator pit. There would be an occurrence report on this incident.

The rigor for monitoring potentially contaminated wounds has not been consistent for all areas and times. There were situations where individuals received substantial wounds and were merely patched up and sent back into the area. For example, one interviewee was changing the die in the extrusion press in the 300 Area one day, when the crane hook straightened and hit him in the forehead. The hook was unapproved for the task and picked up the whole unit, rather than just the die. It straightened, causing the unit to drop and the hook to swing. He had a [redacted] in his forehead and was sent to [redacted]. After being [redacted], they sent him back to work, since the job he was doing was time sensitive. There was no RM around at the time, and the interviewee does not recall special bioassay sampling or monitoring of his wound after this incident.

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There used to be spontaneous combustion fires within the exhaust ducts, and the fine particulates in the dust at the cut of the saws caught fire. This occurred almost monthly.

There was a situation where the roof was lifted off a building in the 300 Area. This was the building used for training personnel on the RECUPLEX process, which occurred in the 200-E Area. The building is no longer there.

After completion of the 100-N Area job, several Millwrights from Kaiser Hill went down to the 300 Area to work at the mock-up reactor. They had a mock-up reactor made of carbon block 4 ft by 4 ft by 4 ft, and the Millwrights were assigned to pick up the blocks and haul them off. The workers could not pick them up, so they tried to crow bar them. The carbon block crow bar broke apart, and the uranium slugs came flying out. They shut down the whole place. There were 50 people from Kaiser Hill and from DOE involved. There was no record of the uranium slugs being installed in the mock-up reactor.

There were areas with contamination in the 100, 200, and 300 Areas. Occasionally, there were small incidents at FFTF, but they were identified and reported promptly. FFTF never had a prolonged period of external contamination concerns. The fuel was handled in hot cells.

Incidents were not unique to the operating period. There have been several incidents during D&D operations. For example, at the beginning of the decontamination effort at 105-C, someone entered an airborne area and inhaled radioactive material. This was BHI's second strike for sending an individual into a posted area without respiratory protection. The first incident had occurred in 224-B. A third incident occurred at 233-S, resulting in an uptake of plutonium.

Separations Area/Tank Farms

At the REDOX facility, there was an explosion where the sample riser caps blew off. Liquid for the sample riser containing radioactive material spilled. This spill took a long time to clean up. The next time it blew, it blew the jumpers off, but the risers stayed in place because of an improvement made.

There was a slurry line that busted at 242-S and it read 100 rad/hr. It was feed time for the evaporators. Workers were getting ready to put it into 102-S. The riser was used to pump make-up feed into 102-S, but it was plugged and the riser cap had not been bolted down. The liquid flowed out the top and left a lake of a solution that spilled out onto the soil. Dump trucks and a leaded cab were used to remove the soil. The area was completely cleaned up, and there is now matting and gravel over this area.

An incident occurred at the 233-S Building where a line ruptured. The operators in the control room heard the Poppy (Alpha detector) making rapid popping sounds (indicated > 40,000 dpm). Since the instruments were prone to instrument surges, they thought the instrument was malfunctioning. One of the operators went to turn off the instrument. As a result, he received a lifetime dose of plutonium contamination.

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There was at least one individual incident (September 1993) where americium exposure existed at the 204 REDOX liquid waste storage tanks. At the liquid railcar unloading near the 204 liquid storage tanks, on the RM's way to a job, he noted that his GM went off scale as he passed the load-out facility. He conducted radiation and contamination measurements of the area and detected alpha and beta/gamma. The technical smears he collected were sent for analysis, and Am-241 was identified. The liquid waste car from the 300 Area overflowed when the liquid waste was transferred from the liquid waste car to the storage tank at 204. No one notified the shift supervisor of the spill.

An RM assigned to PUREX Plant submitted a bioassay sample at Hanford. After a 6-week break in employment at Hanford, with no potential exposure to radiation during the break, the employee returned to Hanford to find out the bioassay sample previously submitted was positive for plutonium. This resulted in assignment of an internal dose of 5 rem. The individual did not believe the results and provided two potential explanations. First, the bioassay bottles were routinely decontaminated and reused; the individual might have received a bottle for sample submittal that had some residual plutonium as a result of inadequate decontamination. The second possibility was that the instrumentation used for counting became more sensitive about this time and could detect internal contamination in the body.

Personnel at the Tank Farms were frequently contaminated during the transfer of waste from the tanks to casks or during similar jobs. These incidents could range from a small amount of contamination on the finger to significant contamination requiring a whole-body count. One occurrence involved a more serious contamination incident when the individual had a flange that was leaking on the top of the tank, and the easiest way to get to it was to remove the lid and get down from the top. The RM set up the job during the night. Operations turned on the system and liquid was released to the top of the tank. This sprayed liquid on the top of the tank. To remove the lid from the cell, the individual had to kneel on the tank, and the contamination was still there. Workers entering this area were grossly contaminated. In those days, you had to be clean before they sent you to town for whole-body counting. It took several showers to decontaminate the individual who knelt on the tank. At the whole-body counter, they put workers on a conveyor, and the counter would move all over to count the minerals or whatever was in the body. Sometimes they put employees on a chair. It was standard procedure to take urine samples after incidents like this. They had a bucket right outside on your doorstep so you could collect it.

Criticality Safety Program

FFTF had an extensive Criticality Safety Evaluation Report (CSER) prepared by the Reactor Safety group. This was a part of the Facility Safety Analysis Report, which was 14 volumes in length. To supplement this, there were technical safety requirements. Criticality Safety Requirement postings were used in specific areas of the facility. There was a training program new employees had to go through. They were assigned to this training for a half or full day per week for the first month they were assigned to the facility. This training strongly emphasized the importance of criticality safety. FFTF used geometry, spacing of fuel assembly (e.g., use of bird

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cages), and special handling of aqueous solutions, even though no one had any reason to be dealing with solutions.

The Nuclear Safety group was responsible for real-time inventory of fissile materials. These individuals operated out of the 308 Building. The inventories of fissile material were computerized for the whole site.

Environmental Monitoring

Starting in the early 1970s, there was a considerable effort to upgrade the atmospheric monitoring system, and much of the original (1940s) instrumentation was replaced. Based on the recollection of one interviewee, there was never a period since the 1940s when environmental monitoring was not a key part of the monitoring. There were several monitoring stations on site, in and around the City of Richland, and across the Columbia River in the agricultural area. This was originally part of the Hanford Reservation. Except for the portion that is part of the Hanford Reach, it is now private again.

There was an animal problem, because the animals were getting into radiation areas. There were tumbleweeds that grew over the burial sites. They had root systems 18-ft to 20-ft deep that absorbed the radioactivity, causing it to spread. One crew was responsible for keeping the burial sites weed free. At one point, the crew even baled tumbleweeds and burned them, creating a radioactive plume.

Records

Some workers have been successful in obtaining their radiation exposure records, while others have not. Several individuals interviewed had the opportunity to review their dosimetry records. Comments were made indicating that many of the dosimetry records provided were illegible or very difficult to read. In some cases, individuals indicated their records appeared to be complete, while in other situations, the records appeared to be incomplete. Interviewees were not aware of any destruction of health and safety records.

In one case, an individual left Hanford and returned several years later. The first year-end annual exposure report the worker received showed a lower accumulated dose than what he previously had when he left the facility several years earlier. The individual questioned the report and forwarded all the radiation exposure reports he had received through the years to Battelle. Battelle re-evaluated and updated his exposure as a result of the information provided.

Dosimetry sent workers their records every quarter at FFTF. Workers also got badge results. When an individual went for a whole-body scan, they were shown their results.

Petition Information

[SC&A explained that one of the issues raised in the petition was that people worked in buildings they were not assigned to. The interviewees provided the following information.]

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> *SC&A: One of the things petitioners are worried about is people who were working in buildings they were not assigned to.*
>
> *Interviewee 1: Whenever I was assigned to work in another area or building, I reported to the shop in that area. I was sent from 200W to 200E.*
>
> *Interviewee 2: We were assigned to other buildings.*
>
> *SC&A: Would it show on your work record?*
>
> *Interviewee 1: I was in lots of different areas that I am sure are not recorded there.*
>
> *Interviewee 2: We were in the 300 Area, but when they had high exposure time in the 100 Area, they would loan us to the 100 Area putting pigtails on process tubes when they were recharged. They recharged lots of them, ~1,000.*
>
> *SC&A: Was there a process of checking into the building?*
>
> *Interviewee 2: You reported to the supervisor.*

And,

> *SC&A: Is there any way for them* [NIOSH] *to know where you worked?*
>
> *Interviewee 1: I don't believe that they can. I can't even remember the numbers of the buildings where I worked. Even for a time card, it would have to show a special number.*
>
> *Interviewee 2: I had to sign an RWP only when I got to N Area. Everyone knew who belonged and who did not.*

And,

> *SC&A: If you moved within the 300 Area from one building to another, would there be a record of it?*
>
> *Interviewee 2: No, there would be no record.*
>
> *Interviewee 3: If there were a record, there might be a calibration slip on a piece of equipment or a QC* [Quality Control] *tag.*
>
> *Interviewees 1, 2, and 3: Our security badge was all we needed.*

The Hanford petition under current consideration was submitted on November 6, 2006. Petitioners would like NIOSH to define "discrete incidents," and explain why the 180-day requirement is not being met.

The primary concerns in the petition center around falsification and completeness of records (i.e., data integrity). Petitioners raised the following concerns with respect to the evaluation report.

- The evaluation report is confusing, unorganized, and does not address lost or destroyed records or affidavits supporting SEC 00057, 57-1, and 57-2.
- The petitioners are uncertain how Rovers and construction workers fit into the SEC definition.
- Access to Hanford records was limited during the development of the petition. Petitioners had to rely on Freedom of Information Act (FOIA) requests, which were often not provided in a timely manner and incomplete. They have no access to records that may be classified.
- Petitioners were not made aware of the documentation available on the Declassified Document Retrieval System (DDRS).
- The petitioners are at a technical disadvantage and cannot effectively respond to the evaluation report. They do not understand the evaluation and would appreciate some type of support from someone knowledgeable of the radiation protection.
- There is a significant concern over the use of surrogate data [e.g., coworker data] and the sample size on which these data are based (i.e., 7 individuals).
- NIOSH and the petitioners interpret the information provided by former workers differently. Petitioners feel NIOSH is not responding to the information provided. NIOSH has not made any reference to the petition affidavits in their evaluation report.
- The petitioners' comparison of data in worker files and in REX indicates that the REX database is not complete.

The petitioners raised concerns regarding the unresolved findings in the review report. Without resolving all of the findings, they believe there cannot be a defensible, claimant-favorable evaluation of **any** petition. The petitioners dispute the fact that NIOSH claims in SEC Petitions 00057-1 and -2 that external dose reconstruction is feasible.

At the Worker Outreach meetings, former employees stated that not everyone wore monitoring devices. They also told how they would pick up monitoring devices at the buildings, and at the end of the shift, they would throw them all in a bucket. There was no monitoring during transportation through the area; buses drove through noxious vapors and yellow clouds. Former workers stated they wore monitoring devices under various layers of clothing and protective gear, and that the monitoring devices were not on areas of the body that were exposed. One of the RadTechs at the Worker Outreach meeting said records of his personnel exposure incidents were not accurate.

There is a lot of credibility given to interviewed experts, and they are referenced repeatedly. Nowhere in this evaluation report does it deal with the affidavits of falsification of records. There are affidavits stating monitoring records were falsified, and that supervisors coerced employees to change records or be sent home without pay.

NIOSH is channeled in only one direction, and that is using only the existing records. One interviewee indicated that the record of his Kr-85 exposure was a false record and the exposure was considerably higher. He was working with a Kr-85 source, which was a 200 to 250 R source, for an hour to an hour and a half. The RM came by and saw that the work procedure was wrong and stopped the job. After that, a simulated test was performed to determine this individual's exposure, since the dosimetry was not capable of reading that high a dose. He was not present to observe this simulated test, and the report shows a much lower dose than he would have received.

During an interview with an individual submitting an affidavit, the individual indicated he worked with the gentleman whose diary is referenced in the SEC petition. The individual [redacted] performed operations in Hood #8 of the RG line. This individual could have received about 10 times the dose, as compared to coworkers. Eventually, he developed [redacted] and had to quit his employment with Hanford due to illness.

The petitioners raised concerns regarding the participation of key Hanford dosimetry personnel in the preparation of the Hanford site profile. One individual was the Project Manager/Principal Investigator for the Hanford External Dosimetry Program (HEDP) from 1979 to 1995. This individual currently works with Dade Moeller and Associates, Inc., an ORAUT subcontractor.

Evaluation Report and NIOSH Worker Meetings

The following clarifications were provided by workers related to descriptions in the NIOSH evaluation report, particularly the 200 Area facility descriptions (Section 5.2.3, "Chemical Separations").

- The ER stated: *According to site health physics documentation, reactor work areas were categorized into danger zones (i.e., red, yellow, and blue), which were subject to worker access limitations* (pg. 23). The 200 Area did not use radiation zones, but just had Radiation Work Permit areas.

- The ER stated: *Two Separations Plants, called the T Plant and the B Plant were operational as of September 1946. Each Plant included a separations building (221 Building) and a reduction building (224 Building). These plants were large, rectangular* *reinforced concrete structures that consisted of a gallery area* (pg. 23). There were actually three gallery areas in these buildings. The Operating Galley was on the top floor of the building. Under it was the Pipe Gallery (middle floor). On the bottom floor was the Electrical Gallery. The Electrical Gallery was even with the cells where all the equipment was. Iron ore was used for shielding instead of aggregate in the 10-ft thick concrete walls.

- The ER stated: *Next this batch was transferred to Building 224 (Bulk Reduction), where 330 gallons were concentrated to approximately 8 gallons of plutonium nitrate paste and further precipitations with hydrogen fluoride and lanthanum salts were performed to remove additional impurities* (pg. 23). The plutonium was a liquid when it was transported. The very first plutonium that was produced was a paste that was hand carried to Los Alamos. But for the period that the statement is referring to, it was a liquid that was transported to Z-plant.

- The ER stated: *Both purified strontium-90 and cesium-137 were transferred to the 225-B Building Waste Encapsulation Storage Facility, where they were converted to solids and encapsulated* (pg. 24). The encapsulated sources still remain stored there under 20 feet of water. This was intended to be for long-term storage.

- There is no discussion of the 233-S Building, which is separate from the REDOX building.

- Concerns were raised about assigning the same dose to all employees in the 300 Area. Some workers were asked to perform special support operations and were actively involved in making improvements to existing processes. This meant they were introduced to non-routine radiation exposure situations that other workers were not.

The operations at Hanford were secret and people didn't always know what they were working with (e.g., thorium, americium, etc.). The SEC should be restricted to people who handle radioactive materials and not specific radionuclides.

There are several situations that occurred at Hanford that would make dose reconstruction difficult. These issues should be addressed in the evaluation report.

- There was an on again/off again practice of finger ring usage. The first finger rings were used in the 1944 or 1945 timeframe. Use of finger rings depended on whether the worker or RM requested them. If an individual was dealing with a hot job with exposure on the order of tens of R/hour, then the RMs would request finger rings. In later years, when they were sending Tank Farm samples to the laboratory, technicians worked directly with these samples. There were times when employees at the lab went to get samples without wearing finger rings. In some cases, they were not issued finger rings. After evaluation of badge readings in about 1978, it was felt laboratory workers should wear finger rings.

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- The biggest gaps would be the indiscretions of the workers. For example, a worker was conducting work with neptunium. This Np was so hot that the RM left the area. The individual then took off his badge and did the work he felt needed to be done.

- Another thing operators did was to take a sample of plutonium nitrate from product cans (this is known as a "thief" sample). This was performed in an open room using a wet towel for contamination control. According to procedures, this was to be performed in a load-out hood. The only time it became an issue is when something went wrong, such as a spill. This practice was known and condoned.

NIOSH conducted three Worker Outreach meetings in 2007 (one in March and two in June). A Hanford Atomic Metal Trades Council (HAMTC) representative was present for all three meetings. The notes from these meetings were not provided to HAMTC representatives union or the petitioners for review, but were posted recently on the NIOSH website.

The overall feeling of some workers attending the meeting was that whenever a worker made a comment, there was an individual in the audience who stood up and disputed the comment. The perspective of some workers is that there is a lack of interest in the statements made by workers.

Miscellaneous

In addition to radioactive material, workers mentioned they were exposed to a number of chemicals. There was suspected exposure to ferrocyanide in the early 1990s during installation of thermocouple trees at the C Farm. There were times at C farm when off-gassing occurred and the odors would make it difficult to breath. In this situation, workers reported that no respiratory protection was used. A larger concern than the radiological exposure at FFTF was the potential reactivity of the sodium used to cool the reactor. Beryllium alloy was used in some fuel end caps.

There was a lot of asbestos everywhere. One interviewee and his crew developed the moisture method of cleaning up asbestos, where they sprayed the material and kept it moist to keep the particulate down. This method was not used until about 1983 or 1984.

During the operation of adding the copper-back plate, which used water-based graphite and oil sprays in the fuel fabrication process, the workers would be engulfed in off gases. There would be flames 4-ft high to get the surface smooth, so it could be extruded. Operators of the extrusion press were exposed to oil dag in the extrusion press area of Buildings 313 and 333. This is the graphite sheen on the liner to the extrusion press. One worker was directed to remove the carcinogenic label from the chemical. The label notified the workers not to get the chemical on their skin. Workers in the area were soaked in the stuff for 10 months of the year. During the extrusion of material, they handled the material with asbestos gloves. Workers had to scrape the transite troughs after each extrusion at the end of the day, so the extruded material did not have any galling on it.

An early Shipping Clerk indicated he issued about a million tanks of welding gases. When Camp Hanford closed, he shipped out the excess materials to the various government holding stations around the country, which amounted to about 3,000 car loads and truck loads of material.

United Nuclear Special Material Controller was responsible for maintaining the inventories for equipment and materials needed to operate the 100-N reactor. This included all kinds of different metals (e.g., Be brazing rings) and chemicals (e.g., silica sand for the water filter basins, bulk coal for the 200 Area power houses, oil, helium). The helium was supplied to 100-N Area from Oklahoma and Texas. Hydrazine was used for 4–5 years for rod cooling systems before the operations personnel were notified that hydrazine was identified as a carcinogen. Dichromate was also used by the operators.

Reactor Operators were required to perform checks in Building 109 where the steam generators were located at 100-N. There were a total of six cells with two steam generators in each cell. This area had a lot of asbestos.

Hanford was involved with the processing and analysis of Zero Power Plutonium Reactor (ZPPR) fuel at one point.

Additional Comments from Interviewers

One interviewee brought a copy of his employment records. He allowed SC&A team members to review them. The employment records included job titles, pay records, performance appraisals, security paperwork, and miscellaneous other forms. It is possible to place this individual in a general area at a specific time. For example, there are performance appraisals placing him in a building on the date of the appraisal. There is also some information on site transfers. Within this set of records, there is no record on a day-by-day basis of where this individual worked. This provides some additional evidence that day-to-day assignment of workers to various buildings and areas may not be in the employment records.

In addition to discussing the petition with the petitioners, SC&A reviewed records the petitioners had collected to support the petition. The records were primarily Hanford radiological and personnel records for individuals providing supporting affidavits. Many of the records were either provided or referenced in the petition.

References

Gerber, M.S., 1995. *Legend and Legacy: Fifty Years of Defense Production at the Hanford Site*, WHC-MR-0293, Revision 2, Westinghouse Hanford Company, Richland, Washington, June 1995.

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APPENDIX D: SUMMARY OF INTERVIEWS RELATING TO BUILDING 324 INCIDENTS

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INTRODUCTION

As a technical support contractor to the Advisory Board on Radiation and Worker Health (Advisory Board), SC&A has been tasked with investigating concerns raised to the Advisory Board and the potential impact of these concerns for active Hanford Special Exposure Cohort (SEC) reviews. The concerns raised to the Advisory Board involve recently reported findings of high radiation readings in the soil under Hanford Building 324.

One component of SC&A's review is a series of interviews with current and former workers with experience related to Building 324. John Stiver and Lynn Ayers of SC&A conducted onsite interviews between March 28 and March 30, 2011. A written response and two phone interviews were provided by individuals who were unable to participate in the site visit. A total of 13 individuals were interviewed, with employment dates ranging from 1948 to the present. The workers were employed by various contractors and the Department of Energy (DOE). Their experience includes research and development (R&D), process operations, engineering, radiological control, maintenance, decontamination and decommissioning (D&D), and project oversight. Some interviewees worked primarily in other buildings, particularly 325 and 327, where related programs were conducted. Their experiences, particularly in regard to radiological controls, were considered relevant, as they performed similar work in similar facilities for the same contractors.

A classification officer was present for all onsite interviews and a telephone interview. Participants were told that the interviews were unclassified, and that they should not disclose any classified information. All interview notes were submitted for classification review and were released to SC&A. A written summary of each interview was prepared, submitted for classification review, and provided to the interviewee for review. Responses have been received from 12 of the 13 interviewees. This summary only includes materials from those responses.

Information provided by the interviewees is based on their personal experience; individuals' statements may need to be further substantiated. This interview summary is provided in that context.

Soil Contamination and SEC Concerns

A former worker was aware that process/glovebox waste drains and piping going to waste tanks had to be double-walled (pipe within a pipe). If the waste in Building 324 had corroded through two layers of pipe, so that the contamination escaped into the soil, it would be difficult to know where the pipe(s) were breached and who was exposed while it was leaking. The concerned individual initially thought the soil contamination was found during post-demolition excavation. If the building was gone, it would not be possible to determine the source of the leak or evaluate the potential for past worker exposures. [After learning that the contamination had been discovered by placing detectors beneath the intact structure, the interviewee expressed an additional concern]: "This means they are only getting partial information and using estimates on the real amount of contamination."

The soil contamination found under Building 324 is not the only instance of remediation crews finding unexpected contamination. When they find a "surprise," how do they know where it came from, how/when it got there, and how many people were exposed to it along the way? How is this cradle-to-grave history taken into account in the SEC review? A number of old burial sites are being excavated at Hanford, as well as decontamination and demolition of many former process buildings. What processes are in place to provide information from DOE to NIOSH about contamination finds and assuring that NIOSH accounts for them in SEC considerations?

Building 324 Facilities and Operations

Building 324 is located in the 300 Area of the Hanford site. [For many years,] Buildings 324, 325, and 327 were shared by Westinghouse and Pacific Northwest National Laboratory (PNNL), which is operated by Battelle. Westinghouse was the facility owner/landlord during the 1980s. Battelle operated specific facilities within the buildings. PNNL took over the full operation of 324 and other buildings in the mid-1980s. PNNL transferred Building 324 to Babcock & Wilcox (B&W), a D&D contractor, around 1997. B&W assumed responsibility for Building 324 and Building 327 from 1996–1997 as a subcontractor under Fluor. They were absorbed directly into Fluor after 1 or 2 years. D&D activities at this time were focused on decontaminating hot cells; stabilizing and removing contaminated material from the cells.

Workers in Building 324 handled a broad range of fission products, including radioactive waste and commercial spent fuel. The work might vary from laboratory work with tracer amounts to work inside hot cells with gross activity. The recipe of nuclides has not changed much since the 1980s.

PNNL/Battelle ran the work in the Radiochemical Engineering Complex (REC) – cells A, B, C, and D. PNNL handled all sorts of radioactive materials in very high quantities in the REC, often in liquid form. Other facilities in Building 324 included the Shielded Materials Facility (SMF), Radiometallurgy Cells, Safeguards Vault [Fissile Materials Storage Vault], waste tank vaults, and Engineering Development Labs (EDL). There were shielded gloveboxes in some areas of 324. Hot cells in the EDL were more like large, shielded gloveboxes, compared to the very large, heavily shielded hot cells in the REC. There were lunchrooms, a reception area, and office areas in the building.

A central Airlock, a Truck Lock, and a Cask Handling Area were shared between the contractors. The central Airlock was like another big cell, but a lot cleaner than the RECs. Dose rates in this area might vary from a few hundred mR to several R, depending on the job. They sometimes worked on equipment in this area also. The Cask Handling Area was where they staged casks going in and out of the hot cells.

In the mid-1990s, [highly radioactive heat sources produced in B-Cell] were stored in A-Cell. Cleanout was in progress in B-Cell. D-Cell was being cleaned out for other missions. The [fissile materials] vault was still full when the building was transferred to B&W.

An operations worker handled Pu, U, and some Th, primarily in SMF. They pulled apart fuel assemblies and reloaded them for FFTF [Fast Flux Test Facility] support. Workers investigated breached or ruptured elements. [The elements were] encapsulated and sent to 327, where they cut up and analyzed the metal. The workers handled a bunch of exotic materials that were irradiated. Most of these were encapsulated. They would package and ship them out to the investigators or send them to 327 for analysis.

An interviewee said there were no research or production campaigns in Building 324 [in the mid-1990s]. Y-90 medical isotope processing occurred in Building 325 [~1995].

There was a significant contrast in conditions between SMF and RECs. The Westinghouse side was supporting FFTF at the time [early 1980s]. They were working on test assemblies, and there were very high requirements for cleanliness. After a campaign for FFTF, workers could make manned entries into the hot cells with mops and buckets. The Battelle side was known as "the dark side." The cells were too hot to enter, so they became dark and dirty. The windows became brown from exposure. Paint deteriorated on the walls, and the concrete absorbed more of the available light. Dust was pulled in through the air plugs.

INFORMATION SPECIFIC TO B-CELL HISTORY AND SOIL CONTAMINATION INCIDENT

B-Cell Operations

The soil contamination reported in November 2010 is located under the REC B-Cell. B-Cell was the highest activity hot cell on [the Hanford] site. The hot cell was under negative pressure, because ventilation throughout the building was designed to draw air from non-radioactive areas towards more highly contaminated areas. Cells in 324 Building were used for radiochemical processing—the work is somewhat "sloppy" by nature. A stainless steel liner covers the floor on top of the concrete, and goes partway up the sides of the cell. Work in B-Cell was done remotely from the first floor gallery. Two circular windows were put in on the second level for a vitrification project in the late 1970s.

[The main focus of R&D activities in B-Cell] was waste treatment technology for high-level nuclear waste. The work they did in the 1960s was laying the groundwork for selecting waste processing technologies. The emphasis was on commercial fuel separations and processing. The first project used waste from the PUREX Plant to simulate commercial waste. Special runs were done without sulfate to give them the full spectrum of fission products. They added Ce-144 and Pr-144 from B Plant to heat it up. They handled about 50 million curies, but the half-lives are about 1 year.

[In the 1970s,] a joint project between 324 and 325 Buildings was to vitrify actual commercial waste. This project was called the Nuclear Waste Vitrification Project (NWVP). They used actual spent fuel for NWVP; they wanted to have all potential waste components present to verify that the vitrification process was feasible. They worked with spent fuel assemblies from the Point Beach power reactor. Fuel assemblies for NWVP were stored in B-Cell. They chopped and dissolved the assemblies in B-Cell, and they sent the material by underground pipe to Building 325. The group in 325 extracted the uranium and plutonium, and the high-level waste was returned to 324 Building for vitrification. Interviewees are not aware of any problems with the inter-building transfer line. It was only used for the NWVP between 1977 and 1979.

They worked with Three Mile Island (TMI) waste in the 1980s, demonstrating the joule heated melter that is now used at modern vitrification plants. Three canisters of wastes from TMI were received to demonstrate the feasibility of waste vitrification. The waste was in the form of ion exchange resin (zeolite).

In the early 1980s, workers were involved in a project to create canisters of high-level waste for the Federal Republic of Germany (FRG). This project brought cesium and strontium solutions into B-Cell. The Cs/Sr source material for the German canister project came from an onsite reactor. It may have been from B Plant. Tens of thousands of Curies of cesium, or more, were brought into B-Cell for the first vitrified log. The material was doped (not actual reactor waste) to demonstrate the vitrification process.

Equipment built up in B-Cell over time. Some equipment in the cell was used for multiple projects, thus there was no need to remove it. There were always cuts in the budget, time, and resources. There was never money in the budget to take out old material, except for the TMI project. TMI was the only time when DOE took the equipment out afterwards and disposed of it in 200 Area. There was a huge cost involved with housekeeping that was hard to justify to management. It was often kicked down the road, but [some supervisors] argued it's cheaper now than it will be later. [In addition to budget issues, a worker also thinks cleanup] wasn't a priority for scientists. They tended to move on and get into the next research project when one project was over. You had to write it into the contract to have them clean up after a project.

[Some interviewees discussed the presence of standing water in B-Cell; there was some disagreement in regard to the time period when water was present.] An interviewee recalled that there was water on the floor of the cell from the late 1970s to early 1980s. They had fuel elements in the racks; water covered them. They had to jet it to waste tanks. The interviewee doesn't recall any standing water in the cell after 1983, when they were getting ready for the heat source project. Another interviewee recalls that the floor of B-Cell was covered with standing water in 1987. The interviewee doesn't know why. There was standing water in B-Cell in the late 1980s—this was intentional. The water had been there all along, maybe before the 1986 spill, at least intermittently. When they dropped equipment or tools, they used the ripples on the water surface to indicate where it had fallen and try to get it.

Major Spills in B-Cell

There was one major spill in about 1968, involving mostly Ce/Pr. They normally prepped the waste on Thursday and Friday for the following week's work. The waste batches were about 500–1,000 liters. On this occasion, when they went in on Monday, Tank 112 was empty. The seals on the bottom outlet pump had failed, and the material had leaked out over the weekend. It went to the floor, drained to the sump, and was pumped to the waste vault, as the cell was designed to work. Some other very small leaks (drips) occurred in the load-out stall. Because of

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the short half-lives and the amount of time, contamination from Ce/Pr spills that occurred in the 1960s would not produce the high dose rates currently reported under B-Cell.

Most of the contamination in B-Cell came from the FRG program. The biggest spill occurred in 1986, when 500 L of liquid cesium nitrate was spilled in B-Cell. This spill is considered the most likely source of the soil contamination. Liquid cesium nitrate was being transferred from one vessel to another. It was a vacuum transfer, so there was no way to measure the liquid volumes during the transfer. After the transfer, workers observed that the volume was lower than it should have been. They found out there was a crack in a weld on a jumper. About 200,000 Ci of cesium had spilled on the floor of the hot cell. This was very well characterized material.

People who ran the processes in these cells documented things quite well, both the processes and the significant contamination incidents that occurred. Any significant spills or leaks that they knew about were documented in the record. There have always been records management requirements in place, at least since [the 1970s]. The researchers complied with those requirements. Individuals who were involved with specific incidents [during the R&D era] do not have these records and do not know where they are now.

The records associated with Buildings 324/325 remained with the facility and were transferred to the new contractor when Battelle turned over the building. The records should have been passed along to each new contractor and/or stored with DOE. If the soil contamination was considered a surprise, how did the contractor perform their due diligence for characterizing the site before beginning the job? In addition to historical records of facility operations and incidents, several workers who did radiochemical processes in these buildings are still available with their institutional knowledge—some of them are still working for the contractors. To what extent did the contractor review historical documentation and talk to workers who have historical knowledge of the facilities?

B-Cell Remediation

Battelle started cleanout of seven hot cells (Buildings 324 & 325) in the late 1980s–early 1990s under a Surplus Facilities Management program. The emphasis of this effort was on recovering equipment and facilities for other uses. The Battelle program encouraged innovation. They made a lot of progress in 18 months, and they did the work safely and cost-effectively. They developed innovative techniques to reduce costs and personnel exposures. The buildings were later transferred to Babcock & Wilcox and other contractors after them.

PNNL began cutting up material and equipment in B-Cell during the 1990s. Nothing was done to the building. They were cutting out equipment and racks, size reducing. There was some dirt on the floor, but mostly debris. Debris in B-Cell really started accumulating during cleanout. There was slag and metal from resizing efforts. [There was equipment such as] saws and torches.

Several cutting methods were used in cell cleanout. Lasers did not work very well. A hydroknife used [high pressure] water with granite powder. The granite clogged up the nozzle.

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When cutting with plasma torches, they used an electronic precipitator to plate out the smoke particles before they got to the filter. There is a report available on the web that shows a photo of a plasma torch cutting a metal plate. The picture is from B-Cell. You can see lead blankets in the photo [that were used for shielding].

The B-Cell cleanout [in the mid-1990s] involved a lot of size reduction and waste removal. They used plasma arc cutters to cut large equipment, racks, and other items down to a size that could fit into a cask for removal and disposal (about 6' x 5'). They used a lot of grout to stabilize the waste material in the SEG casks. Some grout spilled on the cell floor during these operations. They packed about 2 casks per week and passed them out of the cell through the airlock to the Cask Handling Area.

By the 1990s, the floor of B-Cell was covered in dirt and debris. There were a couple of problems with the cell design. One problem was that the manipulator arm was mounted 18 feet above the floor, but it only had a reach of 10 feet. Anything dropped on the floor stayed on the floor or had to be retrieved by the overhead crane. Each research project over the years had added to the accumulation of contaminated equipment and debris. The engineers had designed the floor to have a slight grade, so liquid spills would drain to the sump; there was a sensor in the sump to alarm when liquid was present, so it could be transferred to the HLV [High Level Vault] tanks. However, they didn't account for the dust accumulation from operating the cell at negative pressure over many years. There was a layer of dust 3 to 5 inches deep on the floor of the hot cell. When the cesium spill occurred in 1986, the liquid had soaked into a layer of dust, rather than draining to the sump. When dried, it became a dispersible. This hazard was reported in a Safety Analysis Report in 1993.

From the early 1990s to early 2000s, DOE was involved with RCRA cleanup of the HLV and REC in Building 324. They were dealing with mixed waste in A-, B-, and D-Cells. [Once the materials and equipment in the cells were designated as waste,] DOE was in violation of RCRA [Resource Conservation and Recovery Act] for having RCRA mixed waste in non-permitted areas. The State was not happy; they thought people had deliberately made the mess in B-Cell.

As part of DOE's effort to produce a Closure Plan for removal of dispersible waste from Building 324, a worker with 20 years of experience in Building 324 reviewed historical logbooks. They discovered an incident report from the mid-1980s (before the Point Beach fuel reprocessing). Workers had gone into the crawlspace under the airlock to install a line between B-Cell and the High Level Vault. Workers in the crawlspace noticed cracks in the concrete above them. They discovered that contamination had seeped to the soil in the crawlspace. They removed the contaminated soil and investigated the source. This contamination did not come from B-Cell, but from A-, C-, or D-Cell. The floor of B-Cell is a slab on grade, with no crawlspace or basement beneath it.

The discovery of this information made DOE aware that they might not know about all past incidents, and that it was possible for lined hot cells to have leaks. They realized that they might encounter unexpected contamination during D&D of Building 324. DOE proposed to write into the Closure Plan a process for responding to new discoveries. The process included notifying state regulators and providing an investigation report of the finding within 90 days.

DOE's proposal was accepted by the state regulators and incorporated into the Closure Plan. They had monthly meetings with the State to monitor progress towards the milestones (M-89-02 Progress Monitoring Plan). They met the milestones for removing the dispersible material, using videos to demonstrate compliance.

Dispersible contamination within the cell was handled remotely. Equipment racks were washed down with water before they were size-reduced and removed from containment. During cleanout, they dragged a 5-ton block across the cell to push the waste/debris. Sometimes the block could not break through the crust; it was like concrete. Then they built clam shells to scoop up the debris.

Most of the debris and waste removed from 324, such as the FRG canisters and the grout containers, was TRU [transuranic waste], > Class C (RCRA). There is no end point storage available for it. They moved some waste to the PUREX tunnel. The rest went into shielded containers on a pad in 200 E.

Discovery of Soil Contamination Under B-Cell

The geoprobe measurements [that detected the soil contamination] were done as a proactive response to discovering a breach in the cell liner. The crack in the liner was noted from photos that WCH [Washington Closure Hanford] took of the cell interior to help with determination of cell inventory.

While removing contaminated grout from B-Cell floor and sump, WCH identified a hole in the stainless steel liner at the floor of the sump. After the contaminated grout was removed, a 6-in layer of clean grout was poured over the whole floor, sealing the hole.

They have bounded the horizontal footprint of the contaminated area. It appears to have gotten under the liner and seeped out along the concrete expansion joint along the perimeter of the cell floor. They now have a probe that will go into the cobble layer to verify the vertical bounds of the contamination. They are also planning to pull very small samples of soil (~ 5 cc) for analysis.

General Information Regarding Building 324 and Related Facilities

Construction and Maintenance

JA Jones was the primary construction contractor. They had a lot of highly trained and competent workers on site. JA Jones had very experienced skilled laborers. Facility people escorted them. Workers were paid extra on jobs with special conditions, such as respirator requirements.

There wasn't a big construction workforce in Building 324. Most installations for the hot cell were fabricated outside and passed in. JA Jones would do the fabrication offsite; Battelle technicians did installations in the hot cell.

There was quite a bit of construction in the late 1970s and the 1980s. They built an addition onto the front of Building 324. There were contracts with construction workers, primarily JA Jones and Kaiser, to do decontamination and maintenance in the cells. Millwrights worked on mechanical parts.

Repairs in hot zones were common in the REC and SMF. Hot cell technicians could do complex work with manipulators. For example, a computer-operated CNC [Computer Numerically Controlled] lathe in a hot cell in Building 327 had an electrical failure in the late 1980s. It would cost $1.2 million to pull out, decontaminate, and replace the equipment. A hot cell technician worked with an electrician to figure out how to re-wire the equipment inside the cell. They rebuilt it with manipulators. SMF had cranes and remote detectors. Tools were put in with in-cell design criteria. Most equipment in the SMF was designed so that parts could be replaced remotely.

Ventilation and balance workers check hood flows, air flow, HEPA filters, HEPA vacs, etc. Aerosol tests and smoke tests are used to indicate when filters need to be changed out.

General Safety Culture

Workers based in Buildings 324 and 325 reported that Battelle had an excellent safety program with very competent and experienced people. They took safety very seriously, sometimes bordering on overkill. Procedures were approved by four levels of disciplines, and they were followed precisely. If there was an error in the procedure, it was sent back for review and revision.

It was a good building to work in—good people who worked well together. They did whatever it took to get the job done. In the 1980s, they were still in full production mode. It was very safe; they knew what was right. The safety attitude was very good. They took calculated risks to do the work that needed to be done, but it was well planned and controlled. Everyone had the same mentality. There was lots of planning and open discussions among workers. Most had a good working knowledge of how to do the job safely. The [informal] training program was effective; trainees were paired with experienced workers on the job. You really got to know your buildings. In later years, with more formal procedures and regulations, it became difficult to get things done efficiently.

Workers participated in emergency/contingency planning. For example, a project in the SMF prepared cesium capsules for medical use. The “worst case scenario” they addressed was having a cask full of capsules get dumped on the floor [of the Cask Handling Area]. How would they pick them up in conditions up to 1 million R?

Programs got more formal in the 1970s, and then became less precise as the mission moved from operations and research to construction/D&D. During operational years, precision and communication were very important—shutting off a fan in one area could impact work in other parts of the building. Under D&D, the need for high-level scrutiny was not as great, so the mindset changed.

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Some guys doing hot cell work were focused on getting the job done and thought the RadCon program was someone else's job. They weren't careless—they knew what things were definitely not in their interest and avoided those things—but they made considered choices in other matters where safety issues were secondary to getting work done.

[In the mid-1990s], they had competent staff and good operational protection. 10 CFR 835 was new, so people were adapting to new processes and procedures. A RadCon worker thought it was noteworthy that the RadCon Manager said he would buy lunch for the first RCT [Radiological Control Technician] who called a "stop work," and he did.

In describing the cooperation and "mutual dedication to safety" demonstrated by Battelle and Westinghouse, a worker offered an example from Building 325 that he characterized as a "near miss." A highly radioactive solution had soaked through the HEPA filters, so that it was exposed to a high flow of air that had no additional filtration. It was important to remove the radioactive material before it dried and became airborne. Battelle was responsible for causing the spill, but Westinghouse was responsible for the HEPA filters and downstream ductwork, including monitoring the exhaust air. Battelle workers contacted Westinghouse and they jointly decided that Battelle was in the best position to remove the radioactive material with Westinghouse observers. The work went quickly and smoothly, and no increase was noted in exhaust air. Both companies really do practice safety first.

Chemical safety was lacking in comparison to rad safety. Industrial Hygiene was still in its infancy [in the 1980s]. With PNNL, rad safety was very good—formal programs, well controlled. Chemical safety on the cold side was not well controlled.

Access Controls

Access controls changed over time. A worker who started in the late 1970s does not remember having to go through "super security" in the beginning. Maybe the fence and enhanced security came a couple of years later. In the 1970s, you could come up to the building outside, but you needed a Q Clearance to enter the building.

In the 1980s, security was very tight, with the exclusionary fence in place. There was a fence and a badge house restricting access to the inner 300 Area. There was a fence around 308, 324, 325, and 328 (not 327) with a badge house. [Entry to the fenced area] was monitored by Hanford Patrol. A guard/patrolman in the badge house checked workers' badges as they entered. You had to be on an approved list to enter. Access was controlled by area; workers within the fence could go between buildings. Building 308 did fuel processing and had guards inside the building.

Later, the fence was torn down, they stopped using the guard house, and building access was controlled with prox cards and escorts. The guard house was taken down around 2004.

The fence was removed and clearance requirements went away in the early 1990s. By [the mid-1990s], there were no fences or building zones. You could go wherever you wanted within the 300 Area. A prox card was needed to get in the building; this was controlled by DOE. Now, there is just a CERCLA [Comprehensive Environmental Response, Compensation, and Liability Act] construction fence (chain link). You could get inside the building; high rad keys still control the cells.

When SNM [Special Nuclear Material] was present, access and egress to the SNM was controlled. Egress from the area around the SNM was maintained for compliance with Life Safety Code. By about 2003, the spent fuel was gone.

Within Building 324, there was no free-flowing traffic to the hot gallery areas. You went there for a specific reason. It was well marked, designated as a radiological control area, with egress monitors. People were trained not to enter posted radiation areas.

One interviewee stated there was a card index that controlled access to the operating galleries of the hot cells. To get an access card, you had to have a need for access and rad worker training. The access card to the facility was separate from the ID/dosimetry badge. Another interviewee said Omni-locks were used on doors, basically a key-code lock when areas were not in use.

Non-rad workers were not supposed to enter radiological work areas. They could be escorted to certain radiological areas. There was no physical barrier preventing someone from going into radiological areas. Sometimes someone might get into the wrong area, such as a janitor getting lost in the building. Janitors and managers sometimes wandered where they should not be. They were escorted out and frisked.

Guards coming through on night maneuvers (post-9/11) were not restricted from zones. In case of emergency, they were expected to go in, take care of the emergency, and address radiation/contamination issues after stabilizing the situation.

Radiological Controls

[In the 1980s,] Battelle had its own RadCon group that covered the workers doing the processes. As building owners, Westinghouse [RadCon] people covered maintenance activities, such as filter change-outs. [Westinghouse personnel] covered work in the Radiometallurgy Cells and EDLs. Workers made entries in the East and South cells all the time. The construction crews might bring in their own RadCon or use Westinghouse RadCon. They usually had their own timekeepers for tasks. There was collaborative planning between construction and facility staff to plan staff around the work conditions and the job.

Battelle first assigned Rad Engineers to buildings in 1995. Before that, Battelle had various radiological support roles, but not building-specific field Rad Engineers.

RWPs [Radiation Work Permits] were very general in the 1980s. They weren't tailored to the specific job like they are today. They had some limits, no individual basis; more like a sign. They were required, but they were generally ignored. They were almost all the same, essentially; "Do what the RCT tells you." Workers relied on individual training, knowledge, and professional judgment to respond to conditions and situations encountered in the field.

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[In the 1990s], there were routine and job-specific RWPs. Procedures are in the Hanford RadCon Manual (1994), which mirrored the DOE RadCon Manual. The RWPs covered engineering/administrative controls, dosimetry, limiting conditions, etc. They were rigorous and were followed. RadCon Supervisors and Rad Engineers reviewed and approved RWPs. In some cases, RWP requirements were integrated into work documents for low-risk, routine work. The goal was to consolidate all requirements into one document.

Timekeeping was used to limit personnel exposures for specific jobs, such as decontaminating hot cells in Building 325 or a new crane installation. Timekeeping was used for hot jobs; not so much for routine work. If dose rates were fairly high, they sometimes used timekeeping, either alone or in combination with self-reading dosimetry, to control exposure. They preferred to use self-reading dosimetry and used that when it was available. It usually was.

In the 1980s, timekeeping was used, but not documented. It was not recorded on RWPs. There might be a note on the survey report saying what time restriction was necessary for the conditions. Survey reports have 75-year retention; they should be available.

RadCon would do a pre-job survey and brief the workers. Even when monitoring real-time exposures, the RCT did not tell the workers what to do in response to a high field. The RCT advised them of conditions as they were noted, but only the Ops Supervisor had the authority to direct the workers. Too many people giving directions would cause confusion, hesitation, and increased time and dose.

Preliminary surveys and exposure estimates were made for specific jobs. Real-time dosimetry was not 100% accurate. A supervisor was involved in estimating exposures and planning for hot jobs. They used remote survey equipment to assess conditions for the job. They evaluated the job to be performed considering the work activities and estimating the length of time needed to complete the task. This information was used to make job assignments and determine time limits for the job. They had pretty good confidence in these estimates. The goal was for estimates to be accurate within 5%–10% of the actual exposure for the job, and they met that most of the time. There were 20–40 people making entries, and the workers watched it [accuracy of estimates]. RadCon investigated when the actual values were not consistent with the preliminary estimates.

Room 15 was a filter room. A lot of building prints did not have it listed. It was a very hot area—there was a 3-minute time limit for working in there. That is where they kept A-Frame HEPA filters. There was a lot of grease—it was nasty down there. A worker was involved when the last A-Frame filter was pulled [in Building 324]. It may have been from D-Cell. The job was completed without incident. A carpenter was budgeted about 700 mrem to replenish the grease seal, and they stayed well below that (~300–400 mrem).

They self-monitored at the work location and when exiting radiation areas. At the work location, they monitored with PAM [Portable Alpha Monitor] and GM [Geiger Muller]. When leaving the area, they used whatever monitoring was available. In early years, this was a counter to measure both alpha and beta/gamma on hands, and portable instruments for feet. With time, this improved to include hand and foot counters, and finally one to also monitor the whole body.

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Hand and foot monitors were hard to set up for alpha. Radon interfered. The first portal monitors [whole-body detector] came years later. An interviewee recalled getting portal monitors—PCMs [Personnel Contamination Monitors]—in the 1990s.

If anything, one interviewee said the hand and foot monitors may have been too sensitive. There was a high rate of false alarms—maybe 90% of alarms were false positives. Static electricity caused false alarms. Once, a lady on a tour with high heeled shoes poked a hole in the mylar.

If the monitor was down, someone was stationed there with equipment to frisk people out. Positive results were reported to Radiation Protection, and workers followed their direction in recovering. They also evaluated the work site to see if improvements needed to be made.

When exiting the airlock [in the 1990s], workers went through three stages of monitoring. They did an initial scan within the contamination zone, went through a PCM to exit the contamination area, and a hand and foot monitor to exit the Radiation Buffer Area.

Rad [release] standards for laundry were less stringent than for egress. They got many false positives from frisking that were from laundered clothing and not contamination picked up during the job.

Survey equipment [in the 1980s and 1990s] included SNOOPY (NRC AN/PDR-70 BF3 proportional) for neutrons, PAM for alpha, and GM with various probes for beta/gamma. Cutie Pies and area monitors were used. Other instruments with higher detection ranges were used as well. They used 'teletectors' with 12-ft remote extensions to monitor waste as it was brought to the airlock threshold. RO-7 was another remote detector for process monitoring in cells. It had a long cable that could be put into the cell through a port and positioned with a manipulator. Now, they use a 100 cm^2 detector (DC alpha/beta instrument – Ludlum 2360 with 4390 probe). [Other current instruments include] GMs with pancakes and shielded probes, extendable teletectors, RO-20 dose rate monitor, and rem balls for neutrons.

There was very little alpha monitoring in the hot cells during Westinghouse days. The thought was "there is no alpha" due to the materials used.

Functional test sources were used for daily checks; PNNL Site Services performed calibrations. Documents, reports, and calibration records all had to be maintained. They have lifetime retention and would be PNNL records.

There wasn't much change to the facility over time. The hot cells were designed with negative pressure, and HEPA filters were in place before 1980. Some technology shortfalls were identified from the 1980s:

- From the early days, they wanted to get detectors down to a small size. Very small detectors had geometry problems—they were not seeing the whole field.
- Many correction factors were used. For example, the CP [Cutie Pie] instrument had correction factors for neutrons as well as alpha readings. It's safe to say that most all

readings needed a correction factor. An error in using the right correction factor meant a large difference between the true dose and the worker's reading.

- Air samplers were fixed, based on known/anticipated sources of high airborne concentrations, and their placement was not based on air flow patterns. A later smoke-testing study showed that some were in bad locations, and they had to be moved.
- Early computers using metal tape for programs calculated data incorrectly. The calculations were sent to Seattle to evaluate if the error made a difference.

A worker could not think of any [technology] shortfalls from the 1990s. The Operations groups were very responsive and proactive. The prevailing attitude was "Let's try this."

Engineering controls were usually confinement of the radioactive material and airflow from areas of low contamination to areas of high contamination. Administrative controls were working from areas of lowest dose rate, minimizing the time of exposure, and using protective equipment specified for the task. Controls were already established by 1994. The Operations group had their own ALARA [As Low As Reasonably Achievable] person, who had RadCon experience.

In the gallery, they would wear shoe covers, gloves, and a lab coat. They had area radiation monitoring alarms, so action could be taken if unexpected levels of radiation were present.

Galleries were usually clean. They only designated them as CAs [Contamination Areas] when it became a DOE occurrence to find a speck of contamination on your shoe. It became very costly (about $40K) in lost time for evaluations. It became more cost-effective to have everyone dress out for a CA than to stop, report, and evaluate every situation.

Contamination in the gallery mostly came from manipulator change-outs. Also, water leaked out of plugs during [hot cell] wash-down with the split plug design. Plugs had a split design, so electrical lines could be run through them. Contamination could get out around the plugs [capillary action] and leach out through the plugs [diffusion]. They routinely checked the plugs for contamination. Plugs were sometimes removed; this was a routine, everyday practice. You pulled the plug, put it in a bag, did the job, replaced the plug, and cleaned up the area. An example of good contamination control and monitoring processes was the establishment of a radiological buffer area when pulling the split plugs. The plug design changed later. After the racks came out, shield plugs went over the penetrations.

RadCon got directly involved with cask handling operations, because the exposure potential and the need for worker protection became significant at that point [as material came out of the hot cell].

They used a pressure washer to decontaminate the airlock. When workers made airlock entries, they wore two pairs of coveralls and gloves. Depending on the job, they might have boots and air lines. If liquid or gross airborne contamination might be involved, there was an outer layer of plastic over the coveralls.

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PPE [personnel protective equipment] changed over time. They used full face masks with canisters in the 1980s; air lines were used more starting in the 1990s. They always wore masks when making entries. Properly fitted respirators prevented inhalation exposures. Plastic air suits were used, depending on the level of activity of the particular job. [In the mid-1990s,] they used full bubble suits with air lines for airlock entries. "Cut men" helped the workers by cutting them out of disposable protective suits when the job was completed. Workers were always evaluated for contamination by RadCon.

There were weaknesses in the inventory system—mass balance did not always account for everything. What you shipped out wasn't everything that came in. There was dust, residual, or material lost up the stack.

Stacks were monitored continuously. There were fixed air samplers in the galleries. The filter diameter was about 1 ½ inches. [In the 1980s,] the fixed head air samplers were not based on smoke tests and were not in the best locations. Some CAMs [Continuous Air Monitors] remained in a particular area; additional CAMs would be brought in near the work area when they anticipated a higher potential for airborne contamination. Portable pumps were used when [they wanted readings] closer to the work than the stationary filters. They took high-volume grab samples. The location and type of air sampling were determined by Radiation Protection. RadCon managed the air sampling; instrument technicians serviced the equipment. One interviewee recalled there was not a lot of airborne contamination in 324. It was very rare to get CAM alarms.

[In the 1990s,] they had fixed CAMs in specific locations, such as the galleries. Smoke checks were used to identify appropriate locations for air samplers. There was an initial assessment and probably annual checks afterwards. Fixed heads were checked routinely, about once a week. They would also be checked after jobs.

Grab air samplers, such as the SAIC H-810 high-volume sampler, were used on jobs. For high-risk jobs, they put a grab sampler as close to the breathing zone as possible, between the source and the worker. For example, when people were working on a manipulator port high up on the wall, they strung the grab air sampler up within about 1 foot of the worker. The sampler was close enough to the workers that the noise was bothering them.

Most interviewees do not recall lapel samplers being used. Lapel and breathing zone monitoring did not come into use until after 2005. One interviewee said they sometimes wore breathing zone samplers when going into the airlock. Now the workers are packing 20 pounds of monitoring equipment.

Removing a manipulator for repair was handled very carefully to avoid exposure and control contamination. If the boot was intact, the internal structures [of the manipulator] were not exposed to the cell environment, and they stayed clean. If the boot ruptured, the manipulator would be contaminated. They would pull the manipulator as soon as possible after a boot rupture in order to minimize the contamination. They attempted to decontaminate the manipulator within the cell, then pulled it out through a sleeve and completed the decontamination as needed.

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They shut down the gallery while pulling out the manipulator. When they changed out manipulators, there was plastic all over. They put tubular plastic over the opening from the cold side and covered the manipulator as it came out. There was a decon station in the EDL lab. Workers had continual RCT coverage, and there was a CAM in the vicinity. Contaminations did occur, especially if the manipulator boot was breached. Pipe sleeves on transfer tanks could also cause contamination, but this was rare.

In-cell work was not hands-on, because the materials were too hot. Multiple layers of gloves were worn for most all hands-on work. They typically wore several layers of disposable gloves when work was done in the airlocks. They wore two pairs of surgeon's gloves and one pair of work gloves. Some work was done with bare hands, because gloves interfered with very fine technical work. This was fairly common in the "little cells" in 327, where they handled very fine wires. It didn't happen much in 324.

Hot cell cleanup occurred in 325 Building as they finished one job and prepared for the next. Usually, they removed as much radioactive material as possible, removed any large equipment that did not require excessive shielding, and cut up any other equipment to be discarded into small enough pieces to fit in a solid waste cask. If personnel entry were to be made into the hot cells, they used extensive flushing to reduce background radiation levels. They used remote sensors to measure residual radiation levels. When levels were low enough, they developed plans to provide whatever additional cleaning was needed. Protective equipment requirements were defined in the work permit prepared for the job by Radiation Protection. Some areas of Building 324 could accommodate worker entries into hot cells, but the B-Cell could not be entered because of excessive dose rates.

Eating, drinking, smoking, and chewing were not allowed in the work area. This was tightly controlled; they only ate in the lunchroom. According to one interviewee, it may have been OK to eat in the control room, but food was not allowed in hot work areas or even in the EDL. Another interviewee recalled that there were drinking fountains in contaminated areas. Some people chewed tobacco or gum, but they weren't supposed to do so. Sometimes candy wrappers or cigarette butts were seen, but it was not common. It was against the rules and they would not want to get caught. In later years, they set up areas and surveyed them to create smoking areas.

PNNL does most of the environmental monitoring for the site. The contractor companies did some monitoring, as well. RadCon workers assigned to Building 324 [in the mid-1990s] performed routine surface surveys of the yard around the building. Field characterization for Building 324 was already established by this time. Official reports have a 75-year retention requirement. They are in Seattle, mostly under PNNL records.

External Monitoring

External gamma was a significant consideration in Building 324 during operational years. Most of the external dose for the whole Hanford site came from 324. An interviewee once tried to list the times he encountered dose rates of 100 R/hr or more; he came up with at least a dozen occasions from memory. Another interviewee commented that a worker could get 20mR/day in Building 327 just doing the typical work [without any incidents].

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The external dose of record was monitored by TLD. PNNL Site Services handled this. They still do. PNNL read TLDs and finger rings—the dose of record. Monthly exchange was typical for routine jobs. They would exchange and read dosimeters immediately after hot jobs. Supplemental dosimetry, such as pencils and electronic dosimeters, was managed by the RadCon group. Pocket dosimeters and electronic dosimeters were read by facility RadCon personnel for the individual companies. Supplemental dosimeters were job-specific, not full time. RadCon reviewed PNNL dose reports against their supplemental dosimetry records and evaluated discrepancies.

Neutron dosimetry provided a dose of record only; there were no supplemental neutron dosimeters until about 2006. RCTs used Snoopys and rem balls to monitor dose rates, which were considered in job planning. They might make changes, such as more frequent checking of the TLD, if warranted. Neutrons were not a significant component of work in 324 at that time.

Anyone who had to enter a radiological zone had a Hanford TLD. The majority of construction workers were Rad workers, because most of the work was radiological. They were badged. JA Jones [construction contractor] had their own monitoring and timekeeping personnel.

An interviewee stated that everyone he knew was monitored. Everyone was monitored; non-rad workers just had longer exchange intervals. [Dosimeter exchange frequency was related to work activities.] An individual who worked mostly in the control room and gallery had an annual exchange cycle. A worker who performed operations for the NWVP was on weekly exchange for a while. An interviewee went to monthly exchange, because he was only out in the gallery once or twice a day. Other workers reported monthly and quarterly exchange frequencies. [In the 1980s,] most everyone working in the cells had monthly exchanges. Exempt people were on annual or quarterly exchange.

The majority of people who worked routinely in and around Building 324 were badged, but there were unmonitored people who visited the building (e.g., administrative workers, mail delivery, document copy workers). It would be possible, though not likely or common, for an unmonitored person to get to areas where they might be exposed. In other areas of Hanford in the 1980s, unmonitored people could and did get into areas where they could be exposed.

A manager received reports of dosimetry results for his department from PNNL. He does not recall how often he received these reports. Individuals received annual exposure summaries by mail.

Workers kept their dosimeters with them; it was part of the facility ID badge on a "necklace" that they wore. People kept their badges—took them home. This practice was never changed; it is still done that way. The TLD could be exposed to heat (e.g., put on the dash in a car). Workers were advised not to take their Hanford badge when visiting another site. They were not supposed to be worn in public.

[Interviewees had different experiences in regard to dosimetry compliance.] Some interviewees said they were not aware of any deliberate non-use of badges. Another interviewee recalled that TLDs were sometimes left in lockers, both intentionally and unintentionally. People also put

TLDs in plastic, ostensibly to prevent contamination. A few layers of plastic could knock down the beta dose read by the TLD. [Intentional manipulation of TLD readings] was more common in some areas and buildings than in others. Regulations and enforcement got stronger in the early- to mid-1990s.

Pencils were used in the hot cell area. The operators used pencils and their film badges during airlock entries. Multiple badges and finger rings were issued for specific jobs. Glovebox workers got finger rings if their extremity dose was expected to be about 5 times higher than whole-body dose. Glovebox workers who met the "5 times extremity rule" had routine finger rings; the TLD chips were read monthly. People who did a lot of neutron work got supplemental neutron badges around the 1990s or early 2000s.

Electronic dosimeters and telemetry were used for supplemental monitoring for hot jobs; they were not accurate to measure the dose of record. One interviewee said telemetry would read about ±10% from the TLD. N-chips for neutrons were used when spent fuel was present (not continuous).

They were quick to use innovative technology. For example, Battelle adopted a telemetry system in 1994. The system (SAIC PDX-4) used remote communication to display real-time dose rates from multiple detectors on the body. This system included extremity monitoring. Someone at the monitor could direct the worker to move away from a higher field based on input from dosimeters on his arm or leg. Another worker indicated [the PDX-4] was not rugged enough for their environment [in another work area]. They used PD-4, a gamma detector with remote RF readout, to track dose rates in real time for an area of the body that was of most concern for a specific job.

An interviewee was not aware whether neutron:photon ratios or neutron spectral analysis was done for Building 324. They knew to monitor packages and workers for neutrons. In 324, there were neutrons from FFTF fuel, foreign fuel, etc. "Rem balls" (Bonner Spheres) were attempted. A "SNOOPY" [an NP-2 proportional counter filled with boron trifluoride, BF_3] was used. There was a great disparity between SNOOPY and TLD values. TLDs had to be in contact with the skin to get close agreement (albedo effect), so they would tape the TLD to the worker's chest.

TLDs were not accurate in the 1980s, especially for neutron doses. People would be working in a field of 1 rem/hr neutrons, but the badge would only read a fraction of that. In some situations, exposure estimates were hand-calculated and entered into the dose record. For example, actinide pins had extremely high neutron dose rates. There was greater than 50% (factor of 2) difference between the RadCon readings and the TLD reading. They hand-calculated neutron exposures based on the dose rates for a group of foreign visitors on this project.

[In the Safeguards Vault and Laboratory Area,] there was a glovebox and an open face hood for repackaging or mixing. A procedure limited the number of cans that could be out at a time, but it was not followed. The guys performing inventories and assays of the cans would take out more than allowed, which caused a high dose rate in the area. An operations worker went down [to the Fissile Materials Storage Vault] during a tour with the Tiger Team, and the tour leader left. An auditor noted that an item was not positioned where the inventory indicated, and the worker in

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charge of the vault reached down and moved it to a different shelf. When those present expressed alarm at the move, he moved it back; he did not follow correct procedure for moving the material. There were 5 critiques in 5 days over that event. Another interviewee noted that on one occasion, a worker changed the configuration of material without checking why the material was out of place and if it was safe to move it. [SC&A does not know if the interviewees were referring to the same event or different events.]

The union had an administrative limit of 300 mrem/week for electricians, millwrights, and hot cell workers. The DOE limit was 2 rem/year before that. Electricians, millwrights, and hot cell techs were likely to get 1,100–1,200 mrem/year. For years, they just sent in exception requests for some of these people at the beginning of the year [because they were likely to approach or exceed administrative limits].

They tried to stay within an administrative limit of 1,500 mrem/yr in the 1980s. They tried to keep individual exposures below 300 mrem/week. Typical doses were on the order of 100–200 mrem/week, based on pencil dosimeters. The dose of record from the TLD was not that high.

[When unusual dosimetry results occurred,] they would increase the frequency of dosimetry exchange (i.e., pull the issued dosimeter early to evaluate). The RadCon group had a dosimetry person who would investigate the cause of the unusual result. Findings were documented in an Investigative Operational Dosimetry Report (IODR).

RadCon investigated anomalies between pencil and TLD results. Sometimes they found causes not related to work, such as workers on annual exchanges who put their dosimeter next to a radium dial watch at night, medical injections, etc. Investigating a high pencil reading [from a neutron area] that did not match the TLD, they concluded that bad dosimetry placement affected the TLD result. It was not in contact with the skin.

A worker typically held a survey instrument in his left hand, near the left hip, using his right hand to adjust controls and settings. He wore his TLD on his right hip. He was essentially standing sideways to the source with the TLD on the far side of his body.

Partial body exposure was not a significant issue with hot cell work. Split plugs and swing ports were areas of localized non-uniform external exposure potential; they used ring dosimeters and had good RadCon processes in place. Collimated beams were associated with transfer ports or shielding voids from the hot cells. In the 1980s, the material for the vitrification project was very hot. During manipulator or window change-outs, they could get 50 R/hr beams out of the cell through the shielding. Beam intensity was highly variable over a short distance, depending on position relative to the portal. [RadCon personnel] from Battelle and Westinghouse helped to monitor, due to the large dose rates through the building.

Internal Monitoring

Several interviewees reported routine bioassays not triggered by incidents, but they did not recall the frequency of bioassays. Bioassay needs were determined by Radiation Protection. They

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varied from one-time samples to integrated samples for a full week. At one time, some workers in Building 325 were on a weekly schedule that lasted for a few years. The interviewee doesn't recall the details, but thinks it involved collecting all urine passed from 1 hour before retiring to 1 hour after awakening. Most people were on routine bioassay. An interviewee submitted samples at least annually, depending on the isotopes. An operations worker had routine annual bioassays. Special bioassay was also pulled in response to an event. They would assay for specific radionuclides based on the job, such as Cs, Sr, Pu, H_3. Workers were usually on a bioassay program. Sometimes they would change the radionuclide [being handled] and not get changed to the proper bioassay for a while.

A worker who handled "a bunch of exotic materials that were irradiated" indicated no unique bioassay [1980s]. Most of the materials were encapsulated.

Some interviewees reported routine chest or whole-body counts. Head counts were done for Sr. Chest/head or whole-body counts (e.g., for fission products) were done by PNNL. Whole-body counts were done once a year until a few years ago. The historical contractor was PNNL; the current contractor is AdvanceMed Hanford.

One interviewee had physicals once a year, whole-body counts a few times, and bioassay samples about three times in his career. The bioassays were 24-hour urine collections.

Internal monitoring results were not explained in detail. It was just "below levels." An interviewee doesn't recall much discussion of results—more like passing in the hall and saying, "you're OK."

[In the 1990s,] workers in Building 324 had annual whole-body counts (WBCs) at a minimum. Additional counts were done as needed, when there was airborne contamination or a suspected potential for uptake. WBCs were done near the Federal Building. Bioassay was required for workers who entered contamination areas. They delivered urine collection jugs to the worker's door (at home) and picked them up. It is still done that way now.

Incidents and Unusual Occurrences

If they were working and got any alarm, they would get the RCT. If there were multiple alarms, they would stop work and re-evaluate.

Defining an incident as something not going as planned and requiring an alternative approach, they were pushing the envelope much of the time, and they had a lot of incidents. Usually there was no radiation exposure above allowable limits and no extensive decontamination. Some interviewees did not recall releases or major containment failures. They had other events that could have led to unexpected exposure to employees, and these should have been documented in DOE reports by PNNL Lab Safety. Lab Safety maintained a database of incident reports.

Levels of reporting problems, in increasing order of severity, are off-normal occurrences, incidents, and accidents. An off-normal occurrence could be anything—a personnel contamination event or a new piece of equipment that didn't meet specifications to pass the QA

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inspection. Records of off-normal events should be in the DOE database. Lost work time (e.g., if an injured employee visits a clinic) results in a public report to the state Department of Labor and Industries. DOE contractors are required to submit monthly reports of lost work time to DOE.

[Interviewees had varying perspectives on the frequency and severity of contamination incidents.] One worker got clothing contaminated off and on—nothing serious. There were written protocols for handling skin contamination events. Another interviewee recalled hand and foot monitor alarms, but the contamination came off with duct tape. The interviewee did not recall any skin contamination events that required washing, scrubbing, etc. Another worker said skin contaminations were fairly frequent.

Another interviewee said containment failures, contamination spreads, and skin contaminations were very common in the 1980s. Skin contamination up to 10,000 dpm beta/gamma was not documented if it could be washed off. Wool wax was sometimes used to remove contamination. They packed wool and wax on the affected area, covered it with a glove, and sent the worker home. Skin peels with potassium permanganate were very common. They might do up to three peels.

Another interviewee recalled exposures and skin contamination were fairly common, especially in Building 327. People got contaminated on the face, nose, and areas they touched with a contaminated glove. Usually it was easily removed. Some people had to do skin peels and nasal irrigations. Before portal monitors were in use, a worker once went home with contamination in the worker's hair. When the worker checked his coveralls the next day to reuse them, they were contaminated. They checked the worker's home to make sure the worker had not spread contamination there.

A RadCon worker heard about an incident that occurred before his time. People referred to it as "Black Friday," when 4 or 5 people got contaminated in 1 day. Processes had been changed as a result of this event.

Containment failure was fairly common, but relatively few in consideration of the amount of work performed. An interviewee does not recall any ventilation failures. One RadCon worker did not remember that there were many skin contaminations during [the late-1990s and early 2000s] in Building 324. They had low-level clothing contaminations, but nothing noteworthy. If skin contaminations were common in earlier years (as reported to SC&A in an earlier interview), changes in processes and PPE may have rectified the problem. They did not use rain gear any more; they had bubble suits filled with air. The hood of the bubble suit was taped to the body of the suit, and the whole thing inflated from the incoming air. This kept the workers cooler and tended to push contamination out in the event of a puncture (due to positive pressure inside the suit). After the job, the worker was cut out of the suit in a controlled manner to minimize the potential for skin contamination.

The primary solvent for decontaminating equipment was isopropyl alcohol. They went through gallons of it. If workers did not wear latex gloves, the isopropyl alcohol could carry contamination deeper into the skin.

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You can review DOE occurrence reports to assess the frequency of skin contaminations. One worker recalled about 20 occurrence reports per year; about 6–8 of these were for skin contaminations. About half of the contamination occurrences came from clean laundry release levels being higher than operational detection levels. They would find that someone was hot before leaving the changing room. The other half were found while exiting the airlock. They filmed and did smoke tests, but often couldn't identify the source.

RadCon did follow-up reviews on contamination events. They assigned DAC [Derived Air Concentration]-hours for incidents. A RadCon worker vaguely remembered a DAC-hour tracking form. DAC-hour tracking is traceable to individuals for specific jobs. PNNL would have had the data.

RadCon also participated in pre-job and post-job assessment meetings. When workers got an uptake, they got bioassays and WBCs. Managers also participated in a review/investigation if someone had a positive uptake. They got reports from PNNL, did evaluations and Lessons Learned. On one occasion, there were four minor skin contaminations in 1 day. That was a notable event. They were minor contaminations, but there were 4 in 1 day. They shut down operations to evaluate why they got contaminated and how to correct it.

They did not see beta burns related to Hanford in the 1980s and 1990s. An older worker (now deceased) told an interviewee about the old days (1940s and 1950s) when they used a skin redness chart to estimate exposure. An older worker told an interviewee about an incident where they dumped the payload of a bowling ball cask in the Cask Handling Area. They measured a dose rate of 1 R/hr in the lunchroom. Workers went in without their dosimetry to clean up the spill.

An interviewee was present for a 1986 incident involving Cs-137 in the truck lock. There were at least 4 HEPA filters on an A-Frame filter bank for B-Cell. The spot where they took readings to monitor the filter was about 6 feet away from the filters. The normal trigger to change the filter was when the reading at that location got up to 500 mR/hr. On this occasion, the survey reading was several R/hr at the 6-ft location. An RCT using a teletector on a pole measured >120 R/hr, about a foot from the filters, during removal of the filter bank. A crane cable caught and tipped over the filter bank during the removal procedure. The CAM in the gallery alarmed, and they could read smears on a Cutie Pie. An RCT crawled through high dose areas in the truck lock (behind a shield block) to hook the cable back on the filter bank so it could be righted.

An interviewee recalled an incident when [two workers] got an internal uptake of Cs. When they washed down a cell, water would run into Room 18 in the basement. On this occasion, a plastic bag taped to the wall in Room 18 appeared to contain water. It turned out not to have water; what they saw was a dried water mark, so they inhaled dust from the bag. That room also had a poor exhaust design; the exhauster was above their heads. Nasal smears and a WBC were done and intakes were assigned.

Some millwrights got contaminated in Room 147 once. The cause was not identified conclusively. A high exhauster may have pulled airborne activity past them. A manager had them move the exhaust down low and moved the work table.

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One incident occurred in Building 325 in the mid-1980s; they got lines crossed and shot water into the vacuum system. A puddle of water on the floor had high alpha readings; it was measurable on the second scale for alpha above the water surface. A worker vacuumed it up with a ShopVac, but an RCT kicked it over to spill the water back out to avoid potential criticality.

In July 1989, a B-Cell furnace plug leaked during decontamination by water flushing. Spots outside the cell in Room 18 read up to 500 R/h. The high reported intensities may not have been widespread; they could have been localized readings from hot particles, which did not extend beyond a very small area.

In October 1990, cesium chloride spread through SMF gallery when a contaminated sleeve was withdrawn from south cell.

A maintenance worker was working on shielded pipes in a high radiation area with chain link fence. The worker had to pull the lead shielding and stick a pitot tube in [a pipe] to check the air flow. An RCT took a swipe and left the worker to do the job. He surveyed before the job; the worker doesn't remember him surveying the dose rate during the job. The job was supposed to take 2–3 days. The worker maxed out his dose for the month on his supplemental dosimeter after 1 or 2 days, and he was pulled from the job. [This incident occurred within the last 10 years.]

Waste Management

There were several different liquid waste systems.

- Process water sewers carried non-contaminated waste water.
- There was a retention system with diverters and holding tanks. This system was for chemical waste with only low levels of radioactivity. Retention basins were at Building 340; they checked the incoming waste there.
- The Radioactive Liquid Waste System [RLWS] took chemical and radioactive waste from the hot sinks, etc., from many buildings in the 300 Area to Building 340.

The RLWS was considered to be a controlled location and not part of the environment. For many years, there were no limits on what went there. There were guides for what materials could be dumped, but it included pretty much everything.

Solvents used to decontaminate manipulators and equipment included xylene, TCE, and ethyl and isopropyl alcohol. They became more sensitive to waste issues over time. In the late 1980s and 1990s, they had to use "approved" solvents and lubricants.

Building 340 occasionally had stuff show up that should not have been in that system. If they could not determine the origin, they would call around to the buildings to figure out where it came from. It was fairly common to get calls. An interviewee felt that 324 got blamed or impacted (e.g., fewer receipts allowed) for transfers and surprises that were not their fault. Eventually, the hot sinks were locked down, and they had to be unlocked to send waste out.

A worker recalls that the RLWS got plugged up. They came in and blocked the drains off—the worker does not remember when. After that, they began using wet rags [to clean surfaces]—wipe it down and get a new one. He doesn't recall if this was a temporary practice or permanent change.

Waste transfers from 324 [to the RLWS] were infrequent (when tanks were emptied). Waste was sampled and transfers were approved in advance. Any problems were discussed and resolved. They pumped low-level waste and condensate every 90 days. They did not have any organics in their effluents from 324. Building 327 dumped some acids from the fume hood sinks. They were diluted in retention tanks.

The new [RLWS] system is stainless steel. With the old RLWS, waste often ate through the pipes. Workers (typically from JA Jones) repaired it by welding in a patch of stainless steel.

High-level waste went out in bowling ball casks. This was well managed and controlled. [An interviewee described the use of bowling ball casks to remove waste from Building 325.] Waste was accumulated in each of the hot cells. When they had enough to ship, they would transfer it by vacuum through a jumper station to the cask. They tracked the volume added to the cask and also had a conductivity probe to let them know when the cask was full. When a cask was full, the lines connecting it to the hot cell were disconnected and the fittings were cleaned, if necessary. Fittings were plugged for transfer, the cask was surveyed by smears to verify it met appropriate standards, and it was moved to the truck lock for shipment to the 200 Areas.

GENERAL INFORMATION REGARDING OTHER AREAS OF THE HANFORD SITE

Safety Culture

Some interviewees experienced different safety cultures in other areas of the Hanford site. Every HPT (Health Physics Technician) is different. Some are very thorough; others are not. They were less engaged, more lax, at the tank farms than at other areas. About 50% were slackers.

[An interviewee who worked for multiple contractors in multiple locations] indicated safety cultures were good, except Bechtel. The manager read the safety documents given to him, but once in the field, it was get the job done however you can, even if unsafe. There were gross violations and negligence. People were rewarded for getting things done, and the ends justified the means. It was an ad hoc process—make it up as you go. [This was in the mid- to late-1990s.] One individual was a particular problem. There were hearings about the worker's violations. The Nuclear Chemical Operators had trouble with this worker, too.

- One job involved pumping hexavalent chromium out from the ground near the river; they were pumping into holding tanks to process it through an ion exchange resin. A line (3–4 miles) was drained out on the ground.
- On another occasion, drums of rad waste were [intentionally] tipped over.

- While doing groundwater checks in HR-3 (H Area), rad techs detected something unusual (it may have been tritium) while checking for a different isotope. The discovery was not reported or investigated, because they were not looking for that.
- A worker was reassigned to the waste pad as punishment for reporting problems to management. Some of the drums were sucked in or bloated out. The worker does not know what was in the drums; they contained solids and liquids.

Internal Monitoring

A worker once got a call about [a positive bioassay]; the worker had an elevated Pu level. They asked if the worker had ever worked at PUREX and the tank farms. The worker had worked in those areas. They collected three samples with higher Pu levels. Retesting was inconclusive.

A claimant learned about a positive chest count when NIOSH pulled his DOE files. There [had been] no communication telling him about or explaining exposures. [The exposure may have occurred at tank farms.] They changed the limits and told him he was OK.

EEOICPA Concerns and Questions

Some individuals believe the site uses “national security” and “proprietary” to cover up information. For example, the list of hazardous chemicals at Hanford was initially pretty limited under these rationales until people went and found information publically available on OSTI. How secret can it be if they can find it on the Web? Workers and advocates put pressure on DOE to provide a more complete list.

Claims examiners sometimes obstruct claims—sit on them for months—presuming to make medical judgments they are not authorized or trained to make. These claims should be going through to the medical specialist for assessment. They even get into “dueling doctors” situations—contradicting physician’s findings with DOE doctors—conflicting medical opinions. Patients’ doctors are reluctant to get sucked into that position, so they avoid getting involved with claims in the first place.

How are cancer clusters accounted for under EEOICPA? An individual who works with many claimants sees a lot of the same kinds of cancers, such as pancreatic cancer or glioblastoma. It seems that worker migration would complicate detection of clusters (e.g., a worker who was exposed at Hanford and moves to another site is no longer local when he gets the cancer). Among the people an interviewee worked with at the same facilities, seven have had cancers and six of them (all except the interviewee) have died.