Draft White Paper

REVIEW OF DATABASE USED TO DEVELOP ORAUT-OTIB-0077: EXTERNAL COWORKER DOSIMETRY DATA FOR AREA IV OF THE SANTA SUSANA FIELD LABORATORY

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Prepared by

S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, VA 22182

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1.0 STATEMENT OF PURPOSE

The purpose of this draft report is to present an evaluation of the "Boeing" external dosimetry database for use as a coworker model for Santa Susana Field Laboratory (SSFL) workers, as defined in ORAUT-OTIB-0077 (ORAUT 2009). Our review focuses on the suitability of this database for use as surrogate data that comply with ORAUT-OTIB-0020 (ORAUT 2008) and OCAS-IG-004 (OCAS 2008).

2.0 HISTORICAL MILESTONES LEADING UP TO THIS REVIEW

In August of 2008, SC&A submitted a draft report entitled, *Review of the NIOSH Site Profile for the Santa Susan Field Laboratory* (SC&A 2008). In the review of ORAUT-TKBS-0038-6, *Technical Basis Document for Atomics International – Occupational External Dosimetry* (ORAUT 2006, referred to as TBD-6), SC&A identified a total of seven findings that were subsequently summarized by SC&A in the Issues Resolution Matrix for the Santa Susana Site Profile Review and first discussed by the SSFL Work Group in August 2008, and again in April 2009. Included among seven findings pertaining to external monitoring was Finding 4.6-1, which stated the following:

> *. . . TBD-6 has not cited an external coworker model approach as necessary, and the document does not address the use of a coworker model for those individuals potentially exposed, but not monitored . . .*
>
> *SC&A performed a cursory review of more than 30 dose reconstructions related to badging of radiation workers. Several observations were made in this review. First, it does not appear any of the claimants, including those that were likely defined as radiation workers, were badged for their full employment period. . . . Some employees, who may or may not have worked in areas containing radioactive material, were not badged and therefore were assumed not to have worked in areas containing radioactive materials.*

In response to Finding 4.6-1 and SSFL Work Group discussions, NIOSH issued ORAUT-OTIB-0077, Rev. 00 (*External Coworker Dosimetry Data for Area IV of the Santa Susana Field Laboratory, the Canoga Avenue Facility (Vanowen Building and the De Soto Avenue Facility (sometimes referred to as Energy Technology Engineering Center [ETEC] or Atomics International)* on August 3, 2009.

SC&A reviewed ORAUT-OTIB-0077 and provided comments to the Work Group in a memorandum regarding *Resolution of the SSFL Site Profile and SEC Issues Matrices*, issued on November 9, 2009. At the time of our initial review of ORAUT-OTIB-0077, however, SC&A had not been provided the dosimetry database used by NIOSH to derive annual dose estimates for its coworker model, as given in Tables 2 and 3. SC&A was given access to the "Boeing" dosimetry database in November of 2009.

3.0 A CRITICAL REVIEW OF THE DATA USED BY NIOSH FOR USE IN ITS SSFL EXTERNAL COWORKER MODEL

Section 5.1 of ORAUT-OTIB-0077 identifies the origin of the data used by NIOSH and their limitations, as given in the following statements:

> *The SSFL data was manually entered into a database for an epidemiological study of workers at Rocketdyne (Atomics International) covering the period 1948 to 1999. Exposure information was compiled from the following sources: Rocketdyne radiation safety folders, NRC – REIRS, DOE-REMS, Landauer dosimetry, Individual facilities, the U.S. Army, and the U.S. Air Force. 6,675 workers were monitored for radiation exposure and of those 5,801 were included in the study.* . . . [Boice et al. 2006a] . . . *The number of data points used for each year is shown in Tables 2 and 3.*
>
> *The SSFL database contains dosimetry data for* ***penetrating dose, which is a combination of gamma and fast neutron dose. Because it is difficult to separate statistically significant neutron dose from the penetrating dose*** *and because shallow dose data is not available in the database described above, the* ***neutron dose component (which represented less than 5% of the total data points available) was left embedded with gamma dose, resulting in penetrating dose values that are favorable to claimants. An analysis of average neutron dose revealed that the average value for any individual year was bounded by the 95th percentile values for penetrating dose given in this OTIB.*** [Emphasis added.]

As indicated in the above-cited passage, NIOSH employed a database that was compiled by Boice et al. (2006a) entitled, *Mortality Among Radiation Workers at Rockedyne (Atomics International), 1948–1999.* It should be noted, however, a more detailed/informative description of the dosimetric data used by Boice et al. (2006a) in the above-cited epidemiologic mortality study is presented in a companion publication by Boice et al. (2006b), which is **not** referenced in ORAUT-OTIB-0077. Our review of the NIOSH coworker model will, therefore, make reference to information/data contained in Boice et al. (2006b).

3.1 An Overview of the Boice et al. (2006a) Dosimetric Database

The Boice study was a retrospective cohort mortality study of 5,743 radiation workers with external exposures who were employed for at least 6 months at the Rocketdyne [Atomic International (AI)] facilities in the years 1948 to 1999. Because radiation doses were defined as "lifetime" doses, occupational exposures received at other facilities were included. Nearly 32% (or 1,833) of the 5,743 Rocketdyne/AI workers had also been monitored for external radiation exposure at other facilities, either before and/or after their employment at Rocketdyne/AI. Of the 5,743 workers monitored for external photon exposures, about 10% (or 584 workers) were monitored for neutrons while at Rocketdyne/AI, with another 2% (or 81) of workers with neutron exposures elsewhere. Table 1 provides a summary of the distribution of exposures by exposure location and type of radiation.

Table 1. Number of Workers Monitored and Not Monitored for Radiation at Rocketdyne by Cumulative External Radiation Dose Received Before, During, and After Rocketdyne Employment, Neutron Dose, Internal Lung Dose, and Total Career Dose
(Source: Boice et al. 2006b)

	Cumulative dose (mSv)							
Employment period	**0**	**<5**	**5-**	**10-**	**50-**	**100-**	**≥200**	**Total**
External photon radiation dose								
- Before Rocketdyne	105	482	97	165	39	30	14	932
- While at Rocketdyne	693	3,231	663	925	128	58	45	5,743
- After Rocketdyne	744	369	53	41	12	redact	redact	1,224
- TOTAL career, external photons	608	3,155	646	1,009	166	97	68	5,749
Total career, neutron dose	303	314	35	11	redact	redact	redact	665
Total career, external (photon & neutron)	605	3,149	651	1,012	165	100	69	5,751

Inspection of Table 1 shows that 932 (or 16.1%) of the study cohort had exposure prior to employment with Rocketdyne/AI, and 1,224 (or 21.1%) had exposure after leaving Rocketdyne/AI.

While the integration of **pre-**Rocketdyne/AI, Rocketdyne/AI, and **post**-Rocketdyne/AI exposures is technically sound for the epidemiologic worker study that required estimates of **lifetime** occupational doses, use of these data for an SSFL coworker model is inappropriate, as explained in Section 4.0.

3.2 Review of the Boice et al. (2006b) Database

Redacted annual dose data for the 5,743 workers that represented the study cohort were forwarded by Boeing to NIOSH on October 28, 2008, in the form of an Excel® spreadsheet[*] that consisted of the following three tabs:

- Tab #1 provides redacted demographic data, which identifies each worker by an arbitrary ID number from #1 through #5801. (Note: Although only 5,743 workers had recorded external doses, there were also 58 workers who were **exclusively** monitored for internal exposure.) Key demographic data included (1) the year of hire (by Rocketdyne/IA), (2) the year of termination (by Rocketdyne/AI), and (3) whether the individual had been monitored for internal exposure, external photon exposure, and/or external neutron exposure.

- Tab #2 presents year-by-year "Total External Dose" for years 1940 through 1999, as well as "Total Neutron Dose" for years 1948 through 1999 (in units of mrem).

[*] This database/spreadsheet, in redacted form, is available on the O-drive under the file name SSFL IEIDOSES_10-22-08_Redacted_unprotected.xls. (Note that all worker identification numbers used in this report are randomly assigned numbers.)

- Tab #3 presents annual internal doses to 16 target organs/tissues. However, these data are not relevant to the coworker model, and were therefore not assessed by SC&A.

4.0 ISSUES OF CONCERN REGARDING NIOSH'S COWORKER MODEL

Our review of dosimetry data employed by Boice et al. (2006a and 2006b) and their interpretation and use by NIOSH for surrogate data in the SSFL external dose coworker model has raised the following issues of concern.

4.1 Issue #1. NIOSH May Have Misinterpreted Worker Dose Data Prepared by Boice et al. (2006a and 2006b)

In Section 5.1 of ORAUT-OTIB-0077, NIOSH states the following:

> *The SSFL database contains dosimetry data for penetrating dose, which is a* ***combination of gamma and fast neutron dose.*** *Because it is difficult to* ***separate*** *statistically significant neutron dose from the penetrating dose, . . . the neutron dose component . . . was* ***left embedded*** *with gamma dose, resulting in penetrating dose values that are favorable to claimants.* [Emphasis added.]

SC&A concludes that NIOSH may have misinterpreted dosimetry data contained in Tab #2 of the spreadsheet. In Tab #2, the first set of annual doses in Columns E through BL are labeled "Total External Dose," which may have misled NIOSH to conclude that these values represented the **combined** dose from penetrating photons and neutrons. This erroneous conclusion may have been prompted the two factors: (1) the misleading label of **"Total External Dose"** and (2) the fact that for most data points representing a worker who was monitored for both photons and neutrons in a given year, the "Total External Dose" was well above the "Total Neutron Dose."

Our review of the spreadsheet data, however, revealed numerous data points where the "Total Neutron Dose" exceeded the "Total External Dose." The following sample data points illustrate this potential misunderstanding of the data:

Worker ID	Year	Total External Dose (mrem)	Total Neutron Dose (mrem)
#2968	1956	300	534
"	1957	150	280
#3275	1957	0	224
#3289	1957	0	182
#3305	1957	57	126
#3322	1957	81	144
#3397	1957	0	196
#4182	1959	16	198
#4363	1957	59	198
"	1958	0	180

From this limited data set, it is clear that (1) the "Total External Dose" does **not** represent the combined photon and neutron doses, and (2) neutron doses are **not** "embedded" and "difficult to separate" as stated by NIOSH.

4.2 Issue #2. The Misuse of Termination Dosimetry Data

As acknowledged by NIOSH, Boice et al. (2006a) drew upon dosimetry records from a variety of sources, which likely included **termination reports**, such as the NRC Form 4 (which provides a cumulative Occupational Dose History of a worker). Since the epidemiologic study by Boice et al. (2006a) was primarily interested in establishing a "lifetime" dose, an aggregate dose for a select period of time would have had limited significance to the integrity of the study and was fully acknowledged, as given in the following statements (Boice et al. 2006b):

> *Dose information was available from seven overlapping sources (Fig. 3, Table 2). Care was taken to assure that only non-overlapping dosimetry information was incorporated into the analyses. Occasionally, calendar year exposures were not available, and for such instances the **cumulative dose**, or **termination dose**, was recorded in the calendar year in which it was reported. These combinations occurred primarily for early doses obtained prior to employment at Rocketdyne/Atomics International . . .* [Emphasis added.]

For the purpose of designing a coworker model (with annual doses), the use of an **aggregate dose** is inappropriate/misleading. For example, a worker's previous occupational exposure of 30 rem (which may have represented 10 years of prior employment) should not be assigned to a single year. A sample of annual doses that must be assumed to have represented cumulative/ termination doses are cited in Table 2 below.

Table 2. A Sample of "Annual Doses" that are Likely Cumulative/Termination Doses

Worker ID #	Years Employed at SSFL	Year of Dose Assignment	Ext. Gamma Dose (mrem)
2704	1959–1986	1957	67,205
1587	1962–1981	1954	63,620
3542	1950–1984	1949	44,160
2649	1959–1987	1957	31,275
126	1956–1960	1948	22,458
3205	1956–1985	1955	11,227
4655	1958–1959	1953	11,670
5515	1953–1984	1952	10,567
2769	1961–1995	1952	9,541
1233	1956–1982	1955	9,290
1509	1953–1984	1955	8,135

For example, Worker #2704 was not hired at SSFL until 1959, but had an assigned dose of 67,205 mrem (or 67.2 rem) for the year 1957, which precedes his employment at SSFL by 2 years. All other workers cited in Table 2 were equally assigned high termination doses for a single year that pre-dates their employment by up to 9 years.

The inclusion of **multiple** year (or termination) doses for deriving **yearly** coworker doses cannot be justified technically. In addition to the obvious reason, such prior or post-SSFL exposures occurred at **unspecified facilities** and, therefore, represent **surrogate** data that do **not** comply with criteria specified in OCAS-IG-004 (*The Use of Data from Other Facilities in the Completion of Dose Reconstructions Under the Energy Employees Occupational Illness Compensation Program Act*).

While it can be argued that the improper inclusion of such high "termination doses" in the worker database/SSFL coworker model is claimant favorable, in reality, this impact is highly unlikely for the following reasons:

(1) Due to the fact that the high termination doses are relatively infrequent, their inclusion will principally affect the 95th percentile dose (as cited in Tables 2 and 3 of OTIB-0077)

(2) Based on guidance contained in ORAUT-OTIB-0020, dose reconstruction in behalf of unmonitored workers and workers with incomplete monitoring data will most likely be based on the 50th percentile value, which is unlikely to be affected by a limited number of high termination doses

4.3 Issue #3. The Inclusion of Annual Exposure Data Associated with Non-SSFL Employment Periods at Unspecified/Unknown Facilities

In a random check of the worker dosimetry database, SC&A cross referenced employment periods at SSFL for a given worker against assigned annual doses. Our review showed that for a substantial fraction of SSFL workers, employment periods (and therefore assigned annual doses) at SSLF were short, compared to other employment periods (and annual doses) at unknown/ unspecified facilities.

For illustration, annual assigned doses for Workers #3344 and #5668 are presented in Table 3 below. Worker #3344 was employed at SSLF for 5 years (**redact**), while Worker #5668 was employed at SSFL for 3 years (**redact**).

Inspection of Table 3 shows that for Worker #3344, the first-year dose of 6,186 mrem was a termination dose, followed by 10 yearly doses at unknown facilities before a 5-year employment period at SSFL. Post-SSFL employment/exposures included 9 years with assigned doses and 9 years with no data.

For Worker #5668, the first assigned dose of 11,711 mrem in 1947 must also be assumed to represent a **termination dose** representing unknown/unspecified facilities and an unknown exposure period. This was followed by 12 **annual doses** received at unknown facilities prior to a 3-year employment at SSFL (**redact**). For the post-SSFL employment period, 18 annual exposure doses are available, along with 8 years for which no data were found.

For Workers #3344, #5668, and many others, annual exposures received at facilities other than SSFL dominate their annualized radiation records and involve **unspecified** facilities that may not comply with the surrogate criteria specified in OCAS-IG-004.

Table 3. Annual Doses for Two Workers based on Employment Location

Year	Worker #3344		Worker #5668	
	Ext. γ Dose (rem)	Employment Location	Ext. γ Dose (rem)	Employment Location
1947			11,711	?
1948	6,186	?	10	?
1949	14	?	100	?
1950	1,315	?	60	?
1951	666	?	110	?
1952	92	?	40	?
1953	145	?	150	?
1954	52	?	260	?
1955	0	?	200	?
1956	190	?	390	?
1957	20	?	154	?
1958	–	SSFL	5,605	?
1959	–	SSFL	8,719	?
1960	635	SSFL	3,305	SSFL
1961	–	SSFL	2,950	SSFL
1962	40	SSFL	2,800	SSFL
1963	150	?	1,560	?
1964	320	?	70	?
1965	100	?	40	?
1966	300	?	–	?
1967	0	?	–	?
1968	0	?	–	?
1969	130	?	–	?
1970	0	?	–	?
1971	–	?	–	?
1972	–	?	–	?
1973	–	?	–	?
1974	–	?	0	?
1975	–	?	20	?
1976	–	?	90	?
1977	–	?	130	?
1978	–	?	180	?
1979	–	?	300	?
1980	90	?	210	?
1981			90	?
1982			130	?
1983			40	?
1984			60	?
1985			0	?
1986			0	?
1987			0	?
1988			30	?

An extreme example of the inappropriate use of these data for an SSFL coworker model is their use for the early years. For example, Table 2 of ORAUT-OTIB-0077 cites that the recommended 50th and 95th percentile doses were based on a total of 46 data points for the year 1948.

SC&A extracted the 46 data points (representing "annual" doses) for 46 workers for 1948 and cross-referenced their employment periods at SSFL (see Table 4).

Table 4 shows that for 1948, **not one** of the "46 data points" (cited in Table 2 of ORAUT-OTIB-0077 for 1948) involved a worker who was actually employed/exposed at SSFL in 1948. On average, these 46 workers were only hired by SSFL 6.5 years after 1948. Lastly, Table 4 shows that at least 5 of the 46 "annual" doses likely represented termination doses representing unknown exposure periods.

To further demonstrate the adverse impact of surrogate data involving non-SSFL dose data, SC&A evaluated dosimetry data for the year 1950. As noted in Table 2 of ORAUT-OTIB-0077, available dose data for 1950 included 118 annual dose data points. Based on employment periods at SSFL, SC&A segregated annual exposures based on whether the exposure occurred at SSFL or at an unknown facility. Of the 118 dose data points, 59 involved exposures at SSFL and 59 involved unknown facilities (see Table 5). Analysis of exposure doses yielded the following results:

- For the 59 annual doses received at SSFL, the average dose was **1,112 mrem**.
- For the 59 annual doses received at unknown facilities, the average dose at **462 mrem** was less than one-half those of SSFL.

Thus, for the year 1950, the 59 workers exposed at SSFL had, on average, an exposure of 1,112 mrem, which was more than twice the average annual exposure of 462 mrem received by workers who were not exposed at SSFL. Thus, the inclusion of non-SSFL exposure data has the effect of reducing SSFL worker doses that are more appropriate for use in the coworker dose model.

Table 4. The Inclusion of Exposure at Non-SSFL Facilities in Coworker Database for 1948

Worker ID	Employment Years at SSFL	External Dose for Year 1948
0126	1958–1967	22458.65574
0214	1955–1985	14930
0336	1958–1962	0
0500	1956–1968	0
0600	1957–1969	0
0715	1950–1972	255
0808	1952–1979	0
1003	1963–1967	320
1198	1962–1968	50
1378	1951–1971	0
1428	1955–1962	0
1490	1952–1968	80
1677	1950–1961	30
1805	1958–1968	80
1863	1957–1984	280
2047	1955–1971	105
2456	1949–1975	1737
2616	1962–1965	40
2657	1952–1963	30
2802	1959–1962	95
2849	1955–1969	0
2875	1958–1960	0
2991	1949–1981	2700.606936
3012	1956–1971	0
3017	1954–1962	20
3055	1954–1979	0
3081	1955–1963	0
3163	1949–1979	2284.5
3165	1956–1959	100
3166	1956–1961	50
3200	1963–1965	30
3212	1952–1963	60
3270	1959–1970	30
3275	1957–1989	55
3306	1954–1981	30
3333	1957–1959	320
3344	1949–1984	6186
3352	1951–1984	0
3370	1957–1960	415
3393	1952–1967	0
3397	1957–1967	215
3546	1959–1965	80
3582	1949–1968	0
3811	1951–1962	200
4035	1956–1959	90
5668	1957–1965	10

Table 5. Comparison of Exposure Doses Received at SSFL with Exposure at Unspecified Facilities for 1950

Worker ID	Years of Employment at SSFL	External Dose for Year 1950	Exposure Location	
			SSFL	Unknown
0001	1946–1982	810	X	
0060	1951–1970	555		X
0126	1958–1967	0		X
0187	1949–1955	820	X	
0213	1955–1963	407		X
0293	1971–1977	1275		X
0336	1958–1962	200		X
0360	1950–1991	2644	X	
0405	1950–1952	1250	X	
0563	1946–1952	1144	X	
0600	1957–1969	0		X
0601	1955–1971	0		X
0808	1957–1969	70		X
0816	1949–1958	1136	X	
0888	1959–1978	125		X
1003	1957–1973	100		X
1051	1952–1984	1314		X
1056	1958–1966	75		X
1178	1950–1951	1040	X	
1307	1949–1962	16	X	
1338	1950–1955	1110	X	
1343	1951–1976	1460		X
1378	1951–1971	130		X
1428	1955–1962	30		X
1533	1948–1958	1360	X	
1543	1956–1956	50		X
1656	1952–1982	2235		X
1677	1950–1960	825	X	
1780	1963–1964	11.25		X
1804	1951–1973	834.6043956		X
1863	1957–1984	1550		X
1878	1951–1984	0		X
1986	1964–1967	30		X
2047	1955–1971	65		X
2213	1959–1967	0		X
2243	1949–1963	1164.75	X	
2294	1948–1969	1380	X	
2579	1950–1966	445	X	
2616	1962–1965	60		X
2619	1951–1973	1159.484127		X
2657	1952–1963	80		X
2660	1949–1965	740	X	
2732	1961–1969	1255		X

Table 5. Comparison of Exposure Doses Received at SSFL with Exposure at Unspecified Facilities for 1950

Worker ID	Years of Employment at SSFL	External Dose for Year 1950	Exposure Location	
			SSFL	Unknown
2802	1959–1962	920		X
2875	1957–1960	0		X
2932	1962–1964	515		X
2967	1952–1971	20		X
2991	1949–1981	705	X	
3012	1952–1987	80		X
3017	1954–1962	180		X
3045	1956–1970	120		X
3055	1954–1979	20		X
3073	1950–1981	95	X	
3081	1955–1963	0		X
3143	1958–1967	100		X
3165	1956–1970	120		X
3166	1952–1961	80		X
3200	1963–1965	160		X
3212	1952–1963	130		X
3250	1957–1986	300		X
3260	1957–1970	0		X
3270	1959–1970	20		X
3275	1957–1989	1195		X
3287	1949–1951	1030	X	
3303	1957–1963	1460		X
3306	1954–1981	0		X
3333	1957–1959	260		X
3344	1949–1984	1315	X	
3370	1957–1960	415		X
3385	1951–1999	1243.785714		X
3393	1952–1967	560		X
3397	1957–1958	135		X
3433	1948–1981	965	X	
3554	1982–1984	845		X
3582	1949–1968	1375	X	
3649	1948–1973	1663	X	
3744	1947–1968	1005	X	
3936	1949–1966	1237.5	X	
3943	1951–1973	1213		X
3978	1941–1984	1351	X	
3982	1959–1963	3043		X
4035	1956–1959	60		X
4052	1950–1983	1690	X	
4094	1948–1957	1018	X	
4241	1946–1969	840	X	
4371	1950–1982	740	X	
4376	1950–1972	1765	X	

Table 5. Comparison of Exposure Doses Received at SSFL with Exposure at Unspecified Facilities for 1950

Worker ID	Years of Employment at SSFL	External Dose for Year 1950	Exposure Location	
			SSFL	Unknown
4595	1950–1961	895	X	
4742	1950–1970	1145	X	
4953	1948–1952	2368	X	
5014	1950–1971	80	X	
5207	1952–1987	960		X
5272	1949–1972	2350	X	
5647	1949–1967	1350	X	
5668	1957–1965	60		X
5674	1948–1969	820	X	
5682	1950–1956	325	X	
5684	1949–1952	635	X	
5685	1946–1950	2781	X	
5686	1946–1952	1925	X	
5691	1949–1951	882	X	
5692	1948–1971	990	X	
5693	1948–1954	380	X	
5694	1949–1951	100	X	
5696	1949–1952	820	X	
5698	1950–1952	30	X	
5699	1949–1952	1215	X	
5701	1949–1958	793	X	
5702	1949–1952	943.375	X	
5704	1949–1951	960	X	
5705	1949–1953	2158	X	
5706	1949–1952	1520	X	
5707	1950–1951	2003	X	
5708	1950–1952	775	X	
5710	1950–1951	1910	X	
5714	1950–1954	1625	X	
5715	1950–1953	145	X	
5718	1950–1953	1070	X	

4.4 Issue #4. The Interpretation of "Blanks" and the Potential for Unaccounted Dose

In addition to real numbers (that include "0") for external annual doses, for many workers, there are intermittent "blanks" in their exposure records for time periods of employment at SSFL, as shown below for Workers #19 and #1.

Examples of "Blanks" in Database

Worker #19 (1957–1975)	
Year	**External Dose (mrem)**
1957	–
1958	–
1958	2950
1960	2410
1961	1940
1962	1670
1963	820
1964	4240
1965	–
1966	235
1967	400
1968	270
1969	180
1970	–
1971	150
1972	–
1973	–
1974	–
1975	–

Worker #1 (1946–1982)	
Year	**External Dose (mrem)**
1946	–
1947	–
1948	–
1949	–
1950	810
1951	724
1952	92
1953	125
1954	2594
1955	25
1956	–
1957	–
1958	–
1958	833
1960	55
1961	60
1962	40
1963	100
1964	–
1965	150
1966	0
1967	0
1968	5
1969	20
1970	0
1971	20
1972	0
1973	20
1974	0
1975	–
1976	50
1977	–
1978	60
1979	–
1980	–
1981	–
1982	–

The existence of blanks raises the following two inter-related questions:

Question #1: If the above-cited workers were also claimants, would "blanks" be treated as "unmonitored periods or gaps in dosimetry records" in their dose reconstruction?

Based on guidance presented in **Section 6.0, Step 4, of ORAUT-OTIB-0077**, the tentative answer would be to treat these blanks as incomplete monitoring data and assign the 95th percentile values of the coworker model provided in Table 2 of (ORAUT-OTIB-0077).

Step 4 provides the following guidance:

> *Table 2 lists the results of the coworker analysis. These percentile doses should be used for SSFL workers for whom there are no or **limited** monitoring data . . . In general, the 50th percentile dose can be used as a best estimate of a worker's dose when professional judgment indicates that the worker was probably exposed to intermittent low levels of external radiation. The 50th percentile dose should generally **not** be used for workers who were routinely exposed. For **routinely exposed workers (i.e., workers who were expected to have been monitored and routinely exposed), the 95th percentile dose should be applied**.* [Emphasis added.]

Question #2: For Workers #1 and #19, if dose reconstruction would involve the assignment of 95th percentile coworker doses for "blanks" in their dosimetry records, is it not axiomatic that the current coworker model data are **incomplete**, since Workers #1 and #19 (and many more workers with "blanks") are themselves members of the coworker model?

Stated more simply, the question that needs to be answered is whether workers with potentially incomplete monitoring data can serve as members of a coworker model that, in turn, provides surrogate data for their incomplete monitoring data.

4.5 Issue #5. Neutron Exposures May Either Have Been Totally Ignored or Substantially Under-represented in the SSFL Coworker Model

Data used to derive the SSFL coworker model included 584 workers who had been monitored for neutron exposures at Rocketdyne/AI, and an additional 81 workers who were monitored for neutrons at other facilities (Boice et al. 2006b). At Rocketdyne/AI, exposure to neutrons may have resulted from the operation of 10 nuclear reactors and 7 criticality facilities.

- Neutron doses may have been totally excluded in SSFL Coworker Model

  In Issue #1 of this report, SC&A raised concerns about NIOSH's potential misinterpretation of neutron doses, as stated in Section 5.1 of ORAUT-OTIB-0077:

  > *The SSFL database contains dosimetry data for **penetrating** dose, which is a **combination** of gamma and fast neutron dose. Because it was difficult to separate statistically significant neutron dose from the penetrating dose, . . .*

*the neutron dose component was left **embedded** with gamma dose, resulting in penetrating dose values that are favorable to claimants.* [Emphasis added.]

If NIOSH's incorrect assumption (i.e., of combined/embedded gamma and neutron doses) was used to develop the coworker model, SC&A concludes that the current coworker model does **not** incorporate neutron exposures. As explained above (see Issue #1), the database established by Boice et al. (2006a and 2006b) contains **separate** annual doses for photons and neutrons for the individual worker.

- Alternatively, if SC&A's conclusion (that the current coworker model does not incorporate neutron exposures) is incorrect, then at a minimum, neutron doses have been underestimated within the context of the coworker model for the following reasons:

    1. NTA Dosimeter Limitations. Even if NIOSH's assumption of an embedded neutron dose was correct, the embedded neutron dose would, nevertheless, require modification. Given the absence of empirical data involving neutron spectra for reactors and Pu fuel storage facilities at the SSFL (as well as facilities other than SSFL), the lack of dosimeter calibration methods, and the relative insensitivity of NTA film to neutrons <500 keV (or as much as 1 MeV), there remains an undefined level of uncertainty for recorded/assumedly embedded neutron doses.

    2. Uncertainty regarding the choice of quality factors that were used to define neutron doses. Historically, neutron quality factors are well below those of ICRP-60 (ICRP 1991) values currently used by NIOSH. For neutrons between 0.1 and 2 MeV, a quality factor of 10 was used (which is one-half of the current ICRP-60 value of 20), as had been presumed by Boice et al. (2006b, page 415):

        *It was presumed that the **quality factors 10 for fast neutrons** and 3 for slow neutrons had been used to reflect the relative biological effectiveness of neutrons in comparison with photons . . .* [Emphasis added.]

5.0 SUMMARY CONCLUSIONS

While the dosimetric data compiled by Boice et al. (2006b) were reasonably suited for a retrospective cohort mortality study, this dataset in its current form contains numerous deficiencies and does not meet the standards set forth in OCAS-IG-004.

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