REPORT TO THE ADVISORY BOARD ON RADIATION AND WORKER HEALTH

National Institute of Occupational Safety and Health

Audit of Case PIID* from the Savannah River Site

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Prepared by

S. Cohen & Associates
6858 Old Dominion Road, Suite 301
McLean, Virginia 22101

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1.0 SUMMARY BACKGROUND INFORMATION

This report presents the results of an independent audit of a dose reconstruction performed by the National Institute of Occupational Safety and Health (NIOSH) for an energy employee that worked at the Savannah River Site (SRS) from PIID*, to PIID*. The worker was diagnosed with rectal cancer on PIID*.

SRS operations played an important role in the U.S. nuclear weapons program (DOE 1997). SRS processes included nuclear fuel fabrication, reactor operation, radiochemical processing, uranium recycling, plutonium production, neutron source production, and waste management.

The majority of the worker's radiation exposure was received during employment as an PIID*. As noted in the Dose Reconstruction (DR) Report, the employee worked at several different reactors, including PIID* (only to retrieve spare parts), and in area PIID*, in PIID*.

There is evidence that the worker was exposed as a result of incidents at the PIID*. The PIID* accepts dilute, depleted uranyl nitrate solution from the PIID* and converts it into uranium trioxide powder. Dilute uranyl nitrate solution is sent to A-Line from the solvent extraction process in the PIID*. The PIID* also has a dissolver to prepare a uranyl nitrate solution from the uranium trioxide product and nitric acid when it is required as a process feed stream back into the solvent extraction process in the PIID*. The PIID*, the PIID*, and the PIID* are also located in the PIID*. In the PIID*, plutonium nitrate is converted into plutonium metal or plutonium oxide from onsite and offsite scrap. The PIID* consists of two parallel canyons that constitute the process area. The function of the PIID* is to isolate and purify plutonium, uranium, and neptunium from irradiated uranium. Fission products were also present depending on the age of the material. In the NSR Facility, plutonium from a variety of sources and materials was recovered. These materials contain impurities such as americium and uranium. The isotopic content is not constant in the material or between materials. For example, the un-irradiated reactor core's percent weight ranges from 6% to 12% for Pu-240, 0% to 10% for Am-241, and 60% to 80% for uranium. It is assumed that the feed material is principally enriched uranium (*Technical Basis Document for the Savannah River Site*, ORAUT-TKBS-0003, August 21, 2003).

From the end of PIID* to PIID*, the claimant worked in the PIID* and in the PIID*.
Five heavy-water reactors, designated C, K, L, P, and R, were constructed at SRS in the early 1950s and were located in C Area, K Area, L Area, P Area, and R Area, respectively. Depleted uranium, Np-237, and lithium targets were irradiated to produce Pu-239, Pu-238, and tritium, respectively. In the past, the reactors were also used to convert thorium to U-233, as well as to irradiate targets that produced transplutonic elements, such as curium and californium. (ORAUT-TKBS-0003).

The heavy water production plant in D Area began operation early (1952) in SRS operations to concentrate heavy water from the Savannah River water to moderate and cool the Site's reactors (ORAUT-TKBS-0003).
The claimant was exposed to photon and neutron radiation fields, and was monitored for ionizing radiation doses continuously during his employment at the Savannah River Site. External dose

records received from the Department of Energy (DOE) were reviewed by NIOSH and found to be sufficient for the reconstruction of the external dose. A missed photon dose was assigned by NIOSH for all badge cycles when a zero dose was reported or when no information for a badge cycle was available. Neutron doses from PIID* to PIID* were assigned using a neutron to photon ratio of 0.82 for reactor facilities, in accordance with Section 5.0 of the Savannah River Site Technical Basis Document. Neutron doses after PIID* were assigned as missed dose as appropriate for each badging cycle.

Onsite ambient doses were assessed as part of the dose reconstruction. In addition, the photon doses due to annual occupational medical x-ray procedures were evaluated.

The claimant was routinely monitored for tritium from PIID* up to PIID*. Annual tritium doses were reported together with the external doses, except for PIID*, PIID*, PIID*, and PIID*. Tritium bioassay results received from the DOE were reviewed by NIOSH. Bioassay results were recorded routinely, except for the years PIID* and PIID*. A potential missed dose for tritium was assigned by NIOSH for each year that an annual tritium dose was not reported. Additionally, the missed dose was assigned by NIOSH to the worker for any year in which the reported dose was less than the potential missed dose. A missed dose was assigned every year from PIID* to PIID*, with the exception of PIID* and PIID*, when the DOE recorded dose for tritium was used. The potential missed dose for tritium was used to maximize the potential internal doses received by the worker.

Internal dose monitoring records for radionuclides other than tritium were reviewed. According to NIOSH, most measurement results for non-naturally occurring radionuclides showed an activity less than the level of detection for the given radionuclides and bioassay method. Evaluations of the measurement results that were above the level of detection were made by NIOSH for this dose reconstruction, with the exception of I-131 and Cs-137. Dose from I-131 was considered to be insignificant (for dose to the rectum), and Cs-137 results were less than 35 nCi. Those results were less than what would be expected based on the maximum hypothetical intake described below. The maximum hypothetical intake therefore exceeds the potential intake indicated from bioassay data. To account for potential undetected dose, internal dose was assigned by NIOSH based on the hypothetical intake.

Assigned internal doses for each radionuclide were based on a hypothetical acute intake on the first day of employment equal to the simple average of the largest five recorded intakes for that radionuclide documented at the Savannah River Site (referred to as the “high five” approach). The largest annual dose to a non-metabolic organ from these assumed intakes was calculated for each year from the first year of employment through to the end of the year in which cancer was diagnosed.

Table 1 summarizes the results of NIOSH’s reconstruction of the doses for Case PIID*. The external dose to the rectum was determined by using the dose calculated for the colon. The internal dose to the rectum was calculated based on the maximum dose to any non-metabolic organ, considered by NIOSH as the colon. Using the dose estimate derived by NIOSH, the probability of causation (POC) was determined by the Department of Labor (DOL) to be 36.08% at the 99% confidence interval, and on this basis, the claim was denied.

In summary, a dose reconstruction was performed by NIOSH that included a total of 339 dose data entries to be used for determining the POC. These dose entries are numbers #1 through #339 and are reproduced herein as Appendix A. Throughout this report, reference will be made to select portions of Appendix A; for example, exposure entries #1 through #56 photon dosimeter doses, of which #1 through #28 correspond to photon energies between 30–250 keV and entries #29 through #56 correspond to photon energies >250 keV.

Table 1. Summary of NIOSH-Derived External/Internal Dose Estimates

	Appendix A Exposure Entry No.	Dose (rem)
External Dose:		
▪ Photon Dosimeter Dose	1 – 56	22.732
▪ Missed Photon Dose	214 – 257	4.015
▪ Neutron Dosimeter Dose	57 – 92	38.187
▪ Missed Neutron Dose	258 – 269	2.717
▪ Occupational Medical	311 – 339	0.807
▪ Onsite Ambient	282 – 310	2.764
Internal Dose (Hypothetical):		
▪ Tritium	185 – 213	10.825
▪ All Other Radionuclides	93 – 164	3.015
Total:		85.062

1.1 AUDIT OBJECTIVES

SC&A's audit was performed with the following objectives:

- To determine if NIOSH assigned doses that are consistent with monitoring records provided by the DOE and with information contained in the CATI report
- To determine if the dose reconstruction process complied with applicable procedures that include generic procedures developed by NIOSH and ORAUT, as well as data/procedures that are site-specific to SRS
- In instances when procedure(s) provide more than one option or require subjective decisions, determine if the process is scientifically defensible and/or claimant favorable

In pursuit of these objectives, a two-step process is followed. The first step of this audit is to independently duplicate and, therefore, validate doses derived by NIOSH. This step of the audit process is not only contractually mandated under Task 4, but provides NIOSH and the Advisory Board with a high level of assurance that the SC&A reviewer understands which procedures, models, site-specific data, and assumptions NIOSH used to perform its dose reconstruction. The second step of the audit critically evaluates whether the methods employed by NIOSH are technically defensible, consistent with applicable procedures, and claimant favorable.

Lastly, in compliance with the Privacy Act, this report makes no reference to the claimant's name, SSN, address, or any personal data that might reveal the identity of the claimant.

1.2 SUMMARY OF AUDIT FINDINGS

An overview of SC&A's audit findings for Case PIID* is provided in Table 2 in the form of a checklist. This checklist evaluates the data collection process, information obtained from the CATI interview, and all methods used in the dose reconstruction. When deficiencies are identified by the audit, such deficiencies are further characterized with regard to their impact(s) by means of the following definitions: (1) **low** means that the deficiency has only a marginal impact on dose; (2) **medium** means that the deficiency substantially impacts the dose, but is unlikely to impact the compensability of the case; and (3) **high** means that the deficiency substantially impacts the dose and may also impact the compensability of the case. A full description of deficiencies identified in the checklist is provided in the text of the audit that follows.

Table 2. Case Review Checklist

CASE PIID*	ASSIGNED DOSE: 85.062 rem	POC: 36.08%

No.	Description of Technical Elements of Review	Audit Response			If No, Potential Significance		
		YES	N/A	NO	LOW[1]	MEDIUM[2]	HIGH[3]
A. REVIEW OF DATA COLLECTION:							
A.1	Did NIOSH receive all requested data for the DOE or AWE site from any relevant data source?	✓					
A.2	Is the data used by NIOSH for the case adequate to make a determination with regard to POC?	✓					
B. REVIEW OF INTERVIEW AND DOCUMENTATION PROVIDED BY CLAIMANT							
B.1	Did NIOSH properly address all work history dates/locations of employment reported by claimant?	✓					
B.2	Did NIOSH properly address all incidents/occurrences reported by claimant?	✓					
B.3	Did NIOSH properly address monitoring/ personal protection/work practices reported by claimant?	✓					
B.4	Is the interview information consistent with data used for dose estimate?	✓					
C. REVIEW OF PHOTON DOSES							
C.1	Was the appropriate procedure used for determining:						
C.1.1	- Recorded Photon Dose?	✓					
C.1.2	- Missed Photon Dose?	✓					
C.1.3	- Occupational Medical Dose?	✓					
C.1.4	- Onsite-Ambient Dose?	✓					
C.2	Did the DR properly account for all:						
C.2.1	- Recorded Photon Dose?	✓					
C.2.2	- Missed Photon Dose?	✓					
C.2.3	- Occupational Medical Dose?	✓					
C.2.4	- Onsite-Ambient Dose?	✓					
C.3	Is the recorded/assigned dose properly converted to the organ dose of interest for:						
C.3.1	- Recorded Photon Dose?	✓					
C.3.2	- Missed Photon Dose?	✓					
C.3.3	- Occupational Medical Dose?	✓					
C.3.4	- Onsite-Ambient Dose?	✓					
C.4	Is the organ dose uncertainty properly determined for:						
C.4.1	- Recorded Photon Dose?			✓		✓	
C.4.2	- Missed Photon Dose?	✓					
C.4.3	- Occupational Medical Dose?	✓					
C.4.4	- Onsite-Ambient Dose?	✓					
D. REVIEW OF SHALLOW (i.e., 7 mg/cm^2)/ELECTRON DOSES							
D.1	Was the appropriate procedure used for determining:						
D.1.1	- Recorded Shallow/Electron Dose?	✓					
D.1.2	- Missed Shallow/Electron Dose?	✓					
D.1.3	- Onsite Ambient Dose?	✓					
D.2	Did the DR properly account for all:						

[1] **Low** means that the deficiency has only a marginal impact on dose.
[2] **Medium** means that the deficiency substantially impacts the dose, but is unlikely to impact the compensability of the case.
[3] **High** means that the deficiency substantially impacts the dose and may also impact the compensability of the case.

CASE PIID*	ASSIGNED DOSE: 85.062 rem	POC: 36.08%

No.	Description of Technical Elements of Review	Audit Response			If No, Potential Significance		
		YES	N/A	NO	LOW[1]	MEDIUM[2]	HIGH[3]
D.2.1	- Recorded Shallow/Electron Dose?		✓				
D.2.2	- Missed Shallow/Electron Dose?		✓				
D.2.3	- Onsite Ambient Dose?		✓				
D.3	Is the recorded/assigned dose properly converted to the organ dose of interest for:						
D.3.1	- Recorded Shallow/Electron Dose?		✓				
D.3.2	- Missed Shallow/Electron Dose?		✓				
D.3.3	- Onsite Ambient Dose?		✓				
D.4	Is the organ dose uncertainty properly determined for:						
D.4.1	- Recorded Shallow/Electron Dose?		✓				
D.4.2	- Missed Shallow/Electron Dose?		✓				
D.4.3	- Onsite Ambient Dose?		✓				
E. REVIEW OF NEUTRON DOSES							
E.1	Was the appropriate procedure used for determining:						
E.1.1	- Recorded Neutron Dose?	✓					
E.1.2	- Assigned Neutron Dose?	✓					
E.1.3	- Missed Neutron Dose?	✓					
E.2	Did the DR properly account for all:						
E.2.1	- Recorded Neutron Dose?	✓					
E.2.2	- Assigned Neutron Dose?			✓	✓		
E.2.3	- Missed Neutron Dose?	✓					
E.3	Is the recorded/assigned dose properly converted to the organ dose of interest for:						
E.3.1	- Recorded Neutron Dose?	✓					
E.3.2	- Assigned Neutron Dose?	✓					
E.3.3	- Missed Neutron Dose?	✓					
E.4	Is the organ dose uncertainty properly determined for:						
E.4.1	- Recorded Neutron Dose?	✓					
E.4.2	- Assigned Neutron Dose?	✓					
E.4.3	- Missed Neutron Dose?	✓					
F. REVIEW OF INTERNAL DOSE: BASED ON HYPOTHETICAL MODEL							
F.1	Is the use of the selected hypothetical internal dose model appropriate, based on the likely POC value?	✓					
F.2	Is the use of a hypothetical internal dose model appropriate/conservative, based on claimant's available bioassay data,?	✓					
F.3	Was the hypothetical dose value correctly derived?	✓					
G. REVIEW OF INTERNAL DOSE: BASED ON BIOASSAY/IMBA							
G.1	Was the appropriate procedure (or section of procedure) used for determining likely (>50%), unlikely (<50%), or undetermined POC and compensability?		✓				
G.2	Are bioassay data sufficiently adequate for internal dose reconstruction?		✓				
G.3	Are assumptions pertaining to dates of uptake reasonable/conservative?		✓				
G.4	Are critical parameters (e.g., solubility class, particle size, etc.) used for IMBA organ dose estimates appropriate?		✓				
G.5	Are assigned uncertainties (measurement errors) for bioassay data (used as input to IMBA) appropriate?		✓				

CASE PIID*	ASSIGNED DOSE: 85.062 rem	POC: 36.08%

No.	Description of Technical Elements of Review	Audit Response			If No, Potential Significance		
		YES	N/A	NO	LOW[1]	MEDIUM[2]	HIGH[3]
H.	Total Number of Deficiencies and Their Combined Potential Significance			2	✓		

[1] **Low** means that the deficiency has only a marginal impact on dose.
[2] **Medium** means that the deficiency substantially impacts the dose, but is unlikely to impact the compensability of the case.
[3] **High** means that the deficiency substantially impacts the dose and may also impact the compensability of the case.

2.0 AUDIT OF EXTERNAL DOSES

2.1 RECORDED PHOTON DOSE

Because most of the energy employee's exposure was assumed to have occurred while working at various reactors, photon doses were divided equally between energies with 30–250 keV and >250 keV. In addition, a photon dose correction factor of 1.119 was applied to each photon dose assignment.

Entries #1 through #28 correspond to annual photon doses associated with energies between 30 and 250 keV, and entries #29 through #56 correspond to annual photon doses associated with energies >250 keV.

NIOSH, therefore, derived annual photon doses by taking the DOE assigned annual dose, dividing it by two, and multiplying each of the halved values by 1.119. For example, DOE dosimeter records identify an annual dose of 100 mrem for this claimant for the first year of employment (PIID*). Dividing this value by two and multiplying this value by 1.119 yields two identical values of 56 mrem each. Thus, 56 mrem is assigned for the 30–250 keV energy range and 56 mrem is assigned for the >250 keV energy range for 1955. Entries #1 and #29 of Appendix A correspond to the total dosimeter photon dose for 1955.

For all years and both photon energy ranges, NIOSH calculated a total of 22.732 rem for this claimant.

2.1.1 Reviewer's Comments

SC&A reviewed Section 5 of ORAUT-TKBS-0003 and verified the recommended 50/50 photon split for the two energy ranges (see Table 5.3.4.1-1) for reactor environments and the 1.119 photon dose correction factor (see page 97 in Section 5.3.3.1). SC&A further verified each dosimeter dose value for entries #1 through #56.

While all dosimeter dose entries are correct, the dose entries are, in fact, estimates of mean dose and, therefore, require an assessment of uncertainty. NIOSH, however, entered all 56 measured dosimeter values as point estimates or constants.

OCAS-IG-001, ORAUT-TKBS-0003, and ORAUT-PROC-0006, Attachment D-2, clearly state the need to assign an uncertainty for dosimeter doses under Parameter 2 of Appendix A. For example, Section 5.7.2 of ORAUT-TKBS-0003 states that ". . . Measured doses are treated as normal distribution with s.d. of 30% (or other appropriate value that may be provided in Section 5)."

Section 5.3.5 of ORAUT-TKBS-0003 provides discrete uncertainty values for SRS dosimeters used during various time periods. For reactor workplace, Table 5.3.5-1 identifies uncertainty values of ±50% uncertainty for the years PIID*– PIID*, ±40% uncertainty for the years PIID*– PIID*, and ±20% uncertainty for PIID* to the PIID*.

As a result of NIOSH's failure to incorporate dosimeter uncertainty, SC&A concludes that photon dosimeter doses are not compliant with applicable procedures, are scientifically invalid, and claimant unfavorable.

2.2 MISSED PHOTON DOSES

The dosimeter exchange schedule varies from weekly to biweekly to monthly over the time frame of the claimant's employment period. Based on DOE records, NIOSH assigned a total of 217 zero dosimeter readings for photons (and 151 for neutrons). The DR Report states that "...These numbers were **maximized** to ensure that all possible instances of zero badge reading were accounted for in this dose reconstruction." [Emphasis added.]

In spite of available DOE monthly dosimeter records, which would have provided the correct (but reduced) number of zero readings, NIOSH elected to overestimate these readings for reasons of time/efficiency. Since the method by which NIOSH maximized the number of zero readings is not explained, our audit is limited to a process of inference, as explained below.

For example, entry #214 and entry #236 of Appendix A each give a missed dose value of 240 mrem for PIID*. Since the claimant only began employment on PIID*, we can assume that he was badged for a total of PIID* weeks during PIID*. DOE dosimeter records show that, for the year of PIID*, the claimant was assigned a zero dose. Table 5.5.2-1 of ORAUT-TKBS-0003 also identifies that, in PIID*, film badges were exchanged weekly. Thus, we may conclude that claimant had 24 zero readings in 1954. Table 5.5.1-1 further cites that in PIID*, the two-element film badge had a MDL value (or LOD) of 40 mrem. We, therefore, derived the following missed dose:

missed photon dose (PIID*) = (24)(40 mrem/2)
= **480 mrem**

While spot checks may not be representative of all assigned missed doses, there is reason to believe that the assigned missed photon doses were properly entered and are claimant favorable, as stated in the DR Report.

2.3 RECORDED NEUTRON DOSE

For neutron exposures associated with reactors, NIOSH applied neutron fractions of 15% 10–100 keV and 85% 0.1–2 MeV. In addition, ICRP 60 neutron correction factors of 0.28 for 10–100 keV neutrons and 1.62 for 0.1–2 MeV neutrons were applied, along with an organ dose conversion factor of 1.0.

Because neutron doses before 1971 were not adequately assessed by NTA film dosimeters, all neutron doses before 1970 were derived by means of the neutron to photon ratio method. After 1970, neutrons were measured by TLDs.

2.3.1 Reviewer's Comments

SC&A reviewed the stated parameters for deriving neutron dose by means of the neutron to photon ratio method, as described in Section 5 of ORAUT-TKBS-0003. SC&A verified the 15% and 85% default fractions for the two neutron energy ranges, and the 0.28 and 1.62 ICRP 60 neutron correction factors, as recommended in Table 5.4.2.2-1, as well as the neutron to photon ratio of 0.82. Table 5.5.2.2-2 identifies 0.82 as the 95th percentile value, which implies that derived neutron doses are bounding values that must, therefore, be entered as constant point estimates.

In summary, assigned neutron doses prior to PIID* do not represent recorded neutron doses, but were based on a neutron to photon dose ratio method that was further complicated by the following parameters:

- Both measured and missed photon doses were assumed to represent energies of 30–250 keV and >250 keV in equal proportions
- Equally, neutron doses were split with 15% of the dose presenting neutron energies between 10 and 100 keV, and 85% representing 0.1 to 2.0 MeV
- An ICRP 60 neutron correction factor
- A 95th percentile neutron to photon dose ratio value of 0.82

SC&A's audit of pre- PIID* assigned neutron doses were therefore limited to a few spot checks, as given in the example below:

Example #1: Verification of the PIID* assigned neutron dose of 457 mrem for 10–100 keV neutrons (see entry #58 of Appendix A).

SC&A's Approach:

PIID* neutron Dose = (total photon dose)(ICRP 60 n-CF)(%of n)(n/γ)(95th percentile ratio)
= (total photon dose)(1.91)(0.15)(0.82)

= (total photon dose)(0.235)

where: total photon dose = (recorded dose) + (missed dose)

Appendix A shows that for PIID*, (1) recorded photon dose is the sum of entries #1 (at 56 mrem) and #29 (at 56 mrem), and (2) missed photon dose is the sum of entries #215 (at 470 mrem) and #237 (at 470 mrem).

Thus for PIID*, the total photon dose is calculated at 1,052 mrem. Based on this value, the PIID* neutron dose from neutrons between 10 and 100 keV is given by the following:

PIID* neutron dose$_{10\text{-}100\ keV}$ = (Total photon dose)(0.235)
= (1,052 mrem)(0.235)
= 247 mrem

SC&A's derived value of 247 mrem is about one-half the NIOSH assigned value of 457 mrem shown in entry #58.

Example #2: Verification of the PIID* assigned neutron dose of 2,646 mrem for 100 keV–2 MeV neutrons (see entry #76 of Appendix A):

SC&A's Approach:

PIID* neutron dose$_{100\ keV\text{-}2\ MeV}$ = (total photon dose)(ICRP 60 CF)(% of *n*)
(*n*/γ 95th percentile ratio)
= (1,052 mrem)(1.91)(0.85)(0.82)
= 1,400 mrem

SC&A's derived value of 1,400 mrem is about one-half of the NIOSH assigned neutron dose of 2,646 mrem for 100 keV–2 MeV neutrons.

On the basis of these and other spot checks, SC&A was unable to verify pre- PIID* neutron doses assigned by NIOSH.

Independent of the potential arithmetic errors discussed above is the issue of the assigned exposure rate for dosimeter photon doses and dosimeter neutron doses based on neutron/photon ratios. Since these two different "dosimeter doses" are, nevertheless, received concurrently, SC&A reviewers question why dosimeter doses entered as "acute" for photons and "chronic" for neutrons. While the assumption of an acute exposure rate may be viewed as claimant favorable, it is a scientific paradox to the concurrent neutron exposure that is cited as chronic. For scientific consistency, it would be more proper to assign either acute or chronic to both photon and neutron doses.

2.4 MISSED NEUTRON DOSE

As stated above, for missed neutron dose, NIOSH assumed a maximized total of 151 zero readings. Missed neutron doses were assigned only for the years PIID* to PIID* and correspond to the years when SRS introduced the SRS Hoy TLND. NIOSH apparently also applied the 15% and 85% neutron fractions corresponding to neutron energy ranges of 10–100 keV and 0.1–2 MeV.

Thus, entries #258 through #269 correspond to missed neutron doses for 10–100 keV neutrons, and entries #270 through #281 correspond to 0.1–2 MeV neutrons. Inspection of these two data sets show assigned annual missed neutron doses of 34 mrem (for 10–100 keV neutrons) and 194 mrem (for 0.1–2 MeV neutrons). The only exception for these two values is for the year 1979, when 31 mrem and 178 mrem, respectively, were assigned. For PIID*, a single positive neutron reading of 15 mrem was recorded, which implies a total of only 11 zero readings for PIID*.

As should be noted, all missed doses are entered as being a **geometric mean** value of a lognormal distribution with a GSD of 1.52.

2.4.1 Reviewer's Comments

SC&A independently calculated assigned missed neutron doses based on guidance contained in Section 5.5.2 of ORAUT-TKBS-0003. Guidance contained therein shows that post-1971, neutron badges were exchanged monthly, and the LOD for the SRS Hoy TLND is given as 20 mrem.

It should be noted that guidance in Section 5.5.2 of ORAUT-TKBS-0003 is lacking with regard to the application of the ICRP 60 neutron dose correction factor. Logic, however, would dictate that the 0.28 and 1.62 neutron dose correction factors do apply to missed neutron dose. On this assumption, the following yearly missed neutron doses are calculated for 12 zero cycles:

- Neutron (10–100 keV) = (12)(20 mrem/2)(0.28)
  = 34 mrem

- Neutron (0.1–2 MeV) = (12)(20 mrem/2)(1.62)
  = 194 mrem

In summary, SC&A was able to duplicate the missed neutron doses of 34 mrem and 194 mrem assigned by NIOSH. These values are procedurally compliant and claimant favorable.

2.5 OCCUPATIONAL MEDICAL DOSE

DOE records received by NIOSH state that there were no records for the claimant pertaining to occupational medical x-rays. In the absence of records, NIOSH assumed annual x-rays for each

year of employment. Occupational medical x-ray doses assigned to claimant by NIOSH correspond to entries #311 through #339 in Appendix A.

Table 2.5.1-1 in Section 2.5.1 of ORAUT-TKBS-0003 provides organ dose default values for medical x-rays in behalf of three organ groups. Rectal cancer belongs to those organs classified as Group 3.

2.5.1 Reviewer's Comments

SC&A reviewed Group 3 organ doses for the years PIID* through PIID* and confirmed that the recommended values given in Table 2.5.1-1 were in fact used.

SC&A concludes that for occupational medical exposures, the applicable procedure/data were used. These values are scientifically valid and claimant favorable.

2.6 ONSITE AMBIENT

Although the claimant was monitored for the entire period of employment, onsite ambient doses were nevertheless assigned in order to compensate any erroneous subtraction of elevated ambient levels of external radiation (EALER) that may have been recorded by control badges. The onsite ambient doses assigned were based on the maximum annual doses for any SRS area and scaled to a 50-hour work week. The represented total onsite ambient dose assigned by NIOSH was 2.764 rem. These annual doses are presented in entries #282 through #310.

NIOSH assigned maximum annual doses that correspond to values provided in Section 3.4.1 and Table 3.4-1 of ORAUT-TKBS-003.

2.6.1 Reviewer's Comments

SC&A confirmed that assigned annual doses provided in Table 3.4-1 of ORAUT-TKBS-0003 were, in fact, entered correctly for all years of employment. Thus applicable procedures were followed and assigned doses are scientifically valid and claimant favorable.

3.0 AUDIT OF INTERNAL DOSES

NIOSH states that all DOE records were reviewed for bioassay data for this claimant. Based on this review, NIOSH concluded that these data would result in assigned internal doses that are considerably lower than assigned default values and hypothetical intakes. Default values were assigned annually to tritium doses and hypothetical doses were assigned to all radionuclides other than tritium for a single acute intake on the first day of employment. Guidance for this approach is provided in Section 4.5 of ORAUT-TKBS-0003.

3.1 TRITIUM

For tritium, default annual doses are provided in Table 4.5.3-1 of ORAUT-TKBS-0003. For the years of concern, the annual tritium dose of 355 mrem is given. Entries #185 through #213 of Appendix A correspond to tritium exposures assigned by NIOSH.

3.1.1 Reviewer's Comments

Assigned values match the recommended doses of Table 4.5.3-1 and are, therefore, in compliance with the applicable procedure, and are considered scientifically valid and claimant favorable.

3.2 RADIONUCLIDES OTHER THAN TRITIUM

In order to account for any incidental dose(s) that might have been received but were not detected/documented, NIOSH assigned yearly internal doses based on a single hypothetical acute intake on the first day of employment through the year of cancer diagnosis.

The technical basis for hypothetical internal doses is described in Section 4 of ORAUT-TKBS-0003. Entries #93 through #164 define internal annual doses from alpha and beta radiations. For hypothetical internal exposures, default values are provided in Table 4.5.1-1 of ORAUT-TKBS-0003 for both alpha and beta radiation.

3.2.1 Reviewer's Comments

SC&A reviewed all data entries for hypothetical internal doses and confirmed that these doses correspond to values cited in Table 4.5.1-1.

SC&A concludes that for hypothetical internal doses assigned by NIOSH, the correct procedures were applied, and doses are scientifically valid and claimant favorable.

3.2.2 Generic Comments Pertaining to Internal Dose Models

At this time, we conclude that all assigned internal doses for tritium and nuclides other than tritium are correct and comply with applicable procedures. However there may be a generic flaw in the hypothetical internal exposure model for tritium and all other nuclides that may not only

adversely affect the scientific validity and claimant favorability of this claim, but other SRS claims as well. The following provides a brief explanation.

The potential exception to scientific validity/claimant favorability reflects two issues. The first involves the unconfirmed assumption that all tritium exposures are those involving tritiated water. If, in fact, intakes involved a significant fraction of organified tritium, with a biological/effective half-life that is about 2.3-fold higher, then the assigned doses may be too low.

The second issue is considerably more complex and involves estimated yearly doses from all other internal radionuclides, as defined in Table 4.5.1-1 of ORAUT-TKBS-0003, which in turn were derived from data contained in ORAUT-OTIB-0001. In brief, ORAUT-TIB-0001 models intakes that are based on ICRP 30 biokinetic models instead of the current ICRP 68 models, as required in 42 CFR 82. We believe that the use of ICRP 30 calculated intakes may not be claimant favorable for several important radionuclides, and that ICRP 68 models should have been used to derive intakes.

Although the two issues cited above may impact both **recorded** internal doses (defined by bioassay data and IMBA) and **assigned** hypothetical doses, an agreement has been reached by the Advisory Board, SC&A, and NIOSH to evaluate these issues under Task 1 (i.e., Review of Site Profile).

4.0 CATI REPORT AND RADIOLOGICAL INCIDENTS

The CATI report notes that the claimant responded negatively when asked about any radiological incidents. However, NIOSH's DR Report makes brief mention of DOE records that document skin contamination events that were successfully decontaminated.

NIOSH concluded that these events are likely to have resulted in doses that were well below those assigned to the claimant, as described in Section 3. Correspondingly, NIOSH did not formally investigate these incidents for the purpose of dose reconstruction.

4.1 REVIEWER'S COMMENTS

SC&A reviewed the DOE records for radiological incidents. DOE records show the following:

- For the duration of employment, claimant either lost or damaged his personnel dosimeter eight separate times. The records show that doses were assigned that presumably reflect either co-worker data, area monitors, and/or self-reading pocket dosimeters.

  SC&A concludes that any missed doses were properly accounted for.

- In PIID*, over a period of days to weeks, claimant apparently entered a room with tritium air concentrations given at "1,775 µCi/hr" without the protection of a respirator. Post-exposure urinalysis conducted over several weeks yielded urine concentrations of 13 µCi/l to 22 µCi/l. Based on urine data, claimant was assigned a total body dose of 565 mrem.

- In PIID*, claimant's skin was exposed to process water containing tritium. Based on urine data, it was assumed that claimant assimilated 500 µCi of tritium.

- In PIID*, claimant was contaminated with UO_3 when a hose malfunctioned. The UO_3 powder contaminated his whole body and required claimant to "discard" undergarments/socks. The report states that nasal smears were negative.

- In an incident report dated PIID*, the claimant was exposed to unknown concentrations of UNH dust. Urine bioassay results showed a concentration of 3.3 µg/l for U.

- In an incident report dated PIID*, claimant was apparently exposed to airborne UO_3 at the PIID* for a period of 2 hours. Urine bioassay yielded a concentration value of 1.3 µg/l.

SC&A has evaluated the potential significance of these incidents and concluded that the assigned hypothetical intakes/doses are likely to be well in excess of potential doses that may have resulted from these events.

5.0 SUMMARY CONCLUSIONS

SC&A's audit of this claim found several systemic errors that affect all data entries for a given category of dose assignment. These errors principally reflect the failure to follow procedural guidance and include the following:

- Failure to assign uncertainty to photon dosimeter doses.
- Neutron doses derived from neutron/photon ratio could not be duplicated and may not comply with procedural methodology.
- Two generic issues of concern for tritium and radionuclides other than tritium include the assumption that tritium exists 100% as tritiated water, and the use of ICRP 30 biokinetic models for deriving internal doses for radionuclides other than tritium. These issues, however, will be addressed under Task 1 (i.e., SC&A's Review of Site Profiles).

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APPENDIX A: IREP INPUT

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