# REPORT TO THE ADVISORY BOARD ON RADIATION AND WORKER HEALTH

*National Institute of Occupational Safety and Health*

**Audit of Case PIID* from the Y-12 National Security Complex**

**Contract No. 200-2004-03805**
**Task Order No. 4**

**SCA-TR-TASK4-CNPIID***

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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 who has worked as a **PIID***, **PIID***, and **PIID*** at the Y-12 National Security Complex since **PIID***. The claimant's job duties had him performing work in numerous buildings throughout the facility.

Records suggest that the primary route of exposure to the worker was from external gamma radiation. The worker was provided with dosimeters to measure external exposures throughout the duration of his employment at Y-12. These included film badges (through **PIID***), two-element TLD dosimeters (**PIID***, through **PIID***), and four-element TLD dosimeters (**PIID*** through the present). Periodic urine bioassay sample data indicate minimal uranium intake throughout his years of employment at the Y-12 complex. As a claimant-favorable assumption, the "hypothetical intake" described in Technical Information Bulletin: *Maximum Internal Dose Estimates for Certain DOE Complex Claims* (ORAUT-OTIB-0002, January 10, 2004), was assumed for the worker. In addition, the worker was assigned doses from annual occupational chest x-rays as part of the Y-12 medical surveillance program.

The worker was diagnosed with cancer of the prostate gland on **PIID***. Table 1 summarizes the results of NIOSH's reconstruction of the doses to the energy employee's prostate gland, which yielded a probability of causation (POC) of 10.26% using IREP. Because ICRP 66 and IMBA do not provide the means to derive the doses to the prostate gland, NIOSH used the testes as a claimant-favorable surrogate for the prostate for both internal and external exposures.

**Table 1. Summary of Internal/External Exposures as Estimated by NIOSH**

| | Appendix A Exposure Entry No. | Dose (rem) |
|---|---|---|
| External Dose: | | |
| ▪ Photon Dosimeter Dose | 1 – 3 | 0.368 |
| ▪ Photon Missed Dose | 64 – 83 | 1.640 |
| ▪ Neutron Dosimeter Dose | NA* | — |
| ▪ Neutron Missed Dose | NA* | — |
| ▪ Occupational Medical | 84 – 103 | 1.660 |
| ▪ Onsite Ambient | NC** | — |
| Internal Dose (Hypothetical): | 4 – 63 | 12.151 |
| Total | | 15.819 |

*NA = Not applicable
**NC = Not considered

## 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 the 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

- 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 in this audit. 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.

It must be noted that this audit has been conducted without the benefit of a critical review by SC&A under Task Order 1 of NIOSH's Y-12 National Security Complex Site Profile (documents ORAUT-TKBS-0014-1, -2, -3, -4, -5, and -6). Review of these documents could uncover other problems or issues with the potential to affect this claim. At such time that these site documents are reviewed, it is recommended that dose reconstructions performed in behalf of the ORNL site be revisited to assess any changes caused by new information. Results of the current audit are expressed in terms of whether SC&A found the exposures to have been derived in a scientifically valid manner, and whether we found the doses to have been derived in compliance with applicable procedures and in a claimant-favorable manner.

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: 15.819 rem | POC: 10.26% |
|---|---|---|

| 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: | | | | | | |
| 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? | | ✓ | | | | |

[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: 15.819 rem | POC: 10.26% |
|---|---|---|

| No. | Description of Technical Elements of Review | Audit Response | | | If No, Potential Significance | | |
|---|---|---|---|---|---|---|---|
| | | YES | N/A | NO | LOW[1] | MEDIUM[2] | HIGH[3] |
| 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? | | ✓ | | | | |
| **H. Total Number of Deficiencies and Their Combined Potential Significance** | | | | 6 | ✓ | | |

[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 DOSES

The claimant was provided with an external dosimeter for the entire PIID* period of interest. Since dosimeters were changed quarterly, a total of 80 dosimeters would have been issued to the claimant. Of those PIID* calendar quarters, three dosimeters indicated external whole-body doses in excess of the lower limit of detection. They were 0.024, 0.090, and 0.070 rem in **PIID***, **PIID***, and **PIID***, respectively.

To maximize these three annual doses, the dose reconstructor multiplied these values by the "standard overestimating correction/conversion factor" of 2, as specified in Table 5-2 of ORAUT-OTIB-0008. Since the multiplication of recorded dose by 2 yields the 95$^{th}$ percentile value, there is no need to assign uncertainty and the dose is entered as a constant.

For recorded photon dose, entries #1, #2, and #4 are the maximized doses for the years **PIID***, **PIID***, and **PIID***, respectively. These values were correctly derived, procedurally compliant, and claimant favorable.

## 2.2 MISSED PHOTON DOSE

DOE records indicate that the claimant was monitored on a quarterly bases during the **PIID***year employment period. For efficiency, NIOSH **assumed** a total of 80 dosimeter readings for which the recorded external deep dose equivalent was zero (or less than LOD). (A review of DOE records shows a total of 76 actual number of zero readings.)

For deriving missed photon doses, the dose reconstructor employed **three different procedures** and provided the following explanation:

> From Page 5 and 6 of DR Report:
>
> *To ensure that the estimated dose has been maximized, a multiplication factor of 2 has been applied to the reported and missed annual doses. Application of this multiplication factor overestimates dose to account for uncertainty in dosimeter response and in variability for the dose conversion factor across all organs.*[8] *. . .*
>
> *Based on information provided in the Technical Basis Document for the Y-12 National Security Complex – Occupational External Dosimetry,*[9] *the total number of dosimeter cycles assigned was 80 for photons. . . . Based on information provided in the Technical Basis Document for the Y-12 National Security Complex – Occupational External Dosimetry,*[9] *this results in a maximum potential missed dose for* [claimant] *of 3.280 rem from photons. For the purpose of calculating probability of causation, this value was divided by 2 in accordance with the External Dose Reconstruction Implementation Guideline.*[3]

The above-cited passages from the DR Report identify the following three separate references/ procedures for the calculation of "maximizing" missed photon dose:

1. Reference #3 is OCAS-IG-001, *External Dose Reconstruction Implementation Guideline*, Rev. 1, 2002.

2. Reference #8 is ORAUT-OTIB-0008, *Technical Information Bulletin: A Standard Complex-Wide Conversion/Correction Factor for Overestimating External Doses Measured with Thermoluminescent Dosimeter*, Rev. 00, 2003.

3. Reference #9 is ORAUT-TKBS-0014-6, *Technical Basis Document for the Y-12 National Security Complex – Occupational External Dosimetry*, Rev. 00, 2003.

These three procedures were not intended to be used in combination. By combining these three procedures, NIOSH's dose reconstruction is flawed by a series of errors that fortunately cancelled one another, and resulted in a net and final error that involved the inclusion of a GSD value of 1.52 for a lognormal distribution, when in fact the annual missed doses for entries #64 to #83 from Appendix A should have been entered as constants.

The following summarizes the **misinterpretation** as well as **misuse** of the three cited reference:

- Misinterpretation of ORAUT-OTIB-0008. This procedure identifies a "standard overestimating correction/conversion factor" of 2. However, the procedure states that this factor ". . . can be applied to all deep doses **reported** by DOE sites to arrive at a claimant-favorable estimate of the dose . . ." [Emphasis added.]

  Thus, the first error was the use of the C/C factor as a multiplier of LOD for **missed** doses. For **missed dose,** ORAUT-OTIB-0008 specifies that the maximized dose is simply the product of (LOD)(*n*), where *n* is the number of cycles for which the recorded dose was zero.

- Misuse of Procedure. By combining procedures ORAUT-OTIB-0008 with OCAS-IG-001, the dose reconstructor cites guidance given in OCAS-IG-001, which recommends that for **best estimates**, missed dose is defined by $(LOD)(n)/2$. The use of LOD/2, however, is intended for deriving a **best estimate** of missed dose (as a lognormal value with GDS of 1.52. Thus, the first error is cancelled by the second error and yields a correct dose, which, however, should have been entered as a constant. The net error then is the entry of the dose as a lognormal value with a GSD of 1.52.

These errors would have been avoided if the dose reconstructor had confined the calculation of missed dose to ORAUT-TKBS-0014-6, Table F-6, which defines dosimeter LOD values by time periods, as well as provides maximum annual missed dose.

It must be pointed out that nearly identical series of errors for deriving missed photon doses were committed by two other dose reconstructors (see Case #PIID* and Case #PIID*) among the 15 non-AWE cases reviewed in the report.

While the net impact on assigned doses is **insignificant** (and, in fact, claimant favorable in all three cases), the implication is **not**. SC&A believes that root cause for these errors must be attributed to ambiguous wording/format of procedures, as well as their excess complexity and numbers.

## 2.3 OCCUPATIONAL MEDICAL EXPOSURES

NIOSH also assumed that annual chest x-rays were given as a part of a routine medical surveillance program of workers. These exposures were acute and the photon energies were assumed to range from 30–250 keV. The uncertainty in the x-ray exposures was assumed to be normally distributed, with a standard deviation of 30%. Based on these parameters, a dose of 0.083 rem per x-ray was estimated, or a total of 1.660 rem over the **PIID*** -year period of interest.

The 1.660 rem dose to the testes from 20 medical x-rays is based on the assumption that the claimant received a single conventional anterior-posterior x-ray annually. The estimate of dose to the prostate may have been intended to be claimant favorable, in that NIOSH used the dose to the organ with the maximum dose per x-ray (e.g., the breast, lateral chest view) rather than the dose to the testes (the typical surrogate for the prostate) from the values published in Table 4.0-1 of ORAUT-OTIB-0006 for **PIID*** – **PIID*** exposures. The dose was then increased by 30% to account for uncertainty.

Had the actual value for the testes been used, the estimated dose to the prostate would have been more than three orders of magnitude lower. While the dose estimate provided in the dose reconstruction report is clearly claimant favorable, it is unwarranted and clearly not scientifically valid. Using a parameter value representing dose to the breast rather than the value for dose to the testes when reconstructing a dose to the prostate from chest x-rays detracts from the scientific quality of the dose reconstruction and violates the intent of claimant favorability, as defined in 42 CFR 82.

# 3.0 AUDIT OF INTERNAL DOSES

Records obtained from DOE include periodic urinalysis data from the worker. Samples collected from **PIID*** – **PIID*** contained between 0–20 dpm uranium. Most samples collected after **PIID*** were found with uranium concentrations less than the detection threshold and were less than 1 dpm per day in all but one sample. Between 1–5 mg uranium were reported, based on lung counts conducted during the **PIID***. In vivo lung counts conducted in **PIID*** and **PIID*** failed to find any uranium or actinium. As a result of these relatively low potential intakes, the NIOSH internal dose reconstruction was based on the hypothetical intake described in ORAUT-OTIB-0002. The dose reconstruction report makes reference to the 28 radionuclides included in the hypothetical intake, indicating that the "Site with a reactor" combined with the "uranium site" scenarios were utilized. The list includes all nuclides identified on the CATI report as "present" and most of the nuclides identified, as "unknown" during claimant's employment.

In the interview, the worker indicated participating in breath and fecal monitoring while employed at the Y-12 complex in addition to urine and in vivo monitoring. The only data forwarded for review as part of this audit were urinalysis and in vivo data. NIOSH did not comment on breath or fecal monitoring data in the dose reconstruction report.

The internal dose to the prostate, determined by NIOSH based on the methodology described in ORAUT-OTIB-0002, was 12.151 rem. The NIOSH report does not describe or present the relevant parameter values utilized to determine this dose; it was presumably generated with the Excel® workbooks spreadsheets titled "Maximum Internal Dose Calculation Workbook.xls" and "Maximum Internal Dose Calculation non-Uranium Facility Workbook.xls" developed in support of ORAUT-OTIB-0002.

At the time of the dose reconstruction, the Excel® workbook spreadsheets did not allow for a direct calculation of the prostate dose, and the use of the colon as the highest non-metabolic surrogate organ was, therefore, correct. Nevertheless, it is worth noting that since the time of this dose reconstruction, these spreadsheets have been updated and now include the prostate. For this claim, a direct prostate dose of 10.05 rem was derived, which is about 2.5 rem lower than the more claimant-favorable dose of 12.5 rem assigned by NIOSH.

# 4.0 CATI REPORT AND RADIOLOGICAL INCIDENTS

No radiological incidents were identified in either DOE records or in the CATI report and no inconsistencies were noted that adversely affect the dose reconstruction report.

# 5.0 SUMMARY CONCLUSIONS

Issues of concern in the dose reconstruction for Case PIID* were confined to dose estimates in behalf of missed photon doses and occupational medical exposures.

For missed photon doses, multiple errors reflect the inappropriate combined use of three separate procedures. Nearly identical errors were committed in behalf of two other cases (i.e., Case # **PIID*** and Case # **PIID***), which suggest that the root cause may be the ambiguous guidance provided in these procedures.

For assigned occupational medical exposure, excessively high doses were assigned that reflect the inappropriate substitution of surrogate organs.

# REFERENCES

Kathren, R.L., Shockley, V.E., Thomas, E.M., Taulbee, T.D. 2003. "Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures," ORAUT-OTIB-0006.

NIOSH. 2002. "NIOSH-Interactive Radioepidemiological Program (NIOSH-IREP) Technical Documentation," Final Report. June 18, 2002.

OCAS-IG-001, 2002. "External Dose Reconstruction Implementation Guideline," Revision 1. August 2002.

ORAUT-TKBS-0014-6. 2003. "Technical Basis Document for the Y-12 National Security Complex – Occupational External Dosimetry," November 19, 2003.

ORAUT-OTIB-0002. 2004. "Technical Information Bulletin: Maximum Internal Dose Estimates for Certain DOE Complex Claims," Rev. 00 PC-2. January 10, 2004.

ORAUT-OTIB-0008. 2003. "Technical Information Bulletin for a Standard Complex-Wide Conversion/Correction Factor for Overestimating External Doses Measured with Thermoluminescent Dosimeter," Rev. 00. November 7, 2003.

# APPENDIX A: IREP INPUT

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**APPENDIX A (Continued)**

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