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National Institute for Occupational Safety and Health

Review of the Rocky Flats Plant Special Exposure Cohort (SEC) Petition, SEC-00030

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Prepared by

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

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

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Task Manager: _____ Date: _____ Joseph Fitzgerald	Supersedes: N/A
Project Manager: _____ Date: _____ John Mauro, PhD, CHP	

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ACRONYMS AND ABBREVIATIONS

Advisory Board, The Board, or ABRWH	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AI	Alveolar Interstitial
ALARA	As Low as Reasonably Achievable
Am	Americium
AMAD	Activity Medium Aerodynamic Diameter
ANSI	American National Standards Institute
AP	Anterior-Posterior
AWE	Atomic Weapons Employer
BBO	Button Break Out
Bq	Bequerel
CA-DTPA	Calcium Diethylenetriamene Pentaacetate
CAM	Continuous Air Monitor
CATI	Computer-Assisted Telephone Interview
cc	Cubic Centimeter
CDC	Centers for Disease Control and Prevention
CDE	Cumulative Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CEDR or CER	Comprehensive Epidemiologic Data Resource
CEF	Critical Experiments Facility
Cf	Californium
CFR	*Code of Federal Regulations*
Cm	Curium
cm	Centimeter
Co	Cobalt
cpm	Counts Per Minute
Cs	Cesium
CTW	Construction Trade Worker
D&D	Decontamination and Decommissioning

DAC	Derived Air Concentration
DCF	Dose Conversion Factor
DE	Dose Equivalent
DFRC	Denver Federal Records Center
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOELAP	Department of Energy Laboratory Accreditation Program
DOL	U.S. Department of Labor
dpm	Disintegrations Per Minute
DR	Dose Reconstruction
DTPA	Diethylenetriamene Pentaacetate
DU	Depleted Uranium
EDR	Extended Dose Reconstruction
EE	Energy Employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ER	Electro Refining
ERDA	Energy Research and Development Administration
EU	Enriched Uranium
EXPID	Exposure Identity Number
FRC	Federal Record Center
ft	Foot
ft^3	Cubic Foot
FY	Fiscal Year
g	Gram
GAO	General Accounting Office
GI	Gastrointestinal
GM	Geometric Mean
GMSD	Geometric Mean Standard Deviation
GSD	Geometric Standard Deviation
h, hr	Hour
HAN	Hanford
HEPA	High Efficiency Particulate Air (filter)

HEU	Highly Enriched Uranium
HFO	High-Fired Oxide
HHS	U.S. Department of Health and Human Services
HIS	Health Physics Information System
HP	Health Physics
HPERER	Health Physics External Radiation Exposure Report
hr	Hour
HRA	High Radiation Area
HSDS	Health Sciences Data System
HSP	Health and Safety Practices
HTO	Tritiated Water
ICRP	International Commission on Radiological Protection
ID	Identification
IH	Industrial Hygiene
IMBA	Integrated Modules for Bioassay Analysis
in.	Inch
Ir	Iridium
IREP	Interactive RadioEpidemiological Program
JCUSC	Joint Company-Union Safety Committee
keV	Kilo Electron Volt
kg	Kilogram
KH	Kaiser-Hill
KHAP	Kaiser-Hill Assessment Project
L	Liter
LANL	Los Alamos National Laboratory
lb	Pound
LLNL	Lawrence Livermore National Laboratory
LOD	Limit of Detection
m	Meter
m^3	Cubic Meter
MAA	Material Access Area
MBA	Mass BAlance

MDA	Minimum Detectable Activity
MDL	Minimum Detectable Level
MeV	Mega-electron Volt
Mg	Magnesium
mg	Milligram
ml	Milliliter
min	Minute
mm	Millimeter
MPBB	Maximum Permissible Body Burden
MPL	Maximum Permissible Limit
MPLB	Maximum Permissible Lung Burden
mR	Milliroentgen
mrad	Millirad
mrem	Millirem
mrep	Millirep
MSE	Molten Salt Extraction
NaI	Sodium Iodide
nCi	nanoCurie
NCRP	National Council on Radiation Protection and Measurements
NDRP	Neutron Dose Reconstruction Project
NDT	Nondestructive Testing
NIOSH	National Institute for Occupational Safety and Health
NMMSS	Nuclear Materials Management and Safeguards System
NOCTS	NIOSH-OCAS Computer Tracking System
n/p	Neutron-to-Photon
Np	Neptunium
NRC	U.S. Nuclear Regulatory Commission
NRT	National Response Team
NTA	Nuclear Track A (film)
NTP	Neutron Track Plate
NTS	Nevada Test Site
NUREG	Nuclear Regulatory Commission Guidance Document

OCAS	Office of Compensation Analysis and Support
O-Drive	OCAS Site Research Query Interface Database
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
ORISE	Oak Ridge Institute of Science and Education
OTIB	ORAU Technical Information Bulletin
Pa	Protactinium
Pb	Lead
pCi	Picocurie
PCM	Personnel Contamination Monitor
pdf	Portable Document Format
PHA	Pulse Height Analysis
Po	Polonium
POC	Probability of Causation
PPE	Personal Protective Equipment
ppm	Parts Per Million
PSZ	Perimeter Security Zone
Pu	Plutonium
PuBe	Plutonium Beryllium
PuF_4	Plutonium tetrafluoride
PuO_2	Plutonium Oxide
QA	Quality Assurance
QC	Quality Control
R	Roentgen
R^2	Coefficient of Determination
R&D	Research and Development
Ra	Radium
Rad Worker II	Radiation Worker II
RCA	Radiological Control Area
RCT	Radiological Control Technician
rem	Roentgen Equivalent Man
RFCAB	Rocky Flats Citizens Advisory Board

RFETS	Rocky Flats Environmental Technology Site
RFP	Rocky Flats Plant
RGG	Recommended Concentration Guide
Rh	Rhodium
RHHB	Radiological Health Handbook
RI	Rockwell International
RMRS	Rocky Mountain Remediation Services
RPT	Radiation Protection Technician
RWP	Radiation Work Permit
SAAM	Selective Alpha Air Monitor
SC&A	S. Cohen and Associates
SEC	Special Exposure Cohort
Sr	Strontium
SRDB	Site Research Database
TBD	Technical Basis Document
TBP	Tributyl Phosphate
Th	Thorium
TIB	Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
TTA	Thenoyl Trifluro Acetone
TWMA	Time-Weighted Monthly Average
Type SS	Type Super S
U	Uranium
USARF	United Steelworkers of America Rocky Flats
USTUR	United States Transuranium and Uranium Registries
USWA	United Steel Workers of America
WB	Whole Body
ZPPR	Zero Power Physics Reactor
µCi	Microcurie
µg	Microgram
µm	Micrometer

EXECUTIVE SUMMARY

This draft evaluation report was prepared by S. Cohen & Associates (SC&A) at the direction of the Advisory Board on Radiation and Worker Health (Advisory Board, the Board, or ABRWH). This report documents SC&A's review of the Special Exposure Cohort (SEC) evaluation report prepared by the National Institute for Occupational Safety and Health (NIOSH) for the NIOSH-approved class of Rocky Flats Plant (RFP) workers for the period April 1952–February 15, 2005.

The Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) provides for the U.S. Department of Health and Human Services (HHS) to add certain classes of U.S. Department of Energy (DOE), Atomic Weapons Employer, contractor, and subcontractor employees to the SEC under specified conditions. The rules described in Title 42, Part 83, of the *Code of Federal Regulations* (42 CFR Part 83)**,** *Procedure for Designating Classes of Employees as Members of a Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000,* relate to the process for filing petitions for additions to the SEC and the ways in which NIOSH and its contractors will evaluate the petitions. These rules also specify the role that the Board plays in the process of SEC petition evaluations, which includes advising the Secretary of HHS whether to add a class to the SEC and providing the reasons for the Board recommendation. SC&A, the technical support contractor to the Board, was directed at the Board's January 22–24, 2006, meeting to conduct a focused review of SEC issues related to the RFP SEC petition.

On February 15, 2005, United Steelworkers of America Local 8031 submitted an SEC petition (USWA 2005) for all represented members, past and current, who worked at RFP between April 1952 and February 15, 2005. As noted by NIOSH in its evaluation report (NIOSH 2006a) for SEC-00030 for RFP, the following information was considered sufficient to qualify the petition for evaluation:

> *Periods of inadequate monitoring, lack of monitoring, and/or changes in methodology and procedures over the history of the Rocky Flats Plant which make accurate dose reconstruction over time impossible. Examples include: no routine lung counting until the late 1960s, no monitoring for neutron radiation prior to the late 1950s, and neutron measurements found in error until the 1970s, and the impossibility of accurate dose assessment for high fired oxide exposures.*
>
> *The petitioner asserted by affidavits that energy employees at RFP have either had their doses inaccurately reported or had unmonitored exposures.*

In its qualification of SEC-00030, NIOSH expanded the petitioner-requested class to include all employees of DOE, DOE contractors, and subcontractors (regardless of union membership) who worked at RFP from April 1952 through February 2005 and who were employed for at least 250 aggregated workdays.

In February 2006, SC&A began its SEC evaluation review, consistent with the Board's SEC evaluation criteria of January 16, 2006, and with the SEC draft review procedures being

discussed by the Board (since issued on June 12, 2006), and under the auspices and direction of a working group appointed by the Board. Starting with an identification of SEC-relevant issues based on SC&A's site profile review for Rocky Flats, the working group became the forum for SC&A and NIOSH to exchange technical views, to surface SEC-significant issues, and to ascertain the relevance and importance of these issues to dose reconstruction. Following the issuance of NIOSH's SEC evaluation of Petition SEC-00030 for RFP on April 7, 2006, SC&A's focus shifted to reviewing the technical basis of NIOSH's established conclusions and whether the scope of its evaluation was adequate and complete.

Unlike previous SEC evaluations conducted by SC&A, RFP has more substantial individual dose records available over its 50-year history than other SEC petition sites reviewed to date, to the extent that NIOSH observed that its anticipated use of yet-to-be-completed (at the time) coworker models would likely be minimal (ABRWH 2006b). Therefore, the initial emphasis of the SC&A review centered on high-fired plutonium oxide and the integrity of the data, rather than data completeness, and the subsequently issued external and internal coworker technical information bulletins (issued on May 12 and August 3, 2006, respectively). As it became more evident that the Health Physics Information System 20 (HIS-20) electronic database—the primary RFP electronic dose record—has substantial gaps, particularly in the earlier years of plant operation, SC&A undertook sampling of both this database and raw dose data in the claimant files to ascertain whether there is a sufficient and valid basis for the derivation and use of the coworker models. The "data completeness" issue became particularly important as questions emerged regarding the extent and significance of gaps determined to exist in external dose records for 1969–1970 in RFP nonplutonium facilities and for neutron doses derived for the 1950s.

The presence of so-called high-fired or "Type Super S" plutonium oxide at Rocky Flats and its implications for the feasibility of dose reconstruction were a central issue in the SEC petition. The petitioners saw the relative insolubility of this form of plutonium and its prevalence at the plant, resulting from various fires and high-temperature processes, as fundamental impediments to sufficiently perform an accurate dose reconstruction. In response, NIOSH developed an approach whereby lung doses are calculated using the model outlined in *Human Respiratory Tract Model for Radiological Protection* (International Commission on Radiological Protection Publication 66 (ICRP 1994), together with empirically observed correction factors as described in ORAUT-OTIB-0049 (ORAUT 2007b), and its complementary documents (validated, in part, by autopsy data from the United States Transuranium and Uranium Registries (USTUR)). SC&A validated the NIOSH approach by reviewing the proposed methodology for its scientific validity and claimant-favorable bounding assumptions, as well as evaluating the representativeness of the model cases that form the basis of ORAUT-OTIB-0049. SC&A's evaluation concluded that the empirical approach and its correction factors are claimant favorable, as they typically overpredict actual organ depositions of plutonium, and therefore, this issue does not have SEC implications.

To validate the model cases that are the basis for the empirical derivation of ORAUT-OTIB-0049, SC&A reviewed individual radiation files containing lung and urinalysis data for 25 workers involved in the 1965 fire, the HIS-20 electronic database, data available in the claimant

files of six affected workers, and USTUR data from RFP workers, and compared them with the lung and urinalysis data used in the design cases. That review shows that the model cases selected are conservative and serve to bound doses from the workers involved in the 1965 fire. Following up on NIOSH's indication in working group discussions of its intent to apply ORAUT-OTIB-0049 to all workers with plutonium intakes, SC&A also conducted confirmatory analyses based on historic plutonium oxide exposure scenarios at the plant. With these analyses, SC&A affirms that the ORAUT-OTIB-0049 model bounds early workers who may have been exposed to high-fired plutonium oxide before lung counting was available taking into consideration the qualifying issues discussed in this report.

Many of the working group discussions focused on the adequacy of the radiation dose data and the feasibility of its use in coworker dose models that can bridge gaps in individual claimant dose records or estimate dose for unmonitored workers. Other deliberations focused on data integrity and reliability. If the radiation dose records used in individual dose reconstruction or in the development of coworker models are substantially incomplete, contain pervasive discrepancies, or show evidence of prevalent fraud, it would be infeasible "to estimate with sufficient accuracy the radiation dose that the class received," a key criterion for SEC approval under 42 CFR Part 83.

Since data integrity and reliability are fundamental to dose reconstruction under EEOICPA and for evaluations of SEC petitions, SC&A conducted extensive document searches that included field and urinalysis logbooks and dosimetry processing sheets, as well as in depth review of affidavits, and operational procedures to ascertain whether the integrity of RFP dosimetry data was compromised. SC&A was able to validate some of the comments provided by workers in the petition, during public meetings, or during interviews. Despite that, SC&A did not find conclusive documented evidence[1] of a systemic problem with RFP dose records. The review, however, raised some concerns about the validity of the dose records for workers working high dose rate jobs, in particular. No documentation was found pointing to a deliberate falsification or errant recordkeeping (other than for 1969–1970, as discussed later).

With NIOSH relying on the original DOE-provided individual dose records for dose reconstruction (given acknowledged gaps in the HIS-20 database), SC&A proceeded to evaluate the completeness of those claimant files in a manner that would validate their completeness. This validation process found evidence of substantial gaps in the external and internal dose data for some periods and for some types of workers. NIOSH has not yet demonstrated its ability to fill these gaps for external dose in a manner that would produce bounding dose estimates that would satisfy the requirements of 42 CFR Part 83. There are also substantial gaps in internal

[1] It should be noted that the inconclusiveness cited here stems from an investigation process directed at the "pervasiveness" or "systemic" nature of identified data or recordkeeping discrepancies. While the integrity of dose data is fundamental to reconstructing doses with "sufficient accuracy," it was SC&A's view, in consultation with the working group, that deficiencies in data integrity or completeness only rise to SEC significance when they can be shown to be reflective of the data or recordkeeping as a whole (a "pattern" of occurrence), as opposed to isolated and unrelated instances, and can be corroborated. In some cases, the results of the sampling itself have proven inconclusive or the level of corroborating evidence was not judged to be sufficient as a basis for a revised SEC conclusion.

dose. However, workers with high cumulative doses do not appear to have full-year gaps; hence, it appears that NIOSH should be able to bound internal dose with a coworker model, provided that it uses the available data with due attention to job types.

A related issue involves external dose records for 1969–1970. Based on petitioner comments regarding improper assignment of zeros in worker dose records, SC&A examined annual dose records, year-by-year, and found that for some years, a higher proportion of zeros was recorded, an apparent anomaly most prominent for the 1969–1970 period. When SC&A raised this issue with NIOSH, a number of possible explanations were explored. An explanation involving a change in badging policy was identified as the most credible main explanation. Documentation exists confirming that RFP decided, in early 1969, prior to the fire, not to read quarterly badges in nonplutonium areas for workers with low exposure potential (apparently accepting that badges could be read, as needed, if any exposure incidents occurred). The unread badges were discarded after a few weeks. Though there is circumstantial evidence that the policy had ended by the close of 1970, there remains some uncertainty about when this policy ended or whether this practice (regardless of a sanctioning policy) may have predated or postdated 1969 and 1970, respectively. SC&A has concluded that this practice has significantly compromised the integrity of at least a portion of the 1969 and 1970 external dose record. SC&A concurs with NIOSH's position at a recent Advisory Board working group meeting, during which an agency official characterized the zeros entered for the unread badges as "bad data" and suggested that affected workers be considered "unmonitored" with no recorded dose for the time periods involved (ABRWH 2007). As with the broader data completeness issue, SC&A concludes that an effort needs to be made by NIOSH to amend or construct coworker models to adequately bound the dose for workers affected by these gaps in their dosimetry records.

SC&A examined both the *Internal Dosimetry Coworker Data for Rocky Flats Environmental Technology Site*, ORAUT-OTIB-0038 (Arno et al. 2006), and *External Coworker Dosimetry Data for the Rocky Flats Plant*, ORAUT-OTIB-0058 (Smith 2006), the respective coworker models for internal and external dose assessment. The review addressed the overall technical approach used, including the respective coworker models' scientific validity and degree of conservatism as it relates to the historic dose distribution being addressed. SC&A acknowledges the NIOSH finding that most workers at RFP have individual monitoring records in the post-1960 period, and therefore, relatively few of these workers will require the use of the coworker data to reconstruct their dose. However, some additional work to establish the sufficiency of data to support the coworker models remain, notably from the standpoint of external dose estimation for unmonitored nonplutonium workers in the 1950s.

For the internal dose coworker model ORAUT-OTIB-0038, SC&A supports NIOSH's conceptual approach, but is concerned that the lognormal distribution depicting the monitoring results truncates actual high-end results recorded, and that the 50th percentile derived from the lognormal distribution (applied in practice) would misrepresent the excretion rates at RFP. Given that the uncertainties of historic worker excretion rates are large, as shown by various analyses presented by both NIOSH and SC&A (see Section 6.0), consideration needs to be given to applying a more conservative distribution or adopting a more inclusive dose bounding

approach in the coworker model to assure that internal doses for unmonitored workers can be accomplished with sufficient accuracy.

For the external dose coworker model, SC&A likewise supports NIOSH's conceptual approach, but is concerned that the recommended neutron dose values in ORAUT-OTIB-0058 (Table 7-2) do not sufficiently represent and/or bound the actual doses received by workers during 1952–1958. For example, if the ORAUT-OTIB-0058 derived neutron dose for 1957 of 0.086 rem per year (at the 50th percentile level) is compared to the dose for the appropriate time period of badging for each claimant in a NIOSH provided database, *RFP NP Ratios using NDRP Data for 53–58* (NIOSH 2007d), the recommended neutron dose is much less than the recorded neutron dose (an average of around 80% less). This is apparently a typical result when comparing coworker doses to the recorded doses. NIOSH has stated that the few workers who were monitored for neutrons in the 1952 to 1958 period (only 20 workers were issued monitoring devices for most of the period) were the ones with the greatest exposure potential. However, the evidence in this regard is not conclusive. NIOSH has stated that despite extensive efforts, the NDRP was not able to validate the model on which neutron doses were assigned to those at risk of such exposure in the 1952 to 1958 period by any measured field data. No documentation or data have been located to validate or provide quantitative support for the application of the 1959 data to the 1952–1958 period. Since the NDRP made extensive efforts to perform such a validation, and failed to find data, it appears that none exist. As a result, the 1952-1958 assigned doses to workers at risk of neutron exposure are based on an unvalidated model.

While neither NIOSH's original site profile nor SEC evaluation addressed worker exposures in the decontamination and decommissioning (D&D) era, SC&A found the extension of ORAUT-OTIB-0038 [via *Rocky Flats Internal Dosimetry Coworker Extension*, ORAUT-OTIB-0014 (Allen 2006b)] for unmonitored D&D workers to be acceptable (with the same proviso above of applying a more conservative distribution or adopting a more inclusive dose bounding approach). This conclusion is based on analyses conducted by NIOSH showing that the dose distributions for top-tier contractors and lower tier D&D subcontractors compare favorably, thereby permitting a common coworker model to be applied.

In its evaluation of both the site profile and SEC characterizations, SC&A focused on whether all significant sources of occupational radiation are adequately addressed to assure that claimants are given credit for potential exposures they may have received. In its review of the RFP site profile, SC&A questioned the lack of characterization given potential exposures related to Th-232, Th-228, and other radionuclides (including Np-237, Cm-244, Am-241, and tritium) involved in historic secondary operations at RFP. SC&A's assessment confirms NIOSH's claim that individual dose records contained data that would allow dose reconstruction for other radionuclides including Np-237, Cm-244, Am-241, and tritium. While the evidence is more equivocal for thorium, SC&A concludes that no information has been found to contradict NIOSH's source term characterizations based on available materials balance records and other documentation, and therefore, no SEC issue has been established with respect to the source term.

With regard to the actual performance of thorium dose estimations, however, SC&A questions NIOSH's proposed use of *Air Sampling in the Workplace*, NUREG-1400 (NRC 1993), a generic

Nuclear Regulatory Commission guidance document designed to determine the need for workplace air monitoring. NIOSH's analysis has established the plausibility of using NUREG-1400 to provide a general view of average working conditions. However, SC&A has fundamental concerns with the proposed use of NUREG-1400 to reconstruct most thorium exposures at Rocky Flats. SC&A finds that NIOSH has not demonstrated through its example NUREG-1400 calculations that these estimates are uniformly bounding, and therefore, it would not meet the criteria of 42 CFR 83. While alternative approaches have been discussed within the working group, NIOSH continues to believe NUREG-1400 is valid for application under the specific conditions applying to RFP. As a result, the thorium dose reconstruction matter remains open as an SEC issue.

OVERALL CONCLUSION

In general, SC&A's issues regarding NIOSH's SEC evaluation for RFP concern the latter's ability to validate or demonstrate that it can apply its stated methods, approaches, and coworker models to enable "dose reconstruction with sufficient accuracy," as prescribed by 42 CFR Part 83. While SC&A agrees that these methods and approaches appear to be scientifically valid in concept, the Advisory Board's guidelines for SEC review requires "demonstration that it is feasible to reconstruct individual doses with sufficient accuracy." There are a number of instances where significant concerns remain regarding the adequacy and completeness of data to warrant demonstration by NIOSH that it can reconstruct individual doses for all members of the class with sufficient accuracy. These SEC "conditional" issues have been summarized above, detailed in the report that follows, and can be highlighted, as follows:

1. Where NDRP dose data is used in support of the external coworker dose model of ORAUT-OTIB-0058, SC&A finds that there has been no quantitative validation of neutron dose assignments to workers with neutron exposure potential between 1952 and 1958. The data for such validation do not appear to exist.

2. NIOSH has not developed approaches for bounding thorium-related doses that have been demonstrated as feasible and bounding. SC&A has pointed to likely avenues for developing such estimates, but these approaches have been rejected by NIOSH for use at RFP. As a result, the issue remains unresolved.

3. NIOSH has not demonstrated that its existing coworker model (or an alternative one) provides a bounding dose approach that would meet the criteria of 42 CFR 83, for nonplutonium workers in the 1950s.

4. The validity of the use of 1969 and 1970 external dose data for dose reconstruction is conditional on treating the gaps in the data (and the zeros used to fill them) as periods of unmonitored exposure.

5. The use of the internal coworker model as it has been implemented in practice by NIOSH does not adequately reflect actual higher-end exposures experienced by monitored

workers at RFP. NIOSH needs to demonstrate that its model defines a valid upper bound based on an appropriately conservative dose distribution.

It should be noted that these conclusions are based on information and analyses available to SC&A up through mid-March 2007. Resolution or near-resolution of a number of potential SEC issues were achieved by that time, but some require additional validation or demonstration by NIOSH for confirmatory reasons, as noted above and in this report, and as discussed with NIOSH in Advisory Board working group meetings. A supplement to this report is planned to address these remaining questions, in particular the neutron dose estimation issue.

1.0 SUMMARY OF PRINCIPAL CONCLUSIONS

The following are the principal conclusions S. Cohen and Associates (SC&A) has drawn from its review of the National Institute for Occupational Safety and Health (NIOSH) evaluation of Special Exposure Cohort (SEC) Petition 00030 (NIOSH 2006a).

(1) ***SC&A conclusion regarding the feasibility of dose reconstruction for high-fired plutonium oxide:*** Based on its review of ORAUT-OTIB-0049, and relevant cases that are the basis of the NIOSH approach, SC&A concludes that the use of the empirical model and its correction factors is plausible for estimating annual dose to the lung, systemic organs, gastrointestinal (GI) tract organs and tissues, and extra-thoracic regions for intakes of Pu-239 that are retained in the lung longer than predicted by the normal absorption Type S model. The SC&A evaluation found the empirical approach and its correction factors to be claimant favorable, as they typically overpredict organ depositions. SC&A based its conclusion on a review of methods used by NIOSH to derive the lung dose adjustment factors from in vivo bioassay results and from urine results, as well as the adjustment factors for systemic organs, GI tract, and the extra-thoracic region. SC&A also reviewed the autopsy results, the lung count data, and the urinary excretion data for a representative number of Rocky Flats cases. In addition, SC&A compared the NIOSH approach with a model recently proposed in the literature for exposures to high-fired plutonium oxides at Mayak Production Association, a plutonium production facility in the former Soviet Union.

Based on SC&A's review of all 25 workers involved in the 1965 fire, SC&A concludes that the model cases chosen by NIOSH as a basis for ORAUT-OTIB-0049 are sufficiently conservative for broad use. SC&A also concludes that, when used properly, ORAUT-OTIB-0049, together with ORAUT-OTIB-0038, and a minimum detectable activity (MDA) that includes some extreme conditions, can be applied to specific exposure scenarios at Rocky Flats Plant (RFP) in a claimant-favorable way.

(2) ***SC&A conclusions regarding sufficiency and completeness of external dose data to support dose reconstruction with sufficient accuracy:*** SC&A has analyzed the issue of completeness of dosimetry data in U.S. Department of Energy (DOE) files, which NIOSH views as the primary basis for dose reconstruction for individual claimants. This included a random sample of 32 claimant files and a selected sample of 20 files of claimants who were assessed by Rocky Flats in the 1990s to have high cumulative exposure. SC&A's overall conclusions for the period 1951–1992 (except 1969) are as follows:

(a) There are substantial gaps in external dose data for the 1950s. The investigation of the high cumulative exposure cases indicates that these gaps are likely related to work in what was then called Plant B at RFP and some other areas not associated with plutonium processing facilities.

(b) Extensive badge data exist for Building 44, where the depleted uranium foundry was located. NIOSH should either show that foundry workers, or other workers who may have been at risk of high shallow dose, were routinely badged, or that sufficient data are available for this job type to fill any existing gaps in dose data.

(c) For Plant B (mainly Building 81) workers, NIOSH has not established that backwards extrapolation from the early 1960s into the 1950s, when there are almost no external dosimetry data, provides a bounding dose approach. A suitable approach using appropriate data, such as area monitoring badge data and dust data, remains to be developed for validating the backwards extrapolation.

(d) There are large gaps in internal dose data, notably for the 1964–1992 period, during which almost three-fourths of the workers had gaps of at least 1 year in internal dose measurements. About one-third of the cumulative years of employment had no measurements in the 1964–1992 period. These observations relate to the random sample.

(e) The bioassay data for the highly exposed workers have essentially no gaps for full years. Since the internal dose data for highly exposed workers do not show annual gaps in any period to 1992, it is likely that one or more suitable coworker models designed to appropriately reflect job types and periods of employment can fill the gaps in internal dose (see Section 6.0 on internal dose coworker model).

(f) SC&A has evaluated NIOSH's claim that the dose reconstructions of almost all of the claimants from among the 52 evaluated suffice to demonstrate its ability to do dose reconstruction with sufficient accuracy under Title 42, Part 83, of the *Code of Federal Regulations* (42 CFR Part 83), *Procedure for Designating Classes of Employees as Members of a Special Exposure Cohort Under the Energy Employees Occupational Illness Compensation Program Act of 2000*. This regulation provides that NIOSH must establish "that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class..." SC&A has concluded that the completion of these dose reconstructions itself does not demonstrate that "sufficient information" exists as it relates to 42 CFR Part 83 for members of the proposed class.

Rocky Flats has extensive dosimetry data, but there are also gaps in the data for some periods and some types of workers. NIOSH has not demonstrated its ability to fill existing data gaps for external dose in a manner that would produce bounding dose estimates that would satisfy the requirements of 42 CFR Part 83. SC&A found that in the one instance among the 50 dose reconstructions where NIOSH used the external dose coworker model to fill an external dose data gap for a full year, the results did not demonstrate NIOSH's ability to bound the doses in the areas where gaps have been revealed in this evaluation. However, the availability of data means that there may be approaches to make bounding dose estimates. NIOSH should either develop these

approaches or demonstrate that the existing coworker model is bounding for the specific categories of workers who have gaps in their external dose records.

(3) ***SC&A conclusions regarding sufficiency of neutron monitoring data for 1952–1958 to support dose reconstruction with sufficient accuracy:*** SC&A agrees with NIOSH that there is insufficient neutron monitoring data from 1952–1958 to create a reliable coworker database for use in assigning neutron doses to unmonitored workers during that period. Some 1952–1958 neutron dose data with individual dose identifiers (requested by SC&A in mid-2006), which very recently became available, allow several preliminary benchmark comparisons to be made. These comparisons consisted of comparing the measured neutron-to-proton (n/p) values to those in Table 11.1 of the Neutron Dose Reconstruction Project (NDRP) Report and measured neutron doses to those contained in Table 7-2 of ORAUT-OTIB-0058 (which were derived by using an n/p value of 1.2 from Table 11.1 of the NDRP Report (ORISE 2005)). In its initial investigation, SC&A found that the proposed coworker neutron dose was less than the measured neutron dose 25 out of 25 times at the 50th percentile and 6 out of 25 times at the 95th percentile level. The results of these comparisons indicate that the neutron dose distribution function for the early monitored workers (who had a high potential for neutron exposure) is not the same as the neutron dose distribution function derived from coworker's data used to construct the tables in OTIB-0058. Page 24 of the NDRP states "The N:G building ratios were determined starting in 1959. For the preceding years (1952–1958), the values for 1959 were used without modification, since no other information was available to justify modifying the values." According to NIOSH (NIOSH-SC&A conference call, March 28, 2007), no documentation and/or data has been located that will allow for the direct comparison of the neutron doses received during 1952-1958 to the doses that were assigned by the NDRP or will be assigned using the coworker data in OTIB-0058.

This means that a validation of the coworker model cannot be performed for the 1952-1958 period. NIOSH has stated that the monitored workers in the 1952-1958 period were those with the greatest potential for neutron exposure. The evidence for this assertion is not conclusive. For 1953, for example, the largest doses among the workers in the NDRP were those for monitored workers, providing evidence for the NIOSH assertion. But the contrary was true for some other years (especially in 1954, 1955, and 1956), when the highest doses were those assigned to unmonitored workers as part of the NDRP neutron dose reconstruction. These high-end assigned doses included workers in Building 71, where there was no neutron monitoring until 1957. This provides some evidence that at least some of the workers at risk of neutron exposure who were not monitored may have had higher exposure potential than those who were, if the model used to assign dose by the NDRP is correct.

At this time, it is not possible to arrive at a definitive conclusion regarding the sufficiency of neutron data to bound dose for unmonitored workers who had the potential for neutron exposure in the 1952-1958 period. This may be difficult in the absence of some method to validate whether the assigned neutron doses are, in fact, bounding for unmonitored workers with a potential for neutron exposure.

SC&A is currently investigating the data and methods used in the NDRP Report to assign neutron doses during the period 1952–1958. A supplement to this report will be issued before the next Advisory Board meeting in early May 2007.

(4) ***SC&A conclusion regarding the reliability of dose data to be used by NIOSH in dose reconstruction:*** SC&A, in its evaluation of available records (e.g., safety concerns, field and urinalysis logbooks, dosimetry processing information, and technical reports and procedures), found no conclusive evidence of systemic discrepancies or fraudulent records. The evaluation, however, raised concerns about the validity of the dose records for specific workers working high dose rate jobs, in particular.

SC&A's conclusion is founded on varied and extensive means of validation: (1) review of 49 safety concerns directly relevant to radiation protection and dosimetry; (2) review of over 200 urinalysis and field radiological control logbooks, (3) evaluation of data integrity examples, (4) investigations into dosimetry practices; and (5) investigations into instances of records destruction.

Safety concerns: While these safety concerns do not directly address potential falsification of records, a number of interviewed petitioners had expressed a lack of confidence in the monitoring program as far back as 1971. SC&A reviewed NIOSH's assessment of 49 selected safety concerns from among 4,946 dating from 1970–2004. SC&A concurs with NIOSH that no documented evidence of a systemic problem with radiation dose data was identified in the safety concerns reviewed that would necessarily preclude sufficient accuracy to dose reconstruction.

External dosimetry procedures and investigations: SC&A conducted an evaluation of how doses were assigned when dosimeters or dosimeter components were lost or otherwise compromised. This evaluation was conducted because of the frequent mention in the petition of blackened film, the presence of the notations of "no data available" in the records, the erroneous dosimetry processing, and dosimeter contamination. NIOSH and other site experts have indicated that there was redundancy in the badge that would mitigate this situation. SC&A concurs that, in some instances, this would allow RFP to assign an external dose although portions of the badge were compromised. This redundancy did not exist when the entire dosimeter was compromised or when the site used film badges. SC&A only had informal assurances from RFP radiological control staff that dosimetry investigations were completed and questionnaires filled out. SC&A could find no documentation supporting the fact that these investigations were completed regularly prior to the mid-1980s and doses were assigned based on sound methodology. The existence of positive values would indicate that zeros were not the only doses assigned in instances where dosimeter problems were identified. This preliminary assessment indicates that RFP staff did not appropriately document investigations and appropriate dosimetry investigations may not have been conducted. Accordingly, SC&A was not able to verify the resulting data.

Data integrity examples: SC&A reviewed the NIOSH assessment of 41 examples from affidavits for the SEC petition, Advisory Board meeting comments from April 26, 2006 and April 27, 2006, Advisory Board working group meetings, and discussions with petitioners. SC&A found no documentation pointing to deliberate falsification or errant recordkeeping, despite the numerous petitioners indicating that this had been the case. SC&A was able to validate some of the critical comments made by workers such as the disparity between field exposure conditions and dosimetry data, the frequent occurrence of incidents and fires, and inconsistencies in monitoring programs. During the review, questions were raised about the validity of the dose records for workers performing high dose rate jobs, in particular. Several references to inadequate quality assurance in the dosimetry program were identified throughout claimant files.

Logbook evaluation: SC&A concurs with NIOSH's conclusions that the comparison of urinalysis and field logbook data with individual health physics files demonstrates no indication of systemic discrepancies. Both SC&A and NIOSH had greater than 90% agreement between data in urinalysis and field logbooks, and data in health physics files for urinalysis and dosimetry data. As demonstrated by other SC&A analyses in this report, significant gaps were identified in Health Physics Information System 20 (HIS-20) external dosimetry and urinalysis data, including positive results. SC&A observed that health physics files were incomplete relating to dosimetry investigations, bioassay for radionuclides other than plutonium and uranium, and incident reports. Given concerns over the initial representativeness of logbook sampling, additional reviews were conducted by SC&A for selected time periods and facilities.

Destruction of records: The one particular records destruction example presented (T-690 trailer records) by a former RFP worker was inconclusive; however, other documentation indicated that there was a recommendation to discard dosimeter film from individuals working outside the plutonium areas. Further investigation into whether this did, in fact, occur should be considered by NIOSH as this film was the only legitimate source of dose information for many of these claims.

(5) ***SC&A conclusion regarding the internal dose contribution from Th-232 and other secondary radionuclides:*** In view of the availability of bioassay data, SC&A concurs with NIOSH that estimation of Cm-244, Np-237, and tritium intakes is not an SEC issue. Am-241 does not appear to present an SEC issue given the extensive data available even in the earlier years (1963 onward), as well as lung counting data, whose results are likely to be claimant favorable and would serve to supplement bioassay data, if needed. The declassified materials balance data provided recently by NIOSH, as well as other information, broadly addressed SC&A's concerns about the completeness of the thorium source term data for RFP early operational uses.

Specific conclusions regarding the thorium source term are as follows:

(a) There is no information in available materials balance or other data that contradicts NIOSH's conclusions about thorium processing at Rocky Flats. The material balance

sheets are, taken as a whole, broadly consistent with NIOSH's assumptions about the thorium source term.

(b) SC&A agrees with NIOSH that the maximum amount of thorium at Rocky Flats was ~250 kilograms.

(c) Attribution to Normal Operating Losses was highly non-uniform. Nearly half the cumulative losses up to 1976 occurred in just two years, fiscal year (FY) 1964 and FY 1967. It is noteworthy that neither was the year of the largest processing—the ingot canning and rolling year—1960. The available data are insufficient to establish whether there was much more processing than usual in FY 1964 and FY 1967 or whether the losses recorded in those years actually occurred earlier.

(d) A difference of interpretation remains between NIOSH and SC&A regarding the magnitude and nature of the magnesium-thorium alloy source term persists due to contradictory interview statements and lack of documentation to resolve the large differences implicit in the statements made by site experts from both the Dow Madison and RFP sites. However, subsequent followup with RFP petitioners and former RFP workers produced no corroborating information to substantiate Dow Madison shipments of magnesium-thorium alloy to Rocky Flats, nor did investigations find any further information about its applications there.

In terms of dose estimation methods, NIOSH's analysis has established the plausibility of using *Air Sampling in the Workplace*, NUREG-1400 (U.S. Nuclear Regulatory Commission (NRC) 1993), to provide a general view of average working conditions. However, notwithstanding the availability of alternative methods, the examples provided to date have not validated the use of NUREG-1400 in estimating a plausible upper-bound dose for individual workers at Rocky Flats that would meet the criteria of 42 CFR Part 83. While alternative approaches have been discussed within the working group, NIOSH continues to believe NUREG-1400 is valid for application under the specific conditions applying to Rocky Flats. As a result, the thorium dose reconstruction matter remains open as an SEC issue.

(6) ***SC&A conclusion regarding unread badge data in 1969–1970:*** Based on their analyses of the problem, SC&A and NIOSH concur that there are gaps in the 1969–1970 external dosimetry data for some workers. A significant part of the problem arises from the policy of not reading quarterly badges (with some possible exceptions) instituted in 1969. The termination date for the practice has not been documented, and it likely continued into 1970.

SC&A has concluded that the practices discussed above significantly compromised the integrity of at least a portion of the 1969 and 1970 dose record. During the March 7, 2007, Advisory Board working group meeting, a NIOSH official characterized the zeros entered for the unread badges as "bad data" and suggested that affected workers be

considered "unmonitored" with no recorded dose for the time periods involved (ABRWH 2007). SC&A concurs with this assessment.

There are indications that the policy of not reading issued badges had stopped by the end of 1970. However, NIOSH cited the nonissuance of badges to some prime contractor employees as an explanation for the case of the secretary who had blanks in the dosimetry record from 1963 to 1973 (inclusive). An investigation is needed to determine whether badges were not issued to workers who were assessed to have low exposure potential or whether they were issued and not read as a matter of informal policy (which was then formalized in the first quarter of 1969). In either case, the dose reconstruction for workers with gaps outside of 1969 and 1970 should take into account that the gaps cannot automatically be treated as being equivalent to missed dose (i.e., a badge reading below the limit of detection).

Based on SC&A's review, it appears possible to construct coworker models to adequately bound the external dose for workers affected by 1969-1970 gaps in their dosimetry records. The existing coworker model must be demonstrated to be bounding for the specific times and working conditions involved. Since the practice of not reading badges in 1969 and 1970 was carried out primarily for a worker population similar to the one that was not badged earlier, it should be possible to develop appropriate methods to fill the gaps. With respect to the zero entries made to replace gaps, SC&A recommends that all zeros entered when badges were not read be dropped from the data record and the gaps be identified as such.

(7) ***SC&A conclusions regarding internal dose issues in the coworker model:*** SC&A examined ORAUT-OTIB-0038 (Arno et al. 2006), the coworker model for internal dose assessment, in terms of its conceptual approach, including the overall technical approach used, scientific validity, and degree of conservatism. SC&A accepts NIOSH's position that it is possible to derive a surrogate exposure model for the unmonitored workers based on the distribution of internal doses received by the monitored workers at RFP. However, the use of a model based on the 50th percentile of the excretion rates of the workers (as used in practice), in the way it was derived by NIOSH in the model, may misrepresent the higher exposures experienced by unmonitored workers at RFP. The uncertainties related to a model based on the 50th percentile excretion rates of the workers are large, and as a consequence, dose reconstruction cannot be accomplished with sufficient accuracy.

The ORAUT-OTIB-0038 intake model was derived based on two approaches: a lognormal fit to the bioassay data grouped by year or quarter of a year, and an IMBA intake fit to the 50th percentile excretion rate from the lognormal distributions of several years together. The intake rates derived in ORAUT-OTIB-0038 carry uncertainties related to the following:

(a) The large discrepancies between the high real results and the ones generated by the lognormal curves. The lognormal distribution misrepresents the RFP high-end results

from workers that were contaminated routinely in the course of their work, even after NIOSH removal of the high results from incidents and other events from the distribution.

(b) The 50th percentile, used to derive the intake rates, corresponds to very low excretion rates and depends on the approach NIOSH uses to account for the zero values and on uncertainties related to the MDA values. NIOSH has not discussed or resolved the uncertainties related to the MDA values and their relation to the reporting levels and to the registered bioassay monitoring values.

(8) ***SC&A conclusions regarding adequacy of internal monitoring to support dose reconstruction with sufficient accuracy:*** The petition questions the absence of lung counting capabilities in 1952–1964 and the contention that they were "seldom used" from 1964–1968 (USWA 2005). NIOSH concludes in its evaluation report that "the lack of routine lung counting prior to the 1960s does not preclude dose reconstruction because urinalysis and fecal sampling results are available" (NIOSH 2006a). While NIOSH does not provide much detailed substantiation in the evaluation report to support this conclusion, SC&A agrees that RFP internal doses can be reconstructed using urinalysis and fecal sample results and using claimant-favorable assumptions to complement limited information on exposure scenarios. SC&A reviewed the issue of exposures to fire-related plutonium oxides in the absence of lung counting, and with very low or below MDA excretion results. SC&A concludes that dose reconstruction can be accomplished by the simultaneous use of ORAUT-OTIB-0049, the intake model from ORAUT-OTIB-0038 based on a percentile distribution equal to or higher than the 95th percentile, the missed dose concept using an MDA based on the recovery extreme condition, and the assumption of continuous exposure between two measurements within a limited period of time, no longer than 1 year. (Attachment 3, *Evaluation of Application to Specific RFP cases, Including Unmonitored Workers, prior to the Introduction of In-Vivo Counting*, discusses this last issue in detail.)

(9) ***SC&A conclusions regarding dose estimation for RFP decontamination and decommissioning:*** SC&A concurs with NIOSH's conclusion that it is able to estimate doses with sufficient accuracy for the decontamination and decommissioning (D&D) era of plant operations based on its favorable comparison of termination bioassay data between "top-tier" operating contractors and identified D&D subcontractors. SC&A accepts the concept of applying OCAS-TIB-0014 (Olsen 2006) as an extension of ORAUT-OTIB-0038 for worker populations in the D&D era. However, as noted previously, SC&A finds that the use of a model based on the 50th percentile of the excretion rates of the workers would misrepresent the higher exposures experienced by unmonitored subcontractors at RFP. SC&A supports the use of intake models based on a percentile equal to or higher than the 95th. SC&A also finds OCAS-TIB-0014 incomplete because it does not address in-vivo counting results and the relatively large uncertainties associated with the calculation of doses to the lung from urine data, which are compounded by the complexities introduced by the different types of material encountered in D&D activities producing different urinary excretion patterns. However,

SC&A considers these latter two issues to be "site profile" in nature, i.e., not precluding dose reconstruction with sufficient accuracy, but bearing on the relative claimant favorability or technical correctness.

(10) ***SC&A conclusions regarding the external coworker model:*** ORAUT-OTIB-0058 generally provides reasonable dose reconstruction recommendations for assigning beta and photon doses to unmonitored, or under-monitored, workers at the RFP. General inadequacies or inconsistencies identified are "site profile" in nature, i.e., not bearing on dose reconstruction with sufficient accuracy, with two notable exceptions. One key remaining concern is that the resulting neutron doses from the data contained in Table 7-2 are sometimes excessively low and inconsistent with those given in other RFP documents and data. The average n/p values used to derive Tables 7-1 and 7-2 is 0.85, whereas the NDRP average n/p value is around 2; n/p values from 1972 thermoluminescent dosimeter (TLD) data average around 1.2, and n/p values from 1977–2000 TLD readings average 0.42. Using ORAUT-OTIB-0058 in its present form could result in some workers being assigned neutron doses that are significantly lower than, and not representative of, the doses that were actually received. This is especially true for the period when NTP/NTA film was used (during which neutron dosimetry data are more likely to be missing) and could create SEC issues unless resolved. The other issue relates to validating the existing external coworker model as bounding for workers in nonplutonium areas in the 1950s or, in the alternative, developing specific coworker approaches for those portions of the class.

2.0 BACKGROUND AND INTRODUCTION

2.1 REVIEW PURPOSE

Under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) and Federal regulations defined in 42 CFR Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program*, the Advisory Board is mandated to conduct an independent review of the methods and procedures used by NIOSH and its contractors for dose reconstruction. As a contractor to the Advisory Board, SC&A has been charged under Task 5 to support the Advisory Board in this effort by independently evaluating the RFP SEC petition review.

On June 16, 2005, the Office of Compensation Analysis and Support (OCAS) qualified SEC Petition SEC-00030. The petitioner's class definition is as follows:

> *all employees of DOE, DOE contractors, or subcontractors (regardless of union membership) who worked at the Rocky Flats Plant (RFP) in Golden, Colorado, from April, 1952, through February, 2005, and who were employed for at least 250 aggregated work days either solely under the employment or in combination with work days within the parameters established for other SEC classes (excluding aggregate work day requirements).*

The purpose of this report is to provide a review of the NIOSH evaluation report dated April 7, 2006, for the RFP SEC Petition (SEC-00030), along with other supporting material provided by NIOSH during the various Advisory Board working group meetings. This supporting material addresses the issues raised in the SEC petition and identified by the working group as within the scope of the focused review of the RFP petition, as authorized by the Advisory Board. Mark Griffon of the Advisory Board chaired the working group, with Advisory Board members Robert Presley, Wanda Munn, and Michael Gibson participating. Working group sessions were supported by staff from NIOSH and its support contractor, Oak Ridge Associated Universities (ORAU), and by the Advisory Board's technical support contractor, SC&A.

The results in this report were developed in a series of such working group sessions, punctuated by issue-specific conference calls and submission of various informal issue papers and analyses. The overall SC&A review process has spanned the period beginning with the SC&A review of the NIOSH site profile for RFP in June 2005 to the present, as detailed in the chronology that follows.

2.2 REVIEW CHRONOLOGY

Key milestones of this review process are as follows:

December 30, 2004: The Board authorized SC&A to review the RFP site profile in accordance with approved SC&A review procedures.

August 31, 2005: NIOSH and the Board issued Task Order 5, creating the contractual vehicle and budget to perform SEC-related investigations.

December 8, 2005: SC&A submitted to NIOSH and the Board its review of the RFP site profile, which consisted of a technical review of ORAUT-TKBS-0011-1 through 0011-6 and supporting technical information bulletins (TIBs).

December 13, 2005: NIOSH published an ORAU Technical Information Bulletin (OTIB) entitled *Use of Rocky Flats Neutron Dose Reconstruction Project Data in Dose Reconstruction* (ORAUT-OTIB-0050, Rev. 00) (Smith 2005b).

December 15, 2005: SC&A submitted to NIOSH a *Draft Issue Resolution Matrix for Findings and Key Observations Contained in the Rocky Flats Plant Site Profile Review*, Rev. 00 (SC&A 2005c).

January 16, 2006: The Board working group issued *Report of the Working Group on Special Exposure Petition Review* as a general framework for reviewing SEC petitions and NIOSH SEC petition evaluation reports.

January 24–26, 2006: A full Board meeting was held in Oak Ridge, Tennessee. The Board requested that SC&A perform a focused review of selected SEC issues related to the RFP SEC petition and that these reviews be appropriately performed under Task Order 5. At that time, the Board asked SC&A to help in defining the initial scope of the focused review.

February 7, 2006: Representatives of the Board, NIOSH, and SC&A held a conference call to discuss the initiation and scope of a working group review of technical issues pertinent to the RFP SEC petition. The working group divided the findings of the SC&A site profile review into five matrix issues with potential SEC implications.

February 24, 2006: NIOSH provided preliminary responses to the RFP issue resolution matrix, plus new items transmitted to NIOSH and the working group by SC&A on February 21, 2006. In this working session, NIOSH reported that the issuance of ORAUT-OTIB-0049 was "imminent" and the report would provide details regarding the empirical use of autopsy data as a means to define an upper-bound dose estimation for high-fired plutonium oxide at RFP. The working group and SC&A received a briefing on this approach. Other NIOSH responses concerned a comment that the site profile had, in fact, adequately addressed how lung counting was calibrated against the Am-241 assay of the plutonium, how the NDRP (ORISE 2005) interpreted Nuclear Track A (NTA) film, and the overall completeness of external dose data for dose reconstruction.

February 27, 2006: The working group met in Boston, Massachusetts, to discuss SEC-related issues for RFP.

March 14, 2006: A full Board conference call was held, which included the discussion of RFP-related issues. NIOSH indicated that it had placed several new documents on the O-drive for Board and SC&A review. These included the following:

- Copy of the Super S approach
- Data for 100+ United States Transuranium and Uranium Registries (USTUR) cases
- Spreadsheets for ORAUT-OTIB-0049

March 21, 2006: NIOSH's written response to SC&A comments addressed issues, such as zero dose entries, chips falling out of TLDs, deliberately false entries, and other data reliability issues. SC&A submitted a memorandum to the working group regarding "Rocky Flats Data Integrity Issues" and provided a first draft of a consolidated list of data integrity issues for RFP, as suggested by the Advisory Board chairman, Dr. Ziemer.

March 24, 2006: NIOSH provided written responses to SC&A comments, addressing issues such as unbadged worker exposure to neutrons, neutron energy calibration for NDRP data, and 1970 neutron dose data.

March 28, 2006: The working group held a meeting to discuss RFP-related SEC issues. The group prepared a special SEC issue resolution matrix and used it to facilitate the discussion of the various issues and identify action items so that NIOSH and SC&A can further evaluate the issues. This matrix supersedes the February 27, 2006, version. During the meeting, NIOSH reported on its efforts to obtain the Job-Exposure Matrix developed by Dr. Ruttenber and discussed its followup on a Defense Nuclear Facilities Safety Board (DNFSB) finding of the use of an "inappropriate" low-energy photon detector correction factor, a number of data reliability concerns, and the technical basis for its empirical model for high-fired plutonium oxide dose estimation.

April 5, 2006: NIOSH updated written responses to SC&A comments addressing issues such as average isotopic assay for Am-241 (with buildup) in plutonium, zero entries in dose records when badges are not returned, chips falling out of TLDs, hair and body oils on TLDs, deliberate false entries, unauthorized work practices, workers not wearing badges in production areas, exposure geometry, missing dose records in areas of high exposure, length of workweek, other radionuclides, and completeness of dosimetry records being provided to NIOSH.

April 5, 2006: SC&A provided a trip report following onsite SC&A interviews of petitioners. The report outlined data reliability concerns and proposed lines of inquiry, including the following:

- Employee safety concerns
- External dosimetry investigation processes and procedures
- Review of field logbooks for information contradictory to dosimetry records
- Destruction of records pertaining to personnel monitoring
- Completeness of records provided for dose reconstruction

April 7, 2006: NIOSH issued the SEC Petition Evaluation Report for SEC-00030, RFP.

April 11, 2006: The working group reissued the updated issue resolution matrix, based on discussions at the March 28, 2006, working group meeting and the April 5, 2006, NIOSH response to comments. This update supersedes the March 28, 2006, matrix.

April 12, 2006: The working group held a conference call to continue the discussion of RFP-related SEC issues. NIOSH provided the following documents for discussion:

- February 27, 2006, Matrix Issues and NIOSH Responses
- *Comparison of RFP HIS-20 and Comprehensive Epidemiologic Data Resource (CEDR) Databases for Coworker Bioassay Assessments* (Lochamy et al. 2006)
- *Follow-up Evaluation of RFP HIS-20 and CEDR Databases for Coworker Bioassay Assessments* (Lochamy 2006)

The working group requested that SC&A develop and submit for consideration specific actions to address remaining RFP data reliability issues raised in the SEC petition for NIOSH and SC&A followup, respectively.

April 19, 2006: SC&A submitted to the Board and NIOSH the report Interim Evaluation of Data Reliability Issues: Needed Document Retrievals and Evaluations.

April 20, 2006: The working group held a conference call, during which it discussed RFP data reliability issues. NIOSH provided the following documents for discussion:

- Status of NIOSH action items
- *Independent Investigation into High-Bioassay Results*, National Response Team, NRT-068-05, October 31, 2005
- Coworker TIBs

From this meeting, a revised issue resolution matrix emerged, which included the following issues and actions:

- SC&A has completed its review of ORAUT-OTIB-0049, *Estimating Lung Doses for Plutonium Strongly Retained in the Lung* (ORAUT 2007b), and will include its conclusions regarding the feasibility of estimating doses due to intakes of so-called "high-fired" plutonium oxide in its evaluation report. The report will include consideration of GI tract doses for Super S plutonium exposures.

- In response to issues raised by SC&A regarding the appropriate adjustments for plutonium isotopic ratios and americium in-growth, NIOSH is to outline its approach for determining internal dose from americium.

- NIOSH made several commitments in response to data reliability issues raised by petitioners, including tracking specific "no data availability" cases and reviewing its dose database to determine whether a systemic problem exists. SC&A provided a draft report, *Interim Evaluation of Data Reliability Issues: Needed Document Retrieval and Evaluation*, dated April 19, 2006 (SC&A 2006c), outlining specific data integrity issues. Specific NIOSH followup actions in response included (1) retrieval and review of safety concern reports identified by SC&A, (2) review of specific cases for 1985–1986, where SC&A identified discrepancies between logbooks and personnel dosimetry records, as well as retrieval of similar logbooks from the film and Harshaw TLD period, and (3) retrieval and review of secondary dosimetry, contamination control, and foreman logbooks to ascertain exposure information useful in validating data reliability.

- NIOSH is reviewing or has reviewed specific data relating to SEC implications of "chips falling out of" TLDs, hair and body oils on TLD chips, deliberately falsified dose record entries, unauthorized work practices, inappropriate subtraction of background, and non-wearing of badges in production areas. On the last issue, NIOSH provided preliminary statistical analysis suggesting that this allegation was not a systemic problem.

April 22, 2006: The working group reissued the updated issue resolution matrix, based on the April 20, 2006, working group conference call. This supersedes the April 11, 2006, matrix.

April 25–27, 2006: The Advisory Board held a meeting in Denver, Colorado, during which it discussed SEC issues for RFP and received public statements regarding data reliability issues at RFP. The discussion raised monitoring of D&D workers as a potential issue; neither the SEC evaluation nor the earlier site profile characterized the adequacy of such monitoring.

May 9, 2006: SC&A provided a transmittal of Attachment 2 of the *Draft Review of the NIOSH Site Profile for the Rocky Flats Plant* (SC&A 2006e).

May 12, 2006: NIOSH published Rev. 00 of ORAUT-OTIB-0058, entitled *External Coworker Dosimetry Data for the Rocky Flats Plant* (Smith 2006).

May 30, 2006: The working group met to discuss the remaining SEC-focused issues for RFP. For discussion, SC&A provided an overall draft assessment of external dosimetry issues, including neutron dose estimation. SC&A also provided an updated summary and status of data reliability actions.

June 14–16, 2006: The Advisory Board held a meeting in Washington, DC, during which it discussed SEC issues for RFP. SC&A provided a special briefing for the Board on its preliminary evaluation of the feasibility of estimating dose for high-fired plutonium oxide, a draft of which SC&A submitted to the Board and NIOSH before the meeting.

July 26, 2006: The working group met in Cincinnati, Ohio, to discuss remaining issues in the RFP SEC evaluation. The group updated the issue resolution matrix based on progress achieved and new issues emerging since the previous matrix. This supersedes the matrix of April 22, 2006. NIOSH provided the following documents for discussion at the meeting:

- Spreadsheets for HAN-1 plutonium in lung and HAN-1 urinalysis measurements
- Kittinger logbook with accompanying notes
- Safety concerns list for RFP (beginning in 1971)
- Super S design case identifiers

The revised issue resolution matrix resulting from the discussions included the following new actions:

- NIOSH to provide identifiers for 25 design-basis cases (cases with highest lung burdens) for estimating internal dose from high-fired plutonium oxide involved in the 1965 fire

- NIOSH to provide HIS-20 database with identifiers (name, social security number, and company)

- With regards to additional baseline characterization information for "other radionuclides" (other than plutonium) handled at RFP, including thorium, uranium, americium, and curium, NIOSH to research the material accounting logs to determine the amounts on site and the locations where the materials would have been used

- NIOSH to review SC&A issues regarding early neutron dose data, including use of n/p ratios from later time periods (1970s) for earlier periods (1950s)

- NIOSH to review and explain potential gaps identified in RFP worker dose records for 1969–1970 and a seemingly high number of zero readings for 1969

- NIOSH to retrieve urinalysis logbooks for comparison to HIS-20 database for purposes of validating reliability of bioassay records

- SC&A to review NIOSH statistical analysis regarding cumulative dose (April 20, 2006, response) as a means to resolve allegation that workers frequently were not wearing badges to show conformance with quarterly dose limits

- NIOSH to provide dosimetry data and further evaluation to resolve issue of potential missed dose for a worker in a high-exposure area, the Stacker Receiver area of Building 371

- SC&A to review NIOSH list of RFP safety concerns for 1970–2000 and determine what additional safety concerns (beyond the 16 already selected) should be retrieved and evaluated for their implications for data reliability

- NIOSH to post retrieved logbooks on the O-drive for working group review; NIOSH to sample from three different types of logs from the 1970s to 2000 for production areas of concern (uranium, production, and decontamination)

- NIOSH to review Radiation Worker II (Rad Worker II) training records and site roster for the D&D time period and compare against HIS-20 to determine if all workers (including subcontractor workers) were in the RFP routine bioassay program

- NIOSH to investigate allegation regarding missing worker exposure records in T-690 trailer through interviews with other workers at the site at that time

August 3, 2006: NIOSH published Rev. 00 of ORAUT-OTIB-0038, entitled *Internal Coworker Dosimetry Data for the Rocky Flats Environmental Technology Site* (Arno et al. 2006).

August 14, 2006: NIOSH and SC&A staff held a conference call to discuss remaining issues surrounding application of historic n/p ratios in dose estimation for the early years.

August 31, 2006: The working group met in Cincinnati, Ohio, to discuss the remaining issues regarding RFP SEC evaluation. Using the July 26 issue resolution matrix, the group discussed the following new actions:

- NIOSH will spot-check back-extrapolation of n/p ratios.

- NIOSH will review benchmarks from 1950s and 1970s for consistency and determine whether other "coworker" models would be appropriate.

- Regarding SC&A issues related to ORAUT-OTIB-0058 (external coworker model), NIOSH agreed to (1) obtain HIS-20 data with identifiers and post on the O-drive; (2) recheck values in Tables 7-1 and 7-2 for 1952–1969 using NDRP data in HIS-20; (3) add descriptive language to ORAUT-OTIB-0050 regarding the bases for assuming that n/p ratios in the 1950s would be consistent with later years; (4) scrutinize NDRP Table 1.1 and provide additional explanation; and (5) spot-check coworker methodology by comparing calculated vs. measured neutron doses for 1952–1959.

- SC&A will review and comment on the NIOSH assessment of RFP data reliability allegations and concerns (e.g., NIOSH's "Data Integrity Examples" compilation).

- NIOSH presented results of the RFP materials inventory review, which focused on "other radionuclides, "how much," what "exposure potential," "who was exposed," and over what "time periods." At the working group's request, NIOSH agreed to schedule discussion of classified information associated with inventory at the upcoming Las Vegas meeting of the Advisory Board.

- SC&A questioned ORAUT-OTIB-0038 (internal coworker model); NIOSH will provide for SC&A review an informal "white paper" outlining the approach taken and technical basis.

- NIOSH will provide comparative analysis for HIS-20 and CEDR databases; the working group raised a question regarding the relative completeness of the two.

- NIOSH provided a briefing regarding the Accident Investigation Report for the 1969 fire; the working group commented that a crosswalk of individual data for those monitored during and following the fire is needed.

- Regarding D&D, NIOSH will provide what was identified as internal self-audits of the RFP bioassay program and procedures governing assignment of bioassays during the D&D era (1993–2005). An action item still stands from the July 26 matrix that called for the identification of subcontractors having Rad Worker II training who would have been subject to routine bioassay and validation if, in fact, routine bioassays had been provided.

September 19–21, 2006: The Advisory Board met in Las Vegas, Nevada, to discuss the status of the remaining SEC issues for RFP. The Board held a separate classified discussion on the results of NIOSH's investigation of RFP materials ledgers for "other radionuclides." For thorium, which had been of particular concern, the Board learned that all components were shipped from Y-12 and were mated at RFP with no significant machining and waste streams. For Th-228 "strikes," three to five individuals were involved, but potential exposure was controlled closely; NIOSH will provide the notes from its interview with an RFP site expert. Other radionuclides addressed included U-236, U-237, Sr-90, curium, tritium, Po-210, and depleted uranium (DU).

September 25, 2006: NIOSH reported on its investigation into the Trailer T690 records issue, as indicated by issue resolution matrix 36. The report provides final conclusions, based on interviews with 32 former RFP workers. While some individuals interviewed recalled records being located at this trailer, none could remember what happened to them.

October 4, 2006: NIOSH responded to SC&A's inquiry regarding whether any quality assurance (QA)/quality control (QC) or third-party reviews were done to validate the NDRP database. The response details the efforts made to provide such assurance at the time.

October 19, 2006: SC&A provided to the working group and NIOSH a "sampling" evaluation it conducted on the claimant file data for 12 former workers selected at random for purposes of reviewing data reliability. Given the results, which show apparently significant gaps in many of the files, SC&A asked that the next working group meeting address the issue of the completeness of claimant files.

October 24, 2006: SC&A responded to previous NIOSH transmittal of D&D documents in terms of the completeness of bioassay data to support dose estimation of D&D era workers. The transmittal indicates that two key findings of the audit documents provided raise concerns over

the completeness of bioassay records, including (1) the lack of a consistent technical basis for characterizing work areas as meeting derived air concentration (DAC) hour requirements for bioassay monitoring and (2) the high proportion of D&D workers who did not submit terminal bioassays.

October 25, 2006: NIOSH provided the notes (unclassified) from an interview with a site expert as followup to classified discussion regarding "other radionuclides" handled historically at RFP.

October 26, 2006: NIOSH provided a report regarding lung counts taken following the 1969 fire.

October 27, 2006: SC&A provided its evaluation of two NIOSH papers in a memorandum report, "Thorium-232 and other 'exotic' radionuclides at Rocky Flats—review of NIOSH papers." These reviews raise concerns regarding how the source term for Th-232 was determined, the application of NUREG-1400 (NRC 1993) for estimating intake, consistency with the way Th-232 dose estimation is performed for other DOE sites, and the need for corroborating references to support claims made for other radionuclides.

October 27, 2006: NIOSH completed its review of Rocky Flats logbooks for purposes of ascertaining data reliability and provided its results on the O-drive for working group review. NIOSH indicated that it "found a 96% rate of agreement between data found in various logbooks, and data found in the workers' radiation files." NIOSH concluded that there is "no evidence of a systematic lack of corroboration between logbooks and the individual worker radiation files which would cast doubt on the integrity of Rocky Flats dosimetry data, nor was there any evidence of inappropriate manipulation of workers' dosimetry results."

October 30, 2006: NIOSH provided its *Summary of Investigations Regarding 1969 Data Gap* (NIOSH 2006m), which addresses 136 claimant files that have been identified as missing data for 1969. Of the 136, 35 had no external dosimetry data at all for 1969 for reasons that could not be readily explained. In its review, NIOSH "tested" a number of hypotheses to explain the gap, including "data having been lost as a result of the 1969 fire, a computer reporting problem, and the possibility that some badges were simply not read." NIOSH concluded that (1) the 1969 data gap is much smaller than originally estimated, (2) the patterns observed in the 1969 dosimetry data are consistent with the administrative decision to not read film badges from employees stationed in nonplutonium areas with low exposure potential, and (3) a computer programming error may have contributed to the lack of detail in the dosimetry data (this was later corrected in cumulative totals).

October 31, 2006: The Advisory Board working group provided an updated issue resolution matrix for the Rocky Flats SEC review. This matrix supersedes the previous one dated July 26, 2006.

November 1, 2006: NIOSH responded to issues raised by SC&A regarding radiation doses and recordkeeping during RFP's D&D era (1993–2005). NIOSH does not concur that "any serious

inadequacies which would affect NIOSH's ability to conduct dose reconstruction with sufficient accuracy during the D&D era have been identified."

November 1, 2006: NIOSH responded to SC&A's memorandum and data spreadsheet questioning data completeness based on a limited sampling (12 claimant cases) of RFP dose records. In its case-by-case review, NIOSH responded that it does "not concur with SC&A's conclusion that a review of these files indicates that 'significant problems may exist in data completeness' for the Rocky Flats records. On the contrary, [NIOSH's] review largely substantiated the completeness and integrity of the records reviewed." NIOSH intends to discuss the response further at the upcoming working group meeting.

November 3, 2006: NIOSH responded to SC&A's comments (submitted on October 27) on NIOSH's written analysis of working group questions surrounding Th-232 and other "exotic" radionuclides at Rocky Flats. In its issue-by-issue response for discussion at the upcoming working group meeting, NIOSH disagreed with SC&A's interpretation of historic operational information regarding thorium, reaffirmed its position regarding the applicability of NUREG-1400 for estimating thorium doses at RFP, and indicated the availability of monitoring data for Np-237 and Cm-244.

November 6, 2006: The Advisory Board working group for RFP SEC review met in Cincinnati, Ohio. The agenda included completeness of data, other radionuclides, D&D workers, logbook analysis, the 1969 data gap, neutron dosimetry issues, Super S, safety concerns, and data integrity issues. Actions stemming from the meeting included the following:

- For "completeness of data": SC&A to draft sampling approach to be used in sampling from all claimant radiation files up to 1993; NIOSH to provide access to all needed claimant files.

- For "other radionuclides": NIOSH to provide "semi-empirical" validation of thorium intake model (bounding intakes estimated using NUREG-1400 approach); "available references" regarding other radionuclide use; and September 6, 2006, Freiberg interview notes. SC&A to further review information regarding neptunium and curium provided by NIOSH.

- For D&D: NIOSH to provide termination bioassay data, with distinction made between prime and subcontractors, and substantiate sufficiency of data to support coworker model development.

- For logbook and 1969 data review: NIOSH to post referenced radiation files for SC&A validation review.

- For neutron dosimetry issues: NIOSH and SC&A to schedule an issue-specific conference call to discuss status and required actions.

- For Super S issue: NIOSH to provide SC&A with access to needed DOE raw data to permit sampling and cross-comparisons of 25 model cases for ORAUT-OTIB-0049.

- For safety concerns and data integrity issues raised in the working group review: SC&A to provide its written evaluation.

November 7, 2006: NIOSH posted monthly progress reports from various RFP departments (e.g., Industrial Hygiene, Bioassay, and Chemistry groups) spanning from about 1954 through about 1971.

November 8, 2006: NIOSH suspended existing unrestricted online access by the Advisory Board and SC&A to its NIOSH-OCAS Computer Tracking System (NOCTS) claimant file due to Privacy Act concerns. In a November 9, 2006, telephone call, Larry Elliott, NIOSH OCAS Director, and John Mauro, SC&A Project Director, discussed a new procedure for gaining access to files placed on the O-drive. In this procedure, SC&A will identify the nature of the data access request, the reason for the request, the people who should have access to the information, and the time period involved. Full SC&A access to NOCTS was restored on November 30, 2006, with provisos for Privacy Act protections via direction from the NIOSH Contract Officer.

November 10, 2006: Mark Griffon, Advisory Board working group chairman, distributed the action items from the November 6, 2006, working group meeting on the RFP SEC review.

November 13, 2006: SC&A notified NIOSH of information provided by a site expert and petitioner for the Dow Madison site in Illinois, who, in public statements before the Advisory Board and in interviews with NIOSH, has raised the possibility of "frequent and regular" shipments of thorium material between Dow Madison and RFP from the 1950s through the 1970s.

November 20, 2006: NIOSH provided transcripts of three interviews, along with a response to specific issues, including the relationship between Dow Madison and Rocky Flats, origin of thorium at Dow Madison, and destination of material produced at Dow Madison. In its conclusions, NIOSH stated the following:

> *[NIOSH] found no documentation of any exchange of materials between the two sites in a search of Rocky Flats records. The Rocky Flats materials balance account records do not support the receipt of truckloads of thorium metal from Dow Madison or anywhere else, as the maximum recorded thorium inventory was 238 kg. We have conducted a pretty extensive search of the Rocky Flats records, and interviewed several former workers, and all indications point to very limited handling of Th at Rocky Flats. We have found no indication of "frequent and regular" rail shipments of thorium to Rocky Flats, and no evidence that "tons" of thorium were ever present at Rocky Flats.*

November 21, 2006: SC&A identified for NIOSH followup an RFP internal paper (author unidentified), entitled *Potential Thorium Intake at RFP*, which describes several quantitative

parameters of potential relevance to the question of the significance of thorium use, including production data, materials accounting, and operating losses. The questions are whether the source documents behind these parameters can be located and whether additional documentation or records exist related to this particular paper.

November 22, 2006: NIOSH provided background on the RFP internal paper identified by SC&A as one written in response to alleged thorium content in offsite livestock; however, no source documents were located containing the quantitative data referenced in the document.

November 27, 2006: SC&A provided an interim draft evaluation of RFP safety concerns for working group review. SC&A concurred with NIOSH's assessment of many of the 49 safety concerns and parts of other concerns. SC&A further indicated that, "Although not providing definitive evidence of a systematic problem with RFP radiation dose data that would necessarily preclude dose reconstruction, some of them do highlight historic instances of poor quality control practices."

December 5, 2006: SC&A and NIOSH/ORAU (with the Advisory Board working group present) held an issue-specific conference call to discuss the status of remaining neutron dosimetry issues. SC&A also interviewed Roger Falk, a NIOSH site expert with extensive radiation program management experience at RFP, about historic dosimetry practices and potential data gaps. The following action items from earlier in the year were reaffirmed as needing a NIOSH response:

- A revised copy of ORAUT-OTIB-0058 to reflect recent changes.
- Microsoft Excel spreadsheets that contain the neutron data and photon data that were used to create Tables 7-1 and 7-2 of ORAUT-OTIB-0058.
- An ORAUT-OTIB-0058 guide that will assist SC&A in deriving the values in Tables 7-1 and 7-2 from the data contained in the Excel spreadsheets.
- In the near future, scanned copies of the supervisor reports will be posted on the O-drive. These reports contain the data for determining the n/p values to be used to separate the neutron and photon doses from the composite doses for 1970–1976.
- The results of 60–65 cases from 1952–1959, where NIOSH compares the final doses derived from using the coworker model to the actual measured doses.

December 6, 2006: SC&A and NIOSH/ORAU (with the Advisory Board working group present) held an issue-specific conference call to discuss the remaining SC&A questions about ORAUT-OTIB-0038, the coworker internal dose estimation approach for RFP. Discussion centered on both the conceptual and technical basis for the TIB, with SC&A expressing concerns regarding the application of the TIB for unmonitored workers at RFP whose recorded exposures may not be adequately addressed, even at the 95% level distribution. NIOSH's position is that this distribution is sufficiently conservative and that SC&A's internal dose spreadsheet for

certain years may have been superseded (this was later established). It was concluded that there did not seem to be any remaining SEC-related issues with ORAUT-OTIB-0038, other than the review of the proposed extension for the D&D era.

December 7, 2006: NIOSH provided the working group and SC&A with its review, *Badging of Personnel at RFP*, to address concerns over data gaps. NIOSH concludes that "Review of dosimetry results from three different available sources is consistent with interpretation of the available [RFP internal] memos, indicating that an effort in 1964 brought a significant number of unmonitored occasional-access personnel into the external dosimetry program and in 1974 an effort to bring remaining miscellaneous personnel into the external dosimetry program was accomplished."

December 8, 2006: NIOSH provided the working group and SC&A with its proposed extension (ORAUT-OTIB-0014) of the existing ORAUT-OTIB-0038 for RFP internal coworker data through the D&D era. NIOSH also indicated that it has completed an analysis of termination plutonium bioassay data, which demonstrates that the results for subcontractors are essentially identical to the results for top-tier contractors, and that it is currently working on a similar analysis for uranium.

December 11–13, 2006: The Advisory Board met in Naperville, Illinois. The RFP working group met on December 11 to discuss the current status of RFP review issues and actions as outlined in the working group priority action list of November 10, 2006. Discussion centered on the objectives and scope of the SC&A sampling plan for data completeness that is in preparation, the remaining NIOSH analysis to support its position on thorium, and data comparisons between top-tier and D&D subcontractors. SC&A committed to submitting an interim evaluation report to the working group by its next meeting (January 9, 2007).

December 19, 2006: NIOSH provided its analysis of termination bioassay results for plutonium and for uranium. Results are reported for (1) top-tier contractors, (2) all subcontractors, and (3) D&D subcontractors. The results do not show any significant differences between top-tier contractors and all subcontractors, or between top-tier contractors and D&D subcontractors.

December 27, 2006: NIOSH issued its compendium of historic thorium source term information for RFP, *Summary of Thorium Handling at RFP*, dated December 21, 2006, by Brant Ulsh, Bryce Rich, and Melton Chew (Attachment 20).

January 3–18, 2007: SC&A issued five preliminary drafts of key review sections for working group review and discussion. These are "Response to Data Integrity Examples Analysis" (January 3), "Data Completeness Evaluation" (January 10), "Other Radionuclides" (January 10), "Completeness of Records for 1969 and 1970" (January 11), and "Logbook Analysis" (January 18). These five draft reports are in addition to "Safety Concerns," released on November 29, 2006.

January 26, 2007: During the Advisory Board working group, NIOSH provided its initial reaction to the preliminary draft report sections provided earlier in the month by SC&A.

Discussions centered on clarifying questions and technical counterpoints regarding SC&A's preliminary findings concerning data completeness, data reliability, thorium source terms and dose reconstruction, and neutron dose estimation methods.

February 5, 2007: NIOSH publication of final version of ORAUT-OTIB-0049, *Estimating Doses for Plutonium Strongly Retained in the Lung* (ORAUT 2007b).

February 7, 2007: The Advisory Board met in Cincinnati, Ohio. The Chairman of the Advisory Board working group reported on the status of working group deliberations on the RFP SEC evaluation, with special emphasis on key issues involving completeness of data.

February 16, 2007: SC&A briefed the Colorado congressional delegation regarding preliminary draft review findings.

February 26–March 2, 2007: NIOSH provided its responses to SC&A's preliminary draft report sections.

March 7, 2007: The working group met in Cincinnati, Ohio. Discussion centered around SC&A's review of NIOSH's responses to SC&A's preliminary draft report sections provided in January. The group reached some preliminary resolution on several issues associated with completeness of data and thorium and took final actions to enable final report preparation by SC&A. These actions included further validation of HIS-20 as a basis for the two coworker models, as well as additional information to close out actions for neutron dose estimation and thorium dose modeling.

The working group also requested that SC&A conduct a sampling of records not previously reviewed in the "450 boxes" NIOSH referred to in its logbook evaluation report (NIOSH 2006g). As directed by the working group, this sampling should focus on those periods of time and those facilities that would afford a more "representative" sampling of available logbooks and related documents. The objective was to determine if specific relevant entries or data can be identified in these logs and to what extent these various categories of logs are "data rich" and thus represent a means of database validation.

March 12–16, 2007: SC&A conducted sampling of RFP records at the DOE Legacy Management offices in Westminster, Colorado, and reviewed a total of 153 record sets in hard copy or on microfilm. Data sets were examined to determine if they included individual-specific dose data. SC&A found, in its limited sampling, a number of relevant logbooks containing useful data from the 1970s, 1980s, and 1990s. However, while these entries include individual identified external and internal exposure measurements for a broad range of facilities and time periods relevant to data validation, this new information would not change the conclusions reached by the previous logbook reviews.

March 14, 2007: NIOSH provides, for SC&A evaluation, identified RFP worker neutron doses for the 1953-1958 time period in a document provided on the O-drive, *NIOSH RFP NP Ratios*

using NDRP Data for 53-58. An additional document is being prepared *(NDRP Paired Neutron Gamma Sets).*

2.3 REVIEW SCOPE

The Department of Labor (DOL), with assistance from NIOSH, will perform the task of identifying members of the SEC class. Since this report is a review of the evaluation report prepared by NIOSH, it does not address the protocols that DOL may use to decide which claimants are members of the class. However, this review does include analysis of NIOSH's limitation of the proposed class to certain buildings, since that analysis is part of the evaluation report.

This report includes a review of NIOSH's conclusion that it can reconstruct doses for all employees in the 1952–2005 period other than members of the proposed class. The comments in this review do not address the issue of minimum dose reconstruction for compensation only under 42 CFR Part 82, since the purpose here is to support the Board's discussion of dose reconstruction under 42 CFR Part 83.

In preparing its review, SC&A was particularly attentive to the EEOICPA, which states that a class of employees may be considered part of the SEC if, "HHS [U.S. Department of Health and Human Services] determines that (1) it is not feasible to estimate with sufficient accuracy the radiation dose that the class received; and (2) there is a reasonable likelihood that such radiation dose may have endangered the health of members of the class" (42 CFR Part 82).

In this regard, SC&A assessed the degree to which the evaluation report provided the technical basis for concluding that it is, in fact, feasible to estimate with sufficient accuracy the radiation doses to those members of the class for whom the evaluation report effectively recommends against granting SEC status. In addition, in preparing this report, SC&A drew upon the requirements of 42 CFR Part 83 and the guidance provided by the Board in *Report of the Working Group on Special Exposure Petition Review* (ABRWH 2006a). The following sections discuss each of the SEC-related issues that arose during the issues identification and review process that began with the issuance of SC&A's site profile review report, continued through the issues identification and review process, and concluded with the issuance of the *SEC Petition Evaluation Report* by NIOSH. The issues are not necessarily addressed in the order in which they arose throughout this process. Since the evaluation report contains a new class definition, and since some relevant documents were published at about the time that SC&A was completing its site profile review, this review of NIOSH's evaluation also covers these other issues, as appropriate.

3.0 HIGH-FIRED PLUTONIUM OXIDE

3.1 OVERVIEW OF ISSUES

The Rocky Flats SEC-00030 petition has raised concerns about worker exposures to a unique form of plutonium referred to as high-fired plutonium oxide (PuO_2). Formed at temperatures of 1,000ºC or higher, this plutonium compound has been shown to remain in the lung for much longer times than predicted by the default Type S International Commission on Radiological Protection (ICRP) lung model.

In dose reconstruction, the proportion of plutonium lung burden in the respiratory tract relative to that in systemic tissues profoundly affects the interpretation of bioassay data that may include chest counting and urinalysis. For example, a chest count that assumes Type S plutonium would significantly underestimate the duration of time that plutonium remained in the lung and, therefore, underestimate the lung dose. Even more troublesome is the reconstruction of lung doses based on urinalysis. When urinalysis data are used, the first step in dose reconstruction is to estimate the inhaled intake, based on a model that mathematically describes the relationship between the observed plutonium content in urine samples and the amount of previously inhaled plutonium. For example, the erroneous assumption of default Type S plutonium, for the interpretation of bioassay results from urine samples that corresponds to a high-fired plutonium intake, will significantly underestimate the amount of inhaled plutonium. In addition to the underestimation of the intake, if default Type S parameters are used, plutonium in the lung is further underestimated by the assumption of faster biological removal processes.

NIOSH has acknowledged that high-fired plutonium existed at Rocky Flats and that selected workers may have been exposed. NIOSH has also acknowledged that PuO_2 may exhibit long-term retention in the lung exceeding that predicted by the default Type S model. Correspondingly, NIOSH has addressed these issues in ORAUT-OTIB-0049 (ORAUT 2007b).

As part of SC&A's review of the Rocky Flats SEC-00030 Petition, SC&A has conducted a thorough review of the methodology proposed by NIOSH in terms of its scientific merit and the degree to which outstanding uncertainties are bounded by assumptions that give the benefit of doubt to the claimant. SC&A provided the Advisory Board with this detailed review, presented in Attachment 1, prior to the Board's June 2006 meeting, where SC&A also briefed the Board on its findings.

3.2 SC&A REVIEW METHODS

SC&A reviewed the NIOSH site profile for the RFP (Falk 2004) and submitted its draft review to the Advisory Board on December 8, 2005. In that review, SC&A stated that workers might have been exposed to high-fired plutonium oxides, which are characterized by high plutonium lung burdens in relation to the systemic organ burdens, at long times after exposure. As part of its "focused" review of NIOSH's SEC evaluation for RFP, as requested by the Advisory Board, SC&A has supported the Board's working group review of the high-fired plutonium issue. This review has included an evaluation of draft ORAUT-OTIB-0049 and its supporting analyses, as

well as data related to USTUR autopsy cases. NIOSH used the autopsy cases to validate the conservatism of empirical-based assumptions in ORAUT-OTIB-0049.

The SC&A staff reviewed the methods used by NIOSH to derive the lung dose adjustment factors from in-vivo bioassay results and from urine results, as well as the adjustment factors for systemic organs, GI tract, and the extra-thoracic regions. The SC&A staff reviewed the autopsy results, the lung count data, and the urinary excretion data for a representative number of RFP cases. Cases included individuals who had intakes of the high-fired plutonium oxide, Type Super S (Type SS) absorption type, and other types of exposures to plutonium oxides not necessarily classified as Type SS at the time of the exposures. The review compared post-1965 measured lung count data with autopsy data and the predicted values using the NIOSH ORAUT-OTIB-0049 empirical model. Calculations were performed considering Type S and Type SS material using the urine excretion data, as well as the lung count data. SC&A reviewed the autopsy data for lung, liver, and skeletal plutonium content available in most cases. For living former workers, lung count and urine data were modeled for organ deposition estimates.

SC&A also compared the NIOSH approach with a model recently proposed in the literature for exposures to high-fired plutonium oxides at the Mayak Production Association, a plutonium production facility in the former Soviet Union.

3.3 SC&A CONCLUSIONS

Overall, SC&A agrees with the NIOSH approach for estimating annual dose from intakes of plutonium that are retained in the lung longer than predicted by the normal absorption Type S model, based on the applicability of empirically derived adjustment factors for the lung, systemic organs, GI tract organs and tissues, and extra-thoracic regions. SC&A agrees it is claimant favorable under this approach to apply the adjustment factors if the intake material is unknown and plutonium oxide is a possibility.

NIOSH has identified selected cases of contamination to high-fired plutonium oxides in its "design cases." Among them, the two with the highest retention in the lung were chosen to derive the lung adjustment factors. However, as noted earlier, NIOSH did not explain fully the selection rationale for the design cases. NIOSH needed to demonstrate that the most conservative among the design cases would also be among the most conservative within the whole data file of workers exposed to high-fired plutonium oxides. At the request of the Advisory Board working group, SC&A reviewed the representativeness of the 10 model cases, upon which ORAUT-OTIB-0049 is based, and 19 other cases from the 1965 RFP fire to ascertain whether the NIOSH model envelops the cases and is, therefore, sufficiently conservative for broad use. SC&A also completed an evaluation of the ORAUT-OTIB-0049 application to specific potential RFP exposure cases, including unmonitored workers prior to the introduction of in-vivo counting. Attachments 2 and 3 provide these analyses. SC&A also concludes that doses to systemic organs can be underestimated when calculated from lung measurements.

Based on the review of ORAUT-OTIB-0049 and relevant cases that are the basis of the NIOSH approach, SC&A concludes that the use of the empirical model and its correction factors is plausible for estimating annual dose to the lung, systemic organs, GI tract organs and tissues, and extra-thoracic regions for intakes of Pu-239 that are retained in the lung longer than predicted by the normal absorption Type S model. The SC&A evaluation found the empirical approach and its correction factors to be claimant favorable, as they typically overpredicted the organ depositions.

Based on its review of all 25 workers involved in the 1965 fire, SC&A concludes that the model cases chosen by NIOSH as a basis for ORAUT-OTIB-0049 are sufficiently conservative for broad use (see Attachment 2). SC&A also concludes that when properly applied, ORAUT-OTIB-0049, together with ORAUT-OTIB-0038 and an MDA that includes some extreme conditions, can be applied to cover specific exposure scenarios (Attachment 3 provides examples) in a claimant-favorable manner:

> *However, the over-prediction for Type SS or "Super S" is not an unreasonable approach, considering the uncertainties that exist in the measured values (lung counts and urine assay models), and in particular, the autopsy extrapolations that were made. On this last point, an RFP site expert notes from first-hand knowledge that when the autopsy tissues were analyzed, the tracheal-bronchial lymph nodes and the bronchial-pulmonary lymph nodes were separated out, and the pathologist usually took a small portion of the lymph nodes and the lung tissue at the autopsy. Likewise, the pathologist usually took a portion of the liver, and, only representative samples of bone (a rib, a vertebral wedge, a femur ring, the sternum tree, a very small skull bone sample, part of the time the patella and a collar bone) were collected from which the skeletal deposition was extrapolated. This tissue sampling would contribute to the aforementioned uncertainties.*

With respect to NIOSH responses to other petitioner issues related to high-fired plutonium oxides exposures, SC&A agrees with the positions taken in the evaluation report, as discussed below.

Particle Size

SC&A agrees with the NIOSH proposal of an adjustment factor for particle sizes in calculations of doses to the lung from urine bioassay results, as stated in ORAUT-OTIB-0049:

> *PARTICLE SIZE ADJUSTMENTS FOR RFP PLUTONIUM FIRES*
> *Dose adjustment factors are based on the assumption of a 5-µm activity median aerodynamic diameter (AMAD) particle size (ICRP 1994). For the RFP plutonium fires, a particle size of 1 µm AMAD is recommended (ORAUT 2005). The dose adjustment factors underestimate the annual lung doses by a factor of 2.6 for 1 µm AMAD aerosols because the deposition in the alveolar interstitial (AI) region of the lung is 2.6 times greater for 1 µm aerosols than 5 µm aerosols per unit intake. For energy employees involved in a plutonium fire at RFP (or*

> *any time the dose reconstructor deems use of a 1-µm AMAD particle size appropriate), the dose adjustment factors in Attachment D must be multiplied by an additional factor of 2.6. Note that when the assessment is based on chest counts, the adjustment for particle size is not necessary because the lung deposition is directly measured, i.e., the dose would be adjusted upwards by this factor, but in order to get agreement in the Types S and SS predicted chest burdens, it would then need to be adjusted down by the same factor.* (ORAUT 2007b)

Self-Absorption in High-Fired Particles

SC&A agrees with the NIOSH position that any nontrivial self-shielding of the 60 keV gamma radiation (from the Am-241 daughter upon which plutonium lung counting relies) from a "ceramicized" high-fired plutonium particulate would not be plausible. This is based on the NIOSH calculation of expected reduction in radiation emitted by an assumed ceramically encased particle of 0.12 µm diameter, which showed a reduction of approximately 0.03% in the emitted gamma signal.

Finally, the NIOSH approach for Type SS, high-fired plutonium is effective only if implemented as proposed for all RFP dose reconstruction cases where the intake material is unknown and plutonium oxide is a possibility.

The SC&A analysis applies only to cases where the exposure was due to inhalation. The findings of this report about the proposed NIOSH approach for estimating lung dose and nonrespiratory tract doses are restricted to that exposure route. Specifically, the model may not be scientifically suitable or claimant favorable if the main intake route was via a wound.

3.4 SC&A'S REVIEW OF THE ROCKY FLATS LUNG AND URINALYSIS MONITORING RESULTS FOR THE DESIGN OF THE HIGH-FIRED PLUTONIUM MODEL

SC&A has reviewed the data from the six RFP workers (design data) involved in the 1965 fire, which were used to derive the high-fired plutonium oxides model.

Lung Data (1965 and 1969 Fire)

The lung data used for the design of the model (design data) were compared to the HIS-20 database for the six cases. In the document "Observations of Lung Count Data in HIS-20" (Falk 2006), NIOSH acknowledged that there was a mistake in the units used in the HIS-20 database.

Even after correction for the difference in units, most of the values used for the design cases and the ones from HIS-20 do not match.

NIOSH has responded to SC&A with the correction factors used for reevaluation of the lung monitoring results in HIS-20. These correction factors should be discussed with NIOSH but are not an SEC issue.

One of the individuals whose data were used to design the high-fired plutonium model was a claimant. The original lung data expressed as counts per minutes, µg, or fraction of lung burden in the lung were reported as zeros in the HIS-20 database and were converted into pCi of plutonium in the design data set. The original lung data, when expressed in nCi, match the HIS-20 values, after correcting for the units.

The lung monitoring data from the firefighter who was exposed in the 1969 fire were retrieved from the 1969 logbook (monitoring data from May 11, 1969–August 2, 1969). Data from this worker were also used to derive the high-fired plutonium model. Three very high values recorded in the logbooks were not used in the design data set. The other values were around 20% higher than the original ones.

Urinalysis Data

Original urinalysis data were retrieved from the bioassay logbooks. The 1966 and 1968 logbooks were not available to SC&A. For urinalysis data of this claimant, SC&A found no significant differences between the three data sets (design data, HIS-20, and bioassay logbooks).

3.5 SC&A'S REVIEW OF THE ROCKY FLATS LUNG AND URINALYSIS MONITORING RESULTS FROM FIVE WORKERS INVOLVED IN THE 1965 FIRE WHOSE DATA WERE NOT USED IN THE DESIGN OF THE HIGH-FIRED PLUTONIUM MODEL

Five workers involved in the 1965 fire were claimants, and their lung and bioassay data were compared to the HIS-20 database.

Lung Data

In general, the HIS-20 database for lung results is incomplete. NIOSH acknowledged that there was a mistake in the units used in the HIS-20 database, as described in Falk 2006.

After correcting for the units, the existing results in HIS-20 match the original ones with a few exceptions.

This review found that lung data used to calculate dose for one claimant were applied without the correction factors that NIOSH had applied to the design data set. SC&A believes that if a correction factor must be applied to lung monitoring results in the design data set, it should be applied to results for all claimants.

Urinalysis Data

In general, SC&A found the HIS-20 database for urinalysis results to be incomplete, although HIS-20 values do match the Health Sciences database. From a comparison of activity concentrations between results from the urinalysis record cards and HIS-20, SC&A found that many sampling dates do not match.

In further comparisons for validation purposes, SC&A found that the data from the urinalysis cards match the data in the bioassay logbooks.

The review found that some of the claimants had plutonium intakes prior to the 1965 fire. Those were the cases with higher lung burdens than the design cases. The appendices provide a detailed analysis of these data.

3.6 SC&A'S REVIEW OF THE ROCKY FLATS URINALYSIS MONITORING RESULTS FROM 12 NONCLAIMANT WORKERS INVOLVED IN THE 1965 FIRE WHOSE DATA WERE NOT USED IN THE DESIGN OF THE HIGH-FIRED PLUTONIUM MODEL

SC&A compared the data from the HIS-20 database to the data in the available urinalysis logbooks. Many dates from HIS-20 did not match the ones in the urinalysis logbooks. There are a few differences in the results, but in general, the results from HIS-20 match the ones from the available logbooks.

Only one of the workers without prior exposures to plutonium had sufficient urine data to be included among the design cases.

3.7 SC&A'S REVIEW OF THE ROCKY FLATS USTUR DATA FOR A WORKER INVOLVED IN THE 1965 FIRE WHOSE DATA WERE NOT INCLUDED IN THE HIS-20 DATABASE

Results for two workers who were involved in the 1965 fire were not included in HIS-20. One of them was a USTUR case, and urinalysis and lung monitoring data from this worker were in the USTUR file. This worker died in 1970, and these data could not have been included among the design cases, as the design model is meant to cover long term retention of the high-fired plutonium oxides in the lungs.

3.8 SC&A REVIEW OF THE ROCKY FLATS PLANT DATA FROM THE 25 WORKERS INVOLVED IN THE 1965 FIRE

SC&A has revised the data from the 25 workers involved in the 1965 fire. The raw lung data were modified according to the adjustment factors described in ORAUT-TKBS-0011-5, Attachment B (Falk 2004). These adjustment factors were not discussed with NIOSH but were applied as established in ORAUT-TKBS-0011-5. The initial ppm value of Am-241 was also not discussed with NIOSH. These adjustment factors and the initial ppm value of Am-241 are not

SEC issues for ORAUT-OTIB-0049 but should be the subject of further discussion. SC&A analyzed the data from the 25 workers and concluded that the design cases were correctly chosen. Only one other worker would qualify as a design case, but the inclusion of his data would not have modified the adjustment parameters chosen in ORAUT-OTIB-0049. Attachment 2 shows the details of these comparisons.

4.0 INTERPRETATION OF EXTERNAL DOSE DATA

4.1 INTRODUCTION AND OVERVIEW OF ISSUES

The Rocky Flats SEC-00030 Petition (USWA 2005) has raised issues concerning workers' external dose exposures. The petition presented items that the petitioners believe would prevent adequate external dose reconstruction for RFP workers by NIOSH. These items include concerns about inadequate monitoring, lack of monitoring, changes in methodology, and inconsistency in procedures over the history of RFP. The petitioners provided further details about external dose exposures, handling of dosimeters, and lack of dose records. They included letters and testimonies with the petition attesting to certain incidents throughout the history of the RFP site that could lead to lack of external dose information necessary for claimant-favorable dose reconstructions. Some of the areas identified in the petition were the lack of adequate neutron monitoring in the 1950s; problems with neutron track plates (NTP) and NTA film reading and records; improper storage of workers' and control dosimeters; TLD chips on the floor in the counting room; placement of dosimeter/exposure geometry; and zero or no data available in workers' dose records. The petitioners presented details of these and other areas that they believe demonstrate that it is not feasible to perform dose reconstruction with sufficient accuracy under 42 CFR Part 83 for all classes of RFP workers identified in the petition.

NIOSH has acknowledged that certain areas of external dose records are incomplete and that dose reconstructions for some workers will require correction factors to be applied to doses that were recorded, and assignment of coworker dose data when dose records are incomplete or contain gaps. Additionally, NIOSH has recognized the necessity of assigning missed dose because of the lower limits of detection (LODs) for external dosimeters. To correct the recorded external doses and to assign external doses to unmonitored workers at RFP during the period 1952–2005, NIOSH has recommended using the RFP Occupational External Dosimetry technical basis document (TBD), ORAUT-RKBS-0011-6 (Langsted 2004); the NDRP Report (ORISE 2005); ORAUT-OTIB-0020 (Merwin 2005); ORAUT-OTIB-0027 (Smith 2005a); ORAUT-OTIB-0050 (Smith 2005b); and ORAUT-OTIB-0058, Revision 01 (Smith 2007). NIOSH has stated that it has access to sufficient information to either (1) estimate the maximum external radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class; or (2) estimate the external radiation doses to members of the class more precisely than a maximum dose estimate (NIOSH 2006a, p. 65).

SC&A has reviewed the Rocky Flats SEC-00030 Petition (USWA 2005) and NIOSH's April 7, 2006, evaluation report (NIOSH 2006a). Additionally, SC&A has evaluated the Introduction TBD (Little 2004), the Site Description TBD (Flack and Meyer 2004), the Occupational External Dosimetry TBD (Langsted 2004), the NDRP report (ORISE 2005), ORAUT-OTIB-0020 (Merwin 2005), ORAUT-OTIB-0027 (Smith 2005a), ORAUT-OTIB-0050 (Smith 2005b), and ORAUT-OTIB-0058 (Smith 2007). SC&A has used this information to evaluate whether NIOSH has sufficient data and adequate methods to perform external dose reconstruction with sufficient accuracy under 42 CFR Part 83 by being able to estimate a plausible upper bound for all members of the class. This is not necessarily the same as being able to perform dose

reconstruction for individual workers. Being able to perform dose reconstructions does not, by itself, prove that NIOSH can meet the requirements of 42 CFR Part 83.

4.2 SC&A'S REVIEW METHODS

SC&A has reviewed the above-listed RFP TBDs and TIBs, some of their recent revisions, the NDRP Report, the Rocky Flats SEC-00030 Petition, NIOSH's evaluation report on the petition, and NIOSH's external dose reconstruction example cases. In addition, SC&A has engaged in extensive phone conferences, interviews, and correspondence with the petitioners/workers, NIOSH, and the document authors. SC&A has also accessed and analyzed many of the RFP documents that are available concerning external radiation exposures, dosimetry, dose records, and operational history at RFP from 1952–2005.

SC&A then evaluated NIOSH's overall dose reconstruction approach using the information SC&A had acquired from these documents. For issues concerning neutron exposures, SC&A performed a detailed analysis of two related TIBs, ORAUT-OTIB-0050 and ORAUT-OTIB-0058, and provided NIOSH with an evaluation report for these TIBs. SC&A also examined the NDRP report in the context of ORAUT-OTIB-0058. For issues concerning composite neutron plus photon, photon, and/or beta doses, SC&A analyzed the workers' detailed dose data that were made available to determine the adequacy of the dose records and the applicability of coworkers' dose to unmonitored workers. At times, it was difficult to acquire the details of the annual neutron doses separate from the composite doses along with the workers' identifications (IDs) and work locations for the period 1952–1969. This evaluation is based on the data that have been made available to date and the TIBs currently available.

The following sections detail the results of SC&A's review of the RFP documents, analysis of the available external dose data and its sufficiency for dose reconstruction, and the evaluation of NIOSH's dose reconstruction approach.

4.3 CREDIBILITY AND CONSISTENCY OF RFP DATA

In the evaluation report on SEC-00030, NIOSH concludes that sufficient data exist to reconstruct external doses for all members of the proposed class for 1952 to the present. SC&A agrees that many of the RFP workers' dose records provide the necessary information for adequate dose reconstruction; however, several areas of the dose records raise the concern that claimant-favorable data may not always be present.

4.3.1 Completeness of Records for 1969 and 1970

During SC&A's review, a number of former workers from RFP were interviewed. Many of them expressed particular concern about the May 11, 1969, fire and its relevance to their dose reconstruction. SC&A reviewed DOE records if available for individuals raising this particular concern. In some cases, SC&A noted that on the Occupational Dose Report (handwritten external data summary), the shallow and deep doses were blank. Computer printouts of deep dose results within the health physics file were recorded as zero in the list of 1969 results, in

place of the blanks. Hence, some records contain blanks and zeros, while others, for the same worker and the same badging period, contain zeros only. SC&A has verified that this situation applies to a number of claimants whose employment period included 1969. SC&A also observed that doses during 1970 were significantly lower than those for 1968 or 1971.

In interviews with workers who had gaps in their 1969 records, SC&A asked them if they had been assigned a dosimeter in 1969. The individuals indicated that there was no break in their monitoring and that they did enter radiological areas during 1969 and 1970. Because SC&A encountered this situation in several individual files, it conducted a review of the number of zeros in the file "RFP Coworker Data Stat (NDRP included, HIS-20 Data)" available on the O-drive (NIOSH 2006l). SC&A found a sudden increase in the percentage of zeros from 1968 to 1969. The high percentage of zeros continued during 1970 and then dropped significantly in 1971.

These facts about the external dose records for 1969 and the first part of 1970 raise some questions:

- What was the reason for the blanks in the records?
- How were blanks recorded in dosimetry logs and the HIS-20 database?
- Was there a common reason for the increase in blanks and zeros in 1969 in the individual raw data files?
- What were the reasons for the increase in the zeros recorded in 1969 (relative to 1968)?
- What were the reasons for the increase in the zeros recorded in 1970 (relative to 1968)?
- Did the blank records that were assigned zeros correspond to exposure potential below the LOD for the badges of the time?
- How are the zeros in the dose records from unread and read badges to be distinguished, assuming that the zero results for read badges are less than the LOD?

As a result of the preliminary concerns raised by SC&A, NIOSH evaluated potential hypotheses to explain the gaps, including whether they were related to the May 11, 1969, fire and its subsequent cleanup.

Summary of the NIOSH Analysis of the 1969 Data Gap

In response to SC&A's concern, NIOSH determined that 136 claimants had gaps in dosimetry records for 1969. Further analysis of these individuals indicated that they held a wide variety of jobs from administrative to production. In a few cases, the individual arrived at RFP within the last month of 1969 and may not have had dosimetry results for that year. NIOSH investigated the radiation files of each worker in an attempt to ascertain reasons for the apparent gap. The

investigation centered on 136 claimant files that had been identified as missing data for 1969. Of the 136, 35 had no external dosimetry data at all for 1969 for reasons that could not readily be explained. NIOSH clarified the problem in the following statement (NIOSH 2006m):

> *Only 26% of the records tentatively identified as "missing" were completely missing. Four of those in the table were not RFP employees during 1969 and another 17 were employed for less than a calendar quarter. For nearly 60% of the records there was some data reported, albeit sometimes only a single zero entry of a badge coding of "01" which indicated that the badge was not returned. Therefore, the putative gap is considerably smaller than it seemed originally.*

NIOSH tested several hypotheses to explain the gap, including data having been lost as a result of the 1969 fire, a computer reporting problem, and the possibility that some badges were simply not read. Since data exist for first responders and employees who participated in cleanup operations related to the 1969 fire, NIOSH concluded that the gap was not connected with the May 11, 1969, fire. NIOSH stated (NIOSH 2006m):

> *The external dose monitoring patterns observed in 1969 are consistent with a combination of the policy to not read badges for staff in non-Pu areas on quarterly badge exchange cycles, and a computer problem that arose during this period resulting in dose being reflected only in cumulative dose totals. The programming error that reportedly resulted in a loss of monthly and quarterly detail data for 400 workers certainly would have created an apparent gap in the records for those staff, but would not have impacted their cumulative doses because the gap was discovered and addressed.*
>
> *NIOSH concludes (1) the 1969 data gap is much smaller than originally estimated, (2) the patterns observed in the 1969 dosimetry data are consistent with the administrative decision to not read film badges from employees stationed in non-Pu areas with low exposure potential, and (3) a computer programming error may have contributed to the lack of detail in the dosimetry data, but this was discovered and corrected in the cumulative dose totals. Therefore, NIOSH concludes that dose reconstructions can be performed with sufficient accuracy for claimants employed at Rocky Flats in 1969.*

The working group asked SC&A to review the NIOSH analysis.

Evidence of Systemic Data Gaps

SC&A identified a sudden jump in zero entries from 1968 to 1969. The high proportion of zeros continued into 1970 and then declined in 1971. These data were compiled from the RFP dose data posted on the O-drive (ABdoc review->RF->coworker data->RFP coworker data Stat (NDRP included, HIS20 data) posted 4/17/06). Table 4-1, which summarizes the number of zero entries each year in the HIS-20 database, shows that the percent of zero entries increases dramatically for these 2 years. Both 1969 and 1970 had over 36% zero entries for penetrating

(neutron + photon) external doses, while the previous 5 years (1964–68) showed an average of 9.7% zero entries and the subsequent 5 years (1971–1975) had an average of 10.5%. This is especially relevant because many workers were involved in a major fire that occurred during the second quarter of 1969.

Table 4-1. Percent of Zero Doses Recorded for 1952–2005

	Pene. Dose w/zeros	Pene. Dose w/o zeros		
Year	**# of entries**	**# of entries**	**# of Zeros**	**% of Zeros**
1952	42	42	0	0.0
1953	319	290	29	9.1
1954	353	273	80	22.7
1955	529	426	103	19.5
1956	781	662	119	15.2
1957	918	804	114	12.4
1958	1062	927	135	12.7
1959	1063	1011	52	4.9
1960	1284	1065	219	17.1
1961	1638	1461	177	10.8
1962	2003	1779	224	11.2
1963	2176	2047	129	5.9
1964	***2834***	***2610***	***224***	***7.9***
1965	2826	2639	187	6.6
1966	2888	2658	230	8.0
1967	2902	2530	372	12.8
1968	3101	2690	411	13.3
1969	3471	2197	1274	36.7
1970	3308	2096	1212	36.6
1971	3398	2995	403	11.9
1972	3282	2621	661	20.1
1973	3020	2465	555	18.4
1974	2687	2658	29	1.1
1975	2489	2461	28	1.1
1976	2424	2271	153	6.3
1977	3740	2347	1393	37.2
1978	4176	1781	2395	57.4
1979	3893	2441	1452	37.3
1980	3752	1760	1992	53.1
1981	4060	1496	2564	63.2
1982	4851	2490	2361	48.7
1983	5360	3631	1729	32.3
1984	5673	3607	2066	36.4
1985	6140	3993	2147	35.0
1986	4942	4603	339	6.9
1987	2583	2354	229	8.9

Table 4-1. Percent of Zero Doses Recorded for 1952–2005

Year	Pene. Dose w/zeros # of entries	Pene. Dose w/o zeros # of entries	# of Zeros	% of Zeros
1988	2778	2503	275	9.9
1989	5296	2891	2405	45.4
1990	3369	2602	767	22.8
1991	5641	4951	690	12.2
1992	5831	5429	402	6.9
1993	5313	4534	779	14.7
1994	4839	3198	1641	33.9
1995	4130	2502	1628	39.4
1996	3454	2761	693	20.1
1997	3718	2452	1266	34.1
1998	3470	2036	1434	41.3
1999	3655	2138	1517	41.5
2000	3576	1256	2320	64.9
2001	3443	1518	1925	55.9
2002	3502	1147	2355	67.2
2003	3373	947	2426	71.9
2004	2758	559	2199	79.7
2005	955	562	393	41.2

SC&A investigated whether this sudden increase and then decrease in the number of zeros was indicative of data entry or credibility problems and what the implications might be for dose reconstruction.

SC&A also noted that similar sudden jumps in zeros appeared from 1976 to 1977. The high proportion of zeros persists until 1985 and then drops in 1986. SC&A has not investigated these additional years with high proportions of zeros in detail; however, several changes in the dosimetry program occurred around this time. In 1976, the dosimetry group implemented the Health Sciences Database (Langsted 2004). At about that time, a decision was made to change the background subtraction method for TLD dose determination (Lagerquist 1975a):

> *Beginning January 1, 1976 we will be subtracting background from all external radiation measurements of our employees.*
>
> *This background will be the average of the environmental measurements that we have made on plant site and in nearby communities.*

Lagerquist (1976) indicated that an average background of 0.34 mrem/day was subtracted from the badge. There was also a proposal to record zero for doses less than 10 mrem as stated in a memorandum by Lagerquist "We are considering converting all employee readings of less than 10 mrem to zero also, but we want to look at the 1976 data first. (Lagerquist 1976).

Further, americium operations changed in 1976, and americium recovery was stopped in the late 1970s (Flack and Meyer 2004, pp. 11–12). The end of these operations would be expected to significantly reduce external dose in some plutonium areas. SC&A did not discover comparably large external dose gaps for entire years in this period in its random sampling (see Section 8), indicating that the zeros in these later periods were readings less than the detection limit rather than gaps.

Claimants with Data Gaps

NIOSH identified 136 claimant files as "missing data for 1969," with 26% of these files determined to have no external dosimetry for all of 1969 and others having data for portions of the year. NIOSH listed only one "Fire Protection Engineer" and one firefighter. Table 4-3 contains a subset of the 136 individuals, all with blanks for four quarters of data on their 1969 Health Physics External Radiation Exposure Report (HPERER) in the health physics file. These 19 individuals worked all four quarters during 1969, and most continued employment into 1970. Each also had at least one badge reading in the 1969 Dosimetry Processing logs, where there was no indication of a late or unreturned badge.

Note that Individual 19, listed in Table 4-3, is a firefighter. He indicated in his computer-assisted telephone interview (CATI) that he was involved in "suppressing the fire" and in subsequent fire watches. In fact, he received an in vivo count shortly after the fire for a "potential inhalation from the 776 fire." There is no explanation for the data gap for him in 1969. In its late February 2007 report on the 1969 data gaps, NIOSH presented evidence regarding the external exposure conditions affecting the employees who dealt with the aftermath of the fire:

> *Another piece of information that applies to this claimant is found in the July 24, 1969 memo from Mann to Piltingsrud, shown above. Mann indicates that in the two month period including and immediately following the May 11, 1969 fire the maximum dose received by any of the 208 cleanup personnel was less than 200 mrem. A draft memo originally dated May 16, 1969 states "Fifty special thermoluminescent dosimeter badges have been used so far by Dow employees and members of the investigating team. To date, no significant external exposures have been measured on any one entering Building 776" (1). These contemporary results belie the presumption that significant doses were missed for workers involved in the fire's aftermath. Taken together, the urinalysis results, lung counts and ambient gamma exposure information for the fireman (ID #19) indicate that he did not accumulate a large dose during his fire suppression or fire watch activities.* (NIOSH 2007b, pp. 9–10)

SC&A agrees with NIOSH that external dose gaps for those involved in the aftermath of the fire are not an SEC issue.

The case of an individual not listed in Table 4-3 should also be considered.[2] In fact, he submitted an affidavit within the SEC petition in which he raised concerns that his film badge readings did not match his job duties. He worked as a laboratory technician supporting nondestructive analysis. According to the petition affidavit and the CATI, this individual performed duties in buildings all over the site, including plutonium processing buildings. The 1969 dose on his HPERER was blank for all four quarters. The first three quarters on the 1970 HPERER were recorded as zero with a significant drop in annual exposure for that year compared to doses in 1965-1968. No data from1969 were available for this individual on the Dosimetry by Individual Report or in HIS-20—that is, the year 1969 was missing altogether from the Dosimetry by Individual Report and the worker was not in the HIS-20 external dose database. The recorded deep doses for 1965, 1966, 1967, and 1968 were 1,512, 1,804, 4,130, and 645 mrad respectively, all above the 10% limit. The personnel file indicates that this worker was assigned to Building 444 in 1965 and 1966. For portions of 1967 and 1968, the individual spent time in the plutonium areas. The individual stated in the CATI that he was involved in the 1969 fire cleanup. Within the health physics file are reports indicating that he received an abrasion in 1969 and a puncture wound in 1969 in Building 777. This would indicate that during at least some portion of 1969, he was working in Building 777. It is noteworthy that for at least three quarters in 1969, the individual was formally assigned to Building 444, which was a nonplutonium area even though he was performing work in a plutonium area. There were no densitometer readings in the dosimetry processing logs, and zeros were entered for three quarters in the dose readings with arrows, indicating that his badges were not read. In the fourth quarter, there is a blank in the log, with a notation that the badge was not returned, although he was still listed as being assigned to Building 444. He was on a quarterly badge cycle. This case raises questions regarding the policy of not reading badges for nonplutonium areas that was instituted in 1969. It shows also that individuals entered areas other than those to which they were formally assigned and illustrates as well the complexities introduced into dosimetry issues by the fire and the earlier decision on selective nonreading of quarterly badges.

NIOSH responded to these observations in its February 2007 report as follows:

> *NIOSH investigated this claimant's file and determined that, indeed, doses from 1965–1968 were higher than for 1969 and beyond, however SC&A only considers the doses prior to 1969 and makes no mention of the lower doses in the following years. For most of his career, he was a laboratory technician. In 1967 and 1968, he conducted non-destructive testing in buildings 777 and 991. In December 1968 he was transferred to building 444 and later in September 1969 to building 881 where he was stationed until August 1971. Hence, it is likely that in 1969 he was subject to the badge no-read policy outlined earlier. As demonstrated by his much lower doses in the years following 1969 during which he was stationed outside the Pu areas, his doses were far lower than in the years prior to 1969 when he was stationed in Pu areas. This example validates the premise that*

[2] He was not included in the table because his data are completely missing from the HIS-20 database, making a comparison with the other databases impossible. His name is slightly misspelled in the 1969 Dosimetry Processing Logs. SC&A verified the data by reference to his badge number.

> *workers stationed outside the Pu areas on quarterly badge cycles were at low exposure potential.*
>
> *In May, 1969, he received a puncture and an abrasion to the right hand while doing decontamination in building 776, but a wound count showed no levels above background. Urinalysis results for 1970 and 1971 showed no contamination.* (NIOSH 2007b, pp. 10-11)
>
> *Finally, the Mann memo of July 24, 1969 indicates that no fire cleanup personnel had received greater than 200 mrem. Therefore, this claimant likely did not receive a large dose during the 1969–1970 period. In spite of this, such an unmonitored worker would be assigned a penetrating dose of 2,702 mrem according to OTIB-58, which is a factor if 2.6 higher than any worker involved in the fire cleanup. NIOSH notes however, that this was unnecessary in this case, as the individual's dose reconstruction has been completed, with a probability of causation >50%. Therefore, there was nothing here which prevented NIOSH from completing dose reconstruction with sufficient accuracy.*

The point of SC&A's observations in this case is that workers stationed in nonplutonium areas appear to have been involved in the cleanup after the fire. The NIOSH response confirms this. SC&A agrees with NIOSH that the assignment of dose to those involved in the cleanup is not an SEC issue. The matter is raised here in the context of the gaps for 1969 and whether there are appropriate ways to address these gaps.

On May 11, 1969, a large self-ignited fire occurred in Building 776, and contamination spread to Building 777. A total of 33 firefighters and security guards fought the fire at various times. Personnel were contaminated at levels from a few hundred to greater than 100,000 disintegrations per minute (dpm) alpha/60 cm^2. Dow medical personnel, radiation monitors, body counter technicians, and six U.S. Atomic Energy Commission (AEC) personnel assisted in decontamination, monitoring, and contamination control. In the first 24 hours, 41 employees were decontaminated and checked with the body counter. Initial counts indicated that 15 of the 41 employees had positive plutonium results. The only significant inhalation of plutonium attributed to the fire involved a firefighter who was given an in vivo count after being decontaminated (AEC 1969).

Several radiation monitors relayed to SC&A that they discarded contaminated badges, or discarded badges on significantly contaminated clothing (see Attachment 4). Logbook entries reviewed for other time periods support the practice of destroying contaminated badges in the field (see Attachment 5). This would be a reasonable solution if badges could not be decontaminated because the facility would not have wanted to contaminate the Dosimetry Processing Laboratory. The destruction of contaminated badges may also have contributed to the gaps in 1969. The Dosimetry Processing logsheets for 776 are divided into 776A and 776B. For May 1969, 776A and 776B had a total of 90 and 192 individuals listed, respectively. The logsheets for 776A identified 16 badges as "not returned." Those for 776B identified 59 badges as "not returned." This high level of "not returned" badges may be indicative of badge

destruction in the field when badges were contaminated. This would not be restricted to specific areas on the plant site and would have implications for plutonium as well as nonplutonium area workers.[3]

Again, this issue is raised in the context of addressing gaps in the 1969 time period in question. The SC&A investigation of the completeness of worker dosimetry data (Section 8.0) noted that in several of the cases examined, NIOSH has incorrectly used methods based on the LOD to assess doses at times when there were gaps in the data records. The SC&A discussion of personnel involved in the fire who have gaps in their data records should be placed in this context. A coworker dose assignment is appropriate, rather than a missed dose LOD-based assignment. SC&A concurs with NIOSH that such an assignment is possible based on available data.

Computer Error

Individuals responsible for data processing were actively involved in the development of computer programs for TLD dose calculating programs, data management, and sample scheduling during the early part of 1969. In some cases, they experienced difficulties. The *Status Report—Dosimetry—February, 1969* (Mann 1969a) indicates a data processing error for the year-end (presumably 1968) external exposure data:

> *The year end external exposure data program appears to be correct now. Corrections necessary to the periodic film badge runs have not been made yet. We are not getting satisfactory service from this group (Data Processing).*

The *Status Report—Dosimetry—April, 1969* (Mann 1969b) noted a computer error:

> *The entire film badge program is being rewritten to take care of recent programmer errors. We are furnishing accumulated dose to date data on 400 "lost" employees to up-date their master tape.*

Specifically, it appears from the early 1969 dosimetry progress reports that the data processing group was having difficulties with the year-end external data for 1968. Furthermore, letters in health physics files document a computer error occurring in 1968 (RI 1976). Possibly, the error NIOSH was associating with 1969 is actually related to 1968 data. Adjustments to dose (cumulative or otherwise) were often documented on a letter and placed in the individual health physics file. There is no indication of an adjustment in accumulated dose for 1969; however, letters were present in the health physics files for adjustments made as a result of a computer error in 1968 (RI 1976).

[3] Note that SC&A's screening analysis of minimal data completeness in Section 8 does not include partial year missing data, such as that created by discarding one or two badges in a year.

Nonplutonium Area Badges Not Processed

SC&A concurs with NIOSH that RFP decided not to read nonplutonium area badges in early 1969, prior to the fire. In a letter to Mann, Vogel (1969) recommended that nonplutonium area film badges not be processed because most of the individuals received less than 10% of the in-plant working level:

> *It is recommended that the film badge continue to be issued and worn as it has been but that the film not be processed except for a few specific groups or for particular circumstances…. The circumstances that might require processing of film for some individuals or groups would include accidents, special operations work involving special material, or to reaffirm the validity of this approach.* (Vogel 1969)

Table 4-2 lists the "nonplutonium" area buildings and briefly describes the activities that occurred in these buildings.

Table 4-2. Description of Nonplutonium Buildings as Determined by RFP Radiological Control

Badge Storage Area Building No.	Description of Activities
111	Administrative Building
121	Plant Security and Armory
122	Emergency Medical Services Facility
123	Analytical Health Physics Laboratory
125	Standards Laboratory
331	Vehicle Maintenance and Fire Station
334	Central Shop and Maintenance
440	Transportation Modification Center
441	Production Support
442	Filter Test Laboratory and Warehouse
444	Depleted Uranium Processing
551	General Warehouse
705	Coatings Laboratory
750	Production Engineering Support
881	Manufacturing and General Support
883	Uranium Rolling and Forming Operations
865	Metal Research and Development Laboratory

The specific groups in the nonplutonium areas exempted from this practice included Health Physics Electronics, Health Physics Operations, Nuclear Safety, Uranium Chemistry in Mfg., Production Control in Mfg., and Quality or Nondestructive Testing. While it was not considered necessary to wear the film badge to measure this very low-level chronic exposure, Management

felt it desirable to wear the film badge to measure accidental exposure. Vogel (1969) indicated that implementation of this policy would result in a reduction in film processing workload by at least 1,000 packets per quarter.

The film was to be retained for a several weeks after the regular film badge change before it was discarded (Vogel 1969). The *Status Report—Dosimetry—March, 1969* (Mann 1969c) indicates that the practice of not reading quarterly issued badges was implemented:

> *Quarterly badges for the non-Pu areas will no longer be read routinely, except for a few higher risk groups. The film will be changed as usual, but will not be read unless circumstances warrant.*

A memorandum from Mann to the dosimetry technicians (Mann 1969d) informs them that the policy would be effective with the first quarter change of 1969 and that badges would be discarded not long after return. The memorandum states, "Film from the badges of all other groups [those not processed] is to be saved for three weeks after the exchange, then discarded." SC&A notes that this policy of not reading some workers' badges was instituted **before** the May 11, 1969, fire. SC&A partially concurs with the NIOSH contention that many of the gaps in data are not related to the fire. However, as noted above in the case of the firefighter, it appears that external dose data related to the fire also have gaps.

Unread badges also appear to be indicated when zero is recorded for the dose result, but no density readings are listed for the particular badge as they are for those that are clearly read. After reviewing the Dosimetry Processing Logs, SC&A noted that quarterly badge results are primarily recorded as zero for a number of RFP buildings (e.g., 441, 444, 881, and 883). The lack of density readings persisted through 1969 and 1970. Furthermore, badges from plutonium area workers did have density readings recorded. One difference between 1969 and 1970 was that handwritten Occupational Dose Reports indicated zero in 1970 rather than blank, which was the case in 1969. It is possible that the zeros in the dose columns for deep and shallow dose in the Dosimetry Processing Logs were entered without a corresponding density entry as a matter of convenience. However, it is much more likely that they were zero entries when badges were not being read, since a policy to this effect was instituted in 1969. Other evidence, discussed below, clearly leads to this conclusion. NIOSH's reading of these logs is the same as SC&A's—that these zero entries represent unread badges:

> *Monthly "Status Reports" prepared by John Mann, the manager of the Dosimetry Program addresses the issue of data sheets with zeros written at the top and with arrows down the entire page. The status report dated April 8, 1969, Item A.3 states: "Quarterly badges for the non-Pu areas will no longer be read routinely, except for a few higher risk groups. The film will be changed as usual, but will not be read unless circumstances warrant."* (NIOSH 2006m)

Table 4-3 lists 19 claimants with 1969 gaps from among the 136 individuals initially identified as having data gaps in the Occupational Dose Report. These individuals worked all four quarters during 1969 and most continued employment into 1970. SC&A examined four different data records for these 19 individuals for 1969:

- The Occupational Dose Report, which is the handwritten summary dosimetry report in the Health Physics file.
- Dosimetry History by Individual, which is a computer printout generated prior to the HIS-20 database creation.
- The HPERER, which is a quarterly summary report.
- The HIS-20 computerized database, which NIOSH is using for its coworker model.[4] The individuals also had dose values for 1969 in the RRFP Coworker Stats (NDRP Included, HIS-20) file located on the O-drive. In each case, all the blank values in the HPERER were recorded as zeros in the HIS-20 database.

Examples of the Occupational Dose Report, Dosimetry History by Individual, and HPERER are available in the External Dosimetry TBD (Langsted 2004, pp. 52–55, 61). The individuals also had dose values for 1969 in the *RRFP Coworker Stats (NDRP Included, HIS-20)* file located on the O-drive. SC&A reviewed each of the four external dosimetry sources to determine the dose values entered for 1969.

In all 19 cases, the HPERER data show blanks for the entire year (indicated as "Null" in Table 4-3). In the handwritten Occupational Dose Report in their health physics file, 16 cases show blanks, while 3 individuals did not have such a report in their health physics file. A typed version of an Occupational Dose Report under a different name is not referred to here since it was available for only a few individuals. Table 4-3 indicates "null" only when a blank was documented for each quarter of 1969. Hence, both the Occupational Dose Report and the HPERER data show by their blank entries that the badges of these workers were not read.

In contrast, the Dosimetry History by Individual computer printouts show the following (see Table 4-3):

- Zeros for 10 individuals having 1969 data for the deep dose instead of blanks and a blank for the shallow dose
- No Dosimetry History by Individual in the health physics file for nine individuals (indicated by N/A)

[4] At this stage, SC&A has not established whether the external HIS-20 has been used in individual dose reconstruction.

Finally, the HIS-20 database shows zeros in all 19 cases for both shallow and deep dose. This would demonstrate that, in both the processing logbooks and the computerized databases, unread film was entered as a zero. The entry of zeros for unread badges leads to the conclusion that the sudden increase in zeros in 1969 in the HIS-20 database (Table 4-1 above) is very likely due largely to a zero entry in the database in place of the blanks in the Occupational Dose Reports and the HPERER data. This conclusion is buttressed by the fact that the decision not to read a certain category of badges resulted in a large decline in the number of badges read (1,000 packets per quarter—see above). The other bases for this conclusion include the following:

- The number of zeros from 1968 to 1969 increased from 13.3% to 36.7%.
- Quarterly cycle badges were not read starting in 1969 (Mann 1969c).
- The blanks in some databases show up as zeros in others, notably the HIS-20 database and the Dosimetry History by Individual.
- Workers with blanks (subsequently zeros in the HIS-20 database) were assigned to areas considered nonplutonium work and fit the profile of those referred to in the memorandum for nonreading of issued badges. These blanks, and subsequent zeros, are unrelated to the May 1969 fire.
- The same workers had densitometer readings in earlier periods, but none in 1969.

The practice of recording zeros for dose and providing no densitometer readings in the Dosimetry Processing Logs continues into 1970. The existence of non-zero doses for the same workers in the HPERER records in 1970 indicates that the practice may have changed before the end of the year. This change in recording practice is also reflected in the reduction in the percentage of zeros from 1970 to 1971. SC&A has not found any document that establishes a definitive date for the ending of the practice of not reading issued badges. NIOSH has also not been able to locate any such document but has concluded that the practice of nonreading of badges stopped by the end of 1970 and "earlier for some buildings" (NIOSH 2007b, p. 4).

It is possible that the nonreading of badges of at least some workers started earlier than 1969 and continued later than 1970, as evidenced by the case of a secretary who had blanks in her dosimetry record from 1963 to 1973 (November 6, 2006, working group meeting transcript, pp. 76-78). This raises the possibility that the 1969 policy change was a formalization or continuation of an earlier practice that may have affected a smaller number of workers. However, it is also possible that the employee in question was not issued a badge and that others in a similar situation were also not issued badges even after the dosimeter and ID were combined into one badge in 1964 (see Chapter 8).

In summary, based on information in dosimetry correspondence, Rocky Flats implemented a practice of not reading the assigned quarterly dosimetry badges of nonplutonium workers in the first quarter of 1969. As NIOSH has stated, the Dosimetry Program addresses unprocessed dosimeters by recording zeros on the logsheet and/or arrowing down the page, with zeros

recorded at the top. Figure 4-1 is an example of a logsheet that shows arrowing down the page. The evaluation of 19 claimants with data gaps in the year 1969 determined that the HIS-20 and Dosimetry History by Individual data files contain zeros in cases where badges were not read, contributing to the significant increase in the number of zeros from 1968 to 1969. This brings into question the integrity of those data records and partially substantiates worker claims that RFP recorded zeros when badges were not read (and not just when they were not handed in).

The individuals whose badges were not read were assigned to "nonplutonium" areas as defined by Rocky Flats Radiological Control staff. As shown in Table 4-3, many of these individuals were located in uranium areas where uranium was handled or processed (e.g., 444, 881, and 883). Others were employees who were housed in nonplutonium areas or administrative buildings but visited radiological areas (including plutonium areas) as a part of their job responsibilities.

To further evaluate the exposure of nonplutonium area workers, SC&A compared doses from the fourth quarter 1968 Dosimetry Processing sheet and the first quarter 1969 Dosimetry Processing sheet for 18 individuals. The individuals were assigned to Buildings 111, 331, 441, 444, or 883 during this period. The policy of not reading nonplutonium area badges was implemented in the first quarter of 1969. SC&A compared the logsheets for the fourth quarter 1968 and first quarter 1969. Table 4-3 provides the results of this comparison. Table 4-4 contains the recorded doses for the fourth quarter 1968 and first quarter 1969 from the HPERER in the health physics file. Figures 4-2 and 4-3 are examples of the fourth quarter 1968 logsheets and the first quarter 1969 logsheet. With a few exceptions, the same individuals are included on both sheets. All individuals were on a quarterly exchange cycle, and there was no indication of a late or unreturned badge. The results from the 1969 first quarter logsheet were all zeros or zero with an arrow down the page. As the table and the figures show, doses were not zero in the fourth quarter of 1968 prior to the implementation of the no-read policy. This review also indicated that although badges were not read in the first quarter of 1969, the individual may have readings for later quarters. In these cases, the annual dose for 1969 would reflect the dose from the quarters when badges were read. This implies that gaps in 1969 can occur for only a portion of 1969. Hence, the problem of zeros in the 1969 data record when badges were not read is larger than that indicated when only blanks for the entire year are considered.

External dose exposure potential, notably shallow external dose in some uranium areas, could be very high. This is noted in the Rocky Flats site history (Putzier 1982):

> *In earlier years in handling large quantities of depleted uranium, and to some extent this is true in more recent years, we did have a significant radiation control problem in Building 444. This was not experienced so much in the machining areas but in the part of the foundry operations we call burnout and breakout. Castings were removed by breaking them out of the molds. This operation and the recovery of the material from the casting and handling the molds themselves resulted in very high beta radiation levels. There was an extremely high level of beta radiation associated with this because the first two daughters of ^{238}U are beta emitters and during the molten state of the uranium there is a tendency for*

> *these two daughters to flow to the top and also to show up at the interface of the uranium and the mold itself thereby enhancing the amount of beta radiation coming off from the chunk of the material. We used to use as a rule of thumb that clean uranium metal in equilibrium with at least its first two daughters would give off on the order of 200 mrad per hour beta radiation at the surface of a piece of the metal. This went up by at least an order of magnitude and probably more than that. We can say that we saw readings as high as 2000 to 3000 mrad/hr on castings of depleted uranium that were in the foundry area. Then, too, the dusts which were generated in the burnout and breakout areas settled on various pieces of equipment and from that there were additional beta radiation fields generated. This also resulted in excessive dust in the atmosphere. The housekeeping of these areas was indeed a very important control problem, and as I recall, in those days was handled very well. (Putzier 1982, pp. 74–75 of the pdf file)*

This description of radiological conditions in at least some uranium areas from the 1950s into the early 1980s (though apparently with less intense problems in the later years) shows that external shallow dose rates in some uranium areas were very high—much higher than the theoretical maximum of about 240 mrad/hour contact dose with U-238 metal in equilibrium with Th-234 and Pa-234m. The high dose rates and non-zero doses mean that the zeros that were entered in place of blanks for unread badges cannot be generally interpreted as LOD or LOD/2. NIOSH has made this interpretation in at least some dose reconstructions as revealed by the data completeness evaluation performed by SC&A. These issues, including the locations and periods where there are the largest gaps in dosimetry data, are discussed in more detail in Section 8.0 on completeness of data.

The nonreading of badges and input of zeros in the data records, including the HIS-20 database, in place of blanks raise four distinct issues of data integrity:

- Not reading badges that were issued is not consonant with sound practice, especially since at least some of the workers concerned were known or should have been known to have prior exposures above the LOD of the badge. Throwing away the badge after a few weeks converted a problem of unsound practice to a problem of data integrity because it obviated any possibility of verifying the low exposure assumed in initiating the practice.

- While the practice of not reading badges may have been intended to minimize the work of reading badges of workers judged to have low exposure potential, the facts relating to at least some nonplutonium work indicate that this was an erroneous belief, notably for shallow dose. The practice of nonreading of badges that were issued appears to support a claim in the SEC petition that workers with significant exposure potential had zeros entered in their badge records. This is not a statement about the ability to fill the gaps using a suitable method. Rather, it is a statement about the integrity of the data record in its own right, independent of exposure potential.

- Entry of zeros in some data records when the badges were not read, and were in fact discarded, raises questions about the integrity of the data recording practices. SC&A has

found no evidence of intent to fabricate data. However, SC&A also notes that a record containing zeros for badges that were not read is fundamentally flawed inasmuch as the records do not correspond to the reality of the working conditions of at least some of the affected workers. That part of the record for 1969 and 1970 does not meet the test of scientific integrity of data as it is commonly understood.

- Some workers whose badges were not read appear to have worked in plutonium areas even though their formal assignments shown on the Dosimetry Processing Logs are to nonplutonium areas. Nonreading of such badges, especially during the post-fire period, necessitates the use of appropriate coworker data, which appear to be available.

Conclusions

Based on their analyses of the problem, SC&A and NIOSH concur that there are gaps in the 1969 external dosimetry data for some workers. A significant part of the problem arises from the policy of not reading quarterly badges (with some possible exceptions) instituted in 1969. The practice continued into 1970 as discussed above.

SC&A has concluded that the integrity of at least a portion of the 1969 and 1970 dose record has been significantly compromised by the practices discussed above. During the March 7, 2007, Advisory Board working group meeting, the director of OCAS, Larry Elliot, characterized the zeros entered for the badges that were not read as "bad data" and suggested that affected workers be considered "unmonitored" with no recorded dose for the time periods involved (Rocky Flats working group meeting, March 7, 2007. SC&A concurs with this assessment.

There are indications that the policy of not reading issued badges stopped by the end of 1970. However, NIOSH cited the nonissuance of badges to some prime contractor employees as an explanation for the case of the secretary who had blanks in the dosimetry record from 1963 to 1973 (inclusive). An investigation is needed to determine whether badges were not issued to workers who were assessed to have low exposure potential or whether they were issued and not read as a matter of informal policy (which was formalized in the first quarter of 1969). In either case, the dose reconstruction for workers with gaps outside of 1969 and 1970 should take into account that the gaps cannot be treated as being equivalent to missed dose (i.e., a badge reading below the LOD).

As discussed in the completeness evaluation (Section 8.0), it appears possible to construct coworker models to bound adequately the dose for workers affected by gaps in their dosimetry records. Either the existing coworker model must be demonstrated to be bounding for the specific times and working conditions involved or new coworker models need to be developed. Since the nonreading of badges in 1969 and 1970 occurred primarily for a worker population similar to the one not badged earlier, the development of appropriate methods to fill the gaps should be possible.

SC&A recommendation regarding zero entries to replace gaps: SC&A recommends that all zeros entered when badges were not read be dropped from the data record and the gaps be identified as such. This would ensure that fundamentally flawed data are not being used in dose reconstruction. The dose reconstruction should use coworker data that bound the dose that would have been received in the working conditions in the specific jobs being done by the employees affected by the gaps in 1969 and 1970. Gaps from other periods, due to nonissuance or nonreading of badges, should be treated in the same way. NIOSH must demonstrate that the selected approach(es) bound the dose for the affected members of the class.

4.3.2 Problems with Gaps, No Reading, No Current Data Available, and Zero Entries

In the evaluation report concerning SEC-00030, NIOSH explains the data entries of (1) No Reading, (2) No Current Data Available, or (3) a Zero Entry. The response explains that a missed dose (based on LOD) will be assigned for this period and the total dose recorded at the end of the next period, effectively increasing the total recorded dose.

Data entries of "No Reading," "No Current Data Available," or "Zero" have been an area of controversy during the evaluation of this SEC, even if the dose is actually recorded later in the records. If the dosimeter is actually worn for two periods and then read and recorded, the suggested NIOSH procedure represents a claimant-favorable approach. However, there is no way to be certain that the badge was not lost, damaged, or unreturned if the dose of record shows No Reading, No Current Data Available, or Zero, and the worker's file contains no other information concerning the data entry. Assigning a missed dose based on LOD is not acceptable for lost, damaged, or unreturned badges, as it in no way reflects the actual dose received. Assignment of dose based on adjacent readings is possible, if there are no incidents/accidents (such as fires) during the unmonitored periods to create abnormal exposures.

SC&A's review of 52 claimant files for completeness of data throws additional light on this question. The details are discussed in Chapter 8. For purposes of the external dose coworker model, we note that the SC&A review found significant gaps in internal and external dose records. It is likely that the internal dose gaps can be filled since the data for workers with high cumulative dose did not reveal year-long monitoring gaps. However, external dose data for non-plutonium workers in the 1950s have significant gaps, even among some workers with high cumulative exposure.

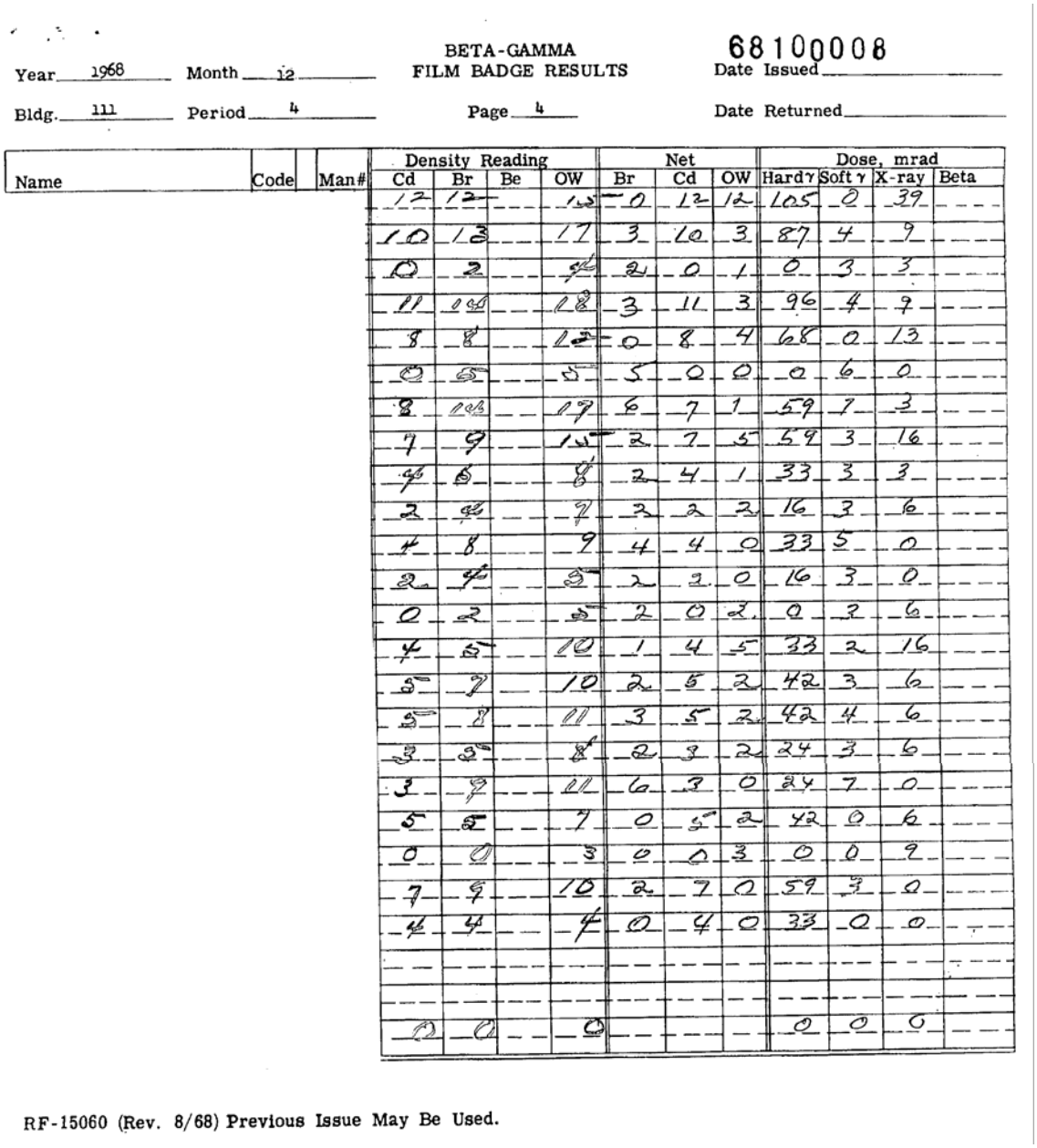
SC&A Evaluation: SC&A concludes that No Reading, No Current Data Available, or zero entries from badges that were worn for two exchange periods do not present an SEC issue for the most part. It remains for NOSH to demonstrate either (1) that the external dose coworker model bounds the dose the nonplutonium workers in the 1950s, or (2) that there are sufficient data for those workers in the 1950s to develop supplementary models that can bound their individual doses.

Table 4-3. A Comparison of Data Sources for Claimants with 1969 Gaps

ID	Job Title	Bldg	Occupational Dose Report 1969	Dosimetry History by Individual 1969	HPERER 1968	HPERER 1969	HPERER 1970	HIS-20 1969	In Vitro 5/11/1969–12/31/1969	In Vivo 5/11/1969–12/31/1969
1	Inspector		Null	N/A	Skin Only	Null	14	0	N	N
2	Maintenance Electrician		No 51-79 datasheet	N/A	362	Null	0	0	N	N
3	Mechanical Maintenance		No 51-79 datasheet	0	14	Null	0	0	N	Y
4	Accountant		Null	0	Null	Null	0	0	N	N
5	Cost Accountant		Null	0		Null	0	0	Y	N
6	Mechanical Development		Null	0	92	Null	23	0	N	N
7	Truck & Labor		Null	0	35	Null	0	0	N	Y
8	Civil Engineer		Null	0	10	Null	0	0	N	N
9	Tool Engineering		Null	0	Skin Only	Null	0	0	N	N
10	QA Inspector		Null	N/A	7	Null	0	0	Y	Y
11	Sr. Material Specialist		Null	0	24	Null	26	0	N	N
12	QC Inspector		Null	N/A	171	Null	0	0	Y	N
13	Production Eng		Null	N/A	38	Null	150	0	Y	Y
14	Facility Engineer		No 51-79 datasheet	N/A	137	Null	19	0	N	N
15	Sr. Fire Protection Engineer		Null	0	14	Null	0	0	Y	N
16	R & D Engineer		Null	N/A	187	Null	144	0	Y	N
17	Sr. Research Mgr.		Null	N/A	Skin Only	Null	188	0	Y	N
18	Inspector		Null	N/A	8	Null	55	0	N	N
19	Fireman		Null	0	23	Null	77	0	Y	Y

Table 4-4. Nonplutonium Area Worker Dose for Fourth Quarter 1968 and First Quarter 1969

ID	Job Title	Work Location	Dosimetry Log Gamma Dose Q4 1968	Dosimetry Log Beta Dose Q4 68	HPERER Deep Dose Q4 1968	HPERER Shallow Dose Q4 1968	HPERER Deep Dose 1969	HPERER Shallow Dose 1969	In Vitro for 1969
101	Electrician		33	95	33	128	Null	Null	N
102	X-Process Opr		142	1240	142	1382	Null	Null	Y
103	Journeyman Machinist		33	1880	33	1913	Null	Null	Y
104	Journeyman Machinist		96	300	96	551	Null	Null	Y
105	Tool Grinder		16	95	16	111	Null	Null	Y
106	Journeyman Machinist		16	95	16	111	Null	Null	Y
107	Journeyman Machinist		16	125	16	141	Null	Null	N
108	Journeyman Machinist		42	80	42	122	Null	Null	Y
109	Inspector		42	80	42	122	Null	Null	N
110	Journeyman Machinist		33	50	33	83	Null	Null	N
111	Mtce Machinist		42	80	48	62	Null	Null	N
112	Journeyman Machinist		16	95	16	111	Null	Null	N
113	Sr. Industry Photographer		74	77	75	77	Null	Null	N
114	Advanced Facility Engineer		137	139	137	139	Null	Null	N
115	Vehicle Driver		164	173	167	173	Null	Null	N
116	Designer I		89	98	92	98	Null	Null	N
117	Equipment Opr		222	632	222	632	Null	Null	Y
118	Equipment Opr		152	832	152	832	Null	Null	Y



BETA-GAMMA
FILM BADGE RESULTS

68100008

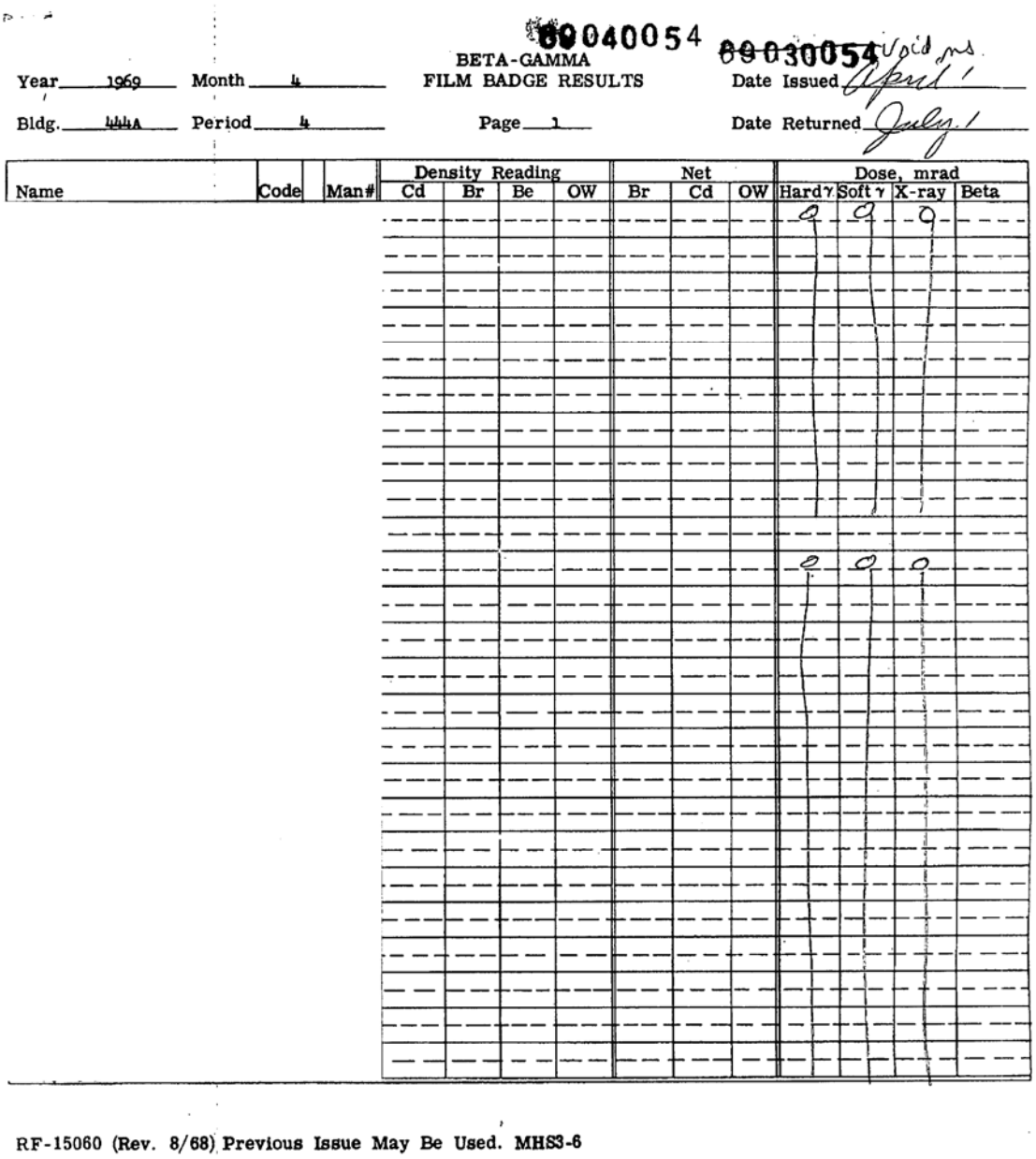
Year 1968 Month 12 Bldg. 111 Period 4 Page 4 Date Issued Date Returned

Name	Code	Man#	Density Reading Cd	Br	Be	OW	Net Br	Cd	OW	Dose, mrad Hard γ	Soft γ	X-ray	Beta
			12	12		14	0	12	12	105	0	39	
			10	13		17	3	10	3	87	4	9	
			0	2		4	2	0	1	0	3	3	
			11	14		18	3	11	3	96	4	7	
			8	8		12	0	8	4	68	0	13	
			0	5		5	5	0	0	0	6	0	
			8	14		17	6	7	1	59	7	3	
			7	9		14	2	7	5	59	3	16	
			4	6		8	2	4	1	33	3	3	
			2	4		7	2	2	2	16	3	6	
			4	8		9	4	4	0	33	5	0	
			2	4		5	2	2	0	16	3	0	
			0	2		5	2	0	2	0	3	6	
			4	5		10	1	4	5	33	2	16	
			5	7		10	2	5	2	42	3	6	
			5	8		11	3	5	2	42	4	6	
			3	3		8	2	3	2	24	3	6	
			3	9		11	6	3	0	24	7	0	
			5	5		7	0	5	2	42	0	6	
			0	0		3	0	0	3	0	0	9	
			7	9		10	2	7	0	59	3	0	
			4	4		4	0	4	0	33	0	0	
			0	0		0				0	0	0	

RF-15060 (Rev. 8/68) Previous Issue May Be Used.

Figure 4-1. Example Logbook Sheet with Zeros Followed by Arrowing Down

Fourth Quarter 1968 Dosimetry Logsheet for Individuals on a Quarterly Cycle from Building 111



00040054 ~~00030054~~ Void ms

BETA-GAMMA
FILM BADGE RESULTS

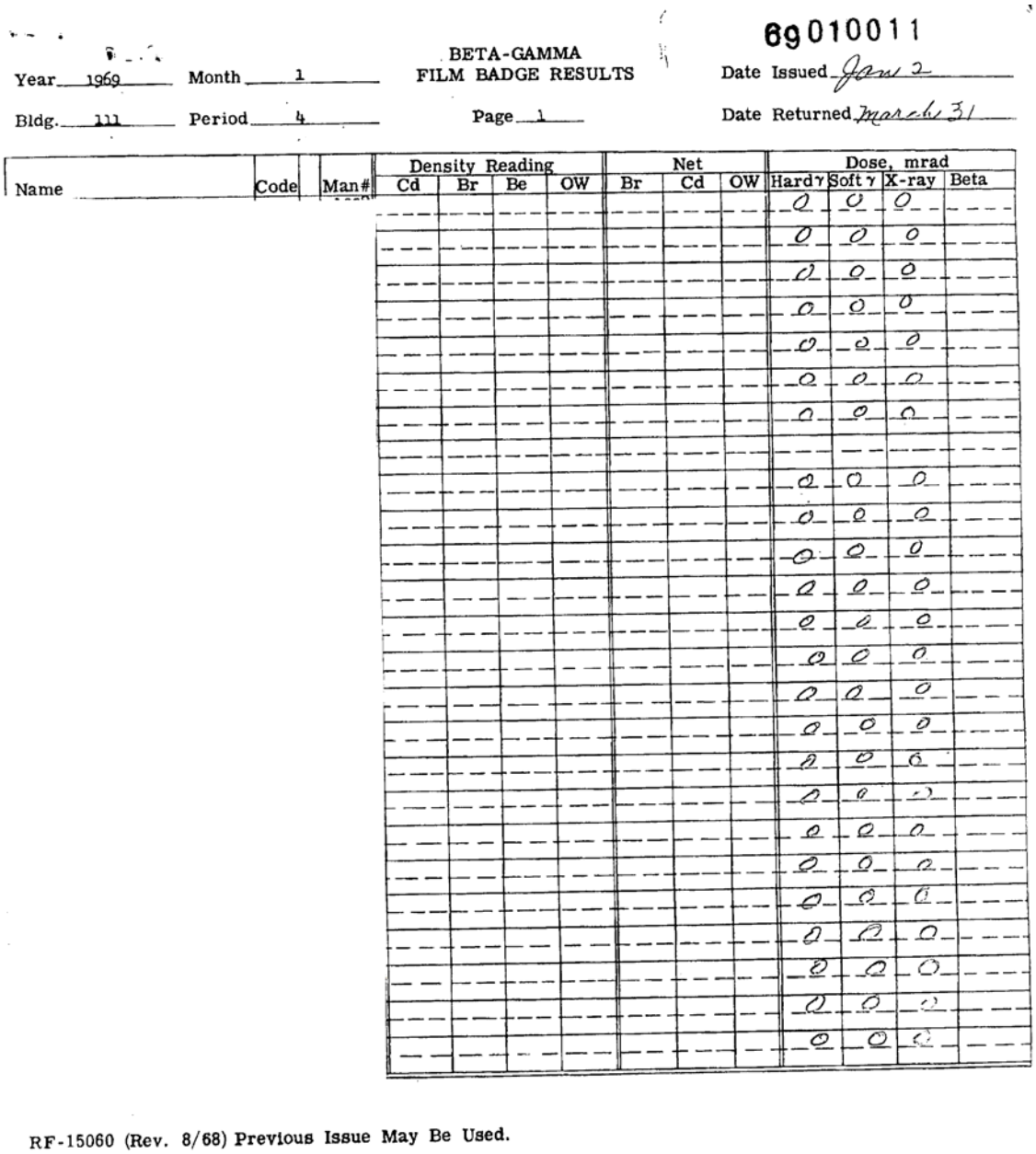
Year 1969 Month 4 Date Issued April 1

Bldg. 444A Period 4 Page 1 Date Returned July 1

Name	Code		Man#	Density Reading Cd	Br	Be	OW	Net Br	Cd	OW	Dose, mrad Hard γ	Soft γ	X-ray	Beta
											0	0	0	
											0	0	0	

RF-15060 (Rev. 8/68) Previous Issue May Be Used. MHS3-6

Figure 4-2. Fourth Quarter 1968 Dosimetry Logsheet for Individuals on a Quarterly Cycle from Building 111



BETA-GAMMA
FILM BADGE RESULTS

69 010011

Year 1969 Month 1 Page 1

Bldg. 111 Period 4

Date Issued Jan 2

Date Returned March 31

Name	Code	Man#	Density Reading Cd	Br	Be	OW	Net Br	Cd	OW	Dose, mrad Hard γ	Soft γ	X-ray	Beta
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
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										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	
										0	0	0	

RF-15060 (Rev. 8/68) Previous Issue May Be Used.

Figure 4-3. First Quarter 1969 Dosimetry Logsheet for Individuals on a Quarterly Cycle from Building 111

4.3.3 Average Worker, Not Maximum Exposed, Monitored Prior to 1964

Another area of data credibility and consistency concern is the fact that page 65 of the evaluation report (NIOSH 2006a) states that in the early 1950s, only groups expected to receive doses greater than 10% of the Radiation Protection Guidelines (called the "threshold dose") received dosimeters. However, this type of badging policy would indicate that the most exposed workers were badged and the number of zero entries would be minimal. If this were true, then in 1964 when the decision was made to badge more workers, presumably with lower exposures, the number of zero entries should have increased noticeably. However, Table 4-1 shows that during the 5-year period of 1959–1963 (before 1964), the average number of zero entries was 10.0% vs. 9.7% for the 5-year period for 1964–1968. This would indicate that workers who were not monitored before 1964 were similar to those who were monitored, at least so far as potential for exposure over the LOD was concerned. NIOSH did provide a recent report concerning RFP external badging practices. While this report does a good job of summarizing the badging policies, it does not add significant information for the period of most concern (1952–1963). (See Attachment 7 for NIOSH's report and SC&A's evaluation.)

SC&A Evaluation: This is a site profile issue, not an SEC issue, apart from the caveat relating to nonplutonium workers in the 1950s noted in Section 4.3.2. However, the use of dose data that is considered the result of monitoring the maximum exposed, when it actually reflects average exposures, could bias the coworker data to low values and result in underestimation of the doses of unmonitored workers. This applies to both photon and neutron exposures.

SC&A Conclusions Regarding RFP Data Credibility and Consistency: SC&A has concluded that for the most part NIOSH has sufficient data and methods to perform external **photon** dose reconstruction with sufficient accuracy under 42 CFR Part 83. However, it remains for NIOSH to demonstrate that it can adequately bound external shallow and deep dose for all nonplutonium workers in the 1950s. Furthermore, several areas could lead to an SEC issue concerning **neutron** doses, as detailed in the following sections.

4.4 DATA AVAILABILITY AND SUFFICIENCY FOR COWORKER MODEL

External dose data are available for many workers at RFP for 1952–2006. However, some situations where dose data are not readily available may cause an underestimate of worker dose. This section discusses several areas of concern.

4.4.1 Analysis of Data to Determine Applicability to Early Unmonitored Workers

The Advisory Board's February 2006 working group meeting in Boston initially addressed the issue of completeness of external exposure data. NIOSH responded to SC&A's concern in the site profile review (SC&A 2005d, Section 5.11.2, pp. 102–104) in a brief summary provided at that meeting. At the meeting, NIOSH stated, "For those individuals who are not badged, the dose reconstruction process uses documented unmonitored dose techniques to estimate dose." The two main areas of SEC concern are the early neutron dose entries used for coworker data in ORAUT-OTIB-0058 and the increase in the percentage of zero entries during 1969–1970 (the

latter is addressed in Section 4.3.1). ORAUT-OTIB-0058 outlines the recommended procedures for using coworker dose data to assign external doses to unmonitored workers at RFP. NIOSH refers to this document and related documents in its evaluation of SEC-00030. Tables 7-1 and 7-2 of ORAUT-OTIB-0058 (Smith 2007) provide averaged coworker data for each year. Note that ORAUT-TKBS-0011-6, Revision 01 (Langsted 2007), was issued February 8, 2007, and ORAUT-OTIB-0058, Revision 01 (Smith 2007), was issued January 8, 2007 (Revision 02 may be issued in the near future). This complicates SC&A's evaluation of the previously issued (April 2006) NIOSH evaluation report of the SEC. Therefore, this report attempts to blend the information contained in these time-sensitive documents into an evaluation that is as current as possible, but could be subject to change in the future, because of the fluidity of the situation.

During its investigation, SC&A found that dose monitoring at RFP falls into four major time frames; therefore, it is most effective to address the issues in each of these time periods. The following summarizes SC&A's current understanding of the proposed neutron and related photon dose reconstruction procedures used by NIOSH for RFP workers for the time periods 1952–1958, 1959–1969, 1970–1976, and 1977–2005. This is followed by SC&A's evaluation of the issues for each time period, especially as they relate to the SEC.

(Note: According to ORAUT-OTIB-0058, when using data from the tables for any of these time periods, the 95th percentile values are to be applied to workers who were likely to have been exposed to radiation, and the 50th percentile values are to be applied to workers who may have been intermittently exposed to radiation. If a worker was unlikely to have been exposed to radiation (e.g., work locations were away from the laboratory buildings that contained radioactive materials), then only the ambient dose will be assigned.)

1977–2005

The following is SC&A's present understanding of NIOSH's recommended procedure for determining neutron and related photon doses for this period when neutron and photon doses for monitored workers were measured using TLDs and were recorded as separate doses:

- Neutron and photon doses will be assigned as per DOE dose records measured by TLD monitoring.

- If neutron monitoring results are not available, an n/p value of 0.42 will be applied to the total of the measured photon plus the assigned missed-photon dose to determine the neutron dose. The n/p value of 0.42 was obtained from the TLD badge results of 1977–2000, as detailed in ORAUT-OTIB-0050, page 8, and will be applied to all work locations.

- If neither neutron or photon monitoring results are available, the worker will be assigned a coworker photon dose each applicable year, as provided in ORAUT-OTIB-0058, Table 7-2, and a corresponding neutron dose as provided in that table, which is 0.42 times (photon dose–the missed dose). Table 7-1 of ORAUT-OTIB-0058 provides the total of the photon plus the neutron dose obtained from Table 7-2.

SC&A's Evaluation: This approach has no known SEC issues. The applicability of using a single n/p value of 0.42 for all years during 1977-2005 and for all work locations could be a site profile issue, but not an SEC issue.

1970–1976

The following is SC&A's present understanding of NIOSH's recommended procedure for determining neutron and related photon doses for this period when the original dose data were stored as a composite neutron plus photon dose value:

- Composite (neutron + photon) doses measured by TLD/film monitoring will be obtained from DOE dose records, if available. Neutron and gamma doses will be separated out from the DOE recorded composite dose by using the separate photon and neutron data contained in the Health Physics TLD Badge Reports for that worker for each monitoring period. The worker's external dose will be assigned according to the separate neutron and photon doses.

- If the worker's composite dose is available, but the separate photon and neutron data are not available, then the n/p values in Table 6-2 of ORAUT-OTIB-0058 will be used to separate out the neutron and photon doses from the DOE-recorded composite dose. The geometric mean (GM) n/p values in Table 6-2 were obtained from the neutron and photon dose data contained in the Health Physics TLD Badge Reports; they range from 0.67 to 1.61, with an overall average of approximately 1.0 for the 5 years of real data (1971, 1972, 1974, 1975, and 1976). For 1970, 1971 was used, and 1972 was used for 1973, because reliable data were not available for those 2 years. The worker's external dose will be assigned according to the separated neutron and photon doses.

- If the composite dose is not available, the worker will be assigned a coworker photon dose for each appropriate year, as provided in Table 7-2 of ORAUT-OTIB-0058 and a corresponding neutron dose as provided in that table, which is based on the n/p value for that year from Table 6-2 of ORAUT-OTIB-0058. Table 7-1 of ORAUT-OTIB-0058 provides the total of the photon plus the neutron dose obtained from Table 7-2. The worker's external dose will be assigned according to the separate neutron and photon doses.

SC&A's Evaluation: This approach has no known SEC issues. The applicability of using a single n/p value each year for all work locations during 1970–1976 could be a site profile issue, but not an SEC issue.

1959–1969

The following is SC&A's present understanding of NIOSH's recommended procedure for determining neutron and related photon doses for this period when some, but not all, workers were monitored with photon and NTA film badges. The NTA films were reread in the NDRP

project for this period. The n/p values for different buildings (mainly plutonium-related) for the years 1959–1969 were calculated and are presented in Table 11.1 of the NDRP Report using the results of matching pairs of neutron and photon film results. These n/p values range from 0.3 to 10, with an average value of approximately 2 (n/p=10 is noted as an upper bound and not an actual measured value).

- For workers who were monitored for both neutrons and photons, doses will be assigned as per DOE dose records, which were measured by photon and NTA film badges, and modified as appropriate using NDRP results.

- If neither original neutron dose readings nor NDRP reread results are available, the n/p values in Table 11.1 of the NDRP will be applied to the total measured photon dose to determine the neutron dose according to the appropriate year and building. When there were gaps in the photon monitoring, NDRP notional neutron doses were not assigned during that period. If the worker was not in one of the listed buildings (Buildings 71, 76, 78, or 91), or the work location cannot be verified, the worker will be assigned a neutron dose based on the n/p value for buildings in the "All Others" category. The average n/p values for the "All Others" building category are approximately 75% of the values for the listed buildings.

- If neither neutron or photon monitoring results are available, the worker will be assigned a coworker photon dose each year, as provided in Table 7-2 of OAUT-OTIB-0058 and a corresponding neutron dose, as provided in that table, which is based on the measured coworkers' photon doses (but excludes any assigned missed doses) and n/p values for "All Other" buildings from Table 11.1 of the NDRP Report (ORISE 2005). Table 7-1 of ORAUT-OTIB-0058 provides the total of the photon plus the neutron dose obtained from Table 7-2.

It is SC&A's present understanding from information obtained from NIOSH that for the period 1959-1969, the NDRP reread-and-dose-assignment project involved the reevaluation of all available NTP/NTA badges for plutonium workers and all other workers including those at criticality facilities and calibration facilities and any in uranium or other areas.

SC&A's Evaluation: Although this approach has no known SEC issues, there are several areas of caution:

- Using the "All Others" building category of n/p values may result in assigned neutron doses (from either the known photon dose or from Table 7-2 of ORAUT-OTIB-0058) that are less than those that would be obtained from using the n/p values from buildings with numbers listed in Table 11.1 of the NDRP.

- The issue related to the increase in the number of zero entries during 1969–1970 and the data gaps during that period is a separate concern, which is addressed in Section 4.3.1.

1952–1958

The following is SC&A's present understanding of NIOSH's recommended procedure for determining neutron and related photon doses for this period when a few of the workers were monitored with both photon and NTP/NTA films badges. The NTP/NTA films were reread in the NDRP project for this period. There were insufficient paired neutron and photon results to create reliable n/p values for each year of this time period. Therefore, the NDRP recommends applying the n/p values derived for 1959 in Table 11.1 of the NDRP to the time period 1952–1958. These n/p values range from 0.6 to 3.6 (depending on building location), with an average value around 1.6.

- For workers who were monitored for both neutrons and photons, doses will be assigned as per DOE dose records measured by photon and NTP/NTA film badges and modified as appropriate using NDRP results.

- If neutron monitoring results are not available, the n/p value for 1959 in Table 11.1 of the NDRP will be applied to the total measured photon dose each year to determine the neutron dose according to the appropriate building. When there were gaps in the photon monitoring, NDRP notional neutron doses were not assigned during that period. If the worker was not in Buildings 71, 76, 78, or 91, or the work location cannot be verified, the worker will be assigned a neutron dose based on the n/p value for the "All Others" building category. The n/p value of 1.2 for the "All Others" building category is approximately 75% of the values of the numbered buildings listed.

- If neither neutron or photon monitoring results are available, the worker will be assigned doses as follows (per ORAUT-OTIB-0058, Rev. 01, dated January 8, 2007):

  – Plutonium worker—The worker will be assigned a coworker photon dose each appropriate year, as provided in Table 7-2 of ORAUT-OTIB-0058, and a corresponding neutron dose as provided in that table, which is based on the measured coworkers' photon doses (but excludes any assigned missed doses) and on the n/p value for "All Others" buildings of 1.2 for 1959. Table 7-1 of ORAUT-OTIB-0058 provides the total of the photon plus the neutron dose obtained from Table 7-2. This is the same procedure as used for the 1959–1969 time period.

  – Nonplutonium worker—The worker will be assigned a coworker photon dose for each appropriate year, as provided in Table 7-3 of ORAUT-OTIB-0058, which excludes NDRP data, i.e., for uranium and other workers. (This procedure may change with Revision 02 of ORAUT-OTIB-0058 (see details below).) Neutron dose will not normally be applied to nonplutonium workers. If the unmonitored worker could have been exposed to neutrons, Table 7-2 for plutonium workers will be used.

SC&A's Evaluation: During the evaluation of this SEC report, SC&A requested, and very recently received, some separated external neutron and photon annual dose data listed by **individual** RFP workers. SC&A has based its evaluation on this available dose data, n/p values,

and NIOSH's recommended dose reconstruction procedures. The following is SC&A's present understanding of the information provided by NIOSH for the period 1952–1958:

- The NDRP reread-and-dose-assignment project involved the reevaluation of all available NTP/NTA badges for plutonium workers and all other workers, including those at criticality facilities and calibration facilities and any in uranium or other areas.

- Only 20 NTPs from Los Alamos National Laboratory (LANL) were available for each badge exchange for 1952-1956 and a limited number of NTA films were available for each badge exchange during 1957-1958 at the RFP. 1959 was the first year of significant badging for neutrons.

- SC&A's comparison of coworker doses derived from 1959 data with measured doses revealed that the measured doses were consistently greater than the median of the coworker dose. This indicated that the distribution of the coworker model and the monitored population is different. NIOSH agreed, stating the monitored population was that at highest risk of exposure and that these workers were in Building 91.

- The SC&A evaluation found that the highest exposures were among the badged workers in some years during the 1952–1958 period. However, in others, such as 1955 and 1956, the highest doses assigned by NDRP were greater than the highest measured doses.

- Because of the very limited quantity of neutron badges available, most of the NDRP neutron doses assigned for 1952–1958 were derived by using n/p values for 1959 from Table 11.1 through the use of notional doses using the n/p method, as opposed to actual badge readings.

- No documentation has been found that could be used to quantitatively compare the neutron doses received during 1952-1958 to the recommended neutron dose assignment derived from 1959 data. Therefore, the assigned NDRP doses for the 1952–1958 period are of questionable validity, as is the coworker model.

During SC&A's phone conference with NIOSH on February 14, 2007, NIOSH indicated that because of the uncertainties associated with the derivation of the data in Table 7-3 in ORAUT-OTIB-0058 for nonplutonium workers, this table may be deleted, and all dose reconstructions for unmonitored workers (regardless of plutonium, uranium, or other work locations) will use Tables 7-1 and 7-2. Therefore, Table 7-3 and the related Table 7-6 for construction trade workers (CTWs) can be removed, and Revision 2 of ORAUT-OTIB-0058 will be issued in the near future. This change will simplify the dose reconstruction process while remaining claimant favorable without excessive dose assignment. However, one area of concern is that the nonpenetrating doses listed in Table 7-1, and perhaps the related Table 7-4 for CTWs, could underestimate nonpenetrating dose for uranium workers. Section 8 of this report provides additional details concerning this subject.

4.4.2 Use of Neutron-to-Photon Ratio Values

NIOSH has recommended using n/p values to assign neutron doses from records that contain composite photon and neutron doses (1970–1976) and to assign neutron doses to unmonitored workers (1952–2005). The preceding section that describes NIOSH's recommended dose reconstruction processes for the time periods 1952–1958, 1959–1969, 1970–1976, and 1977–2005 provides some details of this process.

SC&A's Evaluation: To provide an objective view of the entire external dose data and coworker model using n/p values, the following tables list a summary of the average n/p values as a function of time periods. The values in Table 4-5 indicate a general trend of increasing n/p as neutron-emitting sources came on site, followed by decreasing n/p values as time progresses, which would be expected as knowledge of neutron radiation advanced (i.e., 1959 $\simeq$ 1.5, 1959–1969 $\simeq$ 2, 1970–1976 $\simeq$ 1.2, 1977–2000 $\simeq$ 0.4). However, the 1952–1958 n/p value of **1.2** (ORISE 2005, Table 11.1, column for "All Others" for 1959), which is used in separating photon and neutron doses in Table 7-2 of ORAUT-OTIB-0058, is noticeably less than the average n/p values (**2.0** and **4.9**) in Table 4-6, which are calculated from NIOSH's sampling of dose data in *RFP NP Ratios using NPRD Data for 53–58* and contained in the summary sheet of that file.

Table 4-5. Average n/p Value vs. Time Period, 1952–2005 as per ORAUT-OTIB-0050, ORAUT-OTIB-0058, and NDRP

	1952–1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977–2005
Average of Pu-buildings	1.6	1.6	2.7	2.6	1.5	1.5	1.7	1.3	0.6	0.9	1.2	2.8	1.6	1.6	1.3	1.3	0.7	0.7	1.0	0.4
"All others"	1.2	1.2	1.8	1.8	2.3	2.3	3.0	0.9	0.5	0.6	1.2	1.5	1.6	1.6	1.3	1.3	0.7	0.7	1.0	0.4
Source	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	NDRP	HP	HP	HP	HP	HP	HP	HP	1977–2000 TLD

Notes: 1959 n/p values used for 1952–1958, NDRP.
1962, 1963, and 1964 n/p average values exclude upper-bound value of 10 for Building 91.

Table 4-6. Average Actual Workers' n/p Values from NIOSH's Summary Sheet from RFP Neutron-to-Photon Ratios Using NDRP Data for 1953–1958 File

	1952	1953	1954	1955	1956	1957	1958	Math average	Wt. average
Building #71	-	-	-	-	-	0.4	2.7	1.5	2.0
Building #91	3.8	5.3	-	4.8	11.9	2.3	5.9	5.7	4.9

The n/p values used to calculate the NDRP "notional doses" for the workers during gaps in their neutron monitoring data in 1952–1969 dose records were based on the location of the worker during each year and came from Table 11.1 of the NDRP Report (ORISE 2005). This would result in a range of n/p values from 0.3 to 10 (10 being an upper bound, not a measured value), with an average value of around 2.

The information available illustrates that the n/p values vary greatly between buildings and from year to year for the period 1952-1969 as illustrated in the above tables and in Table 11.1 of the NDRP report. No technical basis has been found to verify if these fluctuations are real (i.e., resulting from physical changes) and are therefore valid, or if some of them are artifacts introduced as the result of other variables that do not concern neutron dose (e.g., changes in badging policies, changes in Am-241 content, etc.). Furthermore, Figure 1.1 (ORISE 2005, p. 111) shows that individual n/p ratios from paired data could range from ~0.1 to ~40 in a single year.

Some 1952–1958 neutron dose data, with individual dose identifiers, which very recently became available, allow several preliminary benchmark comparisons to be made. These comparisons consisted of comparing the measured n/p values to those in Table 11.1 of the NDRP Report and measured neutron doses to those contained in Table 7-2 of ORAUT-OTIB-0058 (which were derived by using an n/p value of 1.2 from Table 11.1 of the NDRP Report). Not many measured values were available, but there were enough to allow some comparisons. This very limited analysis indicates that the 50th percentile should not be used for any significant neutron exposure potentials. In its initial investigation, SC&A found that the proposed coworker neutron dose was less than the measured neutron dose 25 time out of 25 times at the 50th percentile level and 6 out of 25 times at the 95th percentile level. The results of these comparisons indicates that the neutron dose distribution function for the early **monitored** workers (which had a high potential for neutron exposure) is not the same as the neutron dose distribution function derived from coworker's data used to construct the tables in OTIB-0058. The early monitored workers were selected to wear the limited number of badges because of their high potential for neutron exposures. Therefore, a direct comparison cannot be made between the early monitored group and the average radiation worker in 1959. Page 24 of the NDRP states, "The N:G building ratios were determined starting in 1959. For the preceding years (1952–1958), the values for 1959 were used without modification, since no other information was available to justify modifying the values." According to NIOSH (NIOSH 2006n), no documentation and/or data has been located that will allow for the direct comparison of the neutron doses received during 1952–1958 to the doses that were assigned by the NDRP project or will be assigned using the coworker data in ORAUT-OTIB-0058. In other words, there is no way to validate the coworker model for the 1952–1958 period. Roger Falk, NIOSH's site expert for Rocky Flats, stated that the NDRP had tried to validate the model for the 1952–1958 period, but could not find any data to do so.

SC&A performed a check to see if the most exposed badged workers in the 1952–1958 period had consistently higher neutron doses than the neutron doses assigned to those with exposure potential by the NDRP project; however, the results were mixed. In some cases, the measured doses were the highest, while in others, the assigned doses were the highest.

Because of the lack of data or documentation being available to compare the 1952–1958 neutron doses to the 1959 dose data, SC&A is currently investigating the data and methods used in the NDRP Report to assign neutron doses during the period 1952–1958. A supplemental report will be issued separately from this report.

From this analysis, SC&A concludes that the methods and dose data available to NIOSH may allow for neutron dose reconstruction with sufficient accuracy for RFP workers for 1959–2005 using n/p methods. However, for the period 1952–1958, SC&A has concluded that the coworker model has not been demonstrated to be bounding. Further, the unmonitored workers with neutron exposure potential who were assigned doses as part of the NDRP may have been at higher risk in some cases and some years than the monitored workers. The data do not consistently validate NIOSH's claim that the workers with the highest exposure potential were monitored. NIOSH's approach to neutron dose assignment for the 1952–1958 period, including its coworker model, has not been demonstrated to represent a bounding dose under 42 CFR 83. This issue remains open as an SEC issue for the 1952–1958 period.

4.4.3 Evaluation of HIS-20 Database for Use in Coworker Model

The numerical dose data in the HIS-20 database has been used to populate the dose tables in the coworker models, such as ORAUT-OTIB-0058. The external dose data contained in the HIS-20 database has been an area of concern and discussion. SC&A has investigated this database and found that it does not contain all the workers' data for all monitoring periods. However, according to NISOH, this database will not be used for individual dose reconstruction but will be used in the coworker model. SC&A investigation of the HIS-20 database has revealed the following:

- A sample comparison of RFP logbook entries vs. HIS-20 data entries found that some data in the logbooks had not been entered into the HIS-20 database.

- A sample comparison of RFP Progress Report entries vs. HIS-20 data entries found that some data found in the Progress Reports were not entered into the HIS-20 database.

- The data contained in the HIS-20 database are usually the same, or greater in value, than that found in older databases.

- SC&A has reviewed NIOSH's evaluation of the data contained in the HIS-20 database compared to the original records, such as ORAU-OTIB-0058, page 6. The review found that while there are some gaps in the database, the data in the HIS-20 database are generally neutral, or claimant favorable, for use in a coworker model.

- The HIS-20 database contains only composite (neutron + photon) data.

SC&A Evaluation: SC&A has found that although the HIS-20 database is not complete for every monitoring cycle, it does contain sufficient data to allow for its use in conjunction with the

coworker model, i.e., ORAUT-OTIB-0058, to assign sufficiently accurate photon doses for under-monitored or unmonitored workers at RFP for 1952–2005. However, the use of the HIS-20 database for neutron dose assignment, through the coworker model, could lead to insufficient accuracy in neutron dose reconstruction as detailed in the n/p section of this report.

4.4.4 NDRP Applicability Concerns

The NDRP Report provides some of the QA/QC measures used during the reread process, and NIOSH has provided some analysis of the QA/QC procedures used during the NDRP process (Attachment 8).

SC&A Evaluation: SC&A reviewed the NDRP Report for content and its intended use in the site profile review and exploration of SEC issues, but it has not formally evaluated the report as a stand-alone document. SC&A's main concern at this time is not necessarily the QC used during the reread process, but the fact that some of the workers' dose data available for the NDRP process have large gaps and large periods of employment without neutron dose data. Additionally, a recent SC&A review (Attachment 6) of dose reconstruction cases at RFP revealed that a significant number of cases had relatively large gaps in their dose records ($\geq$5 years of data gaps). These findings raise the concern that data with large gaps in monitoring periods may not be valid for use in deriving n/p values, coworker models, and gap-bridging methods. Therefore, these data cannot be used as normal data but must be carefully analyzed for zero/blank entries.

4.5 NEUTRON DOSE DATA ISSUES

In the past, SC&A has expressed concern about using the NTA film calibration for the NTP dosimeters and using only one calibration for NTA film in obtaining the NDRP results. NIOSH and SC&A have discussed these issues. SC&A has assumed that all usable NTP and NTA films were included in the NDRP reread program, not just those for plutonium workers. The following is a summary of SC&A's findings on these issues.

4.5.1 Use of NTA Calibration for NTP Reread

SC&A has reviewed the NTP and NTA film reading process at LANL, which read the neutron dosimeters for RFP during 1952–1956. According to the NDRP Report (ORISE 2005, p. 15), LANL used a calibration factor of 5.55–6.68 mrem-mm^2/track for 3.35 MeV average energy neutrons and 8.33–10.4 mrem-mm^2/track for 5.0 MeV average energy neutrons for the NTPs. The NDRP reread process determined a calibration factor of 22.39–36.94 mrem-mm^2/ track, with an average of 30.86 mrem-mm^2/track for both bare (average energy of 1.4 MeV) and 7 cm of poly moderator (average energy of 0.15 MeV) from a PuF_4 source (ORISE 2005, p. 14), with an average blank reading of 2.01 mrem-mm^2/track for NTA film. A more recent 1990 LANL article, LA-11740-MS (Mallett et al. 1990), recommended using 5.6–10 mrem-mm^2/track.

SC&A Evaluation: In view of the information available, it appears that the use of the NTA calibration of an average of 30.86 mrem-mm^2/track for the reread of the NTP would be reasonable, as recommended on page 16 of the NDRP Report.

4.5.2 Use of One Calibration for NTA Film Reread

Pages 14 and 15 of the NDRP Report present results indicating that NTA film has the same **dose equivalent** response (average of 30.86 mrem-mm^2/track) for bare PuF_4 (average energy of 1.4 MeV) as for a 7-cm poly moderated PuF_4 (average energy of 0.15 MeV), and conclude that the PuF_4 source is an appropriate source to represent (alpha,n) neutron sources and also fission spectra neutrons at RFP (ORISE 2005, p. 15). While SC&A cannot dispute these findings, neither can it find any published data or textbook articles to support them. From the data presented in the NDRP Report, an average of 30.86 mrem-mm^2/track was obtained from the reread of the NTA calibration film exposed to neutron spectra of bare and moderated PuF_4 neutrons. However, it is not evident from the TBDs and TIBs that the neutron spectra at RFP are necessarily covered by these two neutron energy spectra where the NTA film neutron energy threshold is concerned. For example, Figure 3-1 on page 10 of ORAUT-OTIB-0050 (Smith 2005b) shows that NTA film has essentially zero response to neutrons below 500 keV. Therefore, in any situation at RFP where the exposure consisted of neutrons with all energies below the 500 keV threshold, the dose would not be registered by the worker's badge. This would not be a common situation but illustrates the fact that the calibration recommended in the NDRP could underestimate neutron doses in some situations.

SC&A Evaluation: SC&A agrees that in certain exposure conditions, the calibration factors recommended by NIOSH provide for reasonable dose reconstruction. However, NIOSH does not present sufficient evidence that the recommended calibration factors bound the possible neutron energy spectra at all RFP facilities during the period that NTP and NTA films were in use. This would not be an SEC issue, but a site profile issue.

4.5.3 NDRP Data in HIS-20 Database

NIOSH's evaluation report (NIOSH 2006a, p. 36) states that because there was no way to discern the neutron dose, the neutron value in HIS-20 was set to "null" and the deep dose (lump sum or annual composite doses) was applied to the gamma component. (It is assumed from the previous text that this statement applies to the period of 1952–1976.) Then, the evaluation report states the following (NIOSH 2006a, p. 37):

> *Since the NDRP program did not always identify the original gamma dose, it was determined that only the difference in the original neutron dose and the recalculated neutron dose would be incorporated into HIS20…. There were a total of 23,386 NDRP neutron dose records for 5244 individuals used to modify the HIS20 database.*

The statement on page 36 indicates that the original HIS-20 database does not contain separate neutron dose information, but the document then states that the neutron values in HIS-20 would

be set to "null" and only the difference in the original neutron dose and the recalculated NDRP results would be used to modify the HIS-20 database. It is not clear where the original individual neutron doses are stored, and how they can be set to "null," if only lump sum and annual doses are available for that period in the HIS-20 database. Additionally, the document does not state why only 23,386 records were used to modify the HIS-20 database when 87,943 NTA films/NTPs were matched to workers (ORISE 2005, p. 14).

SC&A Evaluation: SC&A has recently received clarification of this issue from NIOSH. It is SC&A's current understanding that the HIS-20 database now contains the additional neutron doses assigned (the delta value plus any notional doses) added to the original composite dose data. Additionally, the 23,386 records referred to in NIOSH's evaluation report are **annual** neutron doses; each contains the information from about 4 reread badges, for a total of 87,943 reread NTPs and NTA films. Given this clarification, SC&A now agrees with NIOSH that this is not an SEC issue.

4.6 USE AND EFFECTS OF LEAD APRONS

NIOSH explains the procedure of adjusting for the effects of wearing a lead apron on page 75 and addresses a particular case on page 72 of the evaluation report (NIOSH 2006a). NIOSH's conclusion is that a lead apron will reduce the dose of record by 0%–15% and that this will be compensated for during dose reconstruction.

SC&A agrees with NIOSH that the neutron dose is generally greater under the lead apron, because it is held close to the body (where the albedo affect is greatest, due to the lower Z materials in the body), as opposed to being on the outside of the apron. Additionally, because lead is not a good neutron absorber, it does not attenuate the neutron dose significantly. NIOSH's conclusions appear to be reasonable and are similar to the conclusions made at the Pantex plant in 1995 (Passmore 1995), except for the reduction of the photon dose by only 0%–15% at RFP; Pantex reported a reduction of 57% in photon dose, which corresponds to an average energy of approximately 175 keV (GPO 1970, p. 138). Photons below about 40 keV would essentially all be stopped by 0.45 mm of lead. A brief summary of photon attenuation as derived from data in the *Radiological Health Handbook* (GPO 1970, p. 138) follows:

keV	Attenuation
<40	100%
150	63%
200	40%
300	19%
400	11%
600	6%
700	5%

Section 7.3.4.1, page 63, of the evaluation report recommends a photon energy range of 30–250 keV. This would correspond to approximately 100% to 30% attenuation over this range of photon energies. In contrast, a photon attenuation of 15%, as recommended by NIOSH, would

correspond to an average energy of approximately 350 keV, and 8% would correspond to approximately 500 keV. NIOSH's dose reconstruction Case C used a lead apron correction factor of 15% for penetrating dose to the head and 11% for shallow dose.

SC&A Evaluation: SC&A agrees that adjustments for the wearing of lead aprons can be made, but does not currently see where the small adjustment factor of 0%–15% is appropriate for workers at RFP. Attachment 9 provides the SC&A analysis of NIOSH's dose reconstruction Case C for a worker who wore a lead apron. While this is not an SEC issue, it is a concern for site profile dose reconstruction.

4.7 REVIEW OF THREE HYPOTHETICAL DOSE RECONSTRUCTION CASES

NIOSH provided SC&A with three hypothetical external dose reconstruction cases (of six total examples, with the other three being internal cases) for review of procedures and methods. SC&A analyzed these three examples to determine if the external dose reconstructions were consistent with present guidelines and recommended procedures, and if sufficient data were available to allow for claimant-favorable dose reconstructions. SC&A reviewed each case with regard to applicable beta, photon, and neutron dose exposures; any data gaps, zero, or less than LOD readings; and any unusual exposure conditions.

4.7.1 Case 1—Hypothetical Neutron Dose Assignment for Monitored Worker, Pre-1970

This case provided an example of neutron dose reconstruction that involved use of the NDRP Report, ORAUT-OTIB-0050, and missed assignments for periods of blank entries.

SC&A Evaluation: While NIOSH was able to provide a reasonable dose reconstruction for this case, there were several areas of concern:

(1) A single n/p value of 0.42 was used for 1970–1976 (which was derived from later 1977–2000 TLD data).

(2) There is a question concerning the completeness of data for 1962–1969. SC&A found significant time gaps in dose data during its recent review of DOE files for 52 randomly selected RFP dose reconstruction cases. Therefore, the assumption that there is complete NDRP data for 1962–1969 may not be realistic for actual worker cases.

(3) In this dose reconstruction case, there were 102 dosimeter cycles when a zero was assigned for photons and only 85 for neutrons. It is unusual to have more missing photon readings than neutron readings.

(4) Assigning a missed dose based on LOD is not acceptable for unmonitored periods or lost/damaged/unreturned badges, as it in no way reflects the actual dose received.

(5) Although the conversion may be correct, it is not clear from the dose reconstruction how the 30–250 keV photon dose and the neutron dose were converted to organ doses using the dose conversion factors (DCFs) available.

4.7.2 Case 2—Hypothetical Beta/Photon/Neutron Exposures with Use of Glovebox

This case provided an example similar to Case 1 with the additional complexity of using a glovebox, which involves using OCAS-TIB-0010 (OCAS 2005) in the dose reconstruction.

SC&A Evaluation: The same five concerns stated in Case 1 also apply to this case. Additionally, concerns about applying ORAUT-OTIB-0010 (ORAUT 2004c) need to be addressed.

(1) The glovebox correction factor was applied to only 8 out of 30 years, although all records indicate that the energy employee worked most of the 30 years using a glovebox, where his prostate would have received a higher dose than indicated by dosimeters located on the trunk of his body. This would appear to underestimate the worker's dose and is not claimant favorable.

(2) The dose reconstruction case states, "The photon correction factor of 2.19 for photons and neutrons was applied to the **selected years** as provided in the *Technical Information Bulletin: Special External Dose Reconstruction Considerations for Glovebox Workers*" [emphasis added] (OCAS 2005). A search of ORAUT-OTIB-0010 (ORAUT 2004c) did not find any use of selected years.

4.7.3 Case 3—Coworker Dose Assignment Needed for Some Years; Lead Apron Correction Factor Used

This case is similar to Case 1, except it includes the use of lead aprons. The same five concerns stated in Case 1 also apply to this case. Additionally, the following concerns about correcting for the use of lead aprons need to be addressed:

(1) The dose reconstruction of this case applied a correction factor of 1.15 to the reported deep dose and 1.1 to the reported shallow dose. These correction factors appear very small in comparison to the attenuation of low-energy photon in lead. Photon attenuation of 15%, as used in this dose reconstruction case, would correspond to an average energy of approximately 350 keV; however, the text in this dose reconstruction case assumes photon energy of 20 keV.

(2) This dose reconstruction case refers to Table 6-8 in ORAUT-TKBS-0011-6, *(DRAFT) Technical Basis Document for the Rocky Flats Plant—Occupational External Dosimetry*, *Rev 01-Draft A*, February 15, 2006. This new version of ORAUT-TKBS-0011-6 could not be found on the NIOSH/OCAS web site or the O-drive to verify the information used in the dose reconstruction. SC&A did find a Table 6-8 in the very recent release of Revision 01 of ORAU-TKBS-0011-6 (Langsted 2007). This table lists bias correction

factors for wearing a lead apron as 1 for shallow and deep photon doses for all cases, except when the badge was worn under the apron; the correction factor is 1.2 for deep dose in unprotected areas only. If the values in this table are correct, the energy of the photons must have been relatively high (>600 keV), and therefore, the apron was of no use if it did not attenuate the photon dose received by the dosimeter (which is to represent the dose that the body received).

4.7.4 Summary of Dose Reconstruction Cases

The preceding list of concerns emerged from analysis of the three hypothetical dose reconstruction cases to determine if the procedures were claimant favorable and reasonable. The results reflect some of the same issues identified by SC&A in the RFP site reviews for actual workers. Attachment 10 provides a detailed report of this evaluation. These concerns are most likely not SEC issues, but they need to be addressed from a site profile basis to ensure claimant favorability.

4.8 SPECIFIC ISSUES

The following are specific issues related to external dosimetry that were addressed during working group deliberations. A number of these are also addressed in Section 5.0, Data Integrity, for their data reliability implications.

4.8.1 Workers' Dosimeter Storage Location May Affect Reading

The United Steelworkers of America Rocky Flats SEC-00030 Petition (USWA 2005) expressed concern that workers' dosimeters were stored in areas that had above-normal radiation fields. The workers were concerned that their badges were stored during nonworking hours on the badge boards located near higher than background radiation fields. NIOSH responds to this concern on page 74 of the evaluation report (NIOSH 2006a), stating, "If the employee's dosimeters were stored in a location where it was exposed to radiation, this exposure would cause his dosimeter badge to register additional dose that he didn't actually receive."

SC&A Evaluation: SC&A has not found evidence that workers' dosimeter badges were stored in higher than normal radiation areas. However, if they were, then the workers' dose records would show a higher dose than the workers actually received, which would be claimant favorable.

4.8.2 Improper Control Badge Storage

The SEC-00030 Petition expressed concern that control badges were stored in areas that had above normal radiation fields. NIOSH states on page 76 of the evaluation report (NIOSH 2006a) that there is no evidence that an identified high-background radiation level was found.

SC&A Evaluation: The SC&A review of available operational and radiological records has not corroborated this as an issue to date.

4.8.3 Crystals on the Floor in Building 123

The SEC-00030 Petition expressed concern that workers saw TLD chips on the floor of the counting room and that this could lead to unrecorded doses that workers actually received. NIOSH responds to this concern on page 75 of the evaluation report (NISOH 2006a), stating, "In these cases, a dose could be estimated from the readings from the remaining crystals."

SC&A Evaluation: SC&A agrees that this is normal dosimetry procedure whenever a chip or two are dropped or missing. However, if a whole tray of loose chips were spilled, then there would be no duplicate chips to read. Assigned dose would then depend on prior or post-dose readings and/or coworker data. However, exposures from incidents/accidents would not be properly recorded using these methods, unless accounted for by other means.

4.8.4 Dosimetry Records from July through October 1984

A group of dose records from July through October 1984 showed neutron dose entries but no gamma dose entries. Because this is an unlikely exposure condition, the SEC-00030 Petition highlighted this issue. NIOSH has determined that the problem with the dose calculation algorithm resulted in the recording of neutron doses that were evaluated as zeros as measured doses (i.e., greater than zero). This problem would result in overestimates of the neutron doses actually received during this brief period.

SC&A Evaluation: In view of the information currently available, SC&A agrees with NIOSH's proposed dose evaluation approach.

4.8.5 Handling of Dense Neutron Film Results

A possible problem was raised concerning dense neutron film evaluation mentioned in an RFP memorandum dated March 16, 1965 (Kirchner and Kittinger 1965). From the first paragraph of the memorandum, it appeared that if the NTA film was dense and neutron tracks could not be read, then a dose of zero was entered into the worker's records. NIOSH analyzed the memorandum and related documents and concluded that a probable dose was assigned to the worker and that the zero entry referred to the fact that the IBM computer would have recorded a zero dose if further investigation was not conducted (Attachment 11).

SC&A Evaluation: In view of the information and analysis provided by NIOSH, SC&A finds that dense neutron film did not preclude reasonable dose assignments in the workers' records.

4.8.6 External Dose Reconstruction Feasibility Conclusion

NIOSH states on page 65 of the evaluation report that it has access to sufficient information to either (1) estimate the maximum external radiation dose for every type of cancer for which radiation doses are reconstructed that could have been incurred under plausible circumstances by any member of the class, or (2) estimate the external radiation doses to members of the class more precisely than a maximum dose estimate.

SC&A Evaluation: SC&A has found, with one exception, that NIOSH generally has adequate information to estimate sufficiently accurate external photon doses to members of a class of workers or estimate the plausible upper bounds for the maximum external photon dose if individual dose records are not available. SC&A understands that NIOSH will perform these dose reconstructions by using the individual dose records in the DOE files if available, or appropriate coworker data and model if individual dose data are not available. The exception relates to external dose data for nonplutonium workers for the 1950s. NIOSH has not demonstrated that it has the data to do a bounding dose analysis for all members of this group of worker; nor has it demonstrated that its coworker model is adequately bounding for these individuals. No documentation/data has been located to validate that use of the 1959 neutron data to estimate dose in the 1952–1958 period.

5.0 DATA INTEGRITY

Data reliability issues figure prominently in the submitted SEC petition. The critical nature of such issues is acknowledged in the draft SEC review procedures of the Advisory Board, which recognizes that establishing data integrity and reliability is fundamental to dose reconstruction under EEOICPA and for evaluations of SEC petitions.

Initially, SC&A was aware of and had access to the primary electronic database for RFP dose records, the HIS-20 database, as well as actual claimant dose records (through NIOSH). As the review progressed, additional sources of dose information were identified, including the Comprehensive Epidemiologic Data Resource (CEDR), a health research database; RFP logbooks, containing day-to-day operational exposure and dose entries; and specific programs and documents containing relevant data (e.g., the Neutron Dose Reconstruction Project, NDRP). The value of these alternative dose records, despite inherent limitations in many of them with respect to scope, completeness, and pedigree, is the ability to compare recorded doses for the same individuals as a means to validate the completeness and accuracy of these databases, and that there exists "sufficient information to estimate the maximum radiation dose," as provided by 42 CFR 83.

At the January 27, 2006, working group meeting in Boston, SC&A noted the lack of corroborating evidence to back up assertions made by both the petitioners and NIOSH's site experts regarding the pervasiveness of dose record discrepancies and their historic origins. In response, and under the charter of an ongoing site profile-based evaluation of SEC-related issues, SC&A decided to directly interview petitioners and other site experts on these concerns and to conduct document searches for such evidence at the Denver Federal Records Center. Following several weeks of contacts with the petitioners, SC&A (Kathryn Robertson-DeMers) conducted onsite interviews with the petitioners to clarify information and identify supporting documentation that could serve to resolve data reliability issues. SC&A also had the opportunity to interview additional individuals who expressed further concerns over issues documented in the SEC petition. One of the outcomes of these investigations was the identification of documents (in particular, logbooks and safety concern reports) that would prove useful in evaluating the merits of many of the data reliability issues raised in the petition.

SC&A noted the lack of corroborating evidence to back up assertions made by both the petitioners and NIOSH's site experts regarding the pervasiveness of dose record discrepancies and their historic origins. Under the broad guidance of the Advisory Board's working group, SC&A decided to interview petitioners and other site experts directly on these issues and to conduct record reviews for such evidence at the Legacy Management's Mountain View facility. Toward this end, SC&A conducted document searches, facilitated by Legacy Management prior to an onsite visit. Select records from document search results were requested and retrieved from the Denver Federal Records Center. During this visit, SC&A reviewed the contents of approximately 26 boxes. SC&A made subsequent records requests based on specific concerns raised during the interviews and reviewed the index of search results provided by Legacy Management for relevance. SC&A asked Legacy Management to pull additional items from subsequent reviews and provide a scanned image of the actual document to both

NIOSH/ORAUT and SC&A. After the initial visit, SC&A **did not** have access to the entire contents of the boxes but only to the specific documents within boxes. A complete list of search results provided by Legacy Management is given in Attachment 12. Many of the records proved not relevant to the SEC petition evaluation review and were not requested.

As requested by the working group, SC&A provided a trip report (SC&A 2006a) regarding this initial records review on April 5, 2006. Although the initial SC&A review was preliminary in nature, it was done to convey progress in investigating RFP data reliability issues to support the time-sensitive SEC review process underway. To ensure coherency and relevance to the SEC review process, the report was organized to comment on, or respond to, specific data reliability issues expressed in the RFP SEC Petition. Some of the original issues were closed during working group discussions; however, five main concerns required considerable followup investigation:

(1) Employee safety concerns
(2) External dosimetry investigation processes and procedures
(3) Review of field logbooks for information contradictory to dosimetry records
(4) Destruction of records pertaining to personnel monitoring
(5) Completeness of records provided for dose reconstruction

Comments presented in this report are based on RFP documentation and technical reports as well as petitioner interviews. The discussion below takes into account responses received from NIOSH and the working group to date and comments made during working group meetings.

Data Access

On March 27–29, 2006, Kathryn Robertson-DeMers of SC&A traveled to Denver to meet with petitioners and review documents. Prior to her arrival in Denver on May 27, 2006, Legacy Management personnel conducted a records search. Based on the search results, SC&A requested some records of interest to be pulled from the Denver Federal Records Center for review. SC&A also identified and requested records from other sources. Additional searches of the records database were conducted while on site and after the visit. The records originally requested were of a broad nature and included technical reports, dosimetry processing logs, secondary dosimetry results, contamination control logbooks, dosimetry receipt logs, and dosimetry procedures. Prior to and during the site visit, SC&A chose records for review that it believed would help answer specific data reliability issues. For example, SC&A requested the dosimetry procedures in order to evaluate the process for assigning dose to workers in the case of damaged, lost, or overexposed dosimeters. Petitioners and their supporters also provided input regarding records that may substantiate data reliability comments made in the petition. Records not available during the visit were later retrieved. However, following SC&A's preliminary review, NIOSH performed the actual review of this record set at the direction of the working group.

In its response to SC&A's April 5, 2006, trip report regarding falsification of records, NIOSH provided the following response (NIOSH 2006d):

> *In the absence of evidence to the contrary, NIOSH stands by our previous response. Although the petitioners have expressed concerns with the reliability of this data, to date no evidence other than worker affidavits has been provided that would support these concerns. In response to a letter to the petitioner dated March 16, 2006, requesting reports or citations supporting allegations of fraud in recording and reporting worker dosimetry results, the petitioner directed NIOSH to Freedom of Information Officer Lisa Bressler. Officer Bressler also directed us to a few other DOE and Kaiser-Hill personnel. NIOSH is currently continuing conversations with these additional personnel, but so far no evidence of criminal and/or fraudulent activities regarding dosimetry records has been located.*

During the course of interviews with petitioners, it became clear that their access to records was limited to Freedom of Information Act requests. The petition included only unclassified sources, primarily available through the United Steel Workers of America Local 8031or individuals. The petitioners were apparently aware of documents that could support petition issues; however, they have not had success in accessing them.

From the interviews conducted and documentation obtained, data reliability issues continued to be of concern, consistent with specific examples provided in the petition:

- Dose records containing blanks or "no data available," especially in situations of high exposure
- External dosimetry investigations related to damaged, lost, or overexposed badges
- Alleged false entries in dose records
- Incomplete dose records
- Exposure to other radionuclides

During the April 12, 2006, Advisory Board working group conference call, SC&A was asked to provide a list of the initial records requested from the RFP records center. In addition to this list, SC&A provided information on the relevance of outstanding records and how these records could be used to potentially answer data reliability issues. The working group assigned NIOSH to follow up on retrieval and review of these records (ABRWH 2006b).

After its initial visit, SC&A conducted additional searches of the records database. Subsequent SC&A requests for records were more specific and were focused on particular data needs, such as retrieving information on the 1969 fire, D&D, and logbooks maintained by key radiological control personnel. SC&A requested this information not only regarding the data integrity issue, but also as documentation related to other findings in this report. For example, SC&A reviewed field logbooks for reference to other radionuclides to help determine timelines for the use of other radionuclides at RFP.

5.1 SAFETY CONCERNS

5.1.1 Background

During the course of interviews with RFP SEC petitioners and others, individuals stated that former supervisors had gone back and modified dose records by replacing positive doses with zeros. When asked by SC&A if they had corroborating documentation, the interviewees indicated they had filed formal safety concerns at the time. The petitioners provided SC&A with a hard copy list of safety concerns. This index, covering 1970–1992, gave only brief descriptions of each safety concern topic. It included concerns related to industrial, chemical, and radiological safety. Given the brevity of the interview visit, the petitioners shared several examples of safety concern files with SC&A. The safety concern files ranged from a single sheet where the issue was resolved on a one-page form, to several sheets where the issue was elevated to the Joint Company-Union Safety Committee (JCUSC). SC&A reviewed the safety concern list provided by the petitioners in order to corroborate the particular concerns cited by the interviewees, as one means to establish whether data reliability may be an SEC-related concern.

In a May 2006 working group meeting on the RFP SEC, a petitioner indicated that Rocky Flats Environmental Technology Site (RFETS), the former operating contractor, once maintained a database of safety concerns that may date to before 1970. The Advisory Board working group asked NIOSH to determine whether such a database existed and, if so, whether it contained early safety concerns relevant to the petition evaluation. A database containing 4,946 safety concerns from 1970 to 2004 was subsequently located in the RFP archived records. The database did not contain any safety concerns identified for the years prior to 1970. NIOSH evaluated the database and identified 33 safety concerns that had potential relevance to the SEC. One safety concern was actually a subset of another safety concern. SC&A also evaluated the database of safety concerns and identified an additional 17 relevant safety concerns. The documentation pertaining to specific safety concerns (that would have relevance to specific SEC data reliability issues) was requested from Legacy Management and imaged copies were provided to NIOSH. The safety concern files include the original safety concern filed by the employees, a supervisory response, and documentation relating to resolution of the safety concern.

NIOSH completed a review of 49 of the safety concern files and provided the analysis to SC&A on October 27, 2006. The evaluations for Safety Concerns 90-169 and 92-048 remain ongoing (JCUSC 1990b, JCUSC 1992c). One safety concern was identical to another and was renumbered by JCUSC. The NIOSH evaluation concludes that the safety concerns with complete reviews do not have a bearing on the data integrity issues included in the petition, and they do not affect the ability to conduct dose reconstruction. NIOSH has indicated that techniques can be used to assign the missing dose. For example, bioassay data before and after a data gap can be used to assign internal dose during the period of time when bioassays were not collected.

Safety concerns identified covered a wide range of subject matter, with some issues closely related to concerns raised in the SEC petition. The time period of the safety concerns range from

1970–2000, with a majority from the 1990s. A few concerns raised questions regarding the accuracy of the personnel monitoring program (internal and external). Other concerns relate to the adequacy of the bioassay program in effectively monitoring personnel routinely and for incidents. Several safety concerns were related to RFP external dosimetry policies and practices, including badge exchanges, dosimeter storage, contaminated dosimeters, and unauthorized practices. Several of the documents discussed general health physics issues, such as the lack of radiation protection technician (RPT) coverage, or noncompliance with procedures.

5.1.2 Analysis

SC&A has reviewed the safety concerns and the NIOSH position related to each safety concern. Attachment 13 provides a list of the safety concerns evaluated, including a description of the concern, the NIOSH position related to the safety concern, and the SC&A response. The review involved evaluation of the safety concern file as well as the response documented by NIOSH in *NIOSH Evaluation of Specific Safety Concerns* (NIOSH 2006e) and *NIOSH Evaluation of Specific Safety Concerns Set 2* (NIOSH 2006f), provided to the working group and SC&A on August 28, 2006, and October 31, 2006, respectively. Safety concerns were considered inconclusive when key information important to resolving individual radiation exposure under the circumstances was not available in the file. For example, individuals expressed concerns about high radiation exposures, but their monitoring status remains unknown. In two cases, NIOSH did not specifically evaluate the data reliability issues presented in the safety concern. In these cases, SC&A prepared an evaluation of the relevance of the issue with respect to falsification of records, dosimetry investigations, and inadequate or incomplete dosimetry data and records. This review includes this evaluation.

In its evaluation, SC&A divided the safety concerns into three categories in relation to the SEC petition. First are those safety concerns that are not relevant to or bear on NIOSH's ability to adequately conduct dose reconstruction; these include concerns such as those related to nonradiological safety issues, hostile work environment, instances when individuals were monitored based on the particular event, lack of communication, and lack of training. Second are issues associated with the processing of dosimeters when the dosimeter or dosimeter components were lost, damaged, or overexposed, or exhibited other problems. The third group includes safety concerns that, in SC&A's view, reinforce claims and statements made in affidavits or public comments. NIOSH continues its investigation of two safety concerns involving lost or invalid bioassay results (90-169) and the inadequacy of the internal and external dosimetry programs (92-048).

5.1.3 Inconclusive Safety Concerns

Three safety concerns (89-259, 94-245, 95-061) and a portion of two additional safety concerns (91-395, 91-496) were considered inconclusive because key information to make a determination was not included in the file provided by RFP.

Safety Concern 89-259 expresses a concern related to the accuracy and trends in cumulative dose (JCUSC 1989a). The issue was not clearly defined, making it difficult to ascertain whether the

issue was directly related to dosimetry or whether it was associated with the health physics goal of monitoring radiation exposures "as low as reasonably achievable" (ALARA). Safety Concern 91-395 states that radiation exposures to employees in Building 664 were too high and unnecessary because grams of plutonium, americium, and uranium were being stored in drums at this location (JCUSC 1991a). It is unclear whether personnel in the building were required to wear dosimetry prior to the establishment of a radiological control area (RCA), or whether the RCA was created prior to the drums arriving. NIOSH has assumed that this is not an SEC issue; however, without the information discussed above, it is unclear how it was able to come to this conclusion.

Safety Concern 91-496 specifically expressed concern regarding the lack of background studies conducted prior to locating the badge storage rack in the tunnel north of Portal 1 (JCUSC 1991b). There was an underlying concern that the radiation and environmental conditions at this location were not appropriate. For periods of time when location-specific backgrounds were used in background subtraction, the safety concern is inconclusive. There is no indication how the background radiation level changed, and if adjustments were applied to retrospective data. For those years when environmental dose levels were used for background subtraction, the location of the dosimeter storage areas would not affect the dosimeter results.

Safety Concern 94-245 involves the confiscation of the TLDs of two workers as a result of safety violations (JCUSC 1994a). NIOSH indicates that performing work without appropriate dosimetry in an RCA may or may not affect the ability to perform dose reconstruction. It further indicates that the employees with confiscated TLDs did not work in an RCA while they did not have a TLD. There seems to be some disagreement regarding this fact. The employees indicated that they did perform radiological work during this time period while JCUSC indicated the employees were not required to perform work in a radiological area without a TLD during this time period. The safety concern file did not include any details regarding the JCUSC investigation. In addition, this safety concern raises the questions of how frequently TLDs were taken away from workers and why. Were these workers prevented from entering radiological areas during this time period? Certainly, if employees were entering radiological areas without TLDs, this would put their amount of external exposure in question and therefore impact dose reconstruction. NIOSH assumes the worker did not enter a radiological area. In SC&A's view, not enough information is provided in the safety concern file to make this determination.

Safety Concern 95-061 discusses a situation where the building manager pulled TLDs from workers in Building 776 as a result of a radiation work permit (RWP) violation (JCUSC 1995a). There is no indication whether individuals having their dosimeters pulled were accordingly banned from entry into the RCAs. The larger concern is whether a simultaneous restriction from radiation areas was enforced. The safety concern did not indicate what restriction was imposed on personnel. Without complete information on these issues, no clear determination can be made with regard to whether they represent data integrity problems.

5.1.4 Safety Concerns Not Affecting the Dose Reconstruction Process

Several of the files reviewed were concerned with field radiological control conditions and not directly related to dosimetry results. Safety Concern 70-2 related to general area radiation levels, adequacy of shielding, storage of plutonium, dry box damage, and inadequacies in criticality drains (JCUSC 1970). As NIOSH indicated, these are important to the health and safety of workers; however, individuals in these areas would have been monitored for internal and external exposure. This safety concern indicates that high dose rates were expected for some groups, and that established administrative exposure levels were exceeded. This would not affect dose reconstruction since these individuals were monitored. Table 5-1 provides the number of individuals who exceeded an annual dose of 5 rem. These data were compiled by the RFP for the period 1951–1986.

Table 5-1. Exposures in Excess of 5 Rem from 1951–1984

Dose Range (Rem)	Number of Individuals Exposed at This Level
5–6	184
6–7	59
7–8	34
8–9	14
9–10	6
10–11	4
11–12	2

Source: RI 1987

General area doses rates will be further discussed in the Section 5.5.2, *Badge Results Not Reflective of Field Exposure Conditions*.

Safety Concern 71-7 related to the inaccuracy of the stack air sampling results because appropriate procedures were not followed by RFP staff (JCUSC 1971a). This concern addressed environmental monitoring issues, which have implications for environmental dose. Environmental dose will be discussed in the extended review of the RFP site profile review.

Issues of job coverage, inadequate notification of health physics staff, violation of procedures, and inadequate field monitoring were raised in Safety Concerns 85-137, 86-186, part of 91-496, 93-124, and 94-080 (JCUSC 1985a, JCUSC 1986a, JCUSC 1991b, JCUSC 1993a, JCUSC 1994b). Although important to a functional radiological control program, these concerns were not directly related to personnel monitoring and dose reconstruction. Other concerns addressed logbook entries for the contents of a tanker truck, hostile work environments, lack of showering facilities and emergency response kits, and inappropriate labeling of confidential information (JCUSC 1989e, JCUSC 1994c, JCUSC 1994d, JCUSC 1994e, USWA 1997, JCUSC 1999a, Anonymous 2000). Safety Concern 95-077 dealt with the appropriate procedure for shipping urine samples through the mail (JCUSC 1995b). Safety Concern 89-148 relates to the lack of procedures available for documenting infractions in radiation monitoring reports (JCUSC

1989b). These concerns were not directly related to personnel monitoring or dosimetry documentation.

Safety Concerns 87-206 and 92-036 (JCUSC 1987a, JCUSC 1992a) brought up issues with the timeliness off issuing external dosimetry supervisory reports. The lapse of dosimeter exchange on the part of external dosimetry staff was raised in Safety Concern 86-13, and the timeliness of processing was raised in Safety Concern 96-182 (JCUSC 1986b, JCUSC 1996). Although less frequent exchange may cause additional uncertainty in the evaluation of the badge (e.g., fading considerations, appropriate background subtraction), it does not constitute an unmonitored situation. The lack of proper distribution of dosimeter results to the field (e.g., supervisor reports) was primarily related to the ALARA program for minimizing worker radiation exposures below external dose limits. The JCUSC raised the issue of manpower shortage in the dosimetry department in Safety Concern 86-13, indicating that the department delayed the usual dosimeter pickup schedule and thus processing for lower risk groups (e.g., during the third quarter of 1985) (JCUSC 1986b). This delay in badge processing may make comparisons being conducted in other areas of this review difficult. In addition, the timely processing of dosimeters is of some concern because backlogs may lead to practices such as not reading dosimeters from perceived low exposure groups. This occurred for some workers assigned to the so-called "cold area," where radioactive material was, in fact, handled. This directly relates to the establishment of coworker dose. Safety Concern 75-34 related to the adjustment of dosimeter results after administration of a medical isotope (JCUSC 1975). If an investigation was conducted to determine the appropriate dose, this practice is reasonable. Safety Concern 90-202 related to questions posed to dosimetry staff about potential exposure from the Cf-252 calibration source (JCUSC 1990a). RFP dosimetry determined that the individuals of concern were monitored for both beta/gamma and neutron exposure. These data can be used in dose reconstruction.

With regard to dosimeter background concerns, the radiation background at the Dosimeter Exchange Board is monitored by a TLD placed in the rack along with those worn by personnel. The methodology used for background subtraction has varied over time. Lagerquist (1975b) indicated that, effective January 1986, the total background subtracted from dosimeters would be environmental background (0.34 mrem/day) with instrument background. TLD operating procedures in 1983 also indicated that the total background subtracted was determined from environment and instrument background (RI 1983). The *Background Subtraction Methodology Study* was conducted by Klueber and Savitz (1999) the second quarter of 1999 at locations across the site. This study indicated that using a location-specific background may create potential problems because the dosimeters were not always stored at the assigned location. Furthermore, the study indicated subtracting backgrounds by location will generally reduce the reported dose (Klueber and Savitz 1999). A TLD background subtraction based on whether the location of the storage area was in a hard-walled or non-hard-walled building was implemented (RMRS 1999). A changed in background subtraction methodology occurred in 2001 when the actual TLD element residual signal together with a time-dependent and location-dependent background resulted in a TLD-specific background, which is subtracted from the dosimeter (RFETS 2001). Methods for background subtraction prior to 1976 were not located. The concerns around this issue relate to whether the location-specific background level is appropriate for background subtraction. Based on the documentation reviewed, the location-specific background was not

used at RFP until 1999. Background subtraction is more appropriately addressed as a site profile issue.

Safety Concern 91-262 questions the practice of wearing dosimetry only when entering RCAs (JCUSC 1991c). The potential for worker involvement in a criticality was of particular concern. There are other means of determining doses for cases in which dosimeters are not worn during a nuclear criticality, as demonstrated with the Y-12 criticality accident in 1958. The JCUSC agreed with the employee that dosimeters should be worn at all times when in the perimeter security zone (PSZ). The operations group expressed concerns that this was not consistent with the health and safety procedures. HSP 18.07, *External Radiation Dosimetry*, updated June 15, 1991, shortly after the safety concern was issued, continued to require that dosimetry be worn in RCAs or when posting required it, and that dosimeters be stored on badge racks (EG&G 1991). The safety concern did not discuss the relative exposure in uncontrolled areas of the building. Available area dosimetry systems could be used to assign a dose for those not required to enter radiological areas, assuming the exposures to the area badges and the personnel are equivalent.

5.1.5 Processing of Lost, Damaged, Overexposed, or Otherwise Compromised Dosimeters

Safety Concerns 85-161, 87-005, 87-038, and 91-490 relate to methods utilized to conduct external dosimetry investigations and provide other examples of individuals questioning the accuracy of the dosimetry system (JCUSC 1985b, JCUSC 1987b, JCUSC 1987c, JCUSC 1991d). Extended external dosimetry investigations are documented in personnel dosimetry files back to the mid-1980s; however, their availability in radiation dose files was not routine until the late 1990s.

Safety Concern 85-161 speaks to the conduct of external dosimetry investigations for questioned doses (JCUSC 1985b). Not enough information is available to determine whether this was a sitewide policy; however, the safety concern provides an example of a case for which a dosimetry investigation was conducted. It is difficult to determine from a secondary source whether an adequate investigation was conducted and whether the response was appropriate to the employee's concerns.

In Safety Concern 87-005 (JCUSC 1987b), a memorandum from R.N. Chanda and G.A. Overholt to P.A. Madsen (Chanda 1987) indicates that a review of the dosimetry records was conducted, and it was determined that the zeros were the result of an individual turning in wrist dosimeters without corresponding body dosimeters. This individual was assigned to the nondestructive assay group in Building 371, where there was a potential for exposure. It is difficult to determine from a secondary source whether an adequate investigation was conducted and whether the response was appropriate to the employee's concerns. Direct data should be evaluated in this case, and the individual's dose should be compared to that of his coworkers performing the same tasks.

Safety Concern 87-038 involved modification of the dosimeter value due to QC issues with the dosimetry results (JCUSC 1987c). No followup investigation of the individual's potential exposure appears to have been conducted. This is directly related to the issue of how dose was

assigned when dosimeters were lost, damaged, or contaminated, or had QC problems. The individual was on a biweekly exchange schedule, indicating the potential for higher exposure. The adjustment to his dose does not reflect this, and adequate justification for this dose is not provided. Questionable data of this type should not be used in dose reconstruction.

Safety Concern 91-496 discussed the employee's responsibility to protect his or her dosimeter from contamination, tampering, misuse, and other compromising situations (JCUSC 1991b). With respect to positive control, no system was in place to prevent individuals from tampering with dosimeters. RFP external dosimetry staff members indicated they evaluated the raw results from each element as an indication of inappropriate dose results. The safety concern did not address the specific process followed by external dosimetry staff to identify and investigate inappropriate dose results.

5.1.6 Safety Concerns Consistent with Statements in Affidavits or Public Comments

SC&A has determined that Safety Concern 71-4 does not provide conclusive evidence of a sitewide issue. It does, however, provide an example of a situation where the worker believed dosimeter badges were not adequately capturing the actual exposure conditions. The safety concern, itself, stated the following (JCUSC 1971b):

My film badge results for Dec. 1970 did not show the high level of neutron exposure which[,] according to instrument readings and film badge results of other monitor[s] on the same special job, should have been expected.

This safety concern mirrors the concerns cited in former RFP worker affidavits that their dosimeters did not reflect actual exposure conditions. The supervisor's response indicated there was an inherent inaccuracy with neutron film dosimetry, and that neutron TLDs were scheduled to replace neutron film. No explanation was given for the failure of the worker's film badge to reflect his coworkers' doses or instrument readings. The petition includes affidavits from employees documenting similar concerns.

Safety Concern 74-61 indicated there was a need for quantitative assessment of radioactive material within the body (JCUSC 1974). Further discussion with RFP radiological control staff having knowledge of this safety concern indicated that the concern was particularly directed at the in-vivo counting system. NIOSH has indicated that in-vivo counting results are not used in its analysis of claimant dose. If this is the case, and individuals were adequately monitored via urinalysis, NIOSH could use bioassay data for dose reconstructions. If, however, NIOSH decides to use lung count data to "bound" intakes, or it is determined that bioassay monitoring was incomplete, this would impact internal dose reconstruction. Furthermore, if the coworker model uses these data, the reliability of these data is in question and must be evaluated further. The concern clearly shows that some workers, even within the radiological control organization, questioned the results they received from dosimetry. Whether dosimetry data were inadequate cannot be determined from the information in the safety concern. This lack of faith in dosimetry results has been raised several times throughout the petition. The safety concern provides a historical reference to these concerns.

Safety Concern 89-037 involves the lack of internal and external monitoring for an employee who worked in the uranium area (JCUSC 1989c). It provides an example of a situation in which missed dose is possible. NIOSH has generic methods for assigning dose where data gaps exist; however, the exact method for addressing data gaps is still under consideration. Of particular concern is NIOSH's method for identifying data gaps and assigning dose for multiple-year data gaps. Although lack of monitoring is not, per se, a data integrity issue, it does have a significant impact on dose reconstruction. In addition, gaps in the data of individuals exposed, but not adequately monitored, cast doubt on the integrity of the data made available for dose reconstruction.

Safety Concerns 84-19 and 86-161 discussed apprehension related to abnormally high or positive in-vivo bioassay results (JCUSC 1984, JCUSC 1986c). Safety Concerns 84-19, 86-169, 89-167, 93-061, 93-193, and 99-013 raised questions regarding the timeliness of bioassay collection or communication of results (JCUSC 1984, JCUSC 1986d, JCUSC 1989f, JCUSC 1993c, JCUSC 1993b, JCUSC 1999b). Safety Concerns 85-109, 89-203, and 92-003 questioned inconsistencies in instrument results (e.g., wound counting) or malfunctions in equipment (e.g., in-vivo counter) (JCUSC 1985c, JCUSC 1989d, JCUSC 1992b). Although delaying communication of bioassay results and subsequent dose assessments is a poor practice, it does not preclude dose reconstruction. Untimely bioassay turnaround times delay the collection of followup samples and complicate the determination of intake conditions. Furthermore, this is not conducive to a good ALARA program. Delaying bioassay, whether urine or fecal, or in-vivo counting for a few days does not prevent the detection of long-lived insoluble radionuclides taken into the body. For soluble material such as tritium, delay in bioassay may affect the ability to detect an incidental intake depending on the length of the delay. Assuming the employee was adequately monitored via urinalysis, and in-vivo counting was not used in dose reconstruction, these issues would not present a problem for dose reconstruction. If, however, NIOSH decides to use lung count data to "bound" intakes, or it is determined that bioassay monitoring was incomplete, this would impact internal dose reconstruction. Furthermore, if the coworker model uses these data, the reliability of these data is in question and must be evaluated further.

Safety Concern 97-176 demonstrates the lack of proper QC within the dosimetry processing laboratory (JCUSC 1997). An employee was given a TLD badge that did not contain thermoluminescent elements. The TLD had been processed, but the elements were not replaced at the time the supervisor retrieved the dosimeter. The radiological control technician (RCT) entered radiological areas with inadequate dosimetry (Baker 1997). This is one of many QC problems encountered by external dosimetry staff throughout RFP operational history.

Safety Concern 98-073 relates to multiple employees working in Building 374 who questioned the accuracy of the monitoring program (JCUSC 1998). RFP dosimetry provided an evaluation of dosimetry results for the particular department that these employees worked in; however, no information was provided for specific individuals to allow a comparison to previous exposures. The external dosimetry department looked at the dosimetry results of process specialists and RCTs for the fourth quarter of 1997 and the first quarter of 1998. Dosimetry indicated that dose for 12 process specialists went down, dose for 7 process specialists went up, and dose for 3 individuals stayed the same. For the same time the RCT doses decreased. The average dose for

process specialists averaged 9.8 mrem in the fourth quarter of 1997 and 6.1 mrem in the first quarter of 1998. It is difficult to ascertain whether there is evidence of inaccuracies in individual files based on a population evaluation that appears to be inconclusive. NIOSH has provided a general hypothesis that inaccuracies did not exist without substantiating it by looking at individual cases. Some basis for this hypothesis should be documented.

NIOSH, in other cases, also provides such hypotheses in response to specific concerns without what SC&A views as an adequate basis or substantiation. In several instances, a broader conclusion regarding sitewide data integrity is made on the basis of an unsubstantiated hypothesis. For example, in relation to Safety Concern 89-037, NIOSH stated the following (NIOSH 2006f):

> *In any event, this appears to be an example of an isolated failure to follow established policies. Corrective actions were taken, and there is no indication that this event constitutes a sitewide data integrity issue, and does not have SEC implications.*

During review of logbooks, the following entry was found, related to an incident involved four RCTs:

> *…do not have dosimetry badges on the board this morning…told to report to class then go to external dosimetry to get badge. Problem is movement of RCTs between buildings, but no paper work sent to change badge board locations.*

This indicates that RFP site dosimetry staff was not always aware of facility changes made by workers and may not have adjusted the worker's monitoring in a timely manner. Although the logbook entry itself does not provide conclusive evidence of a sitewide issue, it certainly indicates that NIOSH may not be correct in its hypothesis that Safety Concern 89-037 is an isolated failure.

The individual safety concerns reviewed did not include any information that taken together would conclusively demonstrate a sitewide issue with data integrity. However, the concerns raise numerous specific examples that bring into question the accuracy of the internal and external monitoring program. Some of these concerns were documented well before the enactment of EEOICPA, underscoring that a number of these concerns were not new.

5.1.7 Safety Concerns Needing Further Basis or Investigation

NIOSH has indicated that Safety Concerns 90-169 and 92-048 require further investigation to determine their relevance to the SEC petition. In Safety Concern 90-169, the worker submitted multiple urine samples, including samples sent off site (JCUSC 1990b). He was told that the first sample was negative. Additional samples were collected. Some samples were lost and another was invalid due to poor chemical recovery. This safety concern appears to provide an example of QC issues in the bioassay laboratory. This may or may not affect multiple individuals depending on the extent of the bioassay laboratory problems. Safety Concern 92-048 questions the adequacy of the internal and external dosimetry programs at RFP and their

compliance with federal requirements (JCUSC 1992c). It further expresses concern over the lack of communication between dosimetry staff and the workforce.

5.1.8 Summary

The safety concerns evaluated provide multiple examples in which radiological control staff would presumably have conducted extended external dosimetry investigations. However, it is difficult to determine from a secondary source whether an adequate investigation was conducted and whether the investigation was responsive to the employees' concerns. A review of former workers' health physics files found evidence that extended external dosimetry investigations were documented back to the mid-1980s; however, the documentation did not routinely appear in the worker's file until the late 1990s. This raises an unresolved concern as to whether external dosimetry investigations were conducted routinely prior to the late 1990s and, if so, why documentation is apparently absent from the health physics file.

A number of safety concerns (74-61, 85-109, 86-13, 86-161, 86-169, 89-037, 89-203, 90-169, 91-496, 92-003, 92-048, and 97-176) relate to the lack of QC in the internal and external monitoring programs. These concerns collectively reinforce issues raised in the petition regarding data quality. For example, the NDRP is provided in the petition as an illustration of petitioner concerns over data quality issues. The NDRP was initiated as a result of questionable accuracy and completeness in neutron dosimetry from 1952 through 1971 (Baker 2002). Other examples of QC issues in the dosimetry program included computer algorithm and transfer errors (RI 1976, Baker 1998), not adjusting monitoring requirements for employees transferred to other areas of the site, loss of bioassay samples, double background subtraction for dosimeters (Savitz 1996), and failure at blind audits (Klueber 1997). SC&A provides a generalized evaluation related to the completeness and accuracy of dosimetry results in its data integrity evaluation, as well as in Sections 4.0 and 8.0 of this report; an evaluation of dosimetry investigation procedures will be provided in Section 5.2, as well.

Safety Concerns 90-169 and 92-048 should be investigated further to ascertain their applicability to the SEC petition. The lack of trust in the internal and external monitoring programs and dosimetry systems exemplified in these safety concerns is the fundamental issue raised by the petitioners.

In conclusion, SC&A concurs with NIOSH's assessments of many of the 49 safety concerns (excluding duplicates) and parts of other safety concerns. While these safety concerns do not directly address falsification of records, a number of them express a lack of confidence in the monitoring at RFP. Although the safety concerns do not provide definitive evidence of a systemic problem with RFP radiation dose data that would necessarily preclude dose reconstruction, some of them do highlight historic instances of poor QC practices.

5.2 EXTERNAL DOSIMETRY PROCEDURES AND INVESTIGATIONS

Two affidavits in the RFP SEC petition raised questions regarding the processing of dosimeters when the dosimeter or its components were lost, damaged, overexposed, or otherwise

compromised. The SEC petition raised concerns regarding crystals falling on the floor, crystals being discharged and reused, crystals being soaked in alcohol, and supervisors asking dosimetry workers to change or delete readings which were in the supervisor's judgment "too high to possibly be correct" (USWA 2005, Part B, page 500). For example, a former RFP janitor recalled that the TLD chips would occasionally dislodge and end up on the floor. When the sweeping was completed, the dosimetry staff sifted through the sweepings to recover lost chips. Approximately 6 to 12 chips were found per day. A second affidavit indicates that at times the TLD reader would fail while the crystal was being read and the data were lost. Another concern related to the breaking of crystals dropped on the floor. Furthermore, the individual preparing the affidavit indicated, "Once these TLDs were heated to a certain temperature, they came out zeroed, so essentially no dose could accurately be reconstructed. When I asked Steve Baker how he handled that, he told me that he applied a "Fudge Factor" to assess dose" (USWA 2005, Part B, page 501). Based on these concerns and those raised by petitioners regarding the lack of agreement between field conditions and dosimeter results, an analysis of the external dosimetry data integrity and methods for dosimetry investigations was conducted by SC&A.

Both SC&A and NIOSH conducted records searches to locate procedures relevant to the dosimetry process, raw dosimetry logs, and other documentation. NIOSH located three procedures related to dosimetry processing and investigations: (1) 4-J88-RDE-0053, *TLD Data Investigation and Abbreviated External Dose Reconstruction* (RFETS 1997a), *(*2) 4-J98-RDE-0071, *Extended External Dose Reconstruction* (RFETS 1997b), and (3) *External Thermoluminescent Dosimetry (TLD)* (RI 1983). Several requests generated by radiological health staff in 1990 and 1991 requesting that field radiological control staff investigate unusual dosimeter results were located; however, information about the actual investigation was not available. The field radiological control staff was asked to perform an investigation in accordance with American National Standards Institute (ANSI) N13.6-1966, 1989 revision, (ANSI 1989) which provides general guidance on appropriate use of dosimetry, and return the results on a form to external dosimetry staff. The exact year when this was implemented is unknown.

An effort was made by SC&A to pull dosimetry processing logbooks to identify particular situations where dosimetry investigations should have been completed (by current standards), evaluate whether the investigations were documented, and determine whether an appropriate methodology was applied for dosimetry investigations. During the records review, the *1985/1986 Dosimetry Problem Logbook* was located, reviewed, and copied (RFP 1986). This logbook contained employee numbers, assigned doses (shallow, penetrating, neutron and/or extremity), and the particular problem with the TLD (e.g., absence of crystals, contamination, processing error). As a means to determine if appropriate investigations were conducted, especially in the case of zeros or blanks, SC&A was asked to provide employee numbers for a subset of individuals listed in the *1985/1986 Dosimetry Problem Logbook* to NIOSH. SC&A provided the requested information on the selected individuals to NIOSH in *RFP Data Integrity Process May 19, 2006* for further evaluation (SC&A 2006b). The recommendations provided to the Advisory Board and NIOSH in the report regarding followup activities are outlined below:

1. *NIOSH should evaluate how doses were assigned under conditions where there were dosimetry problems, how or whether the dose assignment method is documented, and whether the final dose assignment was valid using individuals listed in Table 2 as examples.*

2. *NIOSH should do a similar analysis to the one suggested above for the Harshaw TLD and film time period inclusive of all general plant areas.*

In *NIOSH Evaluation of SC&A's Draft Report on External Dosimetry Procedures*, NIOSH stated the following (NIOSH 2007e):

> *The Working Group has chosen to evaluate the reliability of the radiation files for use in dose reconstruction has been pursued in other ways, most specifically, in extensive comparisons of the information in the workers' radiation files to information in logbooks, and through an examination of the completeness of 52 individual workers radiation files.*

The *1985/1986 Dosimetry Problem Logbook* does address completeness of individual files, but it also provides information for evaluating the dosimetry investigation process. Since petitioners have indicated that records have been falsified, this is one mechanism for evaluating whether there was justification for the questioned doses in the dose of record.

5.2.1 External Dosimetry Processing Issues

The affidavits summarized above raised concerns regarding the process for determining doses when crystals from the TLD system were dropped, damaged, or discharged as a result of reader malfunction or error. In *NIOSH Evaluation of SC&A's Draft Report on External Dosimetry Procedures*, NIOSH provides one possible solution in a situation where crystals are dropped or discharged prior to obtaining a reading (NIOSH 2007e):

> *It is possible that these crystals were read before they were dropped, but some crystals could have been dropped before being read. Systems were in place to interpret a badge with a missing crystal, and badges contained duplicate crystals. In these cases a dose could be estimated from the readings from the remaining crystals. These situations were investigated, and the procedures for doing so were formalized in 4-J88-RDE-0053, "TLD Data Investigation and Abbreviated External Dose Reconstruction" and 4-J98-RDE-0071, "Extended External Dose Reconstruction." The results of these investigations were documented in the worker's Health Physics file, and may or may not have been communicated to the employee at that time. Since instances where badges were missing crystals were investigated, NIOSH concludes that this issue does not prevent NIOSH from performing dose reconstructions of sufficient accuracy.*

The report also states the following:

> *If only a portion of a broken crystal is read, it is appropriate to apply a factor based on the size of the crystal remaining, to estimate the dose that crystal received. Not all information from the badge is lost if one chip is unreadable and a dose estimate can be made from the remaining crystals.*

SC&A concurs with the application of a correction factor for broken chips. It is appropriate to apply a correction factor based on the size of the broken fragments processed, assuming a reasonably accurate assessment of the size can be determined. A dosimetry investigation could also be conducted in this case to substantiate the calculated dose. The use of alcohol for cleaning the crystals prior to processing addresses concerns regarding contamination, such as by oil and hair, on the chips. Petitioners also stated that supervisors asked dosimetry workers to change or delete readings. Section 5.5 of this report addresses this issue.

SC&A selected a subset of entries for individuals from the *1985/1986 Dosimetry Problem Logbook,* which are provided in Table 5-2. The health physics files associated with these individuals were retrieved from RFP for comparison to the logbook entries.

Table 5-2. Individuals with Documented Dosimetry Problems during the Period from March 1985 through July 1986
(selected from RFP 1986)

Case Number	Date	Justification for Change	Dose Investigation Report	Consistency of Doses	SC&A Response
1	4/19/1985	Pen1.xtal >> skin, can't happen [i.e., penetrating results were higher then skin results]	N	IC	The value recorded in the logbook was greater than that observed in the dosimetry file.
2	5/15/1985	Contamination in crystal holder	N	C	The value in the logbook was consistent with the second quarter reading in 1985.
3	5/16/1985	Problems with hot gas reader	N	IC	The value recorded in the logbook was greater than that observed for the second quarter in the dosimetry file.
4	6/10/1985	E/E2 ratio off	N	IC	Although the values presented in the logbook exceeded those for the late June and July readings, review of the specific processing data is recommended.
5	7/1/1985	Bad crystal	N	IC	Although the value for skin dose presented in the logbook was greater than the one from the fourth quarter of 1985 that was the closest result available in the hard copy record. Review of the specific processing data is recommended.
6	7/2/1985	No crystals	N	IC	The logbook value was greater than the processing value from December 31, 1985, that followed the date of concern. Review of the specific processing data is recommended.
7	8/30/1985	Beta reported where no beta exists	N	Y	The logbook value agreed with the information for the August 15, 1985, reading.
8	10/31/1985	Negative neutron ratio	N	Y	The logbook values agreed with the hard copy dose from the fourth quarter of 1985.
9	12/31/1985	Pen1 and skin crystals burned	N	IC	Logbook values were greater than values in both the fourth quarter of 1985 and the first quarter of 1986.
10	12/31/1985	Reader problems on PMT	N	IC	The logbook value was greater than the hard copy penetrating dose for the fourth quarter of 1985 and the first quarter of 1986.

Table 5-2. Individuals with Documented Dosimetry Problems during the Period from March 1985 through July 1986
(selected from RFP 1986)

Case Number	Date	Justification for Change	Dose Investigation Report	Consistency of Doses	SC&A Response
11	2/28/1986	700 and 600 switched	N	IC	The logbook values were element specific and were not converted to a skin dose. Review of the specific processing data is recommended.
12	2/28/1986	Bad crystals	N	IC	The logbook value was inconsistent with the February 1986 hard copy results but consistent with the March 1986 hard copy results. Review of the specific processing data is recommended.
13	1/28/1986	Contaminated badge	N	IC	The logbook values were element specific and were not converted to a neutron and skin dose. Review of the specific processing data is recommended.
14	3/31/1986	Switched xtals	N	IC	The logbook values were element specific and were not converted to a neutron dose. Review of the specific processing data is recommended.
15	3/31/1986	Reader error	N	IC	The logbook values were element specific and were not converted to a neutron dose. Review of the specific processing data is recommended.
Any 331 Worker (Group 1)	3/15/1986	Further investigation revealed that a temporary employee had read these crystals. During normal processing, the technician moves the decimal on the meter two places to the right (divides by 100) before recording data. This converts from the nano couloumb reading on the meter to a mrem value on the sheets. It is our belief that the technician did not move the decimal in these cases. There is, however, no positive proof that this is what happened, so the dose of record will be left as it is entered in the computer from the data sheets.	Not Applicable	See Response	This particular situation involved a group and was not directly relatable to an individual. The data in this case were reported to be high. It was discovered that a temporary employee had read the badges. Dosimetry staff postulated that the nano coulomb reading was not divided by 100 in the conversion to mrem. Regardless, the record reflects the doses as read. This would result in an overestimate of dose and thus would be claimant favorable. It is interesting to note that RFP opted not to conduct a dosimetry investigation for these individuals.

Table 5-2. Individuals with Documented Dosimetry Problems during the Period from March 1985 through July 1986
(selected from RFP 1986)

Case Number	Date	Justification for Change	Dose Investigation Report	Consistency of Doses	SC&A Response
16	3/15/1986	Badge not changed	N	See Response	No dose information was provided. If the badge for the period was not exchanged and the individual was wearing his previous badge, this would not create a problem as long as the badge was eventually processed.

N indicates the logbook dose values did not agree with the hard copy dose values.
Y indicates the logbook dose agreed exactly with the hard copy dose values.
C indicates the logbook values were consistent with data in the hard copy record but did not exactly match.
IC indicates the logbook values were either not provided or were greater than those in the hard copy record. These items require review of specific processing data.

A review of Table 5-2 indicates that 8 out of the 17 entries related directly to issues with crystals. One entry indicated the crystal area was contaminated, two indicated bad crystals, two badges had switched crystals, and one had no crystals. One of the 17 entries stated that no badge was exchanged, and the remaining 8 were associated with reader problems or inconsistent readouts. The redundancy in crystals within a dosimeter, assuming only one crystal was compromised, does provide a mechanism for determining estimated doses from an alternate crystal. In cases involving absence of crystals, badge contamination, and reader errors, the redundancy of crystals in the badge may not provide a method for determining dose, and a dosimetry investigation would be expected based on current practices.

5.2.2 External Dosimetry Investigations

One method of reconciling lost, damaged, overexposed, or otherwise compromised dosimetry results with actual exposure in the field is to conduct an investigation of the potential exposure received by the individual. To evaluate whether dosimetry investigations were conducted, the relative threshold for these investigations, and the methodology utilized, SC&A conducted a preliminary evaluation of information for selected individuals in the *1985/1986 Dosimetry Problem Logbook*, which are listed in Table 5-2 (RFP 1986). The evaluation sought to determine how, based on descriptions provided in the logbook, dose of record was assigned to these individuals. The doses in this logbook and the doses for the same period in the individual's health physics file were also compared for consistency. SC&A also reviewed health physics files for any dosimetry investigations corresponding to the date listed in the logbook for the particular individual.

SC&A found uncertainty existed in how or whether RFP external dosimetry investigations were conducted and documented. According to the *NIOSH Evaluation of SC&A's Draft Report on External Dosimetry Procedures*, conversations with former radiological control staff indicate that occurrences meeting a specified threshold initiated external dosimetry investigations (NIOSH 2007e). While formal procedures were in place for dosimeter processing in 1983 and for external dosimetry investigations by 1997, the individual health physics files do not include documentation until the 1990s. SC&A had expected to be able to determine whether the assignment of doses to individuals in Table 5-2 was based on sound assumptions and methods and whether the derived dose for the investigation was consistent with the dose of record. The absence of records in the health physics files external dosimetry investigations for **all 16** of the individuals evaluated made this difficult. In the case of the group listed, the only explanation is that provided in the logbook itself. The dosimetry logbook contained only dose values (if recorded) without any explanation of how they were derived. Field logbooks did not provide additional insight into the investigation process.

The comparison of the doses in the logbook to those in the hard copy file posed some challenges. The hard copy file often listed a dose for the entire cycle (e.g., quarter) rather than the particular cycle of the dosimeter in question. The dose information for the cycle of, and the cycle immediately following, the dates listed in Table 5-2 was examined. In two cases, the logbook numbers agreed exactly with cycle data located in the hard copy record. In one case, the *1985/1986 Dosimetry Problem Logbook* entry was consistent with the results for the represented

quarter. In several instances, the dose values (e.g., cycle and quarter) in the health physics file were greater than those in the dosimetry logbook. Finally, for five individuals, the logbook did not provide the final dose value in mrem. This comparison would have been more effective if the data for specific badge cycles were available. No mechanism was available to enable a final determination of the legitimacy of the dose of record.

NIOSH provided two examples of dosimetry investigations in *NIOSH Evaluation of SC&A's Draft Report on External Dosimetry Procedures* (NIOSH 2007e). One investigation was for an individual receiving a high exposure over a biweekly cycle during 1964 (Doher 1964, Kittinger 1964). The individual's work activities and field radiation exposure rates were investigated at the request of a supervisor from the chemistry area. The second investigation provided was an investigation conducted as a result of 21 neutron films reported as "too dense to read" (Kirchner and Kittinger 1965). This investigation looked into the job descriptions and work locations of the 21 workers to determine if assigning an overall average dose was appropriate. The field radiological control organization was asked to investigate the most likely exposure received by these individuals. Furthermore, the memorandum indicated that when a neutron badge was "too dense to read," the health physics organization in Buildings 771 and 776 should be notified. It is unknown whether this policy was formally implemented and if it included other areas of the site where neutron exposure was likely. It is also unclear if a similar process was implemented for beta/gamma dosimetry.

SC&A acknowledges that examples of dosimetry investigations conducted prior to the formalization of the procedures were documented either in a formal letter to the file or on an investigation form. It is also true that both positive and zero values can be observed in the available investigations. During 1990 and 1991, hundreds of dosimetry investigations were requested of the field radiological control organization (RFP 1990a, RFP 1990b, RFP 1991). The primary concern regarding the completion of dosimetry investigations focuses on the operational period at RFP, particularly prior to the mid-1980s. In earlier years, documentation of dosimetry investigations is sparse. NIOSH has acknowledged that dosimetry investigations were not documented until a formalized procedure was put in place. The large number of investigations in 1990 and 1991, especially those related to unusual dosimetry results, and the significantly lower number of investigations located prior to this time indicate that the threshold for conducting a dosimetry investigation has changed over time. The relatively higher threshold for investigation in the early years suggests that unusual badge results (if evaluated under later criteria) may have gone uninvestigated.

To date, NIOSH continues to indicate that RFP conducted dose investigations, but with minimal evidence that substantiates that these investigations actually occurred. However, there is no appropriate documentation of these investigations, at least regarding the data reviewed above. This issue has been difficult to resolve because of a lack of substantiation for either the NIOSH or worker comments. It is SC&A's judgment that the NIOSH response has not adequately addressed the concerns expressed by workers over falsification or inadequacy of badge results. The NIOSH response is founded largely on statements by the former RFP radiological control staff, who had been directly involved in the dosimetry program, indicating that investigations were conducted, but the response does not provide further corroborative documentation. On the

other hand, RFP workers contend, both historically and during the course of the petition process, that their dose records are not consistent with their exposure experiences as they recollect them.

To complicate matters, a former dosimetry technician recently indicated to SC&A that his supervisor doctored the numbers of highly exposed badges even after the three technicians had read the badge, as was the policy, and obtained similar results. According to this individual, the supervisor purposely lowered the dose of record (see Attachment 4). In addition, other individuals interviewed by SC&A who would have likely had involvement in investigations have indicated that they were not involved in either collecting data for or completing a dosimetry investigation (see Attachment 4). Neither NIOSH nor the RFP workers have put forth evidence that these dosimetry investigations were or were not conducted for lost, contaminated, or otherwise compromised badges. Insufficient evidence prior to the mid-1980s has been located to date explaining how the dose was assigned, making evaluation of the appropriateness of the method unfeasible. While a technical explanation may exist for badges reading zero in high dose rate situations, the NIOSH responses have not provided such an explanation.

SC&A's concern stems from the possibility of other reasons for these alleged discrepancies, reasons that bear on the data reliability question at hand. It is conceivable that doses were simply recorded as zero when there was an issue. For example, the *Procedure for Assigning Dose to Dense Neutron Films* indicates that at some time historically neutron badges with too much gamma resulted in the assignment of a neutron dose of zero (Kirchner and Kittinger 1965). A more appropriate way of calculating doses would be to perform an investigation into the individual's exposures. Other portions of this section discuss additional examples of cases for which dosimetry investigations should have occurred.

In the absence of investigation results, it is not possible to determine whether doses were adequately assigned when dosimeters or dosimeter components were lost, damage, overexposed, or otherwise compromised. The redundancy of crystals in the TLD would resolve some issues with lost or compromised crystals. In other cases, such as situations where there were no crystals or crystals were contaminated, this redundancy could not be used to assign dose. Furthermore, there was no redundancy in the film badges. To further complicate the evaluation, hard copy and electronic records do not always provide results for the particular processing run. Although at least one instance of a dosimetry investigation was located in a field logbook, the details of the investigation were not provided.

5.2.3 Summary

In conclusion, it is clearly evident that, whether investigations were conducted or not, they were not documented in the personnel radiation exposure files for the 16 individuals listed in Table 5-2. Doses assigned for available investigations contained positive, blank, or zero doses, indicating all dose assignments were not zero. Formal procedures for external dosimetry investigations have been located for 1997 and 1998, and requests for dosimetry investigations are available for 1990 and 1991. Investigations, particularly those located in individual health physics files, are sparse prior to 1990. Two of the 16 individuals had doses in their hard copy record that were identical to information provided in the dosimetry problems logbook, while

others appeared to have higher dose results in the logbook than in the hard copy record. Completing the review would require further investigation of the dosimetry processing log sheets for the particular badge cycle. SC&A only had informal assurances from RFP radiological control staff that dosimetry investigations were completed and questionnaires filled out. SC&A could find no documentation supporting the fact that these investigations were completed regularly prior to the mid-1980s and doses were assigned based on sound methodology. The existence of positive values would indicate that zeros were not the only doses assigned in instances where dosimeter problems were identified. This preliminary analysis indicates that staff did not appropriately document investigations and may not have conducted appropriate dosimetry investigations. In the end, the resulting data are not verifiable.

For situations involving dosimeters that were compromised in one way or another, NIOSH contends that RFP conducted external dose reconstructions or investigations. As mentioned in Section 5.2, documentation of these dose reconstructions or investigations by RFP is lacking in many cases where dosimeter problems occurred. Based on the number of investigations conducted in 1990 and 1991 for unusual badge results, it is evident that the threshold for conducting external dosimetry investigations has changed over time, with the more stringent criteria occurring in later years. Because the criteria changed over time, it is likely that not all unusual dosimetry results were investigated for all periods of time. NIOSH located procedures for dosimetry investigations from 1997 and 1998, which demonstrate the implementation of a formal process. The investigation requests to field radiological control staff indicate that a method for dosimetry investigations was in place at this time. Prior to this, the predominant evidence presented by NIOSH is in the form of verbal statements made by former RFP radiological control staff as well as two examples of evaluations conducted in 1964 and 1965.

5.3 LOGBOOK REVIEW

Multiple workers have raised questions regarding the implications of entries of zero values and "no data available" in the actual dose records. Affidavits provided in support of the petition included discussions of situations where individuals received doses of zero or "no data available" when the field and work circumstances would indicate that external exposure was expected. In addition, petitioners raised the issue of incomplete dose records for workers and spoke of "falsified" dose entries and "manipulated dosimetry." Throughout the SC&A review, petitioners and former workers repeatedly raised these issues. During interviews, petitioners and former workers indicated that field radiological control logbooks (e.g., contamination control logs, RPT logs, decontamination logbooks, and foreman's logbooks) may substantiate the claims made by workers. According to field radiological control personnel, radiation monitors and their supervisors kept logbooks to record daily events, including contamination problems, incidents involving medical intervention or a trip to seek medical assistance, personnel contamination events, spills, records of special air sampling, radiation survey results, posting and downposting activities, respiratory protection posting activities, Selective Alpha Air Monitor (SAAM) alarm response and checks, tritium air sampling and survey data, and/or special whole body dosimetry results. The logbooks contained some information related to individual dose in some cases.

SC&A noted the lack of corroborating evidence to back up assertions made by both the petitioners and NIOSH's site experts regarding the pervasiveness of dose record discrepancies and their historic origins. Under the broad guidance of the Advisory Board's working group, SC&A decided to interview petitioners and other site experts directly on these issues and to conduct record reviews for such evidence at the Legacy Management's Mountain View facility. SC&A conducted onsite interviews with the petitioners to clarify their concerns and ascertain the existence of supporting documents from March 27–29, 2006. SC&A requested records prior to the visit, and DOE's Legacy Management personnel retrieved some of the records from the Denver Federal Records Center.

Those records made available during the onsite visit included health physics progress reports, limited dosimetry processing data, information on tritium, and technical reports. SC&A reviewed the contents of approximately 26 boxes. The records that were not available during the site visit included the field radiological control logbooks. These were not retrieved in time for the onsite visit; however, they were made available shortly following the visit. Through the site visit, SC&A identified documents that might be helpful in evaluating the data integrity issues raised in the petition. As a result, additional searches of the record databases were conducted while on site and after the visit. The logbooks identified by SC&A and subsequently retrieved by Legacy Management included information for 1957–1996. The logbooks originally requested covered both the uranium and plutonium areas.

At the April 12, 2006, working group meeting, SC&A provided a summary of the types of records reviewed during the visit to RFP. SC&A turned over the review of field radiological control logbooks and dosimetry information to NIOSH for completion, including those records retrieve originally for SC&A's review (ABRWH 2006c). SC&A was asked to identify records that were not reviewed during the site visit and provide information on how these records can potentially answer data integrity issues. SC&A submitted *Interim Evaluation of Data Reliability Issues: Needed Document Retrieval and Evaluation* (SC&A 2006c), outlining specific data integrity issues, to NIOSH and the working group on April 19, 2006. This report contained recommendations for logbook and document reviews, including contamination control logbooks, foreman's logs for the radiological control group, RPT logbooks, decontamination logbooks, special TLD results, and dosimeter processing information. SC&A continued to provide noteworthy information identified during searches to NIOSH during the course of the review, both formally and informally. NIOSH was to review the original set of logbooks requested by SC&A during the site visit for information pertinent to the SEC petition. The logbooks containing pertinent information, particularly individual dose data, were to be scanned and made available to the working group. The original intention was to pull logbooks and dosimetry information corresponding to the work location and period of concern for workers providing affidavits or expressing similar comments during the petition interviews. NIOSH was to review the logbooks for information on external exposures, overexposures, unusual exposure conditions, internal exposures, special dosimetry use, and involvement in incidents. The working group also asked NIOSH to retrieve urinalysis logbooks for comparison to the HIS-20 database to validate the reliability of bioassay records.

The NIOSH review was intended to track information provided by those submitting affidavits and during the petition interviews against that contained in the logbooks and dosimetry receipt and processing logs to validate the issues raised in the affidavit or comment. The various sources of dosimetry information were to be utilized to ascertain whether the logbooks mentioned the individuals identified as having concerns (primarily from the affidavits), and if any dose information differed from the dose of record. The health physics files were to be reviewed for documentation related to the years in question, including dosimetry investigations and reported dosimeter results. The dosimetry processing logbooks for the same time period were to be pulled to determine whether there was indication of dosimeter damage or a failure to return the dosimeter for the period in question. The secondary dosimetry results (e.g., chirpers, pocket ionization chambers), maintained in the field radiological control records or individual health physics files in some cases, were also requested to allow for evaluation of primary and secondary dosimetry results. The records search conducted by Legacy Management did not locate secondary dosimetry results. During many of the high-exposure jobs, secondary dosimetry was used to track real time dose. The ultimate goal was to compare documentary information from a variety of available sources and determine if there was, in fact, corroboration. The field radiological control logbooks did not always identify specific individuals providing affidavits or comments; therefore, the focus of the review was changed to verification of data for those individuals with internal or external monitoring information identified in the field radiological control logbooks.

At the July 26, 2006, working group meeting, NIOSH provided a comparison between extracted exposure data from *Logbook 12-12-66 to 12-31-68* (Kittinger 1966) and the individual health physics files. Information included dates of whole body counts, accidents/incidents, and exposures for a specified employee at a specified time. For each example, NIOSH checked the NOCTS database for information matching the employees mentioned in the logbook. A total of 36 individuals selected from *Logbook 12-12-66 to 12-31-68* (Kittinger 1966) were not claimants. If the employee was not a claimant, the radiation files for employees matching the names mentioned in the logbook were requested from DOE. For multiple hits (several radiation files of employees with the same last name), all possible matches were requested. NIOSH then evaluated the logbook data against the data in the health physics file, where available. Information in the logbook and health physics file was evaluated for exact matches if monitoring periods in both sources were identical and for agreement if the logbook cycle covered only a portion of the period identified in the health physics file (e.g., logbook information may cover one month while the health physics file lists only a quarterly value). Individual results evaluated were consistent between the logbook and the health physics files for those individuals reviewed. Although the health physics files for the 36 non-claimants were retrieved and are available on the O-drive, NIOSH evaluated only 19 of the 36 non-claimants. During the meeting, NIOSH was also asked to retrieve urinalysis logbooks for comparison to the HIS-20 database to validate the reliability of bioassay records.

The working group raised the concern that the evaluation of *Logbook 12-12-66 to 12-31-68* only covered the years 1966–1968 and was for individuals assigned to the plutonium areas. As an alternative to a sampling plan for time periods and facilities from 1969 through the 1990s (ABRWH 2006c, pp. 329–337), NIOSH provided *Logbook Review for Rocky Flats* (NIOSH

2006g), a review of RFP logbooks, for purposes of ascertaining data reliability and provided its results on the O-drive for working group review. NIOSH examined a total of 65 logbooks with 43 containing individual data adequate enough to attempt a comparison. Two hundred ninety-six names were pulled from 33 logbooks, including 20 urinalysis processing logs. NIOSH covered nonplutonium areas for 1957–1960 and 1968, plutonium areas from 1964–1971, and urinalysis data from 1960, 1962, and 1964–1971. NIOSH indicated that in reviewing the logbooks to develop a sampling plan, data from after 1971 did not contain worthwhile information for database validation (ABWRH 2007).

NIOSH stated in *NIOSH's Response to Logbook Report* that SC&A was provided with an index of contents for 296 boxes (NIOSH 2007f). Attachment 12 is a compilation of results from all record searches conducted to date. As can be seen in Attachment 12, many of the search results were not relevant to the SEC petition evaluation review and were, therefore, not requested. It is important to recognize that a description of box contents does not equate to the review of box contents.

SC&A conducted a review of the 59 logbooks including the 33 reviewed by NIOSH and compiled logbook entries potentially relevant to the SEC petition as a part of the review of data integrity issues subsequent to the original records request. These logbooks were focused on the 1960s, particularly the 1969 fire, D&D, and included logbooks maintained by key field radiological control staff. The logbook entries of interest were extracted and are provided in three attachments. Attachment 14 contains logbook entries with individual-specific internal or external monitoring, references to special badging, and referrals to medical staff or the in-vivo counter. Attachment 15 represents logbook entries referencing radionuclides other than Pu-239, U-235, and U-238. Attachment 5 contains entries related to field measurements (e.g., surveys, air sampling), incidents, and destruction of badges. Entries were copied as they appeared in the logbook, including retention of abbreviations and misspellings, unless otherwise indicated. Some logbooks were difficult to read due to the poor handwriting and imaging. The reference to logbook pages means the page designated in the logbook (not to be confused with the pdf pages in the scanned version of the logbook). Names of individuals have been removed from the entries to comply with Privacy Act requirements. The following subsections describe the results of these investigations.

5.3.1 Personnel Logbook Entries

Entries linkable to particular individuals, including references to internal or external monitoring, special badging, and referrals to medical staff or the in-vivo counter were of particular interest in SC&A's review. This information was compared with the data in the health physics file and the HIS-20 database to determine consistency between field logbook information and dosimetry data. This was particularly pertinent to the questions raised in the petition regarding blanks, zeros, or "no data available" entries in dosimetry records. NIOSH stated the following in *21 March 2006 SC&A Comments and NIOSH Responses* (NIOSH 2006h):

> *Pre-1964: A blank indicates a period when the worker was not monitored. This situation will be dealt with by applying unmonitored dose using coworker data*

> *(for radiation workers), or by applying ambient environmental dose (non-radiation workers). A zero indicates a monitored period when there was no positive recorded dose. This situation will be dealt with by applying missed dose.*

For the years 1964 and after, NIOSH stated the following:

> *1964 and after: A blank or zero could indicate a period when a badge wasn't returned at the scheduled badge exchange, but was rather retained by the worker for an additional badge exchange cycle. In this situation, all dose recorded on the badge was recorded in one badge exchange cycle, and a blank appeared in the record for the other exchange cycle. A zero entry in the dosimetry records could also indicate that there was no positive dose recorded on the badge. In any case, whenever a blank or zero appears in the dosimetry record, missed dose is assigned.*

"No data available" entries indicate instances when either the badge was not turned in at the scheduled badge exchange, or the badge was turned in but there was a problem with the dosimetry badge. NIOSH proposed to use missed dose, coworker dose, or ambient environmental dose when a blank or a zero appeared in the dosimetry record. The comparison between the individual monitoring data in the field logbooks and the dosimetry files served as a method for validating whether blanks, zeros, and "no data available" could be explained as described above.

NIOSH was to provide a sampling plan for review by the working group that would encompass various years and facilities; however, NIOSH elected to directly implement its plan based on its own judgment of relevant logbooks. As a supplement to NIOSH's investigation, SC&A conducted a preliminary screening to ascertain the usefulness of the logbook data in evaluating data completeness and accuracy. The goal of the screening was to identify individuals in the logbooks who also had both hard copy and electronic dosimetry results readily available for review. Approximately 70 claimants were mentioned in some capacity in the logbook.

The field logbooks routinely refer to "special badging," typically in the context of special dosimetry studies or job-specific usage. Special badging usually occurred with jobs with high exposure potential, such as the Zero Power Physics Reactor (ZPPR) project, work on the americium line, and special projects. In some cases, it was reported in the logbooks that routine dosimeters were worn in conjunction with the special dosimeters, while in other cases the special dosimeters replaced the routine dosimeters. For example, an entry from *Logbook 12/5/66-6/11/67* (RFP 1966a, p. 131) states, "Special film badges are to be worn by people involved with the PuBe Project. Regular film badges are not to be worn." These badges were exchanged as frequently as daily (refer to Attachment 4), and a record of the exchange can be observed on the computer printouts in some claimant files. With a higher frequency of exchange, the badge results are more likely to be below the minimum detectable dose. It is also unclear how the dosimetry record reflected the special dosimeter results.

SC&A also observed in its review that special bioassay samples were not collected in all cases immediately following an incident (particularly minor incidents). Of the incidents reviewed, a majority of these were associated with wounds and skin contamination incidents. The medical record serves as an additional source of incident information that may or may not be reflected in the radiation exposure file. Although SC&A has identified dose data for individuals in a few of the logbooks reviewed, it has been unable to find information on the particular individuals submitting affidavits.

5.3.2 Other Radionuclides

The review gave rise to a concern about the exposure of personnel to radionuclides other than U-235, U-238, and Pu-139. Thirteen of the 59 logbooks reviewed by SC&A mention operations involving secondary radionuclides including U-233, U-237, Pu-236, Pu-238, Am-241, Am-243, Np-237, Co-60, Cf-252, Ir-192, curium, thorium, and tritium. The *1966–1969 Special Analysis Logbook* (RFP 1966b) contained individual-specific bioassay data for January 20, 1966, through January 13, 1969, for Sr-90, Po-210, Np-237, tritium, and thorium. Thorium, tritium, Po-210, Np-237, and curium were encountered at RFP for weapons-part handling and manufacturing. Other radionuclides such as Co-60, Cs-137, and Ir-192 were used for quality assurance testing. Some notable entries included a spill of neptunium and an inadvertent exposure to Co-60 contamination. Inadvertent releases of tritium occurred, with a significant event in 1973 that resulted in a release to the environment as well as to the workplace. Thorium was mentioned in the context of thorium strikes and as ingots in Building 883. Clearly, the logbook entries indicate that numerous radionuclides were handled in some capacity at RFP. The entries also provided some information on the dates these radionuclides were handled. The logbooks demonstrated the potential for both internal and external exposure from radionuclides other than plutonium and uranium. Section 7.0 of this review evaluates exposure to other radionuclides in more depth.

5.3.3 Field Logbooks, Incidents, and Badge Destruction

Attachment 5 includes log entries related to incidents, field measurements, and badge destruction entries obtained from the 59 logbooks. This information pertained to concerns over processing of lost, stolen, or otherwise compromised dosimeters. The logbooks also contained periodic radiation and contamination measurements for high dose rate projects. Field survey information is useful in evaluating why badges may not have reflected the field exposure conditions and/or potential reasons for discrepancies between dosimeters and field exposure conditions.

One particular concern raised in 11 different entries was the destruction of contaminated badges. *Kittinger's Personal Logbook 10/1/57–8/26/60* (Kittinger 1957) and *RFP Logbook 5/10/66-12/3/66* (RFP 1966c) included 11 references to the destruction of badges. Some of these were associated with specific individuals while others were more general comments. The following illustrates one example (Kittinger 1957, p. 13):

> *Destroyed both exchange and permanent badges of [Name] [Badge Number], notified [Name] of security of intent. He asked for no formal notification of*

> *destroyer. I asked guard [Name] to witness, which he did at 9:10 a.m. Badges were cut into small pieces and placed in the hot waste can.*

Kittinger's Personal Logbook 10/1/57–8/26/60 also indicated a general concern over the problem with contaminated badges (Kittinger 1957, p, 104):

> *[Name] informed of the large number of badges that were found contam. He agreed to try to work toward a different badging system that would not require personnel to wear them in the area. He asked that [Name] be notified and his assistance enlisted to get Security to adopt a new system. I contacted [Name] with [Name] approval. [Name] is somewhat interested in the possibility of a film badge type substitution.*

Petitioners and former RFP workers have repeatedly mentioned in interviews that badges were destroyed. The entries in the logbook validate this claim, at least in earlier periods, when badges were contaminated. The frequency of badge destruction is unknown, yet contaminated badges appeared to be a significant enough problem that alternate badging systems were under consideration. Three RCTs interviewed by SC&A confirmed the policy of destroying contaminated badges. The dosimetry staff may or may not have been cognizant of the destruction of badges since this occurred in the field. Contaminated badges were not sent to the processing laboratory to prevent contamination of the laboratory and its instruments. SC&A found that further investigation into this practice is warranted, especially in the uranium areas where there was less containment of radioactive material.

The logbooks also included statements regarding gamma alarm evaluations. One particular entry of interest was included in the *Logbook W.D. Kittinger/R.M. Vogel 6-20-63 thru 10-27-67* (Kittinger and Vogel 1963, p. 96*)*, which stated the following:

> *Gamma alarm evac. At 2:00 PM. Good test. 72 people w/o film badges.*

The exact meaning of this entry is unknown, and it is unclear whether the 72 without film badges were supposed to be wearing them; however, this raises questions regarding the implementation of dosimetry requirements in the field.

5.3.4 Field and Urinalysis Logbook Data Comparison

To investigate the alleged lack of corroboration between dosimetry records and individual doses reported in the field logbooks, SC&A requested dosimetry processing logbooks/logsheets, individual dosimetry files, secondary dosimetry results, and field logbooks corresponding to the work location and time of workers expressing concerns. Information from these logbooks was to be used to confirm issues documented in the petition relating to the adequacy of dosimetry and the occurrence of incidents.

Historical data archived by the Denver Federal Records Center for the RFETS were reviewed by NIOSH and compared to radiological files and claimant files to determine the level of agreement between these data sources. The logbooks reviewed by NIOSH included the following:

- Urinalysis/bioassay logbooks containing primarily or exclusively urinalysis or bioassay data

- Health physics logbooks, specifically radiation monitor, contamination control, and health physics staff logbooks, containing some notes regarding bioassay data, wound counting, in-vivo counting, and external dosimetry data, as well as field radiological control conditions

- Foreman logs, containing foreman's notes for the day, shift notes, meeting notes, and occasionally individual-specific information such as a reassignment of duty, followup monitoring, or clearance for work; less helpful since they contained minimal individual data

- Building logbooks, containing sampling results of floors, walls, equipment, and other surfaces or documenting radiological cleanup of the same

NIOSH stated the following in its logbook evaluation report (NIOSH 2006g):

> *Logbooks were requested from Mt. View RFETS Records staff starting in February 2006. Requests were made to Mt. View by the ORAU Team, and included search terms such as: urinalysis, bioassay, internal dosimetry, external dosimetry, and logbook. Occasionally, specific accession numbers of boxes containing logbook collections were identified and submitted to Mt. View. Dates were not necessarily specified at the start, to keep the search as broad as possible. Since April, Mt. View estimated that over 450 boxes were pulled from the FRC and that NIOSH and ORAU had reviewed over 1,000 documents. Requests were submitted through October, in attempts to find logbooks from all possible years. Logbooks of various types from 1957 through the mid-80s were located, including internal dosimetry logbooks from 1960 through 1971.*

The 65 logbooks reviewed by NIOSH primarily included logbooks requested by SC&A in later records requests. This compilation of logbooks was not intended to be representative of all areas and time periods, but was specifically chosen to obtain information on particular topics such as the 1969 fire, D&D, and logbooks for key field radiological control personnel. Based on the statements above from the logbook evaluation report, NIOSH indicated a total of 450 boxes of records, including logbooks extending into the mid-1980s, were retrieved from the Denver Federal Records Center. Information on which logbooks were retrieved from the Denver Federal Records Center was made available to SC&A February 13, 2007, by Legacy Management. These records sets contained logbooks as well as documentation relating to DAC-hour tracking, the external dosimetry program, the internal dosimetry program, the 1969 fire, and thorium. NIOSH selected the logbooks used in their comparison from among the 65 logbooks available on

the O-drive. In their response to SC&A's draft logbook review (NIOSH 2007e), they indicated that additional logbooks were available, but were expected to contain minimal useful data. This determination was made based on their review of logbooks of the same type. The original list of logbooks requested by SC&A represented the years 1957–1996, and encompassed both plutonium and nonplutonium facilities. SC&A's evaluation initially focused on 59 logbooks with a subsequent review of approximately 175 records sets including primarily logbooks.

NIOSH conducted two discrete comparisons. The first comparison involved the *Kittinger Logbook 12-12-66 to 12-31-68* (NIOSH 2006i). The Kittinger Logbook (Kittinger 1966) was maintained by a supervisor in charge of field radiological control activities and was particularly useful in identifying individual exposures or monitoring information within field logbooks. NIOSH extracted items of interest in the *Kittinger Logbook 12-12-66 to 12-31-68*, defined as any entry in the logbook that gave information of a specific nature that could be compared to information in an employee's radiation file. For example, entries included dates of whole body counts, accidents/incidents, and exposures for a specified employee at a specified time. For several entries, the information identifying the employee was incomplete (e.g., only last name was given, some of which are very common). The working group raised the concern that this comparison covered only 1966–1968 and primarily individuals assigned to the plutonium areas and requested an expanded evaluation of logbooks for additional areas and years. The expanded logbook review by NIOSH examined a total of 65 logbooks with 43 containing individual data adequate enough to attempt a comparison. Names were pulled from 33 logbooks.

In NIOSH's analysis, values in health physics files were determined to either have exact matches (in agreement), to be consistent with logbook entries (either the dose record or logbook entry was not specific enough to determine an exact match), or to be inconsistent. The NIOSH evaluation reported the following (NIOSH 2006i):

> *This evaluation found a 96% rate of agreement between data found in various logbooks, and the data found in the worker's radiation files. We found no evidence of a systematic lack of corroboration between logbooks and the individual worker radiation files which would cast doubt on the integrity of Rocky Flats dosimetry data, nor was there any evidence of inappropriate manipulation of workers' dosimetry results.*

NIOSH indicated the small numbers of confirmed mismatches were consistent with the types of clerical errors expected in a data set composed of hundreds of thousands of dosimetry results (NIOSH 2006i).

SC&A was asked to perform a validation and analysis of the logbook comparisons conducted by NIOSH. SC&A reviewed the information for all the individuals (claimant and nonclaimant) identified and evaluated by NIOSH in both the *Kittinger Logbook 12-12-66 to 12-31-68* comparison and the expanded logbook comparison, except for those whose health physics file was not available. Several logbook entries relating to smaller incidents, badge contamination and/or destruction, and exposure to other radionuclides were added to the SC&A evaluation as a means of investigating these particular topics. SC&A evaluated entries from a total of 33

logbooks for consistency with health physics files and HIS-20 or the equivalent, where data were available. The logbook entries were divided into those related to external exposures and those related to internal exposure. Individuals' exposure identity numbers (EXPIDs) were identified using names and badge numbers. SC&A then used the EXPID to retrieve the results listed in electronic databases. A total of 31, 233, and 38 person-entries were evaluated for external exposure, urinalysis, and in-vivo counts, respectively. Comparison results were recorded as exact matches, consistent, inconsistent, and not available. In the case of urinalysis and in-vivo counts, the date in the individual health physics file and the electronic database had to be within one week of that listed in the logbook. This was considered prudent because there may be a lag in time between a notation in the logbook and information provided in other sources. Percentages were calculated based on the total number of individuals evaluated for a particular area.

SC&A first compared quantitative external dosimetry data to information in the health physics files. The smallest increment of time covering the period in question (e.g., quarterly, cycle) was used for comparison. Each 31 person-entries from the logbooks were compared to information from the *RFP Coworker Stats (NDRP Included, HIS_20)* file. The *RFP Coworker Stats (NDRP Included, HIS_20)* file contains electronic external dosimetry data and is the basis for the RFP external dosimetry coworker model. The file was not helpful in many cases since it primarily contained annual doses. Eleven of the 31 person-entries were compared to data from the hard copy NDRP data printouts in the health physics file. The remainder did not have NDRP data. SC&A compared bioassay data from the urinalysis logbooks to the results from the individual bioassay cards, the Health Sciences Data System (HSDS) printout, and the HIS-20 urinalysis data file, where available. SC&A reviewed the health physics files to determine if reports and/or monitoring data were available for in-vivo counts, wound counts, incidents, skin contaminations, dosimeter issues, and qualitative information. Tables 5-3, 5-4, and 5-5 provide a summary of these data validations. Individual entry comparisons are provided in Attachment 16.

The individuals selected by NIOSH for comparison were primarily from the 20 urinalysis logbooks which included approximately 65% of the sample set. The urinalysis logbooks covered January 1, 1960, through May 11, 1971, and included gross alpha, electroplating, plutonium, and americium results. The field logbooks covered June 4, 1957, through August 24, 1971. Nineteen of the individuals from the *Kittinger Logbook 12-12-66 to 12-31-68* evaluation were also evaluated in the expanded logbook review.

Table 5-3. Summary Results for Quantitative or Semiquantitative External Exposure Logbook Analysis

Description of Entry	Number in Category [1]	Comment	Number Consistent or Exact	Number Value Not Available in Comparison Source	Number Not Consistent
Exposure Values Recorded in Logbook vs. NDRP	11	Original neutron and/or gamma data were compared to the dose values reported in the logbook. Where available, the specific period of time referenced in the logbook was used.	10	0	1
Exposure Values Recorded in Logbook vs. Coworker Stats	31	Seven individuals were not listed in the coworker stats file. In three cases, the value in the field logbook exceeded that in the *RFP Coworker Stats (NDRP Included, HIS_20)* file.	21	7	3
Exposure Values Recorded in Logbook vs. Health Physics File	31	There were six situations where exact matches were found. This corresponded to situations where the logbook provided either the dose for the year or for the quarter. When the dose did not match, there may have been an issue with inadvertent exposure of the badge to neutrons. No investigations were identified in the individuals' health physics files to confirm this.	30	0	1
Extremity Dose	1	Annual dose was greater than the dose through the date of logbook entry.	1	0	0
Overexposure Notation	5	Exposures for the monitoring period were in excess of DOE exposure limits.	5	0	0

The same individual may fall into more than one category.

Table 5-4. Summary Results for Qualitative External Exposure Logbook Analysis

Description of Entry	Number in Category	Comment	Number Consistent or Exact	Number No. with Dosimetry Investigations	Number Not Consistent
Overexposed or Contaminated Film	3	There was no indication of investigations regarding how dose was eventually assigned.	0	3	0
Dose Adjustments	3	There was no indication of dose adjustments in the health physics file.	0	3	0

Table 5-5. Summary Results for Internal Monitoring/Exposure Logbook Analysis

Description of Entry	No. in Category	Comment	Number		
			Consistent or Exact	Inconclusive	Not Consistent
In-vivo Results Recorded in the Logbook vs. the Health Physics Record	37	The inconclusive entries were due to the unavailability of the health physics file with one exception. The incident file for one individual indicated that he was recommended for an in-vivo count; however, there was no evidence that this occurred.	32	4	1
Wound Contamination/ Monitoring	6	All health physics files evaluated had documentation of a wound count for the data in question.	6	0	0
Incident Involvement	12	SC&A chose three additional incidents beyond those selected by NIOSH. These incidents involved a fire and a spill. No followup bioassay was completed following these incidents.	9	0	3
Skin Contamination Events	7	All health physics files evaluated had documentation on a skin contamination event.	7	0	0
Bioassay Results Recorded in the Logbook vs. the Health Physics Record	233	No health physics files were available for eight person-entries; therefore, these were considered inconclusive. The four individuals with inconsistent results had numerical differences between what was listed in the logbook and the health physics file.	220	8	4
Bioassay Results Recorded in the Logbook vs. HIS-20 Results	233	The inconclusive entries were primarily the result of the absence of data in the HIS-20 urinalysis file. The two individuals with inconsistent results had numerical differences between what was listed in the logbook and HIS-20 urinalysis results.	133	98	2
Other Radionuclide Monitoring	2	According to logbook entries, the two individuals were involved in operations with a potential for thorium exposure. SC&A evaluated health physics records for availability of gross alpha and/or thorium analysis. An electroplating result followed within one week of the logbook entry.	0	2	0
Urinalysis Requested	2	Where the field logbook indicated a urine sample was requested, a urine result was found in the general time period.	2	0	0

There were 31 entries with quantitative or semiquantitative external dosimetry results. All but one entry was consistent with the value in the health physics file. Consistency was defined as an exact match or a logbook result that was less than the quarterly dose for the quarter encompassing the badge cycle. In some cases, only the annual dose was available. Where possible, SC&A used the cycle data for comparison. SC&A compared field logbook values with data in the *RFP Coworker Stats (NDRP Included, HIS_20)* file for the 31 person-entries. Dose values were inconsistent in only a single instance. The coworker dose file did not include 23% of the 31 individuals. NDRP data were available for 11 of the 31 individuals. SC&A compared the original gamma and neutron doses on the NDRP printouts to the logbook values for these 11 individuals and found inconsistency in only one instance. Five instances of overexposure notations were examined. Exposures for all five for the monitoring period exceeded the DOE exposure limits. Two instances of contaminated badges were identified; however, the health physics file did not contain a dosimetry investigation. Three instances of dose adjustments were noted in the field logbooks; however, SC&A did not locate documentation regarding these particular adjustments in the health physics file.

Overall, the urinalysis data in the logbooks (field and urinalysis) and the health physics file are comparable. Approximately 94% of the results agree. In eight cases, health physics files were not available. Four individuals had numerical differences between the logbook and the health physics file. Bioassay results were also compared to the values in the HIS-20 database. SC&A found that 58% of the bioassay results from the urinalysis and field logbooks agreed with data in the HIS-20 database. The remaining 42% were absent from the HIS-20 database. These include both plutonium and uranium results, with some representing what SC&A believes are significant bioassay results.

The analysis for in-vivo results was qualitative as specific results were generally not listed in the logbook. If there was an in-vivo count documented within one week of the date mentioned in the logbook, the two sources were considered consistent. SC&A found that 86% of the logbook entries were consistent with the information found in health physics files. One individual did not have an in-vivo count in his health physics file even though he was referred for an in-vivo count. In four instances, the health physics file was unavailable. Six out of six individuals had wound count information in the health physics files for the dates mentioned in the field logbooks. Seven out of seven individual had skin contamination reports in the health physics file for the dates mentioned in the field logbooks. In the case of incidents, those individuals chosen by NIOSH who had incidents noted in the logbooks all had incident reports in their health physics files. Only one of the three additional individuals selected by SC&A had a report related to the incident in the health physics file. In the three cases where an incident report was not available, bioassay immediately (i.e., within one week) following the event was also not available.

In *NIOSH's Response to Logbook Report* (NIOSH 2007f), NIOSH conducted its own review of agreement between the logbooks and the HIS-20 database. The results of its analysis indicated 90% agreement for external exposure, 86% for in-vivo counts, and 92% for urinalysis. At first glance, there seems to be disparity between the results obtained by SC&A and NIOSH. However, SC&A and NIOSH used different methodologies to compare HIS-20 data with field logbook data. SC&A chose to compare all entries (31, 233, and 38 person-entries for external

exposure, urinalysis, and in-vivo counts, respectively) originally selected by NIOSH as well as a few added by SC&A against data in the HIS-20 database. Individuals not in the HIS-20 database were included in the calculation of percentage agreement. For example, SC&A evaluated 233 bioassay person-entries against the HIS-20 database. SC&A also went back to the logbooks and included results recorded as background or a percentage of the maximum permissible limit (MPL) that can be converted to a bioassay concentration. Of these, 133 entries were consistent between the field or urinalysis logbooks and HIS-20, constituting 58% agreement. Qualitative analyses were considered separately. The NIOSH review only included those logbook entries with quantitative bioassay results where data were available in HIS-20. This represented 122 individuals. The 92% matching rate reported in Table 2 of *NIOSH's Response to Logbook Report* (NIOSH 2007f) did not include an analysis for the remaining urinalysis entries originally identified by NIOSH. This difference in methodologies accounts for the seemingly large differences in percentage of matching results between SC&A's evaluation and that of NIOSH.

Special Bioassay Analysis

The *1966–1969 Special Analysis Logbook* (RFP 1966b) included bioassay results for Sr-90, Po-210, Np-237, tritium, and thorium. The NIOSH review indicated the following (NIOSH 2006g):

> *Eight cases from the 1966–1969 Special Analysis Logbook did not have matching information in the radiological files. Six of the eight had results of zero for the analyte of interest.*

NIOSH indicated in its analysis that only 16 out of 24 individuals had bioassay data for tritium, polonium, strontium, neptunium, and thorium. The agreement of only 67% of dosimetry data with urinalysis data in the *1966–1969 Special Analysis Logbooks* indicates a significant gap exists in the health physics files concerning monitoring of other radionuclides (e.g., thorium, tritium, curium, and neptunium).

Data from the field logbooks referencing individuals working with or around radionuclides other than plutonium, americium, and uranium were identified; however, only two individuals had health physics files available. Both individuals were potentially exposed to thorium in 1960. No thorium or gross alpha bioassay data were available; however, electroplating data were available one week after the date of reference in the logbook. Falk (2004) indicated in the internal TBD that site information about possible interferences with this method is not available. The absence of gross alpha and radionuclide-specific data to determine internal exposure from thorium, polonium, neptunium, and other transuranics may prevent assessment of internal dose for these radionuclides. An alternative method would be to assume the bioassay value was equivalent to the plutonium values. *Technical Basis for Rocky Flats Plant—Occupational Internal Dose* (Falk 2004) stated the following:

> *Interferences were likely in the period 1952 through 1962 because of a lack of specificity of the chemical procedure to isolate only the plutonium in the extract. Plutonium results would include some americium and thorium activity.*

It also stated the following:

> *From 1963 to 1977, the ion exchange method significantly reduced interferences from americium, uranium, and thorium. As the PHA system was phased in starting in 1973, the possibility of interferences was further reduced. After 1977, these interferences were not a significant issue for plutonium urine results because all samples were counted on the PHA system.*

The radiochemistry for plutonium allowed only some of the thorium and americium to come through. The analyses that would contain thorium and americium were limited primarily to the pre-1963 time period. If thorium was the predominate radionuclide of concern, as was the case with the U-233 processing, use of plutonium bioassay results may underestimate thorium uptakes. Interferences by polonium, neptunium, and other transuranics were not specifically addressed in documentation reviewed to date. The techniques used for determining internal exposure to alpha emitters would not be useful in determining uptakes of Sr-90. The absence of gross beta or radionuclide-specific data creates a bioassay gap for those exposed to Sr-90. In general, tritium bioassay data is well documented on bioassay cards in health physics files starting in the early 1970s. Prior to this, the tritium bioassay data are sparse. Although the bioassay cards in the late 1960s had thorium as an analysis type, no thorium bioassay results were observed in the approximately 150 individual files examined.

SC&A March 2007 Logbook Review

After reviewing the results of NIOSH's logbook review, SC&A expressed some concern that NIOSH's review may not have captured the full range of activities and time periods of interest to the working group. In response, NIOSH stated the following (NIOSH 2007e):

> *While there are additional logbooks available from Mountain View, these additional logbooks are expected to contain minimal useful data, based on our review of other logbooks of the same type (e.g., contamination control, foreman, etc). The amount of time required to scan and review them is not justified given our results to date.*

Furthermore, it stated the following (NIOSH 2007e):

> *Bioassay logbooks which do contain data that may be traced, were phased out through 1971 as data were electronically recorded.*

NIOSH indicated that a total of 450 boxes had been retrieved from the Denver Federal Records Center (NIOSH 2006g). The working group, with concurrence from NIOSH, asked SC&A to conduct a sampling of records not previously reviewed among the 450 records sets NIOSH referred to in its logbook evaluation report (NIOSH 2006g). This sampling was to focus on those periods of time and facilities that would afford a more representative sampling of available logbooks and related documents. Data sources from both the NIOSH and SC&A records searches were reviewed to identify additional logbooks for areas and time periods without

adequate coverage among the 450 records sets. The objective was to determine if specific relevant entries or data could be identified in these logs and to what extent these various categories of logs were rich enough in individual specific data to represent a means of database validation.

SC&A requested that RFP provide a list of the bar code numbers (or records sets) pulled by both NIOSH and SC&A since the initial records search. Attachment 17 lists records retrieved from the Denver Federal Records Center for review during the March 12–16, 2007, onsite visit. The attachment includes unique identifiers, description of the contents, and comments pertaining to the availability of individual specific monitoring data. SC&A reviewed the information and selected records concentrating on the period 1970–1995 and covering Buildings 371, 431, 444, 559, 561, 707, 750, 771, 776, 777, 778, 779, 881, 883, and 886 and the pond areas. SC&A focused primarily on retrieving the following record types:

- Urinalysis logbooks
- Dosimetry processing logsheets
- Radiological control logbooks (i.e., RPT logs, contamination control logs, radiological control foreman's logs, field radiological control supervisor logs, decontamination facility logs)

Records sets previously reviewed by SC&A were excluded. Safety concerns and individual radiation exposure files were also excluded for this review.

During the period of March 12–16, 2007, Joe Fitzgerald and Kathryn Robertson-DeMers of SC&A reviewed these records at the Legacy Management offices in Westminster, Colorado. SC&A reviewed ~175 records sets in hard copy or on microfilm. A box or roll of film often had multiple bar code or receipt numbers in its contents. Data sets were examined to determine if they included individual-specific data. Many of the records collected required review for classification prior to release to SC&A. Attachment 17 includes a more detailed description of the information found under each bar code or receipt number as well as a notation of whether the records set contained individual monitoring information. Foreman's and contamination control logs contained only minimal references to individual monitoring data interspersed throughout the logbook. Radiological control supervisor and RPT logbooks contained more information on individuals, particularly if there was an incident, personnel decontamination, or wound count (in the field or by medical staff). Many of the records sets described as radiation monitoring survey logbooks contained radiation and contamination survey data, instrument performance or check logs, and special air sampling logs. This information was not directly applicable to individual dose reconstruction.

SC&A identified several records sets that contained urinalysis results or dosimetry processing data. Those not currently available on the O-drive included the following:

- "Hotman" logs with individual urine, blood, and fecal analysis information
- Wound count data
- Americium urinalysis data
- Tritium bioassay data
- Radiation dosimetry badge data by month or quarter
- Special TLD dose measurement information
- Transuranic registry information for individuals
- External dose distribution data
- Gamma-neutron ratios by department for 1981
- Dose rate for various aged and/or shielded material
- Gamma energy distribution data

The records reviewed contained useful data for database validation. A set of 27 entries were selected from bioassay logbooks collected during the visit. Those individuals chosen were not included in previous analyses completed by SC&A. The focus of this review was to compare selected logbook entries with results in the HIS-20 database. Results are presented in Attachment 16, Table 16-7. Both fecal and urine samples were included in the analyses. There was information available on blood assay; however, there was no data for blood in HIS-20. Ten of the 27 entries showed consistency between the logbook and the HIS-20 value. One logbook entry did not match the HIS-20 value. Over 50% did not have data in HIS-20 for the date in question and in some cases there was no data at all in HIS-20. Many of entries absent from HIS-20 were fecal samples taken from a series of logbooks containing individuals involved in significant incidents or the "Hotman" logbooks.

While NIOSH indicated that post-1971 logbooks were not "data rich" (NIOSH 2007f), SC&A has found, in its limited sampling, a number of relevant logbooks containing useful data beyond that year in the 1970s, 1980s, and 1990s. However, while these entries include individual identified external and internal exposure measurements for a broad range of facilities and time periods, which are relevant to data validation, this new information would not change the conclusions reached in the previous logbook reviews.

Conclusion

In summary, the following conclusions can be drawn from the comparison of logbook information with health physics file data and HIS-20 data:

(1) SC&A found individual-specific monitoring information in both field radiological control and urinalysis logbooks. This data included dosimetry data for specific projects and cycles, urinalysis data, incident involvement, and references to wound and in-vivo counts that could be compared to health physics files and the HIS-20 database for validation of bioassay and dosimeter results. The logbook entries validated petition statements related to frequent fires and incidents as well as the existence of high radiation areas. There

were entries mentioning special projects involving radionuclides such as Po-210, U-233, U-237, Pu-236, Pu-238, Am-241, Am-243, Np-237, Co-60, Cf-252, Ir-192, curium, thorium, and tritium. There were 11 entries related to the destruction of badges providing additional examples of situations for which external exposure investigations should have been conducted.

The period of interest for the logbook review discussed at the July 26, 2006, working group meeting (ABRWH 2006c), included both plutonium and nonplutonium areas for the period from 1969–1990. NIOSH covered nonplutonium areas for 1957–1960 and 1968, plutonium areas from 1964–1971, and urinalysis data from 1960, 1962, and 1964–1971. NIOSH indicated that in reviewing the logbooks to develop a sampling plan, data from after 1971 did not contain worthwhile information for database validation (ABWRH 2007).

(2) During a review of logbooks on March 12–16, 2007, SC&A identified a select set of records that were relevant for database validation, including individual identified external and internal exposure measurements for a broad range of facilities and time periods (with relevant entries beyond 1971).

(3) The methodology applied by NIOSH and SC&A to determine the percentage of matching or consistent values between HIS-20 and logbook entries led to a disparity in results. NIOSH selected only those individuals with quantitative data. The percentages were based only on the individuals in HIS-20. SC&A used a more conservative methodology that included all individuals with semiquantitative and quantitative results in the comparison without regard for whether they had data in HIS-20. NIOSH's analysis compared field and urinalysis logbook information for all individuals originally identified by NIOSH to results in HIS-20. Matches for individuals who had no data in HIS-20 were determined to be inconclusive. For example, NIOSH based its percentage on 122 individuals for urinalysis, whereas SC&A based its percentages on 233 individuals.

(4) SC&A found that 96% of the external dosimetry data from 31 individuals had consistent data between the field logbooks and the corresponding health physics file. Of the 31 individuals, 23% were not found in the HIS-20 database and therefore were labeled inconclusive.

(5) SC&A found that 94% of the bioassay results from the urinalysis and field logbooks agreed with the individual bioassay cards in dosimetry records. Eight were considered inconclusive because the health physics files were not available for comparison.

(6) SC&A found that 58% of the bioassay results from the urinalysis and field logbooks agreed with data in the HIS-20 database. The remaining 42% were absent from the HIS-20 database. These include both plutonium and uranium results, with some representing what SC&A believes are significant bioassay results. An additional comparison of entries from logbooks reviewed in March 2007 indicates that > 50% of the entries were not represented in HIS-20 including positive results.

(7) SC&A found that 86% of the entries indicating in-vivo counts in the field logbooks had corresponding in-vivo counts in the individual health physics files. The health physics files were unavailable for four individuals.

(8) NIOSH's finding of agreement of only 67% of dosimetry data with urinalysis data in the *1966–1969 Special Analysis Logbooks* indicates a significant gap exists in the health physics files concerning monitoring other radionuclides (e.g., thorium, tritium, curium, and neptunium). NIOSH did not provide the names corresponding to those evaluated from this logbook to SC&A or the working group for validation.

(9) Entries from logbooks validate the destruction of contaminated badges for at least some cases in the 1950s and 1960s.

(10) The medical record serves as an additional source of incident information that may or may not be reflected in the radiation exposure file.

Logbook entries and internal and external data within the Health Physics records gave no indication of systemic discrepancies where DOE records were available for comparison. However, as previously noted, the logbooks selected by NIOSH did not include entries from 1972–1990 and were heavily weighted towards the plutonium areas. The evaluation by SC&A indicated that health physics files were incomplete relating to dosimetry investigations, bioassay for other radionuclides, and incident reports. Significant gaps were identified in HIS-20 external dosimetry and urinalysis data, including positive results. The evaluation also found that the health physics files were incomplete as they relate to dosimetry investigations, bioassay for other radionuclides, and incident reports. The logbook review yielded minimal information pertaining to discrepancies between field exposure conditions and dosimetry readings raised in the petition.

5.4 DESTRUCTION OF RECORDS

Destruction of records was raised in the petition and again at the Denver Advisory Board meeting. In particular, a former worker shared his concerns related to records disposed of at the onsite landfill. NIOSH summarized the concern as follows (Baker 2006):

> *A concern was raised during the Denver Advisory Board Meeting by a former RFP worker who mentioned that records from an onsite RFP trailer T-690 had been sent to the landfill in the 1989–1991 timeframe. The records allegedly included survey reports and personal radiation exposure files, and appeared to be original records. The records appeared to the worker to have come from areas all over the plant. This trailer housed the Progression Committee and Radiation Operations, including exempt and nonexempt personnel. Allegedly, during a General Accounting Office (GAO) audit, the records were brought to the trailer for temporary storage. The RCTs started to look into these boxes. Three to four weeks later following completion of the GAO audit and upon return to the trailer on a Monday, the worker found the boxes missing. Three to four days later, a truck driver was delivering water to the trailer, and an RCT present asked him if*

> *he knew what had happened to the records. The truck driver indicated that he was called in on the prior Sunday and asked to load the records and dump them in the landfill. Descriptions of the boxes' contents are based solely on the former worker's account.*

NIOSH investigated the concern in an attempt to determine whether this event occurred and the types of records that may have been involved. It also examined the situation in the context of establishing a capability to perform dose reconstruction. NIOSH contacted and interviewed 32 former RFP workers, including individuals who had an office or worked in the T690 trailer, and former radiological control personnel. None of the individuals provided information on the exact contents of the boxes; however, a number of individuals believed that the boxes contained contamination and area survey records, dose reports, and possibly air sampling data from various production buildings. NIOSH concluded the following (Baker 2006):

> *In summary, it can't be conclusively determined from the discussions that any original Individual Radiation Exposure History Files or individual exposure information that should have been contained in those files were included in the boxes of records removed from the T690 trailers. However, the discussions did not identify any specific individual radiation exposure records observed in the boxes and the one medical record that was identified as being in the boxes was located in the Records Repository at the Denver Federal Center. Discussions also indicated the radiation exposure information in the boxes might have been the non-record Quarterly High-to-Low Dose Reports sent to management and radiation protection staff.*

The investigation was inconclusive with respect to whether this was an isolated incident of alleged records destruction at RFP. What is known in relation to RFP's records retention is limited; however, the information described below was available from the documentation.

A memorandum from R.M. Vogel to J.R. Mann (Vogel 1969) made recommendations not to read film in nonplutonium areas outside of the health physics, nuclear safety, uranium chemistry, production control and quality groups. Furthermore, the memorandum recommended discarding the film after several weeks:

> *Should this recommendation be adopted it would necessarily be limited to persons not working in the plutonium areas and would result in a reduction in the film processing workload by at least 1000 packets per quarter. The undeveloped film should be retained for a short time (several weeks) after the regular film badge change before it is discarded.*

Dosimetry data linkable to an individual, especially in the case where they represent the only record, have a records retention period of 75 years. The discarding of this film appears to be contrary to these requirements. In order to verify whether the film was destroyed, SC&A asked Legacy Management to search for beta/gamma dosimeter film. Film was available for 1953–1970 at the St. Louis Federal Records Center; however, it was not organized by building so it is

difficult to determine from the search results whether the film mentioned above was included. Verification would require retrieval of film from St. Louis and a subsequent review, which was not feasible given the time constraints.

In conclusion, the particular records destruction example presented by the former RFP worker was inconclusive; however, other documentation indicated that there was a recommendation to discard dosimeter film from individuals outside the plutonium areas. Further investigation into whether this did, in fact, occur should be considered as this film was the only legitimate source of dose information for these individuals. Dosimetry processing sheets merely indicate the badges were not read.

5.5 RESPONSE TO DATA INTEGRITY EXAMPLES ANALYSIS

5.5.1 Background

On August 25, 2006, NIOSH provided the Advisory Board working group with *Data Integrity Samples Analysis 08-25-06* (NIOSH 2006j), an evaluation of the relevance and possible implications of a number of individual concerns expressed by the petitioners and members of the public. In this document, NIOSH examined "whether or not the described situations or circumstances impair NIOSH's ability to conduct dose reconstruction of sufficient accuracy" (NIOSH 2006j). The NIOSH review focused on the integrity of the data used for dose reconstruction (external dosimetry and bioassay results) and whether dose reconstruction could be performed with sufficient accuracy. Some of the individuals included had completed dose reconstructions. Other examples are from individuals who are not claimants. A total of 41 examples were evaluated, with some containing multiple elements. The examples included concerns or comments from the following sources:

- Affidavits within the SEC petition
- Advisory Board public comment meetings on April 26, 2006, and April 27, 2006 (ABRWH 2006g, ABRWH 2006h)
- Rocky Flats Citizens Advisory Board work session on May 17, 2001 (RFCAB 2001)
- Advisory Board working group meetings
- Discussions with petitioners

The analysis included individual-specific information as well as general concerns. Multiple individuals submitted comments concerning badges that did not reflect field conditions, the occurrence of black badges and subsequent assignment of zero dose, dosimetry processing and recording practices, incidents and their linkage to internal exposure, exposure geometry and partial body exposure, high-fired oxide exposures, and records destruction. During the August 31, 2006, working group meeting, NIOSH indicated that the SEC petition evaluation report included generic answers to questions that arose in the petition affidavits (ABRWH 2006e,

pp. 290–291). The *Data Integrity Samples Analysis 08-25-06* report (NIOSH 2006j) prepared by NIOSH was concerned primarily with evaluating the 41 examples at an individual level. Where examples were individual specific, NIOSH reviewed the individual radiation exposure files and made conclusions based on this information (ABRWH 2006e, pp. 317–323) to further substantiate information provided in the SEC petition evaluation report. These individual examples were used to demonstrate that dose reconstruction was feasible.

The working group asked SC&A to review the *Data Integrity Samples Analysis 08-25-06* report. When assessing this report, SC&A focused on discerning discrepancies in data that are systemic to RFP recordkeeping. The exercise was not interpreted as a review of isolated cases on a worker-by-worker basis. Examples were used in some cases to demonstrate potential difficulties associated with the reconstruction of dose. SC&A reviewed each of the 41 examples in its original context. During this review process, SC&A identified five concerns that were not originally evaluated by NIOSH but are issues that have arisen in the main portion of the petition and/or during working group meetings. These additional examples dealt with unauthorized practices related to dosimeters and completeness of records. In their February 28, 2007, response to SC&A draft data integrity example review, NIOSH provided comments on the additional five concerns (NIOSH 2007f). SC&A had concerns regarding the abbreviated or incomplete descriptions of the issues by NIOSH. As such, SC&A based its responses on the original documentation of the concern and not the NIOSH description provided in *Data Integrity Samples Analysis 08-25-06.*

Some concerns fell outside the purview of EEOICPA Subpart C but were applicable to Subpart E. These were related to chemical exposure or the synergism between radiation and chemical exposure. The synergistic effects of exposure to chemical and radiological hazards are not encompassed by SEC regulations (although addressed in research considerations under EEOICPA). Chemical and mixed exposures are considered directly under Subpart E of the EEOICPA. These concerns should be directed to the DOL under the provisions of Subpart E. Several examples provided information on the internal and external dosimetry program and major incidents. In some cases, no particular concern was defined in the example and a response was not required.

The NIOSH responses to concerns raised in the petition and in other sources were discussed at the August 31, 2006, working group meeting (ABRWH 2006e). The working group requested that SC&A evaluate *Data Integrity Samples Analysis 08-25-06*. In making its evaluation, SC&A examined whether the NIOSH responses to data integrity examples described situations or circumstances that may impair NIOSH's ability to conduct dose reconstructions and if data used in dose reconstruction would be adequate and complete. SC&A evaluated each of the responses provided by NIOSH regarding the applicability of the concern to the ability to perform dose reconstruction, as documented in Attachment 18. This attachment provides the NIOSH summary of the affidavit or other worker comments, the complete NIOSH evaluation (except where specifically noted), and the SC&A response to this evaluation. The responses provided by SC&A are not limited to the individual, but consider the broader implications of the comments. SC&A did not restrict comments exclusively to data integrity, but included comments related to other findings in this report. The topics raised by the commenters covered a diverse set of issues.

Some of the examples provided describe situations with worker safety implications and are therefore of significant importance; however, SC&A evaluated them only in the context of whether or not NIOSH can conduct sufficiently reliable and accurate dose reconstructions. For each example, SC&A either concurred with the NIOSH response, concurred with a qualifying statement, determined the NIOSH response was incomplete, determined the comment and/or NIOSH response was inconclusive, identified information only comments, or indicated that the NIOSH response was inadequate. NIOSH's August 25, 2006, report included a total of 41 examples, which were often subdivided into separate concerns (NIOSH 2006j). SC&A concluded the following:

- Concurrence (57)
- Concurrence with a qualified (11)
- Inconclusive (27)
- NIOSH response is incomplete (9)
- An adequate response has not been provided (14)
- No issue defined in the affidavit requiring response (7)

The above statistics included the five additional concerns identified by SC&A during their review.

5.5.2 Badge Results Not Reflective of Field Exposure Conditions

A number of safety concerns were raised by RFP workers, including elevated backgrounds in dosimeter storage areas, the pulling of dosimetry as a result of an RWP violation without a concurrent restriction on work, and a dosimeter assembled without TLD crystals. Several of these situations should have resulted in a dosimetry investigation. Investigation reports were located for those situations corresponding to the late 1990s as procedures for dosimetry investigations were available. NIOSH has provided a response to the petition comments, public comments, and safety concerns (refer to Section 5.1). The purpose of the analysis below is to demonstrate the magnitude of concerns expressed by workers over the accuracy of the external dosimetry program and the lack of corroborative resolution of these issues to date.

The agreement of film badge results with the corresponding field exposure conditions has been questioned in the petition, highlighted in a number of historical safety concerns, and cited in site expert interviews. Petitioners have provided examples of conditions where individuals were working in a high radiation area for a period of time long enough to receive in excess of the minimum detectable dose, but the individuals had little or no dose recorded. Fifteen individuals who provided comments either in the petition or during public comment periods brought up concerns regarding the accuracy of dosimeters. Safety concerns (71-4, 87-005, 87-038, 92-048, 97-176, and 98-073) issued as far back as 1971 reinforced concerns regarding data quality. NIOSH has explained that it is possible for a detectable dose not to occur (and therefore not be recorded by the dosimeter) even in the presence of high external exposure conditions (NIOSH 2006j). NIOSH made the following statement in Example 5-1 (NIOSH 2006j):

> *As NIOSH has repeatedly discussed, areas were posted with the maximum possible dose rates, and such postings were not intended to be representative of dose rates actually experienced by workers. This is an example of just such a situation. It is easy to understand how a worker in the field could have the impression that he was receiving a high dose (based on postings of maximum dose rates) and be perplexed when his dosimetry results did not reflect this.*

These circumstances are unlikely to explain the concerns for several reasons. First, the postings used at RFP during this period of time for radiation areas included radiation area, high radiation area, and very high radiation area. Based on the dose rate in the room, one of these postings was used. Technicians do not recall having to write in dose rates on these postings (refer to Attachment 4). Secondly, many of the individuals who have made allegations of inaccurate dosimetry readings worked for the radiological control organization and would presumably have an understanding of radiation dose and measurement. In fact, they were likely the individuals making these dose measurements. Improper understanding of radiological field conditions is not likely with these workers. During interviews, site experts listed areas such as the vaults, fluorination, americium line, and stacker retriever systems as work locations where the phenomenon was observed. RPTs were asked about posting areas at maximum dose rates, but did not recall such a practice. Based upon entries in field logbooks reviewed to date, doses in routinely occupied areas (e.g., operator's desk, aisle, control panel) ranged from 3 mR/hour to150 mR/hour and reach several roentgens per hour during bag outs (RFP 1965, RFP 1966a, RFP 1967). Installation of shielding reduced dose rates but did not eliminate dose. Health physics staff tried to maintain exposure rates at work stations of less than 2.5 mrem/hour combined neutron and gamma radiation (Putzier 1982). There were times when this level was exceeded. For example, senior radiation monitors in Building 771 raised a concern related to radiation levels in the general work area exceeding 2.5 mR/hour (JCUSC 1970).

The following case, describing an individual working on the stacker retriever in Building 371, serves as an example of the discrepancies between the dosimeter and field exposure data (USWA 2005):

> *In 1982–1983 Loading nuclear material into the Stacker Retriever in Building 371, 6 quarters out of 8, there is no data available for my dose. This work had very high dose. Up to 8 R/hr. Operators assigned were routinely rotated, due to the high dose, but as a Radiological Control Technician I was not.*

During interviews, this individual noted that his statement was not intended to claim an absence of data but to highlight the absence of dose. *Technical Basis for Rocky Flats Plant—Occupational External Exposure* indicated that RFP apparently recorded doses down to zero (Falk 2004). If this individual were standing in a radiation field of 8 R/hr for 1 minute, the exposure, as measured by a field instrument, would be 133 mR. This exceeds the typical minimum detectable dose. Since contact and 1-foot readings were taken at RFP on an intermittent basis, it is reasonable to assume an individual could spend 1 minute in an area with or approaching the maximum radiation field during the day. Any additional time would increase the accumulated dose. The magnitude of dose this individual received from this task is well

above all quarterly doses received for 1982 and 1983. The disparity between the field exposure rate cannot be explained by a misunderstanding on the part of the individual. NIOSH has not produced an adequate explanation for the badge response.

NIOSH has also chosen not to use secondary sources of radiation exposure data (e.g., chirpers, survey results, pencils) when dosimeter results are in question, although these secondary sources are often the basis for the comments. Example 19-2 made the following statement (NIOSH 2006j):

> *The early "chirpers" were just that—an audible signal to get a "feel" for workers when they entered higher fields of radiation. The badges continued to be the "legal" record of dose. Later, for the work that could be dose-limiting the new generation digital dosimeters were used to monitor on a real time basis the dose accumulation on a daily or more frequent basis, with an audit chirp rate also. They were used for qualitative controls with the personnel dosimeter being the formal dose of record. Workers not familiar with the dosimetry or the control procedure intricacies could get the impression that the dosimeters were faulty. For example, for a short term job the chirp rate could be elevated, with the remainder of the day at lower chirp rates, and the high chirp rate period could be the primary recollection because it was unusual, dramatic, etc. This affidavit does not present any evidence that "management played with numbers to keep techs working in high radiation areas," nor is NIOSH aware of any such evidence.*

In SC&A's view, NIOSH has disregarded a potential source of data that should be considered in the evaluation of unexpected dosimeter values. When using secondary dosimetry as a source of additional information on personnel exposure, consideration has to be given to the limitations of these dosimeter types. Depending on the particular model of chirper, it is possible for the unit to significantly over-respond to low energy x-rays. On the other hand, some of the units will miss photons with energies less than 50 keV. Similar issues would be seen with a pocket dosimeter. The specifics of the chirpers would have to be evaluated for the particular x-ray field of concern. Other secondary dosimetry results such as pocket ionization chambers were not considered by NIOSH, but could provide valuable information on the magnitude of dose received by a worker. Secondary dosimetry, where worn, could serve as a comparison point against primary dosimetry for validation purposes.

In summary, SC&A questions the NIOSH explanation that workers misinterpreted dose rates as a result of the practice of posting areas at the maximum dose rates, and that secondary sources of exposure information are inadequate. NIOSH has not provided corroborating documentation to support its position or evaluated particular instances to demonstrate that its hypotheses are correct. The examples provided above show disparity between field readings and dosimeter results that are not explained adequately in the NIOSH response.

5.5.3 Occurrences of Black Badges

According to NIOSH, the primary reason badges were blackened was as a result of exposure to light and/or heat. In particular, NIOSH stated the following (NIOSH 2006j):

> *It is well known that films can also be blackened by exposure to light. In most cases, film blackening due to light contamination can be distinguished from blackening due to exposure to ionizing radiation. Extreme environmental conditions such as exposure to high temperatures can cause film fogging (refs. Kathren, R.L., Thermal fogging of personnel monitoring film. Health Physics 12, pg. 61–63, 1966, and Brodsky, A. and Kathren, R.L., Accuracy and sensitivity of film measurements of gamma radiation—part I. Health Physics 9, pg. 453–461. 1963). If a badge was blackened due to light contamination, or exposure to high temperatures, it is possible that an investigation would have concluded that the appropriate dose was low or zero.*

In addition, NIOSH suggested relatively high doses of gamma radiation (500–1000 mrem) could cause a film fog making it difficult to analyze the tracks. This would not occur if radiation fields were predominantly from neutron dose rates.

SC&A located a memorandum titled *Procedure for Assigning Dose to Dense Neutron Films* (Kirchner and Kittinger 1965), which stated the following:

> *During the month of January, there were 21 neutron films reported as "too dense to read." This included 19 from Buildings 76/77/77A and 2 from 71.* ***The current procedure is to report these films with a code indicating "too much gamma to read," resulting in an assigned neutron dose of zero****. Present plans are to adjust the procedure and assign an "average" dose to these films. An investigation of the job descriptions and work locations of the 21 personnel involved indicated that assigning an overall average dose would not give the personnel involved a dose representative of their true exposure.* [Emphasis added.]

The memorandum recommends that radiological control operations staff be notified of unreadable badges and that they conduct an individual-specific investigation to determine the most probable exposure (Kirchner and Kittinger 1965). This statement raises questions regarding whether an effort was made to reconstruct dose on an individual basis prior to March 1965 when the memorandum was issued. It also raises questions regarding how RFP determined and documented doses in cases where beta/gamma badges were overexposed. Furthermore, the memorandum indicates that average doses may not be representative of the true exposure received.

In response to SC&A's concern regarding this memorandum, NIOSH indicated that (1) the individuals involved were not arbitrarily assigned a zero dose, (2) the memorandum dated March 16, 1965, recommends conducting investigations of film "too dense to read",

(3) radiological control staff stated that when there was a problem with dosimeters an exposure questionnaire was completed, (4) neutron dose fields were blank on the processing worksheet, but a notation was made of no reading, and (5) the NDRP has replaced neutron dose values recorded at the time (NIOSH 2006k).

NIOSH stated that the neutron fields were blank, yet it has concluded that these individuals were not assigned zero dose. The 1965 memorandum recommended an investigation, but a record of a final dose assignment as a result of that investigation was not found. Presumably, NIOSH based this assumption on information from the NDRP. Assuming that the recommendations were adopted to investigate badges that were too dense to read, as suggested by Kirchner and Kittinger (1965), and exposure questionnaires were completed in this situation, the information should be available for review in the personal radiation exposure file or in an alternate location. The lack of dosimetry investigation reports (or questionnaires) in personal dosimetry files, as described in Section 5.2 of this report, indicates that either these investigations were not documented or that the investigation documentation is in an alternate location than the personal dosimetry records and thus not provided in the claimant information. Furthermore, the policy of arbitrarily recording zero dose prior to March 1965 indicates that neutron data from this era are questionable. As indicated by NIOSH, it will assign the dose derived from the NDRP, for individuals included in this study.

In summary, if the issue of overexposed badges was primarily an issue with neutron films, as stated under Example 22 from the *Data Integrity Samples Analysis 08-25-06* report (NIOSH 2006j), the NDRP study may correct some of these concerns for individuals included in the file. The study will not address high exposures from photons, or neutron exposures for years not included in the NDRP study. As discussed in Section 5.2, there is a lack of dosimetry investigation documentation available in the individual health physics files containing the information used for dose reconstruction. This includes cases where beta/gamma and neutron dosimeters were overexposed. NIOSH has not provided substantiation regarding its assertion that exposure questionnaires and dosimetry investigations were conducted throughout the existence of RFP. Without this information, it is difficult to ascertain how doses from overexposed badges were investigated and documented in the record. No definitive method exists for determining whether doses were assigned appropriately when badges were black without a description of how doses were assigned under these conditions. Clear disposition of questionable badge readings is important to the integrity of radiation records upon which dose reconstruction is to be performed with "sufficient accuracy" under 42 CFR 82.

5.5.4 Dosimeter Processing

The underlying concern with dosimeter contamination, loss, or compromise is that appropriate dose was not assigned in those circumstances. The NIOSH response to Example 9-5 regarding loss of TLD crystals stated the following (NIOSH 2006j):

> *Systems were in place to interpret a badge with a missing crystal, and badges contained duplicate crystals. In these cases a dose could be estimated from the readings from the remaining crystals. These situations were investigated, and the*

> *procedures for doing so were formalized in 4-J88-RDE-0053, "TLD Data Investigation and Abbreviated External Dose Reconstruction" and 4-J98-RDE-0071, "Extended External Dose Reconstruction." The results of these investigations were documented in the worker's Health Physics file, and may or may not have been communicated to the employee at that time. Since instances where badges were missing crystals were investigated, NIOSH concludes that this issue does not prevent NIOSH from performing dose reconstructions of sufficient accuracy.*

The procedures NIOSH references here were implemented in 1997. Investigations have been located in claimant files for this time period. Requests for dosimetry investigations have been located for 1990 and 1991. Prior to this time, information is intermittent, especially in the individual health physics files. Section 5.2 of this report provides a more detailed discussion.

In one comment extracted by SC&A from the Advisory Board public comment period held on April 26, 2006, the worker stated the following (ABRWH 2006g, p. 355):

> *Two chemical operators with many years experience in the Building 771 process area left their positions to work in the dosimetry department. The dosimetry person training them told them if badges returned readings higher than a certain number they were instructed to give the operator zero counts, or no current data available.*

Others have also made similar statements during interviews. It is unclear from the statement whether this was the practice for the dose of record. This would certainly raises concerns related to both individual and coworker data. In the absence of further information, no absolute determination on whether data integrity was actually compromised can be made because of the lack of corroborating documentation.

In summary, in situations where the dosimeter was compromised for one reason or another, NIOSH contends that RFP conducted external dose reconstructions or investigations. As mentioned in Section 5.2, documentation of these dose reconstructions or investigations by RFP is lacking in many cases where dosimeter problems occurred, particularly prior to the mid-1980s. The substantiation provided by NIOSH is limited to procedures for dosimetry investigations from 1997 and 1998, a dosimetry processing procedure for 1983, two examples of investigations conducted in 1964 and 1965, respectively, and verbal statements make by former RFP radiological control staff. Given currently available data and comments provided by workers and NIOSH, it is difficult to determine whether doses for blackened badges were assigned based on sound data or individual judgment.

5.5.5 Contamination Incidents

Petitioners expressed concern regarding the occurrence of incidents at RFP. In its response to petitioners, NIOSH stated the following (NIOSH 2006j):

> *NIOSH grants that incidents occurred during the history of Rocky Flats. However, the occurrence of such incidents does not prevent NIOSH from conducting dose reconstructions with sufficient accuracy. Incidents were reported if they necessitated sending the employee to the Medical Department. If a contamination incident could be successfully addressed on the floor, an incident report may not have been filed. NIOSH grants that it is not always possible to tie an intake to a particular incident. Routine or special request bioassay would detect intakes that may have resulted from unreported incidents. The entire point of the routine bioassay programs is to monitor for intakes that may not be recognized at the time of occurrence and to ensure that internal doses from all intakes are kept below regulatory limits. This worker's radiation file was reviewed and it contains numerous incident reports, including every incident report submitted in support of this affidavit, plus numerous others. Some measurement results showed an activity greater than the level of detection, and internal intakes were assigned. All of this data was available and considered in the dose reconstruction.*

Incident information can provide valuable data on the nature of intakes that occur as a result of the incident. For example, it can define the route of intake or the particular radionuclides being processed at the time. Routine or special sampling during these situations can be used to calculate dose if the appropriate monitoring was conducted following the incident. Unfortunately, the threshold for incident reporting is not clearly defined, and followup bioassay may not be requested after incidents not meeting the threshold for the time period. There is a missed dose potential for tritium dose from activities in Buildings 371, 771, 776, and 881 if sampling is not conducted in a timely manner because of tritium's short biological retention period. NIOSH has developed methodologies to estimate dose from tritium oxide and tritium gas in site profiles for other sites and could do so for RFP. The lack of correlation between an intake date and a positive bioassay sample is not an SEC issue but should receive further evaluation as a site profile issue in the context of best-estimate doses.

5.5.6 Exposure Geometry and Partial Body Exposure

According to the petition, badges did not properly record organ dose due to the proximity of the organs compared to the badge location. Of particular concern were exposures to areas of the body that were not protected when lead aprons were worn. The petition indicated that the head, neck, and other exposed portions of the body received higher doses than recorded by the film badge located beneath the lead apron. NIOSH responded to this concern as follows (NIOSH 2006j):

> *Lead aprons were available and used for a limited number of tasks at RFP. For most years, workers were instructed to wear badges under the lead apron to measure dose to the torso. In 1992 this was changed to instruct workers to wear the dosimeter outside the lead apron to better measure the dose to the head, neck and arms. Field studies to determine the dosimeter response in both locations were preformed. The results of these studies were used to develop bias*

> *corrections to use for dose reconstructions. The use of lead aprons does not preclude sufficiently accurate dose reconstruction. As a result, NIOSH concludes this issue does not have SEC implications.*

Furthermore, NIOSH indicated that OCAS-TIB-010, *Best Estimate External Dose Reconstruction for Glovebox Workers* (Neton 2005), can be used to calculate external exposures for individuals working in a glovebox.

Radiation exposures to specific organs have gone uncaptured by the data available from RFP. For example, employees routinely removed and did not replace lead-lined or water-shielded glove port covers, then would sit in chairs with their heads near the open glove ports. Employees wore the dosimeters on their chests or collars, but exposure to their heads went unmonitored. The presence of multiple glovebox lines in the same room resulted in exposure of the body from multiple angles, including from the side and rear. Another example of nontraditional exposure geometry is the receipt of exposure from sources located on the floor, such as in the vaults. In some cases, a dosimeter worn on the collar or the chest was not representative of the exposure received by specific areas of the body, particularly the lower whole body. NIOSH indicated that partial body exposure calculations can be conducted on a case-by-case basis, and that geometry issues do not preclude dose reconstruction with sufficient accuracy.

In summary, NIOSH indicated in the SEC petition evaluation (NIOSH 2006a) that dose correction factors for lead apron and glovebox use will be incorporated into the RFP external dose TBD or are addressed in TIBs. Although lead aprons protected the front of the trunk, the butcher-type aprons did not shield the arms, legs, neck, and face. The site profile review should consider further whether the dose correction factor developed for lead apron use is adequate for unshielded portions of the body. As long as correction factors can be derived, partial body exposures do not preclude dose reconstruction efforts. NIOSH will have to clearly define when these correction factors or case-by-case evaluations will be applied.

5.5.7 High-Fired Plutonium Oxide

The RFP SEC-00030 petition evaluation (NIOSH 2006a) has raised concerns about worker exposures to a unique form of plutonium, referred to as PuO_2. This material is formed at temperatures of 1,000ºC or higher and has been shown to remain in the lung for extended periods of time. Concerns were raised by petitioners regarding the ability to detect PuO_2 intakes with available monitoring methods. According to a presentation prepared by Piltingsrud for the AEC (Piltingsrud 1966), intakes of radionuclides can go undetected in the urine:

> *For certain refinements in assessing body burdens, a capability for the analysis of feces, blood, and tissue samples is necessary. Recently we have found that certain internal exposures do not lend themselves to this program…. Specifically we have found lung burdens by total body counting which were nearly undetectable in the urine.*

Another concern raised was the appropriateness of the *ICRP Publication 66:Human Respiratory Tract Model for Radiation Protection* (ICRP 1994) for determining dose from uptakes of high-fired oxides. As indicated below, NIOSH agreed that this is a significant issue (NIOSH 2006j):

> *NIOSH agrees that there is evidence of high-fired Pu oxides at the Rocky Flats Plant. The presence of such materials does not, however, affect the feasibility of dose reconstructions. ORAUT-OTIB-0049* [ORAUT 2007b] *describes the methodology NIOSH will use in dose reconstructions potentially involving super S plutonium.*

Section 3.0 of the SEC petition evaluation review provides a detailed evaluation of PuO_2 dose calculations.

With respect to data integrity, the concern is primarily one of determining the application of the ORAUT-OTIB-0049 method. With the release of ORAUT-OTIB-0049 (ORAUT 2007b), NIOSH defined the scope for application of their highly insoluble plutonium model.

> *Plutonium oxide (especially the high-fired variety) is one of the most insoluble forms of plutonium (ICRP 1994, personal discussion with C.W. Sill) typically encountered in the workplace. However, it is not feasible to exclude the possibility that soluble forms of plutonium might become more insoluble over time* [La Bone and Findley 1999; Moody et al. 1994]. *Therefore, the TIB is assumed to apply if the form of the plutonium is not known. This is used as an additional possibility of material type; all possibilities are calculated and the type resulting in the largest dose is applied to be favorable to the claimant.*

In *NIOSH Response to SC&A Draft Report on Data Integrity* (NIOSH 2007g), NIOSH stated that it had addressed this issue in a December 19, 2006, e-mail exchange between NIOSH and SC&A (Ulsh 2006). In response to "Where have you documented which workers will be assessed according to OTIB-0049," NIOSH provided the following answer (Ulsh 2006).

> *OTIB-49 is now being finalized. Once it is signed, we will initiate a Program Evaluation Report to revisit completed claims with a POC<50% to see which should be revised in accordance with the new OTIB. In practice, the claims with the greatest potential to be revised are noncomp lung cases, because assuming super S solubility is claimant-favorable in these situations. Claims completed after OTIB-49 comes into force will be completed in accordance with the OTIB.*

This response merely indicates that noncompensable lung cancer cases will be revisited. In addition, a reference is made to a program evaluation report that has, to date, not been made available.

ORAUT-OTIB-0049 acknowledges that plutonium was strongly retained in the lungs of those exposed in the October 15, 1965, fire (ORAUT 2007b). SC&A recommends that NIOSH consider those exposed in other fires (e.g., 1969 fire, Tunnel fire) and during high temperature plutonium processing. D&D workers are also at risk when they come in contact with residual

material, especially in areas that only became accessible during the demolition of buildings and equipment. Although this is not an SEC issue, a more clearly defined scope in terms of the RFP worker categories may assist dose reconstructors in defining individuals potentially exposed to high-fired oxides.

5.5.8 Destruction of Records

During the Denver Advisory Board meeting, a former RFP worker raised a concern regarding radiological records that he was told were sent to the landfill for disposal (ABRWH 2006h). NIOSH conducted an investigation by contacting individuals who may have some knowledge of the situation. Several other former RFP workers raised similar concerns regarding destruction or modification of records. NIOSH concluded the following (NIOSH 2006j):

> *NIOSH is not aware of any evidence that records it would use for dose reconstruction at Rocky Flats were inappropriately destroyed. Some records, such as original personal dosimetry records, are governed by DOE records retention policies. Other records are not covered by such policies. Further analysis of this concern is not possible without additional details regarding what types of records are at issue.*

NIOSH further stated the following (NIOSH 2006j):

> *No evidence of fraud was provided either in this affidavit or in the public comment made by this individual. NIOSH is not aware of blatantly fraudulent Rocky Flats dosimetry monitoring data/records.*

The review located no direct evidence that indicated occupational exposure records were destroyed. Dosimeter film was disposed of for a subset of workers in the 1969/1970 timeframe (Mann 1969d). A more detailed evaluation of investigations into records destruction is provided in Section 5.4.

5.5.9 Conclusion

Overall, SC&A was able to validate some comments provided by workers in the petition, during public meetings, or during interviews, but did not find substantial documented evidence of a systemic problem with individual RFP dose records partially due to the lack of data. The review raised multiple questions about the validity of the dose records for workers working high dose rate jobs, in particular. However, no conclusive documentation was uncovered pointing to deliberate falsification or errant recordkeeping despite the numerous sources indicating that this was the case. Several references relating to inadequate QA in the dosimetry program were identified throughout claimant files, such as inadequate transfer of data between databases. The apparent absence of records in 1969 and 1970, as discussed in earlier sections of the report, is a significant concern. There is no indication that review of additional information would provide corroborating evidence. Information located to date raises questions regarding the adequacy of

elements of the radiological control program for some time periods; however, that information dose not provide definitive evidence of a systemic issue with the integrity of the data.

5.6 LUNG COUNTS AFTER THE FIRE

The 1969 fire investigation report indicated that 110 people were counted as of June 28, 1969, as a result of the fire (AEC 1969, pg. 94). NIOSH compiled a list of 69 out of 90 individuals reportedly interviewed regarding the 1969 fire. This included first responders as well as managers, supervisors, and support staff. The working group requested that SC&A determine whether claimants among the 69 individuals received in-vivo counts after the fire. Of the 69 individuals, 20 had readily accessible files and were identified for review. These individuals are recorded in Table 5-6. A review of the health physics file for each person was conducted by SC&A to determine whether these individuals received an in-vivo count following the fire. If the individual received his exposure within about 1 year of the fire, the table notes the first plutonium urine sample data and in-vivo count data after May 11, 1969. Three individuals did not receive an in-vivo count in this time period. Of those three, one did not submit a bioassay sample. Of the 20 individuals, 14 mentioned some kind of involvement in the 1969 fire in their CATI. Nine were in-vivo counted within 1 month after the fire. It is important to understand that NIOSH compiled a list of those interviewed about the fire. It did not necessarily involve individuals directly involved with responding to the fire. In fact, the list does not include several individuals known to be involved with the fire. For example, according to the AEC report, 33 fireman and security guards participated in fighting the fire (AEC 1969, pg. 58). The NIOSH list includes only 18 firefighters and security guards.

Table 5-7 shows the number of documented in-vivo counts from May to December 1969 compiled from monthly progress reports.

More than 200 counts were conducted during 1969 relating directly to the fire along with the routine counts. Gross alpha and uranium bioassay processing was curtailed from May 11, 1969, through June 1, 1969 (Piltingsrud 1969b). In those files reviewed, there appeared to be a delay in bioassay sampling for many individuals after the fire.

Table 5-6. Postfire Bioassay for Select Individuals Interviewed after the 1969 Fire

ID Number	CATI[1]	1969 Deep Dose[2]	In Vitro[3]	In Vivo[4]
1	N	3222	6/26/1969	10/17/1969
2	Y	22 (Partial year only)	6/19/1969	5/12/1969
3	Y	Blank	8/5/1969	No
4	N	465	7/31/1969	6/26/1969
5	N	153 (Partial year only)	5/15/1969	5/11/1969
6	Y	137 (Partial year only)	6/26/1969	7/7/1969
7	Y	1519	6/23/1969	12/3/1969
8	Y	38 (Partial year only)	7/9/1969	5/12/1969
9	Y	749	1/13/1970	5/13/1969
10	Y	678	5/21/1969	5/11/1969
11	Y	55	1/13/1970	No
12	Y	39 (Partial year only)	7/19/1972	3/4/1970

Table 5-6. Postfire Bioassay for Select Individuals Interviewed after the 1969 Fire

ID Number	CATI[1]	1969 Deep Dose[2]	In Vitro[3]	In Vivo[4]
13	Y	813	7/18/1969	8/21/1969
14	N/A	8 (Partial year only)	No	No
15	Y	77	5/15/1969	5/11/1969
16	N	1831	7/18/1969	4/22/1970
17	N	351	5/15/1970	4/2/1970
18	Y	28 (Partial year only)	6/11/1969	5/11/1969
19	Y	Blank	7/16/1969	5/12/1969
20	Y	43 (One badge noted as contaminated and discarded as hot waste)	5/14/2006	5/12/1969

1 Mentioned the fire in the CATI
2 Annual deep dose for 1969. Where "Partial year only" occurs, this indicates monitoring data was available for only a portion of the year.
3 First in-vitro sample submitted on or after May 11, 1969
4 First in-vivo count on or after May 11, 1969

Table 5-7. In-vivo Counts Reported for May–December 1969

Month	Total	Fire Counts	Routines	Recounts
May	287	119	100	47
Jun	200	12	113	16
July	195	8	171	38
Aug	306	5	169	21
Sept	312	43	191	16
Oct	349	20	255	29
Nov	235	0	66	112
December	283	0	97	141

5.7 CONCLUSION

Overall, SC&A was able to validate some of the comments provided by workers in the petition, during public meetings, or during interviews, but did not find conclusive documented evidence of a systemic problem with RFP dose records. The review raised multiple questions about the validity of the dose records for workers working high dose rate jobs, in particular. However, no documentation was uncovered pointing to deliberate falsification or errant recordkeeping despite the numerous sources indicating that this was the case. Methods for assignment of missed dose may underestimate doses received by highly exposed workers. Analysis of individual logbook results indicates HIS-20 is incomplete. There was minimal formal documentation of dosimetry investigations prior to 1990, although in 1990 and 1991 hundreds of requests were made to the field for investigations of unusual results.

While further review could answer questions that remain and shed light on the equivocal nature of NIOSH's conclusions for some of the specific issues, there is no indication that such additional review would necessarily provide the desired corroborating evidence. Any further information would have to be presented either by the petitioners or NIOSH. In this context, SC&A has identified issues and inconclusive information related to the integrity of RFP dose data but defers to the Advisory Board and its working group to determine how much sampling review is sufficient.

6.0 INTERNAL DOSE ISSUES

This section presents SC&A's review of the internal dose section of the NIOSH evaluation report for RFP (NIOSH 2006a). The principle issues discussed in this chapter include the published coworker model, evaluation of dose reconstruction examples, and NIOSH's treatment of the dose reconstruction of radiation exposures to americium, thorium, and radionuclides other than uranium (natural, enriched, or depleted) and plutonium that were present in historic operations. The term "other radionuclides" denotes these radionuclides as a group.

6.1 OTHER RADIONUCLIDES

The RFP TBD (Falk 2004) described the overall situation regarding internal exposure potential for radionuclides present at RFP as follows:

> *Workers at Rocky Flats had the potential to receive intakes of plutonium, americium, enriched uranium, depleted uranium, and tritium, as well as miscellaneous other radionuclides. Section 5.2 describes the available source term information, including isotopic composition, solubility, and particle size. Site-specific internal dosimetry information for other radionuclides, such as thorium, curium and neptunium, is rare or not available.* [Falk 2004, pp. 7–8]

The RFP SEC evaluation report (NIOSH 2006a) made the following statement about radionuclides other than depleted or enriched uranium, plutonium, and tritium:

> *Lastly, there have been a number of special projects involving small quantities of other radionuclides. Small quantities of thorium-232 were used in the fabrication of metal parts as early as 1952, as mold-coating compounds, and in analytical procedures. Thorium-228 was noted as being removed from uranium-233 metal in thorium "strikes" during the mid- to late-1960s. Limited amounts of neptunium-237, curium-244, americium-241, and plutonium-238 were employed as tracers into the make-up of Special Order pits to assist research taking place at other facilities, for plutonium-238 as Zero Power Reactor fuel elements, and extraction of americium-241 for special applications. None of these other radionuclides were present at Rocky Flats in high enough quantities to contribute significantly to internal dose potential.* (NIOSH 2006a, p. 44)

The evaluation report does not provide an analysis that demonstrates that these radionuclides could not contribute "significantly to internal dose potential." SC&A's TBD review (SC&A 2005c) and the matrix (Item 29 of the March 27, 2006, matrix for RFP) developed from that review raised the issue of the dose potential of "other radionuclides." Since the publication of the evaluation report, NIOSH and its contractors (collectively referred to as NIOSH below) have done a considerable amount of work on the issues relating to these radionuclides, mainly in response to concerns raised by the working group and SC&A regarding the adequacy of the data and dose reconstruction methods proposed for these radionuclides.

6.1.1 Dosimetry Areas and Bioassay Data for other radionuclides

RFP internal dosimetry areas were divided into four areas (A, B, C, and D), each characterized by certain radionuclides. These were, in fact, the original names of the plants given according to the code names for the kind of materials processed there. Later, the areas were given building numbers. According to the TBD, the kind of bioassay done was specific to the various areas:

> *In the beginning of operations (1952), the Rocky Flats Plant was divided into four distinct sub-plants, plus a general support area. The sub-plants were named A Plant, B Plant, C Plant, and D Plant. The designations A, B, C, and D are significant because they are also the code names for the materials processed in those plants as well for the urinalysis procedures used to analyze those materials. The records of the 1950s do not contain the words: depleted uranium, enriched uranium, and plutonium. Instead, depleted uranium is A material processed in A Plant (buildings numbered 4##, mainly Building 444); enriched uranium is B material processed in B Plant (buildings numbered 8##, mainly Building 881); and plutonium is C material processed in C Plant (buildings numbered 7##, mainly Building 771). D Plant (buildings numbered 9##, mainly Building 991) handled all materials. A nonspecific gross alpha urinalysis method was used for workers in D Plant.* (Falk 2004, p. 38)

The TBD describes the methods of analysis as shown in Table 6-1.

Table 6-1. Methods of Analysis

A	Fluorimeter, reported in micrograms/liter (1952–1956); reported in micrograms/24 hours (1957–1964)
B1	Electroplating, reported in disintegrations per minute per 24 hours (dpm/24-hr) (Note: electroplating, in RFP records, more properly should be called electrodeposition)
B2	Ether extraction, reported in dpm/24-hr
B3	Tributyl phosphate (TBP) extraction (handwritten on some cards)
C1	Carrier precipitation, reported in dpm/24-hr
C2	Thenoyl trifluro acetone (TTA) extraction, reported in dpm/24-hr (Note: on the header of cards for the period 1961–1965, the code C2 is "Pu by Radio Autography"; there is no indication that this method was implemented at RFP)
D	TBP extraction

Source: Falk 2004, p. 38

According to the TBD, the following radionuclides are associated with the various types of analysis described in Table 6-1 (Falk 2004, p. 38):

- A = DU
- B1 = depleted and enriched uranium
- C1 and C2 = plutonium
- B2, B3, D = gross alpha

In discussions of RFP issues, NIOSH initially stated that when radionuclide-specific data are lacking, it would use gross alpha bioassay data and interpret it according to the most claimant-favorable radionuclide present at the facility in question. The evaluation report also makes such a statement (NIOSH 2006a, pp. 51–52, exposure scenarios 4, 8, 12, and 16.). While Table 6-1, taken from the TBD, indicates that gross alpha data appear to be available only for certain RFP areas (B and D, with methods B1 and B2 used in the former case), Roger Falk, NIOSH's site expert, stated that this routine designation of the locations where gross alpha samples were taken did not preclude such samples from being taken in other areas in "special situations" (ABRWH 2006c).

The depth and breadth of the debate that occurred on these various issues and the turns that it took are captured in the transcripts of working group meetings and the associated documents (both those produced by NIOSH and by SC&A). This section assesses the final dose reconstruction approaches proposed by NIOSH rather than recount the details of the technical history of the development of the issues.

NIOSH performed a significant amount of work on issues relating to other radionuclides based on review of classified documents. SC&A did not undertake any classified reviews, as the Advisory Board had not authorized any. However, in the final stages of this work, NIOSH was able to obtain declassified (with redactions) Th-232 material balance sheets. These material balance sheets have been very useful in SC&A's review of NIOSH's analysis of the thorium source term.

6.2 AMERICIUM-241

The Am-241 discussion is divided into two parts:

- *Americium-241 intake estimation*: Process streams where Am-241 was abnormally concentrated relative to plutonium or was in pure form
- *Plutonium depleted in Am-241*: The reliability of using of Am-241 in-vivo counts in areas where the plutonium being processed was depleted in Am-241

6.2.1 Americium-241 Intake Estimation

Americium-241 purification began at RFP in 1957 in Building 771. It was recovered for resale, which continued until the late 1970s. After that time, Am-241 removed from plutonium was sent to the radioactive waste streams in Building 774 (Chem Risk 1992, p. 69, and Flack and Meyer 2004, p. 11). In 1967, a molten salt extraction process replaced the ammonium thiocyanite process.

In response to the concerns about the gap in Am-241 monitoring for operations involving separating and purification of Am-241, NIOSH stated that the initial attempts to extract Am-241 were not successful, as there was very little of it present in the plutonium sent to RFP because of the short time that had elapsed after initial plutonium production. NIOSH based its conclusion

on expert interviews, as stated by Mel Chew, who led the NIOSH research on other radionuclides, during the working group meeting of July 26, 2006:

> *If you think about it, the plutonium that showed up at Rocky Flats in the early years and in the '50's, prior to '63, was fairly fresh plutonium that came in from Hanford. The—the plutonium that didn't come in for the—with the americium content was basically out of the recycled plutonium that was in the weapons that was in the '50s here, and really didn't come back out of the stockpile until '62, '63. All right? And so therefore where we were looking for americium in the early years at Rocky Flats, Wanda said it wasn't there. Right? So you know, I think we were all obviously looking and said—well, assuming it was there. And matter of fact, we confirmed this with a discussion with* [Name]*, and he was responsible for developing the process to start—to start to thinking about separating the americium from the weapons returned. He made a comment very clearly in this document from this discussion with him that they even had a tough time with the metallurgist even finding americium to validate the process. Right? And I happen to know some parts per million contents that I think the specs that came in from Hanford, and Wanda would know this, you know, of her early years, they were very, very low. For deliberate purposes. Right? And so clearly the americium, I think I can say with a fair amount of confidence that the—where we were looking for bioassay, just wasn't there in—in enough significant quantities or a few—I'd hate to say a few atoms, to be humorous here—that was enough to cause any concern, even—especially they even tried to look for it here. Right? But clearly when the weapons returned—did come back in the—in the '63, '64 time period—which makes sense when you really think about it. Okay? When the time period, when we put into the stockpile. Okay? It stays there for a certain amount of years, I think all of you know that, and then we got the return. That's when the americium content really—really start to come up and the americium was separated out, you know, to refresh the plutonium and make better—to make weapons grade plutonium back—to go back into the system again. And also the americium was now concentrated in a form like the molten salt extraction, both to sell the—and sent back to Oak Ridge. And as you know, your americium is widely used, you know, throughout the system for many, many other purposes, even more than the weapons complex. So I'd like to just make that comment is that we cannot see the americium prior to '63, Mark, because it just wasn't there. And that makes a lot of sense.* [ABRWH 2006c, pp. 19–21]

This stands as the last definitive statement by NIOSH on the subject of Am-241 monitoring in the 1957–1962 period. While it appears to be reasonable as a technical hypothesis, SC&A did not perform further verification of weapons returns to RFP, which is mainly in the classified arena, and its associated implications for the 1957–1962 period for Am-241.

Americium-241 bioassay began in 1963 (Falk 2004). However, the TBD advised dose reconstructors not to use these data in dose reconstruction due to interference from Th-228-related alpha particles:

> *The dose reconstructor should use the plutonium urine data instead of the ^{241}Am urine data to assess intakes of weapons grade plutonium. The intake of the ^{241}Am is then calculated from the value of the initial parts per million of ^{241}Am measured or assumed for the plutonium mixture involved in the intake.* [Falk 2004, p. 14]

SC&A raised this issue with NIOSH during the July 26, 2006, working group meeting. NIOSH site expert Roger Falk pointed out that any interference from Th-228 present would result in a higher value of estimated intake, and therefore the result would be claimant favorable (ABRWH 2006c, pp. 28–29). SC&A agrees with this conclusion.

SC&A performed a brief review of the HIS-20 database to check the availability of Am-241 bioassay data. The number of samples increased steadily from 1963 to 1967. This could be due to a ramping up of work and an increasing number of workers involved or a sparseness of sampling in the initial period that coincided with an aqueous Am-241 production process. The process was changed to a molten salt extraction process in 1967 (ABRWH 2006c, pp. 22–23). SC&A raised this issue in its October 27, 2006, memorandum on other radionuclides. NIOSH responded, as follows:

> *Presumably, SC&A is referring to the number of Am bioassay results in HIS20. By our count, there are 475 Am bioassay results in 1963, 1299 results in 1964, 1227 results in 1965, 1406 in 1966, and 2939 results in 1967. This is consistent with Rocky Flats beginning to handle Pu (with ingrown Am) from weapons returned from the field beginning in 1963. SC&A has presented no evidence that there are gaps in Am monitoring, nor is NIOSH aware of any gaps.* [NIOSH 2006b]

This NIOSH explanation quoted in full is plausible on its face, but it was offered without documentation of an increase in the scale of Am-241. The Am-241 production process changed in 1967 from an aqueous to a molten salt process. Hence, dose reconstruction would require sufficient records for the period up to the change in process, since the later (post-1967) data may not be applicable to the earlier period. The TBD explicitly noted the exposure potential for early americium operations to 1967 as follows:

> *The process …was cumbersome, resulted in a disproportionate quantity of waste solutions, and created personnel alpha-contamination exposure problems due to required manual operations and maintenance.* [Flack and Meyer 2004, p. 11]

NIOSH's statement that SC&A did not find gaps in the Am-241 monitoring is true. However, SC&A did not perform the review of classified materials that would be necessary to establish the production-related issues associated with such an investigation.

Lung counting began at RFP in 1964 (Falk 2004). However, meaningful results were not obtained until after the 1965 fire. Some of the data present quality issues, notably data susceptible to interference from the 63 keV gamma from Th-234. Neither the NaI detectors used until 1973 nor the phoswich detectors used until 1976 would have been able to adequately

discriminate between the Th-234 and the Am-241 signals. However, as Roger Falk pointed out during the July 26, 2006, working group meeting, any Th-234 interference would yield a higher in-vivo count and a claimant-favorable result (ABRWH 2006c, pp. 28–29). SC&A agrees with this interpretation so long as Th-234 was not also being used for measuring U-238 lung burden.

SC&A Evaluation:

In the final analysis, given the significant amount of data available even from 1963 through 1966 and in the period after that, the Am-241 issue does not appear to be an SEC issue; especially as lung counting data whose results are likely to be claimant favorable are also available to supplement bioassay data, if needed.

6.2.2 Plutonium Depleted in Americium-241

SC&A has raised the question of how in-vivo counts of Am-241 are to be interpreted in areas where the incoming plutonium might itself have had low Pu-241 content. In that case, the relatively low Pu-241 content would result in relatively low Am-241 content in returned weapons plutonium. Purification of such plutonium could lead to removal of Am-241 to very low levels. This may make assumptions about Am-241 to plutonium ratios in interpreting in-vivo count estimates questionable.

During working group meetings, NIOSH has stated that specifications for weapons plutonium by weapons designers required RFP to maintain a certain isotopic composition of plutonium, including a specified level of Pu-241. The practice at RFP was therefore to mix aged plutonium depleted in Pu-241 with sufficient fresh weapons plutonium to maintain the specified requirement. As a result, the situation of very low Pu-241 content in outgoing plutonium would not arise.

On behalf of NIOSH, site expert Roger Falk provided this explanation with regard to Am-241 levels to be expected in returned plutonium. NIOSH also presented some documentary evidence. SC&A concurs with NIOSH regarding the effort made by RFP to maintain Pu-241 levels in plutonium. However, according to another site expert, "there were exposures to very low ppm of americium, less than 50 to 100 ppm of americium, in Building 771 in the chemical processing area prior to the mixing with the aged plutonium." While in-vivo lung counts were not possible under such circumstances, he noted that, "this occurred in the area where the plutonium was in a soluble form which made it possible to monitor them with urine bioassay."

SC&A Evaluation:

Since Am-241 bioassay data are available, this would not be an SEC issue.

6.3 THORIUM-232

According to the TBD, Th-232 was present and processed at RFP only in small quantities:

> *Beginning in 1952, thorium was used onsite in quantities small enough that effluents were not routinely analyzed for Th. Thorium quantities varied from as little as none to as much as 238 kg in a given month. The principal use was fabrication of metal parts from natural thorium metal (^{232}thorium) and from various thorium alloys. Thorium oxide might have been used as a mold-coating compound in limited experiments. Thorium compounds were used in analytical procedures. In addition, twice between 1964 and 1969, thorium "strikes" were performed to remove gamma-emitting ^{228}thorium from uranium-233 metal needed for fabrication of test devices. The strikes involved a fluoride precipitation and filtration process using natural thorium. Photon radiation from ^{228}Th decay products would have been monitored by standard gamma dosimetry badges in use at the plant. In addition, thorium was used as a stand-in for plutonium or uranium components in development programs (ChemRisk 1992).* [Flack and Meyer 2004, pp. 9–10]

This statement reflects a 1976 paper entitled "Thorium Use at Rocky Flats" (Bistline 1976) that was discussed by the NIOSH, the working group, and SC&A. An unclassified 1976 document as well as compilations prepared by NIOSH of unclassified data from classified sources on the thorium issue seem to substantiate that the largest total inventory of thorium present at RFP until 1976 appears to have been approximately 250 kg.

The development of the issues relating to Th-232 dose reconstruction has run a rather complex course. The following key papers, included as attachments, document that road:[5]

- Attachment 19: NIOSH, *Summary of Potential Intake at RFP*, no date, published in October 2006
- Attachment 20: Brant Ulsh, Bryce Rich, and Melton Chew, *Summary of Thorium Handling at RFP*, December 21, 2006
- Attachment 21: *SC&A Memorandum to the Rocky Flats Working Group, "Thorium-232 and Other "Exotic" Radionuclides at Rocky Flat."* October 27, 2006
- Attachment 22: *NIOSH Evaluation of SC&A's Thorium-232 and Other "Exotic" Radionuclides at Rocky Flats—review of NIOSH Papers*, November 3, 2006

[5] This section is an amended version of a draft version prepared for the RFP working group and posted on the OCAS web site. That version, dated February 15, 2007, is not included here as an attachment.

- Attachment 23: *NIOSH Evaluation of SC&A's Draft Report on Other Radionuclides (thorium)*, February 28, 2007

- Attachment 24: *Interview Regarding Possible Shipments of Alloy from Dow Madison to Rocky Flats*, February 8, 2007

In addition, there are extensive working group meeting transcripts, available on the OCAS web site and not reproduced here.

6.3.1 Thorium-232 Source Term

In its October 2006 paper on the subject (Attachment 19), NIOSH provided data on Th-232-related work at RFP. The main source term for potential thorium air contamination was stated as "Fabrication of metal weapons parts from natural thorium and thorium alloys—machining, shearing, grinding" (Table 1, p. 1). NIOSH has stated that the parts from Oak Ridge were "trimmed and lightly machine" at RFP (Attachment 19, p. 2). The maximum amount of Th-232 in such metal parts was estimated at 60 kg per year, and the potential for "unsealed or loose contaminants from large metal parts is 10% or less" (p. 4), yielding a source term of at most 6 kg per year. NIOSH then applied NUREG-1400, an NRC guidance document, *Air Sampling in the Workplace* (NRC 1993), to this source term to develop an estimate of potential intake for Th-232 exposure at RFP (see Section 6.4.2.2 for NUREG-1400 discussion).

SC&A raised two basic questions relating to the source term aspect of NIOSH's analysis. The first related to the magnitude of the thorium processed and the second to the 10% factor used.

Th-232-related documents had been destroyed at DOE's Fernald plant in the 1970s (ORAUT 2004b). While there is no evidence that thorium-related documents have been destroyed at RFP, the question arose as to whether such destruction had been a wider policy or whether the examined documents represented a complete review of the thorium work at RFP. Furthermore, in the case of Y-12, a closer examination of thorium documents had yielded data indicating far more thorium processing than NIOSH initially believed. SC&A therefore sought some clarity as to the completeness of the thorium source term data that were central to NIOSH's initial conclusion that upper bound doses were very low—so low in fact that they could be ignored (since they were less than 1 mrem in the worst case) (ABRWH 2006d, pp. 213–214). However, SC&A's concerns regarding the completeness of the thorium source term were broadly addressed by the declassified materials balance data and recent communications with NIOSH, though some uncertainties remain (see Section 6.4.1.1).

NIOSH revisited the source term question with regard to the amount of thorium metal processed over the years (as distinct from the amount in the RFP inventory at any time). In its December 21, 2006 report (Attachment 20), NIOSH stated that three thorium metal parts, each weighing about 80 kg, were rolled from 12 in. x 12 in. x 3 in. ingots to metal bars between May and September 1960. Canning of the ingots in mild steel was also performed. According to NIOSH, only 12 workers were involved. An incident occurred during hot rolling of the third ingot in September 1960, and the ingot was cut with a torch and eventually scrapped (see

Attachment 20). Ingot 2 was also scrapped. This new information about thorium processing was presented in the December 21, 2006, report (Attachment 20), but not in the prior (October 2006) NIOSH analysis (Attachment 19). While this new information did not change NIOSH's October 2006 estimate of the maximum inventory of Th-232 at RFP in any year (Attachment 20), it did increase the maximum amount estimated to be processed in any year by a factor of four—from approximately 60 kg (plus small amounts in various processes) to 240 kg for canning and rolling. However, it should be noted that the rolling of these three ingots was experimental, and that SC&A has not come across evidence of further rolling operations.

6.3.1.1 Thorium-232 Material Balance Data

To facilitate the SC&A review, NIOSH undertook to have the RFP thorium material balance sheets declassified. SC&A has reviewed this declassified document (RFP 2007). To the extent the data are available and interpretable, they corroborate the NIOSH source term. However, they are incomplete in certain periods.

Table 1 of the NIOSH October 2006 paper on thorium (Attachment 19) states that thorium was handled and processed at RFP between 1956 and 1993 for the "[f]abrication of metal weapons parts" and the "[f]abrication of thorium substitute R&D components." It also shows that the analytical laboratories used thorium from 1952 to 1993. SC&A understands that thorium processing and use was a sporadic activity at RFP and has taken this into account in its analysis of the materials balance data.

The declassified records show that a monthly balance for thorium was maintained. The records start on March 1, 1953. Hence, no record is available for 1952 and the first two months of 1953. There is also a 1.5-year gap in the data between July 1, 1953, and January 1, 1955, when no monthly balance sheets are available. Finally, almost no data are available between July 1970 and 1987 (inclusive) and only sporadically after that. The gaps are documented in the declassified record itself and summarized in Table 6-2.

In addition, the material balance compilation does not show any data for 1952 or January and February 1953. There was a beginning material inventory of 5 kg of Th-232 on March 1, 1953, indicating receipt of thorium in the period between 1952 through February 1953. Whether any processing occurred during this period is unknown.

Table 6-2. Time Gaps in Thorium Material Balance Data as Indicated in the Data

Dates	Comments
July 1953 to December 1954 (inclusive)	
July 1970 to May 1982	Except for normal operating loss summary (annual) though September 1974
June 1983 to June 1985 (inclusive)	
August 1985 to July 1987 (inclusive)	
October 1989 to February 1990 (inclusive)	
April 1990 to January 1991 (inclusive)	
March 1991 to 1993 (inclusive)	

Source: RFP 2007

For some periods, the gaps in the data shown in Table 6-2 may mean that documents are unavailable for certain time periods, since the materials balance for thorium was performed every month at least into the 1970s, even in the months when there were no receipts and no withdrawals. For the period from July 1953 to December 1954, RFP may not have had any thorium inventory. The ending balance for June 30, 1953, was zero, as is the starting balance on January 1, 1955. Of course, this is not conclusive, but rather evidence that indicates a lack of thorium receipts or processing in this period. A definitive statement cannot be made based on the available information.[6]

The last sheet in the materials balance records provides an annual summary of the normal operating losses from 1952 until September 1974. This summary indicates zero normal operating losses for the FY (July 1 to June 30) 1952 and FY 1954 and negligible losses in FY 1955. This provides further evidence supporting a lack of thorium processing during these specific periods of data gaps.

For the data gap between July 1970 to September 1974, the normal operating losses data sheet lists losses as zero or negligible in all years except FY 1971, when losses are listed as 1 kg. (The rounding in the material balance sheets is generally to the nearest 1 kg of Th-232.) An addition to normal operating losses of 1 kg between September 1974 and 1976 may be inferred from other available documentation. No RFP thorium data of any kind are reported between 1976 and May 1982; the gap in the materials balance sheets for this period extends from July 1, 1970, to May 1982.

[6] SC&A sent an inquiry about the nature of the gaps in the data and received the following response from Brant Ulsh: "I asked Rod Hoffman about this when he sent us the declassified MBA ledgers. Rod said that the periods with no inventory sheets (last half of 1953–end of 1954, and last half of 1970 through Sept. 1987) are consistent with no reportable inventory being onsite during those periods. This is supported, for instance, by the inventory sheet for June, 1953. Note at the bottom it has the following note: "Composition of Ending Inventory: No inventory on hand." There are no further sheets until January, 1955" (Ulsh 2007). However, as discussed in this analysis, this argument applies to the 1953–1954 gap and the post-1982 gaps, but not the 1970–1982 gap.

The materials account shows an ending balance of 102 kg on June 30, 1970, and a starting balance only 1 kg in June 1982. All available data after June 1982 show a material balance of 1 kg. While the data do not exist or are not available for several years in the 1980s, there is no indication of any deviation from a 1-kg material balance.

The declassified materials balance data contain no explanation for the removal of 101 kg from the thorium inventory between June 20, 1970, and June 1, 1982. In response to a query from SC&A about the data gaps, NIOSH gave the following response regarding the inventory of 102 kg at the end of June 1970 and its reduction to 1 kg:

> *Arjun:*
>
> *Here is some additional followup info on your question about the Rocky Flats thorium inventory ledgers. We talked to DOE headquarters, and they checked the information on the Nuclear Materials Management and Safeguards System (NMMSS) database for the fate of the thorium present at Rocky Flats as of June 30, 1970. Recall that we have a Material Balance and Inventory ledger for that month showing an ending inventory of 102 kg. From DOE NMMSS documents, the same quantity was reported on September 30, 1970. As of December, 1970 the inventory dropped 1 kg. The inventory remained unchanged through March 1971. There was then a shipment which comprised >95% of the RFP thorium inventory from RFP to Fernald on June 14, 1971. This is consistent with Fernald being designed as the repository for thorium in the DOE complex right around that time. From the MBA ledgers file currently on the O drive, there are inventories of 1 kg listed for the 6/1/82–5/31/83, 7/85, and 10/87 reporting periods. There is also a report dated 3/28/90 that specifies 1 kg of solid thorium compound present in Bldg 371 as a standard. I surmise from this that after the shipment to Fernald in 1971, the only thorium left onsite at Rocky was this 1 kg standard.*
>
> *Regards,*
> *Brant*

This is a plausible explanation for the inventory change. Fernald was designated as the national thorium repository site in 1972 (ORAUT 2004a, p. 10). The shipment of thorium inventory no longer needed at RFP to Fernald is compatible with that fact, as noted by NIOSH. SC&A has not reviewed the DOE materials safeguards database (which may be classified); according to the e-mail quoted above, NIOSH appears to have obtained the information verbally from DOE. Finally, the shipment of thorium to Fernald does not definitively settle the question of whether thorium was shipped in to RFP, processed, and shipped out some time during the period of the data gap.

In reviewing the material balance records that exist, it is not possible to relate those records to specific periods of processing at RFP. But the data are broadly consistent with the one major use of thorium at the site that is documented—the ingot rollings between June and September 1960

(in two different fiscal years). Data show receipts approximately corresponding to the amounts processed. An entry of total material removed of 172 kg was made for May 1961, and a cumulative entry for removal of 209 kg in that fiscal year to date was shown as well. This is likely related to the two ingots that were scrapped and one that was shipped; however, the material balance sheets contain no direct evidence of what was shipped.

The manner of the entries for normal operating losses creates some uncertainty regarding the times and amounts of processing. The summary sheet for these losses (p. 253 of the material balance document's pdf file) showed that almost half the cumulative losses of 31 kg are attributed to just 2 years—9 kg in FY 1964 and 6 kg in FY 1967. However, the materials balance sheets for these years did not indicate that large amounts of Th-232 were processed during that time. Attribution to losses may have occurred in years after the losses were incurred, but that cannot be established from the monthly data. In other words, the unevenness of the amounts attributed to losses may be due to data recording practices regarding losses. SC&A noted that the data for normal operating losses for FY 1964 in the monthly balance sheets do not show the same amount for the year as the summary sheet. Ten kg are attributed to cumulative fiscal year losses in the June 1964 data sheet (p. 122 of the pdf file) versus 9 kg in the summary sheet.

It is possible that an annual operating loss of 9 (or 10) kg implies considerable processing in that year but no offsite shipments. However, this cannot be established from the available data. This uncertainty may especially affect workers who were at RFP for a few years, since the annual attribution of thorium exposure over long periods would not be available to them to balance out positive and negative source term errors.

Finally, NIOSH has indicated that 32 kg of normal operating losses are compatible with the available data:

> *It is not clear why the reference to a cumulative total of 32 kg Normal Operating Losses indicates operations beyond those discussed in NIOSH's December 27, 2006 report, especially when the 1960 Th ingot operation itself resulted in two of the 80 kg ingots being scrapped. The Normal Operating Losses are tracked on the Materials Balance and Inventory ledgers used by NIOSH in calculating the thorium source term.* [Attachment 23, p. 5]

The declassified materials balance data do not clarify this point because the scrapping of two ingots, 80 kg each, does not appear in the normal operating losses. These ingots were probably shipped offsite in FY 1961 (as noted above) and shown as removals in the materials balance sheets.

SC&A Evaluation:

No information in available materials balance sheets or other data sources contradicts NIOSH's conclusions about thorium processing at RFP. Taken as a whole, the material balance sheets are

broadly consistent with NIOSH's assumptions about the thorium source term. SC&A agrees with NIOSH that the maximum amount of thorium at RFP was approximately 250 kg.

Attribution to normal operating losses was highly nonuniform. Nearly half the cumulative losses up 1976 occurred in just 2 years, FY 1964 and FY 1967. It is noteworthy that neither was the year of the largest processing—the ingot canning and rolling year—1960. The available data are insufficient to establish whether much more processing than usual occurred in these two years (apart from 1960) or whether the losses recorded in those years actually occurred earlier.

6.3.1.2 Magnesium-Thorium and Tungsten-Thorium Alloys

NIOSH has also reviewed a number of other potential sources of thorium exposure. In its December 21, 2006, report, NIOSH also reviewed whether RFP received thorium from the Dow Madison plant and concluded that no pure thorium shipments occurred between these two sites:

> *A review of transcripts of the interviews of Dow Madison workers upon which this question is based reveals that the Dow Madison workers were clearly speaking of shipments of magnesium alloy, of which thorium is a minor component (up to three percent according to the workers). NIOSH further verified this with a follow-up interview of the worker who spoke of shipments of material between the Dow Madison Site and Rocky Flats. In this follow-up interview, the worker recalled frequent shipments to Rocky Flats, and he stated unambiguously that the material was magnesium alloy, not thorium metal. He did not recall the Madison Site ever shipping pure thorium metal to Rocky Flats or anywhere else.*
> [Attachment 20, p. 7]

The December 21, 2006, NIOSH report does not provide conclusive information about alloy shipments to RFP or their exposure potential once received there. During the January 9, 2007, working group teleconference call, NIOSH stated that the worker interviewed on this topic remembered that alloys were shipped by the truckload. SC&A conducted a followup interview with a former Dow Madison worker who participated in the shipping process from 1963 to 1975. Attachment 24 provides the interview summary. According to this worker, about four truckloads per month were shipped from Dow Madison to RFP, with each truck carrying about 40,000 lb of magnesium-thorium alloy. He also remembered that RFP returned magnesium-thorium alloy scrap. If this information is correct, the annual source term for the thorium contained in the sheets of alloy shipped to RFP would be in the tens of tons.

On the other hand, senior former RFP personnel interviewed by NIOSH have stated that RFP did not receive large quantities of magnesium-thorium alloy. None of the personnel remembered shipments from Dow Madison. Furthermore, according to the NIOSH paper of February 28, 2007, the parts that were used at RFP were not fabricated there (Attachment 23):

> *The four site experts subsequently interviewed were unanimous in their view that there were not large quantities of magnesium alloy used at Rocky Flats, and none of the interviewees remembered shipments of such material between Dow*

> *Madison Site and Rocky Flats. The one use of Mg alloy remembered was the pennants in the conveyor line in Building 776, which involved possibly a few hundred pounds of alloy at most. It was not clear whether or not this magnesium alloy contained thorium. It was also stated that the pennants were fabricated offsite by an outside vendor.* [NIOSH February 28, 2007, Attachment 23, p. 7]

The contradictory testimony, implying a difference of several orders of magnitude in the potential magnesium-thorium alloy source term, between the Dow Madison worker who was involved in the shipping process and RFP site experts interviewed by NIOSH has not been resolved. It would have taken a considerable effort to attempt to locate shipping and receiving records for the Dow Madison plant, for instance, to produce supporting documentary evidence. The working group did not authorize such an undertaking. The RFP petitioner offered to locate fellow former RFP workers with recollections of historic magnesium-thorium alloy use. SC&A followed up with calls to the petitioner and attempted to obtain corroborating information regarding Dow Madison shipments of magnesium-thorium alloy to RFP, but was unable to obtain substantive data that would help resolve the conflicting statements. SC&A also contacted other former RFP workers, but obtained no corroborating information to substantiate Dow Madison shipments of magnesium-thorium alloy to RFP or to describe its applications there. This may have occurred because none of the workers SC&A was able to contact about this issue was employed at RFP during the period in question.

SC&A Evaluation:

A difference of interpretation remains between NIOSH and SC&A regarding the magnitude and nature of the magnesium-thorium alloy source term due to contradictory interview statements and lack of documentation to resolve the large differences implicit in the statements made by site experts from both the Dow Madison and RFP sites. However, subsequent followup with RFP petitioners and former RFP workers produced no corroborating information to substantiate Dow Madison shipments of magnesium-thorium alloy to Rocky Flats, nor did investigations find any further information about its applications there.

6.3.1.3 Tungsten-Thorium Alloy Welding Rods

NIOSH has agreed to develop a complex-wide intake estimate for tungsten-thorium welding rods. It also presented an analysis of the issue in its February 28, 2006, paper on thorium at RFP (Section 6 of Attachment 23). SC&A has not reviewed the underlying literature in detail, but is in qualitative agreement that sufficient data on welding with tungsten-thorium alloy exist to enable bounding intake estimates. It is therefore not an SEC issue. SC&A will address it separately as a generic issue in dose estimation should the Advisory Board ask it to do so.

6.3.1.4 Overall Conclusions Regarding the Thorium Source Term

SC&A concludes that, while new information continued to emerge during the course of this review, no information in available RFP materials balance sheets or other data sources serve to contradict NIOSH's conclusions about thorium processing at RFP. Taken as a whole, the

material balance sheets are broadly consistent with NIOSH's assumptions about the thorium source term. Therefore, SC&A does not consider this to be an SEC issue under the circumstances.

6.3.2 Estimating Thorium-232 Intakes

This section will first consider the ingot operations in 1960 and then discuss NIOSH's approach to estimating doses from other thorium processing.

6.3.2.1 1960 Thorium Ingot Operations

Leaving aside the reservations about the source term discussed above, SC&A has concluded that it should be possible to make a bounding dose estimate for ingot operations in 1960. These operations are described in detail in a document from the period (Calabra 1961). Some bioassay data are available, and the minimum detectable amount is known. RFP carried out monitoring of the rolling of the thorium ingots. Limited air concentration data are also available for some of the specific operations, including the incident in September 1960.

In its December 21, 2006, analysis, NIOSH presented its approach to estimating doses from the operations conducted with the 80-kg ingots using air concentration data. For the operation on June 3, 1960, one air sample was at 4.62 dpm/m^3, while the others averaged 1.41 dpm/m^3. NIOSH has combined these data with documented estimates of the times of the operations to estimate intakes for rolling part of the operations. It made a separate estimate for the flame-cutting of thorium related to the September 1960 incident, during which time special air samples were taken (Attachment 20).

The June 3, 1960, air samples are not indicated in the data sheets as breathing zone samples. The use of general air samples whose location is not well specified to estimate intakes for particular workers could result in underestimates, despite some conservatisms in NIOSH's calculation. The use of general air concentration data (or data whose nature in relation to the worker breathing zone is not well known) is not recommended. This was discussed at length in the context of the SC&A review of the Bethlehem Steel site profile and the resolution of the issues that followed. If air concentration data are to be used for RFP, the bounding nature of the data should be established by comparing the values with air concentrations measured at other sites.

The flame-cutting of an ingot on September 22, 1960, was documented and some air concentration data are available (Attachment 20). However, the number of samples is rather limited—four in all (Air Sample records 1960). NIOSH has identified one of these as a "breathing zone" sample (Attachment 20); however, the raw data card itself only stated that the sample was taken "3 ft. from thorium ingot while it was being cut." This is more than an arm's length; it farther than the operator would be from the ingot during the cutting operation; hence, the sample is unlikely to reflect a true breathing zone concentration. In such circumstances, a short distance of a foot or two can make a considerable difference in air concentrations. Hence, the actual breathing zone of the worker doing the cutting may have been higher, possibly much higher. Furthermore, the sampler airflow rate was rather low at 1.7 ft^3/min. The rate is not much

more than might be breathed during very heavy work. SC&A provided a detailed discussion of the flame-cutting issue and possible air concentrations derived from welding data in its supplement to the Bethlehem Steel site profile review (SC&A 2005b, Attachment 4).

Bioassay samples were taken on September 29, 1960, during the pulling of the broken ingot (#3) for the can.

In conclusion, the available air concentration data, taken by themselves, are too sparse to create a bounding dose estimate for ingot operations. They should be compared to data from other sites to validate that the estimated doses are bounding (or not). If this is done, NIOSH should be able to establish a bounding dose estimate. The procedure specified in its December 21, 2006, document does not definitively establish such a bounding dose due to the limited data available and the fact that NIOSH did not use the bioassay data. The flame-cutting operation for one ingot should be compared to some of the welding air concentration data discussed by SC&A in its Bethlehem Steel site profile review.

6.3.2.2 Machining of Thorium Parts from Oak Ridge

NIOSH has conducted an extensive analysis of the applicability of NUREG-1400 to the estimation of thorium intakes for operations at RFP other than the ingot operations discussed above. They include the operations that NIOSH has described as requiring "light" machining of parts received from Oak Ridge, which constitutes the main remaining Th-232 source term that NIOSH has described (Attachments 19, 20, and 23).

NIOSH's intake estimate based on its use of NUREG-1400 for light machining of 60 kg of thorium parts annually was initially 0.024 Bq per year (Attachment 19). This estimate used a 10% loose material factor to reduce the source term by a factor of 10. While NIOSH continues to believe that this is adequate to estimate bounding dose, it agreed in its February 2007 assessment to drop the factor of 10 and hence increase the intake estimate to 0.24 Bq per year (Attachment 23, Section 5).

NIOSH has carried out some validation exercises for the use of NUREG-1400. In its December 2006 report (Attachment 20), NIOSH used the following comparison:

> *A study of air activity measured from similar machining and/or grinding operations was conducted to validate the estimate derived using [the] NUREG-1400 approach. Thus an extensive study by scientists of the AEC Health and Safety Laboratory prior to 1958 was referenced which presents air sampling data from a number of facilities in which a variety of processes were used in the early 1960s time period for processing of uranium. This study was with uranium being processed in large quantities for extended time period of production operations and present a much greater contamination release potential than the light machining or grinding of relatively small pieces of thorium metal during relatively short time periods, but can be used in a high bounding comparison. The releases from similar processes, i.e., milling, grinding, etc., on uranium as*

compared to thorium is also conservative/bounding based upon the differences in the physical characteristics. The melting point for uranium metal is 1690 C and for thorium metal 1845 C. The boiling point is 3500 C for uranium and 5200 C for thorium. Thus values derived for thorium air activity based upon the direct comparison with uranium results below will be higher than those anticipated for thorium.

The air activity levels for the machining and grinding operations, which were performed on the uranium metal parts, were converted to mass concentrations, which were then converted to thorium activity concentrations. This is based upon the assumption that equal mass quantities of thorium to those of uranium would be released. Since thorium metal, oxides and hydroxides are considered insoluble, solubility class S dose conversion factors were used.

Since the work with thorium metal parts was performed on equipment designed for enriched uranium at the Rocky facilities, the machines were shrouded/hooded and were considered in the "vented" category listed in the reference study. [Attachment 20]

Table 6-3, reproduced from the NIOSH report, shows the results obtained.

Table 6-3. Calculation of CDE and Annual DE Dose (in mrem)

Operation	dpm/m^{3}U	µgU/m^3	dpm/m^{3}Th	hr/yr	Bq intake	mrem	DE mrem	
						CDE	1st yr	20th yr
Machining	50	64	16	10	3.1	44 bs	0.25 bs	6.5 bs
						24 lung	5 lung	0.3 lung
Grinding	200	257	63	10	12.6	176 bs	1.0 bs	27 bs
						97 lung	21 lung	1.6 lung

Key: bs = bone surfaces, lung = lung as the organ of reference. For reference, the annual dose equivalent in mrem is given for the 1st year after intake and the 20th. CDE = Cumulative dose equivalent is derived by multiplication of the intake by the dose conversion factor from ICRP 68 (ICRP 1995) in Table 3.
Source: This is a reproduction of Table 6-1 in the NIOSH December 21, 2006, paper (see Attachment 20).

Both the machining and grinding intakes are higher than the highest value of intake (0.24 Bq) that NIOSH has derived from the application of NUREG-1400. In SC&A's view, the example does not establish that NUREG-1400 provides an adequate basis for making a bounding dose estimate. In fact, since the intakes are well over an order of magnitude higher than the new NUREG-1400 estimate, SC&A finds that the comparison reinforces its reservations about the utility of using NUREG-1400 for the stated purpose.

NIOSH has also provided two other examples of its validation of the use of NUREG-1400 (Attachment 23). In both cases, a NUREG-1400 intake estimate is compared with that derived from air concentration data.

In the first example, NOISH used a 1953 thorium source term based on Simonds Saw and Steel air concentration data and compared it to one derived from NUREG-1400 based on the source term. The latter estimate was 315 Bq, while the former was 196 Bq. In other words, according to NIOSH's estimate, the NUREG-1400 estimate exceeded that derived using air concentration data for the same work by a factor of 1.6. The air concentration used was the highest among the weighted averages estimated for different groups of workers.

This example indicates that NUREG-1400 could be an adequate tool to estimate average working conditions for groups of workers. However, the use of weighted averages, particularly with small numbers of measurements for each task, is not appropriate for making bounding dose estimates for individuals. SC&A has discussed this issue in detail in relation to an analysis of potential worker exposure at the Mallinckrodt Chemical Works and the SEC petition that was filed in that context. Specifically, SC&A showed that the uncertainty in a single step, which had three air concentration measurements associated with it, could result in a 95th-percentile intake estimate that was more than double the one derived from the weighted average. In light of that analysis, SC&A concluded that weighted averages could only be used to make minimum dose estimates (SC&A 2005a, pp. 27–29). In other words, it is inappropriate to use them for bounding dose estimates.

The situation in the case of Simonds data is about the same. The value of weighted air concentration used related to only two workers—"Finisher North" and "Hookman North" (Klevin and Weinstein 1953). For Finisher North, only two measurements were associated with the task that indicated the highest air concentration. The same is true of Hookman North. In fact, the raw data sheets for these two workers **indicate that the same air samples were used to estimate the weighted average for both workers**. Hence the entire comparison rests on two air samples for a single task that accounts for about three-fourths of the total weighted exposure. Of course, with only two samples, estimating a 95th percentile is itself fraught with methodological problems, but assuming that a lognormal approach can be applied, the 95th percentile value would be over 400 Bq—that is greater than the value derived using NUREG-1400. Hence, while this example indicates the plausibility of using NUREG-1400 for estimating average doses for worker populations over long periods of time, it does not establish the validity of NUREG-1400 as a method for estimating a bounding dose for RFP thorium workers. This reservation is especially important if operations were sporadic or if they involved unique processes that were not repeated, such as the flame-cutting of a thorium ingot.

The second example, which used the single air concentration measurement taken 3 ft from the job on September 22, 1960, at RFP, is statistically even more tenuous. Contrary to the NIOSH description, the raw data card did not describe this as a breathing zone sample; in fact, it is unlikely that it was a breathing zone sample. There is also no way to estimate an uncertainty for the breathing zone, even if one accepts this single measurement as such, since there is only one data point.

In conclusion, NIOSH's analysis has established the plausibility of using NUREG-1400 to obtain a general view of working conditions on average. However, the examples provided do not

validate the use of NUREG-1400 for estimating a plausible upper bound dose for individual workers at RFP that would meet the criteria of 42 CFR Part 83.

6.3.2.3 Thorium Air Concentration Data from Comparable Operations

Three studies described below (Albert 1966, Adley et al. 1952, and Harris and Kingsley 1959) provide extensive data on air concentrations measured during various thorium processing operations at a number of different sites. These analyses provide a large amount of data that could be analyzed for applicability to RFP. As described in this section, SC&A has evaluated these reports.

The exposure pathway of greatest concern with respect to the machining and other operations with thorium metal and metal alloys containing thorium is inhalation of particles produced during those operations. At the working group meeting held on March 7, 2007, SC&A suggested that a more appropriate strategy might be to use the empirical data for uranium and thorium grinding operations published in the Albert and Adley reports, respectively. These reports appear to provide data directly applicable to the exposure scenarios of concern at RFP, as opposed to the more generic models and assumptions provided in NUREG-1400.

A report on uranium dust in machining and other operations by W. Harris and I. Kingsley, *The Industrial Hygiene of Uranium Fabrication* (Harris and Kingsley 1959), is also relevant. This section summarizes the data in those portions of these three reports that deal with the machining of uranium and thorium. This information discloses the range of uranium and thorium dust loadings, typically expressed in units of mg/m^3, that have been observed in the breathing zone of workers involved in the machining of uranium, thorium, and alloys containing thorium. Once a more complete understanding is gained regarding the conditions under which thorium was machined at RFP, the data provided in this section can be used to select dust loadings that can be used to reconstruct doses to RFP workers who might have been involved in the machining of thorium and alloys containing thorium and for whom NIOSH now proposes to use NUREG-1400. These data should also be used to complement the sparse data available for the 1960 ingot operations to ensure that a suitable bounding estimate of dose is developed. The reports contain job-specific air concentrations and time-weighted data. Under the circumstances at RFP, with intermittent thorium operations, the use of daily weighted averages from other sites would be inappropriate. But the task-specific data from other sites can be used with the knowledge of job durations at RFP to estimate intakes.

The Albert Report

In 1966, Academic Press published a comprehensive manuscript entitled *Thorium, Its Industrial Hygiene Aspects* (Albert 1966). Based on its review of the literature, SC&A believes that this manuscript remains the most authoritative reference on the industrial hygiene aspects of thorium.

Chapter 10 of the manuscript specifically addresses the inhalation hazards of thorium in industry. In particular, Section 2, "Thorium Fires," Section 6, "Rolling, Forging, and Machining," and Section 7, "Thorium-Magnesium Alloys," appear to be either directly or indirectly related to

characterizing the airborne dust loading that might have been experienced by workers at RFP involved in machining thorium metal and/or alloys containing thorium.

Table 10.4 of the manuscript presents data on the concentration of thorium in the breathing zone of workers involved in melting, machining, and forging thorium. Table 6-4 presents excerpts from this table that address various steps associated with machining thorium. (It is assumed that thorium melting and forging operations were not performed at RFP.)

Table 6-4. Excerpts from Table 10.4 of Albert (1966)—Concentrations in Breathing Zone Air Samples (µCi/ml)

Operation Sampled	Number of Samples Collected	Alpha Decay		Beta Decay	
Machining		**After 24 hours**	**After 2 weeks**	**After 24 hours**	**After 2 weeks**
Machining ingots and electrode stubs					
Lathe equipped with local exhaust hose	6	2.49E-9	3.12E-10	1.97E-9	4.59E-10
Lathe enclosed in hood	5	3.9E-10	1.70E-11	5.18E-10	3.1E-11
Sawing ingot (dry)	1	3.5E-11	Note**	1.08E-10	Note*
Crushing and pressing turnings	2	9.59E-10	2.72E-10	1.54E-9	9.67E-10

* Not measured
Source: Lowery 1962

It is difficult to determine how much of the alpha activity is due to Th-232, Th-228, and Ra-224 and its progeny because one would expect Ra-224 (with its 3.64-day half life) and its short-lived progeny to grow rapidly after thorium separation. One would expect the samples taken after 2 weeks to have higher alpha activity than those taken after 24 hours. However, in the table, the samples taken after 24 hours appear to have the higher alpha activity. In order to ensure that the exposures are not underestimated, it is prudent to use the highest measured values as representative of the thorium breathing zone concentrations during machining operations. Consideration must also be given to the number of hours per year a given individual might be involved in machining operations. Evidently, the matter of exhaust ventilation is important and data are available that include the use of such ventilation, as noted in the table above.

The Adley Report

The amount of data in Albert (1966) characterizing the dust loading in the breathing zones associated with machining thorium is limited. However, it includes considerably more data characterizing the dust loading in the breathing zone of workers involved in machining uranium. Since uranium is more pyrophoric than thorium, data characterizing dust loading associated with machining uranium can be used as conservative surrogates for machining thorium. One of the investigations that provides considerable data on the dust loading associated with machining uranium is the Adley et al. report (1952), referred to hereafter as the Adley report. This section summarizes the pertinent data provided in that report.

The Adley report presents the results of a detailed investigation of the health physics issues associated with melting and milling uranium metal at the Melt Plant Building at Hanford. The report describes in detail each step in the handling and processing of uranium rods and provides extensive data on airborne uranium particle/aerosol/fume loading, uranium particle size distributions, and the chemical form of the airborne uranium associated with each type of activity. The data presented in the report were gathered from February 1947 to May 1951. As such, the report may be considered a bounding surrogate for the machining of thorium during the early years of the practice.

The Adley report divides the uranium operations it investigated into the following activities:

- 14 steps associated with the remelt and recovery of uranium turning and chips that were generated during uranium machining operations
- 6 steps associated with uranium rod straightening operations
- 2 steps associated with uranium autoclaving

The report provides a description of each of these 22 steps, along with a complete characterization of the aerosols produced at each step. Many of the steps can be considered applicable, if not bounding, for thorium machining operations that may have taken place at RFP. The first item would likely be the most applicable to RFP.

The Adley report presents a detailed description of the methods used to collect and characterize the aerosols associated with each operation. High-volume air samplers (70 to 100 ft^3/min) were used to collect the samples on pleated filters with a filtering area of 73 in^2. Most air samples were collected at breathing level near the various processes, and some were obtained as close as possible to the points where dust and fume originated. Particle sizes were determined using cascade impactors as well as a thermal precipitator, which deposited particles on glass slides where they could be viewed and measured. The former was used to determine the mass median diameter and the mass distribution, while the latter was used to determine the count median diameter and number distribution.

Table 6-5 presents the results of multiple individual measurements taken at locations that appear to be particularly applicable to machining operations. It shows values that were copied directly from portions of Table II in the appendix to the Adley report. The table provides an indication of the variability of the airborne uranium concentrations associated with a given operation.

These uranium data can be treated as equivalent in mass concentration terms to those of thorium (which would be claimant favorable). In turn, these can be converted into intake estimates for Th-232. It is claimant favorable and reasonable to assume Th-232 in equilibrium with its decay products.

Table 6-5. Summary of Selected Measurements Made at the Hanford Melt Plant Building Investigations

Operation	Suboperation	Results of Multiple Samples Taken from Different Locations/Suboperations within the Facility (10^{-5} micrograms U per cc of air)								
Saw Room Operations	Stripping molds from billets	22	0.9	15	43					
	Sawing billets	87	92	12	59	286	154	122		
	Lathing billets	442	27	4.3	97	20				
	Grinding	23,800	55							
	Sweeping floor	86								
	Miscellaneous	5.3	0.4	127	10	18				
Rod-handling Operations	Unloading rods from freight cars	39	258	15	60					
	Storage bay activities	258	34	5.8	43	65	2.4	277	28	51
Nonproduction Areas	Office	0.5	1.5							
	Counting room	0.3	1.1							
	Toilet	4.2	8.7							
	Smoking room	2.3	1.2	3.5						

Source: Adley et al. 1952

The Harris and Kingsley Report

The Harris and Kingsley (1959) report also provides a comprehensive review of exposures associated with uranium operations, including (1) rolling, (2) forging either by means of hammer or a press, (3) extrusion, (4) drawing, (5) swaging, (6) machining, and (7) powder pressing.

These operations are capable of releasing large quantities of uranium oxide dust to the air. The dust loading associated with many of these operations, especially machining operations, may be considered applicable, if not bounding, for thorium machining operations that might have taken place at RFP. Data from these investigations that appear to be relevant include milling, grinding, belt sanding, planning, and drilling. Table 6-6 shows air concentrations during certain operations. This table was the basis for NIOSH's comparison of NUREG-1400 with machining and grinding operations, discussed above.

Table 6-6. Abrasive Operations (daily averages d/m/m^3)

Operator	No Ventilation	Ventilation
Cutoff	--*	<1
Surface grinder	2000–5000	50–200
Portable grinder	400	50–200
Belt sander	3000	<10
Centerless grinder	5000–6000	50–300

* Never sampled, but very high.
Source: Table 6 of Harris and Kingsley 1959

Comparing the Data and Developing a Bounding Value

The data from the various operations above need to be evaluated in the context of the RFP situation, notably with regard to the time during which the operations were carried out. NIOSH used the Harris and Kingsley data in this way in its December 21, 2006, report (Attachment 20), but opted to continue using NUREG-1400 rather than choose a bounding value based on measurements such as the ones above.

With operational data such as those cited above, NIOSH should be able to develop a bounding value for thorium intakes during operations involving material from Oak Ridge. These data are also useful in evaluating the adequacy of the air concentration data during the various 1960 operations involving ingots. SC&A's analysis of welding fumes in the context of the Bethlehem Steel site profile review would be useful for the thorium flame-cutting operation in September 1960.

The issue of which workers were exposed to thorium in the course of machining of the parts from Oak Ridge would need to be addressed unless a dose is assigned to all workers in the associated buildings and periods.

6.3.2.4 Intakes from Other Thorium-232 Operations

RFP conducted other thorium operations as well. Some of these involved less that 500 g of material; these were regarded as small and were not reported in materials accounting records. Such uses of less than 500 g included (Bistline 1976, p. 1 and pp. 3–4) the following:

For coating molds with thorium oxide
in analytical procedures and development programs ("probably" on numerous occasions)
"as a stand-in or replacements for the more expensive Uranium or Plutonium components in certain phases of development programs. Usually these needs involved small amounts of material, but it nevertheless involved handling Thorium. This type of operation occurred frequently in the past and is occurring at the present time. Each individual use is too small for record keeping but, in the aggregate, it would approach 7 kg of Thorium in a variety of forms at the present moment"

The phrase "in the aggregate" in the last bullet appears to refer to all then-current thorium development programs during 1976; however, SC&A notes that the statement is ambiguous and may refer to a cumulative amount of thorium use in development applications.

NIOSH implicitly proposed to use NUREG-1400 for these small uses as well. In its October 2006 paper (Attachment 19, as quoted below) on thorium intakes, NIOSH stated the following:

Other uses and operations involving thorium at RFP are listed in Table 1. The highest calculated potential internal intakes result from the fabrication of large metal weapons parts for which intakes are estimated above. Smaller quantities assumed for most of the other uses and operations are offset by the thorium being in the form of powders or other more dispersible materials, but still resulting in fractional mrem estimated doses. [Attachment 19, p.5]

However, the argument that doses would be in the "fractional mrem" has not been well established. The source term for these small uses is not individually documented in material control records due to the then-prevailing policy regarding thorium accounts. The higher DCFs for thorium for some organs make one gram of Th-232 radiologically comparable to a far larger amount of uranium (in the worst case, approximately 100 times larger for bone surface dose for the same solubility, using DCFs for committed dose in Federal Guidance Report 13 (EPA 1999) as the basis for the comparison). Hence, small amounts of Th-232 would represent doses that would correspond to those delivered by much larger amounts of uranium for bone surface and several other organs.

NIOSH's attempt at validating the use of NUREG-1400 does not meet the criteria of 42 CFR Part 83, as discussed above. The most recent validation attempts using weighted average air concentration data from Simonds and one air sample from RFP may provide a starting point for a use of NUREG-1400 at RFP for small sources, but a convincing demonstration has not yet been made. It may be possible to choose a single value of air concentration from among the extensive data on air concentrations for various operations that would bound all RFP small operations.

It is likely that a suitable approach for small uses of Th-232 (i.e., those each less than 500 g) can be developed, but this has not yet been done.

The issue of which workers were exposed to thorium in small amounts would need to be addressed unless a dose is assigned to all workers in the associated buildings and periods.

6.4 URANIUM-233 AND THORIUM STRIKES ON URANIUM-233

RFP processed U-233 between 1965 and 1983. The U-233 contained, among other things, up to 50 ppm of U-232. It was processed in the 700-series buildings (771, 774, 777, 777A, 779A), where plutonium was also processed, Building 559 (assay lab), and Buildings 881 and 883 at various times during this period, (ICF 1999).

RFP bioassay results for uranium were in disintegrations per minute (dpm) rather than in terms of weight. Uranium bioassay data are available, and nothing indicates that U-233 operations

were omitted from surveillance that was exercised for less radioactive forms of uranium. SC&A concludes that it should be feasible to estimate U-233 intakes.

The problem regarding Th-228 contamination of U-233, which arose from the presence of traces of U-232 (50 ppm) in the U-233, is more complex. RFP conducted operations to remove the Th-228 from U-233 prior to processing the latter according to customer requirements. NIOSH proposed to use NUREG-1400 to provide an upper bound estimate for intakes of Th-228 during such operations. Its evaluation of the matter in its December 21, 2006, report stated the following:

The previous comparison between conservative values above resulted in a value above the NUREG-1400 estimate. In this case, the Th^{228} extraction with daughters is so grossly overestimated both in terms of total quantity of isotope present and in the demonstrated confinement of the glove box process facilities in which the extraction and waste handling was performed, that the NUREG-1400 estimate is not deemed overly conservative. Air activity that would result in 100 Bq intake would have been cause for a significant release with the subsequent detail in the health physics logs we have reviewed. [Attachment 20, p. 13]

SC&A found the proposed use of NUREG-1400, with an ad hoc reduction in the confinement factor from 0.01 recommended in that document to 3.4E-4, unpersuasive in light of the failure to demonstrate that NUREG-1400 produced bounding doses in the other applications and the gap of two orders of magnitude between the 1 Bq intake estimate and the alarm set point. NIOSH further explained the situation in its February 2007 report as follows:

The discussion regarding a 100 Bq release was simply to bolster the case for NIOSH using a confinement factor of 3E-4 for the Rocky Flats high integrity gloveboxes, rather than the 0.01 default in NUREG-1400. Had the default confinement factor been used instead of the more realistic but still conservative value used by NIOSH, the resulting predicted air concentrations would have been high enough to alarm the CAMs in Building 771. It must be emphasized that this was but one supporting argument for this confinement factor. The most compelling argument is that the gloveboxes were equipped with two in-line high efficiency HEPA filters, and no accident conditions (e.g., glove punctures, seal failures, etc.) were noted in the documentation describing the thorium strikes. Under normal operating conditions, such as those during the thorium strikes, the value of 3E-4 for the confinement factor for the high integrity gloveboxes is justified. The estimate of 1 Bq was based on NUREG-1400 calculations, not on the argument that a 100 Bq release was not possible. [Attachment 23, Issue 34]

SC&A's main concern regarding this issue is not the adequacy of glovebox confinement, but the use of NUREG-1400 for RFP. Air monitoring data in the workplace with functioning gloveboxes at RFP are likely to be plentiful enough to demonstrate that a particular number for intake estimate is reasonably bounding. Yet NIOSH has not attempted to use any onsite air monitoring data but resorted to NUREG-1400, with an ad hoc confinement factor applied as well.

SC&A continues to have reservations about the use of NUREG-1400 instead of onsite data for air concentrations in areas where comparable gloveboxes were used. Since the source terms are known with reasonable accuracy, NIOSH should be able to establish an intake based on air concentration data for other elements, such as Pu-239, and measured confinement factors.

SC&A Evaluation:

In terms of dose estimation methods, NIOSH's analysis has established the plausibility of using NUREG-1400 to provide a general view of average working conditions. However, notwithstanding the availability of alternative methods, the examples provided to date have not validated the use of NUREG-1400 in estimating a plausible upper-bound dose for individual workers at RFP that would meet the criteria of 42 CFR Part 83. While alternative approaches have been discussed within the working group, NIOSH continues to believe NUREG-1400 is valid for application under the specific conditions applying to RFP. As a result, the thorium dose reconstruction matter remains open as an SEC issue.

6.5 REMAINING RADIONUCLIDES

The other radionuclides that SC&A raised in the context of the TBD review matrix or that NIOSH has mentioned in the TBD are Cm-244 and Np-237. These appear to have been used at RFP as tracers and mixed with plutonium. SC&A had also raised the question of the availability of tritium bioassay data. The bioassay data in the HIS-20 database do not represent any of these radionuclides.

In its November 3, 2006, report (Attachment 22), NIOSH agreed that the HIS-20 database does not represent these three radionuclides. Instead, NIOSH provided references to Cm-244 bioassay data and other documentation. Special bioassay results are also available for Np-237. NIOSH also stated that tritium bioassay results are available in claimant files.

SC&A Evaluation:

In view of the availability of bioassay data, SC&A concurs with NIOSH that estimation of Cm-244, Np-237, and tritium intakes is not an SEC issue.

6.6 REVIEW OF THREE HYPOTHETICAL INTERNAL DOSIMETRY DOSE RECONSTRUCTION CASES

NIOSH provided SC&A with three hypothetical dose reconstruction cases for review of procedures and methods used to assign doses, three of them related to internal contamination (Cases 4, 5, and 6). SC&A analyzed these three examples to determine if the dose reconstructions were consistent with present guidelines and recommended procedures, and if procedures allow for claimant-favorable dose reconstruction.

6.6.1 Case 4—Hypothetical Coworker Assignment for Unmonitored Uranium Worker

This case provided an example of a hypothetical worker, potentially exposed to uranium, who worked at RFP from 1956 through 1966. This worker was monitored from 1960 through 1966. All measurement results were below detection limits. The worker had a potential for uranium exposure from 1956 through 1959, but was not monitored during this time. NIOSH calculated the uranium exposure of this worker, based on coworker data for the period 1956 through 1959 and on the bioassay detection limit for the period 1960 through 1966. For the missed dose, a chronic intake rate was assumed using half the MDA for that radionuclide and assigned as the mode dose, with the maximum dose being twice the mode dose.

SC&A Evaluation: While NIOSH was able to provide an adequate dose reconstruction for this case, SC&A identified several areas of concern:

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The worker had a potential for uranium exposure from 1956 through 1959, but he was not monitored. The dose for this period was based on a coworker model that used the 50th percentile to calculate the intake. As a result, the calculated intake rate corresponded to less than half of the theoretical reporting level for uranium in urine. This would not be claimant favorable.

For the period of 1960 through 1966, NIOSH calculated the missed dose using one-half the MDA for the median conditions. In the occupational internal dose TBD (ORAUT-TKBS-0011-5) (Falk 2004), the MDAs for the median and extreme conditions were calculated for the period 1952 through 1971, based on results from the logs. Variations on the number of extreme conditions produced different values of MDA. For uranium, there is about five-fold difference between the MDA for the median and extreme conditions. Under these circumstances, SC&A questions the validity of assigning missed doses based on half the MDA for the median conditions.

6.6.2 Case 5—Hypothetical Assignment for Ingestion of Depleted Uranium

This case provided an example of a hypothetical worker, potentially exposed to uranium, who worked from 1966 through 1969. In a hypothetical incident, the worker ingested DU and had reported positive urinalysis bioassay data. The energy employee worked as a radiation monitor. His primary exposure would have been to DU. His records show that urinalysis bioassay monitoring was conducted three times per year, with no positive results except for one measurement result that showed an activity above the level of detection 5 days after the ingestion incident. No in-vivo monitoring results were available. The worker's primary cancer organ was the colon.

SC&A Evaluation: SC&A reviewed the procedures followed by NIOSH to calculate the intake and dose for the hypothetical incident where a worker ingested DU and had a reported positive urinalysis bioassay data 5 days after the ingestion. In addition, SC&A recalculated the intake and doses due to this hypothetical incident, using alternative software to IMBA. SC&A has concluded that the intake and dose calculated by NIOSH are correct for a single intake associated with an ingestion exposure.

However, SC&A does not necessarily agree with the exposure scenario attributed to this worker. NIOSH has considered that all other monitoring results, recorded as zero (below detection limits), were associated with zero exposures. SC&A considers this approach not claimant favorable. In Case 4, a missed dose based on the MDA was calculated for all monitoring results below detection limits. In this example, calculation of the missed dose using continuous intake by inhalation gives an additional dose to the colon one order of magnitude higher then the accidental ingestion intake. NIOSH did not consider the missed dose in this case.

The exposure scenario used by NIOSH is not claimant favorable. Missed dose associated with continuous exposure through inhalation should have been calculated, with an additional ingestion exposure. In general, NIOSH uses the hypothesis of a continuous intake to calculate missed doses. NIOSH should provide a clear definition for the benefit of the dose reconstructor to avoid different procedures applied in similar cases, as occurred in Cases 4 and 5.

6.6.3 Case 6—Hypothetical Type Super S Material Assignment for Monitored Plutonium Worker with No Chest Counts and Positive Urinalysis Results

This case provided an example of a hypothetical individual who worked from 1961 through 1969 in RFP Buildings 771, 776, and 707 and was exposed to fresh plutonium (100 ppm Am-241). The worker had three positive urinalysis results, two consecutive results in 1963 and one in 1964. No in-vivo monitoring data were available. The OCAS white paper, *Approach to Dose Reconstruction for Super Type S Material (March 21, 2006)* (NIOSH 2006o), was applied to four scenarios—lung cancer, GI tract cancer (colon), systemic metabolic cancer (liver), and systemic nonmetabolic cancer (prostate). The OCAS white paper from March 21, 2006, is now an integral part of ORAUT-OTIB-0049 (ORAUT 2007b).

SC&A Evaluation: SC&A reviewed the procedures followed by NIOSH to calculate the intake and dose for the four cancer hypothetical scenarios. NIOSH assigned to the worker an acute intake on May 6, 1963, and a chronic intake from August 13, 1964, to September 24, 1964. The intake rates for the various radionuclide components (Pu-238, Pu-239, Pu-241, and Am-241) were based on the plutonium mixture of fresh weapons-grade plutonium (100 ppm Am-241). SC&A reviewed the procedures followed by NIOSH to calculate the intakes and doses for the hypothetical worker. In addition, SC&A recalculated the intakes and doses using alternative software to IMBA.

SC&A has concluded that the intakes and doses calculated by NIOSH are correct, for the hypothetical scenario used by NIOSH and Type S, activity medium aerodynamic diameter (AMAD) 5 µm, plutonium intakes. The intakes of the various radionuclide components were also correctly calculated.

The use of a continuous chronic intake from August 13, 1964, to September 24, 1964, produces lower intakes and doses than if a single intake in the middle of the monitoring interval was assumed.

6.6.4 Summary of Dose Reconstruction Cases

SC&A derived the concerns described above from its analysis of the three hypothetical dose reconstruction cases to determine if the procedures were claimant favorable and reasonable. The results reflect some of the same issues identified by SC&A in the RFP site reviews for actual workers. A detailed report of this evaluation is provided in Attachment 25. These concerns are most likely not SEC issues, but they need to be addressed in terms of the site profile to ensure claimant favorability

6.7 DATA SUFFICIENCY AND APPLICATION OF THE INTERNAL DOSE COWORKER MODEL

Issues regarding the derivation and application of ORAUT-OTIB-0038, *Rocky Flats Plant Internal Co-worker Model* (Arno et al. 2006), were raised upon its issuance and discussed at the August 31, 2006, Advisory Board working group meeting. These issues revolved around the following:[7]

- Median MDA versus extreme condition MDA versus reporting levels:

  SC&A had determined that a large percentage of bioassay results for plutonium from 1953–1966 were below the reporting level. Median MDAs after 1962 were higher than the reporting level. SC&A questioned how meaningful results below the MDAs were and how data below these thresholds should be applied in the coworker model.

- The application of a linear distribution to results below reporting levels:

  NIOSH's approach of substituting a linear distribution between zero and the reporting level for the zeros is justified in ORAUT-OTIB-0038:

  > *Furthermore, the linear distribution has an average equal to half of the reporting value, consistent with the general dose reconstruction practice of assigning half of the lower limit of detection for missed dose calculations. Consequently, substituting a linear distribution for these zero entries appears reasonable.* (Arno et al. 2006)

SC&A believed that the basis for this assumption was not clear. The reporting level is not a lower limit of detection. The reporting level is a nonparametric value, unrelated to the real capacity of distinguishing between real measurement results and background or noise counts. Half the reporting level is not a statistically meaningful value and can not be used to justify a procedure.

[7] As categorized in an October 31, 2006, e-mail from D. Allen, NIOSH.

- Whether monitored individuals represent those with the highest exposure potential:

  SC&A questioned the NIOSH evaluation report conclusion that "in general, participation in a bioassay program involves workers who have the largest potential for exposure" and that "....it is unlikely that an unmonitored worker would have received a larger dose than the most highly exposed monitored worker at a site" (NIOSH 2006a). SC&A was concerned with how the coworker model could be derived without establishing the number of workers in specific work locations and the number monitored in each area. SC&A also questioned how an assumed lognormal distribution could be fitted to the available data without knowing statistically whether the sampled worker population was representative of the target population of interest.

In response to these and other issues raised, NIOSH developed its *White Paper—Rocky Flats Plant Internal Co-worker OTIB* for further discussion and issue resolution (provided in Attachment 26). The white paper, authored by D. Allen of NIOSH, addressed four topical issues (Allen 2006a):

(1) Z-score plot approach to determining distribution parameters
(2) Censored data handling
(3) Why MDA does not matter
(4) Linear substitution approach to censored data

SC&A provided feedback to NIOSH on the white paper. In general, SC&A accepted NIOSH's explanation for how the Z-score plot was obtained and the censored data were handled but continued to raise questions regarding the reliability of the measurement results in relation to the MDA. With respect to the linear substitution approach, SC&A did not agree with the basis described for its adoption. In particular, SC&A found the following:

> *The reporting level is not a lower limit of detection. Actually it is below the median MDA and thus it is a value of doubtful meaning in terms of measurement of real activity. The assignment of half of the lower detection limit (half the MDA) is also not scientifically justifiable. The lower limit of detection (MDA) for urine analysis is not a unique value. It will generally vary from sample to sample. The calculation of each sample MDA is based on a normal distribution of activities. The median MDA for all samples is a non parametric value, and thus half the median detection limit (half the MDA) does not have any statistical meaning. In the same way the reporting level is a non parametric value, unrelated to the real capacity of distinguishing between real measurement results and background or noise counts. In the same way half the reporting level is not a scientifically statistically meaningful value and cannot be used to justify a procedure.* [Lipzstein 2006]

In response, D. Allen of NIOSH observed that ORAUT-OTIB-0038 "stops at a point that a distribution of monitored workers is defined...how that distribution is used is outside of the scope of the OTIB" (Allen 2006a). SC&A agreed that the application of the TIB, as opposed to the

TIB itself, is the more relevant SEC issue, and an issue-specific conference call was scheduled for December 6, 2006, to address the three remaining issues originally categorized by NIOSH. The minutes of this discussion are provided in Attachment 26.

In summary, NIOSH noted that it intended to apply the 95th percentile distribution for unmonitored workers and that this approach was deemed sufficiently claimant favorable based on experience at Bethlehem Steel and other sites. SC&A questioned whether this was sufficiently conservative based on what were apparently data points higher than those encompassed by the 95th percentile distribution (i.e., why not higher percentile distributions such as 99th). It was pointed out during the discussion that the RFP dose file had been updated and some of these higher dose values may have been dropped out (because they were linked to isolated incidents and therefore not representative). Additional discussion is needed regarding the representativeness of the database (inclusive of the likely most exposed workers) and its completeness. HIS-20 versus the CEDR initially resolved those issues to the satisfaction of the working group. However, it became clear from later working group interchanges with NIOSH that the median (50th percentile) of the full distribution of internal dose values is actually being applied in the dose reconstructions being performed. While the conservatism of the coworker model has been characterized in working group discussions as an issue related to the site profile and not the SEC, SC&A believes that applying a nonconservative statistical fit to the dose distribution derived from the coworker model can undercut the scientific validity of how the model, itself, is used.

6.7.1 SC&A Technical Analysis of ORAUT-OTIB-0038

At the request of the Advisory Board working group, SC&A evaluated the internal coworker model and its application. As noted above, it was agreed that the SEC-related issues pertained more to the application of ORAUT-OTIB-0038 in terms of the statistical dose distribution used and to the completeness of the HIS-20 database itself, upon which the approach is derived.

6.7.1.1 SC&A Observations on the Interpretation of Zero Monitoring Results, Low Value Monitoring Results, and Reporting Levels

SC&A finds that the application of the linear distribution provided for use in ORAUT-OTIB-0038 as a substitution for low internal dose value results does not have a clear scientific basis. SC&A notes that such a linear distribution was not used for plutonium. For plutonium, NIOSH has used the exact values as they were reported in the dose files and has substituted the zeros by the reporting level of 0.88 dpm/24 hours. While the TIB ranks the 0.88 values, it does not use those values to fit the lognormal distribution. SC&A believes there is no clear scientific rationale to accept that the registered values lower than 0.88 dpm/24 hours are real measurements and that the zeros are equal to 0.88 dpm/24 hours. In ORAUT-OTIB-0038, the intake is derived based on the 50th percentile of a lognormal fit to the bioassay results in a certain period of time (year or quarter of a year). A large fraction of the registered bioassay values are equal to zero. Thus, the 50th percentile depends on the approach NIOSH uses to account for the zero values, low bioassay results, and below reporting-level values.

SC&A notes that the MDA for median conditions was higher than the reporting levels for some of the years for which internal dose data are provided. The MDAs for the median and extreme conditions were calculated for the period 1952–1971 and are presented in ORAUT-TKBS-0011-5 (Falk 2004). The MDA was not discussed in ORAUT-OTIB-0038, and neither of the MDA values was applied to workers with zero or low monitoring results or discussed in relation to reporting levels. SC&A finds that uncertainties in the MDA values bring great uncertainty to a model based on low monitoring excretion values.

Further, the MDA for plutonium is assessed for the median and the extreme condition for the blank, the recovery, the volume factor, and the alpha transmission factor individually and in combination in ORAUT-TKBS-0011-5 (Falk 2004). There is as much as a nine-fold difference between the MDA for the median conditions and the extreme conditions for plutonium for the years 1952–1971. This introduces considerable uncertainty given the relatively low internal dose values reported at RFP and, consequently, to the coworker model based on those low values.

6.7.1.2 SC&A Observations on the Appropriate Statistical Distribution to Represent the Unmonitored Worker

As noted in ORAUT-OTIB-0038, "Statistical methods used to calculate co-worker intake values assume that bioassay results for group of workers have a lognormal distribution" [emphasis added]. Even accepting this statistical distribution, it is not known how to place the unmonitored worker in the group. If the physical samples represent a statistical sample from a population to be characterized, it is important to know the statistical design (or lack thereof) of the procedure used to select the samples. The design of the sampling procedure should be considered before using the data to estimate characteristics of a target population from which the sampled individuals were selected. In sample design, all members of the population must have a known (nonzero) probability of selection into the sample before the results can be considered as representative of the population. This simple requirement defines the population that the samples represent. Using the estimated distribution to represent workers with unknown or zero probability of selection into the sample is a subjective decision, not a statistical one, and should be identified as such. In short, a database full of numbers cannot be used as a representative statistical sample unless the probability of selection is known for all members of the target population, both selected and unselected.

6.7.1.3 SC&A Concerns Regarding the Potential for Internal Exposure of the Unmonitored Worker

NIOSH has hypothesized that unmonitored workers received a lower dose than the highest exposures documented for monitored workers. In the SEC petition evaluation report (NIOSH 2006a), it is explained that **"in general, participation in a bioassay program involves workers who have the largest potential for exposure**" and that "**... it is unlikely that an unmonitored worker would have received a larger dose than the most highly exposed monitored worker at a site**" [emphasis added]. However, NIOSH provides no statistical or quantitative technical basis for this hypothesis. It is quite possible, in the early years when monitoring protocols were

still being developed, that some groups of unmonitored workers might have exposures that could have exceeded the exposures of monitored workers.

An example taken from SC&A's evaluation of RFP external dose assessment history illustrates this point. For neutron exposure, workers in Building 71 were not monitored at all until 1958, even though they were among the employees at highest risk for such exposure. In this case, such a hypothesis that the highest exposed workers were monitored would be incorrect based on actual historic circumstances. Likewise, it is essential for NIOSH to demonstrate that its hypothesis that "participation in a bioassay program involves workers who have the largest potential for exposure" is, in fact, a correct one for internal dose. A number of means are available for such validation, some of which have been used in the past at other DOE sites. For instance, monitored and unmonitored workers can be compared by job types, radionuclide exposure lists, and contaminant air concentrations. Such comparisons would provide a means for NIOSH to test its hypothesis and demonstrate that the worst-case conditions of exposure of unmonitored workers were such that the highest monitored worker measurements would envelop them.

The logbooks from early RFP operations contain some discussions on who should be monitored and which tasks needed monitoring. Thus, it is possible that some workers who were not monitored received high doses and that some practices were only monitored after having been implemented for some time. The example below, from a meeting held in September 1958 extracted from a logbook from 1957–1960, illustrates this fact [Kittinger personal log 10-1-57–8-26-60]:

> *I took position that contamination is not under control in either B1 or B3; cold areas are being contaminated, personnel are easily able to carry contam. Home, and N.P. checks being by-passed. I further took the position that supervision in both Bldgs have shown lack of appreciation of control techniques.*

The fact that some of the workers who were monitored presented high excretion rates puzzled the radiation protection staff. Thus, some jobs that might have presented radiation contamination risks might have been misjudged and workers might not have been monitored, as may be inferred from the following example, from a discussion on high urinalysis results, in September 1959:

> *xxxxx, xxxxx, xxxxx & I had conference yesterday concerning the high urine counts. They have investigated and find no reason.*

The NIOSH data integrity examples (NIOSH 2006j) contain several examples of worker concerns, which raised questions regarding the inclusiveness of the bioassay program in relation to internally exposed workers:

- In the Molten Salts Building (776), a hole had developed in both walls in the double-lined furnace (double lined). The furnace was loaded, heated, and overpressurized, causing it to vent to the atmosphere in the room. Personnel were without respiratory protection at the time. No bioassays were taken.

- Furtive job tasks were conducted outside of normal work controls without airborne contamination monitoring or personnel monitoring. For example, an RCT became highly contaminated, but because the work evolution was not documented, no nasal smears or bioassay samples were taken. This practice was more common than not.

- Many times contamination was washed off without being reported.

- In one case, an energy employee did not have a first urinalysis sample available until 1975, although he worked in hot areas for at least 3 years. Given the lack of safety protocol in the early years, some kind of reading should exist. However, only zeroes are recorded, including for those years when the energy employee was a clerk packer.

- An employee served as a machinist during the 1970 strike with a gap in his bioassay data from 1967–1972. The health physics file contains no indication of a work restriction, and according to the CATI he was involved in incidents in 1961 and 1969. According to his CATI interview, he was given beer when working in Building 881 and asked to finish it within 12 hours. This approach is commonly used to clear highly soluble radionuclides, such as Type F uranium or tritium, from the system. His dose file contained no bioassay data for tritium.

- No bioassay was performed on a man whose mask was so contaminated it had to be shipped as high-level waste.

6.7.1.4 SC&A Concerns Regarding Unrecognized Exposures to High-fired Plutonium Oxides, for which the Bioassays Would Not Detect the Deposited Material

There were numerous fires, large and small, at the RFP plant over its history, many of which apparently occurred without record or notification to the fire department or management. Such fires involved high-fired plutonium oxide (Type SS), which has been shown to exhibit long-term retention in the lung exceeding that predicted by the standard Type S model. One of the major fires at the plant occurred in Building 71 in 1957, and numerous worker may have experienced some intake during, after, or even months or years after the event and may have terminated their employment or died prior to any bioassay sampling. One notable case from the 1957 fire involved a worker who had only one or two urine samples taken after the event, and no fecal analysis performed then or at work termination several years later. The urine samples showed nothing. The worker was found in the RFP recall followup, around 40 years later (when the employee was 90 years old), to have one of the largest lung depositions of plutonium ever recorded at RFP.

Given the very low solubility of high-fired or Type SS plutonium oxide, the workers involved in such fires would likely either contribute to the zero entries in urine bioassay or would not have been monitored further because their earlier bioassay samples were below detection limits. There is no referencing to ORAUT-OTIB-0049 (ORAUT 2007b) in ORAUT-OTIB-0038 models. ORAUT-OTIB-0049, on the other hand, mentions that the methods described in this TIB can be applied to doses from coworker studies for sites where Type SS absorption is

appropriate, but only Type S intakes were assessed. In contrast, ORAUT-OTIB-0038 calculates plutonium intakes as either Type M or Type S, with no mention of unmonitored worker exposure to high-fired nuclides.(presumably, ORAUT-OTIB-0049 would take precedence, although ORAUT-OTIB-0049 can only be applied if the worker had a known exposure to high-fired plutonium oxides); NIOSH should clarify how potential exposures of unmonitored workers to high-fired plutonium will be addressed from the coworker standpoint, given that workers may have been exposed during these unreported small fires or could have been exposed to high-fired oxides or residues during D&D and other activities without knowing that they were exposed to high-fired plutonium oxides.

6.7.1.5 SC&A Observations Regarding the Treatment of High Excretion Rates

A coworker model needs to distinguish whether high excretion cases were routine samples, samples related to incidents, or samples following chelation. This is a significant set of variables that pose a considerable technical challenge for suitable integration into a coworker model.

Without a detailed explanation, NIOSH has excluded the highest excretion data from the data file that provided the basis for deriving the ORAUT-OTIB-0038 model. The Lochamy paper from April 6, 2006 (Lochamy 2006), shows CEDR values in 1964 and 1965 that differ from the ones in the RFETS plutonium file used to generate intake and doses for the ORAUT-OTIB-0038 model. In the RFETS tables, the GM for 1964 is cited as 0.321, and the geometric standard deviation (GSD) is given as 0.996, compared to 0.508 and 3.64, respectively, in the Lochamy table. The Lochamy table gives the number of samples in 1964 for CEDR as 4,976, with a maximum value of 1,800,000 dpm/24 hr, while the RFETS tables for plutonium, used to generate the TIB model, gives it as 4,761 samples, with a maximum value of 2,290 dpm/24h.

In the 1965 RFETS table, the GM for 1965 is 0.227, and the GSD is 0.70, as compared to 0.474 and 2.279, respectively, in the Lochamy table. In the Lochamy table, the number of samples in 1965 for CEDR is 5,168 with a maximum value of 173,000 dpm/24 hr, while the RFETS table for plutonium, used to generate the TIB model, cited 4,900 samples, with the same maximum value of 173,000 dpm/24h. Thus, using the same CEDR database, but apparently excluding different samples and values, the Lochamy table and the RFETS tables used to derive the ORAUT-OTIB-0038 model give different results. NIOSH has not yet provided a definitive explanation for these differences.

SC&A is concerned that the coworker model does not represent the distribution of values to which the overall set belongs. If data from an incident are excluded without known and well-established criteria, then the distribution that remains without the missing data may not be the correct one since the right (high-end) tail of the distribution will be too thin without those values.

6.7.1.6 SC&A Remarks on the Significance of the Intake Rate Derived in ORAUT-OTIB-0038 in Relation to the Excretion Rate

When NIOSH derived the ORAUT-OTIB-0038 intake model based on coworker monitoring data, two sequential fitting approaches were used to interpret the bioassay data. The first one

grouped the bioassay monitoring data by time, and a lognormal distribution was assumed as the best representation of all the RFP worker bioassay results during a certain period of time. The GM and the geometric standard deviation were derived for each time period. The second approach consisted of the derivation of an inhalation intake function that would reproduce the GM bioassay values that were calculated using the first approach.

Approach 1: A lognormal distribution was assumed for the bioassay data, which were analyzed by quarter or year, depending on the amount of data available during the periods. The fitting of the data to a lognormal distribution was statistically acceptable, but many times did not represent well the data at the high end of the results. The acceptance of the lognormal distribution, employing the methodology used in ORAUT-OTIB-0038, deserves some discussion in terms of how well the distribution represents the bioassay results, taking into consideration the significant percentage of values that do not fit the lognormal distribution in relation to the number of positive bioassay results. The discrepancies between the high "real" results and the ones generated by the curve are significant. Depending on the year, these discrepancies may start at the 95th percentile level, as in 1958 (when, for example, in the first quarter, the 95th percentile calculated by the equation was 27.16 and the result that occupies rank 95 is 55.3), or at a higher percentile as in 1966. Analysis of the RFETS table values for 1966, by quarters, provides the following results:

- **1st Quarter:** The 95th percentile as calculated by the lognormal regression equation is 1.6 dpm/24h, and the 95th value (the result that occupies the rank 95, when results are placed in ascending order) is 1.63. The coefficient of determination (R^2) for the equation is 0.64, with larger discrepancies on the high end of the curve. There are 61 values that are higher than the 95th value, the largest one being 230 dpm/24h. There are 42 results at least 10 times higher than the 95th percentile. The 99th percentile as calculated by the equation is 3.23 dpm/24h, and the 99th value is 70 dpm/24h.

- **2nd Quarter:** The 95th percentile as calculated by the lognormal equation is 0.96 dpm/24h, and the 95th value is 0.87. The R^2 for the equation is 0.65, with larger discrepancies on the high end of the curve. There are 58 values that are higher than the 95th value, the largest one being 140 dpm/24h. There are 24 results at least 10 times higher than the 95th percentile. The 99th percentile as calculated by the equation is 1.7 dpm/24h, and the 99th value is 5.17 dpm/24h.

- **3rd Quarter:** The 95th percentile as calculated by the lognormal equation is 0.67 dpm/24h, and the 95th value is 0.63. The R^2 for the equation is 0.73, with larger discrepancies on the high end of the curve. There are 49 values that are higher than the 95th value, the largest one being 110 dpm/24h. Seven results are at least 10 times higher than the 95th percentile. The 99th percentile as calculated by the equation is 1.1 dpm/24h, and the 99th value is 55 dpm/24h.

- **4th Quarter:** The 95th percentile as calculated by the lognormal equation is 1.129 dpm/24h, and the 95th value is 0.95. The R^2 for the equation is 0.68, with larger discrepancies on the high end of the curve. There are 56 values that are higher than the

95th value, the largest one being 160 dpm/24h. There are 23 results at least 10 times higher than the 95th percentile. The 99th percentile as calculated by the equation is 2.09 dpm/24h, and the 99th value is 110 dpm/24h.

NIOSH considered these high values as routine monitoring results. The ones related to accidents or incidents were excluded from the analysis.

SC&A Evaluation:

In conclusion, SC&A considers the lognormal distribution used by NIOSH in these applications not to be representative of the higher bioassay values. Essentially, the recorded high-end dose values are left out. Therefore, the uncertainties derived from the lognormal distribution are misleading since they do not adequately address the contribution of these higher internal dose results. In addition the value of the 50th percentile is an artificial number, not related to any measured value, and thus it is not to representive of the monitored worker excretion rate.

Approach 2: The intake model was derived using an IMBA fit to several years of data. Intakes were not derived for each time period, when a GM would have been derived from the lognormal distribution representing that time period. Instead, an IMBA fit was derived for a period of several consecutive years. For Type M plutonium, for example, just one intake rate was considered for the period from 1952 to 1961. This intake rate theoretically produces excretion rates for 1952 to 1961, which can be represented by the solid line shown in the Figure 6.1, comparing the theoretical fit for Type M materials to the individual 50th percentile excretion rates (Arno et al. 2006). As can be observed, there are large discrepancies between the predicted bioassay results using the derived intake rates for the period (solid line) and the GM results for the different periods (blue dots). The red dots correspond to time periods after 1961.

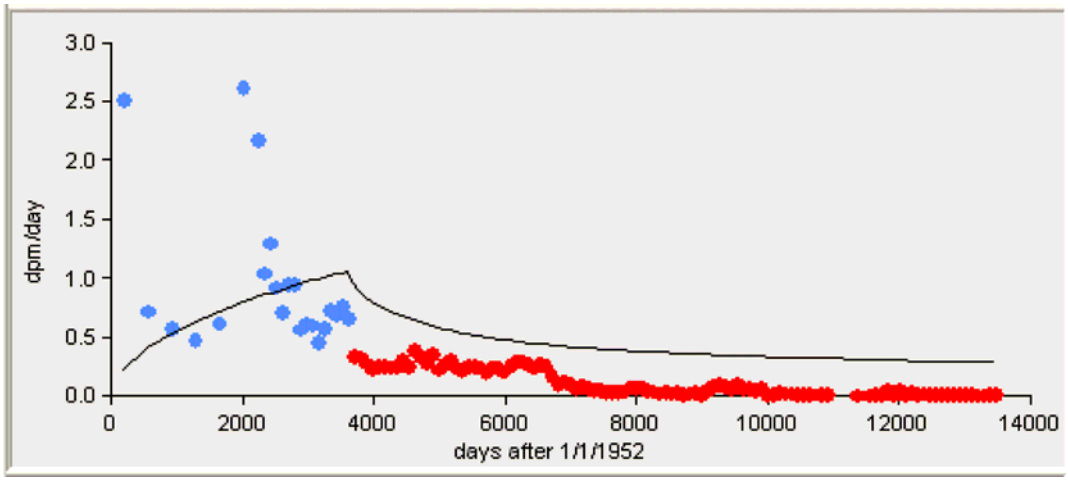


Figure 6-1. Predicted Plutonium Bioassay Results (line) Calculated Using IMBA-derived Pu Intake Rates Compared with Measured Pu-in-Urine Results (dots)
(January 1, 1952, to December 31, 1961, 50th percentile, Type M)
(Reproduced from ORAUT-OTIB-0038, Figure B-21, pg. 29)

The model intake rates do not correspond to the 50th percentile of each period of time analyzed. As shown in the figure above, in some time periods, the dose will be calculated using an intake rate that corresponds to urinary excretion values smaller than the 50th percentile of the excretion rates of the workers for that time period. Using this same modeling approach, the dose calculation using of the 95th percentile would, for some time periods, correspond to urinary excretion rates well below the 95th percentile of the excretion rates of the workers.

SC&A Evaluation:

When NIOSH uses the 50th or 95th percentile intake rates, it should not be understood as the 50th or 95th percentile of the workers intake rates, but to a model intake rate, with some periods of time when the urine excretion rates percentiles from the lognormal distribution will be underestimated and some periods of time when they will be overestimated.

SC&A Conclusion:

SC&A considers the lognormal distribution used by NIOSH in these applications to misrepresent the higher bioassay values incurred by the workers during their routine work at RFP. In addition, SC&A considers the 50th percentile excretion rates from the lognormal distribution to be artificially derived, not corresponding to any measured intake rate, and not representative of the excretion rates of the monitored workers. The model intake rates from the IMBA fit will further underestimate the 50th percentile intake rates during certain periods of time.

6.7.2 SC&A Analysis of the Database Used by NIOSH to Derive the Intake Model Described in ORAUT-OTIB-0038: Comparison of HIS-20 versus CEDR Databases

ORAUT-OTIB-0038 was based on the CEDR database. NIOSH has investigated the differences between the CEDR and HIS-20 databases for RFP workers and has presented information to the working group in reports dated March 26, 2006 (Lochamy et al. 2006); April 6, 2006 (Lochamy 2006); and October 2006 (Cragle 2006). NIOSH used these reports to demonstrate that there is good agreement in the parameter values calculated from either database and used for the generation of coworker data distributions. In those analyses, NIOSH has provided a comparison of the number of records in each database.

The two Lochamy papers and the Cragle paper do not use exactly the same terminology. For example, the Lochamy paper presents the number of samples for a period of time. The Cragle paper presents the number of records for a certain period of time and the number of individuals who were monitored. When the number of records is compared to the number of samples analyzed in a certain period of time, the numbers do not match, as exemplified in Table 6-7:

Table 6-7. Comparison of the Number of Samples Reported by Lochamy with the Number of Records Reported by Cragle

Database	Years	Lochamy	Cragle
CEDR	1973–77	29,559	39,779
HIS-20		28,778	40,180
CEDR	1978–82	32,407	35,789
HIS-20		32,297	44,839
CEDR	1983–85	30,601	17,535
HIS-20		30,575	42,853

The numbers in the Lochamy papers do not exactly match the ones from the HIS-20 database posted on the O-drive by NIOSH. For example, for the period 1953–1957, the number of samples in the HIS-20 database is 3,070, with a maximum of 935 dpm in 1957, while Lochamy's papers cites 3,093 samples for the same period, with a maximum of 10,660 dpm.

According to the Lochamy paper of April 6, 2006 (Lochamy 2006), HIS-20 produces GM (median) and GSD (84^{th} percentile) results larger than CEDR for 1953–1967. In those years, CEDR has more records than the HIS-20 data sets. For 1964 and 1965, the CEDR values presented in the paper are different from the ones in the RFETS plutonium database used to generate intake and doses. In the REFETS table, the GM for 1964 is 0.321 and the GSD is 0.996, as compared to 0.508 and 3.64, respectively, cited in Lochamy. In the 1965 RFETS table, the GM for 1965 is 0.227 and the GSD is 0.70, compared to 0.474 and 2.279, respectively, cited in Lochamy. The differences between the CEDR values and the HIS-20 values cited are higher for those 2 years.

6.7.2.1 SC&A Conclusion Regarding the Use of the CEDR Database

The comparisons of the use of the CEDR database instead of the HIS-20 database focus on the comparisons of the values of the GM and geometric mean standard deviation (GMSD). Both databases contain a large number of zero results that bring the GM to a very low value, most of the time below MDA or reporting levels. Because the lognormal distribution derived for most of these years leaves out recorded higher values, as explained in Section 6.7.1.6, the GMSD is also not representative of the variation that includes the high excretion values.

In summary, based on the comparisons between the CEDR and HIS-20 databases, SC&A considers the ORAUT-OTIB-0038 modeling approach biased, because the GM is only representative of the low excretion rate values. SC&A appreciates that the choice of the best parameters to use in this model in order to make it claimant favorable and at the same time "not unreasonably claimant favorable" is difficult and most of the time subjective. The model parameters have to be reviewed carefully, after considering all possible scenarios of possible

contamination of unmonitored workers. The methodology to be adopted to choose those parameters may create greater differences in doses than the choice of the CEDR database instead of the HIS-20 database.

SC&A Conclusions Regarding the Internal Coworker Model ORAUT-OTIB-0038

SC&A examined ORAUT-OTIB-0038 (Arno et al. 2006), the coworker model for internal dose assessment, in terms of its conceptual approach, including the overall technical approach used, scientific validity, and sufficient degree of conservatism. SC&A accepts NIOSH's position that it is possible to derive a surrogate exposure model for the unmonitored worker based on the distribution of internal doses received by the monitored workers at RFP. However, the use of a model based on the 50th percentile of the excretion rates of the workers, in the way it was derived by NIOSH in the model, will misrepresent the higher exposures experienced by the monitored workers at RFP and should not be used for the unmonitored worker. The uncertainties related to a model based on the 50th percentile excretion rates of the workers are large and as a consequence dose reconstruction cannot be accomplished with sufficient accuracy.

The ORAUT-OTIB-0038 intake model was derived based on two approaches; a lognormal fit to the bioassay data grouped by year or quarter of a year, and an IMBA intake fit to the 50th percentile excretion rate from the lognormal distributions of several years together. The intake rates derived in ORAUT-OTIB-0038 carry uncertainties related to the following:

- The large discrepancies between the high real results and the ones generated by the lognormal curves create uncertainties. The lognormal distribution misrepresents the RFP workers who were contaminated routinely in the course of their work.

- The 50th percentiles, used to derive the intake rates, correspond to very low excretion rates and depend on the approach NIOSH uses to account for the zero values and on uncertainties related to the MDA values. NIOSH does not discuss or resolve the uncertainties related to the MDA values and their relation to the reporting levels and to the registered bioassay monitoring values.

6.7.3 The unmonitored worker's dose should be based on a model that ensure sufficient conservatism and provide for less uncertainty. Adequacy of Internal Monitoring

The petition questions the absence of lung counting capabilities in 1952–1964 and the fact that they were "seldom used" from 1964–1968 (USWA 2005). NIOSH concludes in its evaluation report that "the lack of routine lung counting prior to the 1960s does not preclude dose reconstruction because urinalysis and fecal sampling results are available" (NIOSH 2006a). While NIOSH did not provide much detailed substantiation in the evaluation report to support this conclusion, SC&A agrees that RFP internal doses can be reconstructed using urinalysis and fecal sample results, using claimant-favorable assumptions to complement limited information on exposure scenarios. SC&A reviewed the issue of exposures to fire-related plutonium oxides, in the absence of lung counting and very low or below MDA excretion results. SC&A concluded that dose reconstruction can be accomplished by the simultaneous use of ORAUT-

OTIB-0049, the intake model from ORAUT-OTIB-0038 based on a percentile equal to or higher than the 95th percentile, the missed dose concept using an MDA based on the recovery extreme condition, and assumption of continuous exposure between two measurements within a limited period of time, no longer than 1 year. This last issue is discussed in more detail in Attachment 3.

7.0 DOSE ESTIMATION FOR DECONTAMINATION AND DECOMMISSIONING WORKERS

7.1 BACKGROUND

NIOSH qualified petition SEC-00030 for the time period 1952–2005, which includes the facility closure and D&D phase of operations at RFP, but did not provide a specific evaluation of dose estimation for this period of plant operations. During this period at the plant, various former production buildings were being torn down, equipment decontaminated and removed, and radioactive waste collected and transported off site. First-, second-, and lower-tier subcontractors, under the overall management of two successive integrated contractors (EG&G, Inc., and Kaiser-Hill), were performing much of this work. These workers often moved between specific cleanup jobs on site, as well as on and off site at the RFETS during the cleanup phase of operations between 1993 and 2005. Given the residue of some 40 years of radiological operations, the potential for radiation exposure was significant for D&D workers.

Statements by former D&D workers at the Advisory Board meeting of April 25–27, 2006, in Denver substantiated the need to characterize the exposure potential of specific jobs and address the adequacy of monitoring. One former worker noted that unlike the production era practice of conducting routine bioassays (e.g., monthly urinalyses and whole-body counting), monitoring practices during the D&D era relied on DAC-hour tracking and air sampling results (lapel samplers and area monitoring). These monitoring practices were apparently used to determine the need for special bioassays. However, comments made during subsequent Advisory Board working group meetings contradicted these statements, when ORAUT personnel with RFP site experience indicated that all contractor and subcontractor workers performing work in RCAs needed to have Rad Worker II training and would have been afforded routine bioassays. These personnel also noted that any lapel sampling or DAC-hour tracking used would be secondary to such routine bioassays and would indicate the need for special bioassays and other followup.

7.2 SC&A REVIEW

The Advisory Board working group requested that NIOSH review available data for D&D workers. Specifically, NIOSH was to compare Rad Worker II training records and site rosters for the D&D time period with HIS-20 records to determine if all workers performing radiological work (including lower tier subcontractor workers) were included in a routine bioassay program. The working group also stressed the need to clarify what was meant by "routine" bioassays, given some historic differences in how such bioassays were conducted during the facility closure period at various DOE sites (i.e., sometimes annual bioassays were considered routine, whereas monthly ones were routine during the production era).

The working group also asked that NIOSH provide pertinent internal dosimetry policies and procedures in place during the D&D period. In addition to these documents, NIOSH also identified a series of self-audits of the RFETS dosimetry program conducted in 1996 and 2000. The following documents were placed on the O-drive for SC&A review:

- Kaiser-Hill Company, Rocky Flats Environmental Technology Site, Radiation Protection, Assessment Report, Assessment No. 97-0111-KH, Internal Dosimetry Program (undated; field work for assessment conducted between August 11, 1997, and September 4, 1997)

- Kaiser-Hill Company, Rocky Flats Environmental Technology Site, Radiation Protection, Assessment Report, FY04-111-KHAP, March 25, 2004

- Kaiser-Hill Company, Rocky Flats Environmental Technology Site, Radiation Protection, Assessment Report, Assessment of the Rocky Flats Environmental Technology Site's Internal Dosimetry Program, Assessment No. F400-114-KH (undated; field work for assessment conducted between April 11, 2000, and April 27, 2000)

- Rocky Flats Plant, Procedure 1-16200-HSP-18.20, Revision 0, Routine Bioassay Monitoring Program, February 8, 1992

- Rocky Flats Environmental Technology Site, Procedure PRO-1184-RDI-5802, Revision 0, Routine Bioassay Monitoring, January 5, 2001

- Rocky Flats Plant, Procedure 1-H04-HSP-18.20, Rev. 0, Routine Bioassay Monitoring Program, March 18, 1994

SC&A reviewed these documents and provided specific comments to NIOSH. Attachment 27 provides NIOSH's responses to those comments (November 1, 2006) and SC&A's evaluation of those responses.

7.2.1 SC&A Review of RFP and RFETS Documents from the D&D Era

SC&A's key comments based on its review of these documents include the following:

D&D workers not routinely bioassayed and lacking termination bioassays: One implication of the Kaiser-Hill self-assessments is that later monitoring found D&D workers who may have worked in areas considered to be "cold" to be contaminated with legacy radiological contamination. The 2000 audit found a steady decrease in the proportion of terminating workers who provided a final bioassay sample. By 1999, only 75% of RFETS employees and 62% of lower tier subcontractors received terminal bioassays. Therefore, for those who were exposed to potential intakes because their work areas were not surveyed for potential airborne concentrations of plutonium, or those who did not meet the narrow definition in the procedures, it appears that the termination bioassay program did not have a good backstop. Some of those workers were no longer on site and may have been among those who did not submit termination bioassays and were not Rad Worker II or respirator-qualified at the time; therefore, were never part of the routine bioassay monitoring program. The questions of concern are how many workers were in these circumstances and how would dose estimation be addressed.

The NIOSH response to this issue follows:

> *100% compliance with the termination bioassay requirement was not achieved and indeed is not possible at any DOE site. The vast majority (close to 100%) of termination bioassay samples were less than the decision level (i.e., not different than background) or consistent with known intakes. Workers who didn't submit samples will have maximizing assumptions applied, if appropriate, so this does not appear to be an SEC issue.* (NIOSH 2006a)

SC&A next asked to review the dose distributions cited for terminating D&D workers, with the following lines of inquiry:

- Given the relatively higher lack of compliance by lower level subcontractors to requirements such as terminal bioassays, would it be appropriate to assume that the dose distributions are the same?

- How can an assumption be made about the appropriateness of an upper-bound maximizing assumption for an employee whose internal exposure is unknown (other than applying a dose distribution that may or may not be appropriate)?

If ultimate reliance is placed on the real-time "workplace indicator program and follow-up," SC&A needs to review the records that document the performance of those programs and any follow-up bioassays.

Application of RFP bioassay monitoring procedures: RFP routine bioassay procedures from the early 1990s provide criteria for inclusion in the routine bioassay monitoring program:

> *Individuals routinely performing work in RCAs where the time-weighted monthly average (TWMA) of the air sample results is 0.10 of the DAC or greater, or the maximum value of an air sample result is greater than 0.30 DAC, are required to participate in routine individual monitoring program for that radionuclide.* (RFP 1994)

While it is clear that the Rad Worker II designation became the basis for routine bioassay monitoring, it is not clear how that definition reconciles with these bioassay requirements. Likewise, that designation was clearly based on a presumption of an exposure potential to the individual that could lead to a dose of 100 mrem/year or more. From NIOSH's description, this designation would have included at least two types of D&D workers from a monitoring standpoint: (1) Rad Worker II trained workers who would be bioassayed routinely, would be able to work in RCAs, and were assumed to receive potential annual doses at or in excess of 100 mrem CEDE; and (2) workers who did not have Rad Worker II training but were assumed to be exposed to sources of radiation less than 100 mrem/year. SC&A's interest, in the context of this issue, is in how these two worker categories were determined (individual risk assessment, DAC-hour tracking, etc.), and to what extent the required routine bioassays (for Rad Worker II

workers), termination bioassays (for non-bioassayed workers), and workplace indicator/special bioassays (for both) were performed.

Need to compare Rad Worker II roster with individual bioassay records: SC&A concluded that the identified shortcomings and issues raised about the bioassay of D&D workers make it imperative to compare the Rad Worker II roster after 1993 (which represented the best approximation of which D&D workers were working in radiological areas) with individual bioassay records in order to validate that the workers did, in fact, receive routine bioassays.

NIOSH questioned the "shortcomings" identified and informed the working group and SC&A of the following:

> *While the request to compare the rad worker II-trained employees to bioassay records seems straightforward, in fact it would be quite complex. There is no rad worker II training roster per se. The program worked like this. When it had been one year since each employee's last Pu urine bioassay, the bioassay database queried the training records database to determine the training and respirator-fit status. If the training and respirator-fit status were current, it then queried the HIS-20 database to see if an entry had been made in the previous 12 months. Since site closure, these databases exist in some form, but are not able to communicate as they did when the site was operational. Basically, to do what is being requested, one would have to start with a list of employees and look them up in three systems. For each employee a matrix of the dates of entry into the program, rad worker II training dates, respirator fit dates, HIS-20 entry dates, termination date(s), and bioassay sample dates would have to be set up. Where bioassays appeared to be missing, a memo field would have to be examined. This field might contain such information as, "employee on short-term disability; no sample until return." The hardcopy file might also have to be recalled to determine the exact cause of a failure to submit a sample. Currently, no one on the ORAU/NIOSH side has access to all of the necessary records systems, and we would have to rely on resources from DOE Legacy Management. The return on this investment of time and energy would be a determination that some high percentage of people received bioassay samples on schedule.*
> (NIOSH 2006a)

This response did not change SC&A's conclusion that the documents provided on the issue (bioassay policies, procedures, and self-assessments) did not answer questions about the adequacy and completeness of radiation records associated with D&D activities at RFP. In fact, these documents actually raised additional issues as cited above (i.e., lack of terminal bioassays, lack of integration of lower tier subcontractors into the bioassay program, and proper basis for Rad Worker II training) that NIOSH's response does not sufficiently address. The working group was to address in more detail NIOSH's conclusion that it is too "complex" to validate the routine bioassays conducted for Rad Worker II workers performing D&D. SC&A considered the conclusion that, a priori, validating these bioassays would not be justified in any case, because NIOSH can already predict that "some high percentage of people received bioassay samples on

schedule" (NIOSH 2006a) to be speculative and nonevaluative for purposes of a review in the SEC context. SC&A noted in subsequent working group discussions that, if these data inadequacies are substantiated, at the very least, some consideration should be given to coworker modeling for D&D workers. NIOSH indicated that it was open to that suggestion, although it considered it a TBD issue, not an SEC concern (ABRWH 2006d).

Other issues raised by SC&A (e.g., how Rad Worker II designations were made and the intent and meaning of certain RFETS audit findings) were clarified by NIOSH in its response and accepted by SC&A, as noted in Attachment 27.

7.2.2 OCAS-TIB-0014

In light of the NIOSH finding that a comparison between the Rad Worker II roster and individual bioassay data would be too complex and resource intensive, the working group, following discussion at its November 6, 2006, meeting, requested that NIOSH "provide termination bioassay data (fecal, urine, or in vivo) available for RFETS workers during the D&D period (1993 forward)" (ABRWH 2006d). The working group asked that "this data include information indicating whether each individual worked for the prime contractor or a subcontractor." Secondarily, the group asked NIOSH to "provide for review an assessment of the sufficiency of data to support decontamination and decommissioning (D&D) coworker model development."

In response, NIOSH issued on December 7, 2006, a new OCAS-TIB-0014, *Rocky Flats Internal Dosimetry Coworker Extension* (Allen 2006b), which extends the existing ORAUT-OTIB-0038 (*Internal Dosimetry Coworker Data for Rocky Flats Environmental Technology Site*) (Arno et al. 2006) beyond the latter's 1953–1988 date to Rocky Flats cessation of operations in 2005, thereby encompassing the D&D era. The extension is based on urinalysis data in HIS-20 and provides projected intakes by year.

SC&A finds that OCAS-TIB-0014, which assumes a lognormal distribution fit to uranium and plutonium bioassay results from chronic intakes during the period 1989–2005, is conceptually adequate. However, OCAS-TIB-0014 states that this TIB did not address Am-241 lung data, with the number of such samples dropping significantly in 1990. On the other hand, the December 18, 2006 NIOSH discussion paper *Analysis of Termination Bioassay Results for Rocky Flats during Shutdown and D&D Era (1990 to mid 1995)* (NIOSH, 2006b) (also in Attachment 27) states that lung counting was the preferred method of termination bioassay in the later years of the site. SC&A sought to reconcile these two statements in the context of whether and how OCAS-TIB-0014 addresses in vivo counting results.

7.2.3 Termination Bioassay Data Comparison

As an alternative means to demonstrate the comparability of dose distributions between the broader contractor and D&D subcontractor population, NIOSH provided a comparison of termination bioassay results for plutonium and uranium. Results were provided for (1) top-tier contractors, (2) all subcontractors, and (3) D&D subcontractors. In the cover e-mail accompanying its December 18, 2006, review in Attachment 27, NIOSH concluded that the

results "do not show any significant differences between top-tier contractors and all subs, or between top-tier contractors and D&D subs," and that NIOSH remained "confident that the internal coworker data developed for the D&D era can appropriately be applied to all workers regardless of employer, as necessary" (NIOSH 2006b).

SC&A reviewed the December 18 analysis of termination bioassay results and generally concurs with the NIOSH assessment, although SC&A did need to clarify several outstanding issues (see below). For RFETS, it is apparent to SC&A from discussions with site experts that the extensive use of operating workers (e.g., steelworkers) by the top-tier contractors for much of the initial "hot" radiological work (e.g., initial decontamination and contaminated equipment removal) in place of less experienced subcontractors had a leveling effect on dose distribution between the two groups. This leveling effect is borne out in the NIOSH dose distribution comparisons between the three worker groups. Regardless of the explanation, the similarity of the dose distribution for terminal bioassays between the two worker populations is persuasive on the issue of applicability of coworker models.

However, NIOSH based its review on a comparison of urine samples. The 1992 Routine Bioassay Monitoring Program (1-16200-HPS-18.20) required an annual feces routine sampling for exposure to plutonium, and the Derived Investigation Level for plutonium was based on fecal sampling (RFP 1992). Fecal sampling was required at the end of jobs that had a high potential of an intake greater than the investigation level. The exit request for workers who were in a routine bioassay program for plutonium in their last 12 months on site consisted of three fecal samples.

The 1994 Routine Bioassay Monitoring Program (1-H04-HPS-18.20) defined the exit bioassay requirements for plutonium or americium as urine or lung count for Category I workers and feces or lung count for Category II workers. Category II workers were defined as workers with an elevated risk of internal exposure, while Category I workers would **not** have a high risk of internal exposure (RFP 1994). The following analysis evaluates this issue in greater detail.

7.2.4 Analysis of Fecal versus Lung Count Issue

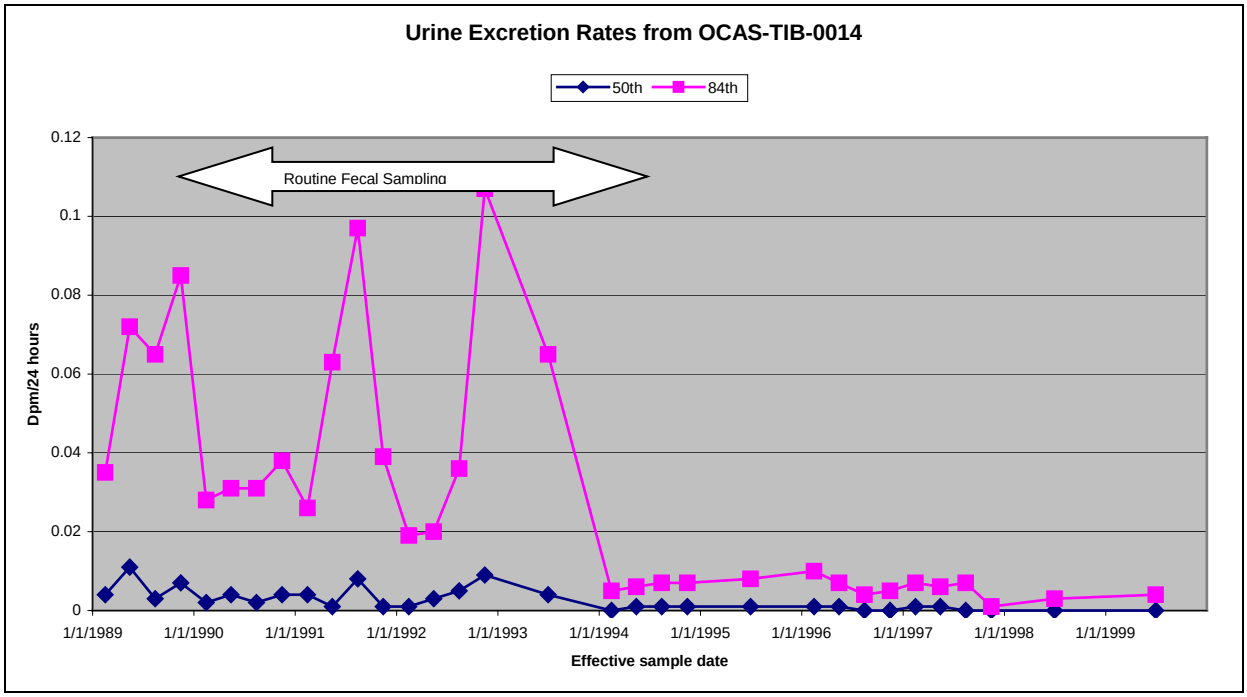
On January 24, 2007, NIOSH issued a document entitled *Response to SC&A Comments on "Analysis of Termination Bioassay Results for Rocky Flats during the Shutdown and D&D Era (1990–2005), December 18, 2006" and OCAS-TIB-0014* (NIOSH 2006c). In this document, NIOSH stated the following:

> *for a time in the early 1990s, Rocky Flat's interpretation of the DOE bioassay requirement was that the minimum detectable dose for the routine program was to be 100 mrem. This concept also applied to termination sampling. The only sampling means available for plutonium which could approach 100-mrem sensitivity was fecal sampling. DOE subsequently clarified its position and routine and exit urine sampling was resumed. The 2/2/1995-version of HSP 18.20 (pp. 36-65, SRDB Ref. ID 24241) eliminated the Category I and II definitions and specified urine or lung count as the exit bioassay.*

> *There were a number of logistical problems associated with large fecal sampling programs that Rocky Flats quickly discovered. The first attempt at off-site contracting for fecal bioassay resulted in all fecal sample results being invalidated due to quality problems. It is believed that most of these workers were subsequently asked to submit a urine sample. It is unclear how many termination fecal samples may have actually been submitted in lieu of termination urine samples, but the number probably was not large. Letters were placed in the individual files indicating the samples were invalid.*
>
> ***Another important point is that the original question involved subcontractors in the D&D era. The analysis included data from 1990–2005. In 1989 production operations were suspended. From 1990 to 1994, Rocky Flats' contractors undertook a massive effort to restart the Plant. However, this effort was mostly to improve the documentation (procedures, etc.) that would allow the restart of production. Maintenance, radiation surveys, and the like were still performed in contaminated areas, but not production, and not major D&D. The decision not to restart and to begin the D&D of the facility was made in 1994. However, the D&D era did not start in earnest until after the new contractor, Kaiser-Hill Company, was brought on in mid-1995. Therefore the use of termination fecal bioassay would not have biased the results during the actual D&D era.***
> [Emphasis added]

NIOSH also noted the following:

> *The coworker extension (OCAS-TIB-0014) used urine results in the HIS-20 database. Most of these were routine results, but some were termination samples or incident-related samples. The years affected by the fecal sampling program were 1990–1994 at most. If there was a significant negative bias introduced, it would be apparent when examining the OCAS-TIB-0014 results. A graphical representation is shown below, in which part of the data in Table A-2 is plotted.*



At first glance this plot may appear to show that the urine results were actually biased high during the time period when there could have been fecal samples collected as the routine bioassay. In reality, this plot shows the improvement in the analytical laboratory procedures over the years. Leading up to the implementation of 10 CFR 835 in 1996, Rocky Flats made a concerted effort to improve the MDA for plutonium in the on-site bioassay laboratory, as well as to contract with the best off-site bioassay laboratories available. The driver was the need to demonstrate that the routine bioassay program could detect 5 rem CEDE. To accomplish this with an annual urine sampling program required world-class laboratories and alpha spectroscopy counting facilities. Most laboratories offering these services could not meet Rocky Flats' MDA and/or QA/QC requirements. The above plot demonstrates that any possible low bias introduced by fecal sampling was insignificant compared to the effect of the plutonium MDAs. (NIOSH 2006c)

SC&A accepts these NIOSH contentions with respect to the remaining question regarding potential bias introduced by use of fecal termination bioassays, especially considering the NIOSH statement that the D&D era did not start in earnest until mid-1995 (which SC&A has corroborated in discussions with former site workers).

7.2.5 Analysis of OCAS-TIB-0014

As noted previously, SC&A accepts the concept of applying OCAS-TIB-0014 as an extension of ORAUT-OTIB-0038 for worker populations in the D&D era. However, SC&A finds that the use of a model based on the 50th percentile of the excretion rates of the workers will misrepresent the

higher exposures experienced by unmonitored subcontractors at RFP. SC&A is supportive of intake models based on a percentile equal to or higher than the 95th. As in its review of ORAUT-OTIB-0038, which OCAS-TIB-0014 extends to the D&D era, SC&A notes that the intake model for OCAS-TIB-0014 was derived using an IMBA fit for a period of several consecutive years. As a consequence, for some time periods, the dose will be calculated using an intake rate that corresponds to urinary excretion values smaller than the chosen percentile (50th or 95th). Thus, when NIOSH uses the 50th percentile or the 95th percentile intake rates, it should not be understood as the 50th or 95th percentile of the workers' intake rates. These rates correspond to a model intake rate that will fit the chosen percentiles, with some periods of time when the urine excretion rates will be underestimated, and some periods of time when they will be overestimated. SC&A considers these uncertainties in the adequacy of the bioassay program and in the completeness of radiation records associated with D&D activities at RFP to be large, and that a coworker model based on the 50th percentile of the bioassay records does not adequately address these uncertainties.

SC&A also finds OCAS-TIB-0014 to be incomplete because it does not address in vivo counting results. For respiratory organ dose calculations, ORAUT-OTIB-0014 recommends applying Type M plutonium, followed by the minimizing Type S intake. If both actions do not yield a probability of causation (POC) > 50%, NIOSH recommends manually fitting the coworker bioassay data for the timeframe of interest for the employee, using the assumption of Type S material. In ORAUT-OTIB-0038, this manual fit of the data includes americium lung data. The uncertainties associated with the calculation of doses to the lung from urine data are large. The correlation of plutonium retention in the lungs with the excretion rate in urine is indirect and depends on the chemical and physical forms. Different matrix materials containing plutonium may have specific dissolution behavior. Absorption parameters depend on the production temperature. The method of formation of the material and its history (temperature, specific surface area) can influence the fraction rapidly absorbed and the long-term retention half-time. The different types of material encountered in D&D activities produce different urinary excretion patterns. As a consequence, there is an increased uncertainty in the association of the urinary excretion rate with lung retention or lung deposition.

7.2.6 Conclusion Regarding Dose Estimation for D&D Workers

SC&A concurs with NIOSH's conclusion about its ability to conduct dose estimation with sufficient accuracy for the D&D era of plant operations based on its favorable comparison of termination bioassay data between "top-tier" operating contractors and identified D&D subcontractors. Subsequent NIOSH-provided analyses that address potential bias introduced by use of fecal termination bioassays have satisfied issues related to SC&A's evaluation of OCAS-TIB-0014, NIOSH's draft bulletin that extends ORAUT-OTIB-0038 (internal dose coworker model) beyond 1988. However, similarly to ORAUT-OTIB-0038, OCAS-TIB-0014 uses the 50th percentile rather than the 95th percentile to derive intakes, which may not be claimant favorable.

8.0 DATA COMPLETENESS EVALUATION

The Advisory Board's criteria for evaluation of SEC petitions include several that relate to the data underlying dose reconstruction (ABRWH 2006a). These criteria fall under the general rubric of the "credibility and validity of the dataset." The intent of these criteria relates to NIOSH's ability to perform dose reconstructions:

> *For each petition evaluation, NIOSH will typically review the available exposure data for that site and then focus on a few key sets of exposure data (including exposure sources) to determine if those data at that site are adequate for completing individual dose reconstructions for all members of the class.* (ABRWH 2006a)

The Board elaborated on the meaning of the term "credibility and validity of the dataset" by specifying the following criteria:

(1) *Pedigree of the Data:* This includes determining "the relation of the exposure monitoring to documented activities at the site during that time period" and ensuring that "secondary sources of data…are consistent with the original data set…."

(2) *Methodology:* This includes an evaluation of "the documented methodology for the data set including whether reliable corrective estimation procedures have been applied and are appropriate."

(3) *Relation to Other Sources of Information:* This includes a demonstration that "the data are appropriate for…estimating the maximum plausible dose for any member of the class."

(4) *Internal Consistency*.

(5) *Representativeness:* This includes considerations of whether the various periods, areas, types of work and processes, source terms, and adequacy of data are "representative of the highest exposed individuals within the class."

The procedures approved by the Board for its contractor in evaluating SEC petitions and in reviewing NIOSH's evaluation reports on SEC petitions also involve an investigation of the completeness of the internal and external dose data sets that NIOSH proposes to use for dose reconstruction for any member of the class (SC&A 2006d).

Initial inquiries focused on the completeness of the HIS-20 electronic database and its relationship to the underlying data. Comparison of the database with information in logbooks and claimant files revealed that the HIS-20 database is incomplete and that workers whose employment ended before 1977 may not be represented in the database. Another database, the CER database, was also found to be incomplete. In response, NIOSH stated that it would rely on individual dose records in DOE files as the principal source of data for individual dose

reconstruction and on the HIS-20 and/or CER electronic database for coworker models. As a result, the completeness of the data in the DOE files became an issue, since those data are the primary source for the NIOSH individual dose reconstructions. This section examines the issue of the completeness of individual dose data as reflected in the Rocky Flats claimant files.

This investigation was necessary because there is no complete compilation of dosimetry data that reflects essentially all the data in the DOE files. Gaps in data—that is, periods when there were no measurements whatsoever—indicate a need for methods to fill those gaps. These gaps are essentially different from zeros in the data records, which reflect measurements below the detectable limit that can be filled in various ways, including by using the LOD or LOD/2 or some value in between. Coworker models may be needed if gaps are significant, or if whole groups of workers were not monitored at certain facilities or in certain periods or both.

SC&A conducted a broad investigation of the completeness of Rocky Flats external and internal monitoring data in claimants' DOE files, using minimal criteria for completeness, to ascertain whether substantial gaps exist that need to be filled. This broad investigation is distinct from a more detailed evaluation that would, for instance, involve a review of each badging cycle for external dose.

SC&A conducted two types of completeness evaluations. In the first, SC&A examined external and internal dose data in DOE responses in the records of 32 randomly selected claimants. The second consisted of examinations of the DOE responses in the records of 20 claimants who were judged by Rocky Flats in the 1990s to have high cumulative radiation doses. The randomly selected cases show the general extent of the gaps in Rocky Flats worker records. An examination of the records of claimants with high cumulative exposures provides a preliminary view of whether there is a basis for filling the gaps in dosimetry data for the rest of the worker population, if such gaps exist. In each case, the investigation of gaps focused on the data in DOE files for a particular claimant. SC&A also did a preliminary evaluation of the job records of the 20 claimants with high cumulative exposures to ascertain whether a pattern existed for certain gaps in the external dose records. (This evaluation does not cover external dose gaps in 1969, which are discussed in Section 4.3.1 of this report.)

The 32 random claims were selected in three waves. An initial set of four (Wave 1) was chosen from among Rocky Flats dose reconstructions already audited by SC&A. These were among the cases randomly selected by NIOSH and presented to the Advisory Board, which selected the cases from across the weapons complex to be audited by SC&A. The next eight (Wave 2) were obtained by picking the first Rocky Flats case for a claimant who was employed for 5 years or more from 1-999 claimant numbers on the NIOSH R-drive, then one case from the 1,000 to 1,999 group, one from the 2,000 to 2,999 group, etc., until there were a total of eight cases. A preliminary analysis was conducted to determine whether the gaps found were sufficient to warrant a further inquiry. Finally, the last 20 (Wave 3) were selected using a randomized search procedure, with the added limitations listed below:

- Two periods, 1951–1963 and 1964–1992, were represented among those selected, so that they could be studied separately. These time periods were selected because Rocky Flats

integrated its security and film badge in 1964. This made the earlier period a statistically different distribution—and indeed, data on the fraction of workers monitored in the first period indicate a fairly steady increase during the years from startup through the early 1960s. The data show a sudden jump in the fraction of employees badged in 1964. Table 8.1 (reproduced in full in Attachment 7), which is taken from a NIOSH paper on Rocky Flats badging practices, shows the percentage of workers badged by year.

- Each claimant file selected represented a claimant who worked at the Rocky Flats Plant for at least 5 years.

- The sampling was done without regard to whether dose reconstruction had been completed. Only files pulled by NIOSH from the dose reconstruction process (17 out of 1,165) were excluded from the sampling.

Attachment 28 describes the sampling procedure for selecting the 20 cases.

The total of 32 cases was selected to provide a reliable picture of the gaps in Rocky Flats workers' DOE records. Table 8.1 shows that larger gaps should be expected in the 1951–1963 period for external dose than in the 1964–1992 period. Note that the frequency of monitoring declined again beginning in 1992. This was the year that production ended and the transition to decommissioning of Rocky Flats began. Decommissioning formally started in 1993.

Table 8-1. Percent Badged

Year	Badged	Year	Badged	Year	Badged	Year	Badged	Year	Badged	Year	Badged
1951		1961	77%	1971	94%	1981	96%	1991	91%	2001	73%
1952	5%	1962	78%	1972	94%	1982	96%	1992	82%	2002	72%
1953	33%	1963	75%	1973	94%	1983	97%	1993	80%	2003	56%
1954	34%	1964	93%	1974	98%	1984	96%	1994	65%	2004	40%
1955	43%	1965	93%	1975	97%	1985	98%	1995	65%	2005	25%
1956	53%	1966	96%	1976	96%	1986	97%	1996	67%		
1957	61%	1967	95%	1977	97%	1987	98%	1997	79%		
1958	63%	1968	91%	1978	98%	1988	98%	1998	83%		
1959	63%	1969	74%	1979	98%	1989	98%	1999	83%		
1960	71%	1970	90%	1980	97%	1990	96%	2000	80%		

Source: ORAU analysis of RFP claimant files

Source: Langsted 2006

Figure 8.1 shows the data in Table 8.1 in graph form.

The data in Table 8.1 and Figure 8.1 should be treated with some caution since they are based on a sample whose representativeness has not been established. Specifically, the percentages are derived from a review of 1,046 Rocky Flats claimant files (Langsted 2006). While this is a large sample, the representativeness of claimants to the entire Rocky Flats workforce, including subcontractors, covered by the proposed SEC class has not been established and no method to do so is evident. Specifically, the job types and periods represented by the claimant file sample may not correspond to the proportions in the worker population. Some job types may not be represented. The practical consequences of this issue are discussed later in this chapter.

Notably, the year 1969 shows a sharp drop in proportion badged. This appears to be the result of equating the gaps in the external dosimetry record as nonmonitoring. Strictly speaking, many badges that were issued were not read, even though they were issued. (See analysis of the 1969 data in Section 4.3.1.) SC&A concurs that unread badges should be treated as if the employee were not monitored in that period.

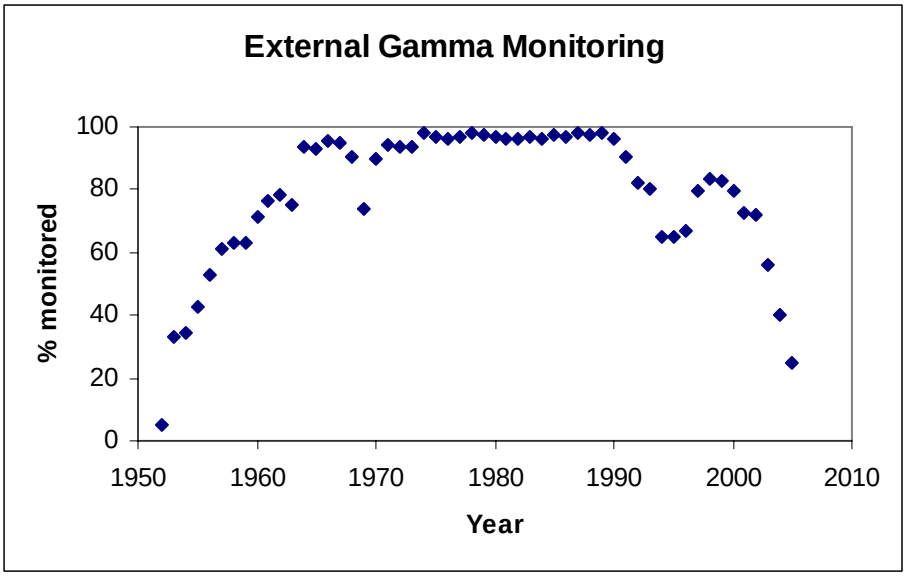


Figure 8-1. Proportion of Workers Monitored for External Dose at Rocky Flats
Source: Langsted 2006

The DOE dose records of the 32 claimants were divided into two periods, 1951–1963 and 1964–1992. This is because a combined ID and film badge was issued in 1964, which resulted in over 90% of the workers being badged until the transition to D&D in 1992. In addition, separate tables were created for external dose (deep gamma) and internal dose. If in any year, there were no external dose records at all (even zeros), but only blanks, that year was counted as a gap in external dose data. (The term "gap" is used both to mean a blank in the records or no measurement indicated in the record. It does not include zeros in the record, which are counted as measurements at less than the LOD.) Note that counting a year as one that has data does not affirm that there are complete data for that year—that is, it does not mean that a record exists for each badge cycle. Similarly, for internal dose data, a year counted as a gap in the data is one in which there was no bioassay (urine or fecal) record and no in vivo count. If there was a data point for any one of these categories in a given year, the year was not counted as a year without data. Gaps for partial years at the start of employment and at the end of employment were not counted. The initial and final year data were rounded to zero, half year, or full year, as follows:

- 0 to 2 months = zero
- 3 to 8 months = half year
- 9 months or more = full year

SC&A also compiled cumulative data on the data gaps. In these cumulative compilations, partial, initial, and final years were counted according to the rounding scheme described.

In addition to the analysis of the 32 cases randomly selected, a sample of 20 cases from among those judged in the 1990s to have the highest cumulative doses (internal committed dose equivalent plus external deep dose) were examined to assess completeness of records for those workers. ORAU performed the exposure assessment in the 1990s as a retrospective. This part of the completeness evaluation has particular relevance for development of coworker models.[8]

8.1 EXTERNAL DOSE—RANDOM SAMPLE

Table 8.2 shows the analysis for the external dose records for the 32 claimants in the random sample.

Table 8-2. Rocky Flats External Dose Data Completeness Analysis—Random Samples

Period	Number of workers	Number with gaps of 1 year or more [1,4]	Percentage of workers with gaps of 1 year or more [1]	Cumulative years employed	Cumulative gap–years[4]	Percentage cumulative gap
1951–1963	14	4	29%	76.5	16.0	21%
1964–1992	30	10 [2]	33%	368	37.0 [3]	10%

[1] This column does not count first or last partial year gaps.
[2] Of the 10 employees with gaps of 1 year or more in 1964–1992, 4 had gaps only in 1992.
[3] 1969 gaps in data may be for part of the year or the full year. This compilation does not count 1969 data gaps as full-year gaps. The 1969 issue is briefly addressed below and more fully in Section 4.3.1 of this report.
[4] A gap is recorded for the year if there are no film badges or TLD data at all for that year. Zero entries are counted as positive indications of recorded data. Only blank records are included in the compilation of the gaps.

The percentage cumulative gap in the external dose data was greater in the 1951–1963 period than in the 1964–1992 period. This result confirms the data compilation by NIOSH presented in Table 8.1, which shows that a significant proportion of workers was not badged in the early period. The proportion of badged workers went from 5% in 1952 to a high of 78% in 1962. Overall, about 21% of the cumulative years worked by the 14 employees had no external dose records (partial years counted as 0 or 0.5 years, as noted above).

The proportion of workers with at least a 1-year gap was about the same in the two periods (about 30%). However, the high value for the latter period is largely due to the transition year of 1992. Of the 10 workers with a gap of at least 1 year, 4 had a gap only in 1992. An investigation into job types may yield insight into the reasons. If the analysis excludes these four, 20% of the workers had a gap of at least 1 year in their external dose records. As noted, this analysis does not include partial-year gaps; as long as one record exists in a given year, that year is excluded from the compilation of data gaps. It is, therefore, a minimal criterion of

[8] This draft report does not include the detailed compilations of the claimant data. These compilations may contain Privacy Act information. The spreadsheets have been sent to the CDC for evaluation of content related to the Privacy Act.

completeness for external dose data. The section on highly exposed workers discusses issues related to dose reconstruction.

SC&A found several records with gaps for all or part of 1969. This finding reflects the cumulative data compilation of monitoring frequency provided by NIOSH and discussed above. However, a specific problem appears to affect 1969 external dose data. In that year, Rocky Flats management decided not to read the film badges of workers on a 3-month badge cycle. The March 1969 monthly status reported this change:

> *Quarterly badges for the non-Pu areas will no longer be read routinely, except for a few higher dose risk groups. The film will be changed as usual, but will not be read unless circumstances warrant.* (Piltingsrud 1969a)

It is not clear whether and when this policy was rescinded. Not reading film badges that were issued and then handed in appears to SC&A to be a questionable practice, which even apparently surprised NIOSH/ORAU consultant and Rocky Flats dose expert, Roger Falk (see Attachment 29).

The problem of blank external dosimetry records before 1969 and after the start of the integration of the ID badge and the film badge in 1964 continued after 1970. For instance, one of the workers in the random sample of 32 had external dosimetry gaps (blanks) from 1963–1973 (inclusive). NIOSH has stated that this worker was not issued a badge (November 6, 2006, working group meeting transcript, pp. 76–79). It is not clear how the nonreading of issued badges is to be differentiated from nonissuance of badges to prime contractor personnel.

During the working group meeting of March 7, 2007, NIOSH stated that not all workers who were prime contractor employees after 1964 were badged. SC&A has not found any clear documentation regarding a policy for determining who was excluded. The NIOSH paper on badging practices (Langsted 2006) does not clarify this problem. For the 1964 combined badges, the paper quotes the 1982 Rocky Flats history as follows:

> *In 1964, we were able to incorporate the dosimetry badge with the security badge. This was an improvement from the standpoint of assuring the employee was indeed wearing a badge while working on the job.* (Rocky Flats History as quoted in Langsted 2006)

This does not indicate that all prime contractor workers were badged. However, the Langsted paper also quotes a 1974 memo that states, "we have issued all employees on plant site (Dow and AEC) a TLD dosimeter" (as quoted in Langsted 2006). This implies that some Dow and AEC personnel may not have been given TLDs from the time of their introduction in 1970, or perhaps film badges from the time of the introduction of the combined film badge and ID in 1964. The NIOSH investigation into badging practices throws some light into who was brought into the badging program in 1974, but it provides no explicit criteria for who was excluded in 1964. The evidence is clearer concerning which subcontractor workers continued to be excluded after 1970 (see below).

8.2 RANDOM SAMPLE—INTERNAL DOSE

Table 8.3 shows the summary data for the random samples for internal dose data from 32 claimants.

Table 8.3. Rocky Flats Internal Dose Data Completeness Analysis—Random Samples [1]

Period	Number of workers	Number with gap of 1 yr or more [2]	Percentage workers with gaps of 1 yr or more [2]	Cumulative yrs employed	Cumulative gap in yrs	Percentage cumulative gap
1951-1963	14	4	29%	76.5	9.0	12%
1964-1992	30	22	73%	368.0	122.5	33%

[1] A gap for a full year is recorded if there are no bioassay data (urine or fecal) and if there are no in vivo data. A single measurement in any of these categories is counted as a year with data. This approach cannot be directly related to dose reconstruction feasibility but provides a modest test of data availability for internal dose.

[2] This column does not count data on first or last partial year gaps.

Surprisingly, nearly three-fourths of the workers in the random sample had at least 1 year of no internal dose measurements in the 1964–1992 period, though the total cumulative working years with no internal dose records was about one-third. Smaller internal dose measurement gaps occurred in the early period. The next section discusses the issues raised by these gaps as they concern internal dose reconstruction for workers with high cumulative exposure.

8.3 SAMPLE OF WORKERS WITH HIGH CUMULATIVE EXPOSURE

As noted, SC&A also analyzed the DOE files of 20 Rocky Flats claimants who were assessed as having high cumulative exposure in a retrospective analysis done in the 1990s. That analysis categorized workers into groups numbered 1 through 4, with 1 representing the lowest cumulative exposures (external plus internal) and 4 representing the highest exposures. SC&A chose 10 claimants from group 4 and 10 from group 3 for analysis. The selection process began with an SC&A request to NIOSH to provide the full lists of claimants in group 3 and group 4. NIOSH provided a list of 22 group 4 claimants. SC&A selected the first five and last five from this list. For group 3, NIOSH sent a list of 35 claimant numbers. SC&A selected approximately every third number from this list until it had a total of 10.

The analysis found no full-year gaps in internal dose data for this group of 20 workers. This applies to both the early (1951–1963) and late (1964–1992) periods. The early period includes 63 cumulative years of employment in the 1950s. The database is apparently sound enough to permit an analysis of the feasibility of one or more coworker models for all members of the class through 1992. SC&A has not performed such an analysis but recommends that the analysis include a review of the data related to workers with high cumulative exposure. This would allow NIOSH to examine the job types represented to determine if they include all those with a potential for high internal exposure relative to the various source terms present at Rocky Flats, or if the exposures for the job types that are represented bound those that are not represented for various periods where production operations or other factors, such as materials brought in or

processed, changed. Additionally, it is important to verify that the available data are sufficient to reconstruct doses due to incidents, especially when exposure was to materials of high or medium solubility. Specifically, in view of the large proportion of workers (nearly three-fourths) in the random sample who had a gap of at least 1 year in their internal dose records, it is essential that the job types of group 3 and group 4 workers be analyzed relative to the workers who have gaps in their data, before a coworker model can be deemed to be suitably claimant favorable.

The picture regarding external dose is somewhat different. There are essentially no full-year gaps in external dose data records for this group of 20 claimants from 1960 onward. However, numerous gaps exist for the 1951–1959 period, notably for claimants in group 3. Specifically, about 62% of the cumulative employment years for group 3 workers lacked any external dose data in this period; the total for group 4 was 19%. Most of the gaps relate to the initial years of employment.

The gaps in the 1950s most likely reflect the partial external dose monitoring for Rocky Flats workers, as discussed above. In an interview, SC&A sought an explanation for these gaps from Roger Falk, a site expert, who responded as follows:

> *They may have started work in a non-radiation area or in a lower job classification. Rocky Flats was a coveted place to work. What I have observed and known to have happened was that anyone would apply for a low-level job, such as Janitor, and work their way up into better positions as he proved himself. I don't know if it happened in the cases that you looked at.* (Attachment 29)

SC&A did a preliminary analysis of the job cards of both group 3 and group 4 workers in order to determine whether any pattern emerged in a screening analysis. It appears that most of the full-year data gaps in the 1950s are associated with work in Production Plant B, which consists mainly of Building 81 (or 881), where enriched uranium was processed. Some gaps occurred for workers in the QC laboratory and the "pipe shop." There were no full-year gaps for external dose data (as defined above) in Production Plant C, where plutonium was processed. SC&A confirmed Dr. Falk's observation that many workers started as janitors or laborers and worked their way up but could not confirm the implication in his statement that the gaps relate mainly to nonradiological work. The progression in job type was rather rapid, and the data gaps do **not** relate mainly to the period of employment in nonradiological jobs. On the contrary, they occur mainly in the years when the employees in question were in radiological areas and mainly in Production Plant B. A review of the job cards, therefore, provides a reasonable explanation for the gaps in the data.

8.4 NIOSH DOSE RECONSTRUCTIONS FOR SAMPLED CASES

A core argument made by NIOSH to assert its ability to reconstruct doses in a manner that meets the purposes of 42 CFR Part 83 is that it has completed dose reconstructions in almost all the cases examined in the data completeness evaluation discussed above. In its February 2007 paper, NIOSH stated the following about these 52 cases and the data gaps in many of the records:

> *There was not a single case where an employment period without monitoring data adversely impacted NIOSH's ability to conduct dose reconstruction with sufficient accuracy, as evidenced by completed dose reconstructions for 48 of the 52 individual claimants examined, 60% of which had probabilities of causation greater than 50%. NIOSH therefore concludes that the monitoring data in the 52 claimants' radiation files is sufficient for dose reconstruction, and therefore does not present an SEC issue.* (NIOSH 2007c)

SC&A finds that the claim that no SEC issue is involved because dose reconstructions have been completed under 42 CFR Part 82 does not fulfill the requirements of 42 CFR Part 83. Specifically, 42 CFR Part 82 allows research to be cut short for purposes of efficiency in either minimum or maximum dose calculations. In the former case, only a partial dose determination is made, since the POC at the minimum dose determined is over 50% and the claim is likely to be compensated. By definition, a minimum dose estimate is not a bounding estimate or an estimate with the accuracy required under 42 CFR Part 83. Similarly, efficiency methods of maximum dose use inputs that can grossly overstate dose and have no clear connection with the employee's work. These dose estimates are used only for denial of claims. In contrast, the dose reconstruction with sufficient accuracy stipulated under 42 CFR Part 83 must use methods that result in estimates that can be used both to compensate and to deny claims. SC&A concludes that, as a general matter, dose reconstructions completed under 42 CFR Part 82 do not necessarily demonstrate the feasibility of dose reconstruction with sufficient accuracy under 42 CFR Part 83.

In the specific case of Rocky Flats, 50 of the 52 cases examined by SC&A in the data completeness evaluation have completed dose reconstructions. Of the 50 completed cases, 31 were compensated, but almost all of them (28 of 31) were minimum dose reconstructions. In 12 of the 28 compensated cases, no external dose was calculated at all; in one case, only medical dose was sufficient to compensate. Of the 19 denials, 15 used an efficiency technique for internal dose for cutting short research (see ORAUT-OTIB-0002 (ORAUT 2007a)). Further, the dose reconstructions do not cover all the job types that are in question here. For instance, the sample of 52 claimants included no foundry workers from the 1950s.

SC&A looked more closely at the workers who had gaps in their external dose records and at the method NIOSH used to complete the external dose reconstruction in such cases. Of the 50 completed dose reconstructions, the cases of 24 workers had gaps of 1 year or more in their external dose records. Of these, NIOSH did not reconstruct the external dose for 13. In 4 of the 11 cases where NIOSH imputed a value to the external dose, it used the LOD as the basis for

doing so. For instance, in one case, a group 3 worker (high cumulative dose) worked in Plant B and had no dosimeter during his employment in the 1950s. The 1950s gap in the energy employee's external dose record was not mentioned in the dose reconstruction report. However, entries in the Interactive RadioEpidemiological Program input tables for 1955–1959 appear to have been obtained by assuming some sort of missed dose distribution corresponding to LOD values; it is not obvious how these values were derived. If these values were derived in this manner, it creates the problem of assuming a dose at or below the LOD when there was in fact no monitoring. In effect, this puts nonmonitoring on a par with a zero-dose reading. This is not scientifically appropriate.

In two of the remaining seven cases, NIOSH used a value of 0.1 rem to fill a 1992 monitoring gap, since that was the value for determining whether a person was badged after 1992. This value appears to be in line with prior monitoring results and the change in policy defining who was to be badged. The year 1992 was a transition year from production to D&D. SC&A broadly concurs with NIOSH regarding dose reconstruction during D&D as it pertains to 42 CFR Part 83. The issue at hand is the ability of NIOSH to make estimates with sufficient accuracy during the production period. These two cases are not relevant to that period.

In one of the remaining five cases, NIOSH used the ambient dose and in another it used 150 mrem per quarter, or half of 10% of the 3-rem quarterly dose limit. None of these cases are relevant to bounding dose estimates for the class.

NIOSH estimated a dose relating to actual badge data and working conditions in only 3 of 24 cases that had a gap of 1 year or more. These cases are relevant to demonstrating the ability of NIOSH to make a bounding dose estimate.

In one case, the worker's highest dose from the period of recorded dose was assigned to the periods where there were gaps, in addition to missed dose. The dose reconstruction report raises the possibility that the badges may have been lost. SC&A is not debating the merits of the claimant favorability of the approach adopted in this case. In the context of the SEC evaluation, the material issue is whether an ad hoc assignment of dose without knowledge of working conditions contributes to demonstrating NIOSH's ability to estimate a bounding dose for filling gaps for members of the SEC class. SC&A believes that knowing the working conditions and relating those working conditions to the dose estimate are crucial to dose reconstruction with sufficient accuracy under 42 CFR Part 83.

In the second case where NIOSH used a dose assignment other than LOD, there was a data gap of 9 years in the 1970s and 1980s. Monitoring records existed for most other years. This gap was filled each year with the value in the year of highest recorded dose (0.32 rem). This case involved a subcontractor employee who was actually not employed at Rocky Flats between early 1975 and 1983 (inclusive).[9] Hence, an assignment of dose is claimant favorable but scientifically dubious, at best. In any case, it is not an SEC issue, since the gap in data is

[9] This is noted in NIOSH 2007c. SC&A verified the termination and restart dates from the DOE records in the claimant's file.

explained by the sporadic nature of the subcontractor employee's work. This kind of dose assignment when the employee was actually not employed is arbitrary (any value may be assigned from zero on up) and is irrelevant to making a bounding dose estimate.

Some internal dose gaps occurred during periods of employment. Out of 23 years, 17 had no internal monitoring data. Since the worker was issued a badged during some of these years, there may well have been potential for internal exposure. No internal dose reconstruction using Rocky Flats data was done in this case; instead, ORAUT-OTIB-0002 was used. This TIB is used to estimate worst-case internal doses only for denial. Hence, for both internal and external dose, these cases illustrate why a completed dose reconstruction cannot be accepted as evidence of NIOSH's ability to estimate a bounding dose for all members of a proposed SEC class. However, SC&A has found that the internal dose gaps themselves are not an SEC issue, since there are no annual gaps for workers with high cumulative doses.

NIOSH used its coworker model in only one case to fill a gap in the dose record. It did so for an employee who had a blank in his 1969 record (full year) and other gaps of less than 1 full year. This employee worked in a variety of areas, including Building 44, which includes the foundry, and plutonium areas. The framework used in the dose reconstruction was that for plutonium workers, which was stated to be claimant favorable. Shallow doses were assigned on the basis of <30 keV photons. The gap for 1969 for <30 keV photons was filled with a coworker model dose of 0.216 rem. Interestingly, all shallow doses in prior years, based on measured and missed dose data, are much higher, ranging from a low of just under 0.5 rem to a high of over 5 rem. The latter dose is higher than the 95th percentile value in the coworker model. The value for coworker dose used in the dose reconstruction for 1969 is lower than all recorded values up to 1968 and two of the recorded values between 1970 and the early 1980s. No part of the dose construction explicitly considered job assignments in the area of potentially high shallow dose, Building 44, even though the person worked in that area, among others. His job assignment card shows that he was assigned to Buildings 44 and 81 in 1969. His dose record does show a sharp drop in shallow dose after the gap in 1969.

In view of the preceding, SC&A concludes that in the only instance among the 50 dose reconstructions in which NIOSH used the external dose coworker model to fill an external dose data gap for a full year, the result did not demonstrate its ability to bound the doses in the areas where this evaluation has discovered gaps.

Finally, NIOSH has completed dose reconstructions at sites for which SECs have subsequently been granted.

In summary, SC&A does not agree with NIOSH's claim that the completed dose reconstructions for the cited cases at Rocky Flats provide evidence of its ability to complete dose reconstructions with sufficient accuracy under 42 CFR Part 83 for all members of the proposed SEC class, or even for those members of the class likely to have the kinds of external dose data gaps discussed above.

8.5 DATA GAPS AND COWORKER MODELS

Since gaps in external dose data are substantial for nonplutonium workers in the 1950s even among workers with high cumulative exposures, it is essential to examine whether the available external dose data are sufficient to fill those gaps. Since all identified gaps for the workers with high cumulative exposures were in nonplutonium areas, SC&A explores the implications of that finding, beginning with the DU area (Plant A, mainly Building 444, also called Building 44), which may have had the greatest exposure potential among the nonplutonium areas. Following this exploration is a discussion of Plant B (mainly Building 81, also called Building 881), where most of the gaps were found.

Because of the beta-emitting decay products of U-238 (Th-234 and Pa-234m), U-238 has a much higher potential for shallow dose than Pu-239/Pu-240. Furthermore, uranium foundry operations resulted in separation of these two decay products, which flowed to the surface of the uranium. In those operations, beta dose rates were as high as 2,000 to 3,000 mrad/h on castings of DU in the early years, which is an order of magnitude higher than equilibrium contact beta dose from uranium metal (Putzier 1982). Contamination of workplace surfaces with dust high in Th-234 and Pa-234m could result in very high and nonuniform skin doses. Since shallow dose measurements from later years may not reflect early radiological conditions, it may be difficult to use later data to retrospectively estimate shallow dose, or even deep dose for uranium workers. Concentrated, nonequilibrium areas of contamination with Th-234 and Pa-234m not shielded by massive uranium metal could also lead to higher deep exposure rates from the various gamma photons associated with these radionuclides (including photon energies of 131 keV, 1.9 MeV, 63 keV, and 92 keV). One way of approaching the problem would be to examine whether there are sufficient data from the nonplutonium areas in the periods of high exposure potential (such as the early period) to allow the creation of a coworker model that would meet the test of 42 CFR Part 83 for dose reconstruction sufficient accuracy.

NIOSH has pointed out that the foundry, where the U-238 disequilibrium with its daughter products would be important, was in Building 44. At the working group meeting of March 7, 2007, NIOSH distributed some samples of film badge dosimetry logbook data sheets for 1953 for Building 44. The data sheets contain worker names and external film badge readings, but no job designations. NIOSH stated that the personnel badged included management. SC&A also investigated the availability of similar data for other years in the 1950s for Building 44, which NIOSH made available and which are also posted on NIOSH's Site Query Database. SC&A verified that data are available for Building 44 for the 1950s, but was unable to ascertain whether foundry workers or other workers at high risk of exposure were systematically included. SC&A has no reason to believe that such groups of workers would have been systematically excluded from the monitoring. However, the dosimetry data sheets do not contain job information, and job types carrying a risk of higher exposure cannot be identified from that data set. Badge exchanges for Building 44 were weekly or biweekly in this period.

A mix of employees, including management, appears to have been badged in Building 44; this, together with the short badge exchange cycle, means that many or most badges were below the LOD. However, some employees clearly had a shallow dose well above the 10% limit

considered to be the trigger point for monitoring, and some had external doses above this limit as well. For instance, one employee in Building 44 had a deep dose of at least 1.4 rem during the third quarter of calendar year 1955.[10]

NIOSH should compile the highest readings for deep and shallow doses for the 1950s in Building 44 and compare them to its coworker model to validate or, if necessary, modify the model. This is unlikely to be an SEC issue if the job types of the highest exposed employees in Building 44 can be determined. This determination should not be limited to claimant files; rather, it should be made from the files of the employees with the highest external doses in the 1950s in Building 44, regardless of their claimant status. These steps are necessary to fulfill the requirements of 42 CFR Part 83, since foundry workers in the 1950s may have been at higher risk of external exposure, notably shallow dose, than plutonium workers during the 1950s.

In its paper evaluating a draft of SC&A's data completeness review, NIOSH stated that there were no external film badge data for Building 81 (part of Plant B) for the 1950s (NIOSH 2007c). It also stated that "[t]he unmonitored periods in the 1950s were primarily for enriched uranium workers in Building 81" (NIOSH 2007c, p. 5).

NIOSH provided examples of the conservatism of its coworker model for Building 81 workers for 1960 (by extrapolating the data available for one quarter to the whole year) and for 1961. SC&A concurs that the coworker model bounds the dose in the examples provided for the years evaluated. However, extrapolating backwards into the 1950s on the assumption that similar processes and lower production levels would result in lower doses is not warranted without specific supporting data. Dust levels can vary widely in the DOE weapons complex and Atomic Weapons Employers even when equipment and production levels are similar. Further, dust levels experienced by individual workers are not necessarily related to production levels, unless production decreases so much that individual workers are no longer doing the job full time. This can affect external shallow dose. Further, external dose rates may also vary depending on the details of how the work was done and the specific enrichments of uranium being handled. Data such as area external dose rates and industrial hygiene dust data from the 1950s are needed to validate NIOSH's assertion regarding Plant B exposures in the 1950s.

In reviewing the documents for available data, SC&A did find a few instances of data for Building 81 for the 1950s, but the badges in question appear to have been issued for special circumstances. For instance, a Co-60 source was present in Building 81 between December 10 and 13, 1956. Some badges were reassigned from Building 83 to health physics personnel in Building 81 for monitoring this exposure.[11] Data for a few people in Building 81 in the month of December are also available in other years in the 1950s. No badges appear to have been routinely issued to any group of Building 81 workers up to 1960.

[10] *Film Badge Results, 1955*, p. 352 of the pdf file of scanned dosimetry data sheets. The cumulative dose for the quarter up to September 2, 1955, was 1.4 rem.

[11] *Film Badge Results, 1956*, scanned Rocky Flats external dose dosimetry data sheets, pp. 369–373 of the pdf file.

It may be possible to establish external dose exposure rates from enriched uranium by an explicit review of working conditions in the 1950s and their comparability to the early 1960s if data such as area monitoring badges and area dust loadings are available for both periods.

These remarks about coworker models are statements of theoretical feasibility. The coworker models themselves need to be developed and tested in actual dose reconstructions.

SC&A checked whether the workers who had gaps were in the HIS-20 database during the periods of the gaps. Of the 52 employees evaluated for data completeness, 26 had gaps of 1 entire year or more in external monitoring. Generally, the gaps identified in the worker dose records were also represented as gaps in HIS-20, except for 1969 (as discussed in Section 4.3.1). This is a positive finding for the HIS-20 database, since unmonitored workers can be identified by the gaps in the electronic database, except for 1969 and probably 1970.

Findings Regarding External Dose Coworker Model for the 1950s

- Significant gaps in external dose data were identified for the 1950s. The gaps are associated with work in nonplutonium areas and are mainly in Plant B.

- Many data sheets for external dose exist for workers in Building 44 (Plant A), but these data are not accompanied by job descriptions or titles. Since foundry workers cannot be identified directly from these data sheets, a determination is necessary that the existing coworker model would cover the highest exposed workers. Alternatively, documentation on badging practices in the 1950s for Building 44 would establish what job types were covered. NIOSH needs to demonstrate that its coworker model would bound Building 44 doses for foundry workers or that monitoring for this group was routine enough to obviate the need for a coworker model.

- Production workers in Building 81 were generally not badged in the 1950s. NIOSH's statements that production peaked in a period after monitoring began, and that major processes were the same in the 1960s as in the 1950s, cannot, on their own, be used to establish the assumption that doses were the same or lower in the 1950s. NIOSH needs data, such as air monitoring and area badging data, to support its conclusion that 1960s data can be used for bounding dose for the 1950s.

Overall conclusion regarding external dose gaps: NIOSH has not yet done the necessary work to develop the bounding dose estimates or to show that its coworker model is claimant favorable for the kinds of gaps that exist for external dose, notably in the 1950s. However, NIOSH could address the gaps in external dose in various ways, such as the use of data from the site and existing or modified coworker models.

Overall conclusion regarding internal dose coworker model: Since the internal dose data for highly exposed workers do not show annual gaps, it is likely that the gaps in internal dose can be filled by one or more suitable coworker models designed to appropriately reflect job types and periods of employment. However, this still needs to be accomplished and demonstrated.

8.6 OTHER ISSUES REGARDING COMPLETENESS OF DOSE DATA

8.6.1 Subcontractor Workers

During the working group's deliberations, NIOSH stated that subcontractors were not necessarily badged, even in the period when the ID badge and film badge were integrated into one device. The data provided by NIOSH and cited above also indicate that the proportion of monitored workers did not reach 100% at any time, but stayed a few percent below that throughout the period of production. According to NIOSH, subcontractor workers, like all other RFP workers in the 1964–1991 period, were required to be monitored when they entered radiological areas (ABRWH 2006d, pp. 74–78). There is also evidence that the badging policies for subcontractor workers covered more personnel in the late 1960s and early 1970s (Langsted 2006).

Of the 52 cases examined, one was for a subcontractor worker. This case had external dose monitoring data for the periods of employment and showed a 9-year gap for a period when the person was not employed at Rocky Flats. For external dose, this example provides some corroboration of NIOSH's statement regarding badging of subcontractor workers. However, there were full-year gaps in the internal dose record during periods of employment and external dose monitoring.

SC&A has found no evidence that subcontractor workers were not monitored when they were in radiological areas. Specifically, SC&A has not found any systemic violation of the policy that would have resulted in unbadged subcontractor workers going into areas with radiological exposure potential. SC&A also notes that between 1964 and 1991, the proportion of unbadged workers was small in almost all years (less than 10% and generally in the 2%–6% range—see Table 8.1 above). The one instance of a subcontractor worker evaluated by SC&A and described above tends to corroborate NIOSH's statement of badging practices.

The issue of attributing a suitably bounding dose for subcontractor workers who were not badged or not monitored for internal dose when they were in radiological areas needs to be addressed, especially for the 1950s and possibly also the 1960s. For 1970 and later, an explicit numerical criterion for badging subcontractor personnel was cited in the NIOSH 2006 paper (however, subcontractor personnel with low exposure potential may not have been issued a dosimeter):

> *6.15.1 Conditions where General Health Physics Surveillance is Not Required*
>
> *a. In areas where penetrating radiation levels are not likely to exceed an average of 0.2 mrem/hr., outside contractor personnel may be utilized. Film badges will not be provided under these conditions unless, on advice of Health Physics, badging is desired for assessing a possible criticality exposure.*" (Putzier 1970)

The maximum potential unrecorded dose for a working year of 2,000 hours would be 400 mrem. Hence, it appears possible to bound the dose for subcontractor workers after 1970, if the policy

was enforced. Some verification would be desirable and may be possible by examining claimant files for subcontractor personnel.

The problem is more difficult for the period prior to 1970 and especially for the 1950s. In the latter case, a large proportion of workers was not badged. The difficulties in regard to subcontractor personnel, such as construction workers, need to be explicitly analyzed. NIOSH has produced TIB ORAUT-OTIB-0052 (ORAUT 2006) on construction workers that includes those at Rocky Flats, and SC&A is in the process of reviewing it. The detailed data on which the NIOSH Rocky Flats assessment of construction workers is based are not yet available.

8.6.2 Unbadged Prime Contractor Workers

At the March 7, 2007, working group meeting, NIOSH stated that a small percentage of prime contractor workers was not badged, even after the introduction of the combined ID and dosimeter badge. The one example identified during the random sampling of Rocky Flats claims was that of a secretary who did not have monitoring for 10 years after the combined ID and film badge was issued. NIOSH has stated that no badge was issued for this worker, but this is not evident in the worker's file. It is also possible that the practice of not reading badges was instituted earlier than 1969, but there is no documentary evidence for this. The policy of nonreading of badges that was spelled out explicitly in 1969 applied to workers on a quarterly badge cycle who were thought to be at a low risk of exposure. The secretary's case, where the gap was much longer than the other sample cases, fits this profile.

If the practice of nonbadging parallels the earlier pre-1964 periods of nonbadging or nonreading of issued badges, it is likely that the practice applied to workers who were thought not to have high exposure potential (see also the discussion of the 1969 external dose records in Section 4.3.1). However, this is an inference; it is not a sufficient basis for demonstrating that a bounding dose approach exists for unbadged workers.

8.7 OVERALL CONCLUSIONS REGARDING COMPLETENESS

SC&A has performed an extensive analysis of the issue of the completeness of dosimetry data in DOE files, which are stated by NIOSH to be the primary basis for dose reconstruction for individual claimants. This analysis included a random sample of 32 claimant files and a selected sample of 20 files of claimants who were assessed by Rocky Flats in the 1990s to have high cumulative exposure (external plus CDE internal). The overall conclusions for the period 1951–1992 (except 1969) are as follows:

- SC&A does not agree with NIOSH's claim that the completion of dose reconstruction under 42 CFR Part 82 for almost all of the 52 cases evaluated for data completeness establishes that it can estimate doses with sufficient accuracy for all members of the class under 42 CFR Part 83.

- Substantial gaps exist in external dose data for the 1950s. The investigation of the high cumulative exposure cases indicates that these gaps are likely related to work in Plant B and some other areas not associated with plutonium processing facilities.

- Extensive badge data exist for Building 44, where the foundry was located. NIOSH should show either that foundry workers, or other workers who may have been at risk of high shallow dose, were routinely badged or that sufficient data are available for this job type to fill any gaps that may exist in dose data.

- For Plant B (mainly Building 81) workers, NIOSH has not established that backwards extrapolation from the early 1960s into the 1950s, when there are almost no dosimetry data, provides a bounding dose approach. A suitable approach using appropriate data, such as area monitoring badge data and dust data, remains to be developed.

- There are large gaps in internal dose data, notably for the 1964–1992 period, during which almost three-fourths of the workers had gaps of at least 1 year in internal dose measurements. About one-third of the cumulative years of employment had no measurements in the 1964–1992 period. These observations relate to the random sample.

- The bioassay data for the highly exposed workers have essentially no gaps for full years. Since the internal dose data for highly exposed workers do not show annual gaps in any period to 1992, it is likely that the gaps in internal dose can be filled by one or more suitable coworker models designed to appropriately reflect job types and periods of employment (see Section 6.7 on internal dose coworker model).

- SC&A has evaluated NIOSH's claim that the dose reconstructions of almost all of the claimants from among the 52 evaluated suffice to demonstrate its ability to do dose reconstruction with sufficient accuracy under 42 CFR Part 83. SC&A has concluded that the completion of these dose reconstructions does not demonstrate that ability as it relates to 42 CFR Part 83 for members of the proposed class.

Rocky Flats has extensive dosimetry data, but there are also gaps in the data for some periods and some types of workers. NIOSH has not demonstrated its ability to fill existing data gaps for external dose in a manner that would produce bounding dose estimates that would satisfy the requirements of 42 CFR Part 83. SC&A found that in the one instance among the 50 dose reconstructions where NIOSH used the external dose coworker model to fill an external dose data gap for a full year, the results did not demonstrate NIOSH's ability to bound the doses in the areas where gaps have been revealed in this evaluation. However, the availability of data means that there may be approaches to make bounding dose estimates. NIOSH should either develop these approaches or demonstrate that the existing coworker model is bounding for the specific categories of workers who have gaps in their external dose records.

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