SC&A S. COHEN & ASSOCIATES
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September 19, 2005

Mr. David Staudt
Center for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

Re: Contract No. 200-2004-03805**,** Task Order 1: Draft Review of the NIOSH Site Profile for the Y-12 National Security Complex

Dear Mr. Staudt:

S. Cohen & Associates (SC&A) is pleased to submit our draft review of the NIOSH site profile for the Y-12 National Security Complex, consisting of our evaluation of "Revision 0" of six technical basis documents (TBDs) for site description, and occupational internal, external, medical, and environmental dose, respectively. We understand that some or all of these TBDs are under active revision and have reflected that understanding with respect to findings and issues that we have identified.

Given the time required for obtaining DOE clearance of this report for public release, SC&A proceeded to brief the Advisory Board on Radiation and Worker Health on the preliminary findings contained in the report at the Advisory Board meeting in St. Louis, Missouri, on July 5–7, 2005. The SC&A team also held a conference call regarding these findings with NIOSH and ORAU team counterparts. However, a more rigorous issue resolution process has not yet been engaged with NIOSH and the ORAU team given delays experienced with classification reviews. Given the nature of issues identified in this draft SC&A report, we request such a working session as soon as mutually convenient and preferably before the October 17, 2005, Advisory Board meeting in Oak Ridge, Tennessee.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, PhD, Board Chairperson
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Draft

ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute of Occupational Safety and Health

Y-12 National Security Complex Site Profile Review

Contract No. 200-2004-03805
Task Order No. 1
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Disclaimer

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S. COHEN & ASSOCIATES: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-TASK1-0007 Effective Date: Draft — September 19, 2005 Revision No. 0 – DRAFT
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Task Manager: _____ Date: _____ Joseph Fitzgerald	Supersedes: N/A
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ACRONYMS AND ABBREVIATIONS

Advisory Board	Advisory Board on Radiation and Worker Health
A-P	Anterior-Posterior
AEC	Atomic Energy Commission
AMAD	Activity Median Aerodynamic Diameter
AWE	Atomic Weapon Employer
Bq	Becquerel
Calutron	California University Cyclotron
CCCC	Carbide and Carbon Chemicals Corporation
CCCD	Carbide and Carbon Chemicals Division
CDC	Centers for Disease Control and Prevention
CEF	Critical Experiments Facility
CER	Center for Epidemiologic Research
CFR	*Code of Federal Regulations*
Ci	Curie
DCF	Dose Conversion Factor
DNFSB	Defense Nuclear Facility Safety Board
DOE	Department of Energy
dpm	Disintegrations Per Minute
DU	Depleted Uranium
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ET	Extrathoracic Region
EU	Enriched Uranium
GSD	Geometric Standard Deviation
HEU	Highly Enriched Uranium
HP	Health Physics
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
keV	Kiloelectron Volt (a unit of energy)
kVp	Kilovolt potential

LD	Detection Limit
µCi	Microcurie
mA	Milliampere
mAs	Milliampere second
MDA	Minimum Detectable Activity
MDL	Minimum Detectable Level
MeV	Million Electron Volts
µm	Micrometers
MMES	Martin Marietta Energy System
mR	Milliroentgen
mrad	Millirad
mrem	Millirem
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NTA	Eastman Kodak Nuclear Track Film Type A
NU	Natural Uranium
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
OTIB	Technical Information Bulletin
PA	Posterior-Anterior
PAL	Plant Action Level
PFG	Photofluorography
PIC	Pocket Ionization Chamber
POC	Probability of Causation
PNL	Pacific Northwest Laboratories
ppm	Parts Per Million
RadCon	Radiological Control
RDGs	Radiation Generating Devices
RU	Recycled Uranium
SC&A	S. Cohen and Associates

SRS	Savannah River Site
TBD	Technical Basis Document
TDEC	Tennessee Department of Environment & Conservation
TEC	Tennessee Eastman Corporation
TIB	Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
TLND	Thermoluminescent Neutron Dose
TRU	Transuranics
Y-12	Y-12 Complex National Security Complex

1.0 EXECUTIVE SUMMARY

During its April 25–27, 2005 meeting, the Advisory Board on Radiation and Worker Health (Advisory Board) made the decision to expedite the conduct of this review to support its review of several Special Exposure Cohort (SEC) petitions submitted by Y-12 National Security Complex (Y-12 or Y-12 Plant) workers. This review was conducted between May 3 and June 30, 2005, by an S. Cohen and Associates (SC&A) audit, and the initial audit findings were presented to the Advisory Board at its meeting of July 5–7, 2005, in St. Louis, Missouri. The St. Louis presentation is provided as Attachment 1.

This review included a classified review at Y-12[1] of onsite records and interviews of site experts by Q-cleared SC&A personnel as well as conference calls between Oak Ridge Associated Universities (ORAU) and SC&A counterparts regarding specific Technical Basis Documents (TBDs) that make up the Y-12 site profile. The TBDs were evaluated for their completeness, technical accuracy, adequacy of data, compliance with stated objectives, and consistency with other site profiles, as stipulated in the *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). As "living" documents, TBDs are constantly being revised as new information, experience, or issues arise; for Y-12, this is the case for a particularly critical TBD, *Y-12 National Security Complex - Occupational Internal Dose,* which was being revised substantially while this review was underway. In addition to this TBD, other Y-12 technical basis documents that were reviewed by SC&A include those for Site Description, Occupational Medical Exposure, Occupational Environmental Dose, and Occupational External Dose. A complete list of the Y-12 TBDs, as well as supporting Technical Information Bulletins (TIBs), that were reviewed by SC&A is provided in Attachment 2.

The Y-12 Plant is one of the oldest facilities in the nuclear weapons complex, having begun operation in 1943 and, by the end of World War II, enriching the uranium ultimately used in the Hiroshima weapon. From its original electromagnetic isotope separation process to a longstanding mission of producing enriched and depleted uranium components for the nuclear weapons stockpile, Y-12 has a long history of handling large quantities of uranium. In its diverse operations spread out over some 531 buildings on 811 acres, up to 40,000 workers during the war years, and a fraction of that in later years, have been employed in a broad variety of job categories, including chemical operators, machinists, pipefitters, assemblers, janitors, electroplaters, electricians, maintenance employees, and various crafts and specialty trades. They have handled uranium, thorium, neptunium, and other production materials in various chemical and metal forms, and in many cases, with residual amounts of contaminants from recycled feed (e.g., plutonium, technetium, americium) or daughter products (e.g., radium-224 and radon from arc melting of uranium and thorium). These materials have been variously cast, rolled, shaped, and machined by thousands of workers over five decades using radiation protection practices that evolved intermittently over that timeframe.

[1] While the review was conducted in a secure area at Y-12, many of the documents reviewed were unclassified or designated as "Unclassified Controlled Nuclear Information " or "Official Use Only." All material generated from worker interviews and document reviews were submitted to classification screening to assure that no sensitive information was inadvertently included in this report.

This review found that the NIOSH site profile (and its constitutent TBDs) for Y-12 to be an adequate accounting of most, but not all, of the uranium exposure and dosimetric history of the plant, falling short in fully characterizing several key underlying issues fundamental to guiding dose reconstruction.

For example, chronic uranium uptake is acknowledged for all workers at Y-12, but the implications of this chronic radiation exposure are not addressed in terms of the "missed dose" it may represent. Likewise, the uncertainties in the bioassay techniques and detection limits used to quantify internal dose are significant issues in dose reconstruction that are not fully addressed in the TBD. A number of issues related to the intake parameters applied in the TBD need to be addressed. For example, the NIOSH intake model does not treat the uncertainties inherent in bioassay measurements to detect intakes from urine samples after exposure to Type S uranium, as found in "high-fired" oxides. The intake model does not take into consideration the 48-hour delay imposed on obtaining urine samples following chronic exposures, which can result in an under-estimation of the internal dose by a factor of about 2–4, depending on lung clearance absorption types. In addition, the intake model does not consider the ingestion pathway despite the fact that eating, drinking, and smoking were routine in contaminated operating areas of the plant until 1989. With the ongoing revision of the Internal Dose TBD and other ongoing assessments, it is understood that some of these issues may already be under review by NIOSH.

The guiding assumption for assigning pre-1961 external dose for unmonitored workers—that the relatively few co-workers that were badged before 1961 represent the "maximally exposed individuals"—has not been corroborated by NIOSH. The TBD accepts that co-worker doses can be used as a surrogate for unmonitored workers, even though only a relatively small fraction (2%−23%) of workers were badged during that period and because it was the stated facility policy to badge those workers whose jobs could expose them to radiation exposure at or in excess to 10% of the radiation protection guides. However, this claim appears to be uncorroborated in the TBD with no referenced badging procedures, personnel selection records, or job-specific exposure survey information. The fact that line supervisors, not health physics personnel, made badging decisions raises doubts regarding this guiding assumption in the absence of such substantiation.

Traditional uranium production exposures (i.e., depleted uranium, enriched uranium, and highly enriched uranium) are characterized, but potentially more hazardous thorium, ^{233}U, and transuranic exposures are not. Few distinctions are made in the TBDs between worker job categories despite these distinctions being critical. Chemical operators and machinists received relatively frequent bioassays and lung counts, while maintenance employees, janitors and security guards did not (although the latter jobs entailed access to all operational areas and exposure to radioactive contaminants). These job categories likely constitute a significant source of potential "missed dose" given the lack of personnel monitoring, job assignment records, and accounts from these workers that their routine work involved access to all onsite operational areas and may have involved activities leading to high exposure potential.

No mention is made of high-fired (black oxide) uranium workers who were on urinalysis as their primary bioassay, with significant intakes not detected by the techniques that were used at

different times, until the late-1990s, when it was discovered that the highly insoluble nature of this material actually required routine fecal sampling as well. Likewise, uranium (and thorium) chip fires are not addressed although they were frequent and filled the operating area with metal fumes.

The importance of accounting for potential "missed" dose from Y-12's history of prevalent workplace contamination is not trivial. Like other uranium production facilities of that era in the Oak Ridge complex – i.e., Fernald, Portsmouth, Paducah, and Oak Ridge Gaseous Diffusion Plant (K-25) – uranium was not seen as a radiological hazard of significance from the 1940s through the 1980s. Widespread contamination was persistent, radiological controls were few, and chronic low levels of uranium uptake were assumed. Eating, drinking, and smoking in contaminated uranium processing areas at Y-12 were not prohibited until 1988–1989. It was standard practice until that time to wait over a weekend to provide monthly urinalysis samples to permit the more soluble uranium to be "flushed out" before counting. Airborne and surface contamination levels for uranium repeatedly exceeded Y-12's "Plant Action Levels" by orders of magnitude without effective corrective action. Respirators were "recommended" for certain jobs, but were not fit-tested and were worn at worker's (and supervisory) discretion. The persistence of these conditions, and lack of compliance with Department of Energy (DOE) requirements and its longstanding "as-low-as-reasonably-achievable" mandate, led to a formal complaint by the Defense Nuclear Facilities Safety Board (DNFSB) to the Secretary of Energy in 1993. The plant suspended operations in 1994 for 4 years for procedural compliance issues, among other reasons. A full characterization in the TBD of such workplace radiological conditions and their implications for past dosimetry and current dose assessment is lacking.

It is in this context that SC&A considered it important to corroborate the "written record" and stated practices with a review of both historic documentation, as well as interviews with longstanding workers. As noted above, what was formally prescribed by either DOE or Y-12 policies and requirements was not necessarily implemented at the plant in practice. Despite substantial findings of noncompliance with radiation protection requirements and procedures, Y-12 did not fully implement changes in radiological practices until the operational standdown of 1994. The degree to which NIOSH confirmed that the improvements in written radiation protection practices, as described in the TBD, were in fact implemented is not documented in the TBD or in NIOSH records of worker interviews.

Issues presented in this report are sorted into the following categories, in accordance with SC&A's review procedures:

(1) Completeness of data sources
(2) Technical accuracy
(3) Adequacy of data
(4) Consistency among site profiles
(5) Regulatory compliance

Following the introduction and a description of the criteria and methods employed to perform the review, the report discusses the strengths of the TBD, followed by a description of the major issues identified during our review. The issues were carefully reviewed with respect to the five

review criteria. Several of the issues were designated as Findings, because they represent deficiencies in the TBDs that need to be corrected, and which have the potential to substantially impact at least some dose reconstructions.

1.1 SUMMARY OF STRENGTHS

NIOSH has supplemented the Y-12 site profile documents with a number of TIBs that provide further direction to the dose reconstructor. These six TIBs, listed in Attachment 2, all have direct bearing on the Y-12 dose reconstruction process. SC&A has reviewed these carefully and has found each to be of significance in providing help to the dose reconstructor. These documents were beneficial in understanding the application of the six Y-12 TBDs to the dose reconstruction process.

NIOSH has provided helpful information on solubilities of uranium compounds and their absorption types, as well as a thorough analysis of the in-vitro bioassay methods for uranium and other radionuclides that were used during the different eras of Y-12 operations. NIOSH has also included a good description of the chest counting methods used for uranium and thorium monitoring.

NIOSH has considered the needed adjustments that had to be made to the dose reconstruction procedures as changes occurred at Y-12 in dosimetry technology, response functions, and changes in radiation fields associated with major work locations. NIOSH has addressed the gamma and neutron energy spectrums and the associated detector responses in order to refine dose potential in the varied Y-12 operations. At the time of the preparation of this report, ORAU had conducted recent visits to the Y-12 Plant to collect information which should address some of the gaps in the internal dosimetry TBD identified in this report.

NIOSH has developed *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* (Kathren 2003) to augment the information regarding x-ray unit output and associated dose. Although this was not made part of the occupational medical TBD, Rev. 01 (Murray 2004b), it is of valuable assistance to the dose reconstructor.

1.2 SUMMARY OF FINDINGS

Finding 1: External monitoring of Y-12 workers was limited to 2%−23% of the workers during the period from 1950 to1961, and no external dosimetry data are readily available for workers for the period from 1948 to1950. Based on worker interviews, routine bioassay sampling among support workers who had access to multiple areas onsite was not implemented prior to 1994. The implications of these limitations in the external dosimetry and bioassay programs may be significant in terms of the potential for missed dose, given the large numbers of workers

involved,[2] and the radiation sources to which they may have been exposed. Support services workers (e.g., janitors, security, maintenance personnel, and crafts such as pipefitters, boilermakers, and welders) were routinely exposed to high-enriched and depleted uranium, insoluble ("high-fired") uranium oxides, thorium, and transuranic contaminants, as well as various source terms associated with Oak Ridge National Laboratory's (ORNL) research and isotope production operations co-located at Y-12. Assigned to cleaning up contaminated plant areas, servicing machining equipment and lathes, and fixing piping and pressure vessels, these workers had free access to all operational areas. Workers indicate that they were given daily work assignments in different plant locations, for which records were apparently not maintained. While the brevity of this review did not permit an extensive records search, NIOSH needs to verify to what extent any records exist for the historic exposure and work assignments of support services and crafts workers. In light of these findings, the TBDs should be especially attentive to how dose reconstruction will be performed for support services and crafts workers who were not routinely badged before 1961, or bioassayed before 1994. A similar issue exists for decontamination and decommissioning workers, as well as construction workers at the plant following the initiation of plant operations.

Finding 2: The guiding assumption for assigning pre-1961 external dose for unmonitored workers – that the relatively few co-workers that were badged represented the "maximally exposed individuals" – has not been corroborated by NIOSH. There were several factors associated with the Radiological Control (RadCon) program, which would influence which workers were badged and how the results were recorded. Line supervisors made all badging decisions for groups and individuals within groups (Patterson 1957) in an era where production often took precedence over safety, which raises doubts over how much weight should be afforded these management assignments. Historic discrepancies in recording badge readings also raise questions. For example: (1) Beginning in mid-1956, all film badges reading "below the minimum detectable [were directed to be] recorded as the average of the minimum detectable reading and zero, instead of being recorded as the minimum detectable" (West 1956a); and (2) "Some fraction" of overall Y-12 film badge results were found to be flawed during 1950–1955 due to incorrect assignment of badges based on an incorrect determination of whether gamma or beta radiation exposure was predominant for a worker (West 1991). These and other issues need to be evaluated to verify that the "maximally exposed individuals" actually received monitoring. Finally, NIOSH used statistical information on exposure of population groups to estimate doses to unmonitored individuals in a way that is not necessarily claimant favorable and does not make provisions for considering supplementary information (e.g., from interviews) in adjusting the statistical parameters used for inferring missing doses. SC&A is concerned that there is not an adequate explanation or reason to assume that the exposures experienced by a monitored worker population group can be used as a surrogate for unmonitored workers.

Finding 3: The internal dose TBD does not adequately address the substantial potential for missed dose, due to historic bioassay practice at Y-12, and applies an incomplete and flawed

[2] SC&A's records review did not identify any documentation that categorized these workers by job category or location of work within the plant; however, some information may be available in personnel employment records. In addition, worker interviews indicated that support and crafts workers represented a significant proportion of Y-12 workers.

intake model. It does not sufficiently assess the dosimetric implications of Y-12 workers being continuously exposed to low-level chronic uranium exposures and having this exposure effectively treated as operational "background" radiation for health physics purposes. The ingestion exposure pathway is not considered, despite it being a likely route of exposure. Co-worker dose assignments do not consider the shortcomings of the uranium urinalysis database, variability in material type, bioassay technique uncertainties, and sampling methodology. NIOSH's use of a 50th percentile intake rate to calculate doses for unmonitored workers based on a lognormal distribution of co-worker urinalysis data for 1950–1988 is not considered claimant-favorable, given the measured high urine activity concentrations. Likewise, the uncertainties in the bioassay techniques and detection limits used to quantify internal dose are significant issues in dose reconstruction and are not fully addressed in the TBD. For example, the NIOSH intake model does not treat the uncertainties inherent in bioassay measurements to detect intakes from urine samples after exposure to Type S uranium, as found in "high-fired" oxides. It also does not address the implications of a 48-hour absence from the workplace by the worker following a weekend before routine urine samples were taken; without an appropriate adjustment, this would lead to underestimations by the TBD model of a factor of 2–4 as a function of lung clearance type. Measured particle size values should be used over a default value of 5 μm (as called for by 42 CFR Part 82), particularly at Y-12, where particle size has been found to range from 1–10 μm.

Finding 4: The internal dose TBD is incomplete in its review of the historic dose contribution of radioisotopes other than uranium. These radionuclides include ^{3}H, ^{90}Sr, ^{99}Tc, ^{210}Po, ^{228}Th, ^{232}Th, ^{239}Pu, ^{241}Pu, ^{237}Np, ^{233}U, and ^{241}Am. Some of these radionuclides were associated with research and development activities, while others were handled in production, either as a source material or as a contaminant, e.g., from recycled uranium. Given their potential radiation exposure significance, thorium, ^{233}U, and transuranic handling are of particular importance to the TBD. While some of these operations are associated with ORNL missions at Y-12, a number of Y-12 workers (e.g., janitors, maintenance, and crafts personnel, as noted above) supported these operations and were potentially exposed to these sources. NIOSH has recognized this issue and ORAU has an ongoing effort to better characterize the radiological significance and exposure records associated with thorium, ^{233}U, and recycled uranium.

Finding 5: SC&A has reservations about the assumptions made regarding the ability of nuclear track Type A emulsion (NTA) film to adequately characterize Y-12 worker exposure due to the limited amount of neutron spectral measurements available. Neutron radiation sources are not adequately defined in the TBD for all potential neutron exposure conditions at Y-12, including spontaneous fission neutrons, moderated (alpha, neutron) sources in solutions/compounds, subcritical and critical assemblies, and moderated neutrons from the 86-inch cyclotron. The assumption that most neutron exposure at Y-12 was from neutron energies greater than 500 keV, and thus would be detected by the NTA film, is not adequately substantiated. In fact, Griffin et al. (1979) and Wilson et al. (1990) state that NTA is a poor detector of film energies between 500 keV and 800 keV. In general, the NTA film response decreases logarithmically as the energy decreases from 1,000 keV to 500 keV. Therefore, NTA may seriously underestimate the true neutron dose, and appropriate correction factors for this underestimate should be applied.

Finding 6: The TBD intermittently mentions the use of various radiation generating devices at the Y-12 plant;[3] however, it does not take into account all radiological hazards associated with operations of these units. There is no discussion of how film badge response to low-energy x-rays may impact the recorded dose or the correction factors that are necessary to compensate for low-energy photon exposures from x-ray fields. Although the TBD recognizes that the 86-inch cyclotron was used for isotope development, there is no discussion addressing the internal dose associated with the isotopes generated from this operation. Finally, other accelerators, although mentioned in technical reports and ORAUT-RPRT-0033 (Kerr 2005b), are not included in the TBD. Although some of these devices may have been operated by ORNL personnel at the Y-12 complex, there is still a potential for exposures to Y-12 personnel, which should be included in the TBD.

Finding 7: The TBDs do not go into enough depth on the varying and changing nature of Y-12 operations and work environments to provide the dose reconstructors with the specific knowledge that is needed for specific group or individual dose reconstructions. It is important to adequately understand the potential hazards and dose potential for each operation performed. Changes in operations that occurred over varying periods and the changing mission of facilities and buildings can also have impacted the doses that individual workers or groups of workers might have received. The ability to reconstruct worker doses in these many unique and varying types of functions is dependent on a better-developed description of individual or group activities and how their operations were modified by redirection in the missions of the facilities.

Finding 8: The occupational environmental dose TBD (Ijaz and Adler 2004) leaves two important exposure pathways inadequately addressed. Inadvertent ingestion of radioactively contaminated soil and inhalation of radionuclides other than uranium need to be more fully developed, if adequate dose reconstructions from these sources are to be effectively taken into account. The ORNL facility handled irradiated thorium and radioactive lanthanum and plutonium, and was near enough to Y-12 to cause exposure to outdoor Y-12 workers from its airborne emissions. The TBD does not address worker exposures to these potential sources. In addition, no data are furnished regarding the activity median aerodynamic diameter (AMAD) or the chemical form of airborne uranium. Further, the empirical approach used to derive atmospheric dispersion factors for the purpose of reconstructing outdoor exposures of unmonitored workers is based on several premises that are not explicitly stated and need to be explored and justified before this approach can be accepted. Specifically, SC&A questions the decision to reconstruct outdoor exposures to airborne uranium using the atmospheric dispersion factors as derived in the TBD. We also question the validity of deriving outdoor inhalation exposures to uranium using source terms and empirically derived atmospheric dispersion factors when actual airborne uranium concentrations are available at outdoor receptor locations.

Finding 9: The TBDs need to better characterize frequent "incidental" sources of workplace radiation exposure. For example, uranium chip fires, which were relatively frequent events (sometimes several times a shift, according to workers interviewed), exposed everyone in the

[3] Including the 86-inch cyclotron, the 9201 proton-accelerating cyclotron, secondary ion mass spectrometers, x-ray photoelectron spectrometer, enclosed beam diffraction equipment, and various x-ray devices; with energies ranging from 15 keV to 9 MeV.

work area to an acute intake of uranium fumes. In other recorded instances, exhaust fans were inoperative, causing a back-flow of contaminated air through ductwork. Radium and its progeny were preferentially vaporized during molten uranium and thorium casting operations (due to having a lower melting point), leading to sharply elevated airborne radioactivity levels (Ammann 1960; West 1965). It is not clear whether the frequency and sensitivity of the historic Y-12 bioassay program would have detected these "spike" releases, particularly where urinalysis was delayed or unduly relied upon for Type S uranium oxides. Such releases, in particular, would need to be addressed where routine air sampling data is used to estimate potential worker uptakes.

Finding 10: Extremity and skin doses should be given attention in the external dose TBD. Depleted uranium metal handling has associated high beta radiation fields leading to elevated hand and arm exposures of material handlers. Similarly, ^{232}Th has beta-emitting progeny that present a radiological hazard for direct handling. Based on a sampling of quarterly health physics reports from building 9206 in the early 1960s, the average quarterly skin dose ranged from 100–400 mrem (0.4–1.6 rem/year) for three categories of monitored workers (mechanical operators, product certification, and chemical operators) in that building. Since only a few workers wore ring dosimeters, it is important to more fully characterize potential beta/gamma fields and worker handling practices and geometries.

1.3 OPPORTUNITIES FOR IMPROVEMENT

Support Workers: Support service workers were often assigned to multiple areas of the site, resulting in potential exposure to any number of processes and radionuclides. Consideration should be given to the adequacy of internal and external monitoring, and availability of reliable dose and job assignment records, for support personnel with respect to the potential exposure conditions.

Incomplete Personal Monitoring Data: The TBD should further substantiate the assumptions used to assign external dose to workers who were not monitored prior to 1961. Consideration should be given to Radiological Control (RadCon) practices, data discrepancies, and recording practices. The applicability of worker population data to individual unmonitored workers should include claimant-favorable assumptions and make provisions for considering supplementary information.

Other Radionuclides: The dose contribution from ^{99}Tc, ^{232}Th and daughters, ^{233}U and daughters, transuranics, and tritium as an impurity in recycled uranium and/or process materials should be elevated in terms the relative impact on internal, external, and environmental dose reconstruction.

Neutron Monitoring: NIOSH should validate the assumption that all sources of neutron exposure, including moderated neutron sources, are of sufficient energy to be detected by the NTA film. Correction factors should be applied where appropriate based on the analysis.

Radiation Generating Devices: NIOSH should include a discussion on radiation generating devices (RGDs) used at the Y-12 Plant encompassing the range of devices, their energy potential, and exposure histories, where available.

Environmental Dose: NIOSH should include inadvertent ingestion from radioactively contaminated soil and exposure to isotopes other than uranium in the assessment of environmental dose. The use of empirically determined atmospheric dispersion factors for estimating the outdoor doses of unmonitored workers should be based on explicitly stated and justified assumptions.

Incidental Exposures: NIOSH should create a list of high-risk jobs and incidents for consideration as a complement to the site profile to inform the dose reconstructor during the individual dose reconstruction process. Such a list would be particularly pertinent to incidental exposures, such as chip fires, which occurred frequently and may have resulted in exposures not addressed in the TBD.

Shallow and Extremity Dose: NIOSH should develop a methodology for assessing extremity and skin dose to personnel in the immediate vicinity of uranium, thorium, or other radioactive material.

Dose Calculation Example: A text example of a hypothetical individual dose reconstruction using recorded records, missed dose assignment, and dose assignments when dosimeters read zero dose should be provided in the TBD.

Use of Site Expert Input: NIOSH should make a greater effort to take into account site expert information and investigate worker accounts. The on-site, first-hand experience of site experts enables them to provide original perspectives and information concerning site practices and exposure histories. NIOSH has incorporated a limited amount of worker input into the latest versions of the TBD.

2.0 SCOPE AND INTRODUCTION

During its April 25–27, 2005 meeting, the Advisory Board made the decision to expedite the Y-12 site profile review. The urgency for SC&A to conduct this review was largely influenced by several Special Exposure Cohort (SEC) petitions that were under review by the Advisory Board at the time, as well as by NIOSH. The review consisted of both classified and unclassified information pertaining to the Y-12 site, with the unclassified review beginning on April 27, 2005, and the classified review and site expert interviews occurring from June 2–15, 2005.

The Y-12 Plant (currently the Y-12 National Security Complex) poses some unique challenges given its lengthy operating history (over 60 years), and classified weapons material and components fabrication history. The specific mission of Y-12 was to separate fissionable isotopes of uranium for use in atomic weapons. However, during its long history, it has processed ^{233}U, neptunium, and thorium, and has had plutonium, tritium, and other radionuclides in its operations either in production, research, or as a contaminant. The plant has had a succession of missions before, during, and after the Cold War, including electromagnetic separation of uranium (1943–1947), production of weapon secondaries, refurbishment and dismantling of nuclear weapon components, storage and processing of uranium and lithium, and production support to the weapons laboratories. From 1943–1947, the Y-12 Plant was operated by the Tennessee Eastman Corporation. Unlike many other DOE and DOE-predecessor facilities, Y-12 has had only a limited number of different management and operating contractors, including the Tennessee Eastman Corporation from 1943 to 1947, and Union Carbide, Martin Marietta (becoming Lockheed Martin), and BWXT, successively, since 1947.

Radiation protection monitoring evolved at the plant as DOE's requirements and safety management practices (and those of its predecessor agencies), and prevailing national radiation protection standards and practices, themselves, evolved over time. Given the secrecy surrounding its activities and DOE's longstanding self-regulation under the Atomic Energy Act of 1954, radiation protection practices at Y-12 did not always keep pace with accepted practices in the regulated commercial sector or even at other DOE facilities. In particular, this was the case for uranium operations, its core mission activity. In the early years at Y-12 (to the 1980s), uranium was not viewed as a radiation hazard of great significance, particularly in contrast with plutonium, thorium, and other radionuclides. As noted in the Internal Dose TBD, early health physics practices recognized the "nephrotoxicity" of uranium to the kidneys as the limiting hazard for low-enriched and depleted uranium. Recognition that extensive direct handling of uranium metal and solutions did lead to cumulative doses of concern, led Y-12 to begin badging certain workers in higher exposure jobs, such as chemical and mechanical operators. Similar recognition of potential intakes of airborne uranium led to urinalysis being provided for a select group of workers beginning in 1954. However, these numbers grew slowly until the 1958 criticality and other circumstances led to a broadening of personnel monitoring beginning with plant-wide badging in 1961.

However, despite improved monitoring and a health physics program seemingly responsive to new or unusual exposure situations, the Y-12 radiation protection program fell short for controlling uranium exposure. Eating, drinking, and smoking were permitted in the uranium

production areas until 1988–1989. Radiation contamination egress monitoring was not instituted until the early 1990s. In-plant radioactive contamination zoning was inadequate, and any worker could enter most process areas without restriction. Respirators were available to workers, but discretionary for all but a few high-exposure jobs; often it was the supervisors who decided whether they would be worn. Plant contamination action levels were exceeded frequently, sometimes by orders of magnitude, without attention to root causes and long-lasting remedies. Operating program unresponsiveness to identified audit deficiencies led both DOE and the DNFSB to cite Y-12 practices in 1988 (DOE 1988) and 1993 (DNFSB 1993), respectively. These complaints, coupled with the 4-year standdown ending in 1998, finally brought about fundamental changes in uranium practices and the full institution of an ALARA philosophy to operations.

The implications of this history are relevant to the TBDs, although not addressed in any meaningful manner. For example, chronic levels of radiation exposure from uranium handling, while recognized, were not seen as a concern and, therefore, not given much attention in the Y-12 dosimetry program. Therefore, missed dose due to chronic uranium exposure should be one focal point of the TBDs. Supervisors were typically given latitude to make decisions regarding which of their workers were provided badging, bioassay, and respiratory protection, and how radiation jobs were performed. Therefore, NIOSH needs to be cautious with respect to the assumptions employed in dose reconstructions regarding radiation protection practices employed at Y-12. With the production exigencies of the Cold War, production was often the first priority and workers were kept at their contaminated workstations for almost the entire workday. Therefore, attention must be given to exposure pathways such as ingestion. These and other operational considerations were considered by SC&A in determining radiation exposure issues that would be influential in ascertaining possible gaps and inadequacies in Y-12's historic radiation dosimetry practices and dose records. In turn, such considerations were the basis of evaluating the technical adequacy and completeness of the NIOSH TBDs.

2.1 REVIEW SCOPE

Under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) and Federal regulations defined in Title 42, Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program,* of the *Code of Federal Regulations* (42 CFR Part 82), the Advisory Board on Radiation and Worker Health is mandated to conduct an independent review of the methods and procedures used by the NIOSH and its contractors for dose reconstruction. As a contractor to the Advisory Board, S. Cohen and Associates (SC&A) has been charged under Task 1 to support the Advisory Board in this effort by independently evaluating a select number of site profiles that correspond to specific facilities at which energy employees worked and were exposed to ionizing radiation.

This report provides a review of the following six documents related to historical occupational exposures at the Y-12 Site:

- ORAUT-TKBS-0014-1, *Technical Basis Document for the Y-12 National Security Complex – Y-12 Site Profile* (Murray 2004a)

- ORAUT-TKBS-0014-2, *Technical Basis Document for the Y-12 National Security Complex – Site Description* (Jessen 2005)

- ORAUT-TKBS-0014-3, *Technical Basis Document for the Y-12 National Security Complex – Occupational Medical Dose* (Murray 2004b)

- ORAUT-TKBS-0014-4, *Technical Basis Document for the Y-12 National Security Complex – Occupational Environmental Dose* (Ijaz and Adler 2004)

- ORAUT-TKBS-0014-5, *Technical Basis Document for the Y-12 Site –Occupational Internal Dose* (Rich and Chew 2005)

- ORAUT-TKBS-0014-6, *Technical Basis Document for the Y-12 Site –Occupational External Dosimetry* (Kerr 2003)

These documents are supplemented by technical information bulletins, which provide additional guidance to the dose reconstructor. A complete list of these documents is available in Attachment 2.

SC&A, in support of the Advisory Board, has critically evaluated the Y-12 Site Technical Basis Documents (TBDs) in order to:

- Determine the completeness of the information gathered by NIOSH in behalf of the site profile, with a view to assessing its adequacy and accuracy in supporting individual dose reconstructions
- Assess the technical merit of the data/information
- Assess NIOSH's use of the data in dose reconstructions

SC&A's review of the six TBDs focuses on the quality and completeness of the data that characterized the facility and its operations, and the use of these data in dose reconstruction. The review was conducted in accordance with *Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004), which was approved by the Advisory Board.

The review is directed at "sampling" the site profile analyses and data for validation purposes. The review does not provide a rigorous quality control process, whereby actual analyses and calculations are duplicated or verified. The scope and depth of the review are focused on aspects or parameters of the site profile that would be particularly influential in deriving dose reconstructions, bridging uncertainties, or correcting technical inaccuracies. This review does not explicitly address the issue of radiation exposures to cleanup workers and decommissioning workers, as that is not addressed in the TBDs.

The six TBDs serve as site-specific guidance documents used in support of dose reconstructions. These site profiles provide the health physicists who conduct dose reconstructions on behalf of NIOSH with consistent general information and specifications to support their individual dose reconstructions. This report was prepared by SC&A to provide the Advisory Board with an

evaluation of whether and how the TBDs can support dose reconstruction decisions. The criteria for evaluation include whether the TBDs provide a basis for scientifically supportable dose reconstruction in a manner that is adequate, complete, efficient, and claimant favorable. Specifically, these criteria were used to determine whether dose reconstructions based on the TBDs would provide for robust compensation decisions.

The basic principle of dose reconstruction is to characterize the radiation environments to which workers were exposed, and determine the level of exposure the worker received in that environment through time. The hierarchy of data used for developing dose reconstruction methodologies is dosimeter readings and bioassay data, co-worker data and workplace monitoring data, and process description information or source term data.

NIOSH/ORAU has acknowledged that ORAUT-TKBS-0014-5, Revision 01 (Rich and Chew 2005) needs to be revised in order to encompass newly retrieved documentation on thorium, recycled uranium, and in-vivo counting (see Attachment 4). NIOSH has stated that they are in the process of modifying the TBD in order to incorporate additional information and to further explain the technical basis for their assumptions. A date of release for Revision 2 to the Internal Dose TBD had not been announced at the time of preparation of this report. To our knowledge, there are no immediate plans to update other portions of the Y-12 site profile (albeit, verbal comments have been made regarding some likelihood that the current TBDs will be supplemented with treatment of extremity exposures).

2.2 REVIEW APPROACH

In past reviews of other TBDs, SC&A's approach has been to engage a team of scientists where every member independently assessed the entire document before coming together for a critical open discussion. Due to the classified nature of many of the documents supporting the TBDs, this approach was not possible. Instead, the review of the TBDs proceeded down two paths, one unclassified and the other classified. To accommodate the need for review of classified documents, two members of the SC&A team with Q-clearances inspected classified and sensitive documents and conducted classified site expert interviews. They prepared an analysis that was not reviewed by the rest of the team, but was submitted for declassification. At the time of the preparation of this report, the classified report was not entirely declassified, and therefore some of the information contained therein is not incorporated into this report. However, we believe that this report is substantially complete.

The classified review itself, while critical to a broader understanding of key dose assessment models and assumptions, was constrained in a number of important ways. First, due to time limitations and the logistics of scheduling appropriately cleared SC&A members, the review was delayed until June 2, 2005, and site expert interviews were not completed until June 15, 2005. Scheduling involved two separate organizations at Y-12 to allow for interview of safety, production, and security personnel. Second, notes taken during the site expert interviews and classified document reviews were only partially cleared and provided to SC&A in time for their use as a reference during the development of this report. Third, normal discourse was precluded

between SC&A team members evaluating the same issues on both sides of the classification divide. As a result, we were unable to collectively discuss and integrate our findings.

SC&A's review of the TBDs and supporting documentation concentrated on determining the completeness of data collected by NIOSH, the adequacy of existing Y-12 personnel and environmental monitoring data, and the evaluation of key dose reconstruction assumptions. Site expert interviews were conducted in a secure facility at Y-12, and Y-12 derivative classifiers screened all notes taken. Records reviews were conducted at the Y-12 classified and unclassified Radiological Records facility. Classified documents reviewed included health physics technical reports, correspondence, monitoring data, and a limited amount of operational information.

Two weeks prior to SC&A's onsite visit, ORAU team members were onsite to conduct site expert interviews and records review including classified records. As a result, ORAU has recently obtained a large number of documents pertinent to the Y-12 TBDs. In order to prevent duplication of effort, Y-12 provided SC&A with correspondence indicating records recently provided to NIOSH, and asked that SC&A obtain copies from NIOSH. NIOSH has indicated that only documents used in the development of the TBDs had been scanned and placed on the O-drive (also referred to as the NIOSH Site Profile Document Database). Most recently retrieved data were not available for review by the SC&A team, as they were not yet posted on the NIOSH Site Profile Document Database and, in some cases, were "Official Use Only" documents. SC&A had limited time to review a portion of these documents during visits to the Y-12 Plant.

In parallel with the classified review, which focused on the validity, completeness, and adequacy of data, and the issues brought to the attention of SC&A by site expert interviews, the rest of the SC&A team conducted a broader review of the various aspects of the Site Profile, including the adequacy and accuracy of film badge data, the analysis of sources of internal dose, etc. This review was conducted by SC&A staff who were not privy to classified information and site expert interviews, and was not submitted for review by DOE classification personnel.

Site expert interviews were conducted to help SC&A obtain a comprehensive understanding of the radiation protection program, site operations, and environmental contamination. Attachment 6 provides summaries of the interviews conducted by SC&A by teleconference or in person in the Oak Ridge, Tennessee, area during the course of this review. The site experts included current and former staff from radiation control, operations, environmental monitoring, maintenance, and other support organizations. These interviews were conducted during the course of the Y-12 site profile review. Each summary is a paraphrase of conversations held with a number of site experts, rather than a verbatim transcript. These statements have been grouped into categories to provide a linkage with various portions of the Y-12 Site profile. References to specific site experts have been omitted for privacy reasons. These individuals were given the opportunity to review the interview summary for accuracy. This is an important safeguard against missing key issues or misinterpreting some vital piece of information.

2.3 REPORT ORGANIZATION

In accordance with directions provided by the Advisory Board and with site profile review procedures prepared by SC&A and approved by the Advisory Board, this report is organized into the following sections:

(1) Executive Summary
(2) Scope and Introduction
(3) Assessment Criteria and Method
(4) Site Profile Strengths
(5) Vertical Issues
(6) Overall Adequacy of the Y-12 Site Profile as a Basis for Dose Reconstruction.

Based on the issues raised in each of these sections, SC&A prepared a list of findings, which are provided in the executive summary. Issues are designated as findings if SC&A believes that they represent deficiencies in the TBD that need to be corrected, and which have the potential to substantially impact at least some dose reconstructions. Issues can also be designated as observations if they simply raise questions that, if addressed, would further improve the TBDs and may possibly reveal deficiencies that will need to be addressed in future revisions of the TBDs. In this review, SC&A has identified 10 findings and has not designated any issues as observations.

Many of the issues that surfaced in the report correspond to more than one of the major objectives (i.e., strengths, completeness of data, technical accuracy, consistency among site profiles, and regulatory compliance.) Section 6.0 provides in summary form a list of the issues, and to which objective the particular issue applies.

The TBDs, in many ways, have done a successful job in addressing a series of technical challenges. In other areas, the TBDs exhibit shortcomings that may influence some dose reconstructions in a substantial manner.

3.0 ASSESSMENT CRITERIA AND METHODS

S. Cohen and Associates (SC&A, Inc.) is charged with evaluating the approach set forth in the site profiles that is used in the individual dose reconstruction process. These documents are reviewed for their completeness, technical accuracy, adequacy of data, consistency with other site profiles, and compliance with the stated objectives, as defined in *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). This review is specific to the Y-12 site profile and supporting TIBs; however, items identified in this report may be applied to other facilities, especially facilities with similar source terms and exposure conditions. The review identifies a number of issues and discusses the degree to which the site profile fulfills the review objectives delineated in SC&A's site profile review procedure.

3.1 OBJECTIVES

SC&A reviewed the site profile with respect to the degree to which technically sound judgments or assumptions are employed. In addition, the review identifies assumptions by NIOSH that give the benefit of the doubt to the claimant.

This review is directed at current TBDs, and does not take into consideration revisions that might be forthcoming. For instance, ORAUT-TKBS-0014-5, Revision 1 (Rich and Chew 2005) was reviewed; however, based on recent data acquisition efforts by the ORAU team, this TBD is undergoing revision by NIOSH.

3.1.1 Objective 1: Completeness of Data Sources

SC&A reviewed the site profile with respect to Objective 1, which requires SC&A to identify principal sources of data and information that are applicable to the development of the site profile. The two elements examined under this objective include: (1) determining if the site profile made use of available data considered relevant and significant to the dose reconstruction, and (2) investigating whether other relevant/significant sources are available, but were not used in the development of the site profile. For example, if data are available in site technical reports or other available site documents for particular processes, and if the TBDs have not taken into consideration these data where it should have, this would constitute a completeness-of-data issue. The Oak Ridge Associated Universities (ORAU) site profile document database, including the referenced sources in the TBDs, was evaluated to determine the relevance of the data collected by NIOSH to the development of the site profile. Additionally, SC&A evaluated records publicly available relating to the Y-12 site and records provided by site experts.

3.1.2 Objective 2: Technical Accuracy

SC&A reviewed the site profile with respect to Objective 2, which requires SC&A to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instruction, including evaluating field characterization data, source term data, technical reports, standards and guidance documents, and literature related to processes that occurred at Y-12. The goal of this objective is to first analyze the data according to sound scientific principles, and then to evaluate this information in the context of compensation. If, for

example, SC&A found that the technical approach used by NIOSH was not scientifically sound or claimant favorable, this would constitute a technical accuracy issue.

3.1.3 Objective 3: Adequacy of Data

SC&A reviewed the site profile with respect to Objective 3, which requires SC&A to determine whether the data and guidance presented in the site profile are sufficiently detailed and complete to conduct dose reconstruction, and whether a defensible approach has been developed in the absence of data. In addition, this objective requires SC&A to assess the credibility of the data used for dose reconstruction. The adequacy of the data identifies gaps in the facility data that may influence the outcome of the dose reconstruction process. For example, if a site did not monitor all workers exposed to neutrons who should have been monitored, this would be considered a gap and thus an inadequacy in the data.

3.1.4 Objective 4: Consistency Among Site Profiles

SC&A reviewed the site profile with respect to Objective 4, which requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. In order to accomplish this objective, the Y-12 TBDs were compared to the Hanford TBDs, the Savannah River Site (SRS) TBDs, and the Iowa Army Ammunition Plant (IAAP) TBD. This assessment was conducted to identify areas of inconsistencies and determine the potential significance of any inconsistencies with regard to the dose reconstruction process.

3.1.5 Objective 5: Regulatory Compliance

SC&A reviewed the site profile with respect to Objective 5, which requires SC&A to evaluate the degree to which the site profile complies with stated policy and directives contained in 42 CFR Part 82. In addition, SC&A evaluated the TBD for adherence to general quality assurance policies and procedures utilized for the performance of dose reconstructions.

In order to place the above objectives into the proper context as they pertain to the site profile, it is important to briefly review key elements of the dose reconstruction process, as specified in 42 CFR Part 82. Federal regulations specify that a dose reconstruction can be broadly placed into one of three discrete categories. These three categories differ greatly in terms of their dependence on and the completeness of available dose data, as well as on the accuracy/uncertainty of data.

Category 1: Least challenged by any deficiencies in available dose/monitoring data are dose reconstructions for which even a partial assessment (or minimized dose(s)) corresponds to a probability of causation (POC) value in excess of 50%, and assures compensability to the claimant. Such partial/incomplete dose reconstructions with a POC greater than 50% may, in some cases, involve only a limited amount of external or internal data. In extreme cases, even a total absence of a positive measurement may suffice for an assigned organ dose that results in a POC greater than 50%. For this reason, dose reconstructions in behalf of this category may only be marginally affected by incomplete/missing data or uncertainty of the measurements. In fact, regulatory guidelines recommend the use of a partial/incomplete dose reconstruction, the

minimization of dose, and the exclusion of uncertainty for reasons of process efficiency, as long as this limited effort produces a POC of greater than or equal to 50%.

Category 2: A second category of dose reconstruction is defined by Federal guidance, which recommends the use of "worst-case" assumptions. The purpose of worst-case assumptions in dose reconstruction is to derive maximal or highly improbable dose assignments. For example, a worst-case assumption may place a worker at a given work location 24 hours per day and 365 days per year. The use of such maximized (or upper bound) values, however, is limited to those instances where the resultant maximized doses yield POC values below 50%, which are not compensated. For this second category, the dose reconstructor needs only to ensure that all potential internal and external exposure pathways have been considered.

The obvious benefit of worst-case assumptions and the use of maximized doses in dose reconstruction is efficiency. Efficiency is achieved by the fact that maximized doses avoid the need for precise data and eliminates consideration of the uncertainty of the dose. Lastly, the use of bounding values in dose reconstruction minimizes any controversy regarding the decision not to compensate a claim.

Although simplistic in design, to satisfy this type of a dose reconstruction, the TBD must, at a minimum, provide information and data that clearly identify: (1) all potential radionuclides, (2) all potential modes of exposure, and (3) upper limits for each contaminant and mode of exposure. Thus, for external exposures, maximum dose rates must be identified in time and space that correspond to a worker's employment period, work locations, and job assignment; similarly, in order to maximize internal exposures, highest air concentrations and surface contaminations must be identified.

Category 3: The most complex and challenging dose reconstructions consist of claims where the case cannot be dealt with under one of the two categories above. For instance, when a minimum dose estimate does not result in compensation, a next step is required to make a more complete estimate. Or when a worst-case dose estimate that has assumptions that may be physically implausible results in a POC greater than 50%, a more refined analysis is required. A more refined estimate may be required either to deny or to compensate a claimant. In such dose reconstructions, which may be represented as "reasonable," NIOSH has committed to resolve uncertainties in favor of the claimant. According to 42 CFR Part 82, NIOSH interprets "reasonable estimates" of radiation dose to mean the following:

> *. . . estimates calculated using a substantial basis of fact and the application of science-based, logical assumptions to supplement or interpret the factual basis.* ***Claimants will in no case be harmed by any level of uncertainty involved in their claims, since assumptions applied by NIOSH will consistently give the benefit of the doubt to claimants.*** [Emphasis added.]

In order to achieve the five objectives described above, SC&A reviewed each of the six TBDs, their supplemental attachments, and TIBs, giving due consideration to the three categories of dose reconstructions that the site profile is intended to support. The six Y-12 TBDs provide

well-organized and user-friendly information for the dose reconstructor when adequate data were available to do that comprehensively.

ORAUT-TKBS-0014-1, *Technical Basis Document for the Y-12 National Security Complex – Y-12 Site Profile* (Murray 2004a), explains the purpose and the scope of the site profile. SC&A was attentive to this section, because it explains the role of each TBD in support of the dose reconstruction process. During the course of its review, SC&A was cognizant of the fact that the site profile is not required by the EEOICPA or by 42 CFR Part 82, which implements the statute. Site profiles were developed by NIOSH as a resource to the dose reconstructors for identifying site-specific practices, parameter values, and factors that are relevant to dose reconstruction. Based on information provided by NIOSH personnel, SC&A understands that site profiles are living documents, which are revised, refined, and supplemented with TIBs as required to help dose reconstructors. Site profiles are not intended to be prescriptive nor necessarily complete in terms of addressing every possible issue that may be relevant to a given dose reconstruction. Hence, the introduction helps in framing the scope of the site profile. As will be discussed later in this report, NIOSH may want to include additional qualifying information in the introduction to this and other site profiles describing the dose reconstruction issues that are not explicitly addressed by a given site profile.

ORAUT-TKBS-0014-2, *Technical Basis Document for the Y-12 National Security Complex - Site Description* (Jessen 2004), is an extremely important document, because it provides a description of the facilities, processes, and historical information that serve as the underpinning for subsequent Y-12 TBDs. Specifically, this document describes an overview of the processes and operations that were conducted at the approximately 531 buildings at the Y-12 site, and the associated sources of exposure relevant to dose reconstruction are covered in Attachment B to this TBD. SC&A's review of this section specifically addresses whether all of the potentially important site activities and processes are described, and whether characterization of source terms is complete/sufficient to support dose reconstruction.

ORAUT-TKBS-0014-3, *Technical Basis Document for the Y-12 National Security Complex – Occupational Medical Dose*, (Murray 2004b), provides a set of procedures for reconstructing the radiation exposures of workers from medical radiographic procedures that were required of employees at the Y-12 site. SC&A reviewed this section for technical adequacy and consistency with other NIOSH procedures, and compared these with the Hanford and SRS site profiles.

ORAUT-TKBS-0014-4, *Technical Basis Document for the Y-12 National Security Complex – Occupational Environmental Dose* (Ijax and Adler 2004), provides background information and guidance to dose reconstructors for reconstructing the doses to unmonitored workers outside of the facilities at the site who may have been exposed to routine and episodic airborne emissions from these facilities. SC&A reviewed this section from the perspective of the source terms and the atmospheric transport, deposition, and resuspension models used to derive the external and internal doses to these workers.

ORAUT-TKBS-0014-5, *Technical Basis Document for the Y-12 National Security Complex – Occupational Internal Dose* (Rich and Chew 2005), presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers. This section

was reviewed with respect to background information and guidance regarding the types, mixes, and chemical forms of the radionuclides that may have been inhaled or ingested by the workers, the recommended assumptions for use in reconstructing internal doses based on whole-body counts and bioassay data, the methods recommended for use in the reconstruction of missed internal dose, and the methods recommended for characterizing uncertainty in the reconstructed internal doses.

ORAUT-TKBS-0014-6, *Technical Basis Document for the Y-12 National Security Complex – Occupational External Dose* (Kerr 2003), presents background information and guidance to dose reconstructors for deriving occupational external doses to workers. This section was reviewed with respect to background information and guidance regarding the different types of external radiation (i.e., gamma, beta, and neutron) and the energy distribution of this radiation to which the workers may have been exposed. We also reviewed the recommendations for converting external dosimetry data to organ-specific doses, the methods recommended for use in the reconstruction of missed external doses, and the methods recommended for characterizing uncertainty in the reconstructed external doses.

In accordance with SC&A's site profile review procedures, SC&A performed an initial review of the six TBDs, their supporting documentation, and the six TIBs. SC&A then submitted questions to NIOSH with regard to assumptions and methodologies used in the site profile. These questions are provided in Attachment 3. A series of conference calls were then conducted with NIOSH, ORAU, and the SC&A team to allow NIOSH to provide clarifications and to explain the approaches employed in the site profile TBDs. A summary of the conference calls with NIOSH, ORAU, Y-12 staff, and SC&A is provided in Attachment 4 and Attachment 5.

An extensive comparison was done between the methodologies used in the Y-12, Hanford, and SRS TBDs to determine occupational medical, environmental, internal, and external doses. This comparison focused on the methodologies and assumptions associated with dose reconstruction and resultant values used to obtain a POC. A detailed analysis is provided in Attachment 7.

Information provided in the conference calls with NIOSH was evaluated against the preliminary findings to finalize the vertical issues[4] addressed in the audit report. There are three levels of review for this report. First, SC&A team members review the report internally. Second, SC&A engages an outside consultant who has not participated in the preparation of this document to review all aspects of this report. The third level, referred to as the expanded review cycle, will consist of a review of this draft by the Advisory Board and NIOSH. The first two levels of review have been completed.

After the Advisory Board and NIOSH have had an opportunity to review this draft, SC&A plans to request a meeting with Advisory Board members and NIOSH representatives to discuss the report. Following this meeting, we will revise this report and deliver the final version to the Advisory Board and to NIOSH. We anticipate that, in accordance with the procedures followed during previous site profile reviews, the report will then be published on the NIOSH Web site

[4] The term "vertical issues" refers to specific issues identified during our review, which were identified as requiring more in-depth analysis due to their potential significant impact on dose reconstruction.

and discussed at the next Advisory Board meeting. This last step in the review cycle completes SC&A's role in the review process, unless the Advisory Board requests SC&A to participate in additional discussions regarding the closeout of issues, or if NIOSH issues revisions to the TBDs or additional TIBs, and the Advisory Board requests SC&A to review these documents.

Finally, it is important to note that SC&A's review of the six TBDs and their supporting TIBs is not exhaustive. These are large, complex documents and SC&A used its judgment in selecting those issues that we believe are important with respect to dose reconstruction.

4.0 SITE PROFILE STRENGTHS

In developing a TBD, the assumptions used must be fair, consistent, and scientifically robust, and uncertainties and inadequacies in source data must be explicitly addressed. The development of the TBD must also consider efficiency in the process of analyzing individual exposure histories so claims can be processed in a timely manner. With this perspective in mind, we identified a number of strengths in the Y-12 site TBDs. These strengths are described in the following sections.

4.1 COMPLETENESS OF DATA

In an effort to be comprehensive in addressing the range of facilities and processes at the Y-12 plant, NIOSH effectively compiled facility-specific information on major facilities and processes. Descriptions were provided for 17 facilities and 5 time periods, reflecting the changing mission over time. A comprehensive and effective overview of key uranium operations, their location, and the dates of operation is provided in the site profile. SC&A considers this to be an important start in providing background information to the dose reconstructors.

In developing the site profile, NIOSH drew upon information contained in 223 reports cited in the reference section. These include annual environmental reports, beginning in 1960, that present data from offsite releases. Process information was drawn from Oak Ridge health studies, the Oak Ridge Dose Reconstruction project, historical overviews, and technical documents primarily from public sources. NIOSH/ORAU met with the Y-12 Labor and Trades Council on November 9, 2004, to identify worker concerns and discuss the Y-12 TBDs. This interaction with workers helps to provide valuable insight into site operations and programs. In addition, the issuance of several TIBs and follow-up data captures at the Y-12 facility reflect an ongoing effort by NIOSH to continually improve the background information and guidance provided to the dose reconstructors.

4.2 ADEQUACY OF DATA

The TBDs benefited from having access to information and data that were compiled as a part of the Y-12 National Security Complex programs, as follows:

(1) Radiological control personnel have implemented improved procedures and technologies over time to reduce radiation dose to workers, and have improved personnel monitoring programs.

(2) Historical documentation of the Radiological Control program, including research activities, is well documented.

(3) Evaluations were performed for special projects to identify the radiological hazards associated with radionuclides and how they differed from the uranium handled daily.

(4) Y-12 implemented environmental monitoring, including stack monitoring, in-perimeter monitoring, and offsite monitoring.

(5) Starting in 1961, dosimeters were coupled with security badging, which helped to ensure that all personnel were monitored for external radiation exposure.

Although Y-12 had significant quantities of personnel monitoring data, as well as field radiological control data, there are gaps in the information. Only a fraction of the population was monitored for external exposure prior to 1961, and support workers were not placed on routine bioassay programs, as compared to their operational counterparts. There are also problems with the adequacy of data, particularly with regard to neutron dosimetry, early period external monitoring, and radiobioassay data.

4.3 TECHNICAL ACCURACY/CLAIMANT FAVORABILITY

The Y-12 TBDs exhibited the following strengths in terms of their technical accuracy and claimant favorability:

(1) NIOSH has supplemented the Y-12 site profile documents with a number of TIBs that provide further direction to the dose reconstructor. Attachment 2 lists six technical documents that all have direct bearing on the Y-12 dose reconstruction process. SC&A has reviewed these carefully and found each to be helpful to the dose reconstructor. These documents are beneficial in understanding the application of the six Y-12 TBDs to the dose reconstruction process.

(2) Medical x-ray and photofluorography procedures have been investigated thoroughly to determine the radiographic techniques used at the Y-12 Site. The Y-12 occupational medical TBD (Murray 2004b) provides tables representing four distinct periods of time where doses estimates for individual organs are provided for both photofluorographic chest x-rays and posterior/anterior chest x-rays. Explicit consideration of photofluorographic examinations is especially important because of their potential for relatively large exposures, as compared to conventional radiographs recorded on photographic film.

(3) In light of the fact that very little, if any, x-ray output measurements are available for the period from 1943 to 1947 at Y-12, ORAUT-OTIB-0006 (Kathren 2003) has addressed dose potentials and uncertainties from occupationally related diagnostic x-rays in a generic manner that is also applicable, for the most part, to Y-12. Thus, NIOSH has made a credible effort in ORAUT-OTIB-0006 to address the technical factors affecting diagnostic x-ray dosage, application of technical factors, default values to use during dose reconstruction, other factors that can potentially affect patient dose with their uncertainties, and an uncertainty analysis that is useful in reconstructing diagnostic medical x-ray doses.

(4) NIOSH has developed ORAUT-0TIB-0015 (Groer 2004) to introduce the Bayesian method for estimating the parameters of a lognormal distribution used to impute missing data. The document also presents comparisons of the Bayesian approach with estimates obtained using the classical maximum likelihood approach. Use of the Bayesian predictive distribution is more claimant favorable than the use of a lognormal distribution with fixed point-estimates of the parameters, because the predictive distribution is more widely spread than any single lognormal distribution with fixed-point estimates. However, we do have some concerns that a simpler and less computationally intensive approach could have been developed without sacrificing claimant favorability.

(5) NIOSH has provided a good discussion on solubility of uranium compounds and absorption types. NIOSH correctly points out that the absorption type can be based on the monitoring data, claimant-favorable assumptions, or both.

(6) NIOSH has provided a good description of in-vitro bioassay methods used for uranium at different times at Y-12. NIOSH has developed information on the in-vitro bioassay program for the four different eras of operations, which facilitates dose reconstructions tailored to the specific isotopes of uranium dominant in that era.

(7) NIOSH has provided a good description of chest-counting methods used for uranium and thorium at different times at Y-12. NIOSH points out that claimant-favorable assumptions for uranium should be based on conversions of 93% enrichment for ^{235}U and natural isotopic abundances for ^{238}U.

(8) NIOSH has put a great deal of effort in developing ORAUT-OTIB-0029 (Brackett 2005). This TIB allows the dose reconstructor to use all available bioassay urine data to derive the intakes based on co-worker data from the Y-12 site. However, there are some issues that SC&A feels NIOSH needs to address or modify in order for the dose reconstructor to properly derive intakes that are more claimant favorable. The methodologies in ORAUT-OTIB-0029 are only effective if the quality of the input data is found to be adequate. In some cases at Y-12, the data quality is sometimes suspect.

(9) There was a considerable effort to characterize the radiological source terms for routine processing of DU, EU, and HEU. The site description outlined operations over the period of operations for major Y-12 facilities. Although the evaluation of Y-12 operations focused on uranium processing, there were a number of operations (e.g. processing of other materials, disassembly of weapons) that are not addressed in the site description.

(10) The external dose assessment methodology considered adjustments for changes in dosimetry technology and response functions, and radiation

sources/fields associated with many major workplace locations. Gamma and neutron energy spectrums, and corresponding dosimeter responses, are explicitly considered in the site profile.

(11) The documents addressed the external radiation doses to workers in some detail during the time frame of the 1950s to the 1990s. The external dosimetry TBD (Kerr 2003) provides detailed discussions of the historical administrative practices, the monitoring techniques and dosimeter exchange frequencies, and the dosimeter technology used for beta, photon, and neutron dose measurement.

(12) ORAUT-RPRT-0032 (Kerr 2005a) and ORAUT-RPRT-0033 (Kerr 2005b) offer supplemental information that benefits the dose reconstruction process. The documents discuss external hazards for particular areas at Y-12. This information should be incorporated into the TBD to further support the assumptions and methodologies discussed in the TBD.

4.4 CONSISTENCY AMONG SITE PROFILES

Although Y-12, Hanford, and SRS all handled uranium, there are differences in the facility designs, processes, and radiological practices. In some cases, these differences require site-specific assumptions in dose determinations. The assumptions developed in the medical occupational exposure TBD, as seen in Table A.7-1, Attachment 7, are consistent among the sites. In the case of Y-12, Rich and Chew (2005, pg. 6) states:

> *…uranium isotopes in various chemical and physical forms have been the primary contributors to internal doses to workers…The primary focus, thus, on internal dose has been on uranium compounds and alloys over the wide range of ^{235}U enrichment.*

This is also the case with the uranium areas at both Hanford and SRS. All three sites have addressed the receipt of recycled uranium and the potential for exposure to impurities in this material. The Y-12 TBDs have, however, improved on the discussions found in the Hanford and SRS TBDs. In general, the default parameters for input into IREP have remained consistent between the TBDs.

4.5 REGULATORY COMPLIANCE

The TBDs' use of personnel monitoring data and environmental monitoring data to determine dose is consistent with the requirements outlined in 42 CFR Part 82, as follows:

- Where in-vivo and in-vitro analyses are available, this information is provided for use in determination of internal dose.

- Where routine beta/gamma and neutron dosimeters are available and adequate, this information is provided for use in determination of external exposure.

- Where environmental measurements are available, these data are used as the basis for environmental dose.

NIOSH has effectively complied with the hierarchy of data required under 42 CFR Part 82 and its implementation guides for monitored workers.

5.0 VERTICAL ISSUES

SC&A has developed a list of key issues regarding the Y-12 Site Profile. These issues relate to each of the five objectives defined in SC&A 2004. Some issues are related to a particular objective, while others cover several objectives. Many of the issues raised below are applicable to other DOE and Atomic Weapons Employer sites, and should be considered in the preparation and revision of other site profiles.

5.1 ISSUE 1: UNMONITORED SUPPORT SERVICES AND CRAFTS WORKERS

The TBDs do not address the potential radiation exposure of specific categories of unmonitored workers, e.g., support services and crafts workers. TKBS-0014-5 (Internal Dose)(Ijax and Adler 2005) acknowledges that its Section 5.4 on "unmonitored dose" is "not complete for all operations and/or radionuclides." This TBD speaks to only two instances where "sufficient monitoring information might not be available in the worker records:" 1943–1947, where it was noted that, "little or no monitoring was performed," and 1948–1950, where it is noted that data for "fluorometric analyses of urine and blood" could not be located. For TKBS-0014-6 (External Dose)(Kerr 2003), it is noted that:

> *Missed photon dose to Y-12 workers may occur for the following reasons: (1) the worker was not monitored before 1961, (2) there is no recorded dose for short periods of time after 1961, and (3) the worker's dose during a monitoring period was recorded as zero because the dosimeter response was less than the MDL.*

This TBD goes further and notes that:

> *If a worker's routine duties and work location remained essentially the same during the 1950s and early 1960s, it may be feasible to use his recorded annual doses in the early 1960s to estimate his missed dose prior to 1961. Methods are being investigated at present based on department numbers, job descriptions, and work locations that might be used to estimate annual doses for other workers who were not monitored for external radiation exposure prior to 1961 and did not remain in the same jobs during the 1950s and early 1960s.*

In terms of facility or location information, the TBD notes that:

> *Information has not been found that is adequate to describe the potential missing photon dose by facility or location within the Y-12 Plant. This is particularly true during the early years when the missed photon dose was most significant due to the frequent exchange of film dosimeters and the higher MDLs.*

The above limitations would apply to estimations of potential missed neutron dose, as well. All of these factors make it unlikely that dose estimations can be made or even bounded because monitoring records do not exist for most of these employees, no reliable job or work locations are recorded, and they moved frequently between different radiological areas of the plant.

Where some limited monitoring or job location records do exist, these records may not be reliable, because the monitoring was typically intermittent and not likely representative of the range of exposure experienced by workers. Department, building, or work location records are not necessarily reliable, because workers indicated that they were listed as being in one department or at one location when they actually performed work for other departments or at different plant locations.

5.1.1 Potential Exposure of Y-12 Support Services Workers

The percentage of unbadged workers ranged from 2%–25% from 1950–1961, respectively, with no routine external data from 1948–1950 (no records have been found for the period 1943–1947). Many of these unmonitored workers were support services personnel, such as janitors, steamfitters, maintenance personnel, various skilled crafts, laborers, and guards. Based on worker interviews, routine bioassay monitoring among support workers who had access to multiple areas of Y-12 radiological operations was not implemented prior to 1994 (when Y-12 operations were suspended by DOE). Prior to that time, a number of support services and other non-production personnel, who may have been monitored via bioassay and in-vivo counting, were removed administratively by Y-12 management based on revised action levels and what was considered to be "negligible" readings at the time (McLendon 1972). Departments removed in 1972 from such routine bioassay included all process maintenance (except Building 9206).

By the nature of their jobs and work assignments, these workers were routinely exposed to highly enriched and depleted uranium, insoluble ("high-fired") uranium oxides, thorium, transuranic contaminants, and various source terms associated with ORNL's research and isotope production operations. Based on worker interviews, janitors and maintenance personnel were assigned to clean up HEU solution spills and areas of excess contamination. One janitor interviewed noted that he had to wear a respirator just to sweep the steps in Building 9212, which were used by production workers on their way to a local break room. Security guards recall seeing "green sludge" from piping in some areas of building 9212 during tours. Others indicated that they provided janitorial and maintenance support to ORNL operations, including an operational area known to contain plutonium in glove boxes. Much of the work was done on off-shift periods (after hours) without direct supervision and (according to workers) without always following radiological procedures. Work assignments were done on a daily basis and support personnel would find themselves in different parts of the plant at any given time, with the exception, apparently, of those support workers assigned permanently to certain operational areas. For some workers, their work location of record, if it exists, was not necessarily the area of the plant where they performed their work.

While routine exposure records are lacking for many support services workers, maintenance personnel permanently assigned to production operations were monitored regularly (starting in 1954), along with chemical operators and mechanical operators. Their exposure histories are instructive as to the potential for intake that existed for even those not directly involved in production activities.

For example, the Y-12 Quarterly Health Physics Report of March 5, 1963 (Y-12 1963) reported that, of the 42 maintenance personnel receiving in-vivo counting, 5 exceeded the Plant Action Level (PAL) for uranium or thorium (requiring either removal from the radiological workplace or repeating the counting at a later date). The average uptake level determined for maintenance workers for that quarter was 57% of the PAL (compared with 80% of the PAL for chemical operators and 31% of PAL for mechanical operators). For an earlier quarterly period, the third quarter of 1962, 41 maintenance personnel were counted with no one exceeding the PAL's for uranium or thorium, and an average count of 9% of the PAL for uranium and 6% of the PAL for thorium. (McLendon 1963).

5.2 ISSUE 2: PRE-1961 EXTERNAL DOSE

The guiding assumption for assigning pre-1961 external dose for unmonitored workers—that the relatively few co-workers that were badged represented the "maximally exposed individuals"—has not been corroborated by NIOSH. There were several factors associated with the Radiological Control (RadCon) program that would influence which workers were badged and how the results were recorded. Line supervisors made all badging decisions for groups and individuals within groups (Patterson 1957) in an era where production often took precedence over safety. Such practices raise doubts over how much weight should be afforded these management assignments. Historic discrepancies in recording badge readings also raise questions. For example, beginning in mid-1956, all film badges reading "below the minimum detectable [were directed to be] recorded as the average of the minimum detectable reading and zero, instead of being recorded as the minimum detectable" (West 1956a). In addition, "some fraction" of overall Y-12 film badge results were found to be flawed during 1950–1955 due to incorrect assignment of badges based on an incorrect determination of whether gamma or beta radiation exposure was predominant for a worker. These issues need to be evaluated to verify that the "maximally exposed individuals" actually received the monitoring.

Finally, statistical information on monitored worker **populations** has been used to reconstruct the exposures experienced by unmonitored **individuals** in a way that is not necessarily claimant favorable and does not make provision for considering supplementary information (e.g. from interviews) in adjusting the statistical parameters used for inferring missing doses. SC&A is concerned that there is no adequate explanation or reason to suppose that dose received by an individual differs from the monitored population dose by a constant factor.

5.2.1 General

The general situation that the TBD presents is that external radiation was not a large issue at the Y-12 facility during its years of operations. Internal exposure was the primary concern, even after the external monitoring program was established.

> *Health physics was preoccupied with* [the] *internal exposure problem and* [was] *not paying too much attention to external monitoring* [between] *1956–1960.* (West 1993)

While the potential for external radiation doses may not have been as large as at some other AEC/DOE facilities, the potential for radiation exposure was not negligible at Y-12. For example, ORAUT-RPRT-0032 (Kerr 2005a) and ORAUT-RPRT-0033 (Kerr 2005b) give a more complete picture of the radiation fields present at Y-12 through the years. ORAUT-RPRT-0032 (Kerr 2005a, pg. 136) shows a plot of average annual dose verses year from 1952–1978; the average was around 170 mrem/year.

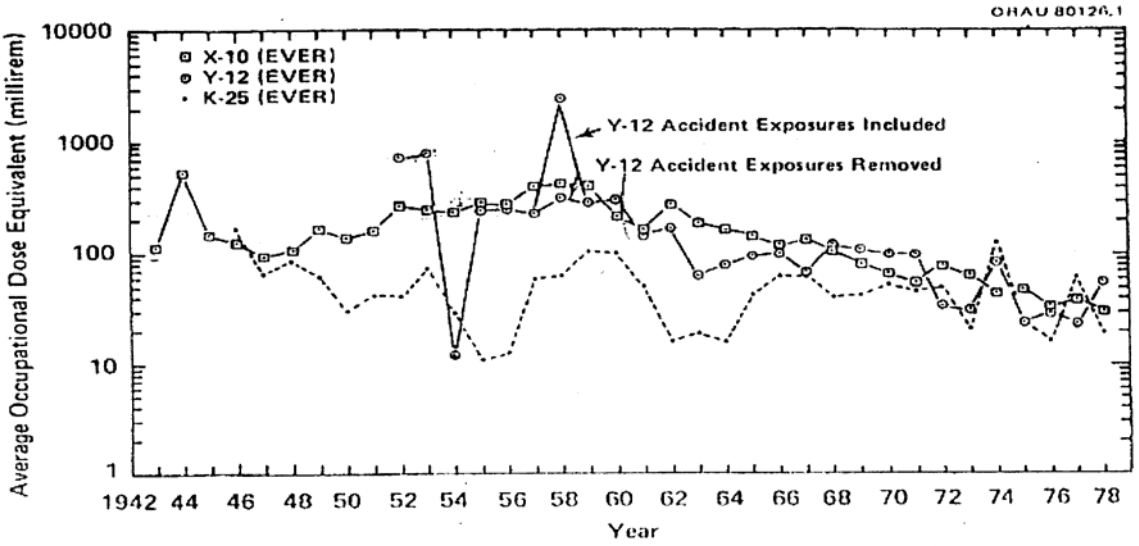

Figure 1: ORAUT-RPRT-0032 (Kerr 2005a) Attachment 1, Page 136

5.2.2 Tennessee Eastman Corporation

The TBD does not provide a complete historical account for dose reconstruction during the period of 1943–1947. This is illustrated by:

- The number of workers involved is not discussed and is quite large
- Levels of uranium in air were extraordinarily high at the Calutron operations
- There is little if any evidence of respiratory protection
- Individual worker dosimetry was virtually non-existent
- By the late 1940s, AEC officials and advisors were made aware that uranium workers were being excessively exposed to airborne levels of uranium well above the default limits meant to protect against radiation set in World War II

Between 1943 and 1947, the Tennessee Eastman Corporation employed approximately 40,000 workers, including a large number of women (Herken 2002), to operate the Calutrons and to

recover and process uranium for weapons in Y-12 buildings 9201-1, 9201-2, 9201-3, 9201-4, 9202, 9203, 9204-1, 9204-2, 9204-3 ,9204-4, 9206, 9207, 9211, and 9212 (Polednak 1982).

> *By any scale, the operation there was mammoth. Plans called for installing a pair of 500-tank Calutron race tracks end-to-end in twin two-story buildings, each measuring four football fields long. The racetracks were on the second story; pumps and plumbing for the vacuum system occupied the first floor. Logistic and personnel requirements were in proportion. Every pair of vacuum tanks required an individual operator seated at a console, continually adjusting the current to focus on the beam. An army of technicians was needed to monitor the orange uranium-oxide feed material for the beam and later scrape the errant green "gunk" -- uranium salts dissolved in carbon tetrachloride -- from the insides of each tank. An army of chemists would separate out the silvery white powder containing uranium-235 that was left in the receivers following each week-long run* (Herken 2002).

ORAUT-TKBS-0014-5 (Rich and Chew 2005, pg 23) states:

> *From 1943 to 1947 limited monitoring occurred, for which data cannot be retrieved.*

West (1993) indicated that there was no external monitoring program for the period of 1943–1947. NIOSH has not included a methodology for determining either internal or external dose for this period of time. Although the Advisory Board voted to recommend a Special Exposure Cohort for the TEC years of operation, some methodology for dose reconstruction for non-SEC cancers should be included in the TBD.

5.2.3 Monitoring from 1948–1949

Weekly film badge monitoring began on a small fraction of the Y-12 population in 1948. Pocket ionization chambers (PICs), which are insensitive to beta radiation, under-respond to low energy photons, and are not very reliable, were also worn and read daily (West 1993). Monitoring during this period of time was focused on Assay Laboratory Radiographic Shop, Spectrographic Shop, and "Metal" Machine Shop workers (Kerr 2003, pg. 8). During this 3-year period, the percentage of monitored workers increased from about 1% to about 8%.

The external dosimetry data is not readily available for the period from 1948–1950 for use in dose reconstruction. ORAUT-TKBS-0014-6 (Kerr 2003, pg. 8) states the following:

> *The external monitoring data for Y-12 workers from 1948 to 1950 are not readily available by Social Security Number (SSN) and are not being supplied by Y-12 in response to Energy Employees Occupational Illness Compensation Program Act (EEOICPA) requests…* (Souleyrette 2003)

Given the limited subset of workers monitored and the lack of data available for dose reconstruction, the TBD should provide a bounding method for assigning dose for 1948–1949 assuming one can be developed.

5.2.4 Monitoring from 1950–1961

A two-element film dosimeter replaced the PIC as the primary dosimeter in 1950. With the introduction of a formal external monitoring program, all personnel working with depleted uranium, discrete gamma or beta sources, x-rays, or fission products contaminated materials were asked to wear film badges (McLendon 1960).

Administrative practices for recording dose varied through time, adding to inconsistencies in the monitoring program. The program from 1952–1955 differed from the program implemented in 1950–1951. Instead of assigning a zero to the weekly film badge results less than zero, the minimum detectable dose was assigned when a badge result was available. West (1993) describes a second administrative practice complicating the interpretation of film badge results for the 1952–1955 time frame:

> *During this period another practice was followed that further increased the difficulty of estimating dose from these data, in that an administrative decision was made as to which kind of radiation a person was liable to be exposed and to* [whether] *his/her dose was interpreted as beta or gamma depending on this administrative decision. The determined dose or the <MDL assigned dose was attributed to this type of exposure. There also seemed to be some change in thinking on this matter with years in that in 1952 essentially all cases spot checked had all gamma's and no gamma's or betas. In 1953, 4 of the 14 cases spot checked showed only beta dose. In 1954 and 1955, 13 of the 14 doses spot checked showed only beta doses* (West 1993).

Further inconsistencies in recorded data were introduced when West (1956) implemented the following policy:

> *Effective the 22nd week* [of] *1956 (May 22 to June 2), all film badges which show a reading below the minimum detectable will be recorded as the average of the minimum detectable reading and zero, instead of being recorded as the minimum detectable. It is felt that this procedure will result in more accurate cumulative results on the persons who quite frequently have badge results below the minimum detectable.*

Clearly there are uncertainties associated with this data that require further investigation on the part of NIOSH if these values are to be used in individual dose reconstructions. The administrative decision on whether dose was to be assigned as beta or gamma casts doubt on whether a given dose can be appropriately assigned to shallow or deep dose. Review of dosimetry processing logbooks may be necessary to determine the usability of this data.

5.2.5 Missed Photon Dose

Missed photon dose may occur when (1) the worker was not monitored, (2) there is no recorded dose, or (3) the workers dose during the monitoring period was recorded as zero when the dosimeter response was less than the MDL. The potential for missed dose at Y-12 is greatest among workers not monitored prior to 1961 due to the select monitoring criteria. ORAUT-TKBS-0014-6 (Kerr 2003, pg. 30) presents methods that may be used to establish missed dose prior to 1961. This methodology is further described in ORAUT-PROC-0042 (Kerr and Smith 2004), which is used by NIOSH to account for incomplete personal monitoring data prior to 1961. The methodology is based on an extrapolation of the population dose distribution for workers monitored from January 1961 to December 1965. A scaling factor is derived for each worker having monitoring data in this period. Problems could arise in obtaining a claimant-favorable dose for some workers, such as the following:

- Workers who were unmonitored and terminated prior to 1961
- Workers who were unmonitored and switched to low-radiation or non-radiation jobs just prior to 1961
- Workers who performed a number of different jobs, prior to and/or after 1961
- Workers whose job assignments are unclear or undocumented prior to and/or after 1961

Appling the methods referred to in the TBD (Watson 1994) requires knowledge of and similarity of jobs for the two time periods (prior to and post-1961). Consideration also needs to be given to the changes in radiological controls and improved techniques over the course of operation.

ORAUT-PROC-0042 (Kerr and Smith 2004) provides an alternative method for assigning dose under the following conditions:

- Worker does not have monitoring data for five quarters between January 1961 and December 1965
- Worker was only employed prior to 1961
- Worker was never monitored for external radiation
- Worker has evidence of external exposure in their records

The procedure directs the dose reconstructor to use a scaling factor of 1 and the "population dose distributions for monitored workers" (Kerr and Smith 2004).

The Y-12 policy was to monitor workers **expected** to receive doses greater than 10% of the limits set forth in the radiation protection guides (RPGs) (30 mrem/week photon and 60 mrem/week beta) (Kerr 2005a). As a result of this policy, the TBD concludes the following (Kerr 2003, pg. 8):

> *Records of radiation dose to individual workers from personnel dosimeters worn by workers and co-workers are available for the employees with the highest potential for external radiation exposure from 1950 to 1961 and for all workers from 1961 to the present.*

During the period of 1950–1961, only certain individuals were included in the film badge or external monitoring program. The percentage of workers monitored by film dosimeters increased from about 6% to less than 25% between 1950 and 1960 (see Figure 6.1-1 of ORAUT-TKBS-0014-6)(Kerr 2003). West (1993) analyzed the number of persons monitored from computerized and hard copy records for 1950 to 1960. The number of personnel monitored ranged from 148 in 1950 to 1,295 in 1960. Starting on June 30, 1961, "nearly all personnel were monitored" (Kerr 2003, pg. 8), and the number of personnel monitored jumped four fold (Kerr 2005a). Information on the change in population dose during this switch, especially by department, was not provided.

Line supervisors made all badging decisions for groups and individuals within groups (Patterson 1957) in an era where production often took precedence over safety. This practice raises doubts over how much weight should be afforded these management assignments. Line supervisors were responsible for administering the safety rules and regulations, including (1) informing all concerned employees, within the limits of security, of potential radiation hazards and the necessary safeguards established to guard against them; and (2) arranging for participation in the established personnel monitoring program (Patterson et al. 1957).

> *Assignment to Film Program -- Supervision, with the assistance of the Health Physics Department, decides which groups and which persons within a group shall be assigned to the routine film monitoring program, and keeps current the list of persons assigned.*
>
> *The supervision makes a request, either oral or written, for the Health Physics Department to add persons to or remove persons from the film badge program.*
>
> *The Health Physics Department sends the request to the monitoring laboratory giving all the necessary data on a "Film Badge Assignment Request" form.*

With monitoring requirements being determined by line supervision, there is no guarantee that the monitoring recommendations were consistently implemented. This fact, coupled with the lack of concern over external monitoring and the attitude of line organizations towards safety, casts doubt on the validity of the TBDs assumption that the highest exposed workers were monitored.

A 1988 appraisal conducted by the Oak Ridge Operations Office (DOE 1988) stated the following:

> *ES&H personnel expressed concern about enforcing compliance issues. Some line organizations are either ignoring or are nonresponsive to ES&H audits/recommendations.*

This appraisal is indicative of the commitment of line management to the safety program. Consistency in the external monitoring program would have occurred when Health Physics took responsibility for the issuance of dosimeters. There is no indication in the TBD or supporting documents reviewed as to when this occurred.

In summary, the dose reconstruction methodology utilized for pre-1961 exposures should consider the following:

- The methods used to validate that the highest exposed workers in the work force were badged.
- Consistency in the decisions made by line management to add personnel to the external monitoring program, including support personnel.
- The balance of production verses safety in the workplace.
- Selective bias due to administrative criteria that assigned badges and type of exposures, a priori, is a confounding factor.
- The methods outlined in the TBD are not claimant favorable if the pre-1961 badging was effectively cohort badging of various groups. If cohort badging was widely used at that time, the use of the dose distribution for this group would not necessarily be a claimant-favorable surrogate for other unmonitored workers at that time.
- No documentation has been found describing the criteria used to identify those workers who were monitored, such as by random monitoring or temporary 100% monitoring.
- Maintenance and janitorial employees, and some inspectors and material inventory handlers, were not monitored routinely, yet had full access to Y-12 radiological control areas.
- Rovers, whose work included cleaning contaminated areas, fixing contaminated process equipment, and moving material, may not have been in a department that was considered for monitoring.
- If records do exist that demonstrate that the individuals that were monitored were selected because they had the potential to experience the highest exposures, this information needs to be presented in the TBD.

Each of these issues should be addressed prior to assuming that the worker population that was badged reasonably and reliably bounds the exposures experienced by non-monitored workers prior to 1961.

5.2.6 Statistical Application for the Assignment of Missed Dose

The purpose of ORAUT-OTIB-0013 (Frome and Groer 2004) is to apply the Bayesian method to estimate missing measurements in time periods prior to 1961 for each individual who was monitored in at least five quarters from 1961 to 1965. As stated in the TIB, "the method is based on the assumption that the individual's potential for exposure during the 1950s is similar to that from 1961 to 1965, and that the individual's doses differ from the population dose by a constant factor." This factor is the individual scaling factor N described above. This factor is applied in each time period to adjust the population dose found in that period either up or down, depending on the average relationship between an individual's doses and the population doses in the time periods after 1960 when the individual was monitored. Individual doses in each period with missing data are simulated in Crystal Ball (an Excel add-in product) using the appropriate population lognormal distribution for that period, after the individual scaling factor is applied. The distribution is truncated to remain between the 1st and 99th percentile of this lognormal distribution.

The purpose of ORAUT-0TIB-0015 (Groer 2004) is to introduce the Bayesian method for estimating the parameters of a lognormal distribution used to impute missing data. The document also presents comparisons of the Bayesian approach, with estimates obtained using the classical maximum likelihood approach.

The lognormal model used in ORAUT-OTIB-0015 (Groer 2004) contains four types of parameters. The first two are the common shape and scale parameters for the lognormal distribution, F^2 and log($), which are constant for all times and all employees. A third type of parameter ($:_t$) provides an additional set of scale factors, which are used to model the variation in the population for different time periods *t*. These terms reflect the requirement to account for time trends in the pattern of exposure. A fourth type of parameter is used to estimate an additional set of scale factors (N_k) for each individual, *k*, who was monitored in some but not all time periods. The variation of individual exposures from general population exposures is accounted for using this parameter. The scale factors for individual exposures do not depend on time.

Use of the Bayesian approach permits derivation of an analytic expression for the joint distribution for all parameters, given the observed data. This joint distribution reflects the uncertainty in the parameter estimates. Use of the Bayesian approach also permits calculation of the predictive distribution for a future observation obtained from the distribution estimated in each time period for any individual. The predictive distribution is obtained by averaging over all possible parameter values, using the joint distribution of the parameters as weights.

Use of the Bayesian predictive distribution is more claimant favorable than the use of a lognormal distribution with fixed point-estimates of the parameters, because the predictive distribution is more widely spread than any single lognormal distribution with fixed parameter estimates. However, there is a fundamental assumption that the use of observations obtained from the time periods when an individual is monitored may be used as a "surrogate" for the missing observations in other time periods. This is particularly a concern because in most cases,

the missing observations occur in the earlier time periods when monitoring was less complete, using less sophisticated equipment, and operations were conducted with fewer safety controls. While this approach may be unbiased based on the available monitoring data, it does not appear to be claimant favorable.

First, the statistical measures shown in Table 1 of OTIB-0013 (Frome and Groer 2004) (μ and σ) are treated as true measures of the characteristics of the underlying lognormal distribution, rather than estimates. It is instructive to plot these data by quarter. This is shown in Figure 2 below.

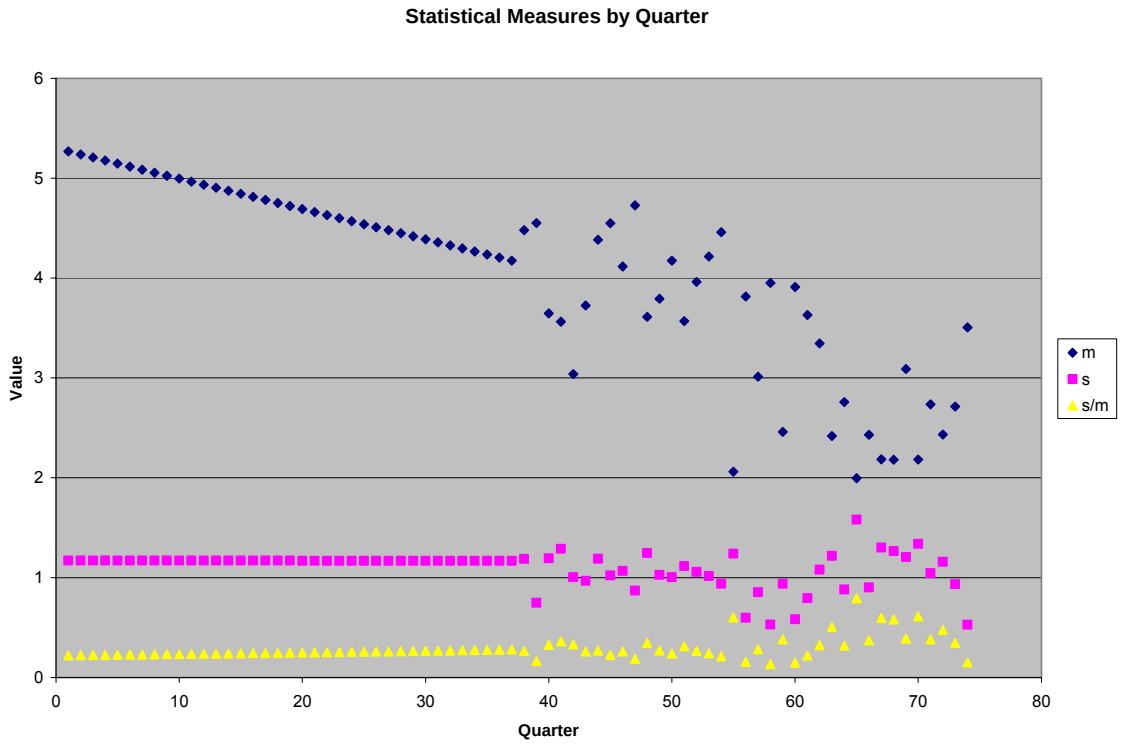

Figure 2: Statistical Measures by Quarter from Table 1 of ORAUT-OTIB-0013 ($m = \mu$, $s = \sigma$)

For both μ and σ, we have two distinct periods. The first runs from quarter 1 to quarter 37 (which is the third quarter of 1956). Over this period, there is a smooth and continuous trend in both quantities. This is because the estimates come from a regression analysis on 147 workers with dose measurements over the period. The second period occurs subsequently. In this case, results are estimated from observations on a quarter-by-quarter basis, and the data exhibit considerable scatter. This scatter could be due to two effects; these are actual variations in workplace conditions from quarter to quarter and the limited size of the database. The second of these should be less important, as most relevant workers should be included, so we are not in the situation of extrapolating from a small sample to a much larger population. We, therefore, take the view that this variation is due to changes in workplace conditions. At a population level, a similar degree of variability should exist before the third quarter of 1956. Therefore, the values of μ and σ used for quarters before the third quarter of 1956 are estimates and not the true values.

This means that there is an additional degree of uncertainty that is not taken into account in the method used. This additional uncertainty should increase the effective σ of the distribution (by integrating over the potential distributions in each quarter). However, as can be seen from examining the values used for σ, these are constant for all quarters before the third quarter of 1956 and are similar to the typical value after that time.

Section 3.0 of ORAUT-OTIB-0013 (Frome and Groer 2004) made the following assumption, which we believe is flawed:

> *The method is based on the assumption that the individual's potential for exposure during the 1950s is similar to that from 1961 to 1965, and that the individual's doses differ from the population dose by a constant factor.*

Our concern is that there is no reason to assume that the dose received by an individual differs from the population dose by a constant factor. Over the period of interest, the size of the population changed markedly. Figure 3, recreated from ORAUT-OTIB-0013 (Frome and Groer 2004), which is taken from Watkins et al. (2004), illustrates this point.

Figure 1: Annual Film Badge Monitoring of Y-12 Workers for Gamma Exposure

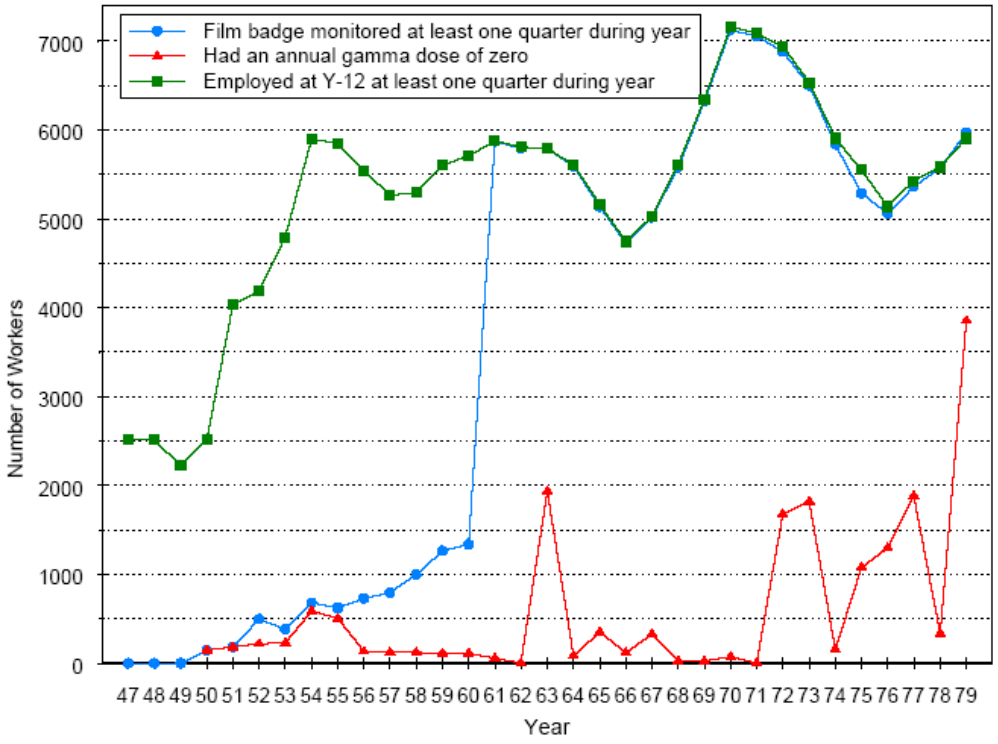

Figure 3: Annual Film Badge Monitoring of Y-12 Workers for Gamma Exposure (Watkins 2004)

Note the trends both in total numbers of workers and in those monitored through to 1960. Note also the jump to complete monitoring of the workforce after 1961. A worker performing a specific job with his own particular trend in dose is being compared with a population, which exhibits an overall trend in dose, because various individual jobs within that population exhibit trends in dose and because the mix of jobs being undertaken will change. In particular, the change in monitoring philosophy in 1960 will have brought a large number of jobs into monitoring that were not previously represented in the population. In this context, it is of interest to note that the first quarter of 1961 is quarter 55 in Figure 2 above. Careful examination of that figure suggests an alternative interpretation; with μ having a typical value of around 4.0 between quarter 38 and quarter 55, and then jumping down to a lower value of around 3.0 from quarter 56. From these considerations, it is evident that the analysis makes two jumps of logic:

- It assumes that the difference between an individual's dose and the population dose from 1961 to 1965 can be used to infer the difference between that individual's dose and the population dose in the earlier period, even though there was a complete change in monitoring philosophy and consequently in the size and variety of work experience of the monitored population;

- It assumes that the time trend in individual exposure mirrors the typical time trend in overall population exposure.

The fallacy of the latter can be readily appreciated by considering an individual who worked unmonitored in a relatively high-exposure task in the late 1950s and was then moved to a low-exposure task in 1960. In 1961, he would have been monitored because of the change in philosophy. In this case, his post-1961 exposure might be lower than the population average, but his pre-1961 exposure might be higher than the average.

Our review of this protocol reveals that NIOSH attempted to develop a statistically sophisticated protocol for filling in missed dose during the early years that, in theory, is statistically valid, but in practice, is not necessarily claimant favorable. In addition, when implementing this procedure as part of our audit of individual cases, we found the procedure difficult to implement, time consuming, and, in the end, not substantially more robust than much simpler, readily understandable, and more claimant-favorable approaches to filling in missing dosimetry.

5.3 ISSUE 3: RADIOBIOASSAY AND INTERNAL DOSE CALCULATIONS

Potential missed dose associated with inadequate bioassay techniques and sampling delays should be further investigated to determine the impact on internal dose calculations. The detection limits for uranium prior to 1989 are only established on a provisional basis. There are uncertainties regarding the determination of lung counting detection limits for ^{235}U and ^{238}U lung counts that can lead to missed dose. The parameters associated with the intake model used to calculate missed internal dose may not reflect actual exposure conditions. These issues must also be considered in the development of co-worker data.

Several technical accuracy and data completeness issues concerning assignment of internal exposures were identified. ORAUT-TKBS-0014-5 (Rich and Chew 2005) is incomplete with respect to exposures to radionuclides other than uranium. The site profile does not provide information relevant to the calculation of uncertainties in bioassay techniques that were implemented at Y-12.

The range of solubilities at Y-12 has not adequately considered the wide range of materials to which an individual worker could have been exposed. There is an absence of consideration of low-level, chronic exposures by a majority of the population, which is clearly described in Y-12 historical monitoring documents. Co-worker dose assignments do not consider the shortcomings of the uranium urinalysis database, variability in material type, bioassay technique uncertainties, and sampling methodology.

5.3.1 General Information

The Y-12 internal dosimetry TBD and ORAUT-OTIB-0029 (Brackett 2005) were evaluated to determine if adequate guidance was provided to perform a dose reconstruction of internal dose. The TBD was assessed with the following criteria:

(1) Does the TBD provide adequate background information?

(2) Does the TBD provide technically sound assumptions for the calculation of internal doses?

(3) Does the TBD provide guidance for addressing missed internal dose for monitored and unmonitored workers?

SC&A determined that the internal dosimetry TBD has some deficiencies with regard to uncertainty and missed dose (see Issue 3), and does not provide the detailed background information and guidance on exposure to radionuclides other than traditional mixtures of uranium (see Issue 4). Also, no urinalysis data is available prior to 1948, and data cannot be found for 1948–1950. Co-worker data is to be applied to the 1948–1950 time period; however, there is no reference to ORAUT-OTIB-0029 (Brackett 2005) that provides information on the assignment of co-worker dose. The guidance is incomplete, often confusing, and in some cases, appears to contradict guidance provided in other NIOSH documents.

The Y-12 internal dosimetry TBD (Rich and Chew 2005) is presented in two general sections; the main body of the report and Attachment 5A. The main body of the report contains a detailed description of the following:

- The in-vitro minimum detectable activities (MDAs), counting methods, reporting protocols, and interferences
- The in-vivo MDAs, counting methods, and reporting protocols
- Limited information on the assignment of dose to unmonitored workers
- Limited discussion of radiobioassay techniques for radionuclides other than uranium

- Discussion of Y-12 uranium solubilities

There is an extensive discussion on uranium solubility at Y-12. However, there is limited direction to the dose reconstructor on the process and assumptions that should be used to calculate internal dose. NIOSH has indicated in the TBD that the dose reconstruction methodology for unmonitored workers for some operations and radionuclides has not been completed. Attachment 5A of the TBD contains conventions used in Y-12 internal dosimetry reports, general uranium solubility assumptions to be used, in-vivo detection limits, and in-vitro detection limits. The attachment is not all inclusive of the directions provided for dose reconstruction in the main text.

The TBD is supplemented by ORAUT-OTIB-0029 (Brackett 2005) and presumably ORAUT-OTIB-0002, *Technical Information Bulletin – Maximum Internal Dose Estimates for Certain DOE Complex Claims* (Rollins 2004). ORAUT-OTIB-0029 (Brackett 2005, pg. 3) states the following:

> *There are instances of energy employees who, for a variety of reasons were not monitored for internal exposure during the course of their employment at a U.S. Department of Energy (DOE) facility, or whose records of such monitoring are incomplete or unavailable. In such cases, data from coworkers may be used to approximate an individual's possible exposure.*

ORAUT-OTIB-0002 (Rollins 2004, pg. 3) indicates that this TIB is to be used under the following conditions:

> *The purpose of this Technical Information Bulletin (TIB) is to provide a method to facilitate timely processing of claims under the Energy Employee Occupational Illness Compensation Program Act (EEOICPA 2000), which involve cancer to an organ with little or no reported internal dose from internally deposited radionuclides that might be associated with work at DOE complex sites.*

There is no reference to these TIBs, which apply to the Y-12 National Security Complex, in the internal dosimetry TBD. With such limited guidance provided in the TBD, it is difficult to access NIOSH/ORAU methodologies applied to internal dose reconstruction.

5.3.2 Particle Size

The TBD has assumed a 5 µm AMAD as the default particle size for Y-12 dose reconstructions. Particle sizes differ by chemical form, process temperature, and facility. ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 10) states the following:

> *For different times and different processes, reported particle sizes ranged from less than 1 to over 10 µm (physical). Steckel and West (1966) reported a positive correlation between uranium oxide particle size and process temperature.*

Although Y-12 originally assumed a default particle size of 8 µm, the default particle size was later changed to 1 µm (Ashley et al. 1992, Snapp 1995). There is no differentiation provided for particle size by operation. The TBD has justified the use of a default particle size of 5 µm AMAD based on Y-12's application of the latest ICRP guidance for the lung model, methods and models, and weighting factors (Rich and Chew 2005, pg. 10). Furthermore, the TBD states the following (Rich and Chew 2005):

> *In terms of lung deposition and retention, the 8 µm AMAD class Q material is closer to 5 µm AMAD Type M material than to 1 µm AMAD class Y material, as shown in Figure 5.3.*

The analysis correlating in-vivo analysis with uranium process materials completed by Steckel and West (1966) gives an average particle size range of 0.12 µm for Salvage II operations to 3.5 µm for burned uranium chips. This average particle size was derived from the portion of the process sample that was less than 150 µm, which constituted from 0.2% for Reclaimed Sand to 99.8% for high-fired UO_2.

The default particle size applied in the TBD conflicts with the direction provided in 42 CFR Part 82, which specifically states a default 5µm AMAD particle size is only applicable in cases were there is no information on particle sizes available. There were several particle size studies completed at Y-12, which indicate that a default 5µm AMAD particle size may not be appropriate for all processes at Y-12.

Although SC&A recognizes that the use of 5µm AMAD particle size is claimant favorable when particle sizes are smaller than the default and doses are back calculated from urine results, the opposite happens when workers are exposed to larger particle sizes. In this case, workers might have had equivalent doses to certain organs underestimated. SC&A recommends that the studies conducted at Y-12 concerning particle sizes be reviewed, and the probability of exposure to particles sizes larger than 5µm be calculated. The most claimant-favorable particle size measured at Y-12 should be considered for each particular cancer type.

5.3.3 Uncertainties and Detection Limits of the Bioassay Techniques

The uncertainties in the bioassay techniques and detection limits used to quantify internal dose are not fully addressed in the TBD and may affect internal dose reconstruction.

5.3.3.1 Uncertainties in Bioassay Techniques

For the early times, NIOSH reports that uranium concentrations in urine samples were underestimated. After the change in analytical technique in 1952, reported urinary uranium concentrations increased. ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 23) states the following:

> *Early in the Union Carbide management at Y-12, the fluorometric method was reassessed. Extraction methods were used starting in 1949 and 1950 (CCCC*

> *1949, p. 7; UCC 1950, p. 14). By the first half of 1952, a technique involving small (0.2 ml) aliquots of raw urine had been put in place (CCCC 1953, p. 28). However, after this change in technique was instituted the urinary uranium concentrations increased greatly as shown in Table 5.7. This raises concern that the technique used before May of 1952 could have underestimated the urinary concentrations.*

The small volumes of raw urine used for fluorimetry (as little as 0.2 ml) may not be representative of a good homogeneous sample, which needs to be taken into consideration in the analysis. The principle of using multiple samples, which provides some control on homogenization, was not instituted until the mid-1950s. Also, the statement above from ORAUT-TKBS-0014-5 (Rich and Chew 2005, pg. 23) references Table 5-7, "Typical uranium enrichment materials at Y-12 with calculated and inferred RU contaminant levels." Table 5-7 specifically addresses recycled uranium and does not speak to this issue present above. SC&A was not able to identify a table in the TBD discussing the increase in urinary uranium concentration after May 1952. The lack of needed reference causes confusion.

In relation to uranium analysis by electrodeposition, ORAUT-TKBS-0014-5 (Rich and Chew 2005, pg. 23) states the following:

> *In 1951, methodological problems leading to underestimates of a factor of two were noted and corrected. The information available was not sufficient to determine if the records themselves were corrected.*

The lack of confidence in bioassay results was also mentioned. For example, for uranium analysis by electrodeposition and alpha counting (1950–1989), it is reported in ORAUT- TKBS-0014-5, (Rich and Chew 2005, pg. 24) that "precision of any one sample was acknowledged to be relatively low." Furthermore, on page 20, the following is mentioned in relation to urine excretion:

> *The fraction of the daily void volume was estimated on the basis of the time between the sample void and the previous void… The use of the rate method to estimate daily urinary excretion contributed to the uncertainty associated with any given measurement.*

This practice continued until 1989, when routine samples were collected over a 24-hour period (Rich and Chew 2005, pg. 20). At a minimum, the volume of urine voided should have been recorded and compared with the typical volume excreted in 24 hours. This approach is not ideal, as the dilution of urine depends on fluid consumption. A better and extensively used technique is to measure the creatinine content of the sample and to use this to estimate the fraction of 24-hour excretion.

In addition to the lack of confidence in measurement techniques, there were difficulties with contamination in the Building 9995 urine laboratory, which invalidate the results of urine analysis during July 1954 (West 1954a). There continued to be contamination problems through

at least September of that year (West 1954b). There is no mention of this contamination issue in the TBD or its relative impact on the urinalysis data available.

5.3.3.2 Detection Limits

The detection limits for uranium before 1989 are only established on a provisional basis. ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 21) reports the following regarding fluorometry from 1945 to 1989:

> *Given the limitations of the rate method of estimating daily urine volumes, uncertainty in the excretion volume is likely to contribute significantly to the uncertainty associated with detection limit of a single measurement.*

Furthermore, ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 21) reports in relation to enriched uranium in urine by gross alpha counting from 1945 to 1989:

> *Each disk was counted twice (on two different proportional counters) for 30 min per count. If the two results from a single disk did not agree within tabulated limits, a third count was made (UCC 1966, p.6) and two concordant counts were used. If the average results of the two disks from the same sample did not agree within specified limits, then two more plates were prepared volume permitting (UCC, 1966, p.6). The expression of potentially censored data of this sort in terms of formal detection limits is not straightforward and no detailed analysis of the statistics of this process has yet be found… The L_D is provisionally assumed as 46 dpm/d before 1965 and 25 dpm/d after 1965.*

Although the interpretation of potentially censored data of this type is difficult in a statistical sense, the use of multiple samples and measurements eliminates the errors arising from contamination problems and equipment malfunctions.

ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 30) reports the following:

> *Due to the uncertainty about actual methods for determining the lung counting detection limits, for dose reconstruction purposes and based on a review of the Y-12 data, the ^{235}U and ^{238}U lung count detection thresholds are assumed to be 130 µg and 13.5 mg, respectively, through 1990.*

These limits of detection are the ones reported for 1959.

The TBD indicates that no description of the conversion count rate to activity to mass has been found (Rich and Chew 2005, pg. 30):

> *The analyte reported was based on the area in which the employee worked. Individuals working in NU or DU areas had results reported as ^{238}U, and workers in enriched areas had results reported as ^{235}U. Claimant-favorable assumptions*

> *should be based on conversions of 93% enrichment for ^{235}U and natural isotopic abundances for ^{238}U.*

SC&A discovered a letter specifically addressing the *in vivo* counter conversion factor in 1959 (UCNC 1959).

> *Since the resolution on the in vivo counter is not perfect, the empirically determined conversion factor for normal uranium differs for …[other Types]. The reason is that some of the 90 keV gammas from the daughter products of U-238 are counted when one is counting the 186 keV region. Since the ratio of daughter products of U-238 and U-235 cannot always be assumed to be constant, the factor for normal uranium shown below can only be said to apply to uranium whose U-235 and U-238 daughter products exist in the same ratio as in the material on which the calibration was made.*

This information should be retrieved and used to evaluate the adequacy of the early *in vivo* counting data. In-vivo counting conversion factors are not trivial and can affect the internal dose calculated from such results.

There are also questions concerning detection limits for radionuclides other than uranium. The detection limit for plutonium before 1988 "has not yet been identified" (Rich and Chew 2005, pg. 22).

SC&A finds the document incomplete in terms of retrieving information on limits of detection and counting efficiencies. There should be some workers capable of giving reliable information on the methods that were used in the 1980s or as early as the 1970s. The document is incomplete in terms of providing information relevant for the calculation of uncertainties to the bioassay techniques that were used at Y-12. NIOSH/ORAU recognizes that elements of the TBD are incomplete in relation to in-vitro and in-vivo detection limits:

> *L_D values for some historical techniques remain to be identified, and will be reported in subsequent revisions as available.* (Rich and Chew 2005, pp. 43-44.)

Furthermore, NIOSH/ORAU has continued to capture data on in-vivo counting and will integrate this information into subsequent revisions of the TBD (see Attachment 4).

5.3.4 Interferences

The selected background interferences to uranium excretion contradict values present by Eckerman and Kerr (1999) in their uranium exposure study. The ratios of $^{234}U/^{238}U$, which is used to distinguish natural uranium, are not realistic. NIOSH is not applying the background corrections described in Section 5.2.4, *Interferences* (Rich and Chew 2005, page 27). As a result, NIOSH/ORAU indicated this section would be removed in subsequent revisions of the TBD (see Attachment 4).

5.3.5 Potential for Ingestion Exposure Pathways

The ingestion pathway of internal exposure has not been considered in the TBD. Given the lack of contamination controls indicated by radiological control program audits, ingestion seems a likely route of internal exposure. In a DOE Oak Ridge Operations audit conducted in 1984 (DOE 1984), DOE alludes to the potential for ingestion uptakes:

> *The act of smoking or consuming foodstuffs with contaminated hands represent a clear-cut internal exposure pathway to workers at Y-12. This practice cannot in the opinion of the appraiser be considered ALARA.*

Y-12 continued to allow eating, drinking, and smoking in radiological areas until 1988–1989, and did not practice egress monitoring (DOE 1986; DNFSB 1993).

The amount of uranium that enters through ingestion is important in terms of bioassay results and doses per Bq excreted. For example, if a worker's exposure had lasted 1 year, the 1-year committed equivalent doses to the different organs, per Bq ^{234}U excreted after the weekend at the end of the working year, is illustrated in Table 1.

Table 1: One-Year ^{234}U Committed Equivalent Doses per Bq ^{234}U Present in Urine after Weekend Urine Sample, Collected at the End of 1-Year Exposure

	F Sv/Bq excreted	M Sv/Bq excreted	S Sv/Bq excreted	Ingestion f1=0.02 Sv/Bq excreted	Ingestion f1=0.002 Sv/Bq excreted
Adrenals	7.69E-05	3.32E-05	2.67E-05	7.59E-05	7.59E-05
Bladder Wall	8.21E-05	3.55E-05	2.84E-05	8.09E-05	8.09E-05
Bone Surface	8.57E-03	3.69E-03	2.96E-03	8.45E-03	8.45E-03
Brain	7.69E-05	3.32E-05	2.66E-05	7.59E-05	7.59E-05
Breasts	7.69E-05	3.32E-05	2.67E-05	7.59E-05	7.59E-05
Esophagus	7.69E-05	3.32E-05	2.67E-05	7.59E-05	7.59E-05
St Wall	7.79E-05	3.76E-05	1.40E-04	1.41E-04	7.30E-04
SI Wall	7.92E-05	4.36E-05	3.10E-04	2.36E-04	1.71E-03
ULI Wall	9.09E-05	9.68E-05	1.74E-03	1.05E-03	9.95E-03
LLI Wall	1.18E-04	2.19E-04	5.04E-03	2.91E-03	2.91E-02
Colon	1.02E-04	1.49E-04	3.16E-03	1.85E-03	1.81E-02
Kidneys	7.95E-03	3.49E-03	2.82E-03	7.84E-03	7.84E-03
Liver	3.51E-04	1.49E-04	1.18E-04	3.47E-04	3.47E-04
Muscle	7.69E-05	3.32E-05	2.68E-05	7.59E-05	7.59E-05
Ovaries	7.69E-05	3.32E-05	2.68E-05	7.59E-05	7.70E-05
Pancreas	7.69E-05	3.32E-05	2.67E-05	7.59E-05	7.59E-05
Red Marrow	9.02E-04	3.87E-04	3.11E-04	8.90E-04	8.90E-04
ET Airways	8.13E-05	6.84E-02	3.05E+00	7.59E-05	7.59E-05
Lungs	1.24E-04	1.29E-01	4.27E+00	7.59E-05	7.59E-05
Skin	7.69E-05	3.32E-05	2.66E-05	7.59E-05	7.59E-05
Spleen	7.69E-05	3.32E-05	2.67E-05	7.59E-05	7.59E-05
Testes	7.69E-05	3.32E-05	2.66E-05	7.59E-05	7.59E-05

	F Sv/Bq excreted	M Sv/Bq excreted	S Sv/Bq excreted	Ingestion f1=0.02 Sv/Bq excreted	Ingestion f1=0.002 Sv/Bq excreted
Thymus	7.69E-05	3.32E-05	2.67E-05	7.59E-05	7.59E-05
Thyroid	7.69E-05	3.32E-05	2.66E-05	7.59E-05	7.59E-05
Uterus	7.69E-05	3.32E-05	2.66E-05	7.59E-05	7.59E-05

Years of Exposure to ^{234}U: 1 year
Collection of after weekend urine sample: last month, of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work
Excretion of ^{234}U in urine entirely due to inhalation exposure of Type F material (F)
Excretion of ^{234}U in urine entirely due to inhalation exposure of Type M material (M)
Excretion of ^{234}U in urine entirely due to inhalation exposure of Type S material (S)
Excretion of ^{234}U in urine entirely due to ingestion of soluble material (f1=0.02)
Excretion of ^{234}U in urine entirely due to ingestion of insoluble material (f1=0.002)

As can be seen from Table 1, doses coming from the ingestion pathway should not be ignored, especially in the case of cancer to the gastrointestinal (GI) tract. Figures 4 and 5 graphically represent the information provided in Table 1.

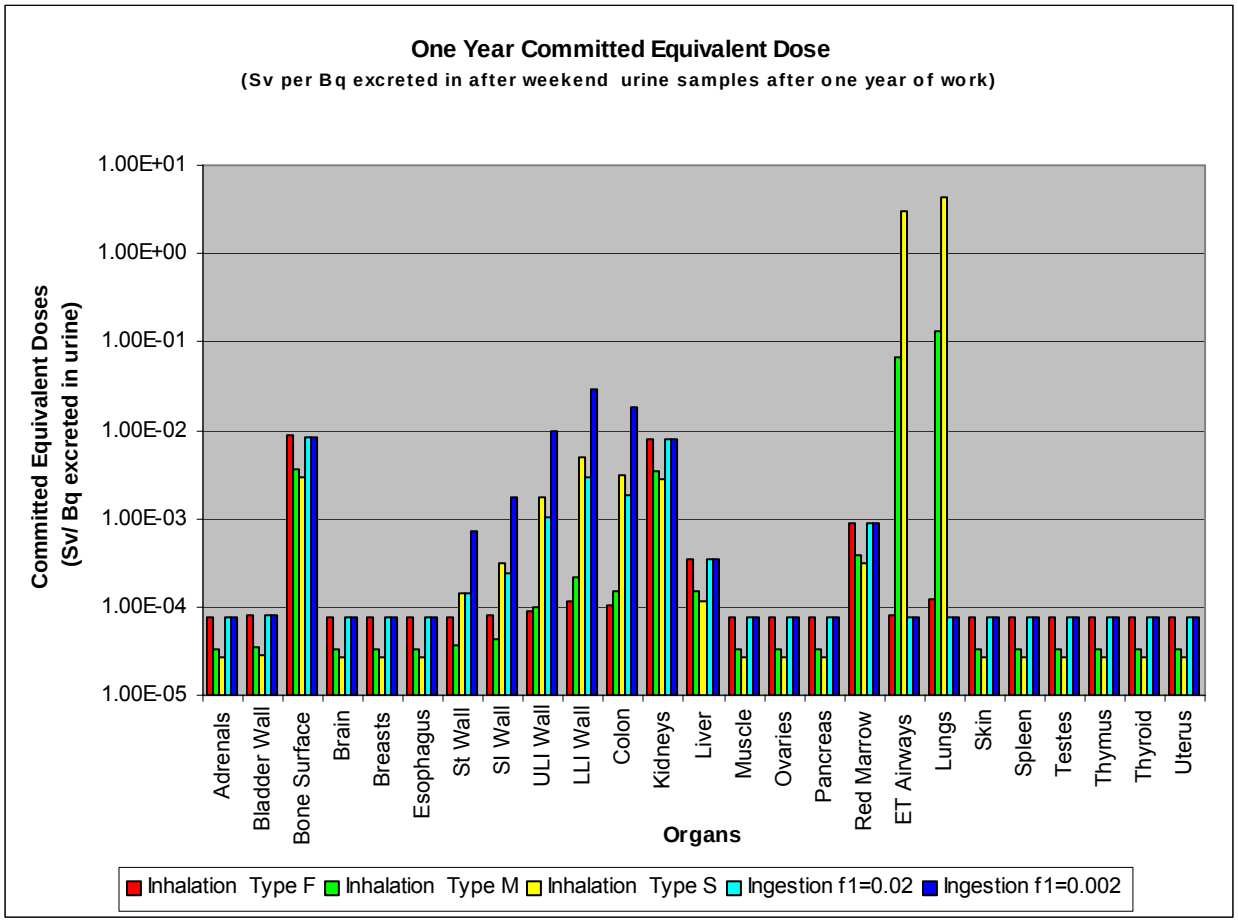

Figure 4: One-Year Committed Dose in Sv per Bq Excreted in After Weekend Urine Samples after One Year of Work

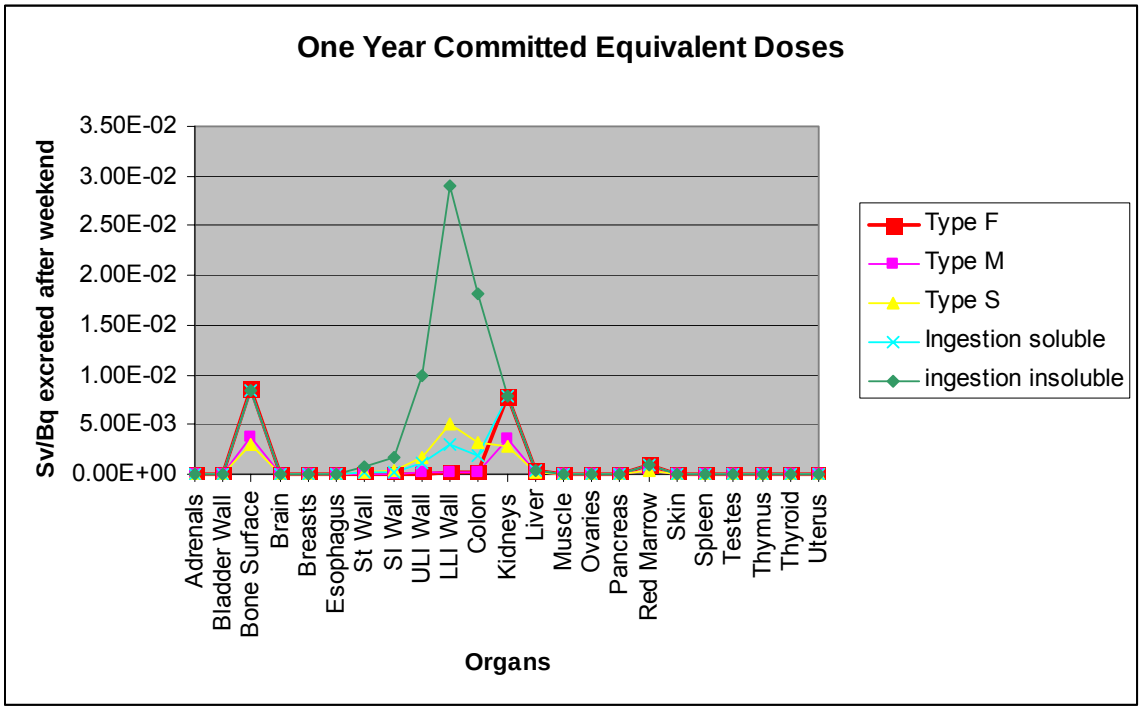

Figure 5: One-Year Committed Equivalent Doses

SC&A recommends that ingestion of uranium compounds be included as a part of the internal dose for GI tract.

5.3.6 Co-worker Dose Assignment

ORAUT-OTIB-0029 (Brackett 2005) is intended to supplement the internal dose TBD (Rich and Chew 2005). This TIB is directed to energy employees who, for a variety of reasons, were not monitored for internal exposure during the course of their employment at Y-12, or whose records of such monitoring are incomplete or unavailable. In such cases, data from co-workers may be used to approximate an individual's possible exposure.

Several problems exist with the model used to assign doses to individuals based on co-worker results. The database of uranium urinalysis records for the Y-12 site for 1950–1988 from Oak Ridge Institute for Science and Education (ORISE), Center for Epidemiologic Research (CER) was used without questioning the accuracy of these records. The records were used, although there were problems with the database, as stated in ORAUT- OTIB-0029 (Brackett 2005, pg. 3):

> *The database results are in units of disintegrations per minute (dpm)/day, although original urinalysis results were reported in terms of either mass or activity concentrations, depending on the measurement method. The assumptions used to convert mass results to activity concentrations for inclusion in the database are not known, nor are the assumptions used to normalize spot sample results to 24 hours.*

5.3.6.1 Choice of the 50th Percentile Intake Rates

Bioassay results were obtained from the ORISE CER Dosimetry Database, which contains uranium urinalysis records from the Y-12 site for 1950–1988 (Brackett 2005, pg. 3). The urine records from the database were analyzed by month and were fit into a lognormal distribution. The 50th and 84th percentiles were calculated for each month.

The intake rates were calculated using the Integrated Modules for Bioassay Analysis (IMBA) Expert Office of Compensation Analysis and Support (OCAS)-Edition computer program. Intakes were assumed to be chronic exposures via inhalation. The monthly bioassay results were used to obtain a series of inhalation intakes. ORAUT-OTIB-0029 (Brackett 2005, pg.6) advises the use of the 50th percentile intake rates to calculate doses.

There is no explanation on the choice of the 50th percentile. SC&A did not have access to the database, and thus could not validate the assumption that the urine activity data is appropriately fitted by a lognormal distribution. Monthly urinary results from Y-12 workers from 1952–1988 were characterized by NIOSH as being typical of a lognormal distribution. As expected with data that can be modeled by a lognormal distribution, the urine activity results must be positively skewed for each month during the 28 years. SC&A does not agree with the choice of the 50th percentile to characterize the unmonitored worker's intake from co-worker data as a claimant-favorable approach. A more appropriate claimant-favorable assumption is to use the upper 95th percentile urine activity to calculate intake rates and doses.

The last 10 years of the Table A-1 of the TBD, for example, are characterized by 50th percentile values below the detection limits for natural uranium (11 dpm/d), showing that the majority of the data were below detection limits. The high value of the geometric standard deviation, on the other hand, is a hint to the fact that the positive values probably are much higher than the detection limits. The intake rates as derived for March 1, 1978 to September 30, 1984 and from October 1, 1984 to December 31, 1988 are very small, and lead to equivalent doses to body tissues and organs that are also insignificant. This is clearly not a claimant-favorable approach, since many of the workers presented high urine activity concentrations as a consequence of high intakes of uranium. Since the high results are consistently measured every month (each month results are characterized by the positively skewed lognormal distribution), one can conclude that contamination was happening regularly at Y-12. Even for Type S uranium, whose excretion rate decreases very slowly, the conclusion stays the same. The contribution of 1 month of chronic exposure to the activity of a urine sample collected at the end of the following month does not justify the results on Table A-1. The uranium activity of Type S compounds in urine samples taken 1 month post-exposure are expected to be 5 to 10 times lower than post-weekend samples taken during the month of chronic exposure. Thus the existence of a lognormal distribution every month, with the parameters described in Table A-1, leads to the conclusion of regular, monthly exposures at Y-12. SC&A considers that the claimant-favorable approach to workers not monitored is to consider them exposed to the higher level of contamination that was characteristic of Y-12.

5.3.6.2 Material Types

Uranium urine results were fit using Type M and Type S material. Exposures to Type F material were not considered, although in ORAUT-TKBS-0014-5 (Rich and Chew 2005), it is specifically reported that workers were exposed to uranium compounds of different solubility, including soluble material. For example, ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 7), reports the following:

> *The uranium compounds with which Y-12 has worked ranges from highly soluble to very insoluble. …. Exposures to soluble compounds were monitored from the closing days of World War II by clinical tests of renal function and by fluorimetric tests for uranium in urine.*

Furthermore, ORAUT- TKBS-0014-5 (Rich and Chew 2005, pg. 31), states the following:

> *From 1948 to 1950, fluorimetric analysis of urine and blood were conducted as part of general medical surveillance to prevent kidney damage from exposure to soluble uranium compounds; these data cannot be found at this time. Coworker data will be applied to this time period.*

This paragraph specifically implies that co-worker data should cover the lack of bioassay data for soluble uranium compounds for this time frame. ORAUT-TKBS-0014-2 (Jessen 2005, pg. 8) also contains information on exposure to soluble compounds of uranium, which is illustrated on Table 2.9-1 (pg. 21).

The interpretation of results from urinary excretion of uranium Type F materials after 48-hours absence from work produce intake rates that result in doses that, depending on the time of exposure and organ (primarily systemic organs), can be higher than if Type M or S were used. The values presented in Table 2 illustrate these findings. These data are calculated for a worker exposed for 1 year to chronic, constant daily intakes. Figures 6 and 7 graphically represent the Table 2 Committed Equivalent Dose.

Table 2: One-Year ^{234}U Committed Equivalent Doses per Bq ^{234}U Present in Urine after Weekend Urine Sample, Collected at the End of 1-Year Exposure

	Type F	Type M	Type S	Dose comparison	Dose comparison
	Sv/Bq excreted	Sv/Bq excreted	Sv/Bq excreted	TypeF /TypeM	Type F/ Type M
Adrenals	7.69E-05	3.32E-05	2.67E-05	2.32E+00	2.88E+00
Bladder Wall	8.21E-05	3.55E-05	2.84E-05	2.31E+00	2.89E+00
Bone Surface	8.57E-03	3.69E-03	2.96E-03	2.32E+00	2.90E+00
Brain	7.69E-05	3.32E-05	2.66E-05	2.32E+00	2.89E+00
Breasts	7.69E-05	3.32E-05	2.67E-05	2.32E+00	2.88E+00
Esophagus	7.69E-05	3.32E-05	2.67E-05	2.32E+00	2.88E+00
St Wall	7.79E-05	3.76E-05	1.40E-04	2.07E+00	5.56E-01
SI Wall	7.92E-05	4.36E-05	3.10E-04	1.82E+00	2.55E-01

	Type F	Type M	Type S	Dose comparison	Dose comparison
	Sv/Bq excreted	Sv/Bq excreted	Sv/Bq excreted	TypeF /TypeM	Type F/ Type M
ULI Wall	9.09E-05	9.68E-05	1.74E-03	9.39E-01	5.22E-02
LLI Wall	1.18E-04	2.19E-04	5.04E-03	5.39E-01	2.34E-02
Colon	1.02E-04	1.49E-04	3.16E-03	6.85E-01	3.23E-02
Kidneys	7.95E-03	3.49E-03	2.82E-03	2.28E+00	2.82E+00
Liver	3.51E-04	1.49E-04	1.18E-04	2.36E+00	2.97E+00
Muscle	7.69E-05	3.32E-05	2.68E-05	2.32E+00	2.87E+00
Ovaries	7.69E-05	3.32E-05	2.68E-05	2.32E+00	2.87E+00
Pancreas	7.69E-05	3.32E-05	2.67E-05	2.32E+00	2.88E+00
Red Marrow	9.02E-04	3.87E-04	3.11E-04	2.33E+00	2.90E+00
ET Airways	8.13E-05	6.84E-02	3.05E+00	1.19E-03	2.67E-05
Lungs	1.24E-04	1.29E-01	4.27E+00	9.61E-04	2.90E-05
Skin	7.69E-05	3.32E-05	2.66E-05	2.32E+00	2.89E+00
Spleen	7.69E-05	3.32E-05	2.67E-05	2.32E+00	2.88E+00
Testes	7.69E-05	3.32E-05	2.66E-05	2.32E+00	2.89E+00
Thymus	7.69E-05	3.32E-05	2.67E-05	2.32E+00	2.88E+00
Thyroid	7.69E-05	3.32E-05	2.66E-05	2.32E+00	2.89E+00
Uterus	7.69E-05	3.32E-05	2.66E-05	2.32E+00	2.89E+00

Years of Exposure to ^{234}U: 1 year
Collection of after weekend urine sample: last month, of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work

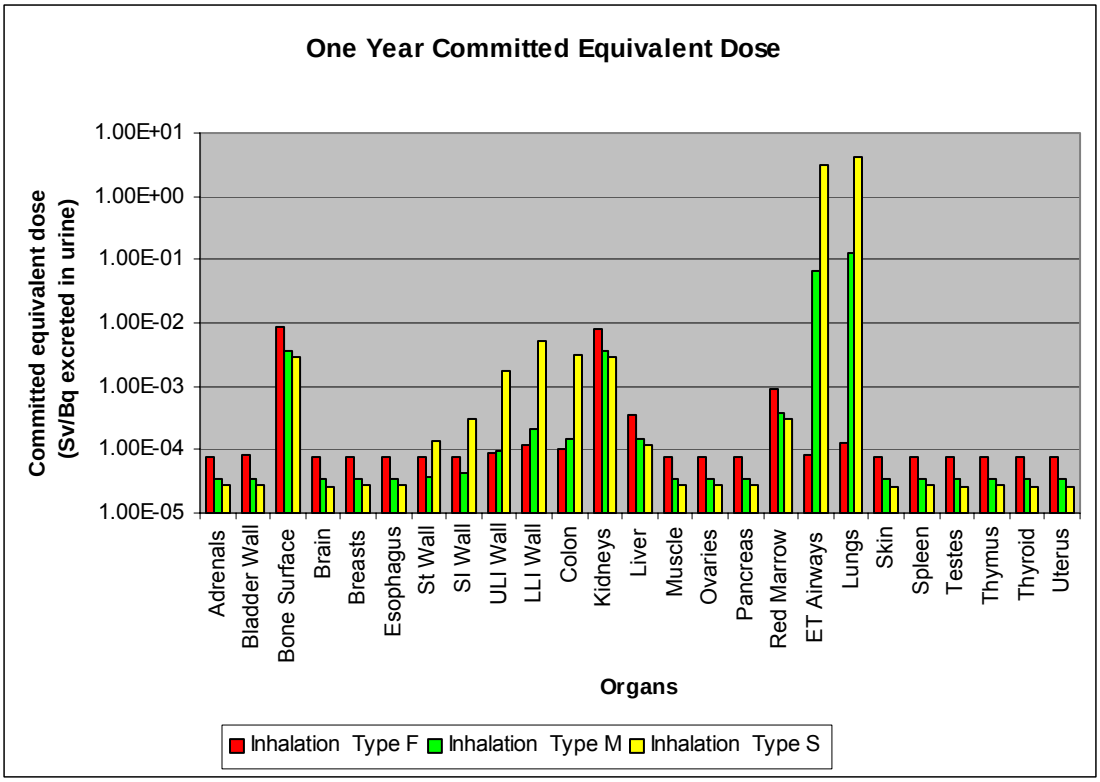

Figure 6: One-Year Committed Equivalent Dose for All Organs

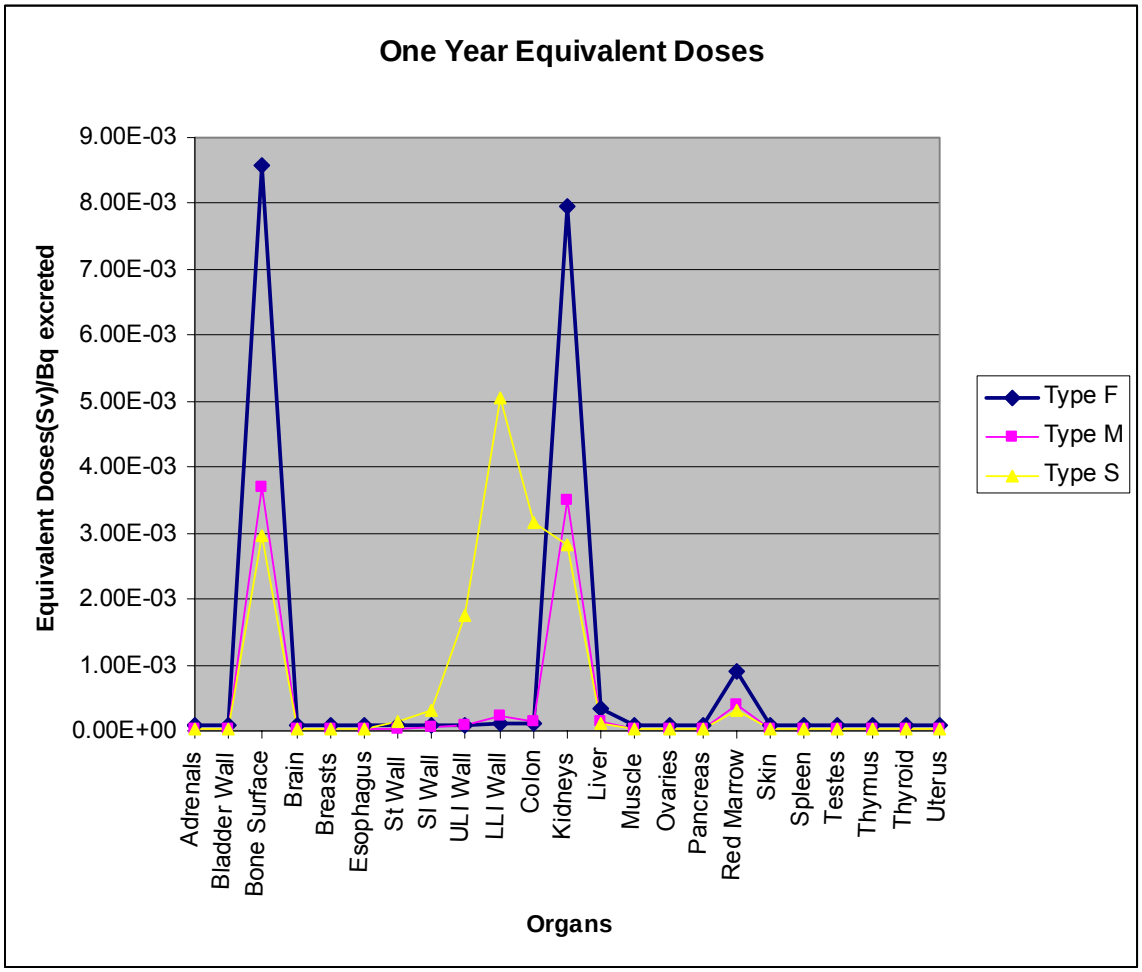

Figure 7: One-Year Equivalent Doses for Non-Respiratory Tract Organs.

SC&A finds the assumption that doses should be assigned based on exposures to uranium compounds of solubility Types M and S, without considering Type F compounds, not claimant favorable, for many cancer sites. This assumption does not follow instructions given in 42 CFR Part 82, which specifically states the following:

> *…, if the solubility classification of an inhaled material can not be determined, the dose reconstruction would use the classification that results in the largest dose to the organ or tissue relevant to the cancer and that is possible given existing knowledge of the material and process.*

The ingestion pathway of exposure was not considered in the derivation of co-worker data. The amount of uranium that enters through ingestion is very important in terms of interpretation of bioassay results and conversion to organ equivalent doses per Bq excreted. The use of bioassay results to back-calculate intake and doses will produce higher doses for certain organs, if the ingestion pathway of exposure is used, instead of the inhalation pathway. As seen in Figure 8, ingestion of insoluble compounds results in doses to the GI tract that are higher than if inhalation

was assumed. SC&A finds that it is not claimant favorable to ignore the ingestion pathway of internal contamination. The ingestion of insoluble compounds should be included as a part of the internal dose in cases of GI tract cancers.

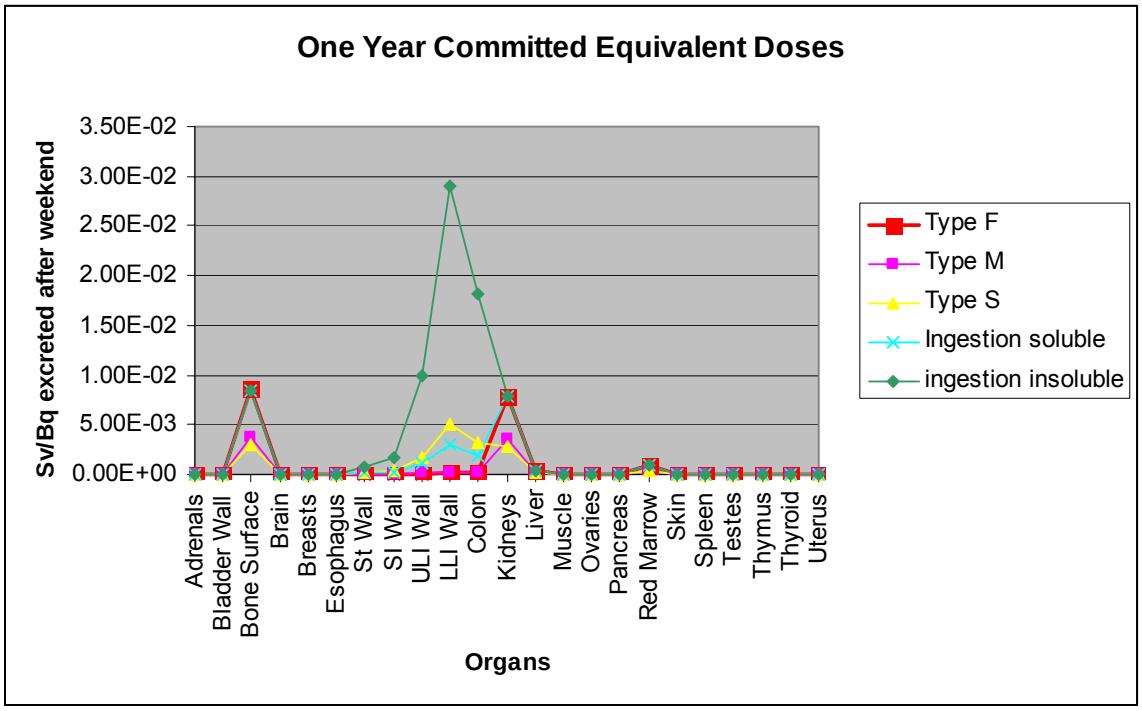

Figure 8: One-Year Committed Equivalent Doses from Ingestion of Insoluble Compounds

5.3.6.3 Post-Weekend Sampling

ORAUT-OTIB-0029 (Brackett 2005, pg. 4) states:

> *Because of the nature of work at Y-12, a chronic exposure pattern best approximates the true exposure conditions for most workers with a potential for intakes.*

A chronic constant intake was assumed by NIOSH, and the results were interpreted without considering when the samples were taken.

ORAUT-TKBS-0014-5 (Rich and Chew, pg. 20) confirms this practice:

> *…the primary urine collection method was a spot sample submitted Monday morning before entering the work area.*

The TBD derived intakes by back-calculated doses based on urine results and by fitting bioassay results for different periods. However, the TBD did not consider the 48-hour absence from work. As a result, the intake rates derived in ORAUT-OTIB-0029 (Brackett 2005) are lower

than those calculated with the same data, but considering end-of-weekend excretion samples. The doses to be assigned using these derived intake rates are not claimant favorable.

The interpretation of bioassay results for chronic exposures of workers should take into consideration the day of the week on which samples are taken. In this way, the short-term components associated with lung clearance will be accounted for, since the early clearance component(s) of excretion may introduce a significant difference before and after an interruption in exposure, e.g., the weekend. For uranium exposures, the 48-hour waiting period prior to submitting urine samples is particularly relevant.

The TBD did not consider the fact that urine samples were collected after a 2-day absence from work. The model used by NIOSH assumed that the worker was exposed for a full 7 days per week, and did not take into consideration the depletion of uranium in the system after the 2-day absence from work. This approach resulted in an underestimate of the uranium intake and exposures experienced by the workers. In order to quantify the magnitude of the underestimate of dose as derived by NIOSH, SC&A performed a series of dose calculations which take into consideration the fact that the urine samples were collected on Monday morning after some of the uranium was excreted over the weekend. For example, after 1 year of exposure, the amount of uranium excreted in urine using the NIOSH/ORAU intake model as compared to the SC&A approach is underestimated as follows:

(1) For Type F compounds, 4.3 times lower than if samples were assumed to be taken after the weekend

(2) For Type M compounds, 2.2 times lower than if samples were assumed to be taken after the weekend

(3) For Type S compounds, 2 times lower than if samples were assumed to be taken after the weekend

It is not clear how many working days per year were used by NIOSH/ORAU, and it is likely that working schedules of the Y-12 personnel were variable by job title and time period. Even if one assumes that NIOSH conservatively considered a 6 or 7 day a week exposure, instead of a 5 day a week exposure, this small overestimate of intake will not account for the underestimate of intake from the post-weekend sampling. For example, even if exposures were 6 days per week, the model will still underestimate the annual exposure by the following:

(1) For Type F compounds, 3 times for workers on a 5 days a week schedule and 3.7 for workers on a 6 days per week schedule

(2) For Type M compounds, 1.6 times for workers on a 5 days a week schedule and 1.9 for workers on a 6 days per week schedule

(3) For Type S compounds, 1.5 times for workers on a 5 days a week schedule and 1.7 for workers on a 6 days per week schedule

SC&A has included Type F compounds in the comparison, because workers at Y-12 were exposed to soluble forms of uranium classified as absorption Type F by the ICRP. As previously

mentioned in this report, Y-12 personnel worked with uranium compounds ranging from highly soluble to very insoluble. Intake rates should be recalculated using the fact that urine samples were collected after a minimum of a 48-hour absence from the work area. This delayed sample collection practice should also be considered for monitored personnel.

5.3.6.4 Particle Sizes for Co-worker Application

ORAUT-OTIB-0029 (Brackett 2005, pg. 4) summarizes the breathing rate and particle size assumptions for co-workers as follows:

> *Intakes were assumed to be via inhalation using a default breathing rate of 1.2m^3/h and a 5-µm activity median aerodynamic diameter (AMAD) particle size distribution.*

This value was consistent with the default value recommended by the TBD (Rich and Chew 2005, pg. 10); however it is not consistent with the particle size data collected by Y-12, as discussed earlier in the report.

SC&A recommends that particle size studies conducted at Y-12 be reviewed, and the probability of exposure to particles sizes larger than 5µm should be considered for co-worker data. Workers exposed to larger particles might have had equivalent doses to certain organs underestimated, when assuming a 5µm AMAD particle size. Although the default particle size is consistent with the value recommended in the TBD, this value may not be indicative of the particle sizes encountered in all operations at Y-12.

5.4 ISSUE 4: OTHER RADIONUCLIDES

The TBD is incomplete in its review of the historic dose contribution of radioisotopes other than uranium. These include ^{3}H, ^{90}Sr, ^{99}Tc, ^{210}Po, ^{228}Th, ^{232}Th, ^{239}Pu, ^{241}Pu, ^{237}Np, ^{233}U, and ^{241}Am. Some of these radionuclides were associated with research and development (R&D) activities, while others were handled in production, either as source material or as a contaminant from recycled uranium. While some of these operations are associated with ORNL operations at Y-12, a number of the Y-12 workers (e.g., maintenance and janitorial personnel) supported those operations and were potentially exposed to these sources. NIOSH has recognized this issue, and has directed ORAU to begin evaluating the significance and dose contribution of some these materials.

ORAUT-TKBS-0014-5 (Rich and Chew 2005, pg. 7) states the following:

> *…although the calutrons in bldg 9204 were left operational for R&D in improving the production of the calutron concept and separating other element isotopes. Eight calutrons were still operating as late as 1997. This program produced an inventory of 225 isotopes from nearly every element in the periodic chart. The 86-inch Cyclotron started operation in 1950 and continued to operate until 1980…Polonium isotopes and alpha airborne activity are the mentioned*

> *internal dose concerns…There were programs in these R&D efforts, which involved plutonium and workers could have plutonium bioassay results in their records. When claim information indicates that a Y-12 worker was involved with research activities involving the Calutron, cyclotron (accelerator), fusion work, or plutonium (except in the case of recycle uranium (RU) exposure, which is addressed in this section), consideration must be given to possible exposure to radionuclides other than uranium.*

In ORAUT-TKBS-0014-5 (Rich and Chew 2005, pg. 12), several radionuclides are listed as being radionuclides of concern. These radionuclides are ^{3}H, ^{90}Sr, ^{99}Tc, ^{210}Po, ^{228}Th, ^{232}Th, ^{239}Pu, ^{241}Pu, ^{237}Np, ^{233}U, and ^{241}Am. Other radionuclides cited are ^{210}Po and for organizations outside Y-12, ^{60}Co and ^{95}Zr/^{95}Nb. Furthermore, site experts indicated in interviews that radionuclides processed or worked with at the Y-12 plant included ^{3}H, ^{232}U, ^{233}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{228}Th, ^{232}Th, and ^{241}Am.

5.4.1 Recycled Uranium

Recycle uranium was received at Y-12 starting in the late 1950s. (see Attachment 8). Specifications were established for impurities in recycled uranium; however, this was not done until March 1997 (Cox et al. 1997). The health physics division analyzed incoming material for ^{106}Ru, ^{144}Ce, ^{95}Zr, transuranics, and other radionuclide concentrations to ensure it was within specifications. Health Physics tracked the ratio of impurities to uranium. As recycled uranium passed through chemical processing, impurities and uranium daughters were removed from the product, but concentrated in the raffinate. As a result, the West End Treatment Facility is considered a transuranics area. Technetium has become a concern more recently (see Attachment 6).

Overall, the Y-12 TBD contains the most detailed and comprehensive treatment regarding exposures to recycled uranium of any TBD reviewed by SC&A to date. It also provides a reasonable framework for addressing missed doses from exposures to recycled uranium. This approach is a marked improvement over previously reviewed site profiles, where recycled uranium was an issue.

Yet, some important gaps remain that NIOSH should address relative to: (1) process knowledge to better inform dose reconstruction; and (2) potential external penetrating radiation exposures from recycled uranium in the early period of the Y-12 when external radiation monitoring was highly limited.

5.4.1.1 Lack of Adequate Y-12 Process Information for Recycled Uranium

The TBD provides default assumptions for internal dose reconstruction based on "the maximum values of documented RU levels in the Y-12 process streams and thus represent claimant-favorable values, and which can apply on a plant-wide basis" (Table 5.8 Rich and Chew 2005). This approach assumes that the maximum claimant-favorable values can be obtained by NIOSH/ORAU from (DOE 2000b). The TBD also had to rely on data on trace contaminants

collected from other sites, such as the Feed Materials Production Center at Fernald, Ohio (Rich and Chew 2005). Measurements used in the TBD are suspect because as late as 1985:

> *…formal specifications on the maximum quantities of transuranics and fission product elements do not exist between the Y-12 plant and feed material suppliers…Informal specifications in the form of "gentlemen's agreements' did evolve and have been used over time… A formal, technically sound, understood and accepted specification for maximum transuranic and fission product contaminants in uranium recycle material has probably never existed either within or between sites…* (DOE 1985).

Documentation or the lack thereof regarding the nature of these informal staff-level "gentlemen's agreements," and their changes over more than 30 years should be addressed by NIOSH. For instance, it is quite possible that early staff-level agreements between sites and within the Y-12 complex were significantly less stringent than later "gentlemen's agreements." Transcripts from the Y-12 Preservation Program, as noted above by the DNFSB staff, in which some 240 Y-12 employees provided information contained in transcribed interviews between 1993 and 1997, may be helpful in addressing this gap in knowledge regarding the changes in recycled uranium contaminant limits.

Moreover, it appears that sampling for trace contaminants was not directed primarily toward worker protection but rather to ensure successful processing. The DOE's 1985 Task Force states the following (DOE 1985):

> *Limited samples exist on the transuranic and fission product content of recycle material receipts, processing streams, and product streams. As in the case of the FMPC* [Feed Material Production Center in Fernald, Ohio], *Y-12 has not been required to maintain accountability data on plutonium, or other transuranic elements, or fission products.*

The Task Force also states the following (DOE 1985):

> *…samples are taken primarily for uranium accountability, operational safety, and operational control. In general, accountability samples for transuranics are not taken for transuranic (plutonium and neptunium) or fission product elements introduced, processed or removed from the process.*
>
> *In summary form, the current Y-12 recycle material sampling policy associated with transuranic and fission product elements is as follows:*
> - *Sample each batch of receipts*
> - *If batches received are small, samples from batches are composited*
> - *Sample one out of every ten of the product batches being returned to the SRP*
> - *Sample process side streams on a limited frequency (usually annually)*
>
> *Note these are not accountability samples.*

Given the very limited sampling of "process side streams," the values of trace contaminants used in the TBD may not be representative of the concentrations encountered in different processing stages. Better knowledge of the processing of recycled uranium is necessary to adequately inform dose reconstruction. There are some processes where contaminants such as transuranics were concentrated, particularly high-heat processing and combustion, which should be considered in dose reconstruction.

In 1985, the DOE task force on recycled uranium noted the following:

> *Recent (November 1984) sampling of the S-3 Pond sludge found Pu-238, Pu-239, Pu-240 and Np-237 in the sludge…Based on limited sampling since 1977, the Y-12 staff has noted a buildup of fission products in both the liquid and solid waste streams as a result of processing recycle material*. (DOE 1985)

As the following table indicates, dose reconstruction associated with processes where byproducts were generated as ash at the Paducah Site indicate significant exposures to transuranics.

Table 3: Estimated Bone Surface Doses from Recycled Uranium to Workers at the Paducah Gaseous Diffusion (Committed Dose Equivalent – CDE in a Year) (DOE 2000c)

Average Air Concentrations	Maximum Air Concentrations
48.06 -- 188 rem	599.24 -- 2,238 rem

A preliminary review of the processes involving the recycle of uranium from chemical separations plants and other Y-12 streams indicates that there are several stages where trace contaminants could be concentrated in circumstances where workers could be exposed to levels higher than reported in Y-12's sampling data used by NIOSH. Subsequent recovery operations involve several steps in which trace contaminants could be concentrated, potentially exposing workers. Recovery operations consist basically of the following:

(1) Burning combustibles—a stage where trace contaminants could be concentrated in ash, which may result in worker exposures.

(2) Dissolving or leaching solids.

(3) Purifying the uranium-bearing solutions by liquid-liquid extraction. The processing of waste streams from primary and secondary extraction stages could also concentrate trace contaminants.

(4) The purified uranyl nitrate hexahydrate (UNH) solutions are denitrated to uranium trioxide (UO_3). This process involves a calciner, which denitrates UNH solution to uranium trioxide powder. Nitrogen oxide produced in this process is passed though a two-stage scrubber and exhausted to the stack. Maintaining adequate containment of radionuclides is critical, as was the case at the Portsmouth Gaseous Diffusion Plant, which " was not able to maintain adequate containment of the radioactive materials

during operating periods" (DOE 1985). Also, bag house residues may contain concentrated trace contaminants.

(5) The UO_3 is then reduced to uranium dioxide (UO_2) in a fluid bed reactor. Off-gas filtration may concentrate contaminants.

(6) The UO_2 is transferred to a hydrofluorinator in which hydrogen fluoride gas is introduced to yield uranium tetrafluoride, (UF_4) powder.

(7) The UF_4 is then sent to furnaces used to sinter uranium oxide to a ceramic grade U_3O_8.

(8) Finally the U_3O_8 is reduced to metal in a "Bomb Reduction" process. The reaction takes place at elevated temperature and reduced pressure in a closed vessel.

Attachment 8 shows the process flow for uranium at the Y-12 Plant.

Sources of off-site recycled uranium were not limited to DOE reactors and other uranium plants, but also included recovered uranium from commercial reactor fuel. Apparently, recovered uranium from the Dresden reactor "B Core" fuel was shipped from the Savannah River Site (DOE 1997) and processed at Y-12 (Cox 1997). The Dresden 1 reactor was the first commercial nuclear power plant that went on line in 1959. Some of the reactor's spent fuel was composed of irradiated thorium and uranium oxide and was estimated to contain 76.5% ^{235}U, 9.7% ^{233}U, and 140 ppm of ^{232}U (Cox 1997).

NIOSH should undertake validation of the secondary sources it has used to ensure that it has provided adequate bounding estimates for the highest impurity concentrations in recycled uranium.

5.7.5.2 External Exposure from Recycled Uranium

The TBD does not address exposures to photons and neutrons that are associated with recycled uranium, particularly prior to 1961—a period when 85% to 90% (depending on the year) of the Y-12 workforce was not monitored for external radiations (Watkins 1994). NIOSH should address these potentially significant missing doses.

In 1985 DOE reported the following regarding worker exposures and recycling at Y-12:

> *The exposure records of recycle material workers were compared with those within the same operating departments. The results of this comparison shows that recycle material workers, on the average, had about 2.7–3.0 times the external radiation exposure as other workers in the department.* (DOE 1985)

Since a review done by Y-12 management in 1985 clearly shows a significant increase in external doses to recycle material workers, it is reasonable to expect that external doses to Y-12 recycle workers were likely to have been higher prior to 1961, when far less importance was

given to external radiation by Y-12 management. Only after the criticality accident in 1958 at Building 9212, which resulted in very high doses and immediate illness to several unmonitored workers, did the Union Carbide Management realize the importance of external monitoring for all workers (West 1993).

Radionuclides of concern, which NIOSH should consider for purposes of external dose reconstruction include ^{103}Ru, ^{106}Rh, ^{125}Sb, ^{95}Zr, ^{95}Nb, and ^{137}Cs, and ^{144}Ce, and decay products of ^{232}U, which is discussed in more detail later in this section.

5.4.2 Uranium-233 Production

Between 1953 and 1961, thousands of kilograms of recycled uranium received from chemical separation plants was processed at Y-12 (DOE 1985). Recovered uranium from reactor recycle handled at Y-12, in some instances, had ^{233}U contents as high as <98% and ~95%. Uranium-232 contaminants were as high as 218 ppm (Cox 1997). Of particular concern is exposure to ^{232}U contaminants. Uranium-232 is co-produced with ^{233}U by irradiation of thorium, and is 60 million times more radioactive than ^{238}U. This is due to high-energy gamma radiation emitted in the decay scheme of ^{232}U daughter products (^{228}Th, ^{244}Ra, and ^{228}Tl). Even though ^{232}U concentrations are small, its gamma radiation constitutes a potentially significant external hazard. A 2000 DOE contractor made the following assessment:

> *A 50 ppm U-232 content equates to approximately 13R/hr at 1 foot and with extrapolation, a 5 to 10 ppm content would emit approximately 5R/hr [at 1 foot].* (Frieboth 2000)

The implications are that the TBD will need to carefully consider the magnitude of external exposures that might have been experienced by unmonitored workers who worked in the vicinity of ^{233}U production.

Y-12 was also involved in processing of ^{233}U; however, no guidance is provided on when internal dose from ^{233}U is to be assigned in the internal dosimetry TBD. There is no discussion of the potential external exposure from ^{232}U daughters. Also not considered was the potential for exposure from salvage material. West and Roberts (1962) describe the ^{233}U processing as follows:

> *In the early part of 1962, the Y-12 Plant undertook the fabrication of metallic U-233. This was accomplished by chemical conversion of a nitrate solution of U-233 to metal and metallurgical fabrication to the desired parts.*

West and Roberts (1962) further discuss the health physics concerns associated with this material:

> (1) *High alpha activity (the specific activity of the material is about 150 times that of the highest assay uranium routinely processed), and*

(2) *Gamma radiation buildup created by the daughter products of the contaminant U-232 accompanying the U-233*

The Y-12 Health Physics groups recognized the special precautions necessary for work with this material, including use of containment; prohibiting eating, drinking, and smoking in the production areas; requiring personal and clothing surveys with portable instruments upon exit; and providing supplemental dosimetry for workers directly involved in processing of material.

As the material was processed, the ^{232}U daughters were concentrated:

> *Activities in this process concentrated the U-232 daughters in the salvage and reduced them in the product material by a factor of about two. Under conditions of this processing, this effect was of little significance. However, under other operating conditions, this concentration in salvage material could require special consideration.* (West and Roberts 1962)

In these operations, it was reported that 500 grams of ^{233}U received as uranyl nitrate solution contained 40 ppm of ^{232}U (West and Roberts 1962). Although there were special precautions taken during processing, it is unclear whether the same considerations were given to salvage operations. Potential exposures should be evaluated against the personnel monitoring used at the time of exposure. For example, if the feed material was type F material as indicated by West and Roberts (1962), the 48-hour delay prior to sampling will impact the activity in the urine sampled.

The TBD should provide additional information to the dose reconstructor relating to operations involving ^{233}U, ^{232}U, and daughters, and provide guidance on when to assume an uptake of these radionuclides. The TBD should discuss the extent to which recycled uranium with potentially hazardous amounts of ^{232}U may have been processed at Y-12. Furthermore, the TBD should consider the impact of exposure to ^{233}U, ^{232}U, and daughters during the handling of salvage operations and waste management activities. The analysis should consider time since purification.

5.4.3 Thorium Workers

The internal TBD provides only a limited discussion of potential thorium and thorium daughter exposure as a result of production activities (^{232}Th) or as a contaminant of recycled uranium (^{228}Th). Some discussion of bioassay techniques used at Y-12 for the detection of ^{228}Th, ^{230}Th, and ^{232}Th is needed, because thorium was an integral part of manufacturing operations at Y-12. There were heavy thorium campaigns in the 1960s, as indicated by the following (Oliver 2001):

> *The Y-12 NSC began processing thorium in the early 1960s. Thorium metal in pellet form was pressed and/or rolled, formed, and machined. Metal scraps and chips were salvaged and also pressed into electrodes to be used in the arc-melting process.*

The following primary activities, by facility, occurred as part of this process:

- *Pellet/scrap preparation, arc melting, crop and trim machining and sawing occurred in 9201-5*
- *Mold press sintering, ingot forging and annealing after first cold roll, and final inspection/assembly were performed in 9204-2*
- *Ingots were canned prior to first cold roll in 9201-1*
- *Cold and hot rolling were conducted in 9215*
- *Cleaning and final plating were conducted in 9206*
- *Machining activities were conducted in 9766*
- *Development activities were conducted in 9202*

Thorium is highly radiotoxic because of its long biological half-life and high effective energy. West (1965) recognized the health physics hazards associated with thorium production at Y-12.

> *These chemical and metabolic characteristics cause it to have a long biological half life in the lung and bone. These long half lives, coupled with its highly effective energy for internal damage because of the large number of alpha-emitting daughters, cause it to be considered a highly radiotoxic isotope.*

Coupled with a long biological half-life that mitigates against effective urinalysis detection and the lack of a sufficiently energetic gamma component to permit ready in-vivo detection (detection via daughters requires comparison of ratios), thorium presented significant control challenges at Y-12 (McLendon 1960; West 1962).

As the material is processed, thorium daughters are concentrated (West 1965).

> *In Y-12 experience, concentration of these less noxious daughters associates itself with two situations: (1) there is a concentration of beta and alpha-emitting isotopes which come after thoron in the decay chain due to the fact that thoron escapes from the parent material because it is a noble gas, and (2) radium daughters are separated during operations involving high temperatures.*

Radium-228 and ^{224}Ra exposures can be significant hazards, and internal dose must not overlook the potential contribution of dose from these daughters. Although Y-12 evaluated airborne concentrations and monitored workers with in-vivo counting, it is uncertain how extensive the monitoring program was and how frequently hands-on and support personnel were monitored. Although some of the work with thorium was in a contained system, some portions of processing (e.g., rolling, machining) were conducted in open areas (West 1965). Machinists handling thorium did not take any special precautions grinding and shaping thorium metal (see Attachment 6).

Moreover, there was a potential for crossover contamination to uranium production areas. This was a serious concern, because Y-12 contamination monitoring techniques (i.e., smearing) could

not distinguish between thorium and uranium contamination (West 1962), nor could it be easily picked up in urinalysis. In a February 1963 report, such a "crossover" contamination of plant areas with thorium was reported in Building 9201-5. Thorium contamination was tracked out of the thorium production areas, leading to a "drastic increase in removable surface contamination in the arc furnace area which has resulted in spread to adjacent areas" (Sanders 1963). It was noted that this was not a breakdown in equipment, but a problem with procedures and operating techniques. Compared with a PAL of 50 d/m/100 cm^2, removable contamination in excess of 25,000 d/m/100 cm^2 was smeared in the operations area, with 3,000–13,000 and 2,000–8,000 d/m/100 cm^2, respectively, being smeared in adjacent non-thorium plant areas (e.g., beryllium loading dock and Building 9204-4). It is not clear how frequent such crossover contamination incidents were or how potential worker exposure to thorium contamination was assessed, given the dosimetry challenges cited. As a potential source of missed dose at Y-12, the Internal Dose TBD needs to address this issue and characterize its significance for the dose reconstructor.

The TBD should provide additional information to the dose reconstructor relating to operations involving thorium and its daughters, including consideration of concentrating daughter products during processing and waste management. Chemical and metallurgical processes can displace the equilibrium existing in the original source material. Further guidance on when to assign thorium uptakes and what default assumptions should be used during various phases of thorium processing should be provided.

5.4.4 Technetium and Tritium Exposure

Although the presence of tritium is acknowledged in the ORAU-TKBS-0014-5 (Internal Dose)(Rich and Chew 2005) little is provided characterizing the relative significance of tritium exposure at Y-12, which categories of work or workers would likely involve potential exposure, and whether workers **not bioassayed** for tritium would have been likely exposed due to proximity to tritium sources. Presumably, tritium could have resulted from weapons package returns and dismantlement activities, and therefore, workers involved with those operations or workers who may have frequented those operational areas may have received exposure and may or may not have been bioassayed.

Technetium is a high specific-activity contaminant whose source is likely recycle uranium feed material.

In a 2001 Y-12 plant assessment of "atypical radionuclides," the following statement is made:

> *A total of 40 samples were taken and analyzed for tritium. The analysis indicated that the activity levels were below the laboratory MDAs, i.e., below the established values of Appendix D of 10 CFR 835 and DOE Order 5400.5.* (Y-12 2001)

A similar conclusion was reached for technetium. However it is not clear, given the passage of time and where samples may have been taken, whether this recent survey sufficiently

characterizes historic source terms for these radionuclides and can be used as a basis for characterizing past worker exposures to both technetium and tritium. From this standpoint, SC&A questions the assertion in ORAU-TKBS-0014-2 (Jessen 2005) that contemporary surveys, such as this one, following extensive decontamination activities at the plant over time and the passage of time itself can be seen as confirming "that the historical specification ensured that uranium was the dominating radiological hazard, even against current regulatory requirements." The TBDs need to address the significance of such exposure to determine the reliability of what monitoring took place and what the potential for missed dose may have been.

5.4.5 Neptunium

ORAUT-TKBS-0014-2 (Jessen 2005) notes that the "primary sources of transuranic materials (TRU) [$^{238\text{-}240}$Pu and ^{237}Np] were from the SRS and the Idaho Chemical Processing Plant (ICPP). However, the SC&A review indicates that Y-12 fabricated ^{237}Np alloy rods in specific campaigns in the 1960s for which radiation measurements of the rod containers were found to be about 250 mR/hour gamma 2 inches from the container (about 15 times that from uranium metal) (Francke et al. 1966). Y-12 also apparently considered and may have actually processed neptunium in the mid-1990s in Building 9203 (Thomas 1995). Given that the relative radiological hazard of ^{237}Np was found to be about 250 times that of Y-12's uranium production material (Francke et al. 1966), there is a need for the TBDs to better characterize which workers were involved in these specific processes and how they were monitored.

5.4.6 Plutonium and Other Radionuclides

The TBD addresses plutonium as a radionuclide of concern in the ORNL Y-12 facilities and as a contaminant of recycled uranium. Plutonium was not limited to recycled uranium and research activities. In fact, there were processes involving plutonium that plant managers denied for many years. The TBD assumes Y-12 employees did not support the ORNL operations involving radionuclides other than uranium. This was not the case for support organizations, such as security, janitorial services, maintenance, etc. (see Attachment 6).

Plutonium contamination was also a concern regarding salvage beryllium from Rocky Flats returns (West 1961). It was necessary for Y-12 to establish an acceptance level for plutonium contamination of 3.7×10^{-2} grams Pu/gram beryllium.

The following statement was made regarding processing transuranics at the Y-12 plant:

> *Additional, various short-term projects associated with component fabrication were performed at Y-12. Some of these involved transuranic material although they were not related to the processing of recycled uranium. These operations were performed in Buildings 9202, 9205, 9212, and the 9215 M-Wing Machine Shop.* (Oliver 1997).

Furthermore, the Health Physics group published uranium and plutonium urinalysis reports by building to keep line supervision informed of the various analyses made, including urinalysis and

air sampling data. A review of several of these reports indicated that a limited number of personnel from Buildings 9204-3, 9205, and the Special Materials Testing group were monitored for plutonium (West 1954c; West 1956b; Wollan 1954). There were also plutonium air sampling results from these areas. The inclusion of personnel from these areas in a plutonium bioassay program is indicative of work with plutonium in these areas. Plutonium was separated in the Calutrons, and was handled at the "plutonium laboratory" and Building 9203 (see Attachment 6). Historically, some parts or components were "sputtered" with plutonium.

The internal dosimetry TBD and dose reconstruction procedures instruct the dose reconstructor to assign internal dose from plutonium and other transuranics under the following conditions (Rich and Chew 2005):

(1) *When bioassay data is available for the radionuclide, and*

(2) *When work involved handling of plutonium such as in Research and Development (R&D)*

Although information is provided on impurity concentrations in incoming recycled uranium, there is no direction provided to the dose reconstructor on when internal dose should be assigned for these impurity radionuclides. There is no mention of potential missed dose by individuals who entered plutonium production and testing areas but were not included in the plutonium bioassay program (e.g., support services personnel).

There is no further mention regarding the process and possible exposures in the R&D of the Calutrons in Building 9204-3 or exposures in the production of the 225 isotopes produced. There is no information on exposures to polonium isotopes and alpha airborne activities. There is no description of the work involved and exposures to plutonium, except for the case of recycled uranium exposure. There is no further mention or description of possible exposures to radionuclides in research activities involving the Calutron, cyclotron (accelerator), and fusion work. There is no description of the work involving exposure to ^{232}Th or ^{3}H, or what is meant by "for organizations outside Y-12, ^{60}Co, and ^{95}Zr/^{95}Nb."

In summary, SC&A finds that the TBD does not adequately characterize the potential exposure to impurity radionuclides in recycled uranium. Consideration was not given to the concentration of these impurities and subsequent disposal of the raffinate in the Y-12 waste stream. Potential exposure from production operations with ^{233}U, thorium, plutonium, and other radionuclides has not been considered.

5.5 ISSUE 5: NEUTRON DOSIMETRY AND EXPOSURES

Neutron dosimetry is considerably more complex and difficult to assess than beta/photon dosimetry. Principle difficulties in assessing neutron dose relate to the technical capabilities of past dosimeters used at Y-12. Initially, Nuclear Track Type A emulsion (NTA) film was introduced at Y-12 in 1948 and used through 1989. From 1980–1989, it is assumed that Y-12 used the same neutron monitoring system as ORNL. This system used a combination of NTA film and thermoluminescent neutron dosimeters (TLNDs). It is unclear from the TBD during

what overlapping years both NTA film and TLNDs were used for neutron monitoring at Y-12. Since 1989, neutron dose has been measured using an albedo-type dosimeter.

SC&A has reservations about the assumptions made regarding the ability of NTA film to adequately characterize Y-12 worker exposure. Neutron radiation sources are not adequately defined in the TBD for all potential neutron exposure conditions at Y-12, including spontaneous fission neutrons, moderated (alpha, neutron) sources in solutions/compounds, subcritical and critical assemblies, and moderated neutrons from the 86-inch cyclotron. The assumption that most neutron exposure at Y-12 was from neutron energies greater than 500 keV, and therefore would be detected by the NTA film, is not adequately substantiated. In fact, Wilson et al. (1990) state that NTA is a poor detector of film energies between 500 keV and 800 keV. Fix et al. (1997) state that the threshold is about 700 keV and may be as high as 1 MeV. In general, the NTA film response decreases logarithmically as the energy decreases from 1,000 keV to 500 keV. Therefore, NTA may seriously underestimate the true neutron dose, and appropriate correction factors for this underestimate should be applied.

5.5.1 Neutron Energy Spectra Characterization

ORAUT-RPRT-0033 (Kerr 2005b) indicates that occupational exposure to neutrons was largely confined to the years 1952–1962 and to certain departments. During this period of time, 143 individuals have had positive neutron dose at Y-12. Furthermore, the TBD states the following (Kerr 2003, pg. 32):

> *It was also noted previously that there are a lot of recorded zeros in the neutron dose data for Y-12 workers for two reasons: (1) a worker's NTA film was not developed and read, or (2) a worker's NTA film indicated a neutron dose equivalent that was less than the film's MDL, approximately 50 mrem.*

Prior to 1962, the NTA film had a detection limit of 100 mrem. From 1949–1957, the badge exchange rate was biweekly, changing to monthly starting in 1958. By 1961, badges were exchanged quarterly (Kerr 2005b). Site experts indicated that when neutron badges were not read, the dose was recorded as a zero in the dose of record. The higher detection limit and the frequent exchange rates in the early years, and the NTA threshold of around 700–800 MeV, cast suspicion on the ability of early neutron dosimetry to effectively measure neutron exposure.

An adequate characterization of the neutron exposure conditions in light of the limitations of the neutron monitoring program should be further evaluated in order to insure the assumptions that neutron exposures were confined to particular years, departments, and energies are validated. Neutron spectrum measurements are limited to measurements made by PNL of the Calibration Laboratory in Building 9983, the Enriched Uranium Storage Area in Building 9212 B-wing, and the Nondestructive Assay Laboratory in Building 9720-5. ORAUT-RPRT-0033 (Kerr 2005b, pg. 12) further elaborates on the potential areas of exposure to neutrons, including areas in the following buildings:

- Assay Laboratory (9203 Room 8, 9205)

- Criticality Experiments Facility (critical assembly and reactor research)(9213)
- Electromagnetic Research (9201-2, 9204-3)
- Health Physics (9983 Calibration Laboratory)
- Instrument Department (9737)
- Chemical Operations (9202, 9206, 9212)
- Cockcroft-Walton linear accelerator
- 5-MeV Van de Graf accelerator.

NIOSH should also addresses potential exposures from neutrons associated with recycled uranium, as indicated in the following statement:

> *Neutrons of approximately 2 MeV energy are generated by the interaction of alpha particles from uranium with the nuclei of fluorides and other low-Z atoms. The magnitude of neutron flux will vary based on the total activity of uranium (which is a function of enrichment, U-233 and U-232 content) and the chemical compound in question (mixing U and F)… As a result, this concern is primarily associated with UF_4 and UF_6 or with materials containing beryllium, lithium or aluminum.* (Cox 1993)

In 1997, it was proposed at Y-12 that limits be placed on recycled uranium contaminants, so as to reduce the risks of neutron exposures (Cox 1997). NIOSH should determine the extent to which the risks of exposure to neutrons, particularly thermal neutrons, from recycled uranium have occurred, because of the presence of contaminants and inherent process chemicals that may have served to enhance neutron flux.

Other areas not considered in the site profile for potential neutron exposure include plutonium handling areas and other areas where highly enriched uranium may have been stored or processed outside the 9212 B-wing. The potential of exposures from lower-energy fission neutrons emitted from uranium and transuranic material was also not sufficiently addressed in the TBD. This is a potential area of missed or underestimated dose, because exposures from fission-energy neutrons could result in neutrons below the threshold of NTA film.

The TBD should be augmented to include additional information outlined in ORAUT-RPRT-0033 (Kerr 2005b) and site expert input, which provided valuable information of the flow process of material from receipt onsite to shipment offsite. Although the TBD has likely addressed the highest potential exposure scenarios from neutron, there is further investigation required to ascertain whether unmonitored neutron exposure occurred for individuals not directly involved in hands-on operations of neutron-producing material.

5.5.2 NTA Film Response

The TBD recommends the use of NTA film to assign neutron exposure based on neutron spectral studies of limited areas known to have neutron sources. The Hanford and Savannah River Site TBDs clearly reject the use of NTA film, based on the neutron energy spectra and the relative response of the neutron dosimeter. The focus in these site profiles was to apply a facility-

specific neutron-to-photon ratio to the penetrating dose to obtain a neutron exposure. These neutron-to-photon ratios were derived from the same NTA dosimeter information classified as inadequate for use in determining neutron dose. The Y-12 TBD abandons this approach, stating that the NTA film did not underestimate the neutron exposure, and thus does not need adjustment for under-response.

> *The recent PNL measurements also indicate that the past NTA film dosimeters worked reasonably well in the Y-12 workplace because Ra-Be and Po-Be neutron spectra used to calibrate them were reasonably well matched to the workplace neutron spectra. These measurements suggest that the NTA film dosimeters missed less than 10% of the neutron dose equivalent at the Calibration Laboratory of Building 9983 and less than 5% of the neutron dose equivalent at the Enriched Uranium Storage Area of Building 9212 and the Nondestructive Assay Laboratory of Building 9720-5.* (Kerr 2003, pg.27).

The TBD states that the neutron-to-photon ratios for the Calibration Laboratory, Enriched Uranium Storage Area, and the Nondestructive Assay Laboratory are 8:1, 1:1, and 25:1, respectively (Kerr 2003). Furthermore, the TBD states that neutron-to-photon ratios can only be used for the Enriched Uranium Storage Area in Building 9212. The TBD indicates that the neutron-to-photon ratios for the Calibration Laboratory and the Nondestructive Assay Laboratory, when applied to the photon dose, would overestimate the neutron exposure.

The TBD assumes that 90–97% of the neutrons were above a step-function threshold of 500 keV (or even above a 700-800 keV threshold), and were detected by the badge. This implies that 90–97% of the neutron dose is read and recorded in the worker's dose file. The threshold assumed in the TBD conflicts with the accepted threshold of >700 keV used in other TBDs, such as for the Hanford site, and may be as high as 1 MeV (Fix 1997). ORAUT-TKBS-0014-6 (Kerr 2003, pg. 17) acknowledges that there are limitations in NTA film with respect to low-energy neutrons.

> *In general, the response of the NTA film decreases with decreasing neutron energy that are greater than a **threshold** energy estimated to be about 500 keV… Results reported at the first AEC Neutron Dosimetry Workshop in 1969 indicated that laboratory dose measurements made with NTA film were about **one-half** to **one-fourth** of those measured with other methods including the TLND. . . The response of both dosimeters is **highly dependent** upon the neutron energy spectra, and both dosimeter types require matching the laboratory calibration neutron spectra to the workplace neutron spectra for **reliable** results.* [Emphasis added.] (Vallario et.al. 1969)

Given the potential underestimation of neutron dose, an attempt should be made to determine the expected neutron energy spectra under actual workplace conditions and in a variety of situations, and then apply the appropriate correction factors for each major work area in order to adjust the recorded neutron dose to the most likely neutron dose actually received. The amount of neutron spectral data is limited to a few areas, which were available for analysis during 1990. This does not necessarily represent neutron exposure conditions at earlier time periods, given the change in

material types and quantities and the level of operations prior to the PNL study. Neutron energy spectra shift fairly rapidly towards lower energies as surrounding material is added, especially hydrogenous material, ultimately affecting the response to the NTA film.

The TBD states that there are uncertainties in the details of the actual neutron dosimetry program from 1980–1989 prior to the complete implementation of the TLND. This coincides with higher production rates observed in the 1980s. There are implications that Y-12 used the same dosimeter as ORNL. This neutron dosimeter contained both NTA film and a TLND (Berger and Lane 1985). With individuals wearing both types of neutron dosimeters over the same exposure period, the NTA film response can be compared to the TLND response, which is capable of measuring both slow and fast neutron exposure. If the assumptions made in the TBD that the neutron spectra was composed of energies above the NTA threshold, the results from both dosimeters would be nearly the same. Further investigation on exactly what the monitoring program at Y-12 entailed during these years and subsequent comparison of NTA film and TLNDs is a method of comparison that should be investigated to determine the extent of the possible under-response in NTA film at Y-12.

SC&A concludes that NTA film dosimeter data might be deficient, resulting in under-estimation of true neutron exposures. Therefore, the use of such data for dose reconstruction may not be claimant favorable without validation of NTA results with TLND and field survey instrument results. The reference of a 500 keV threshold value for NTA film is not consistent with other technical documents, which state NTA film is a poor detector of neutron energies between 500 and 800 keV (Wilson et al. 1990). Fix et al. (1997) state that the threshold is about 700 keV, and may be as high as 1 MeV. The TBD's reference that more than 95% and 97% of the neutron dose is above the NTA film threshold is misleading, since it "suggests" that the film's response/accuracy is 95% to 97%. The response of NTA to neutrons between 500 keV and 1,000 keV varies by 2 orders of magnitude, as seen in Figure 6.3.2.2-1 (Kerr 2003, pg. 17). The implication is that there is a 95–97% response of the NTA film in this energy range, which is not the case.

Further evaluation of the energy spectra is required to validate the assumption that correction factors of 1.10 (i.e., 90% of the neutron dose was recorded) for workers in the Calibration Laboratory and 1.05 (i.e., 95% of the neutron dose was recorded) for workers in the Enriched Uranium Storage Area of Building 9212 and the Nondestructive Analysis Laboratory are sufficient to account for under-response in the NTA film. Additional correction factors for areas with potential neutron exposure should be developed and applied as appropriate.

5.6 ISSUE 6: RADIATION GENERATING DEVICES (RGDS)

The TBD intermittently mentions the use of radiation generating devices at the Y-12 plant; however, it does not take into account all radiological hazards associated with the operation of these units. Also, the TBD does not discuss how the film badge response to low energy x-rays may impact the recorded dose, and what correction factors are necessary to compensate for low-energy photon exposures from x-ray fields. Although the TBD recognizes that the 86-inch cyclotron was used for isotope development, there is no discussion on what the isotopes of

concern for internal dose may be from this operation. Finally, there is no discussion on smaller cyclotrons that may have operated for only a short period of time. Although some of these devices may have been operated by ORNL personnel at the Y-12 complex, there is still a potential for exposures to Y-12 personnel, which should be included in the TBD.

Radiation generating devices are briefly discussed as a source of radiation exposure in ORAUT-TKBS-0014-2 (Jessen 2005, pg. 18). The TBD lists linear electron beams, electron beam welders, scanning electron microscopes, x-ray photoelectron spectrometers, secondary ion mass spectrometers, enclosed beam diffraction equipment, and x-ray equipment. Energy emitted ranged from 15 keV to 9 MeV. ORAUT-TKBS-0014-5 (Rich and Chew 2005, pg. 6) discusses the use of a proton-accelerating cyclotron used from 1950–1980 in Building 9201-2. This unit produced an inventory of 225 isotopes over the course of operations creating the potential for internal exposure to polonium, airborne alpha activity, and other possible radionuclides. Although the TBD indicates that the dose reconstructor should consider the potential of intakes from radionuclides other than uranium, no additional guidance is provided. ORAUT-RPRT-0033 (Kerr 2005b) also provides information on the 86-inch cyclotron, which was a significant source of neutron exposure at the Y-12 site. The information from ORAUT-RPRT-0033, which provides further information on the role of and radiological hazards associated with the cyclotron, has not been incorporated into the TBD and would benefit the dose reconstruction process. Furthermore, there are other accelerators that are not mentioned in the TBD that pose both internal and external exposure potentials.

5.6.1 X-ray Machines

Industrial x-ray units and other potentially high-exposure sources were used at Y-12 for nondestructive testing and instrument calibration. Among these units were 10 x-ray machines that were in use in this area, ranging in size from 40 kVp, 16 mA to 1 MeV, 10 mA (Emerson 1951). Struxness (1949) states that a 1 MeV, 3 mA unit was installed in Building 9212 during January 1949. Center (1950) indicated that x-ray fields were also an issue with the high-voltage rectifiers used in many systems. Other devices that could have generated x-ray fields included linear electron beams, electron beam welders, scanning electron microscopes, x-ray photoelectron spectrometers, and secondary ion mass spectrometers.
In addition to routine exposures from x-ray units, there were accidental exposures from x-ray units, resulting in substantial doses. In 1961, an x-ray overexposure occurred when a worker in Department 2259 was exposed to an x-ray beam without realizing the machine was in operation at the time. The worker received 4,646 mrem of exposure, 93% of the Radiation Protection Guide at the time (McLendon 1962). On April 25, 1965, two employees were inadvertently exposed to an x-ray beam while attempting to radiograph a welded part. The machine experienced a short circuit, and the unit began operating continuously although the unit appeared to be shut off. When a third employee entered the room with an audible pocket radiation monitor, the two operators discovered the unit was on. The resulting whole-body doses to the 2 men were 19 and 11 rem. Portions of the one worker's hand received an estimated dose of 3,500 rem (AEC 1965). There are clear situations when dealing with x-ray or other collimated units where portions of the body could have experienced significantly higher doses than those

recorded on the film badge. The TBD should explore the potential exposure condition during work with these types of units, especially for inadequately monitored or unmonitored workers.

In addition to the x-ray-producing devices, the site used both portable and stationary gamma and photon sources at the Biological Sciences facilities (Dickens 2003):

- 1,300-Ci and a 65 Ci ^{137}Cs source at Bldg 9207
- 80-Ci ^{137}Cs source at Bldg 9779-2
- 3.9-Ci ^{252}Cf (800 mrad/h at 1m, neutron + gamma) at Bldg 9983-17

A 10-Ci Cobalt source was installed at the Y-12 complex in January 1949 (Struxness 1949).

The source of radiation exposure from these units would be from the x-ray and gamma photons themselves, ranging in energy from 40 kVp to 1.33 MeV. The 2 MeV neutrons from the relatively large ^{252}Cf source could also have potential for exposure to workers. The TBD should include discussion on the relative response of dosimeters from radiation emissions of this type and correction factors for under-response in the dosimetry system. For example, there is no indication in the TBD whether film badges were calibrated to match the x-ray energies emitted by x-ray equipment. Adjustments for low-energy photon exposure, similar to x-ray exposures at Y-12, was a part of the program at Hanford and resulted in an increase in the recorded deep dose by applying a fraction of the open window measurement to the deep dose. At the Savannah River Site, a special calibration curve was applied to badge results for dosimeters potentially exposed to low-energy photons, such as workers in plutonium areas or medical x-ray technicians.

5.6.2 Accelerators

Several accelerators were in use at the Y-12 plant. Many of these accelerators were used by ORNL at Y-12 for research and development activities and isotope production. Accelerators included the 86-inch cyclotron, the 63-inch cyclotron, the 22-inch cyclotron, and the Van de Graff accelerator.

The subject of Y-12 personnel exposure to radiation produced by the 86-inch cyclotron is not mentioned in TKBS-0014-6 (Kerr 2003). ORAUT-RPRT-0033 (Kerr 2005b) provides a more detailed description of the 86-inch cyclotron as a potential source of neutron exposure, as follows:

> *Much of the neutron dose to workers at the Y-12 Plant in the 1950s appears to be associated with research activities at the 86-Inch Cyclotron. The neutron-to-gamma dose ratios may have been quite large in the stray neutron fields in normally occupied areas near the cyclotron, but they were probably moderated by additional exposures to gamma rays from neutron activated materials in the cyclotron vault.*

The 86-inch cyclotron was operated from 1950–1980s in Bldg. 9201-2 at Y-12 by ORNL. This radiation source created slow and fast neutrons (Center 1950). As of 1950 this unit was

accelerating protons up to 26 MeV at up to 5 mA of current to study (p,n) reactions on copper. A neutron flux of 10^6 n/cm^2/sec was measured inside the pit with 5 ft of concrete wall and ceiling shielding around the pit, with two maze openings. Health physics problems were encountered from the zinc activation in the copper targets with a 50-microampere beam for a few seconds, causing 20 R/hr readings, but with a short half-life. Therefore, the targets were allowed to cool and were handled with lead gloves, with plans to install remote handlers (CCCC 1951). The isotope production program caused the most exposure. Additional shielding was added around door/maze and refrigerant pipe penetrations (Struxness 1953). Each worker in the vicinity of this unit was assigned a film badge, two pocket ionization chambers sensitive to gamma and two pocket ionization chambers sensitive to thermal neutrons. No permanent record of these dosimeter results was maintained, because the purpose of their use was to minimize exposure. Film badge results from this area for the first half of 1952 are provided in Table 6.

Table 4: Exposure Analysis in the 86-inch Cyclotron Area for January 1, 1952–July 1, 1952 (Struxness 1953)

Exposure Range (mrem/week)	Number of Exposures
< 100	1,144
100 – 300	88
300 – 500	11
500 – 1,000	4
>1,000	3

In addition to external exposures, high airborne concentration levels existed in the alignment dock because of contaminated equipment held over during shutdown. During shutdown, air samples ranged from 16–2,077 dpm/m^3. (Struxness 1953). Other radiological hazards, such as activation of equipment and materials, and potential exposures from target material have not sufficiently been discussed.

Four additional accelerators used at Y-12 included the 63-inch Cyclotron, the 22-inch Cyclotron, the Cockcroft-Walton linear accelerator, and the Van De Graff accelerator. The 63-inch Cyclotron was designed to accelerate triply ionized nitrogen atoms at any energy up to 25 MeV at 1 to 10 microamperes. No shielding was planned for this unit (Struxness 1952), which was to begin operations in July 1952. The 22-inch Cyclotron was installed in one of the beta tracks for use as an aid in studying ion sources, beam deflection, and associated problems. This system accelerated protons up to 2 MeV. The predominant radiation hazard was from x-ray generation. There were some issues with water leaks and liner damage associated with this unit (Livingston and Zucker 1961). A Cockcroft-Walton linear accelerator capable of producing a maximum of 1×10^{10} fast neutrons per second and a 5-MeV Van de Graff accelerator capable of producing a fast neutron flux of 560 n/cm^2/s near the target, were also installed at the Y-12 facility (Kerr 2005b).

The main radiation hazards around these accelerators would be prompt gamma and neutron radiation, and decay gamma and beta radiation from activated targets and structural components. Additionally, operators and maintenance personnel that worked on the structural components and

target holders may have been exposed to both external and internal radioactive compounds from such things as radioactive copper and other metals during Dee repairs, electrical repairs, and other maintenance activities. This is particularly true of work inside the units.

Incidents of internal exposures from working on such accelerators did occur at some other research facilities during this era. For example, at a 60-inch cyclotron in 1962, a crew of 10 workers acquired body burdens of up to 9 nCi of ^{65}Zn from inhaling fumes from soldering radioactive copper. Some accelerator workers at an 88-inch cyclotron showed positive for alpha, beta, and gamma internally deposited radioisotopes (Patterson 1973, pgs. 528 and 529).

The development of a D&D source of mono-energetic neutrons was mention in a 1950 letter from C.E. Center to S.R. Sapirie of the AEC (CCCD 1950) as a potential source of slow and fast neutrons. No other references to these experiments were found.

5.6.3 Critical Assemblies

A letter from the Pile Hazard Committee dated January 9, 1947 (Leverett 1947) discussed the safety issues with the pile that was being built at that time at Y-12. The Critical Experiments Facility (CEF) was operated at Y-12 by ORNL from 1950–1992. There were four major incidents at the facility during its operations, but no major personnel overexposures occurred as per E. Dickens (Dickens 2003, pg. 32).

Prompt thermal/fast neutrons and gamma-rays could have been present in and around the CEF, as well as activation products that presented gamma, beta, and alpha exposure potentials. From the information available (Kerr 2005b, page 20), it appears that, in the later years, they were aware of the radiation fields present at the CEF. However, not much has been said concerning the early years of the facility or if any prototype assemblies were constructed in the very early years at Y-12 (1947–1950) before the CEF was finished.

In view of the potential internal and external exposures to Y-12 workers directly operating or supporting operations of these units, it would seem appropriate to include some discussion of Y-12 CEF and prototype assemblies, and the potential exposure conditions associated with each unit. Discussions on effectiveness of personnel monitoring, such as external dosimeters and bioassay techniques to determine exposure to personnel, should also be included as a part of the discussion. A portion of this work has been completed in ORAUT-RPRT-0033 (Kerr 2005b); however, this information is not integrated into the TBD or referenced by the TBD.

5.7 ISSUE 7: DESCRIPTION OF HISTORIC Y-12 OPERATIONS AND RADIOLOGICAL CONTROL PRACTICES

The TBDs do not go into enough depth on the varying and changing nature of Y-12 operations and work environments to provide the dose reconstructors with the specific knowledge that is needed for specific group or individual dose reconstructions. It is important to adequately understand the potential hazards and dose potential for each operation performed. Changes in operations that occurred over varying periods and the changing mission of facilities and

buildings can also impact the dose that individual workers or groups of workers might have received. The ability to reconstruct dose in these many unique and varying types of functions related to a worker's dose potential in a specific job is dependent on a better-developed description of individual or group activities and how their operations were modified by different mission redirection.

5.7.1 Operational Process Descriptions

The TBD acknowledges that buildings at Y-12 underwent several changes to accommodate mission demands. These changes should be more fully developed in the TBDs. Sufficient details should be provided about each process and the radiological practices employed at that time, and the degree to which these practices were effective in monitoring and minimizing doses to workers.

Thousands of nuclear weapons were produced between 1945 and 1990. As the primary uranium foundry complex for the nuclear weapons program, there is little doubt that Y-12 had a significant role in the production of the vast preponderance of U.S. nuclear warheads. In fact, as observed by Y-12's operating contractor, BWXT, "Every weapon in the nation's stockpile has some components manufactured at the Y-12 Complex" (BWXT 2003).

In the late 1940s, the Y-12 Plant began making uranium weapons parts, which up to that point, had been made at Los Alamos. In 1953, the Y-12 Plant began producing lithium-6 and "secondaries" for the newly developed thermonuclear weapons. In 1962, the AEC decided to consolidate uranium component production at the Y-12 Plant, and existing capabilities at Rocky Flats were transferred to Y-12. Beginning in 1982, Y-12 began to store the stockpile of heavy water produced by SRS, a potential source of tritium.

From 1943 to the present, Y-12 Plant's activities have encompassed the following:

- Separation of ^{235}U (Jessen 2005) — 1943–1947
- Manufacturing fission-fueled nuclear warheads (Cochran 2005) — early 1950s to the mid-1960s
- Manufacturing nuclear weapons components, including primaries, and thermonuclear secondaries (canned subassemblies (CSA)) (Cochran 1987; DOE 2002a) — mid-1950s to 1992)
- "Special projects," such as reactor fuel production (Klein 1994), and processing of ^{233}U (West 1962; Cox 1997) — 1950s and 1960s
- Disassembling fission-fueled nuclear warheads (Norris 2004) — early 1950s to 1992
- Disassembling thermonuclear weapons secondaries (Norris 2004; DOE 2002b) — mid-1950s to the present

- Storing weapons components, various highly-enriched uranium compounds (DOE 1996), small nuclear reactors (Klein 1994), spent reactor fuel, sealed sources and other materials containing actinides (DOE 1994b; DOE 2005a), and other nuclear materials (DOE 1996) — 1940s to the present

Since 1994, when enriched uranium metal production was shut down for criticality safety reasons, Y-12 has been undergoing refurbishment and upgrades of processing equipment to resume production. There have been tons of highly-enriched uranium held-up in deteriorated process equipment and in packages, awaiting stabilization, packaging, and safe, secure storage (DOE 1996).

The TBD does not provide complete information on the manufacturing, assembly, disassembly, and storage of nuclear weapons and weapons components. Specifically, the TBD does not provide (1) information regarding important process changes, "special projects," and radiological incidents (2) complete data on radionuclides of concern, and (3) information regarding problems related to radiological controls and other exposure risks, including those in the present time frame.

Y-12 was actively involved in the dismantling of warheads since the end of the Cold War (Norris 2004). A part of these activities included disassembly of secondaries and subsequent storage. Highly enriched uranium is also stored at the Y-12 plant upon completion of disassembly. As of 1996, there was a backlog of units awaiting processing, stabilization and storage at the facility (DOE 1996). The TBD for the Y-12 plant should provide a chronology of the nuclear warhead types manufactured and disassembled at the site similar to that provided by NIOSH for the Iowa Army Ammunition Plant (Leonwich 2005).

Given the magnitude of production of the U.S. nuclear arsenal, the complexity of the Y-12 operations, and the deteriorated state of facilities (many between 40 and 62 years in age), the TBD only provides cursory information regarding processes that are necessary for the dose reconstructor to understand the degree and extent of radiological hazards to workers.

Y-12's "9212 complex" serves as an example of the complexity of the operations of many of the operations at Y-12 that need to be more fully described in the TBD. The TBD contains several references to 9212 and acknowledges that, "9212 housed the largest chemical operations for EU purification recovery and chemical conversion as well as normal and DU machining operations" (Jessen 2005), and "more than 100 operations and processes were performed in this complex" (Jessen 2005). However, the TBD does not provide much detail of specific processes in this large and important operation.

The HEU assessment for Building 9212 provides important details regarding "special operations" not included in the TBD, including:

- *Packaging and shipment of uranium metal and oxide for research/medical reactor fuel fabrication,*

- *Operation of an evaporator for the processing of low uranium content solutions such as mop water…;*
- *Receipt and storage of HEU from Rocky Flats;*
- *Receipt and storage of solutions from the plant laboratory.* (DOE 1996)

In terms of incidents at the 9212 facility, the HEU assessment notes the following:

> *A review of the Occurrence Reporting System indicated that since 1990, there have been 130 reportable Off-normal events (category III) and eight Unusual Occurrences (Category II) pertaining to the enriched uranium operations at the 9212 Complex. The preponderance of the Off-normal events was uranium contamination incidents (75). The next largest group of events were releases from exhaust stacks (17).*

Prior to the utilization of the occurrence reporting system, the following significant events took place in Building 9212 (DOE 1996):

- *Improper uranium transfer (1990)*
- *Exceeding criticality safety limit in a 55-gallon combustible drum (1989)*
- *Uranium release from stack 42 (1987)*
- *Operator uranium exposure (1986)*
- *Uranium chip fire (1985)*
- *Uranium accumulation in exhaust stack (1983)*
- *Large geometry plastic bag used to collect uranyl nitrate leak (1967)*
- *Criticality Accident in C-1 wing (1958)*

Significant information pertaining to specific activities and changes in Y-12's numerous buildings that span the history of the site is missing. NIOSH should provide a greater depth of analysis on how these processes impact the dose to the worker. Without a better understanding of these details, the dose reconstructor is limited in his or her ability to adequately characterize dose to the claimant for all the different types of jobs performed and for potential exposure to situations that may not have been adequately monitored.

5.7.2 Radiological Controls

NIOSH has not provided enough information regarding the radiological controls in place (or lack thereof) for the operations at Y-12 that pose the greatest potential for significant exposures by job category and facility location. Especially in the early days, lack of adequate radiological controls can lead to worker doses that may be missed in the process of dose reconstruction. Such worker doses may not be identifiable without this understanding of the effectiveness of the radiological controls in place in specific locations, during specific evolutions, and for work practices where significant dose is possible. This appears to be even less developed for "legacy contamination."

Perhaps the most telling of a number of independent health physics reviews that have been conducted of Y-12 radiation protection practices was an April 1993 review that was conducted by professional staff of the DNFSB (1993). That these findings were made after the contamination control program upgrades of the mid to late-1980s are significant and indicative of the deep-rooted radiological management practices at the facility. This review found the following:

> *…there are numerous instances where Y-12 is not in compliance with DOE Order 5480.11, the DOE Radiological Controls Manual, or consensus standards. In many of these cases there is no documented technical justification for the condition and no compensatory measures are in place.* (DNFSB 1993)

The review further noted the following:

> …*it appears that DOE-ORO and MMES* [Y-12 operating contractor] *do not feel they have the resources to implement many of the mandatory requirements of the DOE Radiological Control Manual.* (DNFSB 1993)

The DNFSB staff review detailed a spectrum of long-standing programmatic deficiencies in the occupational radiation protection program:

- **Contamination control: "**Some of the most basic tenets of contamination control are not being followed in many facilities at Y-12. This condition greatly increases the possibility of the spread of contamination to uncontrolled areas and the unnecessary exposure of personnel to contamination" (DNFSB 1993).
- **Personnel monitoring: "**Personnel monitoring is not currently required at egress points from all routinely occupied loose surface contamination areas at Y-12…" (DNFSB 1993)
- **Anti-contamination clothing: "**Personnel in some known loose surface contamination areas at Y-12 (including areas where there is no egress monitoring) normally wear only lab coats and shoe covers as anti-contamination clothing" (DNFSB 1996).
- **Break areas:** "…personnel are allowed to exit posted contamination areas and enter eating areas after surveying only their hands and donning a clean lab coat and shoe covers over potentially contaminated clothing" (DNFSB 1996).
- **Personnel decontamination:** There are numerous boundary control stations at Y-12 where personnel are required by procedure to wash their hands before monitoring for potential skin contamination [in violation of the DOE Radiological Controls Manual and standard industry practice].
- **Training:** Current training procedures and practices at Y-12 do not ensure radiation workers complete all radiation safety training required by DOE Order 5480.11 prior to being allowed unescorted access to radiological areas (DNFSB 1993).

In 1995, the staff of the Energy Department's Defense Nuclear Facility Safety Board reported the following:

> *The mission most relevant to safety is one of processing the backlog of in-process materials at Y-12.* ***In Building 9212, these materials occupy space in the hallways and operating corridors and some have been present for more than 40 years.*** *The in-process materials do not meet the criteria for interim or long-term storage and no criteria for in-process storage have been developed. In-process materials form the largest portion of the "material at risk" considered in Building 9212 accident analyses and contribute significantly to the dose consequences of those accidents. These materials pose the greatest risk for spills, decomposition, or criticality safety infractions, make inventories difficult, and increase worker exposure risks due to their location in the workplace.* (DOE 1995) [Emphasis added]

According to the DOE's 1996 HEU vulnerability assessment, legacy contamination was considered a significant vulnerability to workers:

> *Beginning in 1988, significant upgrades to Radiological Control Programs were initiated. Prior to 1988 controls were in place for materials leaving the production area of the Y-12 plant. However, uranium contaminated items could be stored essentially anywhere within the western end of the plant. Uranium contaminated items could also be freely transported between production buildings without rigid controls to prevent the spread of uranium contamination. Because of these past practices, low-level alpha contamination exists in various places throughout the western end of the plant. The most logical spaces for uranium contamination to exist have been surveyed accordingly.*
>
> *However, a comprehensive survey has not yet been completed. Workers can be at risk from contamination that is the result of nearly 50 years of nuclear weapons manufacturing in two ways. First, there is always some risk of a small radiation exposure through inhalation or ingestion of uranium contamination outside radiological control areas. Secondly, the large operating spaces that are contaminated require in facility workers to be 'fully dressed out' in anti contamination clothing and sometimes respiratory protection for extended periods of time. In addition, the presence of radiological controls in outdoor areas (e.g.,* ***rooftops****) present a potential for spread of contamination due to precipitation or windblown vegetation.* [Emphasis added] (DOE 1996)

Unfortunately, in recent times, unexpected exposure from uranium contamination has resulted in significant personnel exposures. The following describes a contamination incident that occurred in September 1998:

> *…elevated levels of uranium were observed in bioassay data for one individual working in Building 9212 E-Wing casting operations…A total of 12 individuals are under radiological work restriction and about 60 operations and support personnel are being monitored for elevated levels. Possible causes under review*

> *include overall E-Wing contamination control and work practices in the casting knockout line and material handling areas in E-Wing*" (DOE 1998a).

Subsequently, the following was reported:

> *…bioassay (fecal) results for one E-Wing worker have exceeded the LMES administrative control level of 1000 mrem/year (i.e., 1124 mrem CEDE). He and three other workers who are approaching this limit have had their administrative control level increased to 1500 mrem.* (DOE 1998b)

In March 2000, the inability to remove contamination sources persisted, as evidenced by the following:

> *In many of the unoccupied spaces around the Y-12 Plant, bulk waste containers and numerous bags have been accumulating (see item on 9212 E-Wing). Much of this waste is defective or obsolete hardware, renovation debris, or combustible trash, much of it potentially contaminated with uranium compounds.*
> (DOE 2000a)

Slow progress in nuclear material stabilization and removal has been exacerbated by difficulties in accessing historic process information. In 2002, the DNFSB staff noted the following (DOE 2002b):

> *On Monday, the site representative and an NNSA facility representative toured Building 9201-5 (Alpha-5). Of the approximately 500,000 ft² structure, only about 10 - 20% is utilized by Depleted Uranium Operations to operate a vacuum arc remelt furnace and associated support operations. The remainder of the building contains material and equipment that was either abandoned in place or has been shifted from other facilities for indefinite storage.* ***It is apparent that the very large inventory of deserted and abandoned material will be a challenge for future deactivation and decommissioning efforts. Of particular concern is the appropriate identification of hazards given the questionable control of previous shutdown activities.*** *At the time parts of the facility were deactivated, the facility was parsed into approximately 80 "capability units" (CUs). A series of deactivation walkdown packages for ~25% of the CUs were completed by 1997, but funding limitations resulted in the termination of the effort.* ***An additional source of information on potential hazards is from interviews of approximately 240 veteran employees conducted under the Y-12 Knowledge Preservation Program during the 1993 to 1997 time frame. Transcripts of these interviews are searchable through a sophisticated database, but a priori knowledge is essential to understanding the content of the search results. It is apparent that information important for efficiently assessing safety of future decommissioning activities is dispersed among several organizations and will require a substantial effort to appropriately characterize hazards associated with decommissioning the facility.*** [Emphasis added] (DOE 2002b)

The accumulation of HEU for storage at Y-12 has increased because of the return of weapons components, shipments of excess HEU from other DOE sites, and the safety-related delay in resuming uranium recovery operations. Despite the eventual full resumption of recovery operations in the 9212 building, HEU storage inventories may increase to the bounding quantity for off-site shipments of 98.4 metric tons (DOE 1996):

> *Increased storage has the potential to increase the level of radioactivity exposure to workers, either due to higher volumes of material or storage of different types of material. The net effect is that the potential for higher levels of radioactivity exposure to workers could require new radiological controls or potentially result in higher exposure to workers.* (DOE 1996)

Unfortunately, the inability to remove and process potential sources of contamination continues to plague the site as of 2005. These long-standing problems can significantly impact the quality of dose reconstruction, which NIOSH should address.

> *Building 9204-4 personnel determined that seven drums containing machine chips were not vented. Some of these unvented drums have been loaded since 1990; several other drums containing depleted uranium chips are vented or have pressure relief devices. The chips are supposed to be in water but no drum inspections are known to have been performed and the water levels in the drums are not known.*
>
> *The chips are being stored as there is no current processing/disposition path for the chips due to a processing concern. A February 2001 Y-12 technical report was identified addressing depleted uranium machine chip storage. This report noted the pyrophoric and reactive (hydrogen generation in water) nature of the material. The report provided 'recommendations' that chips be stored in water with vented drums and that inspections be conducted on a regular basis to check for water level, drum condition and any chip corrosion or sludge. The report noted 'Interim storage of chips under water is considered acceptable only when it is unavoidable.'* (DOE 2005b)

The lack of radiological control, especially in the case of contamination control and environmental release, should be discussed in the TBD in relation to the potential for routine and special exposure conditions. These issues pose major obstacles to dose reconstruction by NIOSH. Of particular importance to dose reconstruction are the transcripts of interviews by veteran Y-12 employees generated by the "Y-12 Knowledge Preservation Program," as noted above. NIOSH should seek to obtain these transcripts from the DOE in an expeditious manner.

5.8 ISSUE 8: OCCUPATIONAL ENVIRONMENTAL DOSE

This section of the Y-12 site profile review addresses the TBD for Y-12, *Occupational Environmental Dose* (Ijaz and Adler 2004). In the remainder of this section, the report of Ijaz and Adler (2004) will simply be referred to as the TBD.

5.8.1 Additional Exposure Pathways

The TBD addresses only two exposure pathways; inhalation of the three naturally occurring uranium isotopes—^{234}U, ^{235}U, and ^{238}U—in ambient air, and external exposure to direct penetrating radiation. There are at least two other potential pathways that need to be addressed; (1) inadvertent ingestion of radioactively contaminated soil and other finely dispersed radioactive materials, and (2) inhalation of radionuclides other than the three naturally occurring uranium isotopes. These pathways are discussed below.

5.8.1.1 Inadvertent Ingestion

Whenever individuals perform outdoor work, there is a potential for ingestion of soil and other windblown particulates that are larger than the respirable particles. This pathway is traditionally included in dose assessments (see EPA 1997). This pathway is always difficult to assess, but a scoping calculation should be performed to place an upper bound on the dose that could be delivered.

5.8.1.2 Other Radionuclides

According to Ijaz and Adler (2004), Station HP-12 (also known as HP-32) was dedicated to monitoring for fission products. Since this station was just outside the Y-12 facility, and operated during the period 1959 – 1970, an effort should be made to uncover these data. Furthermore, Station 40, also on the Y-12 perimeter, monitored ^{131}I, other fission products, and transuranics. The TBD should attempt to quantify or provide upper-bound estimates of the concentrations of such other nuclides.

Buddenbaum et al. (1999) report that the X-10 facility handled irradiated thorium, radioactive lanthanum, and plutonium. Airborne effluent emissions from that plant included ^{233}U. This isotope has a much higher specific activity, and somewhat higher effective dose coefficients, than the other uranium isotopes. Thus, if this nuclide was included in the total uranium, expressed in $: g/m^3$, measured at the Y-12 facility, it would have a significantly greater radiological impact. Furthermore, when ^{233}U is produced by irradiating ^{232}Th in a reactor, ^{232}U is an inevitable by-product. Although its mass concentration is in the range of 5–50 ppm in the uranium metal, it has an extremely high specific activity, due to its short (68.9-y) half-life, and has effective dose coefficients that are several times higher than those of ^{234}U.

Although the ORNL facility was about 6 km from Y-12, this source could prove to have a significant impact during periods of high releases, depending on the wind rose and other meteorological conditions. At the very least, the TBD should provide a scoping analysis to demonstrate that releases from facilities other than Y-12 would have no significant impact on workers on that site, if the authors have reason to believe that this is the case.

5.8.2 Inhalation of Uranium

The radiological assessment of the inhalation of uranium particulates on site at Y-12 involves two issues: (1) average activity concentrations of uranium isotopes in the ambient air,

(2) chemical form (i.e., lung clearance type) and particle size. We will first discuss the methodology that the TBD used to calculate the historical uranium air concentrations.

5.8.2.1 Average Activity Concentrations of Uranium

The TBD used annual-average air concentrations of uranium, expressed or calculated as mass loadings (e.g., kg/m^3), from four stations within the Y-12 perimeter, coupled with estimates of the mass of uranium released each year from the Y-12 facility, to calculate values of annual-average values of atmospheric dispersion coefficients (P/Qs) for uranium releases. Although this is a straightforward mathematical exercise, we question the validity of this empirical P/Q approach for estimating uranium concentrations in the ambient air for periods for which no air concentration data are reported in the TBD.

Emprical P/Q Approach: General Observations

The empirical P/Q approach is based on several premises that are not explicitly stated and which need to be explored and justified before this approach could be accepted.

(1) All the occupationally related airborne activity originates at Y-12. Y-12 is part of the ORR complex, which includes other sources of radioactive material. The varying correlation of the airborne uranium concentrations to releases from Y-12, especially at Station 12, calls this hypothesis into question. (See also the discussion under "Other Radionuclides" earlier in this section.)

(2) In Section 4.2.5, the TBD attributes the poor correlation at Station 12 to the paucity of data. The smaller number of data points (8 vs a maximum of 17) does not account for the virtual lack of correlation shown in Figure 4.2.5-4. If anything, fewer data points would lead to a better correlation, both on mathematical grounds (fewer degrees of freedom), and on physical grounds, because meteorological conditions would vary less during a shorter time period. Despite this lack of correlation, the TBD uses the Station 12 data in creating a framework for dose reconstruction.

(3) Resuspension of uranium deposited on soil, both inside the Y-12 perimeter and off site, is ignored. Resuspension of deposition during previous years could contribute to the uranium concentration in air, yet is uncorrelated to uranium releases from Y-12. Although one of the authors observed that the topography and ground cover of the area would lower the potential for resuspension,[5] scoping calculations or upper-bound estimates of the potential exposure from resuspension should be included in the TBD (Ijaz and Adler 2004).

(4) The influence of other sources of uranium—releases from sources outside Y-12 or resuspension from onsite soils—is clearly indicated by the data for 1993. The uranium release of 3 kg for that year is the lowest during the period that Stations 2 and 12 were operating, and the second lowest during the 17-year operating period of Stations 4 and 8. The 1993 calculated P/Q's for all four stations are the highest of any year that these

[5] See minutes of telephone conference among ORAU, NIOSH, and SC&A staff members dated June 10, 2005.

stations operated. The data from Station 2, which SC&A subjected to an independent statistical analysis, show a **negative** correlation between the calculated P/Q's and the annual releases of uranium—the lower the releases, the higher the P/Q.

(5) The TBD states that the calculated P/Q's follow a lognormal distribution *with a high-end tail.* Yet, in assigning 95th percentile values, where the high-end tail would have the greatest influence, that aberration from lognormal behavior is ignored. An examination of the data in Tables 4.2.3-1/4 reveals the following:

A. Station 2: Out of 12 calculated P/Q's, 1 is significantly higher than the 95th percentile value (2.00×10^{-14} vs. 1.31×10^{-14}). Statistically, the highest of 12 values would correspond to the 92nd percentile.

B. Station 4: Out of 17 calculated P/Q's, 1 is over 1.7 times higher than the 95th percentile value (8.73×10^{-14} vs. 5.03×10^{-14}). Statistically, the highest of 17 values would correspond to the 94th percentile.

C. Station 8: Out of 17 calculated P/Q's, 2 are higher than the 95th percentile value. Statistically, the second highest of 17 values would correspond to the 88th percentile.

D. Station 12: Out of only 8 calculated P/Q's, 1 is higher than the 95th percentile value. Statistically, the highest of 8 values would correspond to the 88th percentile.

(6) The above observations clearly indicate that the distributions are not lognormal, and that the assumptions used by ORAU to calculate the 95th percentile P/Q's are not claimant favorable, aside from the questions raised earlier in this discussion about the validity of the empirical P/Q approach. This conclusion is further buttressed by our statistical analysis of the Station 2 data, which exhibit the best correlation between the annual releases and the annual average air concentrations of uranium. Subjecting the calculated P/Q's to the *W* test (Gilbert 1987, Section 12.3.1) shows that there is a 10% to 50% probability that the distribution is lognormal. In other words, there is a better than a 50% chance that the distribution is **not** lognormal.

(7) The estimates of uranium releases from Y-12 cited in Tables 4.2.3-1/-4 are taken from Buddenbaum et al. 1999. The estimates for the years 1983–1988 were independently calculated by these authors, and are, in general, significantly higher than the estimates provided by DOE. The releases for 1988 and later years are based on DOE reports and were not recalculated. The use of such mixed data in calculating the empirical P/Qs appears to make a significant contribution to the scatter in the results. The P/Qs for 1983–1988 for the three stations—2, 4, and 8—for which such data are tabulated are listed in Table 5. The values for each station display coefficients of variation[6] with a range of 19%–34%, and an average of 25%. In contrast, the coefficients of variation for the years 1989–1999 (1989–1994 for Station 8) display coefficients of variation with a range of 136%–230%, and an average of 173%.

[6] Defined as the ratio of the standard deviation to the mean

Table 5: Calculated P/Q for Three Stations at Y-12 Facility (m^{-3})

Station Year	2	4	8	Average
1983	4.37E-15	6.27E-15	1.24E-14	
1984	4.98E-15	7.74E-15	7.19E-15	
1985	5.08E-15	1.22E-14	1.24E-14	
1986	4.75E-15	1.49E-14	1.11E-14	
1987	2.68E-15	7.17E-15	8.08E-15	
1988	3.94E-15	7.11E-15	8.38E-15	
Mean	4.30E-15	9.23E-15	9.93E-15	
C_v[a]	19.1%	34.5%	21.3%	25.0%
1989	7.56E-15	1.89E-14	2.33E-14	
1990	8.67E-15	1.29E-14	1.51E-14	
1991	3.12E-15	4.44E-15	1.08E-14	
1992	4.72E-15	2.06E-14	1.21E-14	
1993	2.00E-14	5.03E-13	1.30E-13	
1994	2.08E-15	5.00E-15	3.33E-15	
1995	1.00E-13	4.00E-14		
1996	9.00E-15	9.00E-15		
1997	1.51E-14	2.50E-14		
1998	1.10E-15	1.10E-14		
1999	2.00E-14	2.00E-14		
Mean	1.74E-14	6.09E-14	3.24E-14	
C_v	155%	230%	136%	173%
Ratio[b]	4.0	6.6	3.3	

[a] Coefficient of variation

[b] Ratio of 1983–1987 mean to 1988–1999 mean (1988–1994 for Station 8)

Clearly, the data for 1983–1988 show much better correlations between the measured concentrations and the estimated releases. For Stations 4 and 8, for which complete data are listed for 1983–1999, the ratios of the average P/Qs for 1989–1999 to the average P/Qs for 1983–1988 are 4.0 and 6.6, respectively. There are three possible explanations for these results:

- The releases for the years 1989–1999 have been under-reported
- There were sources of uranium other than the releases from Y-12 for those years—such sources would make a greater contribution during the years following 1988, when the reported releases from Y-12 decreased dramatically
- The method of measuring and/or calculating the airborne uranium concentrations changed during this period

Utilization of All Available Data

The TBD states that uranium air concentrations were not available after 1999. However, the Tennessee Department of Environment and Conservation (TDEC) continued to collect samples and analyze them for gross " and gross $. Since the objective is to estimate doses from the inhalation of airborne activities, a conservative upper-bound estimate could be derived by assuming that all the gross " activity was ^{234}U. Since the effective dose coefficients for the inhalation of this isotope are approximately 10% higher than those for ^{235}U or ^{238}U, such an approach would result in reasonable, yet claimant-favorable, estimated doses. These data should be listed in the TBD for use by dose reconstructors.

Calculation of Uranium Concentrations in Air

As a general observation, we disagree with the decision to base the dose reconstruction on the calculated P/Q's, especially for years for which measurements of air concentrations exist. The purpose of dose reconstruction is to determine the doses to individual claimants, not to maintain a uniformity of approach, which disregards real data in favor of a statistical construct that might not be claimant favorable.

The methodology for calculating the air concentrations of the uranium isotopes, which are listed in Attachment D to the TBD (Ijaz and Adler 2004), is unclear. Our attempts to replicate some of the data in Attachment D using the information in the main body of the TBD were unsuccessful. We have requested a more detailed explanation of this methodology,[7] but have not yet received a response. Furthermore, some of the data in Table 4.2.4-1, which are the basis of the data in Attachment D, are themselves suspect. Notably, based on the masses of the ^{238}U releases listed in the fifth column of that table, the ^{238}U activities released in 1994 and 1995 should be 0.008 and 6.7 H 10^{-4} Ci, respectively, rather than 0.002 and 0.0021 Ci, as listed.

SC&A is puzzled by the decision of the authors to list combined activity concentrations for ^{234}U and ^{235}U. These data are based on the releases calculated by Buddenbaum et al. (1999). According to these authors:

> *Uranium activity amounts for ^{234}U and ^{235}U were combined to add a level of conservatism to the Task 6 screening assessment. . . . It would be appropriate to evaluate these uranium isotopes separately during a refined dose assessment such as one associated with a complete dose reconstruction study.*

Listing these isotopes separately would result in a more comprehensive guide to dose reconstructors and would be consistent with profiles of other DOE sites. The data needed for such a listing are tabulated by Buddenbaum et al. (1999).

We also question the statement, "…it is conservative to assume that the air concentrations reported from 1996 to 2002 are equal to the concentrations reported for 1995" (Ijaz and Adler

[7] See minutes of telephone conference among ORAU, NIOSH, and SC&A staff members, June 10, 2005.

2004, pg. 26). First, there are no air concentration data listed for the years 2000–2002. The TBD states that the data for these years, collected by TDEC, are not usable. (We question that assessment, as discussed earlier in the present report). More important, this statement is contradicted by the data that are listed. The annual average concentrations at Station 4 for the years 1996–1998 are higher than for 1995. Furthermore, the data in Table 4.2.4-1 shows that the uranium releases in each year from 1996 through 2001 were higher than in 1995. Such discrepancies in the TBD are troubling, in that they may be indicative of a lack of technical review and/or quality control for at least this portion of the TBD.

There is little guidance to dose reconstructors for applying the data tabulated in Attachment D. The tables list both 50th and 95th percentile values. Presumably, the 50th percentiles are to be used as the best estimates, and the 95th percentiles as the upper bound values. As mentioned earlier, the calculated 95th percentile values are not upper bounds, as they are exceeded by annual average P/Q's at each of the four monitoring stations.

Finally, the contributions of ^{236}U are ignored in Attachment D. Concentrations of ^{236}U, which are listed in Tables 4.2.3-1/4, are comparable to those of ^{238}U and should be taken into account.

Overall, the use of empirical P/Q's to estimate uranium concentrations in the ambient air does not provide scientifically valid or claimant-favorable guidance to dose reconstructors.

5.8.2.2 Data Adequacy

No data are furnished regarding the AMAD or the chemical form of the airborne uranium. As a general practice, NIOSH assumes an AMAD of 5 :m. However, Buddenbaum et al. (1999) states the following:

> *Studies have been conducted at Y-12 to characterize uranium particle sizes in effluents. These studies indicated that, under normal conditions, uranium oxide particles were predominantly composed of small particles with typical mean diameters of 0.05 to 5 micrometers (millionths of a meter, :m). . . . Based on review of this information, one micrometer diameter uranium oxide particulates was the form of uranium assumed to have been released for the purposes of the Task 6 screening assessment that is presented in Section 4 of this report.*

Such information is required by dose reconstructors, who need to assign dose coefficients to the uranium isotopes.

Finally, detailed information on the chemical forms of uranium should be furnished in the TBD (Ijaz and Adler 2004). NIOSH typically has assumed either Type M or Type S for inhaled uranium, using the form that is more claimant-favorable for a particular cancer. However, uranium in hexavalent form, including such compounds as UF_6 and UO_2F_2, corresponds to Type F (ICRP 1994). Bruce et al. (1993) states the following:

> *On May 11, 1956, a hydrogen line to the Building 9206 UF_6 reduction area broke. This caused incomplete conversion of the UF_6 to UF_4. The chemical traps*

> *which were provided to capture the UF_6 in such an emergency were filled to capacity at the time of the break, and UF_6 was allowed to escape to the atmosphere. The escaping UF_6 was visible as UO_2F_2 smoke as it was emitted from the vent stack… Other accidental releases of UF_6 may have occurred at Y-12, but none were identified during this investigation.*

In the absence of more specific information, dose reconstructors should be instructed to consider all three lung clearance Types (F, M, and S) in selecting the most claimant-favorable effective dose coefficient to use in individual cases.

5.8.3 External Exposure

5.8.3.1 Utilization of All Available Data

We question the conclusion in the TBD that the aerial surveys performed by the EG&G Remote Sensing Laboratory cannot be used for dose reconstruction. By spanning a period from 1973 to 1989, they provide a historical record of the external exposures on the site. Such data could be used to provide a temporal trend, and should be combined with the 1985–1987 scoping survey. The spatial resolution of the aerial surveys is comparable to the size of the grid blocks in the scoping survey. Furthermore, the exposure rates calculated at 1 m above ground, as presented in the aerial survey reports, are more relevant to dose reconstruction than the ground level rates measured in the scoping survey.

5.8.3.2 Calculation of External Dose

We have questions about the methods used to convert the results of the scoping survey into dose rates. Given the purpose of the survey and the instruments used, we believe that the exposure rates were based on the count rates registered by the sodium iodide crystal in the survey meter. Such meters are commonly calibrated with a ^{137}Cs source—the scale on the rate meter is set to the calculated exposure rate at the location of the detector. This calibration is thus valid only for the principal ^{137}Cs (-ray and will vary significantly with photons of different energies. The meter readings should be converted to dose rates in air (i.e., air kerma) using calibration curves, which can be obtained from the manufacturer of the meter in question or from manufacturers of similar instruments, and the known spectrum of the uranium isotopes deposited on the ground. (See the response curve for a 1” x 1” NaI crystal provided in Figure 9). The aerial survey data, which includes some spectral analysis, would be useful in this regard. The air kerma, in turn, should be converted to dose equivalent rates, using tables in ICRP Publication 74 (ICRP 1996) for the appropriate exposure geometry.

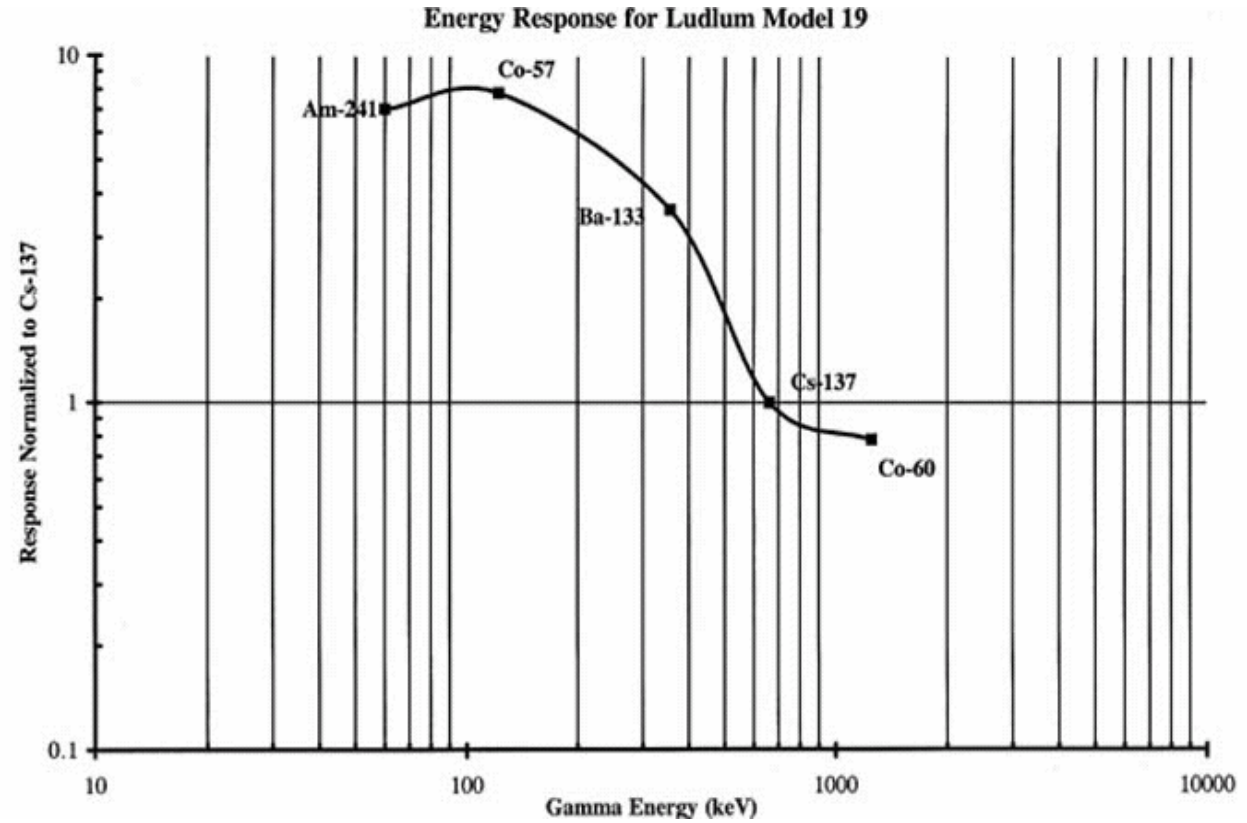

Figure 9: Energy Response of a Typical Survey Meter with a 1-inch NaI Crystal (Ludlum 2000)

5.9 ISSUE 9: FREQUENT "INCIDENTAL" SOURCES OF CHRONIC WORKPLACE RADIATION EXPOSURE

While we are aware that accidents and incidents are not addressed in site profiles, there is a class of incidents at Y-12 that were frequent enough to stand as a chronic source of acute workplace exposure, and widespread enough to affect a large number of workers in the work area involved. These include uranium and thorium chip fires, which were due to the pyrophoric nature of metallic uranium and the fine machining that was done with the material at Y-12.

These fires, according to workers interviewed, occurred as often as several times an 8-hour shift, and ranged from small ones that the workers were responsible for extinguishing to larger ones that filled the entire operating area with uranium fumes. In some cases, the fires were intense enough to consume the lathe or machining tool itself.

While special monitoring was not performed for workers exposed to chip fire air contaminants, air sampling was performed for major chip fires. The Y-12 Quarterly Health Physics report for the 4th quarter of 1962 (Y-12 1963) provides the following air sampling data taken during and after uranium chip fires in Building 9212.

Table 6: Air Sample Data During and After Uranium Chip Fire

Location	Samples	% PAL	d/m/m^3
9212 Room 1008 (after chip fire and during cleanup)	4	100%	3,847
9206 – Room 15 (during chip fire)	2	50%	140
9206 – Room 100 (during chip fire)	1	100%	221

While wearing of respirators and proper ventilation were recommended during cleanup, no records were found to confirm if precautions were taken by workers.

Another example of a chronic source of "incidental" exposure of Y-12 workers are elevated airborne levels of uranium contamination due to failures of the building exhaust fans or, in the case of Building 9206, problems associated with the incinerator. The average quarterly airborne uranium activity (1962, 4th quarter) for the Mechanical Operations area of Building 9206 was 41 d/m/M^3, which was almost 60% of the Y-12 airborne contamination PAL. The report concludes that most of this elevated contamination was due to "backflow of air through the ducts at a time when the exhaust fans were off" (McClendon 1963). Given that the SC&A review of quarterly health physics reports was limited to a sampling of what was made available by Y-12, it is not clear what the historic frequency of these exhaust failures may have been; however, it is clear that they were treated as incidental occurrences despite their obvious contribution to worker exposure.

Similarly, the Building 9206 incinerator was an intermittent source of airborne contamination in that building during its operation up until the mid-1980s. Various quarterly health physics reports from the early 1960s until the 1980s attribute elevated levels of airborne contamination to in-plant releases of uranium particulates from the incinerator in Room 25. In 1962, it was noted that the PAL for airborne uranium particulates (70 d/m/M^3) in Building 9206 had been exceeded for the 4th quarter, with an average reading of 150 d/m/M^3, with the "chief contributor" being the incinerator (the average airborne level in the incinerator room itself was 934 d/m/M^3 for the quarter). In 1985, it was noted that the airborne uranium contaminant levels would have exceeded Environmental Protection Agency then-proposed limit of 36 d/m/M^3 for 7 months, 3 quarters, and for the entire year of 1984 (West 1985). It was noted that a new incinerator had been scheduled for installation in FY1986.

Another source of exposure is not addressed in the TBDs, but likewise could have lead to acute sources of internal exposure for workers involved with uranium and thorium melting and casting operations. Because the progeny of both uranium and thorium (radon and ^{226}Ra for the former, and thoron and ^{224}Ra and ^{228}Ra for the latter) have lower vaporization or melting points than their parent source materials, they are preferentially "boiled" off during arc furnace melting. For thorium, airborne activities of these daughter radionuclides have been measured as high as 20,000 times the Maximum Permissible Limit as thorium metal ingots were removed from casting molds (Ammann 1960). It is not clear from the TBD whether the potential significance of this exposure was addressed in the Y-12 external (for beta) and internal (particularly for radon and thoron) dosimetry programs. One of the Y-12 workers interviewed indicated that in-plant radon monitoring had been conducted, but that any positive readings had been attributed to natural sources, such as building materials.

The TBDs need to better characterize "incidental" sources of chronic workplace exposure. Situations that may not have been adequately covered by normal monitoring procedures need to be considered on an individual basis to assure correct dose assignment.

Y-12 historically had no formal process for recording incidents prior to Occurrence Reporting. In some cases, the Radiological Control Organization generated reports or memorandums if the incident was considered "significant" (see Attachment 6). Although individuals may have been on monitoring programs during these incidents, it is important to ascertain any special exposure conditions which may have affected the accuracy of personnel monitoring such as nonuniform exposure or geometry factor for external dose, or radionuclides, mode of intake, and chemical form for internal dose. Unmonitored or inadequately monitored workers may have been involved in undocumented incidents that may have resulted in unexpected exposures. Further consideration should be given to evaluating the availability of incident and work restriction data and its applicability to the dose reconstruction.

5.10 ISSUE 10: SKIN AND EXTREMITY DOSES

The TBD does not provide a technical basis for excluding non-penetrating doses from acute non-routine exposures. Starting in 1948, the film badges used at Y-12 had an open window and a cadmium filter to aid in distinguishing between beta and photon exposures (Kerr 2003, pg. 13). With guidance provided in Attachment F of the TBD, it is unclear why non-penetration dose is not assigned, given the availability of data. There is also no information available on shallow dose exposures to skin of the extremity; although the original extremity dosimeter was used as early as the 1940s for some workers.

The Y-12 Plant handled a variety of radionuclides over the period of operations. Many of these radionuclides or their progeny were beta emitters. Depleted uranium and enriched uranium have been the predominant materials processed at Y-12. These radionuclides can result in beta dose to the skin, and in some cases, the breast and testicles. The beta emitters of interest from depleted uranium are ^{234}Th and ^{234m}Pa resulting from the decay of ^{238}U. For ^{235}U, ^{231}Th is the primary source of beta exposure. Although enriched uranium results in some beta exposure, depleted uranium is the primary beta hazard, due to the high-energy beta and decay rate of ^{234m}Pa. Dose rates to the extremities from handling can be considerably higher due to the proximity of the extremity verses the whole body (Thomas and Bogard 1994).

Processing and handling of thorium and ^{233}U also lead to beta exposure. The ^{232}U impurity in ^{233}U presents both a beta and gamma exposure hazard. As the ^{232}U concentration increases, the dose rates associated with the material increase. The ^{232}U daughters ^{212}Bi and ^{208}Tl emit energetic betas with maximum energies of 2.26 MeV and 1.8 MeV, respectively. For example, the beta dose rate at 1 foot from a 1-kilogram thin disk of ^{233}U with 1 part per million ^{232}U is 10.3 mrad/hour. The total surface dose rate is 1.2 rad/hour for the same disk aged for 60 days (Owen 1964). Thorium-232 and daughters emit betas with maximum energies of 12 to 2,260 keV. Calculated surface dose rates from ^{232}Th in equilibrium with its daughters have been reported as 107 mrads per hour. External exposure potential can increase with the concentration

or separation of thorium daughters (West 1965). Closer proximity to these materials yields higher beta exposure, such as with extremities during handling operations.

5.10.1 Acute Beta Doses and Routine Nonpenetrating Doses

The TBD appears to indicate unspecified issues with the estimation of non-penetration doses. Those performing waist-level uranium-handling jobs could have received beta doses (both acute and chronic) to the skin, testicles, and breasts from their work. Also, beta dose to the extremities may have been considerably larger than whole-body non-penetrating dose, especially for workers handling radioactive material. The TBD (Kerr 2003, pg. 9) states the following:

> *Information presented in this section pertains to the analysis of these records and does not address parameters regarding skin and testicular or breast radiation dose that may result from acute exposure to beta-particles in generally non-routine workplace exposure situations*.

Attachment F of the TBD (Kerr 2003, pg. 41) gives the following directions with respect to estimation of organ dose in cases of skin, testicular, and breast cancer:

> *The information needed to evaluate claims is directed to the technical parameters of the annual estimates of the primary organ dose that is calculated from the dosimeter interpreted personal dose equivalent, Hp(10), and Hp(0.07) in the case of skin, testicular, and breast cancer. These are used as a consistent basis of comparison for all years of Y-12 occupational external dose starting in 1950.*

It is unclear from the passages above whether this means the record for non-penetrating dose should be considered adequate or inadequate. SC&A notes that Kerr (2003) does not direct the dose reconstructor to Addendum F of ORAUT-PROC-0006, *Dose Reconstruction Project for NIOSH – External Dose Reconstruction* (Merwin 2003), which provides a procedure for shallow dose calculations as follows:

> *Under certain limitations, it has been determined that the calculated doses for skin cancers can be assured of being claimant-favorable if a factor of 2 is applied to deep doses reported by the site post-1980 (and, for 1970 and later cases if an organ DCF is also applied), and when shallow doses are calculated according to the instructions provided below. Therefore, external doses of complex-wide skin, breast, and testicular cancers can be calculated according to this procedure.*

OCAS-IG-001, *External Dose Reconstruction Implementation Guide* (NIOSH 2002), emphasizes that the external electron exposures are to be considered in the case of skin cancer. In the cases of breast and testicular cancers, electron exposure evaluations for beta particles with energies of > 1 MeV should be conducted. OCAS-IG-001 does not state that dose reconstruction for skin, testicular, or breast cancer is excluded for "acute exposure to beta-particles in generally non-routine workplace exposure situations" (Kerr 2003, pg. 9). The TBD should explain why this exclusion has been made and provide the technical basis for the decision.

5.10.2 Extremity Exposure

Both depleted uranium and thorium billet handling has associated high beta radiation fields leading to elevated hand and arm exposures for material handlers. The original extremity dosimeter used at Y-12 in the 1940s was crude and consisted of film attached to the hand with electrical tape. Later, some chemical operators began wearing dosimeter rings when handling transuranics, particularly plutonium. From film badge readings, Y-12 distinguished between "penetrating" dose and "skin" dose. Recorded average skin dose was highest for mechanical operators (i.e., machinists) and product certification personnel. For five quarters in 1961–1962, the average skin verses penetrating dose by work category was as follows:

Table 7: 1961–1962 Average Skin and Penetrating Dose by Worker Category

Job Title	Sample Size	Skin Dose (mrem)	Penetrating Dose (mrem)
Chemical Operations	523	125	60
Mechanical Operations	1,750	280	60
Product Certification	451	330	60

In terms of skin-penetrating radiation ratio, the machinists and product certification personnel had higher ratios of 4:1, as compared with chemical operators at close to 2:1.

The source of the radiation is obvious. For depleted uranium billets in the Y-12 foundry, the surface readings for some were as high as 2 R/hour. Control actions were necessitated to provide shielding for handlers and nearby workers, including covering the billets and setting up partial shielding (McLendon 1960). For thorium, there is an external exposure potential due to four beta emitters with maximum energies ranging from 12 to 2,260 keV. As detailed in *Health Physics Considerations Associated with Thorium Processing*, calculated beta dose rates at the surface of ^{232}Th metal in equilibrium with its daughters and 3 years after separation from its progeny "has been reported as 107 and 40 mrads [per hour], respectively" (West 1965). It is noted that this compares with 240 mrads from uranium in equilibrium with its daughters (West 1960).

The TBD should explain why extremity exposure data is excluded from consideration and provide the technical basis for the decision. Verbal communications from ORAU indicate that extremity dose considerations are being considered for inclusion in the next revision of the TBD.

6.0 OVERALL ADEQUACY OF THE SITE PROFILE AS A BASIS FOR DOSE RECONSTRUCTION

The SC&A procedures call for both a "vertical" assessment of a site profile for purposes of evaluating specific issues with respect to adequacy and completeness, as well as a "horizontal" assessment pertaining to how the profile satisfies its intended purpose and scope. This section addresses the latter objective in a summary manner by evaluation of (1) how, and to what extent, the site profile satisfies the five objectives defined by the Advisory Board for ascertaining adequacy; (2) the usability of the site profile for its intended purpose, i.e., to provide a generalized technical resource for the dose reconstructor when individual dose records are unavailable; and (3) generic technical or policy issues that transcend any single site profile that need to be addressed by the Advisory Board and NIOSH.

6.1 SATISFYING THE FIVE OBJECTIVES

The SC&A review procedures, as approved by the Advisory Board, require that each site profile be evaluated against five measures of adequacy, i.e., completeness of data sources, technical accuracy, adequacy of data, site profile consistency, and regulatory compliance. The SC&A review found that the NIOSH site profile (and its constituent TBDs) for Y-12 represents an adequate accounting of the "core" uranium exposure and dosimetric history of the plant, but falls short in fully characterizing underlying issues that are fundamental to guiding dose reconstruction. In some cases, these issues will impact other site profiles. Many of the issues involve lack of sufficient conservatism in key assumptions or estimation approaches, incomplete site data or incomplete analysis of that data, or incomplete reflection of operational or dosimetry history. Section 6.0 summarizes the key issues. Detailed evaluation of these issues is provided elsewhere in the report.

6.1.1 Objective 1: Completeness of Data Sources

The breadth of data sources used as a basis for the Y-12 site profile is evident in the 223 reports cited as references, including historical reports, correspondence, and other technical documents. The ORAU team includes health physics personnel with long histories within the Oak Ridge complex who have extensive knowledge of key dosimetry assessments and other documentation, which aided in identifying and gaining access to data sources. As noted in Section 4.0, NIOSH effectively compiled facility specific information for major facilities, and proceeded to characterize the types and relative importance of various radiological hazards that may have contributed to internal and external dose. Furthermore, NIOSH/ORAU have recognized gaps in the existing TBDs, and participated in follow-up data captures at the Y-12 and development of supporting technical documents.

However, the site profile falls short in its critical evaluation of pertinent records and purposeful use of site expert interviews to ascertain potential monitoring or records gaps throughout Y-12's lengthy history, with an objective of determining the extent and significance of missing or unmonitored worker dose. SC&A found that existing unclassified and classified information sources point to a number of significant sources of such gaps, including unmonitored support

service workers, presence of radionuclides other than uranium, and unrecorded chronic low level uranium uptakes. These issues are directly pertinent to the conduct of dose reconstructions, and will require further records review and evaluation on the part of NIOSH (some of which has already been initiated with respect to internal dose assessments for thorium, ^{233}U, and recycled uranium).

Furthermore, the TBDs do not go into enough depth on the varying and changing nature of Y-12 operations and work environments to provide the dose reconstructors with the specific knowledge that is needed for specific group or individual dose reconstructions. It is important to adequately understand the potential hazards and dose potential for each operation performed. Changes in operations that occurred over varying periods and the changing mission of facilities and buildings can also impact the dose that individual workers or groups of workers might have received. The ability to reconstruct dose in these many unique and varying types of functions related to a worker's dose potential in a specific job is dependent on a better-developed description of individual or group activities and how their operations were modified by different mission redirection.

Radioisotopes other than uranium requiring further assessment include ^{3}H, ^{90}Sr, ^{99}Tc, ^{210}Po, ^{228}Th, ^{232}Th, ^{239}Pu, ^{241}Pu, ^{237}Np, ^{233}U, and ^{241}Am. Some of these radionuclides were associated with research and development activities, while others were handled in production, either as a source material or as a contaminant, e.g., from recycled uranium. Given their potential radiation exposure significance, thorium, ^{233}U, and transuranic handling is of particular importance to the TBD. While some of these operations are associated with ORNL missions at Y-12, a number of Y-12 workers (e.g., janitors, maintenance, and crafts personnel, as noted above) supported these operations and were potentially exposed to these sources. In addition, the environmental TBD has not considered release of radioactive materials other than uranium although processing involved other radionuclides.

Although radiation generating devices, including x-ray-producing equipment and accelerators, were associated with operations at Y-12, there is little mention of these units, the radiological hazards associated with them, and the effectiveness of the dosimeters to measure these radiations. There is also no mention of the potential internal exposures from target material and maintenance activities.

The TBD has included a discussion of the 1958 criticality accident involving overexposures to eight individuals. There are, however, other frequent "incidental" sources of workplace radiation exposure involving many workers over the course of operation that are not addressed in the site profile. These incidents involved uranium chip fires, failure of engineering controls, and vaporization of radium and its progeny during molten uranium and thorium casing operations. It is not clear whether the frequency and sensitivity of the historic Y-12 bioassay program would have detected these "spike" releases, particularly where urinalysis was delayed or unduly relied upon for Type S uranium oxides. Such releases, in particular, would need to be addressed where routine air sampling data is used to estimate potential worker uptakes.

6.1.2 Objective 2: Technical Accuracy

The site profile accurately characterizes Y-12's radiation dosimetric practices over its history, but fails to sufficiently scrutinize past assumptions and practices, which would be considered non-conservative in current accepted practice. As noted earlier, an overriding assumption that guided the early and mid-history of the plant was the prevailing acceptance of chronic low-level uranium uptakes as insignificant hazards and not subject, in practice, to routine ALARA considerations, exposure assessment, and dose estimation. With this historic context in mind, SC&A examined all historic assumptions that guided both internal and external dose assessment for uranium at the chronic, lower concentrations at Y-12. Interviews were conducted with longstanding workers, historic internal plant correspondence was reviewed, and site health physics personnel were interviewed regarding practices. It was found that the TBDs seemingly have the same "blind spot" that existed in the former Y-12 health physics program with respect to occupational low-level chronic uranium exposure.

For example, the uncertainties in the bioassay techniques and detection limits used to quantify internal dose are significant issues in dose reconstruction and are not fully addressed in the TBD. The TBD intake model does not consider the 48-hour delay imposed on obtaining urine samples, which leads to an under-calculation of the chronic daily intake rate for uranium by a factor of 2–4, depending on lung clearance class. It neglects the ingestion pathway, despite the fact that eating, drinking, and smoking were routine in contaminated operating areas of the plant until 1988–1989. Dose assignments do not consider the measured particle sizes, the most claimant-favorable solubility type for the organ of concern, and the uncertainties associated with bioassay techniques and sampling methodology.

While the TBD concludes that an appreciable percentage of neutrons were detectable at Y-12 given the "hard" energies involved, this assumption is based on a limited amount of neutron spectral measurements conducted in 1990, and a more recent PNNL study at three specific locations. A full analysis of all potential neutron exposure conditions at Y-12, some elaborated on in ORAUT-RPRT-0033 (Kerr 2005b), has not been completed. The assumption that most neutron exposure at Y-12 was from neutron energies greater than 500 keV, and thus would be detected by the NTA film, is not adequately substantiated. There has been no consideration in the TBD for the poor detection of neutrons between 500 keV and 800 keV by film badges.

The occupational environmental dose TBD (Ijaz and Adler 2004) leaves inadvertent ingestion of radioactively contaminated soil and inhalation of radionuclides other than uranium inadequately developed. NIOSH needs to examine more closely the radiological assessment of the inhalation of uranium particulates onsite at Y-12, which represents a source of worker exposure. The empirical χ/Q approach is based on several premises that are not explicitly stated, and which need to be explored and justified before this approach can be accepted.

Extremity and skin doses should be given attention in the external dose TBD. Depleted uranium metal handling has associated high beta radiation fields leading to elevated hand and arm exposures of material handlers. Similarly, ^{232}Th has beta-emitting progeny that present a

radiological hazard for direct handling. Since few workers wore ring dosimeters, it is important to characterize potential beta/gamma fields, and worker handling practice and geometry.

6.1.3 Objective 3: Adequacy of Data

Data gaps were evident in the TBDs, which were not adequately addressed in attendant analysis. For example, while NIOSH accepts that less than 25% of all Y-12 workers were monitored externally from 1950–1961, and no external data is readily available for 1948–1950, it assumes these individuals are the "maximally exposed" workers given the stated policy of the time. However, given that line supervisors made all badging decisions for groups and individuals within groups (Patterson 1957) in an era where production often took precedence over safety, legitimate doubts can be raised over how much weight should be afforded these management assignments. Historic discrepancies in recording badge readings also raise questions. For example, beginning in mid-1956, all film badges reading, "below the minimum detectable [were directed to be] recorded as the average of the minimum detectable reading and zero, instead of being recorded as the minimum detectable" (West 1956). In addition, "some fraction" of overall Y-12 film badge results were found to be flawed during 1950–1955 due to incorrect assignment of badges based on an incorrect determination of whether gamma or beta radiation exposure was predominant for a worker (West 1991). While documentation may exist to corroborate or correct for badging assignments, this information is not provided as a basis for applying the co-worker dose estimation model.

Similarly, while production workers may have participated in routine monitoring programs, routine bioassay sampling among support workers and many crafts, who also had full access to radiological areas onsite, was not implemented prior to 1994. Questions arise as to the effectiveness of the bioassay methods to detect highly insoluble ("high-fired") uranium oxides to which some workers were exposed either routinely or during incidents. This is particularly the case prior to the routine use of fecal and/or lung counting, as urinalysis can be insensitive to highly insoluble uranium. Two-day delays in sampling and limited sampling frequencies may not have been adequate to detect acute intakes of Type F materials.

6.2 OBJECTIVE 4: CONSISTENCY AMONG SITE PROFILES

Y-12, Hanford, and the SRS are all DOE facilities that have handled uranium, thorium, tritium, and transuranics. The 300 Area of both Hanford and SRS handled large amounts of uranium, which is often the predominant radionuclide in these areas. Y-12 primarily processed uranium; however, there were operations involving thorium, tritium, and plutonium. Although the operations are not identical at the three sites, the general approach to monitoring at the three sites was similar. In addition, considerable material received by Y-12 was shipped to and from the SRS. NIOSH has appreciated the distinctions between each of the three sites, and tailored its TBD assumptions and analytic approaches to the unique histories and conditions at each site, while mirroring those assumptions and approaches where justified. The SRS and Hanford site profiles predate the Y-12 site profile; therefore, NIOSH benefited greatly from these earlier efforts.

An extensive comparison was performed by SC&A to compare and contrast the methodologies used in the Y-12, Hanford, and SRS TBDs to determine external, internal, medical, and environmental dose. These comparisons focus on the methodologies and assumptions associated with dose assessments and the derivation of values used to obtain a probability of causation for individual claimants. A detailed analysis is provided in Attachment 7 to this report. This table demonstrates, in detail, where the Y-12, Hanford, and SRS site profiles differ or agree on a number of important assumptions.

There are some inconsistencies noted between the Y-12 site profile and other site profiles. For example, the Hanford and SRS site profile discount the use of NTA film as an adequate measure of neutron dose in favor of applying neutron-to-photon ratios. The Y-12 site profile, in contrast, defends the use of NTA film based on a limited neutron spectral measurement, and applies a correction factor to account for the undetectable lower-energy portion of the neutron spectrum. Likewise, the Y-12 TBD has not examined the film badge corrections for low-energy photons, such as those encountered with x-ray units.

Hanford, SRS, and Y-12 all have Type F material, but the Y-12 TBD discounts the significance of this solubility type at Y-12. This position is questionable because the Type F solubility type is more claimant-favorable for some organs.

ORAUT-TKBS-0014-6 (Kerr 2003, pg. 31) states that missing doses can be calculated by multiplying the MDL by the number of zero dose results. In the Hanford document, ORAUT-TKBS-0006-6 (Kerr 2003, pp. 47 and 75), and the Nevada Test Site document ORAUT-TKBS-0008-6 (Rollins 2004, pg. 14), it is suggested that the missing doses be calculated by multiplying the MDL by the number of zero dose results divided by 2. This appears to be an inconsistency between these respective site TBDs that needs to be corrected or explained.

6.2.1 Objective 5: Regulatory Compliance

With one exception, NIOSH has complied with the hierarchy of data required under 42 CFR Part 82 and its implementation guides. 42 CFR Part 82 recommends the use of the default 5 µm particle size only in cases were there is no information on particle sizes. This is not the case with the Y-12 facility, as stated in ORAUT-TKBS-0014-5 (Rich and Chew 2005, page 10).

6.3 USABILITY OF SITE PROFILE FOR INTENDED PURPOSE

SC&A has identified seven criteria that reflect the intent of the EEOICPA, the Final Rule, and the regulatory requirements of 42 CFR Part 82 for dose reconstruction. Because the purpose of a site profile is to support the dose reconstruction process, it is critical that the site profile assumptions, analytic approaches, and procedural directions be clear, accurate, complete, and auditable (i.e., sufficiently documented). SC&A used the following seven objectives to guide its review of the Y-12 site profile TBDs to determine whether they meet these criteria:

Objective 1 – Determine the degree to which procedures support a process that is expeditious and timely for dose reconstruction.

Objective 2 – Determine whether procedures provide adequate guidance to be efficient in select instances where a more detailed approach to dose reconstruction would not affect the outcome.

Objective 3 – Assess the extent to which procedures account for all potential exposures and ensure that resultant doses are complete and are based on adequate data.

Objective 4 – Assess procedures for providing a consistent approach to dose reconstruction, regardless of claimants' exposures by time and employment locations.

Objective 5 – Evaluate procedures with regard to fairness and the extent to which the claimant is given the benefit of the doubt when there are unknowns and uncertainties concerning radiation exposures.

Objective 6 – Evaluate procedures for their approach to quantifying the uncertainty distribution of annual dose estimates that is consistent with and supports a DOL probability of causation estimate at the upper 99% confidence level.

Objective 7 – Assess the scientific and technical quality of methods and guidance contained in procedures to ensure that they reflect the proper balance between current/consensus scientific methods and dose reconstruction efficiency.

6.3.1 Ambiguous Dose Reconstruction Direction

The external dosimetry TBD (Kerr 2003) lacks clarity and specific instructions regarding the assignment of external dose, specifically application of correction factors to recorded and missed dose. NIOSH has not provided the requisite instructions to ensure that workers who perform waist-high operations are assigned an appropriate dose estimate as claimants who have developed skin, testicular, or breast cancer. There is a need for further development in the TBD regarding geometric correction factors and how they are derived from calibration and workplace experiences. Additional elaboration on the origin of the correction factors is needed to evaluate their validity. Furthermore, there is no clear guidance on when to apply the geometric correction factors.

Table 6.3.3.2-1 (page 19 of the TBD) states that the **angular response** of Y-12 neutron dosimeters is likely too low, because of its lower response at non A-P angles (the text before this table discusses both NTA film and TLNDs). However, Table 6.3.4.3-1 (page 26) states that the NTA film response is likely too high, because of its increased response at other than A-P angles, and that the TLND response would decrease at other than A-P angles. This conflict needs to be resolved or clarified.

The recorded neutron or missed neutron dose is to be adjusted by the ICRP 60 correction factors in Table F-5 (Kerr 2003, page 44) and an example for a worker in the storage area is provided on page 43. Additionally, ORAUT-TKBS-0014-6 (Kerr 2003, page 45) instructs the dose reconstructor to multiply the MDL by a factor of 1.05 or 1.10, depending on location, but does

not include the ICRP 60 correction factors. It is unclear from reading the TBDs what correction factors are to be applied when, and if they are (or are not) to be applied sequentially.

The internal dosimetry TBD (Rich and Chew 2005) provides a good description of the historic internal dosimetry program; however, it is unclear from the TBD what data is used in the evaluation of internal dose and how missed internal dose is assigned. NIOSH has clearly outlined the process to be applied for deriving co-worker doses where monitoring was lacking; however, the corresponding assumptions used to derive dose to monitored workers is unclear.

6.3.2 Inconsistencies and Editorial Errors in the Site Profiles

There are numerous editorial errors and inconsistencies in the TBD causing confusion. Although there are numerous TIBs or other technical reports that supplement the directions in the TBD, there is no reference to these. Attachment 9 provides a complete list of the editorial errors in the TBDs identified during this review.

6.4 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues were identified that are common in the Y-12, Hanford, and SRS site profiles and, in some cases, represent potential generic policy issues that transcend any individual site profile. These issues may involve the interpretation of existing standards (e.g., oro-nasal breathing), how certain critical worker populations should be profiled for historic radiation exposure (e.g., construction workers and early workers), and how exposure itself should be analyzed (e.g., treatment of incidents and statistical treatment of dose distributions). NIOSH indicates that it may develop separate TIBs in order to address these more generic issues. The following represents those issues identified in the Y-12 site profile review that SC&A believes represent transcendent issues that need to be considered by NIOSH as unresolved policy or generic technical issues.

(1) Direction on the applicability of the TBD and/or TIBs to individual dose reconstructions is absent.

(2) Mobility of work force between different areas of the site should be addressed. Site expert testimony that many workers moved from one plant to the next is a complicating factor. Establishment of an accurate worker history is crucial in such cases. This will be especially difficult for family-member claimants.

(3) Statistical techniques used in the application of the data to individual workers should be further considered and substantiated.

(4) Dose from impurities and/or daughter products in radioactive material received and processed at sites should be assessed as a contributory exposure source.

(5) The significance of various exposure pathways and the assumptions made that influence dose contributions need to be considered (most notably) for solubility, oro-nasal breathing, and ingestion.

(6) Analysis needs to be performed regarding how "frequent or routine incidents" should be addressed given the possibility that such "spike" exposures may be often missed by routine monitoring as a function of how often and in what manner it was conducted.

(7) Availability of monitoring records for "transient or outside workers," e.g., subcontractors, construction workers, and visitors who may have potential exposure while working on or visiting a facility, should be ascertained.

(8) Dose to decontamination and decommissioning workers should be assessed. Many facilities have large-scale D&D operations, which extend back many years. Decontamination and decommissioning operations often require working in unknown situations, which may provide unique exposure situations.

7.0 REFERENCES

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ATTACHMENT 1: REVIEW OF THE NIOSH SITE PROFILE FOR THE Y-12 NATIONAL SECURITY COMPLEX

Presentation to the Advisory Board on Radiation and Worker Health
Joseph Fitzgerald
July 5, 2005
St. Louis, Missouri

Y-12 Review: Background

- Advisory Board expedited Y-12 review at April 27 meeting to support review of SEC petitions
- SC&A review conducted May 3-June 30, 2005, including classified records and onsite interviews
- Focused on current ORAU team TBDs
- Three site visits to Y-12
- All interview notes, doc reviews, and draft report reviewed by derivative classifier at Y-12
- Conference calls held between TBD reviewers and ORAU authors
- Report to be submitted late-July

Y-12 Review: TBDs Reviewed

- Y-12 Site Profile (Introduction)
- Site Description
- Occupational Medical Dose
- Occupational Environmental Dose
- Occupational Internal Dose
- Occupational External Dose

Y-12 Review: Supporting Documents Reviewed

- *Technical Information Bulletin – Occupational Dose from Elevated Ambient Levels of External Radiation*
- *Technical Information Bulletin: Individual Dose Adjustment Procedure for Y-12 Dose Reconstruction*
- *Technical Information Bulletin: Bayesian Methods for Estimation of Unmonitored Y-12 External Penetrating Doses with a Time-Dependent Lognormal Model*
- *Internal Dosimetry Coworker Data for Y-12*
- *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge Tennessee: Part 1 – Gamma Radiation*
- *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge Tennessee: Part 2 – Neutron Radiation*
- *Accounting for Incomplete Personal Monitoring Data on Penetrating Gamma-Ray Doses to Workers in Radiation Areas at the Oak Ridge Y-12 Plant Prior to 1961*

Y-12 Review: Site Description

- Operating contractors: TEC, 1943-1947; Union Carbide, 1947-1984; MMES/LMES, 1984-1998; BWXT, 1998-present.
- Construction contractors: Rust Engineering, MK Ferguson, Bechtel Jacobs
- Secure site with 531 buildings on 811 acres
- Worker population variable over time: 4,700 employees today; 11,000 during peak production; about 40,000 during TEC years

Y-12 Missions

- Electromagnetic separation of uranium (1943-1947)
- Production of secondaries and cases
- Refurbishment and dismantling of nuclear weapons components
- Storage and processing of uranium and lithium materials and parts
- Production support to weapons laboratories
- DOD and NASA program support

Y-12 Review: TBD Strengths

- Internal dosimetry TBD undergoing revision to include a more extensive treatment of radionuclides other than uranium
- Y-12 internal and external monitoring techniques detailed
- Beta exposure under investigation as a complex wide issue
- “Radiation generating devices” TIB under development.
- Recent records retrieval efforts have been more comprehensive
- TBD is supplemented with a number of TIBs and reports that provide further direction to the dose reconstructor
- Improved approach in addressing recycled uranium, compared with other TBDs reviewed

Y-12 Historic Radiation Protection Program for Uranium

Y-12's HP program had sound features and conducted extensive monitoring, but fell short for uranium:

- Eating, drinking, smoking permitted in uranium production areas until 1988; no egress monitoring (DOE, 1988; DNFSB, 1993)
- Lack of formal worker radiation protection training (DNFSB, 1993)
- Inadequate in-plant radioactive contamination zoning (DOE, 1988; DNFSB, 1993)
- Limited shielding for beta/gamma radiation from depleted uranium (DOE, 1988)
- Respirators were available but discretionary for all but a few high exposure jobs; supervisors often decided (DOE, 1988)
- Plant action levels exceeded frequently (sometimes orders of magnitude) without lasting remedies (Y-12 Quarterly HP reports, 1960s era)
- Line programs unresponsive to identified radiation protection deficiencies (DOE, 1988)
- Large backlog of uranium materials, some remaining in work areas for several decades

Y-12 site expert/workers interviews

- Interviews with:
  - 8 BWXT environment, safety and health personnel
  - 25 BWXT production and maintenance personnel
  - 3 Wackenhut Services, Inc (WSI) security guards
- Employment histories back to 1969
- Key comments (corroborated by multiple workers):
  - Workers moved often between operations
  - Workers employed at more than one Oak Ridge site during career
  - Overtime common
  - Y-12 support workers (e.g., maintenance, janitors) serviced ORNL operations at Y-12 and entire plant area
  - Plutonium, ^{233}U, and thorium present at the facility as a process material and contaminant
  - Plutonium contamination exists in sealed gloveboxes
  - Fecal analysis replaced urinalysis belatedly in 1998 for insoluble uranium oxides
  - Selective breathing zone sampling was utilized in the work area
  - Management compelled workers to remain at work stations; number of instances of production taking priority over safety in past history

Y-12 Review: Available Radiation Monitoring Data

- High uranium air concentrations and no external monitoring data for 1943-1947
- Less than 25% of workers monitored externally from 1948-1960
- No external monitoring data readily available for 1948-1950
- No urinalysis data located prior to 1948
- Lung counting initiated in 1958 as a result of thorium production
- Uranium urinalysis initially limited to production workers, but expanded to include other workers starting in 1954
- Significant reduction in urinalyses (whole departments) in 1972 with increased reliance on lung counting
- Limited tritium and plutonium bioassay initiated in 1957
- Routine fecal sampling program initiated in 1998

Y-12 findings

- Y-12 TBDs need to clearly address support workers who were not routinely badged before 1961, nor bioassayed before 1994
  - Maintenance and janitorial employees, and some inspectors and material inventory handlers not monitored routinely, yet had full access to Y-12 radiological control areas
  - Exposed to HEU, insoluble uranium oxides, thorium, TRU, ORNL neutron sources
  - Work included cleaning contaminated areas, fixing contaminated process equipment, and moving material.
  - No records apparently exist regarding work location assignments

Y-12 findings

- TBDs need to better characterize “incidental” sources of chronic workplace exposure
  - Uranium chip fires were relatively frequent incidents (perhaps several times a shift) that filled operating areas with uranium fumes
  - Exhaust fans sometimes turned off in operating areas leading to back-flow of contaminated air through ducts
  - Exposure from radon and radium preferentially vaporized from molten uranium and thorium metal in casting operations
  - Absence of formal incident documentation

Y-12 findings

- Internal dose TBD incomplete in its treatment of historic dose contributions of radionuclides other than uranium
  - Y-12 handled ^{3}H, ^{90}Sr, ^{99}Tc, ^{210}Po, ^{228}Th, ^{232}Th, ^{239}Pu, ^{241}Pu, ^{237}Np, ^{233}U and ^{241}Am
  - Some used in experimental activities, others in production as source material or recycled feed contaminant
  - Thorium and neptunium processing particularly important
  - Plutonium involved with “sputtering” of components during production; also as contaminant in LANL/RF “returns”
  - Y-12 support workers likely exposed to nuclides associated with ORNL operations
  - NIOSH recognizes issue and ORAU has ongoing assessment of thorium, ^{233}U, and recycled uranium

Y-12 findings

- Potential for missed dose at Y-12 should be more completely addressed
  - Unmonitored categories of workers
  - External doses to recycled uranium workers prior to 1961
  - Uncertainties and detection limits of bioassay techniques
  - Radioactive material solubility and particle size assumptions
  - Ingestion pathway
  - Application of co-worker data
  - Adequacy of bioassay techniques
    - Frequency of sampling vs. type of material
    - Appropriateness of bioassay techniques for insoluble uranium oxides

Y-12 findings

- External Dose - Neutron radiation fields not defined sufficiently:
  - Potential neutron fields not adequately addressed to validate NTA film response; mostly hard-neutron spectra data by PNL were used. Other sources that need to be considered are:
    - Spontaneous fission neutrons
    - Moderated (α, n) sources in solutions/compounds
    - Subcritical/critical assemblies
    - Moderated neutrons from the 86” cyclotron

Y-12 findings

- External Dose - Radiation fields from radiation generating devices (RGDs) need to be addressed:
  - By 1950, 10 non-medical x-ray machines were installed at Y-12, ranging from 40 kVp, 16 mA, to 1 MeV, 10 mA
  - Not apparent that appropriate workers were monitored with the correct dosimeters as RGDs became more common in late 1940s and early 1950s
  - 86" cyclotron received little mention, but was one of largest contributors to neutron dose at Y-12 (ORAU-RPRT-0033)
  - Other potential radiation exposure sources include 10 Ci ^{60}Co unit and experimental pile assembly
  - Exposures from these sources were real possibility (i.e., overexposure to radiographic x-ray unit in 1965)

Y-12 findings

Prior-to-1961 dose assignments:

- The methods outlined in the TBD are valid if the pre-1961 badged workers were the highest exposed workers in the work force
- Selective bias due to administrative criteria that assigned badges and type of exposures, *a priori,* is confounding factor
- The methods outlined in the TBD are not claimant favorable if the pre-1961 badging was effectively cohort badging of various groups; this would represent average exposure only if the badged individuals were truly representative of the cohort
- No documentation has been found for methods used at Y-12 to ensure that the most highly exposed workers were monitored, such as by random monitoring or temporary 100% monitoring

Y-12 findings

Potential missed internal dose associated with intake model:

- Intake model needs to consider Type F uranium compounds in addition to Types M and S compounds
- Intake model needs to consider different particle sizes present at Y-12
- Intake model needs to consider ingestion pathways, in addition to inhalation
- Intake model needs to address uncertainties in bioassay measurements and capacity to detect intakes from urine samples after exposure to Type S uranium compounds
- Intake model needs to reflect 48 hour delay in obtaining urine sample from worker
- Intake model needs to consider more claimant favorable sampling distribution (e.g., 95^{th} percentile) from co-workers database

Y-12 Findings

- Occupational Environmental Dose TBD should consider additional pathways
  - Inadvertent ingestion of radioactive materials
  - Inhalation of radionuclides other than uranium (e.g., thorium)
  - Airborne uranium and other radionuclides from off-site sources (e.g., ORNL)
  - Exposure to uranium fumes from burning of DU chips

Y-12 findings

- Extremity and skin doses should be given attention in the TBDs
  - Uranium metal handling has associated high exposure of hands and arms
  - ^{232}Th similarly has beta-emitting progeny that present radiological hazard for direct handling
  - Average quarterly skin dose (Bldg 9206, 1961-1962):
    - Mechanical operators: 100-180 mrem N = 1750
    - Product certification: 220-320 mrem N = 451
    - Chemical operators: 230-370 mrem N = 523
  - Use of ring dosimeters limited to specialized activities
  - ORAU team review of issue ongoing

Conclusions

- Review found that the Y-12 site profile to be an adequate accounting of the “core” uranium exposure and dosimetric history of the plant. However, the TBDs can be improved (and work is already underway by the ORAU team) to better characterize the significance and implications of actual operational and dosimetric practice.
- Particular attention is needed for:
  - Adequacy of bioassay program for detection of insoluble uranium oxides, acute uptakes, and radionuclides other than uranium
  - Past bioassay practice for high-fired uranium oxides
  - Use of co-worker external dose assignments before 1961
  - Spectral field basis for assumptions on NTA threshold assumptions
  - Ingestion pathway
  - Unmonitored or intermittently monitored workers routinely working in production areas
  - Adequacy and completeness of environmental dose methodologies

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ATTACHMENT 2: NIOSH TECHNICAL DOCUMENTS CONSIDERED DURING THE REVIEW

Technical Basis Documents

ORAUT-TKBS-0014-1, *Technical Basis Document for the Y-12 National Security Complex – Y-12 Site Profile* (Murray 2004a)

ORAUT-TKBS-0014-2, *Technical Basis Document for the Y-12 National Security Complex – Site Description* (Jessen 2005)

ORAUT-TKBS-0014-3, *Technical Basis Document for the Y-12 National Security Complex – Occupational Medical Dose* (Murray 2004b)

ORAUT-TKBS-0014-4, *Technical Basis Document for the Y-12 National Security Complex – Occupational Environmental Dose* (Ijaz and Adler 2004)

ORAUT-TKBS-0014-5, *Technical Basis Document for the Y-12 Site –Occupational Internal Dose* (Rich and Chew 2005)

ORAUT-TKBS-0014-6, *Technical Basis Document for the Y-12 Site –Occupational External Dosimetry* (Kerr 2003)

Technical Support Documents

ORAUT-OTIB-0013, *Technical Information Bulletin: Individual Dose Adjustment Procedure for Y-12 Dose Reconstruction* (Frome and Groer 2004)

ORAUT-OTIB-0015, *Technical Information Bulletin: Bayesian Methods for Estimation of Unmonitored Y-12 External Penetrating Doses with a Time-Dependent Lognormal Model*, (Groer 2004)

ORAUT-OTIB-0029, Internal *Dosimetry Coworker Data for Y-12*, (Brackett 2005)

ORAUT-RPRT-0032, *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge Tennessee: Part 1* – Gamma Radiation (Kerr 2005)

ORAUT-RPRT-0033, *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge Tennessee: Part 2 – Neutron Radiation* (Kerr 2005)

ORAUT-PROC-0042, *Accounting for Incomplete Personal Monitoring Data on Penetrating Gamma-Ray Doses to Workers in Radiation Areas at the Oak Ridge Y-12 Plant Prior to 1961* (Kerr and Smith 2004)

ATTACHMENT 3: KEY QUESTIONS FOR NIOSH/ORAU REGARDING SITE PROFILE DOCUMENTS

SITE DESCRIPTION (ORAUT-TKBS-0014-2)

1. During the course of your preparation of the TBD, how extensive was your review of classified documents pertinent to dose reconstruction? Which documents were reviewed?

2. The TBD states that Y-12 manufactured nuclear weapons components. Can you elaborate, on an unclassified basis, what general types of components were manufactured, handled, or processed?

3. Page 5: It is likely that classified information will be relevant to reconstructing doses at an individual claimant level. How will this information be redacted in a way that allows the dose reconstructions to be adequately scrutinized?

4. Does NIOSH have any estimates of and historical timelines for nuclear materials flow (i.e., uranium-233, recycled uranium, and other nuclear materials) from production and AWE sites going to Y-12 for storage, processing, and shipment?

5. Given the historical relationship between the Y-12 Laboratory and Oak Ridge National Laboratory, particularly between 1943 and the early 1970s, has NIOSH determined if radiation exposure data are accurate and complete for people who cycled in and out of these two labs during that time period?

6. A significant fraction of the total estimated amount of recycled uranium generated in the DOE complex was processed at the Y-12 plant. Has NIOSH ascertained: (a) what processes were likely to concentrate trace radiological contaminants that could be inhaled or ingested; (b) if individual personnel dosimetry for Y-12 RU workers is accurate or complete; and (c) whether workplace measurements in areas processing recycled uranium are sufficient to support current assumptions in the TBD?

7. Table 2.3-1, ORAUT-TKBS-0014-2, lists radionuclides of concern by building number. What is the meaning of the N/A listed for uranium and ^{239}Pu?

8. Table B.4-3, ORAUT-TKBS-0014-2, lists radiological work permit bioassay indicators for routine uranium handling jobs. Is the use of the bioassay indicator specific to particular years? If so, which years?

9. There were several operations performed by ORNL personnel at the Y-12 plant. Are the individuals associated with these operations considered Y-12 or ORNL workers? Have you investigated how these operations may have affected the dose to Y-12 workers?

10. Has NIOSH investigated whether thorium-232 fuel for the Molten Salt reactor or any other reactor was ever fabricated at Y-12?

11. Is there a databank for incidents at Y-12?

12. Pages 6 and 7: What other uranium compounds were used and in what contexts? In particular, was the use of these other forms widespread?

13. Page 7: Electromagnetic operations beyond 1947 were directed towards research on new radionuclides for medical or other uses, such as separation of lithium. This must have meant that off-batch processing operations were conducted. Inadequate radiological control in individual operations could have resulted in high exposures of the limited numbers of workers involved. Are there ways of associating individual workers with those operations, determining the radiological controls in force and their implementation, and recovering monitoring data relevant to individual dose reconstruction? Also, could there have been other off- batch processing operations that could have given rise to significant operational exposures, e.g. handling of large amounts of Np-237 recovered at plants such as Fernald?

14. Page 7: Although operations were mainly weapons-related, with the plutonium present likely being of low "burnup," it is still surprising that Pu-240 is not listed in Table 2.3-1. Here and elsewhere, is Pu-239 actually Pu-239/240?

15. Page 8: Both fusion research and weapons-related activities can involve the handling of substantial quantities of tritium. Tritium gets a brief mention in the appendix to this document and in other documents, but the operations involving handling of tritium are not discussed. Is there any reason for this lack of TBD citation and guidance? Could this topic be expanded upon given the available data?

16. Page 11: From Section 2.4.6, it seems that the new filters may not have operated effectively from their installation in 1955 through July 1956. As well as large material losses, could high worker exposures have occurred over that period, e.g. in trying to get the new filter system to operate efficiently?

17. Page 15: The first assessment of the S-3 ponds indicated that no special precautions were required for clean-up work. However, the second survey seems to have indicated that precautions were required. Is this correct and was work on capping the ponds undertaken without such precautions between the two assessments? If so, have the radiological consequences been assessed?

18. Page 19: Two of the default solubility assumptions comprise a mixture of Class S and Class M. In interpreting the data, was consideration given to using a single class with a solubility intermediate between Classes M and S rather than assuming separate contributions from the two classes with different solubilities?

19. Page 20: In Table 2.9-1 not all the uranium compounds are assigned solubility classes. Why is this? If ammonium diuranate should not be assigned to a single class (see footnote to the table), how should the assignment in the table be interpreted?

20. Page 21: IMBA is used in other technical basis documents reviewed, but for Y-12, a DOSE-66 code is used. Why has the DOSE-66 code been given precedence, and has a comparison been made between IMBA and DOSE-66 in interpreting the Y-12 bioassay data?

21. Page 29: In Table B.4-1, why are Pu-238 and Pu-239 assigned to different solubility classes? How is this reconciled with Table B.4-2?

22. Page 30: Why is H-3 as vapor first mentioned in Table B.4-2 and not discussed in the main text?

23. Page 30: Table B.4-4 gives average data. Are the proportions of S and M available for each individual data point, so that a measure of variability can be obtained?

OCCUPATIONAL MEDICAL DOSE (ORAUT-TKBS-0014-3)

1. The TBD (pg. 6) indicates that from 1943 to1947, pre-employment chest x-rays were taken with a photofluorographic (PFG) unit as evidenced by the 4 x 10 inch films found in medical records. What is known about the probable dose from these chest x-rays? What is known about the calibrations of these units?

2. The TBD (pg. 7) indicates that at Y-12, no factors were identified for Type I and II equipment and, as such, organ doses were based on assumed technique factors, and that these were developed on the basis of x-ray techniques contemporary with the time period 1943–1968. Since the x-ray technique factors may not be reliable and default values for entrance kerma have been developed for use in calculating organ dose conversion factors, what can you tell us about the default values for the three most commonly used occupational medical diagnostic x-ray procedures, i.e., PA, lateral, and PFG chest films?

3. Did Y-12 perform lateral chest x-rays? If so, how were these doses calculated?

4. How was sufficient conservatism built into the determination of default values to ensure with near certainty (>99% confidence) that the actual exposures from the specified procedures mentioned in ORAUT-TKBS-0014-3 would not exceed these default values, thus ensuring claimant favorability?

5. What was the skin-to-surface distance assumed for occupational medical x-rays (i.e., photofluorography and standard chest x-rays)?

OCCUPATIONAL ENVIRONMENTAL DOSE (ORAUT-TBKS-0014-4)

1. ORAU addresses only two exposure pathways: inhalation of uranium in ambient air and external exposure to direct penetrating radiation. Whenever individuals perform outdoor work, there is a potential for ingestion of soil and other windblown particulates that are larger than normally respirable particles. This pathway is traditionally included in dose

assessments (see EPA "Exposure Factors Handbook"). What is the basis for not including inadvertent ingestion of radioactively contaminated soil and other finely dispersed radioactive materials?

2. There are several references in this TBD to monitoring of fission products. What is the basis of not including consideration of inhalation of radionuclides other than uranium?

3. The TBD states that uranium air concentrations were not available after 1999. However, since TDEC continued to collect samples and analyze them for gross α and gross β, uranium air concentrations could be estimated from these measurements from the ratios of uranium concentrations to the gross α and gross β measurements made in earlier years. What is the basis for excluding these data from developing the guidance for dose reconstruction?

4. Data regarding the AMAD or the chemical form of the airborne uranium is required by dose reconstructors, who need to assign dose coefficients to the uranium isotopes. Does NIOSH attempt to determine the AMAD and the specific chemical form of uranium?

5. The empirical χ/Q approach is based on several premises which are not explicitly stated and which need to be explored and justified before this approach can be accepted. For example:

    a. All of the occupational-related airborne activity originates at Y-12. Y-12 is part of the Oak Ridge complex, which includes other sources of radioactive material. The inconsistent correlation of monitored airborne uranium concentrations elsewhere on the Oak Ridge reservation to releases from Y-12, especially at Station 12, calls this hypothesis into question.

    b. In Section 4.2.5, the TBD attributes the poor correlation at Station 12 to the paucity of data. The smaller number of data points (8 versus a maximum of 17) does not account for the virtual lack of correlation shown in Figure 4.2.5-4. We believe that fewer data points would lead to a *better* correlation, both on mathematical grounds (fewer degrees of freedom), and on physical grounds: meteorological conditions would vary less during a shortened time period. Should the Station 12 data not be used in creating a framework for dose reconstruction, due to this lack of correlation?

    c. Resuspension of uranium deposited on soil, both inside the Y-12 perimeter and off site, is not included. Resuspension of deposition during previous years would contribute to the uranium concentration in air, yet is uncorrelated to uranium releases from Y-12.

    d. The influence of other sources of uranium—releases from sources outside Y-12 or resuspension from on-site soils—is indicated by the data for 1993. The uranium release of 3 kg for that year is the lowest during the period that Stations 2 and 12 were operating, and the second lowest during the 17-year operating period of

Stations 4 and 8. The 1993 calculated χ/Q's for all four stations are the highest of any year that these stations operated. At least for the data from Station 12, which SC&A subjected to an independent statistical analysis, there is a *negative* correlation between the χ/Q's calculated by ORAU and the annual releases of uranium: the lower the releases, the higher the χ/Q.

e. The TBD states that the calculated χ/Q's follow a lognormal distribution *with a high-end tail.* Yet, in assigning 95th percentile values, where the high-end tail would have the greatest influence, that aberration from lognormal behavior is not addressed. An examination of the data in Tables 4.2.3-1 through Table 4.2.3-4 reveals the following:

   (i) Station 2: Out of 12 calculated χ/Q's, one is significantly higher than the 95th percentile value (2.00×10^{-14} vs. 1.31×10^{-14}). Statistically, the highest of 12 values would correspond to the 92nd percentile.

   (ii) Station 4: Out of 17 calculated χ/Q's, one is over 17 times higher than the 95th percentile value (5.03×10^{-14} vs. 8.73×10^{-14}). Statistically, the highest of 17 values would correspond to the 94th percentile.

   (iii) Station 8: Out of 17 calculated χ/Q's, two are higher than the 95th percentile value. Statistically, the second highest of 17 values would correspond to the 88th percentile.

   (iv) Station 12: Out of only eight calculated χ/Q's, one is higher than the 95th percentile value. Statistically, the highest of eight values would correspond to the 88th percentile.

The above observations indicate that the distributions are not lognormal, and that the assumptions used by ORAU to calculate the 95th percentile χ/Q's are not claimant favorable, aside from the questions raised earlier in this discussion about the validity of the empirical χ/Q approach. This conclusion is further buttressed by our statistical analysis of the Station 12 data,[1] which exhibit the best correlation between the annual releases and the annual average air concentrations of uranium of the four monitoring stations. Subjecting the calculated χ/Q's to the *W* test[2] shows that there is a 10% to 50% probability that the distribution is lognormal. In other words, there is a better than a 50% chance that the distribution is *not* lognormal.

6. As a general observation, we question the decision to base the dose reconstruction on the calculated χ/Q's, *even for years for which measurements of air concentrations exist.* If the purpose of dose reconstruction is to determine the doses to individual claimants, not

[1] Our ability to perform numerical analyses on the data in the TBD is hampered by the password protection of the PDF files of this and other OCAS documents. This protection prevents us from copying the tables into our own software. Allowing SC&A unrestricted access to the contents of these documents would enhance our ability to analyze these data.

[2] Richard Gilbert (1987). *Statistical Methods for Environmental Pollution Monitoring,* Section 12.3.1.

to maintain a uniformity of approach with a bias towards a statistical construct as opposed to available real data, it is not clear how NIOSH's approach in this instance can be considered claimant favorable.

7. The methodology for calculating the air concentrations of the uranium isotopes, which are listed in Attachment D to the TBD, is unclear. Our attempts to replicate some of the data in Attachment D, using the information in the main body of the TBD, were unsuccessful. Furthermore, some of the data in Table 4.2.4-1, which are the basis of the data in Attachment D, are themselves suspect. Notably, based on the masses of the ^{238}U releases listed in the fifth column of that table, the ^{238}U activities released in 1994 and 1995 should be 0.008 and 6.7×10^{-4} Ci, respectively, rather than 0.002 and 0.0021 Ci, as listed. Can NIOSH clarify the methodology used in constructing the Attachment D tables, and how it verifies the data in Table 4.2.4-1?

8. On p. 26, the TBD states: ". . . it is conservative to assume that the air concentrations reported from 1996 to 2002 are equal to the concentrations reported for 1995." First, there are no air concentration data listed for the years 2000 – 2002. The TBD states that the data for these years, collected by TDEC, are not usable. More important, this statement is contradicted by the data that are listed. The annual average concentrations at Station 4 for the years 1996 – 1998 are higher than for 1995. Furthermore, the data in Table 4.2.4-1 show that the uranium releases in each year from 1996 through 2001 were higher than in 1995. Can NIOSH clarify these seeming inconsistencies?

9. NIOSH needs to furnish guidance to dose reconstructors for applying the data tabulated in Attachment D. The tables list both 50^{th} and 95^{th} percentile values. Presumably, the 50^{th} percentiles are to be used as the best estimates, and the 5^{th} percentiles as the upper bound values. As mentioned earlier, the calculated 95^{th} percentile values are not upper bounds, as they are exceeded by annual average χ/Q's at each of the four monitoring stations. Can NIOSH clarify why such guidance is not needed?

10. The contributions of ^{236}U are missing in Attachment D. Concentrations of ^{236}U, which are listed in Tables 4.2.3-1 through Table 4.2.3-4, are comparable to those of ^{238}U and should presumably be taken into account. Can NIOSH clarify why these data are not provided?

11. We question the conclusion made in the TBD that the aerial surveys performed by the EG&G Remote Sensing Laboratory cannot be used for dose reconstruction. By spanning a period from 1973 to 1989, they provide a historical record of the external exposures on the site. Such data could be used to provide a temporal trend, and should be combined with the 1985 – 1987 scoping survey. The spatial resolution of the aerial surveys is comparable to the size of the grid blocks in the scoping survey. Furthermore, the exposure rates calculated at 1 m above ground, as presented in the aerial survey reports, appear to be more relevant to dose reconstruction than the ground level rates measured in the scoping survey. Can NIOSH further justify why these data are not usable for this purpose?

12. Given the purpose of the survey and the instruments used, we believe that the exposure rates were based on the count rates registered by the sodium iodide crystal in the survey meter. Such meters are commonly calibrated with a ^{137}Cs source—the scale on the rate meter is set to the calculated exposure rate at the location of the detector. This calibration is thus valid only for the principal ^{137}Cs γ-ray and will vary significantly with photons of different energies. The meter readings should be converted to dose rates in air (i.e., air kerma), using calibration curves that can be obtained from the manufacturer of the meter in question, or from manufacturers of similar instruments, and the known spectrum of the uranium isotopes deposited on the ground. (See the response curve for a 1" x 1" NaI crystal, below). The aerial survey data, which includes some spectral analysis, would be useful in this regard. The air kerma should in turn be converted to dose equivalent rates, using tables in ICRP Publication 74 for the appropriate exposure geometry. Can NIOSH clarify why the above approach would not be justified?

OCCUPATIONAL INTERNAL DOSE (ORAUT-TKBS-0014-5)

1. The TBD (pg. 24) indicates that methodological problems occurred during the early period of uranium bioassay, resulting in an underestimate by a factor of two. How has NIOSH/ORAU accounted for this underestimation in the dose reconstructions?

2. The TBD (pg. 13) discusses process streams of uranium. Included in the process streams are what are termed as "solvent extraction raffinates." What are "solvent extraction raffinates"? Is this a process that may concentrate particular radionuclides including daughter products?

3. The chemical forms of uranium at Y-12 include S, M and F type materials. What is the basis for the use of Type M material from 1948-June 1998 without regard to the type of cancer?

4. Provide an example of how the recycled uranium impurities are accounted for in the dose reconstruction.

5. In the TBD (pg. 23) there is a reference to section 5.4.2 for discussion of missed doses. This section appears to be missing. Is it going to be included in the near future? The TBD mentions that there is a concern that the technique used before May 1952 could have underestimated the urinary uranium concentrations. How is the dose reconstructor going to deal with these underestimates of urinary uranium concentrations ?

6. Was tritium dose included in the whole-body dose at Y-12?

7. Is NIOSH considering issues of frequency of monitoring during the remediation of the S-3 ponds (Section 2.6 of the Site Description)?

8. Has NIOSH investigated the incidents or the potential for acute exposures during the remediation of the S-3 ponds?

9. How does NIOSH plan to address early period internal dose issues?

10. What were the processes involving Th-232 at Y-12?

11. Page 7: Is there any explanation for why no urinalysis data have been found prior to 1948? The fluorometric technique should have been well established by that date. What steps are in hand to resolve this issue? Does the discussion of lack of urinalysis prior to 1948 (p. 5, vol. 5) mean that NIOSH is not doing dose reconstruction for the early period at this time?

12. Page 8: From the earliest days, it was recognized that 'insoluble' uranium (except for high-fired oxides) exhibited a solubility intermediate between Classes W and Y. This was addressed in one way by defining Class Q. However, was any attempt ever made to develop a model specifically for these uranium compounds and to then interpret the Y-12 data explicitly with that model? More generally, this report addresses joint interpretation of the urinary and fecal data, but says nothing about interpreting these data in conjunction with the chest counting data. Has such an overall analysis been attempted either at the level of the individual or in relation to groups of workers with similar exposure histories?

13. Page 9: Figure 5-2 gives a composite urinary excretion curve for 157 individuals. This conforms quite well to Class M behavior. However, this is not unexpected at a plant where a wide variety of uranium compounds of different degrees of solubility were used. It would be much more interesting to see the curves for the individual workers to see if they span the full range from Class F to Class S (or even beyond). Is this possible?

14. Page 10: The particle sizes range up to large values (10 μm physical diameter). Are there particle size data for respiratory zone relative to general area monitoring and can any useful relationships be established between the two?

15. Page 11: There is some indication in the appendix to the report that distinctions were made between routine and special monitoring. It seems likely that special monitoring would have been triggered by individual incidents. Could an account be given of the special monitoring program employed, including triggers for special monitoring, duration of follow up and any analyses of the results that have been undertaken?

16. Page 20: Can the constant 8 in equation 3.1 be reconstructed based on a detailed knowledge of the assay procedure used?

17. Page 21: Here and elsewhere a nominal counting efficiency of 0.5 cpm/dpm is used. Bearing in mind that this is for counting of a disk, this is the maximum possible value that can be achieved. This seems implausible. Can details of the counting geometry be provided, so that this issue can be examined?

18. Page 22: For the recent data on uranium in urine by alpha spectrometry, have comparisons been made with other methods, e.g. ICPMS or AMS? More generally, how

well are the various assay procedures used verified by inter-laboratory comparison exercises?

19. Page 27: Fecal sampling is effective at recording recent intakes of insoluble materials by ingestion and inhalation. Has consideration been given to whether fecal samples obtained at an interval of 53 days give a meaningful representation even of chronic intakes, which will exhibit considerable temporal variability?

20. Page 35: From what source can Wilcox (1999) be obtained?

INTERNAL DOSIMETRY CO-WORKER DATA

1. This report appears to, first, average urinary excretion data over individuals, and then interpret the results in terms of Class M and Class S intakes. Can NIOSH clarify why this was done, as the results must reflect different numbers of workers in different contexts? Also the results will inevitably be smeared in time because of the different time courses of exposure of the individual workers, as each worker will have been associated with multiple determinations of uranium in urine. Why was this analysis not undertaken on an individual-by-individual basis? This would have yielded a much richer understanding of the range of exposure conditions.

2. Given that multiple intake periods were used, the fitting model should be able to give a very accurate representation of the data. However, there are significant divergences for the Class M result (Figures A-9 and A-10), and these are much worse for the Class S analysis (Figures A-19 and A-20). These divergences arise from fitting data for each of the intervals separately and then adding the results. Why was this done instead of undertaking a simultaneous joint fit to all the intervals, or at least rescaling each of the individual fits by an overall normalization factor to give a better overall fit? (However, this remark should be seen in the context of the previous consideration that an individual-based analysis is to be preferred to the group analysis presented here).

3. OCAS-TIB-0029, *Internal Dosimetry Coworker Data for Y-12* calculates the 50^{th} and 84^{th} percentiles for urinalysis data. What is the basis for choosing the 84^{th} percentile?

4. Many of the tables and graphs in OCAS-TIB-0029, *Internal Dosimetry Coworker Data for Y-12* are missing the time period from 5/1/1952-7/31/1953. Is this intentional or should this time period appear in all relevant tables and graphs?

OCCUPATIONAL EXTERNAL DOSE (ORAUT-TKBS-0014-6)

1. Has NIOSH determined specifically which 25% of the population was monitored from 1949–1960?

2. NIOSH/ORAU has developed a photon dose correction factor for those workers who wore their dosimeter at their collar when the radiation source was at their waist. This is specific to unloading and sorting DU scrap materials, shearing of large pieces of scrap

materials, cleaning of the scrap materials, crucible loading during the melting and casting operations, and materials sampling (pg. 43). How are dose reconstructors able to distinguish individuals involved in these tasks from other individuals?

3. Considering the fact that some workers, especially those performing waist-level uranium handling jobs, could have received beta doses to the skin, breast, and testes, why has NIOSH/ORAU opted not to address them?

4. Elaborate on the statement (pg. 8), "The fabrication of weapon parts was expanded over the years to include other radioactive and non-radioactive material."

5. Does Table 6.3.4.3-2 (pg. 27) include zero badge results, including those from NTA badges not processed?

6. From the TBD, it is not clear if beta (and low-energy photon) doses were measured and entered into the worker's record and used in dose reconstruction. It states in several places that the two-element film badge, and the TLDs, had an open window and an effective 1 g/cm^2 filter. But it never states whether the open window dosimeter was read and recorded in the dose records. Was the shallow dose read and recorded as a shallow dose, Hp(0.07)? Will this information be used in dose reconstruction?

7. There were likely many accidents and/or incidents (e.g., 1958 Criticality Accident) that resulted in unexpected exposures to workers. How extensively has NIOSH/ORAU investigated the likelihood of other accidents and/or incidents that may significantly impact worker exposures?

8. Page 16, Section 6.3.2.2 is somewhat confusing. Does the summary below adequately characterize the Y-12 neutron monitoring history?

   1943–1950 = No neutron monitoring
   1950–1980 = NTA film
   1980–1985 = NTA film for fast neutrons + TLND for other energy neutrons
   1986–1989 = TLND only
   1989–2003 = Albedo-type TLND for proper Hp(10)

9. In the fourth sentence of Section 6.3.2.2 (Page 16), it states that between 1980 and 1989 there is a serious gap in the neutron dosimetry information for Y-12. If the neutron dosimetry was as listed above, why is this? It appears that the serious gap in neutron monitoring occurred from1943–1950.

10. Page 18, Table 6.3.3.1-1 states in the radiation quantity bias section that the calibration sources used may have caused a slight (about 3%) under-response in the recorded dose. This is the only place that the figure of 3% appears. How was the value 3% derived, and is it used anywhere in the dose reconstruction process?

11. Has NIOSH ruled out the possibility that radiation exposure was higher for Y-12 workers exposed to external penetrating radiation from handling recycled uranium (which may include other uranium isotopes, such as uranium-232), than for other Y-12 workers in other operations?

12. The TBD seems to ignore assignment of external dose for 1943–1950. In the absence of records, why has the TBD not developed a methodology for assigning upper bound external doses based on field radiological or source term data?

13. Why does the TBD assume that NTA film can effectively record neutron exposure at 500 keV and above, when the effectiveness of the NTA film falls off significantly between 500 and 1000 keV?

14. The PNL neutron spectrum report does not necessarily represent the neutron spectra in the field, especially with fission neutrons. What other basis does NIOSH/ORAU have for the assumption that 90%–95% of the neutrons in the field are detected by the NTA film?

15. Why has NIOSH opted to use primarily NTA film results at the Y-12 Plant, yet they have specifically excluded the use of these results at other facilities such as Hanford and the Savannah River Site?

16. NIOSH/ORAU has prepared ORAUT-RPRT-0032, *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1 – Gamma Radiation* and ORAUT-RPRT-0033, *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 2 – Neutron Radiation*. How are these reports related to the external dosimetry TBD? Are they intended to provide direction to the dose reconstructors?

17. ORAUT-PROC-0042, *Accounting for Incomplete Personnel Monitoring Data on Penetrating Gamma-Ray Doses to Workers in Radiation Areas at the Oak Ridge Y-12 Plant Prior to 1961*, provides direction on how to assign photon doses prior to 1961. What is the purpose for assigning a scaling factor? Explain how the scaling factor is applied to the dose reconstruction.

Document Requests:

(1) List of Classified Documents Used in the Preparation of the TBD
(2) Full-scale color representation of the four sets of aerial survey reports
(3) Reports relating to the scoping survey reference in the Environmental TBD.

ATTACHMENT 4: SUMMARY OF CONFERENCE CALLS ON SC&A QUESTIONS PROVIDED TO NIOSH

Dates: June 7, 2005, Medical TBD
June 7, 2005, External TBD, Part I
June 8, 2005, Site Description TBD
June 8, 2005, Internal TBD
June10, 2005, Environmental TBD (Provided in Attachment 5)
June13, 2005, External, TBD, Part II (Combined with Part 1 Above)

Y-12 Occupational Medical Dose TBD Conference Call Summary

Date: June 7, 2005
Subject: Occupational Medical Dose TBD, ORAUT-TKBS-0014-3 Rev. 00 PC-1, (Murray 2004)
Time: 9:00 to 9:45 a.m.

Individuals who participated included:

ORAU: William Murray, Elyse Thomas, and Ed Scalsky
NIOSH: Tim Taulbee and Greg DeCecco
SC&A: John Mauro, Joe Fitzgerald, Tom Bell, Hans Behling, and Ron Buchanan

SC&A: How much is really known about the number of photofluorographic (PFG) films that were taken in the 1943 to 1947 timeframe. Steve Wiley in his April 10, 2002 summary letter stated *"…to the best of our knowledge, there is no evidence of any fluoroscopic chest x-ray examinations performed at the Y-12 Medical x-ray Department*"(Wiley 2002). The TBD, however, in Section 3.3, page 6 uses the Graham 1946 letter that documents the order of 600 Eastman single coated x-ray films from Oak Ridge Hospital to come to the conclusion that: "Thus, it is clear that pre-employment chest x-rays were taken with a PFG unit from 1943 to 1947 as evidenced by 4" x 10" films found in the medical records and purchasing records." What do you know about the number of PFG chest films taken from 1943 to 1947 and what groups received them?

ORAU: We don't know a lot more than what you have stated. We did find evidence in the individual medical records of the presence of 4" by 10" chest films, which makes it seem clear that they did take PFG films. We have documented that a PFG unit was sent to Y-12 by our find of a telegram that Y-12 sent to General Electric in Nashville about the set up of the PFG unit. We also have the information that 6000 films were ordered from Eastman as you stated from the Graham 1946 request. We also have found out that there were several groups on which PFG chest films were more commonly used:

Food Handlers
Cafeteria Workers
Uranium workers

SC&A: For those workers who have PFG chest x-rays multiple times a year, did their medical records record each PFG chest x-ray examination?

ORAU: We also have evidence from their medical records that these groups often had several of these PFG films done each year. There would often be 3-4 PFG x-rays, which seems to capture the number of times the PFG x-rays were taken.

SC&A: Does this mean that the frequencies of occupational posterior/anterior chest x-rays at Y-12 in Table 3C-1, page 15 of the occupational medical dose TBD based on Wiley 2002, could be greater so that some workers got more frequent chest x-rays?

ORAU: In the case of those special groups who got multiple PFG chest x-rays, the frequency would be greater. It is possible that this might be true for some others but the individual medical record is likely to document them.

SC&A: SC&A has a concern about how accurate the 3.0 cGy (3.0 rem) entrance kerma default dose for photofluorographic chest x-rays are. How well documented is this entrance kerma dose of 3cGy for PFG x-rays? If this is off by a lot, it could mean a big difference in the skin entrance kerma dose. I realize this is addressed in ORAUT-OTIB-0006 (Kathren 2003), in Section 3.3 and Table 3.3-1, page 17, but I wondered what you have found on this subject.

ORAU: You are correct, the most we know is what is in OTIB-0006 and Ron Kathren is very credible. We had access to what Ron Kathren was preparing as we were finalizing the Y-12 occupational medical dose TBD.

SC&A: It is noted in ORAUT-OTIB-0006, Rev. 02, page 17, (Kathren 2003) that additional information is available about Table 3-4, page 8 of the occupational medical dose TBD. Since this was available as the occupational medical dose TBD (ORAUT-TKBS-0014-3, Rev. 00 PC-1, 2004) was being finalized, would it not have been beneficial to provide this information in the occupational medical dose TBD?

ORAU: Since we knew the OTIB-0002 would follow our occupational medical dose TBD shortly, we decided to let the OTIB-0002 provide the details.

SC&A: It is noted in the occupational medical dose TBD stated "The medical practices used at Y-12 are assumed to have followed the adoption of standards of radiology practice during the 1930s and 1949s to minimize dose to the patient. However, there is the potential for significant dose from occupational medical x-ray examinations, depending on the type of equipment, the technique factors, the number of photofluouographic (PFG) examinations typical in the early years, and the number of radiographic examination (Cardarelli et al. 2002)." On what basis did you make that assumption?

ORAU: It was the information provided in the Cardarelli 2002 reference cite that led us to make that assumption. We also spoke with an x-ray medical technologist that worked at Y-12 and also

collaborative this assumption. He was there in the early period, left for a while and returned in 1971. We, however, have no information on the calibration of these early chest x-ray units.

SC&A: On page 9 of the occupational medical dose TBD, you have stated that: "Other variables, such as the use of screens and grids, reciprocity failure, film speed and development would not affect the beam output intensity. On what basis did you make that assumption?

ORAU: Although we did not go into detail on this point in the occupational medical dose TBD, Ron Kathren in OTIB-0006 does provide the rationale for this assumption.

SC&A: It is noted in the occupational medical dose TBD, page 7, Table 3-2, that the description of the Type II machine used from 1948 to 1968 that the Type II equipment is unknown. However, in Table 3-3 on the same page specific technique factor are provided for each type of x-ray equipment included the Type II machine. How can you be certain that these technique factors for the Type II machine in Table3-3 are correct? Wiley 2002 also mentions that the exact model of the medical diagnostic x-ray machine was unknown and that the filtration was unknown. This would imply that knowing anything about measurement output is also lacking.

ORAU: We know little more that what was provided in Wiley 2002. The x-ray technologists advised us that the unit used was similar to standard units in use at that time and provided us information on the Type II x-ray machine at Y-12. As we stated in Section 3.4, page 7 of the occupational medical dose TBD, in the period from 1943 to 1947, no actual x-ray output measurements are available.

SC&A: We note in Wiley 2002, that he states that radiation exposure from the early chest x-ray units was 30 mr for the period between mid 1940s to early 1960s. It drops to a radiation exposure of 20 mr between the early 1960s and January 1982 and after that was further reduced to 10 mr. How do these radiation exposure values relate to the entrance kerma values in Table 3.4, page 8 of the occupational medical dose TBD? For instance that table shows the entrance kerma in cGy for the pre-1970 period for a posterior/anterior Y-12 chest x-ray as 0.2 cGy (or 0.2 rem).

ORAU: We believe that the 30 mrem in the early period is the dose measurement in air. That is then converted into a skin entrance kerma dose by methods described in the NCRP Report No. 102 (NCRP 1989) cited in footnote "a" of Table 3-4.

SC&A: How were the organ doses from photofluorographic chest x-rays (rem) in Table 3C-2, page 17, of the occupational medical dose TBD determined? Did you use the entrance kerma of 3.0 rem and multiply it my some factor provided in ICRP 34 (1992)? I bring this up because if there are questions about how accurate these organ doses are, then a claimant may have gotten more organ dose that these might indicate.

ORAU: Our understanding is that ICRP 34 (1992) actually provided the organ doses for each of the organs listed in Table 3C-2.

SC&A: We note in Table 3C-2 that there is an organ category called "Remainder". What organs fall into that category?

ORAU: "Remainder" represents any other organ that is not available in the list of organs. This is addressed by ICRP 34 (1992) and is catch all if you can't find the organ you are considering.

SC&A: It is interesting to note that the organ "skin" in Table 3C-2 has the highest organ dose. Is the PA dose to the front of the body or the skin of the back: Also would prostate fall under Remainder"?

ORAU: Yes skin does have the highest organ dose to be claimant favorable. The doses in Table 3C-2 is an exit dose so that it is the dose to the skin of the back. Prostate cancer falls under the organ "Urinary bladder"

SC&A: If you are dealing with a skin cancer on the face, do you then use these exit doses at the posterior surface of the back.

ORAU: In the case of skin cancer to the face, we would modify to dose estimate to take into account the dose to the skin of the face.

SC&A: Is there a reason why Table 3.1-2, page 16 in OTIB-0006 was not utilized in the occupational medical dose TBD. This table has wealth of summary data on actual beam measurements for that might be applicable to Y-12 as well.

ORAU: Since this Table 3.1-2 is actually for the Hanford site, we found that some of it was not applicable to Y-12 and this did not include it in the occupational medical dose TBD.

SC&A: Can you tell us more about the medical impacts of the June 1958 Y-12 criticality incident.

NIOSH: There were eight workers who were involved in the Y-12 criticality accident. They were all followed closely at the time and their medical records provide a lot of documentation. The dosimetry was quite well done. These have been well written up in the literature and a search on the "O" drive under "criticality" should bring up the pertinent documents. Six of these workers have since filed claims and all six have been awarded.

SC&A: Did these workers later develop cancer?

ORAU: Yes, all six got cancer.

SC&A: Since you have no data on beam output, how well do you think you can characterize entrance skin kerma for the older Type I and Type II x-ray machines?

ORAU: Since there was no collimation during these early periods, we have assumed the maximum beam size was delivered which is the most claimant favorable assumption we can make.

Y-12 Occupational External Dosimetry TBD Conference Call Summary

Date: June 7, 2005
Subject: Occupational External Dosimetry TBD, ORAUT-TKBS-0014-6, Rev. 00, (Kerr 2003)
Time: 9:00-10:30 am EDT

Individuals who participated included:

ORAU: Bill Murray, and Elyse Thomas
NIOSH: Tim Taulbee and Greg DeCecco
SC&A: John Mauro, Ron Buchanan, and Bob Alvarez

Date: June 13, 2005
Time: 10:00-11:00 am EDT

Individuals who participated included:

ORAU: George Kerr, Ed Scalsky, Bill Murray
NIOSH: Stu Hinnefeld
SC&A: Ron Buchanan, Tom Bell, and Kathy Robertson-DeMers

ORAU General Comments:

We will mainly concentrate on the Y-12 TBDs related to external dosimetry, and not on dose reconstruction or internal dose issues.

SC&A: Has NIOSH determined specifically which 25% of the population was monitored from 1949–1960?

ORAU: Workers that had the potential to be exposed to radiation in the Assay Labs, Radiographic Shop, Spectrographic Shop, and the Metal Machine Shops., as well as any X-ray workers and radioisotope handlers were badged.

SC&A: NIOSH/ORAU has developed a photon dose correction factor for those workers who wore their dosimeter at their collar when the radiation source was at their waist. This is specific to unloading and sorting DU scrap materials, shearing of large pieces of scrap materials, cleaning of the scrap materials, crucible loading during the melting and casting operations, and materials sampling (pg. 43). How are dose reconstructors able to distinguish individuals involved in these tasks from other individuals?

ORAU: These workers are identified through interviews and job changes in their personnel files. If they performed that kind of task, the 1.34 x correction factor will be applied to their recorded dose.

SC&A: Considering the fact that some workers, especially those performing waist-level uranium handling jobs, could have received beta doses to the skin, breast, and testes, why has NIOSH/ORAU opted not to address them?

ORAU: While this version of the TBD does not cover this subject, a revised TBD will be issued that includes this dose reconstruction (DR).

SC&A: Elaborate on the statement (pg. 8), "The fabrication of weapon parts was expanded over the years to include other radioactive and non-radioactive material."

ORAU: The unclassified information is contained in Pages 6-8 of TKBS-0014-02. Some other information will come out in the revised TBDs/TIBs concerning deuterium, thorium, and beta dosimetry; perhaps by fall of 2005. The history of Y-12 by Wilcox might also provide some additional information.

SC&A: Does Table 6.3.4.3-2 (pg. 27) include zero badge results, including those from TLND (not NTA) badges not processed?

ORAU: Yes. It includes all issued neutron badges. All neutron badges during this time period were read. It would also include zero or MDL reading also. The MDL was small, in the order of a few millirem.

SC&A: From the TBD, it is not clear if beta (and low-energy photon) doses were measured and entered into the worker's record and used in dose reconstruction. It states in several places that the two-element film badge, and the TLDs, had an open window and an effective 1 g/cm^2 filter. But it never states whether the open window dosimeter was read and recorded in the dose records. Was the shallow dose read and recorded as a shallow dose, Hp(0.07)? Will this information be used in dose reconstruction?

ORAU: Yes, the open window and filtered film was read, recorded, and will be used in the DR process. The penetrating Hp(10) dose includes the gammas plus neutron dose and the Hp(0.07) includes the penetrating plus the skin dose. Most of the beta dose was received by the metal workers. A future TIB will be issued that will address the beta and low energy photon dose in further detail.

SC&A: There were likely many accidents and/or incidents (e.g., 1958 Criticality Accident) that resulted in unexpected exposures to workers. How extensively has NIOSH/ORAU investigated the likelihood of other accidents and/or incidents that may significantly impact worker exposures?

ORAU: NIOSH's instructions were not to include accidents/incidents in the TBDs, unless they involved a significant number of workers, such as the 1958 criticality accident. The DR can obtain information concerning this issue in the individual worker's files, or interviews.

SC&A: Page 16, Section 6.3.2.2, is somewhat confusing. Does the summary below adequately characterize the Y-12 neutron monitoring history?

1943–1950 — No neutron monitoring.
1950–1980 — NTA film.
1980–1985 — NTA film for fast neutrons + TLND for other energy neutrons.
1986–1989 — TLND only.
1989–2003 — Albedo-type TLND for proper Hp(10).

In the fourth sentence of Section 6.3.2.2 (Page 16), it states that between 1980 and 1989 there is a serious gap in the neutron dosimetry information for Y-12. If the neutron dosimetry was as listed above, why is this? It appears that the serious gap in neutron monitoring occurred from1943–1950.

ORAU: NTA film for neutron monitor was most likely used on a routine basis around 1950. Most of the neutron dose at Y-12 was because of the operation of the 86" cyclotron between 1950 and 1961. During 1962–1980 the ORNL operation of this unit did not involve Y-12 workers. Neutron doses were so small during 1980–1989 that ORNL processed the neutron dosimeters for Y-12. Therefore, this processing information would be at ORNL. There is not really a problem with the neutron dose, but Y-12 records do not contain the details because of the ORNL processing.

SC&A: About how many Y-12 workers received neutron exposures?

ORAU: Until ORAU reviewed the Y-12 epidemiology studies, there was a lot of uncertainty on this. It appears that up to 1980, there were 375 positive neutron recorded doses for approximately 143 workers. Some of these were assigned the MDL of 50 mrem. The dose was often less that the MLD but the MDL dose of 50 mrem was assigned anyway. From 1962 to 1980 there were no neutron doses or is was so low that it couldn't be detected by the NTA film. Then around 1980, Y-12 switched over to the neutron albedo dosimeter. There was some medical isotope production done in the early 1980s, but this was done by X-10 workers. There were so few Y-12 workers involved that they sent all the neutron dosimeters to X-10 for processing. During 1989 and 1990, dosimeters were either read at ORNL or X-10.

SC&A: The TBD seems to ignore assignment of external dose for 1943–1950. What is being done to develop a methodology for assigning upper bound external dose based on field radiological and source term data, particularly for neutrons?

ORAU: We have found little monitoring data for 1943 to 1950 and it appears that there was not much of a neutron problem during this period. With the (n/alpaha) reaction in UF_4 it is doubtful that you could measure the neutron fluence. I think they used the Ying and Yang dual ionization chamber. This was written up by Hurst and Richie in the late 1940s.

SC&A: It appears the external film badge was not perfected until about 1948. What did they use for monitoring prior to that?

ORAU: At Y-12, the started with the Victoreen ionization chamber. In 1940, they switched to the use of the film badge. During 1948–1949, Y-12 used both the film badge and the pocket ionization chambers. An extrapolation process was used where needed. A report providing more details on this is in preparation for NIOSH review.

SC&A: Then what you are saying is that there will not be many dosimetry records prior to 1950. Is that correct?

ORAU: During the Tennessee Eastman Company (TEC) period, most of the concern was about x-rays from high voltage tubes in the calibration panels and the rectifiers (high voltage vacuum tubes.) During this period, the pocket ionization chambers were the only area monitors. They used the Victoreen R chambers (pocket dosimeters) to ensure they were minimizing x-ray dose from the Calutron high voltage panels.

SC&A: Page 18, Table 6.3.3.1-1 states in the radiation quantity bias section that the calibration sources used may have caused a slight (about 3%) under-response in the recorded dose. This is the only place that the figure of 3% appears. How was the value 3% derived, and is it used anywhere in the dose reconstruction process?

ORAU: This value was taken from NBS-85 (1962). This 3% correction factor is so small that it is likely that it would not be applied by the DR as it is within the noise range of the calibration and film badge reading process. The uncertainty of calibrating and reading the film badge is about 10% and the 3% is just a part of that.

SC&A: Has NIOSH ruled out the possibility that radiation exposure was higher for Y-12 workers exposed to external penetrating radiation from handling recycled uranium (which may include other uranium isotopes, such as uranium-232), than for other Y-12 workers in other operations?

ORAU: The RU workers were monitored for radiation exposures. We are currently working on addressing the beta doses, either from first-principles or the opened literature.

SC&A: The TBD seems to ignore assignment of external dose for 1943–1950. In the absence of records, why has the TBD not developed a methodology for assigning upper bound external doses based on field radiological or source term data?

ORAU: The records to date do not indicate any significant neutron sources before 1950 when NTA film was first used. Photon exposures were monitored using "R" chambers, gamma-film badges, and pocket ionizations chambers.

SC&A: Why does the TBD assume that NTA film can effectively record neutron exposure at 500 keV and above, when the effectiveness of the NTA film falls off significantly between 500 and 1000 keV?

ORAU: This was the threshold chosen for Y-12. If the threshold was raised to 800 keV, it probably would not make much difference in total neutron dose because most of the neutrons were not of the lower energy fission spectrum at Y-12.

SC&A: The PNL neutron spectrum report does not necessarily represent the neutron spectra in the field, especially with fission neutrons. What other basis does NIOSH/ORAU have for the assumption that 90-95% of the neutrons in the field are detected by the NTA film?

ORAU: There were very few fission neutrons at Y-12. The critical assembly was most likely the only significant source because (alpha,n) produced neutron exposures were extremely low in the work environment. The major source of neutrons, besides the 86" cyclotron, was the radioisotope sources, such as RaBe, PuBe, and AmBe; the PNL measurements match these sources. Most of the sources were in shielding facilities. Most calibration sources were kept in pigs and only brought up by remote control. Therefore, there is likely not much exposure from these radioisotope sources. The Y-12 neutron report covers some of this dating back to 1949 to the early 1950s.

SC&A: Why has NIOSH opted to use primarily NTA film results at the Y-12 Plant, yet they have specifically excluded the use of these results at other facilities such as Hanford and the Savannah River Site?

ORAU: Most of the neutron energies at Y-12 were above the NTA film threshold. Therefore, the NTA film is more applicable at Y-12 as compared to other AEC/DOE sites that had more fission neutron spectra. The use of n/p ratio measurements to estimate neutron doses is addressed further in the ORAUT RPRT-0033 document, which is available for use by the DRs when needed. Usually if you don't see a positive neutron dose then you can assume that workers were not exposed to neutrons.

SC&A: NIOSH/ORAU has prepared ORAUT-RPRT-0032, *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 1 – Gamma Radiation* and ORAUT-RPRT-0033, *Historical Evaluation of the Film Badge Dosimetry Program at the Y-12 Facility in Oak Ridge, Tennessee: Part 2 – Neutron Radiation*. How are these reports related to the external dosimetry TBD? Are they intended to provide direction to the dose reconstructors?

ORAU: Yes, they are available to the DRs and can be used to supplement the TBDs.

SC&A: It is stated on page 7 of the external dosimetry TBD that the fabrication of weapon parts was expanded over the years to include other radioactive and non-radioactive materials. What are some of these other radionuclides?

ORAU: Y-12 process lithium, DU, ^{233}U and thorium. We have been looking at the potential for beta dose and are trying to develop methods to deal with these other radionuclides. A report by William Wilcox published in 1999 provides an overview of the history of Y-12 and may have some information that can help address this. Hand doses are covered in the internal dose TBD. In Rev. 01 of the internal dose TBD, there is a lot of data on thorium air sampling and whole

body counting conducted when workers were suspected of being exposed to thorium. In over 100,000 whole body counts taken, only 160 were found to be positive. 400 to 500 have been found to be below the MDL of 6 mg for thorium. A thorium TIB is being reviewed by OCAS that will, when published, provide a lot of new information. Some of the data on this is still "Official Use Only" but what is unclassified will be made available to the public.

SC&A: The external dosimetry TBD, page 8, mentions that for the later program involved in the fabrication of weapons parts, that only about 25% of the workers were monitored up to the time of the criticality accident at Y-12 in 1958. What were the groups that were monitored?

ORAU: The workers that were monitored were those in the SA Lab, the metal works facility, the spectrographic metal shop, the metal machine shops and the assay labs. It has been hard to find specific data. Much of it is in documents which contain classified as well as some unclassified data and cannot be easily used prior to be cleared for release by the declassifiers. What we are seeing is that if area monitors indicated that workers could exceed 10% of the guidelines at the time, these workers were put on monitoring programs. If they changed jobs and no longer in jobs that might result in them getting over 10% of the guidelines, they were taken off the monitoring program or added if they were found to move to jobs where they might exceed 10% of the guidelines. These workers were tracked and we find evidence of this is the procedures at Y-12. Monthly reports and health physics reports often provide these kinds of details. We have found that a 1962 summary report has quarterly gamma doses recorded which also includes beta skin doses. These seem to be pretty well kept up in following these workers. In more recent years, at least from experience from X-10, superiors had to approve work permits that involved workers who went into area where the 10% of the dose guidelines might be exceeded. Health physics staff tracked workers on a day to day basis. They used pocket dosimeters and if found a worker exceeded 0.5 rem, they would pull the worker's film badge and have it developed right away. In more recent years, health physics supervisors are under a mandate to ensure no workers do no exceed the 2 rem/year occupation exposure limit set by DOE regulations. In general, workers have been well tracked.

SC&A: Is there anything new on the Y-12 SEC petitions?

NIOSH: There are three SEC petitions for Y-12. There is some information on the NIOSH website about these, and it is possible that two of these are already or may soon be posed on the website.

SC&A: ORAUT-PROC-0042, *Accounting for Incomplete Personnel Monitoring Data on Penetrating Gamma-Ray Doses to Workers in Radiation Areas at the Oak Ridge Y-12 Plant Prior to 1961*, provides direction on how to assign photon doses prior to 1961. What is the purpose for assigning a scaling factor? Explain how the scaling factor is applied to the dose reconstruction.

ORAU: The purpose of the scaling factors is to allow the DR to scale up the calculated pre-1961dose for a worker that had higher-than-average dose data in the post 1961 period. This will takes in consideration that the worker most likely worked in a higher-than-average radiation

environment before 1961 and therefore should be assigned a higher than average dose for the pre-1961 period.

Y-12 Occupational Site Description TBD Conference Call Summary

Date: June 8, 2005
Subject: Site Description TBD, ORAUT-TKBS-0014-2 Rev. 01, (Jessin 2005)
Time: 9:00 to 10:30 a.m.

Individuals who participated included:

ORAU: William Murray, Karen Jessen, and Ed Scalsky
NIOSH: Stu Hinnefeld
SC&A: Joe Fitzgerald, Hans Behling, Joyce Lipsztein, Bob Alvarez, Kathy Robertson-DeMers, Tom Bell, and Ron Buchanan

SC&A: There is much about the history at Hanford that is not thoroughly covered in the Site Description TBD. A Health and Human Services Document published in December, 1996 provides a very detailed review of operations at Y-12 up through October 1996. This provides a very detailed look at the operations conducted at Y-12. It appears that NIOSH has not thoroughly reviewed and used this data. There were many operational changes that occurred within each facility and across the Y-12 site that can significant impact the dose reconstruction process. The process histories provided in the HEW, 1996 document provides an important chronology of what happened in different buildings and with different processes at the Y-12 site.

ORAU: The Y-12 documents were the third ones prepared and came early in the development of the site specific TBDs. Rev. 00, which came out in March 2003, was supposed to be a general discussion of Y-12 activities and was not supposed to include all the data or to have the kind of detail you describe.

SC&A: The operations and activities at the Y-12 site were a dynamic process. New processes were being added and some dropped as the site evolved. There was a mixing of workers around the Y-12 site, between different facilities on the Y-12 site and even to different area with a specific building or facility. There is a need to link processes with the specific records for the operation, building or facility. There is often, especially in the early period when there was no bioassay for each type of operation. To do an adequate job of reconstructing dose, the DR needs to know more about what facility the claimant is working at and the process in which he or she is involved. It is also important to refer to any databank that might be available to account for accidents, fires, explosions or off-normal incidences that would affect the claimant's dose.

ORAU: We all wish there was more time to help develop this clearer picture on the type of process and what the individual claimant likely encounter, but the accelerating schedule to get these TBDs out for us often precludes getting into this level of detail.

SC&A: We realize that, due to fact that some issues are still classified, it is best to use the information that is in the public domain. SC&A has an unclassified CDROM that contains information on work at Building 99-102. If you provide a point of contact, SC&A will be glad to share a copy of the CDROM with you.

ORAU: We would be most interested in getting a copy. Let's work out the details after this call.

SC&A: Regarding question 4 in our list of site description TBD questions sent to NIOSH on May 25, 2005, we note the TBD mentions the handling of recycled uranium (RU) at Y-12, but does not provide any estimates of dose or the timelines when RU was handled. A Task Force was convened in 1985 to review the use of RU at Fernald, but the Task Force, looked at Y-12 as well. Their report, not the report in 2000 that dealt with mass balances, addressed this review. Y-12 has also done its own assessment which explains the handling of RU by workers and which groups of workers did not handle RU at Y-12. It seems the highest dose to workers were gamma exposures. Y-12 and Savannah River Site (SRS) had a handshake agreement on what the specifications were but we have not been able to locate any written information on these specifications and what trace contaminants were present. There is also information on plutonium work at Y-12 in the PU Out of Specification (POOS) document. Such specifications are important to locate. As you might know, Fernald had to shut down their RU line because they had problems with specifications and it was found that they had more RU there than the specifications indicated were possible. At Y-12 and SRS, there are no formal specification standards, only these gentlemen's agreements. Since they were not measuring for trace contaminants, there is a potential for missed dose from these trace contaminants of RU.

ORAU: It was not possible to get into this kind of detail as we prepared the Site Description TBD. Table 2.4-1, does provide information on the process chronology of operations that we found.

SC&A: The CDROM we indicated we are willing to send to you should help to expand upon Table 2.4-1. It is important to know the relationship on what was being handled, when it occurred and at what facilities. Y-12 was handling ^{233}U because we know that Hanford had sent some 200 Kg. to Y-12. There was keen civilian and military interest at the time on how the ^{233}U was to be used. Unclassified specifications have been found that state that this was only 8 Kg. It is also known that Rocky Flats was using ^{233}U. It looks like at Y-12 in the 1960s that tons of ^{233}U were processed at Y-12 that was in nitrate solution. ORNL might have a handle on this. We have noted that at Hanford they tried to control this to < 15 ppm.

ORAU: We have found no information on the use of 233U when the data was retrieved from Y-12. Much of the data on ^{233}U is still classified. We only focused on records provided by Y-12.

SC&A: We also understand that recent efforts by Mel Chew has uncovered a number of documents that will better define the use of thorium at Y-12 and that this was a major focus of Mel Chew's visit to Y-12 recently.

ORAU: Yes, that is correct.

SC&A: In the review that Mel Chew did, we hear that he focused on ^{232}Th and ^{228}Th, on whole body counting and air sampling.

ORAU: Yes, that is correct. The documents that Mel Chew collected are now on the ORAU database "O" drive.

SC&A: Oak Ridge and Y-12 workers seemed to be working back and forth between these facilities, which make it hard to track who was responsible for their dosimetry. There were also some Oak Ridge National Laboratory (ORNL) facilities at the Y-12 site. Some of the analyses done on Y-12 workers were ORNL analyses. We wonder, do these fall under X-10 dosimetry or Y-12 dosimetry?

ORAU: There were 3 or 4 facilities to which ORNL workers and staff had access to at the Y-12 site. Some of the ORNL health physics staff did help on Y-12 analyses.

SC&A: Did Y-12 health physics staff have radiation safety overview or did the X-10 health physics staff have this overview?

ORAU: ORNL work at X-10 is covered in the ORNL Site Profile TBD.

SC&A: Y-12 maintenance personnel were known to show up at the X-10 projects. Y-12 maintenance personnel went to K-12 and X-10 personnel went to K-12 as well.

ORAU: Yes these did occur. We have to rely on claimant's personal file and the CADI to determine where and when a claimant worked at these different facilities.

SC&A: A maintenance employee at Y-12 told us that ORNL called him to work in the Biology Building at ORNL. How is this handled?

ORAU: We assume that this would come up in the CATI interview with the claimant. For the most part, work at Y-12 was covered by Y-12 health physics personnel.

SC&A: It appears that if a Y-12 employee was on loan to K-25, that his dosimetry would still be considered Y-12 work. Is that correct?

ORAU: We don't see this level of detail, because we do not handle these aspects here at Y-12.
SC&A: We can assume then that an X-10 worker is subject to radiation safety controls from X-10 health physicists?

ORAU: That's what we understand.

SC&A: Pertaining to question 7, Table 2.3-1 shows some "NA" notation for some of the buildings listed. Does that mean that the actual building number is not available or that it is not

listed for security reasons? Although a footnote "a" is shown in the table, footnote "a" is not discussed below the table.

ORAU: It just means that it is not available.

SC&A: In regard to question 5, it seems like more information is needed to determine if radiation exposure data are accurate and complete for people who cycled in and out of the Y-12 Laboratory and ORNL during the period between 1943 and the early 1970s. The building numbers, i.e., the "not available" in Attachment B, Table B.1-1 make it difficult for the dose reconstructor to handle determine radiation exposure data.

ORAU: Yes, you are correct. This kind of cycling between buildings occurred even into the late 1980s and early 1990s.

SC&A: It seems it will be important to get a better feel for this.

ORAU: We hope to be able to do this.

SC&A: A Department of Energy Defense Program survey done might be a way to do this. Is this report still classified? This included a highly enriched uranium (HU) vulnerability assessment. This should help to give you some idea of the extent of the problem. The TBD would be strengthen if it included this historical information and postulated on the dose reconstructor will need to do to develop a dose for the worst case situation.

ORAU: We did not have this document at the time we wrote the Rev. 01 Site Description TBD. It appears that SC&A sees and has access to documents that NIOSH does not have. We have been hampered by the shutdown of the Y-12 library which has made it difficult to find Y-12 documents. We don't know where they sent their documents when they shut down the Y-12 library. Some of them have been found at the ORNL library, but only some of them are there. George Kerr might know something about where these documents were sent and perhaps you can ask him this on you conference call next Monday, June 13, 2005.

SC&A: It is possible what was once publicly available documents may no longer be available because they may have been subsequently classified.

ORAU: We went to the site and did exhaustive research is what was there. We think we have recovered a lot of the important documents. It's hard to tell if some of these were later classified.

SC&A: ORNL tried to use state-of-the-art measuring devices and dosimetry, but in the early days they were operating out of the old wooden buildings which made efforts to clean up contamination difficult. There are some reports on this. Have any of these Y-12 reports been declassified?

ORAU: No, I think many are still classified. The only possible help might be the data on thorium in the occupational internal dose TBD. It is likely that many of these documents may be "Official Use Only" and not actually classified higher than this.

SC&A: In regard to the electromagnetic isotope separation (Calutron) plant operated in the first era from 1942 to 1947, were you able to find any dosimetry data or to document to potential for dose from uranium contamination?

ORAU: No.

SC&A: Can you tell us more about what is involved in the Y-12 Special Exposure Cohort (SEC) petitions. We understand that Lew Wade may be able to provide some background data on them but we have not seen yet the actual SEC Petitions?

NIOSH: There is background information on the three Y-12 SEC Petitions in a June 6, 2005 Federal Register Notice. Two of these three SEC Petitions are under review by NIOSH and I believe I just saw them posted on the ORAU web site.

SC&A: In regard to question 10, on whether ^{232}Th fuel for the Molten Salt reactor or any other reactor at Y-12 was ever fabricated there, is it likely the Mel Chew review will address this. It appears that Mel Chew may be the only person who will be able to address this.

ORAU: Mel Chew, with the recent records he has just found at Y-12, would be the best person to answer that.

SC&A: In reviewing the HU vulnerability assessment study, we note that the ^{228}Th has some hard gamma. Thus exposure to these hard gammas at Y-12 could be important for workers doing thorium processing evolutions. It is also unclear whether or not, workers were exposed to ^{232}U, in particular the dose from its daughter products. The new Mel Chew data on thorium will be important. SC&A has provided some useful information on ^{232}U in our soon to be released Hanford Site Profile Review Draft Report.

ORAU: George Kerr, is our subsequent conference call, can perhaps comment on the internal dose considerations of thorium and ^{233}U as well.

SC&A: In regard to question 11, have you located a databank for incidents at Y-12? The only one we have found was established in 1990. The Y-12 Vulnerability Assessment refers to such a listing of incidents in the 1970s and 1980s but we are not sure any existed prior to that.

ORAU: We only have information on incidents or accidents that impact a large number of individuals. The criticality accident in 1958 is mentioned in the Site Description TBD. We have not covered many specific such incidents unless they are major incidents like the criticality accident. We presume a worker's involvement in such an incident or accident will be identified in the CATI interview or in the individual claimant's personal file.

SC&A: What is considered "large numbers of individuals"?

ORAU: We handled these when we first wrote our TBDs on an individual basis and only address major incidents in the TBD. Now we have been adding in more data in the TBDs especially when there are large numbers of people involved, it's a large area, or there are significant doses involved in the incident.

SC&A: In the Y-12 vulnerability assessment document, there were situations that RadCon felt were significant. How has NIOSH made adjustments to the dose reconstruction process as a consequence of contamination spread listed? There are instances reported where contamination was carried around without first going through a decontamination process. The whole west side of Y-12 was totally contamination with uranium and various groups were coming and going into these areas. How does NIOSH adjust doses to take this into account? As noted in our issue 13, this applies to other uranium chemicals as well.

ORAU: The Calutron Plant did not operate too long. It was shut down in 1947 and a new gaseous diffusion plant replaced it. After 1947, additional health physics resources were put in place to address controls for contamination spreads. Now the Calutron Plant is used for stable radionuclides. In our TBD we were not able to get into how effective Y-12 was in controlling such contamination spreads, we just documented that this was a problem.

SC&A: How effective have you been in characterizing off-batch processing operations and special campaigns like we brought up in our issue 13 in our questions list? It is not clear how NIOSH is handling dose reconstructions for these special campaigns. Medical isotope production is yet another area like this.

ORAU: These kinds of issues are so specific and they are too small to have the opportunity to address. We try to address these for individual claimant's but not so much in the TBDs.

SC&A: NIOSH may want to rethink how you present these varying dynamics. The function ongoing in the building at each point of time is undergoing a lot of change. It is important that the TBDs provide the dose reconstructor with an idea of what is going on at specific times and in specific facilities.

ORAU: As we get additional information, we try to do that.

SC&A: In regard to question 13, actual operations at Y-12 could give rise to significant operational exposures while handling large amounts of ^{237}Np and yet this is not addressed specifically in the TBD.

ORAU: We did not find information yet documenting such ^{237}Np handling operations at Y-12. In our discussion yesterday, during our external dose TBD conference call, we did address ^{240}Pu, and ^{239,240}Pu while discussing question 14. Under radionuclides of concern in Section 5.1.5 we did note that ^{237}Np was a radionuclide of concern. The DRs have the latitude to look into the specifics. In the TBD we have only covered the primary ones. Some you can talk about and others you cannot.

SC&A: It seems that it will be important to learn more about these off-batch processing operations since there is likely to be inadequate radiological controls in individual operations. NIOSH needs to better characterize these so as to better identify those which may have high exposures related to them. This is important for contaminated process streams as well. In our question 14, we also inquired about why plutonium likely to be of low "burnup" was not discussed. We note that Hanford operations involved production of ^{240}Pu. We wonder where it was going and if Y-12 did not receive a lot.

ORAU: We presented this and discussed this at our Mel Chew meetings. It was discussed that ^{240}Pu would only be present in small quantities and thus would represent little dose impact. The TBD has taken a look at ^{238}Pu and ^{239}Pu.

SC&A: In regard to question 15, did not the handling of substantial quantities of tritium, warrant a discussion in the Site Description TBD?

ORAU: As we mentioned during our external dose conference call yesterday, there was only a pilot program for tritium stated at Y-12 which ran for only a short time. That program was never implemented since they found that there were never significant quantities of tritium at the Y-12 site and that doses to tritium were negligible. That is why the TBD is so sparse on this subject.

SC&A: Did Y-12 ever store spent fuel?

ORAU: There is no evidence that spent fuel was ever stored at Y-12.

SC&A: In regard to question 16, in Section 2.4.6 it appears that new filters may not have operated effectively from their installation in 1955 through July 1956. What can you tell us about that? We note there have been several ventilation upgrades over the years and one is in process now.

ORAU: Let's defer that to our discussions on internal dose this afternoon.

SC&A: Regarding question 17, it was noted that the first assessment of the S-3 ponds indicated that no special precautions were required for clean-up work. However, the second survey indicated that precautions were required. Was work on capping the ponds undertaken without such precautions between the two assessments?

ORAU: We will have to look into that.

SC&A: On page 20 of the TBD, two default solubility assumptions are give that comprise a mixture of Class M (90%) and Class S (10%). In interpreting the data, was consideration given to using a single solubility class intermediate between Classes M and M? On page 21, three default solubility assumptions are given for workers who participant exclusively in the urine bioassay program. Can you please comment on that?

ORAU: Someone at Y-12 gave us this solubility information. We would have to ask him about this. IMBA can't handle Class Q when you input your data.

SC&A: Actually, IMBA can handle this by changing input data about the lung; you just have to know how to do it. A 50%S and 50%M might not work well for organ dose. It is hard to understand why Type S is used for lung dose and not Type M.

ORAU: We will have to take this up with our Y-12 expert.

SC&A: In our question 20, we noted that on page 21 of the TBD, Y-12 used a DOSE-66 code while IMBA is used in other technical basis documents SC&A has reviewed. DOSE-66 was developed in 1990 but was not validated until 2000. Why was the DOSE-66 given precedence? We need a reference on this?

ORAU: DOSE-66 may be covered in the Y-12 internal dose TBD that Bryce Rich and Mel Chew published in May 2005. The original author, Howard Prichard, has passed away.

SC&A: Who is the internal dosimetrist at Y-12 with who you consulted?

ORAU: Mike Saulyiette is the ORNL dose we referred to.

SC&A: In regard to our question 19, in Table 2.9-1 on page 21 of the Site Profile TBD, we note that all the uranium compounds are assigned solubility classes. Can you address these gaps?

ORAU: Several of these are not radioactive.

SC&A: In regard to our question 21, in Table B.4-1, why are 238Pu and 239Pu assigned to different solubility classes? How is this reconciled with Table B.4-2?

ORAU: We would have to have our Y-12 internal dose expert this question.

SC&A: In regard to our question 22, why is tritium vapor not discussed in the TBD text?

ORAU: Because the Tritium Pilot Program was never finalized and they found dose potential from tritium to be negligible.

SC&A: Table B.4-4 gives average data. Are the proportions of S and M available for each individual data point given so that a measure of variability can be obtained?

ORAU: This is left to judgment of the dose reconstructor.

SC&A: Can you tell us more about the 86" Cyclotron?

ORAU: Look at the X-10 TBD for that information.

SC&A: Did Oak Ridge operate the Calutron at Y-12?

ORAU: See the discussion in the ORNL TBD.

Y-12 Occupational Internal Dose TBD Conference Call Summary

Date: June 8, 2005
Subject: Occupational Internal Dose TBD, ORAUT-TKBS-0014-5 Rev. 01, (Rich and Chew 2005)
Time: 1:00 to 2:30 pm

Individuals who participated included:

ORAU: William Murray, Bryce Rich, Mel Chew, Elizabeth Brackett, and Ed Scalsky
NIOSH:
SC&A: Joe Fitzgerald and Joyce Lipsztein

SC&A: The TBD (pg. 24) indicates that methodological problems occurred during the early period of uranium bioassay, resulting in an underestimate by a factor of two. How has NIOSH/ORAU accounted for this underestimation in the dose reconstructions?

ORAU: All dose reconstructions to date have employed efficiency methods, so this issue would not be confronted until dose reconstructions require best estimates. Only 2 years, 1950–1951, are affected and the underestimate can be compensated through extrapolation back from succeeding years' data. For earlier years, one can take the ratios of results recorded and use adjustment factors for correction factors.

SC&A: The TBD (pg. 13) discusses process streams of uranium. Included in the process streams are something identified as "solvent extraction raffinates." What are "solvent extraction raffinates"? Is this a process that may concentrate particular radionuclides including daughter products?

ORAU: These are metallic impurities removed by chemical columns designed to remove metals from uranium solutions. Certain impurities, such as trace radionuclides, may be concentrated by this process and this is captured through the default ratios used in calculations.

SC&A: The chemical forms of uranium at Y-12 include S, M and F type materials. What is the basis for the use of Type M material from 1948-June 1998 without regard to the type of cancer?

ORAU: This assignment was based on information from site records. Uranium at Y-12 is likely to be either Type S or M. A variety of dose modeling curves are available based on solubility, with ORAU using the most claimant favorable.

SC&A: Provide an example of how the recycled uranium impurities are accounted for in the dose reconstruction.

ORAU: Rev 01 of the TBD does include recycled uranium impurities for purposes of dose reconstruction. Two defaults are commonly used: best estimates for long-term exposure; and maximum credible at the 95 percentile CL.

SC&A: In the TBD (pg. 23) there is a reference to Section 5.4.2 for discussion of missed doses. This section appears to be missing. Is it going to be included in the near future? The TBD mentions that there is a concern that the technique used before May 1952 could have underestimated the urinary uranium concentrations. How is the dose reconstructor going to deal with these underestimates of urinary uranium concentrations?

ORAU: Yes, both sections 5.4.1 and 5.4.2 were deleted in this revision of the TBD, but references to these sections were inadvertently left in. More detail for the dose reconstructor will be included in the next revision which is underway.

SC&A: Was tritium dose included in the whole-body dose at Y-12?

ORAU: Yes, but it was not present in any appreciable quantities at Y-12.

SC&A: Is NIOSH considering the issue of frequency of monitoring during the remediation of the S-3 ponds (Section 2.6 of the Site Description TBD, ORAUT-TKBS-0014-2 (Jessen 2005)? Has NIOSH investigated the incidents that occurred or the potential for acute exposures that may have existed during the remediation of the S-3 ponds?

ORAU: ORAU acknowledged that two different evaluation reports for the S-3 pond remediation were referenced which apparently contradict each other regarding the significance of potential radiation exposures.

SC&A: How does NIOSH plan to address early period internal dose issues?

ORAU: There is no discernable Eastman data for the 1943–1946 time period. OTIB 29 – relies on internal dose co-worker data for 1947–1988 time period; there is a need to extrapolate back results because of underestimates back to Calutron shutdown. No internal dose data exists before 1950.

SC&A: What were the processes involving ^{232}Th at Y-12?

ORAU: ORAU has reviewed Y-12 ledgers for thorium receipts. It came in as a "gel," pressed into forms by machinery, and rolled in the DU facility. Y-12 had been sensitive to the need for precautions in handling thorium; monitoring included routine lung counting and air monitoring. It was processed extensively during 1962–1976, with limited processing from 1985–1988. Work done in the early 1950s was limited to research and development.

SC&A: On page 7 of the TBD, it mentions that no urinalysis data have been found for Y-12 prior to 1948. Is there any explanation for why no urinalysis data have been found prior to 1948? The fluorometric technique should have been well established by that date. What steps are in

hand to resolve this issue? Does the discussion of lack of urinalysis prior to 1948 (p. 5, vol. 5) mean that NIOSH is not doing dose reconstruction for the early period at this time?

ORAU: Eastman statements were found in old papers that acknowledged the use of fluorometric procedure for uranium dosimetry. However, no dose records have been located.

SC&A: Page 8 of the TBD: From the earliest days, it was recognized that 'insoluble' uranium (except for high-fired oxides) exhibited a solubility intermediate between Classes W and Y. This was addressed in one way by defining Class Q. However, was any attempt ever made to develop a model specifically for these uranium compounds and to then interpret the Y-12 data explicitly with that model? More generally, this report addresses joint interpretation of the urinary and fecal data, but says nothing about interpreting these data in conjunction with the chest counting data. Has such an overall analysis been attempted either at the level of the individual or in relation to groups of workers with similar exposure histories?

ORAU: The Q class was used briefly at Y-12, but is no longer used. IMBA can handle class Q, if need be. For the 1950s, co-worker data is relied upon.

SC&A: Page 9 of the TBD: Figure 5-2 gives a composite urinary excretion curve for 157 individuals. This conforms quite well to Type M behavior. However, this is not unexpected at a plant where a wide variety of uranium compounds of different degrees of solubility were used. It would be much more interesting to see the curves for the individual workers to see if they span the full range from Type F to Type S (or even beyond). Is this possible?

ORAU: No. NIOSH does not think it is useful, because workers worked at several different places, with several different jobs, thus being exposed to all solubility types

SC&A: Page 10 of the TBD: The particle sizes range up to large values (10 μm physical diameter). Are there particle size data for respiratory zone relative to general area monitoring and can any useful relationships be established between the two?

ORAU: The workers were assigned to different work locations and thus we do not think it is useful to try to characterize the particle sizes of different processes and areas. NIOSH uses the default 5 μm for particle size.[1]

SC&A: Page 11 of the TBD: There is some indication in the TBD's Appendix that distinctions were made between routine and special monitoring. It seems likely that special monitoring would have been triggered by individual incidents. Could an account be given of the special monitoring program employed, including triggers for special monitoring, duration of follow up and any analyses of the results that have been undertaken?

ORAU: We do not think this is useful data.

[1] Although not discussed during the conference call, there are other particle size distributions that could result in higher doses. This issue is addressed in the main body of this review.

SC&A: Page 20 of the TBD: Can the constant "8" in equation 3.1 be reconstructed based on a detailed knowledge of the assay procedure used?

ORAU: No, there is no information.

SC&A: Page 21 of the TBD: Here and elsewhere, a nominal counting efficiency of 0.5 cpm/dpm is used. Bearing in mind that this is for counting of a disk, is this the maximum possible value that can be achieved.? This seems implausible. Can details of the counting geometry be provided, so that this issue can be examined?

ORAU: We agree that this counting efficiency is not plausible.

SC&A: Page 22 of the TBD: For the recent data on uranium in urine by alpha spectrometry, have comparisons been made with other methods, e.g. inductively coupled mass spectrometry (ICPMS) or accelerator mass spectrometry (AMS)? More generally, how well are the various assay procedures used verified by inter-laboratory comparison exercises?

ORAU: It is not our job to verify inter-comparison of techniques.

SC&A: Page 27 of the TBD: Fecal sampling is effective at recording recent intakes of insoluble materials by ingestion and inhalation. Has consideration been given to whether fecal samples obtained at an interval of 53 days give a meaningful representation of chronic intakes since there is considerable temporal variability?

ORAU: We cannot explain the 53 days interval for obtaining fecal samples. We know that this frequency comes from an analysis done by (Eckerman and Kerr 1999), and it is explained in the Y-12 bioassay documents, that have been retrieved by SC&A.

SC&A: Page 27 of the TBD (Interferences): The methodology used to adjust results for background is different from the one recommended by (Eckerman and Kerr 1999) for the Y-12. Why?

ORAU: NIOSH will not adjust for background. We will probably take out this section on the next revision of the document.

SC&A: Page 35 of the TBD: From what source can the referenced document (Wilcox 1999) be obtained?

ORAU: We will provide that document to SC&A.

Internal Dosimetry Co-worker Data

SC&A: This report appears to, first, average urinary excretion data over individuals, and then interpret the results in terms of Type M and Type S intakes. Can NIOSH clarify why this was done, as the results must reflect different numbers of workers in different contexts? Also the

results will inevitably be skewed in time because of the different time courses of exposure of the individual workers, as each worker will have been associated with multiple determinations of uranium in urine. Why was this analysis not undertaken on an individual-by-individual basis? This would have yielded a much richer understanding of the range of exposure conditions.

ORAU: It is impossible to do this analysis on an individual–by –individual basis, because of the enormous amount of data.

SC&A: Given that multiple intake periods that were used, the fitting model should be able to give a very accurate representation of the data. However, there are significant divergences for the Type M result (Figures A-9 and A-10) of the TBD, and these are much worse for the Type S analysis (Figures A-19 and A-20). These divergences arise from fitting data for each of the intervals separately and then adding the results. Why was this done instead of undertaking a simultaneous joint fit to all the intervals, or at least rescaling each of the individual fits by an overall normalization factor to give a better overall fit? (However, this remark should be seen in the context of the previous consideration that an individual-based analysis is to be preferred to the group analysis presented here).

ORAU: As we said above, it is impossible to do this analysis on an individual–by –individual basis, because of the enormous amount of data.

SC&A: OCAS-OTIB-0029, *Internal Dosimetry Coworker Data for Y-12* (Brackett 2005) calculates the 50^{th} and 84^{th} percentiles for urinalysis data. What is the basis for choosing the 84^{th} percentile?

ORAU: In order to obtain the standard deviation.

SC&A: Many of the tables and graphs in OCAS-TIB-0029, *Internal Dosimetry Coworker Data for Y-12* are missing the time period from May 1, 1952 to July 31, 1953. Is this intentional, or should this time period appear in all relevant tables and graphs?

ORAU: They should not be missing.

SC&A: Did NIOSH take into consideration that urine samples were collected on a Monday morning, after a minimum of a 48-hour absence from the work area?

ORAU: We did not take into consideration the 48 hours absence from work area. We will verify if results would have been different if we had assumed a 48 hours absence from work area.

ATTACHMENT 5: SUMMARY OF ENVIRONMENTAL CONFERENCE CALL WITH NIOSH AND SC&A

Date: June 10, 2005

Subject: Occupational Environmental Dose TBD, ORAUT-TKBS-0014-4, Rev. 00, PC-2 (Ijaz and Adler 2004)

Time: 1:30 - 2:30 pm

Individuals who participated included:

ORAU: Ed Scalsky, Tim Adler, Mel Chew, Bryce Rich, Bill Murray, Talaat Ijaz
NIOSH: Stu Hinnefeld
SC&A: Bob Anigstein

This summary first presents the original question or comment, identified by number, that was distributed in advance to ORAU and NIOSH, as it appeared in the original transmittal. This is followed by a summary of the discussion of each question. The speakers are identified by the organization they represent. The cited statements are condensed summaries or paraphrases rather than verbatim quotes.

1. The TBD addresses only two exposure pathways: inhalation of uranium in ambient air and external exposure to direct penetrating radiation. Whenever individuals perform outdoor work, there is a potential for ingestion of soil and other windblown particulates that are larger than the respirable particles. This pathway is traditionally included in dose assessments (see EPA Exposure Factors Handbook"). What is the basis of neglecting inadvertent ingestion of radioactively contaminated soil and other finely dispersed radioactive materials?

   SC&A: Was there a scoping evaluation? Was it considered?

   ORAU: TBD was based on CDC dose reconstruction, which did not address inadvertent ingestion. TBD parameters only list inhalation & external exposure. Someone higher up decided that dust resuspension & inadvertent ingestion were not pathways to be addressed.

   NIOSH: I think it would be a relatively minor contribution to exposure. It may be possible to evaluate magnitude. If I'm wrong, we would have to address that.

   ORAU: Resuspension also not considered because Y-12 site consists of buildings, asphalt parking lots, and roads. Resuspendable material would have been washed away. Vegetative cover near the southern boundary, not a significant area.

   SC&A: What about off-site deposition that could be blown on site?

ORAU: Mostly highly wooded areas that would have required significant winds to generate clouds of dust that would have been blown on site. Quite minor pathway for uranium.

2. There are several references in this TBD to monitoring of fission products. What is the basis of neglecting inhalation of radionuclides other than uranium?

SC&A: Since there was monitoring for other nuclides, including fission products, shouldn't they have been addressed in the TBD?

ORAU: We relied heavily on the CDC dose reconstruction, which did screening assessment for Y-12. Screening assessment, done for off-site dose, included Pu and Np, but concluded U only nuclides of concern.

NIOSH: We will pursue it further with ORAU.

3. The TBD states that uranium air concentrations were not available after 1999. However, since TDEC continued to collect samples and analyze them for gross α and gross β, uranium air concentrations could be estimated from these measurements, using the ratios of uranium concentrations to the gross α and gross β measurements made in earlier years. What is the basis of excluding these data from developing the guidance for dose reconstruction?

SC&A: Was it not possible to prorate TDEC gross alpha from previous years to give U activities for later years?

ORAU: TDEC measurements were made in $\mu g/m^3$. Using these data would have required knowledge of isotopic ratios. If total U exceeded criteria, TDEC would then do isotopic analysis.

SC&A: TBD states that measurements were gross α and gross β. Same isotopic mix could be assumed so as not to ignore data.

Back & forth discussion on TDEC measurements.

SC&A: Observation: TDEC measurements should be made available to dose reconstructors.

Back & forth discussion on methods to be used to reconstruct doses for years after 1995.

4. Data regarding the AMAD or the chemical form of the airborne uranium is required by dose reconstructors, who need to assign dose coefficients to the uranium isotopes. Has NIOSH attempted to determine the AMAD and chemical form of these particulates?

SC&A: Chemical form and AMAD should be furnished. Indoor default is 5 μ,[1] but outdoor is often 1 μ.

ORAU: The original scope of work was to provide air concentrations.

NIOSH: Presume there is no or insufficient data on chemical form or solubility class. DR's[2] use the most favorable solubility class, probably S or M, for a specific claim. Uncertain about particle size. Typically use 5 μ, since pollutants generated in industrial setting.

SC&A: Why not compare 1 μ and 5 μ AMAD and use the more claimant-favorable assumption?

NIOSH: We haven't typically done that.

ORAU: Particle size was not measured.

5. The empirical χ/Q approach is based on several premises which are not explicitly stated and which need to be explored and justified before this approach can be accepted.

   (a) All the occupationally-related airborne activity originates at Y-12. However, Y-12 is part of the ORR complex, which includes other sources of radioactive material. The varying correlation of the airborne uranium concentrations to releases from Y-12, especially at Station 12, calls this hypothesis into question. Has NIOSH considered any alternate approaches to estimating the airborne uranium concentrations?

   (b) In Section 4.2.5, the TBD attributes the poor correlation at Station 12 to the paucity of data. The smaller number of data points (8 vs a maximum of 17) does not account for the virtual lack of correlation shown in Figure 4.2.5-4. We believe that fewer data points would lead to a *better* correlation, both on mathematical grounds (fewer degrees of freedom), and on physical grounds: meteorological conditions would vary less during a shorted time period. Has NIOSH considered eliminating the Station 12 data in creating a framework for dose reconstruction, due to this lack of correlation?

   (c) Resuspension of uranium deposited on soil, both inside the Y-12 perimeter and off site, is not included. Resuspension of deposition during previous years would contribute to the uranium concentration in air, yet is uncorrelated to uranium releases from Y-12. Has NIOSH considered adjusting the airborne uranium concentrations by estimating the activity in the soil, perhaps by employing the surveys of external exposure rates, and employing a resuspension factor?

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[1] Micron (μm)

[2] Abbreviation for "dose reconstructors."

(d) The influence of other sources of uranium—releases from sources outside Y-12 or resuspension from on-site soils—is indicated by the data for 1993. The uranium release of 3 kg for that year is the lowest during the period that Stations 2 and 12 were operating, and the second lowest during the 17-year operating period of Stations 4 and 8. The 1993 calculated χ/Q's for all four stations are the highest of any year that these stations operated. At least for the data from Station 12, which SC&A subjected to an independent statistical analysis, there is a *negative* correlation between the χ/Q's calculated by ORAU and the annual releases of uranium: the lower the releases, the higher the χ/Q. How does NIOSH plan to resolve this issue?

SC&A: We are somewhat skeptical about the empirical χ/Q approach. Has any other approach been considered?

ORAU: This goes back to the original scoping assessment. Atmospheric modeling was done for all 3 sites on the ORR. Contribution from other 2 facilities to Y-12 is minimal at best. There are problems with atmospheric modeling at Y-12 due to the complex terrain.

SC&A: Agree that analytical approach is difficult and questionable. However, correlation between releases and concentrations is poor in some cases. Note that the year there is the smallest release—3 kg—from Y-12, there is also consistently the highest χ/Q. Presumably, if you had zero releases, the concentrations would be far above zero. This indicates that there were contributions from other sources.

ORAU: Except for Station 12, correlations are from 0.95 – 0.7. Don't agree that correlations are that poor.

SC&A: Overall scatter is fair. Station 12 with correlation 0.19, should not be used. Not scientifically valid. For every station, 1994, with the smallest release, produced the highest χ/Q. Unless you believe in a coincidence of wind patterns that cause higher concentrations at all 4 stations, this is a clear indication that there were other sources that are being neglected.

ORAU: That's for just one year, right?

SC&A: That one year emphasizes it, because the release is so small. If you go to the highest year, so if 1984 has 300 kg vs 3 kg, yet the concentration does not track that. Anyway, that's an observation—this may be an estimate, but we question if it's really claimant favorable

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ORAU: Is that observation based on that one year?

SC&A: That one year brings the whole concept into question. The concept is that releases from the Y-12 plant are correlated with the concentrations. There should be some adjustment factors to make it more claimant favorable.

6. The TBD states that the calculated χ/Q's follow a lognormal distribution *with a high-end tail.* Yet, in assigning 95th percentile values, where the high-end tail would have the greatest influence, that aberration from lognormal behavior is not addressed. An examination of the data in Tables 4.2.3-1/4 reveals the following:

   (a) Station 2: out of 12 calculated χ/Q's, one is significantly higher than the 95th percentile value (2.00×10^{-14} vs. 1.31×10^{-14}). Statistically, the highest of 12 values would correspond to the 92nd percentile.

   (b) Station 4: out of 17 calculated χ/Q's, one is over 1.7 times higher than the 95th percentile value (5.03×10^{-14} vs. 8.73×10^{-14}). Statistically, the highest of 17 values would correspond to the 94th percentile.

   (c) Station 8: out of 17 calculated χ/Q's, two are higher than the 95th percentile value. Statistically, the second highest of 17 values would correspond to the 88th percentile.

   (d) Station 12: out of only eight calculated χ/Q's, one is higher than the 95th percentile value. Statistically, the highest of eight values would correspond to the 88th percentile.

   The above observations indicate that the distributions are not lognormal, and that the assumptions used by ORAU to calculate the 95th percentile χ/Q's are not claimant favorable, aside from the questions raised earlier in this discussion about the validity of the empirical χ/Q approach. This conclusion is further buttressed by our statistical analysis of the Station 12 data, which exhibit the best correlation between the annual releases and the annual average air concentrations of uranium of the four monitoring stations. Subjecting the calculated χ/Q's to the *W* test[3] shows that there is a 10% to 50% probability that the distribution is lognormal. In other words, there is a better than a 50% chance that the distribution is *not* lognormal. Has NIOSH considered an alternate statistical approach that is more claimant favorable?

   SC&A: Not sure if DR is supposed to use 95th percentile. 95th percentile calculated from lognormal distribution is not, in fact, the 95th percentile of the data because of the high-end tail.

   ORAU: Our conclusion was the same as yours. The correlation to a lognormal distribution was very vague and questionable at best and was not included in the initial report. However, DRs had a requirement that the data fit some sort of distribution. In the end, the decision was made by DRs to provide 95th

[3] Richard Gilbert (1987). *Statistical Methods for Environmental Pollution Monitoring,* Section 12.3.1.

percentile, knowing full well that the distribution of the data did not fit well with a lognormal distribution.

SC&A: It is our understanding that IREP does not require a distribution. It will accept single values. A single value could have been assigned—simply the highest. Given that you have 17 data points, the highest of those could have been represented as the 95th percentile.

ORAU: If you look at Table 4.2.3-1 through -4, the maximum value is printed.

SC&A: I know it is.

ORAU: The selection of the value to be used was not our recommendation, it was the recommendation of the DRs.

SC&A: Can NIOSH address that?

NIOSH: From a DR standpoint, you can choose a high value that would be an upper end of what could occur. The difference between selecting the 95th percentile and the highest value, dosimetrically is not going to be consequential.

SC&A: It can make a 2- to 3-fold difference. We realize that the DR has latitude, but the idea of the TBD is to provide them with direction. Our recommendation would be that the direction be more clear, rather than leaving it to the individual DR.

7. NIOSH decided to base the dose reconstruction on the calculated χ/Q's, *even for years for which measurements of air concentrations exist.* Since the purpose of dose reconstruction is to determine the doses to individual claimants, not to maintain a uniformity of approach, what is the justification for disregarding real data, especially in cases where the use of such data may be more claimant favorable?

SC&A: If you have years where you have air measurements, that would be the more reliable data. The idea is to have the best dose for each claimant, rather than have artificial consistency. Our comment would be to that NIOSH should reconsider if the DRs should not be directed to use the actual air concentration. To disregard measured data in favor of a fitted curve doesn't seem to be claimant favorable or scientifically valid.

NIOSH: Suppose you had a year where the measured data was lower than the calculated χ/Q value?

SC&A: I would use whichever one is the more claimant favorable between the two, or use the measured data and say the calculated values should only be used in the absence of measured data.

NIOSH: Either way, you feel that would be an acceptable approach?

SC&A: Yes, you can't argue with the fact that it's measured data, but you should put an uncertainty on it.

8. The methodology for calculating the air concentrations of the uranium isotopes, which are listed in Attachment D to the TBD, is unclear. Our attempts to replicate some of the data in Attachment D, using the information in the main body of the TBD, were unsuccessful. Furthermore, some of the data in Table 4.2.4-1, which are the basis of the data in Attachment D, are themselves suspect. Notably, based on the masses of the ^{238}U releases listed in the fifth column of that table, the ^{238}U activities released in 1994 and 1995 should be 0.008 and 6.7 H 10^{-4} Ci, respectively, rather than 0.002 and 0.0021 Ci, as listed. Would NIOSH clarify the methodology used in constructing the Attachment D tables, and verify the data in Table 4.2.4-1?

SC&A: I could not reproduce the numbers in tables in Attachment D. Perhaps we could get an example calculation.

ORAU: Yes.

9. On p. 26, the TBD states: ". . . it is conservative to assume that the air concentrations reported from 1996 to 2002 are equal to the concentrations reported for 1995." However, there are no air concentration data listed for the years 2000 – 2002. The TBD states that the data for these years, collected by TDEC, is not usable. More important, the statement quoted above is contradicted by the data that are listed. The annual average concentrations at Station 4 for the years 1996 – 1998 are higher than for 1995. Furthermore, the data in Table 4.2.4-1 shows that the uranium releases in each year from 1996 through 2001 were higher than in 1995. Can NIOSH justify the assumption quoted above?

SC&A: There are data for Station 4 for 1996 - 1999.

ORAU: The enrichment is needed to calculate isotopic ratios.

SC&A: The releases in 1995 are the lowest for the years 1944 - 1995, a total of 2 kg U. However, 1996 - 2001 are all higher than 1996.

ORAU: Figure 4.3-2 shows decreasing releases.

SC&A: The data in the figure end with 1995. We recommend increasing the release estimates for 1996 - 2001 in proportion to the total releases in those years, or performing some other adjustment.

10. The tables in Attachment D list both 50th and 95th percentile values. Presumably, the 50th percentiles are to be used as the best estimates, and the 95th percentiles as the upper

bound values. As mentioned earlier, the calculated 95th percentile values are not upper bounds, as they are exceeded by annual average χ/Q's at each of the four monitoring stations. Can NIOSH explain how these data are to be used by dose reconstructors?

[This question had been discussed earlier.]

11. Concentrations of ^{236}U, which are listed in Tables 4.2.3-1/4, are comparable to those of ^{238}U. Why are the contributions of ^{236}U ignored in Attachment D?

    ORAU: We used the same isotopes as the CDC dose reconstruction, which did not include ^{236}U.

    SC&A: Agree that ^{236}U would not make a large contribution to the dose, but from a scientific standpoint, it should be addressed.

12. The TBD states that the aerial surveys performed by the EG&G Remote Sensing Laboratory cannot be used for dose reconstruction. However, by spanning a period from 1973 to 1989, they provide a historical record of the external exposures on the site. Such data could be used to provide a temporal trend, and should be combined with the 1985 – 1987 scoping survey. The spatial resolution of the aerial surveys is comparable to the size of the grid blocks in the scoping survey. Furthermore, the exposure rates calculated at 1 m above ground, as presented in the aerial survey reports, appear to be more relevant to dose reconstruction than the ground level rates measured in the scoping survey. Has NIOSH compared the dose rates based on the aerial surveys to those of the scoping survey, and has it considered developing a time-dependent dose rate based on both sets of data?

    ORAU: There were problems with the legibility of the black & white copies of the aerial survey data. We heard comments from Oak Ridge staff about discrepancies between data collected by a helicopter and a fixed-wing aircraft.

    SC&A: The original full color maps can be purchased from the RSL—we had, in fact, obtained these maps for an earlier study. We recommend that the aerial survey data be used to supplement the ground survey.

13. Given the purpose of the survey and the instruments used, the exposure rates would have been based on the count rates registered by the sodium iodide crystal in the survey meter. Such meters are commonly calibrated with a ^{137}Cs source—the scale on the rate meter is set to the known exposure rate at the location of the detector. This calibration is thus valid only for the principal ^{137}Cs γ ray and will vary significantly for photons of different energies. Has NIOSH attempted to convert the meter readings to dose rates in air (i.e., air kerma), using calibration curves which can be obtained from the manufacturer of the meter in question, or from manufacturers of similar instruments, and the known spectrum of the uranium isotopes deposited on the ground? Has it considered using the spectral

analysis in the aerial survey data, and then converting the air kerma to dose equivalent rates, using tables in ICRP Publication 74 for the appropriate exposure geometry?

ORAU: The ground survey data was all that was available.

SC&A: You could use the energy-dependent calibration curves to convert the readings, based on the known energies of the isotopes in question.

NIOSH: Did the survey over- or under-estimated the actual concentrations?

SC&A: The uranium concentrations would most likely be over-estimated, while nuclides with gamma energies > 660 keV would be under-estimated.

The conference ended with ORAU agreeing to e-mail the example calculations for Attachment D to SC&A early next week.

ATTACHMENT 6: SITE EXPERT INTERVIEW SUMMARY

<RESERVED>

ATTACHMENT 7: CONSISTENCY BETWEEN Y-12, HANFORD AND SRS SITE PROFILES

Table A.7.1 Occupational Medical Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Sites

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Frequency of chest x-rays (Default)	1943 – Present Pre-placement & At termination 1943 - July 18, 1988, annually July 18, 1988 – present Time of entry into asbestos and beryllium areas July 18 – March 1998 Active & Previous beryllium workers July 18, 1988 – June 30, 1993 Every 10 yrs – Under 30 Every 5 yrs – 30–45 y/o Every 3 yrs – Over 45 March 1998 – present Annually – all asbestos workers Every 3 yrs – previous and active asbestos workers and previous beryllium workers (Murray 2004, pg. 15)	Posterior-Anterior View: Before 1946 – 1/1982: Pre-employment, annual, and termination 1/82-1/83: Pre-employ-ment, annual, and termination for over 50 years; Biennially for 40-49 years; Every third year for 39 years or younger. 1/83–3/90: Biennially for over 50 years; Every third year for 40–49; and Every five years for 39 years and younger. 3/90–present: Every 5 years Lateral chest x-rays also given periodically prior to 4/1997.	One annual x-ray procedure for each year or partial year.
Organ Dose Conversion Factors	Obtained from ICRP 34 (1982) for organs outside the chest cavity (Murray 2004, pg. 15)	Obtained from ICRP 34 (1982)	Obtained from ICRP 34 (1982)
Substitute dose conversion factors for thyroid, eye/brain, ovaries and analogues, testes, and uterus	Doses for organs not listed in ICRP 34 but specified in IREP code are determined by analogy and anatomical location as indicated in Table 3.5, pg. 9 (Murray 2004)	Use DCFs for lung for all other organs in thoracic cavity; for organs in abdomen, use DCFs for the ovary (Scalsky 2003, pg. 10) Use substitute dose conversion values outlined in Table 5.1-1, ORAUT-OTIB-0006	Use substitute dose conversion values outlined in Table 5.1-1, ORAUT-OTIB-0006 (also Table 2.6, SRS TBD) prior to 1970 (Scalsky 2004, pg. 50).
IREP Radiation Rate	Acute	Acute	Acute
IREP Radiation Type	Photons, 30-250 keV	Photons, 30-250 keV	Photons, 30-250 keV
IREP Dose Distribution Type	Constant	Constant	Constant
Total uncertainty	30%, pg. 10 (x-ray dose multiplied by 1.3 and entered as a constant	30% (x-ray dose multiplied by 1.3 and entered as a constant)	30% (x-ray dose multiplied by 1.3 and entered as a constant)
Conversion Factor from PA to Lateral	Kathren et al, to be published, pg. 7	2.5	2.5

Table A.7.1 Occupational Medical Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Sites

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Chest Thickness	PA indicates a posterior/anterior view, the average PA chest measures 26 cm, pg. 7	Standard chest thickness is 22-24 cm. For chest thicknesses of 25-27 cm, increase the dose by a factor of 1.5. For chest thickness of >27 cm, increase the dose by a factor of 2. (Scalsky 2003, pp. 8 & 17)	PA View: 26 cm Lateral View: 34 cm No corrections for varying chest thicknesses are mentioned in the TBD.
Analogue organ for Thymus	Lung, pg. 9	Lung	Lung
Analogue organ for Esophagus	Lung	Lung	Lung
Analogue organ for Stomach	Lung	Lung	Lung
Analogue organ for Bone Surface	Lung	Lung	Lung
Analogue organ for Liver, gall bladder, spleen	Lung	Ovary	Lung
Analogue organ for Remainder Organs	Lung	Ovary	Lung
Analogue organ for Urinary/bladder and colon/rectum	Ovary	Ovary	Ovary
Analogue organ for Eye/brain	Thyroid	Thyroid	Thyroid
Skin dose	Skin dose is entrance skin kerma, multiplied by a backscatter factor of 1.35 from NCRP 102, Table B-8, pg. 17 and 18 footnote (Murray 2004)	Skin dose was determined by multiplying the ESE by the backscatter factors of 1.35 and 1.4 for HVLs of 2.5 and 3.5 mm Al, respectively (Scalsky 2003, pg. 158).	Skin dose was determined by multiplying the ESE by the backscatter factors of 1.35 and 1.4 for HVLs of 2.5 and 3.5 mm Al, respectively (Scalsky 2004, pg. 158).
Posterior-Anterior View X-ray Techniques[1,2,3]			
<1946	1943–1947 kVp: 80, pg. 7 mAs: 200 SSD: 2.95” (7.5 cm), pg. 10	kVp: Unknown mAs: Unknown SSD: 72” (183 cm) ESE: 120 mR	Not Applicable
2/1946 – 12/ 1950	1948- 1968 kVp: 80 mAs: 200 SSD: 2.95” (7.5 cm) ESE: Not specified	kVp: 80 mAs: 25 SSD: 72” (183 cm) ESE: 79 mR	Not Applicable unless pre-employment is indicted.

Table A.7.1 Occupational Medical Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Sites

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
1/19/51 - 1/1/57	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 80 mAs: 10 SSD: 72" (183 cm) ESE: 79 mR	kVp: 80 mAs: 30 SSD: 152 cm No Collimation ESE: 108 mR
1/1/57 – 4/1959	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 80 mAs: 10 SSD: 72" (183 cm) ESE: 79 mR	kVp: 80 mAs: 30 SSD: 152 cm No Collimation ESE: 108 mR
4/1959 – 12/1970	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 80 mAs: 10 SSD: 72" (183 cm) ESE: 40 mR	kVp: 80 mAs: 30 SSD: 152 cm No Collimation (prior to 1970) ESE: 108 mR
1/1971 – 1/1983	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 80 mAs: 10 SSD: 72" (183 cm) ESE: 40 mR	kVp: 110-120 mAs: 10 SSD: 152 cm ESE: 44 mR
1/1983 – 7/1985	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 100 mAs: 10 SSD: 72" (183 cm) ESE: 35 mR	kVp: 110-120 mAs: 10 SSD: 152 cm ESE: 44 mR
8/1985 – 3/1990	2/1948 – present kVp: 80 mAs: 200 SSD :2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 100 mAs: 10 SSD: 72" (183 cm) ESE: 35 mR	kVp: 120 mAs: 7.5 SSD: 152 cm ESE: 33 mR
Posterior-Anterior View X-ray Techniques[1,2, 3]			
3/1990 – 4/1997	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 110 mAs: 6.7 SSD: 72 " (183 cm) ESE: 21 mR	kVp: 120 mAs: 7.5 SSD: 152 cm ESE: 33 mR
4/1997 – 2/1998	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 110 mAs: 10 SSD: 183 cm ESE: 17 mR	kVp: 120 mAs: 7.5 SSD: 152 cm ESE: 33 mR
2/1998 – 5/1999	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95: (7.5 cm), pg. 10 ESE: Not specified	kVp: 110 mAs: 5 SSD: 183 cm ESE: 11 mR	kVp: 120 mAs: 7.5 SSD: 152 cm ESE: 33 mR
5/1999 – present	2/1948 – present kVp: 80 mAs: 200 SSD: 2.95" (7.5 cm), pg. 10 ESE: Not specified	kVp: 110 mAs: 5 SSD: 183 cm ESE: 11 mR	kVp: 120 mAs: 7.5 SSD: 152 cm ESE: 33 mR

Table A.7.1 Occupational Medical Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Sites

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Photofluorography			
Technique Factors	X-rays were done at Oak Ridge Hospital or Y-12, Techniques are unknown. pg. 7	kVp: 80 to 100 kVp mAs: not specified SID: 102 cm ESE: 1.53 R Applies 1945 to 1962	kVp: 100 mAs: 60 SID: 102 cm ESE: 1.5 R Applies from 1951–1957

[1] Refer to Scalsky 2004, pp. 41-47 for SRS x-ray technique discussion.
[2] Refer to Murray 2004, pg. 18 for Hanford x-ray technique summary.
[3] Available data indicate the x-ray beams used at Hanford were collimated. (Scalsky 2003, pg. 8).
[4] N/A = not applicable; PA = posterior-anterior; LAT = lateral; kVp = kilovolt potential; mAs = milliampere-second; SSD = source-to-skin distance; ESE = entrance skin exposure.

Table A.7.2 External Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Missed Photon Dose Application	Applies to workers with not recorded dose because (1) they were not monitored before 1961, (2) there is no recorded dose for short periods of time after 1961, and (3) the worker's dose during a monitoring period was recorded as zero because the dosimeter response was less than the MDL. (Kerr 2003, pg. 30)	Applies to workers with no recorded dose because they weren't monitored or their results are unavailable; and Workers who have a zero recorded dose, (Fix 2004, pg. 75).	Applies to workers with no recorded dose because they weren't monitored or their results are unavailable; and Workers who have a zero recorded dose (Scalsky 2004, pg. 111).
Missed Photon Dose Methodology	Multiply the MDL by the number of zero dose results to estimate the maximum potential missed dose. (Kerr 2003, pg. 31)	Divide the MDL by 2, and multiply by the number of zeros and not monitored periods (Fix 2004, pg. 75). Table 6E.6 (Fix 2004), provides potential maximum photon dose by year.	(1) For a claimant-favorable maximum potential missed dose, use the limit of detection (LOD) multiplied by the number of zero doses (Scalsky 2004, pp. 111 and 238) (2) Divide the limit of detection (LOD) 2, and multiply by the number of zeros and not monitored periods; (Scalsky 2004, pg. 242), or (3) Missed doses are added to measured doses and treated as a constant.
IREP Dose Distribution Type for missed photon dose	The selection of a normal distribution for the "Type" determines the definition of Parameters #1 and #2. For a normal distribution, Parameter #3 is not used and Parameter #1 is the mean of the distribution of recorded dose for each year of monitoring. (Kerr 2003, pg 41 and 43)	Lognormal distribution with a geometric standard deviation of 1.52.[1] The assessment at Hanford was based on the assumption that uncertainties from individual sources followed independent lognormal distributions. For each uncertainty source, a factor is assigned reflecting bias (B) and a 95% uncertainty factor (K); the uncertainty factor was determined so that the interval obtained by dividing and multiplying by this factor would include 95% of all observations (Fix 2004, pg. 27).	(1) When using the Limit of Detection (LOD)/2 methodology, a lognormal distribution with a geometric standard deviation of 1.52 in Parameter 2 of the IREP input is used (Scalsky 2004, pg. 116). (2) When simply adding the missed and measured dose, a constant is used.

Table A.7.2 External Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Missed Neutron Dose Application	It is possible to calculate The missed neutron dose at Y-12 using the MDLs because the neutron dosimeters were calibrated with neutron sources that had energies similar to those encountered in the workplace and more than 90% of the neutrons to which workers were normally exposed had energies greater than the 500-keV threshold of the NTA film dosimeters. (Kerr 2003, pg. 46)	Assign a missed neutron dose if the individual worked in a facility with a potential for neutron exposure, The vast majority of neutron dose to Hanford workers was received at the 200 West Area Plutonium Finishing Plant (PFP) facilities (pg. 74.) There is potential for significant missed dose in the 300 Area plutonium laboratory (308, 309, 324), the 100 Area reactor facilities (i.e., reactors, (B, D, F, H, DR, C, KW, KE), the 300 Area accelerator (3754B), the calibrations facilities (3745, 318) and the Fast Flux Test Reactor (pg. 73). (Fix 2004).	Assign a missed neutron dose if there is neutron monitoring between 1958 and 1962, if there is neutron monitoring in 1971 or later, or there is indication of use of the 17 keV calibration curve for interpretation of beta/gamma film. Also applies to those who worked with Cf or Cm, maintenance workers, those involved in the PuAl target campaign, and those on routine plutonium bioassay. If the recorded neutron dose is greater than the calculated dose, the calculated dose is used (Neton 2003).
Missed Neutron Dose Methodology	If the MDL for NTA film is used in estimating the missed neutron dose, it should be multiplied by 1.10 for workers in the Calibration Laboratory and by 1.05 for workers in the Enriched Uranium Storage Area of Building 9212 and the Nondestructive Analysis Laboratory. It is also possible to estimate missed neutron dose in some facilities by use of neutron-to-photon dose ratios (NIOSH 2002). However, the only Y-12 facility where a neutron-to-photon dose ratio is expected to provide a reasonably reliable estimate of the missed dose is for workers in the Enriched Uranium Storage Area of Building 9212. (Kerr 2003, pg. 46-47)	A neutron-to-photon ratios is applied to missed and recorded photon dose for nonmonitored worker and workers with inadequate neutron monitoring. The upper 95% value is used for the maximizing technique. The mean value is used for the best-fit technique (Fix 2004, pg. 75-77).	A neutron-to-photon ratios is applied to missed and recorded photon dose for nonmonitored worker and workers with inadequate neutron monitoring (i.e., prior to 1971). The upper 95% value is used for the maximizing technique. The geometric mean value is used for the best-fit technique (Scalsky 2004, pg. 240-241). After 1970, the assignment of missed dose is based on the limit of detection provided in Table E-10 (Scalsky 2004, pg. 241-242). It appears that an ICRP 60 correction factors is applied to missed dose; however, this is unclear in the TBD (Scalsky 2004, pg. 110).

Table A.7.2 External Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
IREP Dose Distribution Type for missed neutron dose	In order to calculate the neutron dose input to IREP (see Table F-1), the recorded neutron dose must be separated into neutron energy groups as shown in Table F-3 and subsequently converted into ICRP 60 methodology (ICRP 1990). (Kerr 2003, pg. 43)	Lognormal distribution with a geometric standard deviation of 1.52.[1]	Lognormal distribution with a geometric standard deviation of 1.52.[1]
IREP Exposure Rate	Acute for beta and photon, and Chronic for neutron Kerr 2003, pg. 41)	Acute for beta and photon Chronic for neutron (Fix 2004, pp. 8, 59, and 69, respectively)	Acute for beta and photon Chronic for neutron (Scalsky 2004, pg. 87 and 235, respectively).
IREP Radiation Type (default)	Photon, 30-250 keV p.20 Electron, > 15 keV Neutron 0.1-2 MeV (Kerr 2003, p. 23)	Photon, 30-250 keV Electron, > 15 keV Neutron, 0.1-2 MeV (Fix 2004, pg. 29)	Photon, 30-250 keV Electron, > 15 keV, Neutron, 0.1-2 MeV (Scalsky 2004, pp. 49, 236, and 237, respectively)
Organ dose conversion factor	Once the adjusted photon and neutron doses have been calculated for each year, the values are used to calculate organ doses of interest using the NIOSH External Dose Reconstruction Implementation Guideline (NIOSH 2002). Parameter #2 is the standard deviation of the normal distribution for the organ dose. The individual dose result for each dosimeter exchange period will be available to calculate the mean and standard deviation for each year. If not available, the adjusted organ dose can be used for each year and a default standard deviation value used for parameter #2. (Kerr 2003, pg. 46)	The dose conversion factors for each, organ, radiation type, and energy ranged from OCAS-IG-001 are used. If the exposure geometry cannot be determined, default values are found in Table 6E-9 (Fix 2004, pg. 77). No separate value is provided for the maximizing approach.	For the maximizing approach, a value of one is used, pg. 61.. For the best-fit analysis, the dose conversion factors in the external dosimetry guide for the relevant exposure geometry. OCAS-IG-001 Appendix A (NIOSH 2002) contains a detailed discussion of the conversion of measured dose to organ dose equivalent, and Appendix B contains the appropriate dose conversion factors (DCFs) for each organ, radiation type, and energy range based on the type of monitoring performed. (Scalsky 2004, pg. 242)
Exposure geometry	Default exposure: Likely non-compensable workers – 100% AP Compensable worker – 50% AP, 50% ROT Compensable supervisor –	Default exposure: Likely non-compensable workers - 100% AP Compensable worker – 50% AP, 50% ROT Compensable supervisor –	Default exposure: Likely non-compensable workers - 100% AP Compensable worker – 50% AP, 50% ROT Compensable supervisor –

Table A.7.2 External Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
	50% AP, 50% ISO (Kerr 2003, pg. 34)	50% AP, 50% ISO. (Fix 2004, pg. 77)	50% AP, 50% ISO. Dose reconstructor has the option to choose the most appropriate exposure geometry for the individual. (Scalsky 2004, pg. 242)
Photon Adjustment Factors (Recorded Dose)	Multiply reported deep photon dose by a factor of 1.34 to estimate Hp(10). There is one group of Y-12 workers for which an adjustment in the recorded photon dose is recommended (see Section 6.3.4.1, pg. 19-29). These workers performed waist-level handing jobs in DU process areas (see Table 6.3.4.1-1, pg. 20)).	No adjustment for the multi-element dosimeter, TLD, or gamma dose. For 200 Area plutonium workers prior to 1957, the 20% of the open window dose is added to the penetrating dose (Fix 2004, pg. 73).	Multiply by 1.119 for years prior to 1987. Multiply by 1.039 for 1987. No adjustment is needed post 1987, (Scalsky 2004, pg. 238). Note: Taylor et al. (1995) indicates that the 1.119 adjustment factor should be applied through 1985 and the 1.039 adjustment factor should be applied for 1986. No correction is required for 1987 and after.
IREP Dose Distribution Type for recorded photon dose	Constant , pg. 43	Constant.[1]	Constant. The adjustment factor encompasses the uncertainty so no additional uncertainty factors are included. [1]
Recorded Neutron Dose Adjustment Factor (Prior to 1971 – SRS; Prior to 1972 Hanford)	The missed neutron dose at Y-12 using the MDLs because the neutron dosimeters were calibrated with neutron sources that had energies similar to those encountered in the workplace and more than 90% of the neutrons to which workers were normally exposed had energies greater than the 500-keV threshold of the NTA film dosimeters. (Kerr 2003, pg. 46)	NTA film is considered inadequate for use in dose reconstruction due to the energy dependence. The missed neutron dose approach is applied for this period of time (Fix 2004, pg. 48).	NTA film is considered inadequate for use in dose reconstruction due to the energy dependence. The missed neutron dose approach is applied for this period of time. If the measured dose from the NTA is greater than the calculated dose, this value is used and the ICRP 60 conversion factor is applied (Scalsky 2004, pg. 238).
Recorded Neutron Dose Adjustment Factor (7/78-12/83)	The recorded dose equivalent is a combination of all neutron energies. In order to calculate the neutron dose input to IREP (see Table F-1), the recorded neutron dose must be separated into neutron energy groups as shown in	When using of the four-chip HMPD during the period of its use from July 1978 through December 31, 1983 in Hanford 200 and 300 Area plutonium facilities only, multiply the recorded neutron dose by 1.35. At all other times, divide the dose into the facility specific	In order to calculate the dose input for the IREP, Table E-1, the recorded neutron dose must be separated into neutron energy groups as shown in Table E-3 and subsequently converted to ICRP 60 (1990) methodology

Table A.7.2 External Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
	Table F-3 and subsequently converted into ICRP 60 methodology (ICRP 1990). The dose fractions by neutron energy group and the associated ICRP 60 correction factors for the various neutron exposure areas at Y-12 are summarized in Table F-5. (Kerr 2003, pg. 43)	neutron energy bins, and multiply by the ICRP 60 conversion factor (Fix 2004, pg. 74).	(Scalsky 2004, 235-238).
Recorded Neutron Dose Adjustment Factor (1/72-6/78, 1/84 – present)	Divide the recorded neutron dose into the facility specific neutron energy bins, and multiply by the ICRP 60 conversion (Kerr 2003, pg. 43)	Divide the recorded neutron dose into the facility specific neutron energy bins, and multiply by the ICRP 60 conversion factor (Fix 2004, pg. 74).	In order to calculate the dose input for the IREP, Table E-1, the recorded neutron dose must be separated into neutron energy groups as shown in Table E-3 and subsequently converted to ICRP 60 (1990) methodology (Scalsky 2004, 235-238).
IREP Dose Distribution Type for recorded neutron dose	Constant	Constant[1]	Constant The adjustment factor encompasses the uncertainty so no additional uncertainty factors are included. [1]
Shallow Dose Adjustment Factors	The information needed to evaluate claims is directed to the technical parameters of the annual estimates of the primary organ dose that is calculated from the dosimeter interpreted personal dose equivalent, Hp(10), and Hp(0.07) in the case of skin, testicular, and breast cancer. These are used as a consistent basis of comparison for all years of Y-12 occupational external dose starting in 1950.	Shallow dose adjustments factors are not addressed in the TBD.	Shallow dose adjustments factors are not addressed in the TBD or SRS TIBs.

Table A.7.2 External Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Low-energy photons (< 30 keV)	The TBD mentions no adjustment for low-energy photons.	The stated Hanford practice to include 1/5 of the shallow dose based on a 16-keV calibration to the deep dose for Hanford plutonium facilities workers could resolve this source of potential under-response around 17 keV (Fix 2004, pg 26). For 200 Area workers prior to 1957, the 20% of the open window dose is added to the penetrating dose, (pg. 14).	1954–1981 Subtract the reported deep dose from the shallow dose for plutonium workers. 1982-present. Plutonium workers are those individuals that worked in 321M, 221H – B line, 221F – B line, 772F, 235F, 773A, 736A, and other plutonium storage areas (Neton 2004). (For testicular, breast, or skin cancer)
IREP Dose Distribution Type for recorded shallow dose	Not Included in the TBD.	Not included in the TBD.	Shallow dose is addressed from a technical perspective in the TBD, but no direction is provided to the dose reconstructor (Scalsky 2004, pg. 97).
IREP Radiation Type for recorded dose	The primary IREP screen used to input dose parameters is illustrated in Table F-1. Assume 30-250 KeV with a normal when entering distribution parameters. The input to these fields is obtained from the Y-12 dose of record. Kerr 2003, pg. 41.	Specific to the particular facility for beta, photon, and neutron dose. For example, in the reactor area 100% of the beta doses is assumed to be >15 keV, 75% of the photon dose is >250 keV, and 25% of the photon dose is 30-250 keV (Fix 2004, pg. 29).	Specific to the particular facility for beta, photon, and neutron dose. For example, in the reactor area 100% of the beta doses is assumed to be >15 keV, 50% of the photon dose is >250 keV, and 50% of the photon dose is 30-250 keV (Scalsky 2004, pg. 98).

[1] These parameters were obtained from review of several dose reconstruction IREP input sheets.

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Particles Size (default)	5 micron (Rich 2005, pgs 8 & 10, and 11)	5 micron (Bihl 2004, pg. D-10)	5 micron (Scalsky 2004, Section 4.0, Attachment D)
Intake Type (default)	Chronic prior to stand-down, the Y-12 program default modeling assumption was Class Q (90% Super W, 10% Y) 8 um AMAD – pg. 41. However, during a 1994 to 1998 stand down period, it is assumed to be acute occurring at the midpoint of a quarterly sampling frequency – pg. 12 (Rich and Chew 2005)	Chronic (Bihl 2004, pg. 7-9)	Chronic (Scalsky 2004, Section 4.0, Attachment D)
Default Excretion Volume	Nominal 1.4 L/day – pg. 21 (Rich and Chew 2005)	Uses a urinary excretions value of 0.2 ug/d for elemental analyses, 0.15 dpm/d for ^{234}U and ^{238}U and essentially anything detected for ^{235}U (Bihl 2004, pg., 27)	1.4 liters/day (Volumes less than 1.4 liters/day are corrected by normalizing the actual volume to 1.4 liters/day. Samples recorded as activity per 1.5 liters are not corrected.) (Scalsky 2004, pg. 70)
Solubility Class	Exposure to Type M material from 1948 to July 1998, appears to be the more likely absorption type. After July 1998, exposure to absorption Type S material is more likely. However, the absorption type may be based on the monitoring data and/or claimant favorable assumptions. – pg. 10. Uranium compounds handled at Y-12 range from highly soluble to very insoluble- pg. 6. For a workplace as varied as Y-12, it is clear that no single solubility or particle size will apply to all workers – pg. 9 Therefore, claimant favorable assumptions should be made regarding solubility and uranium activity ratios - pg.25 Exposure to Type M material from 1948 to June 1998 appears to be the most likely absorption type. After June 1998, exposure to absorption Type S material is more likely – pg. 43 (Rich and Chew 2005)	For the maximizing approach, the most claimant favorable solubility type for the organ of interest is used. For the best-fit approach the most appropriate solubility type can be used. Inhalation class and lung absorption type for uranium is found in Bihl 2004, Table 5.2.5-3, pg. 24).	For the maximizing approach, the most claimant favorable solubility type for the organ of interest is used. For the best-fit approach the most appropriate solubility type can be used (Scalsky 2004, pg. 85).

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Intake Date for Hypothetical Intake (excluding tritium)	TBD does not specify.	First day of employment or the first day of operation of the facility where the worker was assigned. For separation plants, chronic intakes would apply from either the first day of work for the worker or the start up of the plant, December 1944 for T Plant and April 1945 for B Plant (Bihl 2004, pg. 8).	Acute inhalation on January 1 in the first year of employment (Scalsky 2004, pg. 85; Brackett 2003, pg. 3).
Tritium Missed Dose Application	TBD does not specify.	Assigned to workers who worked in 108-B, the 300 Area Test Reactors, and in some cases where work location was unknown or variable. Those who never wore a dosimeter and had no bioassay results were assigned environmental doses (Bihl 2004, pgs. 21–22).	Assigned to workers monitored for external dose, but having no bioassay. For workers not in the dosimetry or bioassay monitoring program, the missed internal dose is based on environmental intake only. Scalsky 2004, pg. 84; Duncan 2003, pgs 6 and 12)
Basis for Tritium Missed Dose	Not included in the TBD	Tritium urinalysis was not perfected until 1961. Liquid scintillation counting for tritium likely was started in 1958 (Bihl 2004, pg. 21-22). From 1949 to 1960 the MDA was 5 uCi/L and from 1961 to 1981 the MDA as 1 uCi/L. Later in 1982 the MDA changed to 10 dpm/ml and in 1991 to 20 dpm/ml, (Bihl 2004, pg 22). Tritium intakes were accounted for as part of external dose until about 1986-87 (TBD does not explain methodology), when they were entered in the dose database as internal dose (Bihl 2004, pg. 12 & 22).	Dose calculated based on the tritium reporting level for a particular time period (Scalsky 2004, pg. 67; Duncan 2003, pg. 6).

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Hypothetical Intake Application	Hypothetical intake applications not discussed in TBD	Applied to individuals who wore a dosimeter but did not have any bioassay (Bihl 2004, pg. 48).	Applied to claims with non-metabolic and digestive tract cancers (Scalsky 2004, pg. 85; Bracket 2003, pg 2).
Basis for missed internal dose from radionuclides other than tritium	(1) From 1950 to 1989, collection of routine urine samples for fluorometric analysis of uranium was initiated – pg. 23. (2) The internal dosimetry program has included limited monitoring for Cs-137, Tc-99, thorium, plutonium, Ac-228, and tritium, among other radionuclides. (Rich and Chew 2005, pg. 43)	(1) Individuals with no external or internal monitoring data were assigned an environmental internal dose, (Bihl 2004, pg. 48) (2) For those individuals with external monitoring but no or limited internal monitoring, the approach was year dependent. For 1947 through 1952, daily intakes at 10% of the respiratory protection required value for 40 hours/week were assumed. Iodine was assumed to be at 0.1 times the vapor index. For 1953 through 1988, daily intakes were based on an exposure to airborne concentrations at 10% of the limiting air concentration for four hours per week, (Bihl 2004, pg. 49). (3) From 1989 through the present, a daily exposure at 5% of the limiting air concentration for 4 hours per week was assumed, (Bihl 2004, pg. 50). (4) For monitored workers with no confirmed intake, a maximum intake is	(1) Individuals with no external or internal monitoring data were assigned an environmental internal dose (Scalsky 2004, pg. 84; Bracket 2003, pg. 2). (2) For those individuals with external monitoring but no or limited internal monitoring, an annual missed tritium dose and environmental dose from uranium, plutonium and ^{131}I are assigned as internal dose. It is also reasonable to pick a fission or activation product that produces the largest dose to the organ of interest dose (Scalsky 2004, pg. 84; Bracket 2003, pg. 8). (3) Highest five intakes for various nuclides are applied to those individuals with non-metabolic or digestive system cancers (Bracket 2003, pg. 2).

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
		determined by using the MDA of the last sample as an upper bound (Bihl 2004, pg. 47).	
Radionuclides included in the Hypothetical Intake	Not discussed in the TBD.	Variable by facility and organ of interest. Alpha intakes are assigned for the Plutonium Finishing Plant (PFP), the 200 Area Fuel Separations Plants, U-Plant, C-Plant, the 300 Area Fuel Fabrication Facilities 209E, 120, 324, 325, 327, the tank farms and evaporator facilities (0.5 times the alpha intake), and where work location in unknown or highly variable. Alpha intakes are based primarily on ^{234}U or ^{239}Pu. Beta/gamma intakes are assigned for all facilities ***except*** PFP, 209E, 120, the 300 Area Fuel Fabrication Facilities, 108-B, and U-Plant. Tritium intakes are assigned for the 108-B Building, the 300 Area Test Reactors, and in some situations where work locations are unknown or variable. The particular beta/gamma radionuclide and its solubility class are determined based on the organ of concern. For some facilities and periods of time it is specified (Bihl 2004, pp. 51-52).	^{241}Am/^{241}Pu (M), ^{244}Cm (M), ^{60}Co (S), ^{137}Cs (F), ^{237}Np (M), ^{238}Pu (M), ^{239}Pu (M), ^{90}Sr (F), ^{234}U (F), and ^{238}U (F). (Bracket 2003, pg. 9)
Default Activity Ratios Pu Mixture	Due to the uncertainty in the U-233 to U-232 ratio process, claimant-favorable assumptions should made about solubility and uranium activity ratios. (Rich 2005 pg. 25)	Not specified in the TBD.	Ten-year old 12% plutonium mix (Scalsky 2004, pg. 66).

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Activity Fractions for other Mixtures	Not discussed in the TBD.	Activity fractions are provided for uranium mixtures, Table 5.2.5-3, pg. 24, weapons and fuel grade plutonium, Table 5.2.1-3 pg. 16, and recycled uranium impurities. Table 5.2.5-2, pg. 24. Default mixtures based fission product urinalysis was developed by time period and organ of concern (Bihl 2004, pg. 10, Attachment D).	Activity fractions are facility dependent. The activity fractions are taken from the Internal Dosimetry Technical Basis Manual (WSRC 1990). The information for these ratios was obtained from safety analysis reports, personal interviews, open literature, etc.
Radionuclides of Concern for Monitored Workers	In addition to 234U, 235U, and 238U, the following radionuclides are identified in the TBD: ^{3}H, ^{90}Sr, ^{99}Tc • ^{228}Th, ^{232}Th, • ^{232}U, ^{233}U, ^{236}U • ^{238}Pu, ^{239}Pu, ^{241}Pu • ^{237}Np, ^{241}Am ^{60}Co and ^{95}Zr/^{95}Nb for organizations outside Y-12, (Cofield 1961) • ^{210}Po • ^{40}K, ^{137}Cs (Rich and Chew 2005, pg. 12)	Radionuclides of concern were based on the *in vivo* and *in vitro* bioassay data of the individual, or the minimum detectable activity for a particular radionuclide. Radionuclide assumptions varied by facility and organ of interest (Bihl 2004, pg. 13).	Radionuclides of concern were based on the *in vivo* and *in vitro* bioassay data of the individual (Scalsky 2004, pgs. 66 & 67). Although the TBD provides activity fractions in Attachment A, it is not clear how these activity fractions are used in dose calculations.
Tritium Dose for Monitored Workers	As of 1957, personnel engaged in processing materials with a potential for tritium contamination submitted three urine samples per month – (Rich 2005 pg. 26)	Tritium urinalysis was not perfected until 1961. Liquid scintillation counting for tritium likely was started in 1958 (pg. 21-22). From 1949 to 1960 the MDA was 5 uCi/L and from 1961 to 1981 the MDA as 1 uCi/L. Later in 1982 the MDA changed to 10 dpm/ml and in 1991 to 20 dpm/ml (pg. 22). Tritium intakes were accounted for as part of external dose until about 1986–1987 (TBD doses not explain methodology), when they were entered in the dose database as internal dose	Based on the reporting level if the tritium bioassay is less than this level, or the actual bioassay result if it is greater than the reporting level. Organically Bound Tritium and Stable Metal Tritides are not considered (Brackett 2003, pg. 6).

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
		(pp. 12 & 22). (Bihl 2004, pg. 12 & 22)	
Internal Dose for radionuclides other than tritium	The primary focus on internal dose control has been on uranium compounds and alloys over a wide range of 235U enrichment. At times, the uranium compounds processed may have contained impurities with radiological health implications. Pg. 7 Uranium has always been the dominant contributor to collective internal dose at Y-12. Monitoring for other radionuclides has been performed on a limited basis – pg. 16 Analyses for other radionuclides were performed on an as needed basis - pg. 20 (Rich and Chew 2005)	Based on either actual bioassay values for positive values. Based on a chronic intake over the entire exposure period with the last sample assumed to be at the MDA (Bihl 2004, pg. 47).	Based on either actual bioassay values or detection levels for bioassay techniques. For non-metabolic cancers, the maximizing approach is used (Scalsky 2003, pg. 85).
Basis for pre-bioassay program doses	Urine by fluorometry (usually for an individual who worked in areas with natural/depleted uranium; prior to 1950, also used for workers in enriched uranium areas - pg. 11 and 21. Plutonium in Urine by gross alpha counting. Was used before 1988 – pg. 22 (Rich and Chew 2005)	Air concentration tolerance or limits. (Bihl 2004, pg, 7)	Not included in the TBD.
Ingestion	Not included in the TBD.	Assigned during periods were air sampling was used to determine internal dose. The quantity is based on the air concentration level or on the guidance provided in *Estimation of Ingestion Intakes* (NIOSH 2004). (Bihl 2004, pg. 8)	Not included in the TBD.
Surrogate Radionuclide in IMBA for $^{65}Zn/^{95}Zr$	Not included in the TBD.	Not included in the TBD.	^{137}Cs used as a surrogate. Surrogate Adjustment factor = 2.43. (Brackett 2003, pg. 9)
Surrogate Radionuclide in IMBA for $^{106}Ru/^{144}Ce/^{95}Nb$	Not included in the TBD.	Not included in the TBD.	Radionuclides not available in IMBA. ^{90}Sr used as a surrogate. Surrogate Adjustment factor = 7.25

Table A.7.3 Internal Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
			(Brackett 2003, pg. 9).
Surrogate Radionuclide in IMBA for $^{242}Cm/^{252}Cf$	Not included in the TBD.	Not included in the TBD.	Radionuclides not available in IMBA. ^{244}Cm used as a surrogate. Surrogate Adjustment factor = 1.09 (Brackett 2003, pg. 9).
IREP Radiation Types for Hypothetical Intake	Not included in the TBD	Alpha[1] Beta: >15 keV[1] Photon: > 250 keV[1] Tritium: < 15 keV[1]	Alpha Beta: >15 keV Tritium: < 15 keV (Bracket 2003, pgs. 8 & 12)
IREP Dose Distribution Type	Not included in the TBD	Constant[1]	Constant (Brackett 2003, pg. 12)
Internal Dose Uncertainty	The use of the rate method for determination of NU and DU to estimate daily urine excretion, and hence radionuclide elimination, contributed to the uncertainty associated with any given measurement. (Rich 2005 pg. 20)	For the missed dose assignments, the value entered includes the uncertainty. For dose assignments based on monitoring data, the following values can be applied as a standard deviation: (1) 0.3 times the MDA or reporting level, or (2) 0.5 times the MDA for chest counting. Actually report errors can be used if available (Bihl 2004, pg. 46). For air concentration data, a triangular distribution with zero as the minimum, the derived values as the mode, and twice the mode as the maximum is used (Bihl 2004, pg. 7).	For the missed dose assignments, the value entered includes the uncertainty. [1] No direction is provided to the dose reconstructor for dose assignments based on monitoring data.
Other Comments	None.	Informs the dose reconstructor of limited use radionuclides such as ^{14}C, ^{232}Th, radon, ^{90}Y, ^{227}Th, ^{227}Ac, and ^{32}P (Bihl 2004, pg. 32)	None.

[1] These parameters were obtained from review of several Hanford dose reconstruction IREP input sheets.

Table A.7.4 Environmental Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Application	The data from the scoping survey should be used to calculate an external dose for unmonitored workers (Foley and Carrier 1990). The dose rates shown in Table D-7 represent the external exposure rates measured site wide. The exposure rates were converted to dose equivalent rates assuming a quality factor of one (1). (Ijaz and Adler 2004, pg. 45)	Environmental doses are assigned to personnel with no bioassay and no evidence of having worn a dosimeter at the Hanford Site (Bihl 2004, pg. 48).	Apply the annual internal and external environmental dose for each full or partial year of employment for the maximizing approach. Dose reconstructors are instructed to use only the maximum annual intakes in Table C-17 for the maximizing approach (Scalsky 2004, pg. 179). For the best-fit approach, modifications can be made for partial year of employment. No environmental dose is assigned if the background is not subtracted from the workers badge (Scalsky 2004, pg. 62).
Sources of Environmental Releases Considered	There are two potential sources of external exposures received by workers at the Y-12 facility: 1. Exposures from the deposition of radionuclides released as a consequence of facility operations, 2. Exposures received from radiation levels emanating from buildings and storage areas. (Ijaz and Adler 2004, pg. 45)	T-plant particles and iodine, B-Plant particles and iodine, REDOX particles and iodine, PUREX particles and iodine, Z-Plant particles, reactor noble gases, and tritium from 108B Building (Savignac 2003, pg. 18).	The TBD heavily references the Cummins (1991) and CDC (2001) documents, and dose not include many of the base assumptions from those reports in the TBD. It is apparent that releases from the reactors and separations areas were considered.
Source Term Basis	Aerial radiological surveys and flyovers for collimated sources (pg. 28); waste disposal area report (pg 28); outdoor radiological and chemical scoping surveys (pg. 29); and data for Y-12 monitoring stations (pg. 38) (Ijaz and Adler 2004)	Hanford Works environmental reports; Methods for Estimating Radiation Doses from Short-Lived Gaseous Radionuclides and Radioactive Particles Released to the Atmosphere During Early Operations at Hanford (Till et al. 2002).	*Radioactive Releases from the Savannah River Plant 1954–1989* (Cummins 1991), *Savannah River Site Dose Reconstruction Project Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released from the Savannah River Site* (CDC 2001), SRS meteorology data, SRS environmental reports for 1993-2001.

Table A.7.4 Environmental Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Methodology	Due to the limitations of the available data and the complexity of modeling releases, an alternative approach was developed for estimating airborne uranium concentrations. An empirical relationship was developed using on site measured air concentrations and estimated uranium release estimates. This approach circumvents the need for air dispersion modeling by providing a direct relationship between uranium air concentrations and uranium releases. (Ijaz and Adler 2004, pg 14)	Puff advection (RATCHET) model (Savignac 2003, pg. 14)	Gaussian model (Scalsky 2004, Section 3.1.1)
Type of Releases	Concentrations of airborne uranium within the Y-12 perimeter were measured from 1983 through 1999. This seventeen-year period represents less than 30% of the operational history of the site. In addition, these data were not collected during the time operations and releases were at their maximum. Therefore these data cannot be used as estimators of historic air concentrations. Prior to 1983, the various networks of air monitoring stations in and around the ORR were established to monitor for the FP releases. (Ijaz and Adler 2004, pg. 13)	Calculations included routine and identified non-routine releases. Estimates include inhalation of radionuclides in air, direct external radiation from plumes, and physical contact with particulate radionuclides on skin.	The TBD heavily references the Cummins (1991) and CDC (2001) documents, and dose not include many of the base assumptions from those reports in the TBD.
Ventilation Rate (m3/year)	2,400 (default); pg. 27 Based on an exposure assumption of 2000 hours/year and an inhalation rate of 1.2 m3 hour. (Ijaz and Adler 2004, pg. 38)	2,400 (default); Based on 1.2 m^3/hour ± 0.4 m^3/hour (Savignac 2003, pg. 16)	2,400 (default); Adjustments can be made for light and heavy work (Scalsky 2004, pg. 162).

Table A.7.4 Environmental Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

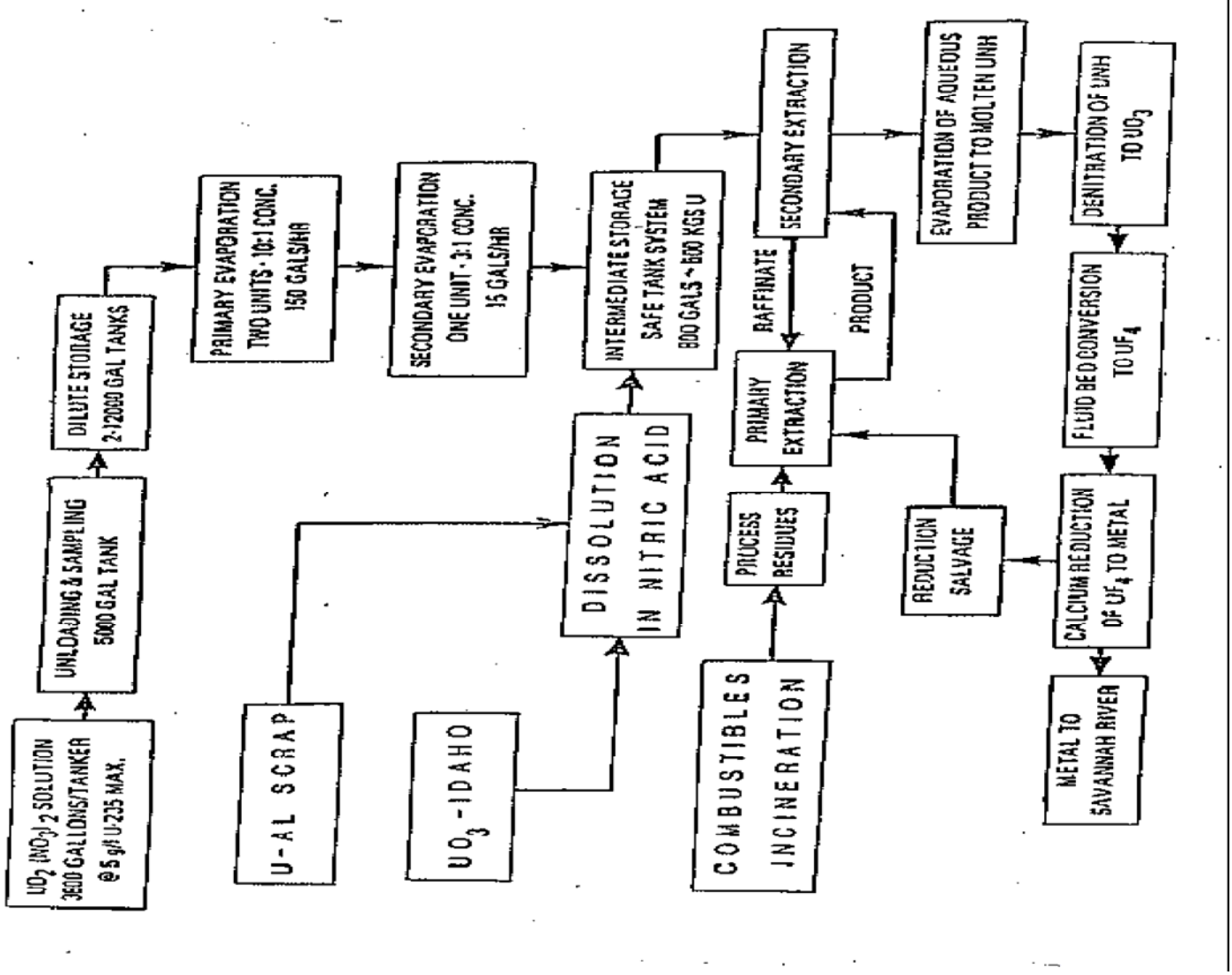
Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Exposure Time (hours/week)	40	40 (Savignac 2003 pg. 24)	40 with a 1.25 conversion factor to increase the exposure time to 50 hours per week (Scalsky 2004, pg. 61).
Mobile Workforce	Information not included in the TBD.	Information not included in the TBD.	Assign the maximum dose listed for any area onsite.
Facility Specific Workforce	Information not included in the TBD.	Information not included in the TBD.	Assign the maximum dose listed for any area onsite for the maximizing approach. Assign an area specific environmental dose based on the work location of the worker for the best-fit approach (Scalsky 2004, pg. 61).
Radionuclides Considered for External Dose	$^{234/235}$U, ^{238}U – pg. 27 Aerial surveys identified specific radiological sources including 60Co, 234mPa and 137Cs. – pg. 28 (Ijaz and Adler 2004)	$^{)41}$Ar, ^{131}I, ^{106}Ru (Savignac 2003, pgs. 19 and 23)	^{41}Ar, (Scalsky 2004, pg. 60)
Radionuclides Considered for Submersion Dose		^{41}Ar (Savignac 2003, pg. 17)	^{41}Ar, (Scalsky 2004, pg. 59)
Submersion DCF	Information not included in the TBD.	Federal Guidance Report No. 13, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, 1999.	Assumed values from the Federal Guidance Report 12 (EPA 1993). (Scalsky 2004, pg. 60)
Radionuclides Considered for Internal Dose.	Occupational Internal Dose TBD has yet to be released.	^{3}H, ^{131}I-^{131m}Xe, ^{144}Ce-^{144}Pr, ^{137}Cs-^{137}Ba, ^{239}Pu, ^{103}Ru-^{103m}Rh, ^{106}Ru-^{106}Rh, ^{90}Sr-^{90}Y, ^{95}Zr-^{95}Nb (Savignac 2003, pg. 8)	^{3}H, ^{131}I, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{234}U, ^{235}U, and ^{238}U (Scalsky 2004, pg. 51)
Soil	Outdoor radiological and chemical scoping surveys provided measurements of both gamma ray exposure rates and the collection of surface soil samples. Specific parameters are not specified in the TBD. (Ijaz and Adler 2004, pg. 6-7)	Not included in the TBD.	Density = 1,600 kg/m3 Surface Factor = 0.08 Resuspension Factor =1E-9/m (Scalsky 2004, pg. 59)
Liquid Effluents	Not included in the TBD.	Not included in the TBD.	Not included in the TBD.

Table A.7.4 Environmental Exposure Default Assumption Comparison for Y-12, Hanford and the Savannah River Site

Description of Assumption	Y-12 Oak Ridge	Hanford	SRS
Organ Dose Conversion Factor	Not included in the TBD.	Not included in the TBD.	1.0 is used in the maximizing approach. The organ dose conversion factors in the external dosimetry guide for the relevant exposure geometry are used in the best-fit analysis (Scalsky 2004, pg. 61).
IREP Rate	Chronic	Chronic[1]	Chronic (Scalsky 2004, pg. 61)
IREP Radiation Type	Photon, 30-250 keV	Photon, 30-250 keV[1]	Photon, 30-250 keV ^{41}Ar , 100% photon, > 250 keV (Scalsky 2004, pp. 60 &61)
IREP Dose Distribution Type	Constant	Constant. Doses and intake quantities provided with a geometric mean and standard deviation. There is no direction on how these values should be entered into IREP.	Constant. Doses and intake quantities provided with a 50th-percentile and a geometric standard deviation. A 95th percentile for the source term is estimated as 25% greater than the 50th percentile (Scalsky 2004, pg. 60).
Special Considerations for Uranium and Plutonium	Non mentioned in the TBD.	Not applicable.	The isotope yielding the maximum organ dose was assumed at 100% rather than applying a mixture (Scalsky 2004, pg. 59).
Other	Aerial surveys identified specific radiological sources including 60Co, 234mPa and 137Cs. Other sources included collimated sources and x-ray machines located in buildings. Multiple flyovers indicate that these sources were not in constant operation. (Ijaz and Adler 2004)	The four chemical separations plants, T Pant, B Plant, REDOX Plant and the PUREX plant, along with the plutonium handling Z plant are shown in Figure 4.1.1 to be the most important release points at Hanford (Savignac 2003).	1955 values are assigned to 1952, 1953, and 1954 (Scalsky 2004, pg 54)

[1] These parameters were obtained from review of several Hanford dose reconstruction IREP input sheets.

ATTACHMENT 8: URANIUM PROCESS FLOW AT THE Y-12 PLANT (DOE 1985)



ATTACHMENT 9: EDITORIAL ERRORS IN THE TBD

ORAUT-TKBS-0014-3

Best Estimate" Doses in Attachment 3C Tables Are in Error

There are errors in the Attachment 3C Tables. Guidance provided in Attachment 3C (Murray 2004) would assign an organ dose for "best estimate" that is 30% higher than the "maximized" organ dose. The occupational medical TBD (Murray 2004) lacks adequate development of medical x-ray technical factors that were subsequently provided in ORAUT-OTIB-0006 (Kathren 2003). This leaves the TBD sections without an adequate discussion of these factors. NIOSH has not provided guidance for determination of x-ray dose in claimant cases involving cancer on the skin of the face. X-ray dose is usually determined by the exit dose to the skin of the back. The dose potential from photofluorography chest x-rays during the early years was based on an National Council on Radiation Protection, NCRP Report 102 (NCRP 1989) which may not be representative of the photofluorography unit at Y-12.

ORAUT-TKBS-0014-3 identifies the fact that, at Y-12, four different x-ray units were used between 1943 and the present for performing standard chest x-ray procedures. Correspondingly, Attachment 3C of the TBD provides four separate tables (i.e., Tables 3C-2, 3C-3, 3C-4, and 3C-5) for organ doses associated with chest x-rays.

- Section 3C.3.1, *Assignment of Organ Doses from X-ray Procedures:* ***Maximizing Approach for Dose Reconstruction***, provides the following guidance for maximizing dose estimates:

Organ doses from X-ray procedures have been calculated and are presented in Tables 3C-2, 3, 4, and 5. The organ doses assigned for each X-ray procedure are the **highest** doses to any organ in the relevant group as listed in Tables 3C-2 to 5. *[Emphasis added.]*

Thus, it must be assumed that organ doses cited in Tables 3C-2 to 5 have already been 'maximized." However, this assumption conflicts with Section 3C.2.3 that follows, as explained below.

- *Section 3C.2.3,* Assignment of Organ Doses from X-ray Procedures: Best Estimate Approach for Dose Reconstruction*, provides the following guidance for assigning a* ***best estimate*** *of organ dose:*

For the dose calculation, a normal distribution is applied with a standard deviation of 30%. The value of the standard deviation is equal to the mean value times 30%. Thus, the dose reconstructor should multiply the organ doses listed in Tables C-2, 3, 4, and 5 by 1.3.

In summary, the guidance provided in Attachment 3C of the TBD would assign an organ dose for "best estimate" that is 30% higher than the "maximized" organ dose. This is obviously an error!

ORAUT-TKBS-0014-6

Neutron Monitoring Methods and Records

Page 11, Table 6.3.1-1, Row 2 under neutron dosimeters, shows that from 1980–1989 the NTA film was used for fast neutrons and TLND dosimeters for other energy neutrons. This appears to be in contradiction to that stated on Page 16 for the period of 1986–1989 where TLND only was used for neutron dose determination. This apparent contradiction needs to be corrected.

In Table 6.3.1.1, Page 11, of the TBD, NTA film is listed as being used from 1950–1980, but in Table 6.3.1.2, Page 12, NTA film is listed as being used from 1948–1960 and in Table 6.3.2.1, Page 14, it list the start of NTA film use in 1949. This apparent conflict needs to be corrected.

Page 19, Table 6.3.3.2-1, states that the *Angular response* of Y-12 neutron dosimeters is likely too low because of its lower response at non A-P angles (the text before this table discusses both NTA film and TLNDs). However, Table 6.3.4.3-1, Page 26 states that the NTA film response is likely too high because of its increased response at other than A-P angles, and that the TLD response would decrease at other than A-P angles. This conflict needs to be resolved or clarified.

Film Badge Energy Response

Page 15, Figure 6.3.2.1-1 shows the two-element film badge to over respond in the 77 keV to 200 keV photon energy range as compared to Hp(10). However, the first paragraph on Page 16, and Table 6.3.2.1-1, states the range is 118 keV to 208 keV.

Table 6.4.2.1.1 Footnote

Page 30, Table 6.4.2.1-1, footnote b, list the figure number as 4.6.2-1; it should be Figure 6.4.2.1-1.

Table 6.4.2.2.1 ICRP 60 Correction Factors

Page 30, Table 6.4.2.2-1, and the text above it, uses the term "ICRP 60 correction factors". Actually, these factors appear to be derived from site specific terms, using ICRP 60 (ICRP 1990). They are not directly from ICRP 60. Rewording this term would make it more applicable.

ORAUT-TKBS-0014-6 (Kerr 2005, pp. 28 & 43) states that the dose should be adjusted by a factor of 1.34 for workers in the DU process waist-level handling operators prior to 1991. The TBD, however, does not specify the starting date for the use of this adjustment in photon dose. Clarification is needed concerning the application of this dose adjustment factor.

ATTACHMENT 10: URANIUM SEPARATION PROCESS (1943–1947)

The TBD does not provide a complete historical account for dose reconstruction during this period. This is illustrated by:

(a) The number of workers involved is not discussed and is quite large;

(b) Levels of uranium in air were extraordinarily high at the Calutron operations;

(c) There is little if any evidence of respiratory protection;

(d) Individual worker dosimetry was virtually non-existent; and

(e) By the late 1940s, AEC officials and advisors were made aware that uranium workers were being excessively exposed to airborne levels of uranium well above the default limits meant to protect against radiation set in World War II..

Between 1943 and 1947, the Tennessee Eastman employed approximately 40,000 workers, including a large number of women ((Herken 2002)) to operate the Calutrons and to recover and process uranium for weapons in Y-12 buildings 9201-1, 9201-2, 9201-3, 9201-4, 9202, 9203, 9204-1, 9204-2, 9204-3 ,9204-4, 9206, 9207, 9211, and 9212 (Polednak 1982).

> *By any scale, the operation there was mammoth. Plans called for installing a pair of 500-tank Calutron race tracks end-to-end in twin two-story buildings, each measuring four football fields long. The racetracks were on the second story; pumps and plumbing for the vacuum system occupied the first floor. Logistic and personnel requirements were in proportion. Every pair of vacuum tanks required an individual operator seated at a console, continually adjusting the current to focus on the beam. An army of technicians was needed to monitor the orange uranium-oxide feed material for the beam and later scrape the errant green "gunk" -- uranium salts dissolved in carbon tetrachloride -- from the insides of each tank. An army of chemists would separate out the silvery white powder containing uranium-235 that was left in the receivers following each week-long run* (Herken 2002).

By 1948, the Atomic Energy Commission's (AEC) manager of the Oak Ridge site *"submitted a report on radiation history of employees,"* which was reviewed by the contractor and AEC representatives, including the AEC's Advisory Committee for Biology and Medicine (ACBM). (AEC 1948) The report recommended:

> *(1) a terminating employee be provided with a statement that he has not exceeded the permissible exposure to radiation, or* ***if he has exceeded the permissible exposure he be made aware of this fact by the physician giving the exit interview;*** [Emphasis added] *(2) that there be a clearer policy on release of information on radiation exposure records and other medical records to the*

> *contractor's insurance and life insurance companies; (3) that the terminating employee be advised that if he is to work with radiation in the future his new employer can make arrangements to procure his past radiation exposure history; (4)* ***that a group of qualified radiologists and physicians be available for consultation by any person who feels that he has been damaged by radiation at an AEC installation.*** [emphasis added] (AEC 1948)

According to the minutes of the meeting of the ACBM in December 1948,

> *…a full discussion ensued and each item was considered in detail.* ***It was the opinion of the Committee that in place of the stated recommendation a terminating employee should be advised at the exit interview as to the care that the A.E.C. utilizes in protecting each employee.*** *[emphasis added]* (AEC 1948)

Subsequently, in June 1949, the ACBM Committee was given a presentation given by Dr. Sterner regarding exposure to workers in uranium processing plants. (AEC 1949) According to the presentation:

> *The original levels that were set during the earlier days were 500 micro-grams per cubic meter for insoluble uranium dust and 150 micro-grams per cubic meter for soluble.* ***We considered a hazard at that time a chemical hazard and not a radiation hazard,*** *[emphasis added] however on reconsideration there is now an opinion put forth that even as low as 50 micro-gram, per cubic meter, there is a questionable hazard from long-term alpha emitters. 50 micrograms per cubic meter is equivalent to about 70 alpha- counts per minute, per cubic feet and that is the pinch mark present at which we are striking for control in these plants.* (AEC 1949)

Sterner also informed that uranium processing workers were being excessively exposed –some at levels 125 times greater than the default standard adopted in World War II. (AEC 1949).

By 1982, a retrospective dose assessment done by ORAU of workers at the Tennessee Eastman Company (TEC) Y-12 facility was published. (Polednak 1982) The study excluded all female workers. The authors reported that certain operations, particularly recovery areas, involved "concentrations as high as 9,000 ug/m^3" (Polednak 1982). It was not definitively determined if workers wore respirators. Moreover, "Job titles (such as 'operator') were not precise enough to identify workers with highest exposure" (Polednak 1982).

The authors assumed that all alpha chemical workers were exposed to an average concentration of insoluble uranium compounds of 150 ug/m^3. (Polednak 1982) On this basis, workers employed for one year during this period "could have received lung doses of about 6.3 rad or 130 rem in the 130-year period" (Polednak 1982).

Although uranium dust concentrations were found to be lower in the beta chemistry area, enrichment levels were at least 15% ^{235}U and about 0.5% ^{234}U, resulting in a dose estimate for one year of work of about 20 rad or 400 rem over 30 years (Polednak 1982).

In light of the historical information cited in this review, the use an average air concentration of 150 ug/m^3 by Polednak el al does not appear to be claimant friendly, and should be given particular attention by NIOSH.