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July 16, 2006

Mr. David Staudt
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Subject: Contract No. 200-2004-03805, Task Order 1: Review of the NIOSH Site Profile for the Mound Laboratory Site, SCA-TR-TASK1-0012

Dear Mr. Staudt:

SC&A is pleased to submit to NIOSH and the Advisory Board our draft *Review of the NIOSH Site Profile for the Mound Laboratory Site*, commonly referred to as the Mound Site Profile.

If you have any questions or comments on this report, please contact John Mauro at 732-530-0104. We look forward to discussing this draft report with NIOSH and the Advisory Board.

Sincerely,

J J Mauro

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

Review of the NIOSH Site Profile for the Mound Laboratory Site

Contract No. 200-2004-03805
Task Order No. 1
SCA-TR-TASK1-0012

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S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation and Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-TASK1-0012 Effective Date: Draft – July 16, 2006 Revision No. 0 – Draft
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Task Manager: _________________________ Date: ___________ Joseph Fitzgerald	Supersedes: N/A
Project Manager: _________________________ Date: ___________ John Mauro, PhD, CHP	

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ACRONYMS AND ABBREVIATIONS

Advisory Board	Advisory Board on Radiation and Worker Health
AP	Anterior-Posterior
AEC	Atomic Energy Commission
AEDE	Annual Effective Dose Equivalents
AMAD	Activity Median Aerodynamic Diameter
BIO	Basis for Interim Operations
Bq	Becquerel
BWXT	BWX Technologies, Inc.
CAM	Continuous Air Monitor
CEDE	Committed Effective Dose Equivalent
CFR	*Code of Federal Regulations*
Ci	Curie
cpm	Counts per minute
D&D	Decontamination and Decommissioning
DAC	Derived air concentration
DCF	Dose correction factor
D_L	Decision Level
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
dpm	Disintegrations per Minute
DR	Dose Reconstructor
DTPA	Diethylenetriaminepentaacetate
EDS	Energy Dispersive X-ray Spectroscopy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
GI	Gastrointestinal
GSD	Geometric Standard Deviation
HHS	Health and Human Services
HPNO	Health Physics Number
HPO	Health Physics Office
HT	Elemental Tritium
HTO	Tritium Oxide or Tritiated Water

ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
keV	Kiloelectron Volt
kVp	kilovolts peak
LANL	Los Alamos National Laboratory
LAT	Lateral
LOD	Limit of Detection
LSC	Liquid Scintillation Counting
µCi	Microcurie
MCW	Mallinckrodt Chemical Works
MDA	Minimum Detectable Activity
MEMP	Miamisburg Environmental Management Project
MeV	Million electron volts
MMCIC	Miamisburg Mound Community Improvement Corporation
mrem	Millirem
nCi	nanocurie
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NTA	Eastman Kodak Nuclear Track Film Type A
NTD	Non-destructive testing
NTS	Nevada Test Site
OBT	Organically bound tritium
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
OSTI	Office of Scientific and Technical Information
OTIB	ORAU Technical Information Bulletin
OW	Open Window
PA	Posterior-Anterior
PAM	Portable alpha meter
pCi	pico curies
PFG	Photofluorography
PIC	Pocket ionization chamber

POC	Probability of Causation
ppm	Parts Per Million
RadCon	Radiological Control
RCCC	Radiological Control Coordinating Committee
RCT	Radiological Control Technician
Rem	Roentgen equivalent man
RFP	Rocky Flats Plant
RTG	Radioisotope Thermoelectric Generator
RWP	Radiation work permit
SC&A	S. Cohen and Associates
SEM	Scanning Electron Microscope
SMT	Stable Metal Tritide
SOP	Standard Operating Procedure
SRS	Savannah River Site
SSD	Skin to Surface Distance
SSN	Social Security Number
STC	Special Tritium Compound
STP	Stable Triated Particulate
SWP	Specific work permit
TA	Technical Area
TBD	Technical Basis Document
TIB	NIOSH Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
WD	Waste disposal
Y-12 Plant	Y-12 National Security Complex

1.0 EXECUTIVE SUMMARY

This report provides the results of an independent audit conducted by S. Cohen and Associates (SC&A, Inc.) of the technical basis documents (TBDs) that make up the site profile developed by NIOSH for the Mound Site. This audit was conducted during the period October 18, 2005–May 30, 2006, in support of the Advisory Board on Radiation and Worker Health (Advisory Board) in the latter's statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) to conduct such reviews and advise the Secretary of Health and Human Services (HHS) on the "completeness and adequacy" of the EEOICPA program.

The Mound Laboratory site in Miamisburg, Ohio, played an important role in the U. S. nuclear weapons program and was first established as a pilot operation in Dayton, Ohio, in the summer of 1943. Monsanto accepted the responsibility for the chemistry and metallurgy of polonium at predecessor facilities that were conducted there under the Dayton Project. The Dayton site's primary activity in its early years was to extract Po-210 from radioactive feedstock received from the Hanford Works to fabricate atomic bomb radiological initiators and other weapons components. The Mound Laboratory became the first permanent U.S. Atomic Energy Commission (AEC) facility in May 1948.

The initial role of polonium production expanded to include nuclear weapons component development and production, and such secondary missions as radioactive waste management and recovery, the use of radioactive materials for non-weapons purposes, and the purification of nonradioactive isotopes for scientific and commercial research. A key collateral mission over the years has been the development, engineering, manufacturing, and evaluation of explosive components for the nuclear weapons program.

Starting in the early 1950s, Mound developed radioisotopic thermoelectric generators (RTGs) for primary use as a self-contained power source for spacecraft. Tritium-handling technologies began in the mid-1950s and consisted of both research and production missions, which continued throughout the operational history of the plant. Other missions included the manufacturing of enriched stable isotopes for medical, industrial, and general research; development of chemical heat sources; and development of technologies for radioactive waste management.

Mound Laboratory was managed by four principal operating contractors over its more then 50-year existence, starting with Monsanto from 1946–1988 and EG&G from 1988–1997, during the production era, and Babcock and Wilcox of Ohio (1998–2002) and CH2M Hill Mound (2002–present) managing decontamination and decommissioning (D&D) and site closure activities following cessation of operations. During the D&D phase, BWXTO decontaminated and decommissioned 57 buildings and transferred 127 acres to the Miamisburg Mound Community Improvement Corporation (MMCIC) for future use (BWXT 2006).

The review included two separate weeks of unclassified interviews with over 20 site experts (primarily former Mound workers) by SC&A personnel at the Ohio Field Office center at the Mound closure site and a conference call with additional former workers, as well as extensive non-classified document retrieval at the Dayton Federal Records Center in Dayton, Ohio. A classified document retrieval effort had been planned at Los Alamos National Laboratory (LANL), where it was subsequently learned that the Mound classified records file at LANL had been disposed of the year before (see Secondary Finding 16). Questions were submitted to NIOSH and its technical support contractor, ORAU, during the course of this review, and a conference call was held between the SC&A review team and their ORAU counterparts on June 8, 2006, regarding specific issues surrounding the contents of specific TBDs that make up the Mound 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. A complete list of the Mound TBDs, as well as supporting documents, that were reviewed by SC&A is provided in Attachment 1.

This review found that the site profile characterized the primary radiological exposure sources, but failed to address fully the exposure implications of these and other radiation sources, as well as the potential impact of identified deficiencies in historic dosimetry program implementation. Whereas the early polonium, and later tritium and plutonium exposures and dosimetry are characterized, the implications to dose reconstruction of metal tritides, high-fired Pu-238, and radon are not adequately addressed. Likewise, the "established" radiation dosimetry program is discussed in terms of what limits of detection (LOD), minimum detectable activity (MDA), monitoring frequencies, and badging policies were the policy and site practice at the time, without qualifying this information with past and current information regarding how effectively the dosimetry program was actually carried out. This is particularly critical for a site such as Mound Laboratory, where issues arose in the 1990s regarding deficient management of the bioassay program that were sufficiently serious to warrant a federal court order and Price-Anderson Act civil enforcement actions by DOE (DOE 1999b).

In this context, SC&A found that the site profile did not address the bioassay program deficiencies identified in 1997 nor indicate for dose reconstruction purposes to what extent these program failures would have dose estimation implications for previous years. These issues, as documented in a 1997 DOE report, included failures of workers to submit required bioassay samples, use of outdated (and elevated) MDA values, failures to meet bioassay sampling cycle times, and other procedural violations. The internal dose TBD does not address these deficiencies in the bioassay program in terms of how it may have adversely impacted who received bioassays, how bioassay was carried out, and how dose was actually recorded.

With respect to sources of radiological exposure, the site profile provides dose characterization data for metal tritides, radon, and Pu-238, but does not fully address the uncertainties involved with conducting dose estimation. For example, metal tritides (particularly hafnium tritide) were used more extensively at Mound than at many other DOE sites, and were found to be of very low solubility. Given the lack of recorded doses and without any documented facility characterization for metal tritides until the early 1990s, it is not clear from the TBD how NIOSH would assign dose without knowing where metal tritides were handled, who was exposed, and what quantities may have been available for intake.

Similarly, for radon exposure in the SW and R buildings, NIOSH has based upper-bound dose estimation on a single-spot air sample taken in 1979 in SW-19. Other Mound facility radon dose assumptions are based on a 1989–1990 UNC Geotech building-by-building baseline survey. However, the representiveness of these values is uncertain, given the long time frame of this problem (1950s–1970s) and the likely high radon exhalation rates through foundation cracks in the SW and R buildings, which were constructed over extensive radium-226 contamination located in the abandoned and since buried “old” cave. Likewise, former radiation control technicians interviewed noted that informal experiments were conducted to demonstrate that operation of negative pressure hoods in these facilities led to markedly increased radon exhalation through the building foundations. The demonstrably elevated radon concentrations associated with these sources were a continuing problem for the overlying production facilities, and was not even partially remediated until venting of these subterranean sources was undertaken in 1980. The TBD’s assumption that the uncertainty of these measurements (for thoron and actinon, as well as radon) is “a factor of at least 10” is the apparent basis for the choice of a geometric standard deviation (GSD) of 3 to compensate for these uncertainties. However, with little data for radon and no useable data for thoron and actinon, this would not be a sufficient basis for assuming that a technically plausible upper-bound had been determined.

For Pu-238 microspheres, which were fabricated at Mound for many years through an extremely high-temperature fabrication process, the site profile defines their solubility as Type S without addressing the implications of initial biokinetic retention on incident or near-term urinalysis. While the integrity of the Pu-238 particles may be susceptible to physical factors, such as “greater specific gravity and therefore a greater energetic alpha recoil” (ORAUT-TKBS-0016-5), leading to more transfer to body fluids as observed by the site profile, it has been also found from past exposures that this phenomenon takes time to be realized, leading to a delay in urinalysis detection. In the absence of viable in-vivo monitoring, such a delay may lead to missed dose if a worker was not continuously monitored following exposure, e.g., where production workers were reassigned or with support personnel who would not have been bioassayed regularly.

It is not clear from the internal dosimetry TBD (Millard 2004), how dose estimation would be performed for maintenance and support workers who were not classified as radiation workers and who had access to Mound radiological operations. No guidance is provided in this TBD with respect to missed dose calculations for unmonitored workers, such as this category of support personnel whose actual jobs (contamination spill cleanup, equipment maintenance, janitorial functions) could have led to exposures comparable to radiation workers, and whose access to various Mound buildings may have led to a variety of radionuclide exposures over their job history.

SC&A’s external dose issues are primarily directed at how the TBD addressed dose estimation in the early years of Mound operation. The retrospective use of external dose distribution data from the 1949–1959 operating period to Mound’s earliest periods (1943–1948) is questionable, given the difference in radiological operations, dose limits, and control practices. Worker exposure to beta radiation sources was prominent in a number of operations, but is not addressed sufficiently in the TBD to enable a dose reconstructor to establish when reliable beta and extremity dose records are available for specific operating periods. The familiar issue of whether "cohort" badging was being implemented in the 1947–1959 time period is not evaluated, so as to establish how workers were selected for badging and whether the "maximally exposed" individuals were among them. Likewise, the dose estimation implications of the energy dependence of neutron track emulsion type A (NTA) film use are not addressed, so that it is clear what correction factors will be assigned for Mound workers exposed to neutron sources with energies less than 1 MeV (and which workers and which work locations would have been affected).

Decontamination and decommissioning (D&D) activities at Mound are not addressed from the standpoint of historic radiation exposure history and dose estimations. While this experience is relatively recent (1993–2005) and founded on contemporary radiation protection standards and technology, it is also clear that a fundamental shift occurred with this transition regarding potential radiation hazards and radiological control philosophy. At least one site expert, a former worker familiar with Mound's radiation dosimetry program before and after this transition, noted that D&D workers were monitored with lapel samplers and derived air concentration (DAC) hour criteria as their primary dosimetry, as opposed to the routine bioassay radiation workers received during production. (According to this same source, this practice was modeled directly after that of Rocky Flats Plant (RFP), which was undergoing D&D at the time and was seen widely as a model within DOE). A former Radiological Control Technician (RCT) indicated that lapel samplers were assigned randomly among a group of D&D workers, and often did not represent the maximally exposed individual. The site profile is essentially silent on any treatment of radiation exposure experience during this period and for dosimetric techniques applied by BXTO and CH2M Hill, the two operating contractors responsible for the bulk of D&D and waste management activities.

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 TBDs, 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 FINDINGS

Finding 1: Inadequate bioassay techniques and procedures may have led to under-reporting and missed dose. The radionuclide-specific application of detection limits and minimal detectable activities criteria as cited in ORAUT-TKBS-0016-5, Occupational Internal Dosimetry TBD (Millard 2004), do not include treatment of historic issues related to inadequate bioassay techniques and procedures that may have led to significant under-reporting and missed dose at Mound. While many of these issues were documented for the D&D era of the 1990s, they also have clear implications for the operational time period at Mound that preceded them. A 1997 DOE report documented failures of workers to submit required bioassay samples, use of outdated and elevated MDA values, failures to meet bioassay sampling cycle times, and lack of adherence to the established bioassay program, all of which had earlier contributed to a Price-Anderson Act noncompliance civil penalty. The TBD does not evaluate this history as it pertains to deficient program implementation where it may have adversely impacted who received bioassays, how bioassay was carried out, and how dose was actually recorded.

Finding 2: Potential doses from insoluble metal tritides not sufficiently addressed. Insoluble stable metal tritides (SMTs) and stable tritiated particulates (STPs) were used in various applications at Mound during its operational history. It is clear from internal documentation that there was not an adequate means of detecting exposures or even monitoring SMTs and STPs before 1999. Before that time, hafnium tritide and other SMTs were routinely handled in gloveboxes in various process areas of the SW complex with internal dosimetry and monitoring designed not for STPS, but for elemental tritium (HT) and tritium oxide (HTO). A March 26, 1999, Defense Nuclear Facilities Safety Board Staff Report (DNFSB 1999) highlighted this deficiency and noted that during the production era in the SW, R, and T facilities, and during the deactivation and decommissioning phase, workers were not properly monitored for SMTs and STPs, and proper work controls were not in place. The DNFSB staff review went on to note that "past characterization efforts to identify and locate SMT contamination were limited…as of the time of the staff review (DNFSB 1999), a rigorous characterization program had not yet been fully developed…" While ORAUT-TKBS-0016-5 (Millard 2004) states that a lung clearance Class S should be assumed for metal tritides other than lithium, it is not clear from the scientific literature and site expert interviews whether this assumption is valid for higher "Z" SMTs, such as hafnium tritide. It is also not clear where SMT contamination existed at Mound, given that characterization of metal tritides by specific location within a room or building was not initiated at Mound until 1992. With no NCRP- or ICRP-accepted dose model for metal tritides, NIOSH has not provided a sufficient technical basis for its assumed Class S solubility designation.

Finding 3: Chronic unmonitored indoor radon dose to process workers from underlying radium cave and tunnel not adequately addressed. ORAU-TKBS-0016-5 (Millard 2004) acknowledges radon as an internal dose concern in SW-19 (due to exhalation into the building area from radium and thorium processing wastes from the "Old Cave"), and relies upon limited air monitoring data from 1979–1980 coupled with a more comprehensive characterization study conducted in 1989 (UNC Geotech 1990), which is summarized in a June 2000 BWXT report (BWXT 2000), for its assumed building-by-building Rn-222 dose reconstruction assignments in

Table 5-14. However, the air-sampling measurements from 1979–1980 were limited in location and do not necessarily reflect potential radon air concentrations in various parts of the SW and R building complex, (R building was implicated in former RCT interviews), nor can it be assumed they reflect concentrations that existed in previous years. From former RCT interviews, it was noted that considerable radon exhalation was experienced through foundation cracks in SW (alpha meters would "peg out"); concentrations of radon in such areas would be expected to be elevated over other locations. Furthermore, the rate of radon exhalation and, therefore, the ambient indoor concentration, reportedly increased considerably whenever negative pressure hoods were used in SW and R buildings, which was relatively frequent. The TBD (Millard 2004) does not present substantiated radon characterization data for the SW and R process areas prior to the venting of the underlying cave and tunnel areas in 1980; the limited 1979 spot air measurements and much later site-wide characterization do not provide a technically plausible basis to reconstruct radon dose for that period. Likewise, the TBD's assumption that the uncertainty of these measurements (for thoron and actinon, as well as radon) is "a factor of at least 10" is the apparent basis for the choice of a GSD of 3 to compensate for these uncertainties. However, with little data for radon and no useable data for thoron and actinon, this would not be a sufficient basis for assuming that a technically plausible upper bound had been determined.

Finding 4: Potential doses from high-fired plutonium-238 and thorium-232 not sufficiently addressed. It has been found that plutonium that has been exposed to extreme temperatures (e.g., in excess of 1,000°C) undergoes metallurgical reactions and upon inhalation, exhibits a very long retention time in the lungs that exceeds the default absorption types specified by the current ICRP lung model. While this so-called "Super S" type of plutonium has already been addressed in ORAUT-OTIB-0049 (OCAS 2006) for Rocky Flats, it is not clear how this empirical approach would apply to Pu-238 microspheres at Mound (there is no current ICRP treatment of the biokinetics of Pu-238). These microspheres were formed through high-temperature heating processes and were designed for use in thermal generators. The Occupational Internal Dosimetry TBD (Millard 2004) notes that "in general, Pu-238 compounds are more soluble than Pu-239 due to greater specific gravity and therefore a greater energetic alpha recoil for Pu-238," but does not provide definitive guidance on the projected urine excretion rate for high-fired Pu-238 microspheres, and what adjustment factors would be needed for urinalysis results.

For example, it is unlikely that an exposure to a high-fired Pu-238 oxide will be detected, measured, or noted until some time after the event. This is due to the fact that the highly insoluble high-fired Pu-238 oxide will not be detectable in the urine, and because of the lack of penetrating photons from the Pu-238, it will not be detectable through lung counting with any reasonable MDA sensitivity. Thus, significant unknown exposures may have occurred and remained undetected for months. This becomes an even more significant issue in light of the policy described in Millard's 2004 TBD of discontinued monitoring of workers after they were moved to other projects, and the fact that administrative personnel and support personnel were not monitored routinely.

With respect to high-temperature processing of Th-232 feed material, ORAUT-TKBS-0016-5 observes that "the caustic treatment was likely to have been a high-temperature process that would have resulted in such refactory and highly insoluble thorium compounds as thorium dioxide." However, Attachment 5A of this TBD, which provides the lung clearance class for each compound handled in Mound facilities, lists thorium isotopes from thorium refining as Class "M," as opposed to Type S, or perhaps more appropriately, "Super S." Apart from this seeming contradiction, it is not clear what the implications are of worker exposure to such high-fired thorium compounds.

Finding 5: Use of 1949–1959 dose data for modeling earlier years (1943–1948) is questionable. A modal dose of 50 mrem/week for neutrons and 50 mrem/week for photons (i.e., neutron to photon ratio of 1:1) is cited in ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) for 1949–1959, and recommended for assigning doses for the period 1943–1948 (pages 14 and 22). While these dose assignment criteria are apparently based upon badged worker dose records, no data is provided to substantiate the selection of the 50 mrem/week dose value. 50 mrem/week equates to 2.5 rem/year, which is much less than the allowable limits in 1943–1949 of, first, 26 rem/year, and then, 15 rem/year, as noted on page 15 in ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004). Therefore, a worker could have received 6–10 times the proposed assigned dose and still have satisfied the guidelines in place at Mound at the time. The facilities, working conditions, dose control policies, accidents/incidents, and knowledge of hazards and exposure controls were sufficiently different between the two eras that the use of 1949–1959 dose data for earlier workers could lead to significant underestimation of exposures. Other methods need to be considered to arrive at claimant-favorable doses.

Finding 6: Historic beta exposures not sufficiently characterized. Beta dose reconstruction is not sufficiently covered in the Occupational External Dosimetry TBD (ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004). Periods when reliable beta dose and extremity dose records are not available need to be identified. Beta skin doses from contamination and organ and/or extremity doses from handling beta-emitting materials close to the body and hands need to be further addressed. Table 6-23 on page 35 of the TBD provides a list of numerous beta-emitting isotopes that presented external dose hazards at the Dayton/Mound facilities from 1943 to 2000. While the TBD provides some information concerning beta/low-energy photon dosimetry for this period, it appears scattered and incomplete. Without dose records available for analysis, it is not possible to determine if and when skin doses were recorded, or how LOD, zero, and blank readings were handled. The potential for underestimating beta dose is not sufficiently covered in the present TBD.

Finding 7: Assessment of personnel badging policy during early years needs further review. While ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) indicates that all radiation workers were badged during 1949–1962, it is also apparent that roughly only 15%–20% of total Mound workers were, in fact, badged during 1947–1959. It is important to know who was considered a "radiation worker" and how they were selected for badging, as this has dose consequence. In that era, it was not uncommon to conduct "cohort badging," where supervisors would select "representative" workers to wear dosimeters to record doses for specific operations or buildings. It is also clear that radiation hazards were not well recognized during that time period. This resulted in some workers not being monitored during a period when not all radiation hazards were recognized. The TBD does not clearly address these issues by clarifying the basis for how monitoring was conducted, nor which worker categories were badged (i.e., was everyone inside the plant area—security, crafts, maintenance, janitorial, etc.—considered "radiation workers," or just those routinely handling radioactive materials?). These issues need to be reviewed and substantiation provided that the maximally exposed workers were badged, and that there is a means to estimate radiation dose to unmonitored support workers with access to production areas. Additionally, it is not stated if all post-1949 workers who were badged were monitored for both neutron and photon radiation, or if some were only monitored for photons.

Finding 8: Problems with NTA film Neutron Doses. It is not clear from the present TBD (Proctor and Algutifan 2004) if or when the neutron doses records for **badged** workers are being corrected for the low energy response and fading of NTA film (especially at low neutron energies), for what years, and if and how the neutron-photon values are being used in neutron dose reconstruction. As at other nuclear facilities, Mound became aware of the NTA film's under-response to neutrons below 0.8–1.0 MeV in the 1960s. However, it is not obvious that the dose reconstructor has sufficient detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons, with less than 1 MeV of energy, at the numerous facilities at Mound that produced neutron exposures throughout the years. Other issues of internal consistency were noted in the TBD, including inconsistencies in given neutron-to-photon ratios for various operational periods, neutron flux to dose conversion factors used in 1947–1969, and NTA film fading in the 1950s and 1960s.

Finding 9: The decontamination and decommissioning (D&D) era of Mound operations is not sufficiently addressed. Monitoring practices, particularly internal dosimetry, are not specified in the TBD for the D&D period (1992–2003) at Mound. At least one site expert, a former worker familiar with Mound's radiation dosimetry program before and after this transition, noted that D&D workers were monitored with lapel samplers and DAC hour criteria as their primary dosimetry, as opposed to routine bioassay. (This practice was apparently modeled directly after that of the RFP, which was undergoing D&D at the time and was seen widely as a model within DOE). A former RCT indicated that lapel samplers were assigned randomly among a group of D&D workers and often did not represent the maximally exposed individual. The site profile is essentially silent on any treatment of radiation exposure experience during this period and dosimetric techniques applied by BXTO and CH2M Hill, the two operating contractors responsible for the bulk of D&D and waste management activities. For example, while the internal dose TBD indicates "personal BZ air-sampling data should be used in preference to air-sampling data and no other means of estimating dose is possible," no guidance is provided regarding the inherent limitations of BZ air sampling and its conversion to assumed internal dose. It is also not clear to what extent first, second, and third-tier subcontractors were "captured" in the site's dosimetry program and Mound's central records. It is also not clear how a co-worker dose model would be applied for unmonitored workers located adjacent to D&D operations, and whether resuspension of radioactive particulates was an onsite issue during D&D.

Finding 10: Missing internal dose estimation methods for unmonitored workers, e.g., maintenance and support personnel, not provided. It is not clear from the internal dosimetry TBD (Millard 2004), how dose estimation would be performed for maintenance and support workers who were not classified as radiation workers and who had access to Mound radiological operations. For example, in one instance in the TBD's recommended approach for assigning tritium internal dose, it asserts that "doses would not be assigned to any administrative or other non-radiological workers," although tritium use and contamination was common in many Mound buildings. However, no guidance is provided in this TBD with respect to missed dose calculations for unmonitored workers in the category of support personnel, whose actual jobs (contamination spill cleanup, equipment maintenance, janitorial functions) could have led to exposures comparable to radiation workers, and whose access to various Mound buildings may have led to a variety of radionuclide exposures over their job history. It is also not clear how the designation of "radiological worker" was historically defined at Mound, and how workers were selected on this basis for bioassay for various operations.

Finding 11: Concerns over application of Detection Limit vs. MDA. There are potential missed doses for workers at Mound who were not monitored or recorded and had doses assigned, based on either the detection limits or MDA values, that could have significant impact on determining a claimant's total dose at Mound. In the case of protactinium, the TBD (Millard 2004), Table 5-7, lists "**Detection limit (dpm)"** for protactinium, also noted as the "MDA" in the caption preceding the table**.** The above statement from the TBD thus implies that the action level and reporting limits are the same. If this is the case, then the missed dose (those not resampled and unmonitored administrative personnel) would include all those having urine samples less than 2.2 cpm $24hr^{-1}$, which also equates to 300 mrem wk^{-1} or 15 rem yr^{-1}. This could be a very significant missed dose where no follow-up sampling would have been done for those administrative personnel, maintenance personnel, and those who may have had exposure just prior to discontinuation of work on the project.

1.2 OPPORTUNITIES FOR IMPROVEMENT

(1) The external dose TBD (Proctor and Algutifan 2004) needs to make it clear if the "dose of record" for the workers has been modified with the necessary adjustments or not. These adjustments would include Tantalum shielding of 60 keV gammas; NTA film track fading and low-energy threshold; and TLD signal fading and decreased response at high neutron energies. The TBD provides a lot of information concerning adjustments to the "Missed" dose calculations based on LOD, but none concerning the worker's dose of record and its adjustments for use during dose reconstruction.

(2) The issue of how zero and/or blank entries were made in the dose of records needs to be addressed in the external dose TBD (Proctor and Algutifan 2004). This applies to both monitored workers and the doses used to assign co-worker data to unmonitored workers.

(3) The external dose TBD (Proctor and Algutifan 2004) could be improved by addressing the issue of beta doses and records in a more concise manner. Presently, it is mentioned occasionally in the TBD, but it is not presented in a way that allows the reader a good picture of what, and when, beta doses were of concern. It is also not

made clear how beta doses were monitored, or what will be done during dose reconstruction concerning periods when beta doses were not monitored/recorded.

(4) No information or justification is provided in the TBD (Proctor and Algutifan 2004) for recommending the use of the 1949–1959 external dose data to assign 50 mrem/wk for neutron and photon doses for 1943–1948 workers. The TBD needs to provide some technically sound reasoning and data to support their recommendation.

(5) The external dose TBD (Proctor and Algutifan 2004) does not make it clear who was badged and when. It uses the term "radiation worker" when describing who was badged, but does not state what defined a radiation worker. The TBD needs to investigate who was and was not badged, and the method(s) used to select those who were badged.

(6) The current version of the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), does not adequately address the issues of insoluble SMTs. These insoluble forms were not properly monitored, and recommended methods in the TBD for dose reconstruction are inadequate. More recent publication of studies of these insoluble tritides are not addressed, as discussed in Vertical Issue 5.2. It is suggested that the TBD (Millard 2004) use the approach agreed upon for these tritides in the site profile for the Savannah River Site (SRS).

(7) The ORAUT-TKBS-0016-5 (Millard 2004) acknowledges radon as an internal dose concern in SW19, and the TBD relies upon limited air monitoring data from 1979–1980 coupled with a more comprehensive characterization study conducted in 1989. However, the air sampling measurements from 1979–1980 were limited in location and do not necessarily reflect potential radon air concentrations in various parts of the SW building complex, nor can it be assumed they reflect concentrations or production conditions that existed in previous years. The characterization provided for the dose reconstruction in the present TBD (Millard 2004) does not provide a technically plausible basis to reconstruct radon dose for the early period prior to 1980s.

(8) The ORAUT-TKBS-0016-5 (Millard 2004) addresses the fact that Pu-238 was produced under high-temperature conditions (plasma torch), which would produce a high-fired oxide form. This material has been shown to react differently in the lungs than the air-oxidized form of Pu-238. This is discussed in a U.S. Transuranium Registry paper (TR 1995) and at Los Alamos in papers by both (Hickman 2003) and (Cheng 2004). There issues, as noted in Vertical Issue 5.4, need to be addressed in the revised Mound Occupational Internal Dosimetry TBD.

(9) The ORAUT-TKBS-0016-5 TBD (Millard 2004) relies heavily on the King report (1995) for identifying radionuclides of concern in buildings. Decontamination and decommissioning characterization reports at the time of D&D lead us to believe that other radionuclides were present in many of these buildings that were not monitored for in the earlier days and are not addressed in the TBD (Millard 2004). The TBD also

does not indicate whether workers were monitored and sampling carried out for these other radionuclides during the time of decontamination and demolition of buildings. The practices of monitoring for the radionuclides, identified by King, as well as other found nuclides needs to be addressed for periods involving D&D activities.

(10) NIOSH apparently has not made full use of the Meyer historical document (Meyer 1992) regarding the recovery efficiency of polonium that could make a significant change in the dose commitment calculation.

(11) The current version of the Occupational Environmental Dose TBD, ORAUT-TKBS-0016-4 (Hysong et al. 2004), was published with asserted data gaps of information before 1971. Future revisions need to include additional information pertaining to new environmental monitoring and effluent data collected, since the original publication of the current TBD. It also should include any applicable information that comes from NIOSH responses to pending SC&A questions.

(12) Section 3 of the Mound Plant Technical Basis Document for Occupational Medical Dose TBD, ORAUT-TKBS-0016-3 (Algutifan et al. 2006), makes reference to occupational dose guidelines in Revision 2 of ORAUT-OTIB-0006 (Kathren 2003) as its basis document for estimating medical dose. Kathren 2003 has since been revised. Revision 3, “Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures” (Kathren and Shockley 2005) provides a more reasonable basis for assumptions regarding estimation of worker medical exposures at Mound. The SC&A review evidences that the Occupational Medical Dose TBD (Algutifan et al. 2006) recognizes the total lack of exposure data and protocols that existed prior to 1980. The TBD (Algutifan et al. 2006), in Table 3.2, details technique factors for x-rays prior to 1980 that are based solely on assumptions taken from Revision 2 of OTIB-0006 (Kathren 2003), not actual measurements.

(13) Specific dose estimations in the Occupational Medical Dose TBD, ORAUT-TKBS-0016-3 (Algutifan et al. 2006), for occupational x-rays are also derived for the period 1980 to 1988, from ICRP Report 34 (ICRP 1982) and NCRP Report 102 (NCRP 1989). This is an important issue, in that estimated medical doses based upon this research are not an actual measurement of dose from the Mound x-ray unit. For the period of 1988 – present, there were measurements made by the State of Ohio.

(14) The Occupational Medical Dose TBD (Algutifan et al. 2006) states there is no physical evidence to show if photofluorography (PFG) to do chest screenings occurred at Mound. In the absence of documentation, the TBD (Algutifan et al. 2006) directs that dose assessors not include the use of PFGs in their dose estimations.

(15) Additionally, the TBD (Algutifan et al. 2006) does state that all medical x-rays administered, in conjunction with routine or special exams, are considered as part of occupational exposure; however, only pre-employment and routine chest exams are mentioned to be used by dose assessors.

2.0 SCOPE AND INTRODUCTION

The review of the Mound Site profile was conducted from October 18, 2005–May 30, 2006.

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 (Advisory Board) is mandated to conduct an independent review of the methods and procedures used by the National Institute for Occupational Safety and Health (NIOSH) and its contractors for dose reconstruction. As a contractor to the Advisory Board, S. Cohen and Associates (SC&A, Inc.) 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 technical basis documents (TBDs) related to historical occupational exposures at Mound Site:

- ORAUT-TKBS-0016-1, *Technical Basis Document for Mound Site – Introduction, Rev. 00* (Vollmer 2004a)
- ORAUT-TKBS-0016-2, *Technical Basis Document for Mound Site – Site Description, Rev. 00* (Vollmer 2004b)
- ORAUT-TKBS-0016-3, *Technical Basis Document for Mound Site – Occupational Medical Dose, Rev. 01 PC-2* (Algutifan et al. 2006)
- ORAUT-TKBS-0016-4, *Technical Basis Document for Mound Site – Occupational Environmental Dose, Rev. 00* (Hysong et al. 2004)
- ORAUT-TKBS-0016-5, *Technical Basis Document for Mound Site – Occupational Internal Dose, Rev 00* (Millard 2004)
- ORAUT-TKBS-0016-6, *Technical Basis Document for Mound Site – Occupational External Dosimetry, Rev. 00* (Proctor and Algutifan 2004)

These documents are supplemented by technical information bulletins (TIBs), which provide additional guidance to the dose reconstructor. A complete list of these documents is available in Attachment 1.

Implementation guidance is also provided by so-called “workbooks,” which have been developed by NIOSH for selected sites to provide more definitive direction to the dose reconstructors on how to interpret and apply TBDs, as well as other available information.

SC&A, in support of the Advisory Board, has critically evaluated the Mound Site TBDs for the following:

- 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 *SC&A 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.

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 viewed from the lens of 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.

2.2 REVIEW APPROACH

SC&A's review of the TBDs and supporting documentation concentrated on determining the completeness of data collected by NIOSH, the adequacy of existing Mound personnel and environmental monitoring data, and the evaluation of key dose reconstruction assumptions.

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 Mound 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 have a substantial impact on at least some dose reconstructions. Issues can also be designated as secondary issues if they simply raise questions, which, if addressed, would further improve the TBDs and may possibly reveal deficiencies that will need to be addressed in future revisions of the TBDs.

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.

In many ways, the TBDs 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

SC&A 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 Mound Site Profile, supporting TIBs, and dose reconstruction worksheets; 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.

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 Mound 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 Mound. 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 Mound TBD was compared with the LANL and the SRS site profiles. In particular, this dealt with how each site handled and is handling dose reconstruction for workers exposed to stable metal tritides and Pu-238 high-fired oxides.

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

ORAUT-TKBS-0016-1, Rev. 00, *Technical Basis Document for Mound Site – Introduction* (Vollmer 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 or 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-0016-2, Rev. 00, *Technical Basis Document for Mound Site – Site Description* (Vollmer 2004b), is an extremely important document, because it provides a description of the facilities, processes, and historical information that serve as the underpinning for subsequent Mound TBDs.

ORAUT-TKBS-0016-3, Rev. 01, PC-2, *Technical Basis Document for Mound Site – Occupational Medical Dose* (Algutifan et al. 2006), provides an overview of the sources, types of exposure, and the frequency of exams that workers potentially received.

ORAUT-TKBS-0016-4, Rev. 00, *Technical Basis Document for Mound Site – Occupational Environmental Dose* (Hysong et al. 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.

ORAUT-TKBS-0016-5, Rev. 00, *Technical Basis Document for Mound Site – Occupational Internal Dose* (Millard 2004), presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers.

ORAUT-TKBS-0016-6, Rev. 00, *Technical Basis Document for Mound Site – Occupational External Dose* (Proctor and Algutifan 2004), presents background information and guidance to dose reconstructors for deriving occupational external doses to workers.

In accordance with SC&A's site profile review procedures, SC&A performed an initial review of the six TBDs and their supporting documentation. 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.

NIOSH provided responses to the SC&A questions that can be found in Attachment 4.

A conference call was 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 this conference call with NIOSH, ORAU, and SC&A is provided in Attachment 5.

Attachment 6 provides a summary of the currently recommended dose reconstruction procedures that NIOSH has provided in the Occupational External Dosimetry TBD (Proctor and Algutifan 2004).

Attachment 7 provides a history and chronology of stable metal tritides at Mound Laboratory (Final Draft 2 report).

Information provided in the conference call with NIOSH was evaluated against the preliminary findings to finalize the vertical issues[1] 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 of these have been completed.

After the Advisory Board and NIOSH have 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 accord with the procedures followed during previous site profile reviews, the report will then be published on the NIOSH Web site 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.

3.2 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 that claims can be processed in a timely manner. With this perspective in mind, we identified a number of strengths in the Mound site TBDs. These strengths are described in the following sections.

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[1] 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 to have a significant impact on dose reconstruction.

(1) NIOSH's use of the Wayne King document on radionuclides by location at Mound (King 1995) has provided a comprehensive baseline of historic radionuclide use at Mound (with the possible exceptions listed below). The Site Description TBD, ORAUT-TKBS-0016-2 (Vollmer 2004b), effectively summarized the radionuclides handled and room locations where work was done in HH Building (Table 2-4, pg. 14). Likewise, similar listings are included in the Site Description TBD, ORAUT-TKBS-0016-2 (Vollmer 2004b), for PP Building (Table 2-5, pg. 15); R Building (Table 2.6, pp. 16–17); SM Building (Table 2-7, pg. 18); SW Building (Table 2-8, pp. 19 and 20); T Building (Table 2.9, pp. 20–22); T Building (Table 2-9, pg. 23); and WD and WDA Buildings (Table 2-10, pg. 24). Within the text of the Site Description TBD (Vollmer 2004b), radioisotopes used and the rooms where they were used in numerous other Mound buildings were also provided. One interviewee (see Attachment 2) said that in spite of these extensive listings, some room numbers and the isotopes used in these rooms had not made it into these summaries. It is also apparent from worker interviews that D&D characterization studies may have shown the presence of radionuclides in certain facilities not identified as such by the King report.

(2) NIOSH in the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), is to be commended for recognizing and dealing with corrections necessary to take into account recovery problems with metabolized Po-210 prior to 1964 and the poor recoveries of Pu-238,239 prior to 1960, and for making these corrections for the years prior to 1964 and 1960, respectively.

(3) The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), provides a useful Table 5-1, page 9, which lists primary bioassay programs with reported radionuclide action levels in counts per minute for a urine sample, workers who were monitored, and frequency of monitoring.

(4) Section 5.3.1, pages 14–27 of the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), provides an effective summary of the primary radionuclides handled by workers at Mound. In addition Section 5.3.2, pages 27–36 of the TBD (Millard 2004), provides a nice overview of the secondary radionuclides used at Mound. Table 5.20 (page 38) in the TBD (Millard 2004) also provides a useful summary of analytical methods and detection limits (MDAs) that assists in the proper evaluation of bioassay data, as well as a means to assign missed dose.

(5) 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.

4.0 VERTICAL ISSUES

SC&A has developed a list of key issues regarding the Mound 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 AWE sites and should be considered in the preparation and revision of other site profiles.

4.1 ISSUE 1: INADEQUATE BIOASSAY TECHNIQUES AND PROCEDURES MAY HAVE LED TO UNDER-REPORTING AND MISSED DOSE

The radionuclide-specific application of detection limits and minimal detectable activities criteria as cited in ORAUT-TKBS-0016-5, Occupational Internal Dosimetry TBD (Millard 2004), do not include treatment of historic issues related to inadequate bioassay techniques and procedures that may have led to significant under-reporting and missed dose at Mound. While many of these issues were documented for the D&D era of the 1990s, they also have clear implications for the operational time period at Mound that preceded them.

One of the more comprehensive lists of alleged deficiencies was identified by the Union representing Mound workers following a significant concern that arose with urinalysis of actinium-227 samples. The bioassay program issues included the following (OCAW 1998):

- Lack of funding to develop and validate "…a state of the art radiobioassay procedure for urine and fecal matrices…"
- Inadequate radiological contamination detection
- Lack of sufficient hold-up time "…for Actinium 227 bioassay samples to allow an ingrowth factor of at least 0.75 for Thorium 227 before analysis"
- The use of an elevated Minimal Detectable Activity (MDA) to determine positive bioassays; "MDA's were calculated using only square roots of the reagent blank counts for a limited number of samples only," instead of a proper MDA in accordance with ANSI standards
- Failure to perform bioassays, particularly for exposure to Ac-227, which accumulated in improper storage modes and remained unanalyzed for a period of years
- Failure of the contractor bioassay laboratory to establish Energy department accreditation
- Discarding of low recovery bioassays, especially incident samples
- Failure to update standard operating procedures

A previous dose reconstruction performed by MJW at Mound (MFW 2002b) was performed, in part, to address these and other issues that raised doubts regarding the adequacy of Mound bioassay measurements. However, this dose reconstruction apparently only addressed workers with recorded monthly doses above 10 mrem, which leaves uncertainty regarding the balance of workers who received no dose corrections as to the appropriateness of their selection for bioassay, the adequacy of their bioassay, and how MDA was applied.

In 1997, DOE (DOE 1997) made the following finding:

> *…it was determined that approximately 108 workers performing radiological work activities under the auspices of at least 20 different Radiation Work Permits had failed to submit samples for bioassay as required. …These violations occurred because the most current, accurate laboratory data were not used to evaluate worker bioassay sample results. In fact, the Minimum Detectable Activity (MDA) values for some radionuclides, […], had not been updated since 1992. …As a result of these practices, a situation occurred where positive dose for workers would not have been identified, evaluated and recorded. For example, you identified that for [a radionuclide], the most current, accurate laboratory data provided a detection capability that was six times lower than the historical MDA that was in use for dose assessment. By failing to use current, accurate data for calculating worker exposure to [a radionuclide]… individual workers could have received internal doses up to [specified value] which would have been recorded as a zero dose in the workers records.*

These problems persisted. By 1998, DOE (DOE 1998) reported the following violations under its Price-Anderson Act authority:

> *(1) failure to ensure the continuity of bioassay services as required by the Mound Radiobioassay Laboratory Quality Assurance Plan, (2) failure to meet bioassay sample cycle times as required by the Internal Dosimetry – Radiobioassay Laboratory Memorandum of Understanding, (3) failure to provide timely notification to workers of positive bioassay results, (4) failure to adequately implement quality improvement processes for the bioassay program, (5) failure to formally control design interfaces between vendor software and Mound data bases, and (6) failure to adequately assess management processes to ensure that management tools, i.e., internal audits, were adequate to identify and correct bioassay program problems.*

According to DOE (DOE 1998):

> *These problems occurred because of a continuing culture of non-adherence to your established bioassay program requirements by your staff. Additionally, there was a clear lack of communication between the Radiobioassay Laboratory analytical function and the Dose Assessment function as well as failure to understand the implications to the workers when the bioassay program did not fulfill its obligations. DOE is concerned because the violations and deficiencies associated with these issues are not isolated events and reflect a management*

> *failure across several organizations responsible for the safe operation of the site. Further, despite the attention to the Mound bioassay program over the last several years by DOE, including the issuance of civil penalties to the previous contractor, significant deficiencies continued to go uncorrected.*

Moreover, the use of outdated and elevated MDA values was found by the DOE Price-Anderson Enforcement Office to be widespread throughout the Energy department complex (DOE 1999b). In this DOE 1999b memorandum to contractors, DOE stated the following:

> *Contractors should establish and document a clear basis for the prospective determination as part of the contractor's existing internal dosimetry program and/or technical basis documents. Such documents should include the technical rationale used by the contractor for including or excluding populations of radiological workers from monitoring for internal deposition of radioactive materials. Contractors should maintain these documents as part of the contractor's record system… DOE is primarily concerned with the programmatic implications of repetitive and long-term bioassay program problems that have not been corrected by the contractor. DOE expects the contractor to effectively manage and implement their documented bioassay programs including being knowledgeable of the extent of any deficiencies.*

It is not clear if Mound (and other DOE sites) came into compliance with DOE internal dosimetry requirements, leaving the possibility of false-negative and under-reported bioassay readings. The TBD (Millard 2004) needs to address to what extent these reported historic deficiencies in the Mound bioassay program may have adversely impacted who received bioassay, how bioassay was carried out, and how dose was recorded.

4.2 ISSUE 2: POTENTIAL DOSES FROM INSOLUBLE METAL TRITIDES ARE NOT SUFFICIENTLY ADDRESSED

Insoluble stable metal tritides (SMTs) and tritiated particulates (STPs) were used in various applications at Mound during its operational history. It is clear from internal documentation that there was not an adequate means of detecting exposures or even monitoring SMTs and STPs before 1999. Before that time, hafnium tritide and other SMTs were routinely handled in gloveboxes in various process areas of the SW complex, with internal dosimetry and monitoring designed not for STPS, but for elemental tritium (HT) and tritium oxide (HTO). A March 26, 1999, Defense Nuclear Facilities Safety Board Staff Report (DNFSB 1999) highlighted this deficiency and noted that during the production era in the SW, R, and T facilities, and during the deactivation and decommissioning phase, workers were not properly monitored for SMTs and STPs, and proper work controls were not in place. The DNFSB staff review went on to note that "past characterization efforts to identify and locate SMT contamination were limited…as of the time of the staff review (DNFSB 1999), a rigorous characterization program had not yet been fully developed…" While ORAUT-TKBS-0016-5 (Millard 2004) states that a lung clearance Class S should be assumed for metal tritides other than lithium, it is not clear from the scientific literature and site expert interviews whether this assumption is valid for SMTs such as hafnium tritide. It is also not clear where SMT contamination existed at Mound, given that characterization of metal tritides by specific location within a room or building was not initiated at Mound until 1992. With no NCRP- or ICRP-accepted dose model for metal tritides, NIOSH has not provided a sufficient technical basis for its assumed Class S solubility designation.

Dose reconstruction for SMTs and STPs are complex, problematic, and contain major uncertainties, due in part to the rapidly evolving state of scientific understanding regarding their internal dosimetry. Because tritides may leach out in the lung fluids, and then be incorporated into body water, they may also produce organically bound tritium from contact with lung tissue. This further complicates the metabolic process.

Particle size is also a critical factor for dose reconstruction. Given the numerous activities at Mound over the years involving production, handling, and the residual collection of tritides in the workplace, it appears unlikely that particle size distribution can be assigned to specific tasks, particularly in the absence of air concentration and bioassay data until recent years. As noted by the DOE:

> *Deposition fractions affect clearance rates of particulates from the lung to the gastrointestinal (GI) tract. Since urine excretion of tritium dissolved from tritiated particulate over time is a function of those particles that have not cleared from the lung, interpretation of urine excretion curves can extract particle size information. This requires extended monitoring without additional tritium intakes. When tritiated materials and sizes are likely to range broadly, it will be difficult to provide material identification and size characterizations in the workplace. Moreover, although dissolution rate data are available for several materials, these data do not include all the possible combinations of materials and particle sizes that might be encountered.* (DOE 2004a, pg. 36)

Dose reconstruction guidelines need to be more specific and have more instructions and backup materials to enable claimant-favorable estimates of high doses from insoluble tritides for workers with job assignments and in work areas that had the potential for higher exposures.

> [Note: According to a draft literature review conducted in January 2006 by the International Commission on Radiological Protection (ICRP 2006) the following compounds were tentatively identified with following lung clearance categories:
>
> - Titanium tritide – Class Moderate
> - Zirconium tritide –Class Moderate
> - Carbon tritide – Class Slow
> - Hafnium Tritide – Class Slow]

The DOE Handbook 1184-2004, *Radiological Control Programs for Special Tritium Compounds* (DOE 2004), mentions the Special Tritium Compound (STC) forms of tritides. The DOE handbook (DOE 2004a) assigns an S lung clearance class for purposes of dose calculations for organic [(CH2)n], rust [~FeO(OH)], and titanium, zirconium, and hafnium tritide compounds. The Handbook explains the assumptions of tritium dissociation that the ICRP Publication 71 (ICRP 1996) uses. However, they only provide absorption into the bloodstream for tritiated water vapor (HTO) and organically bound tritium (OBT), which are much more soluble than hafnium tritide. This does not provide much guidance for the highly insoluble forms of tritides.

However, studies of hafnium tritide reported by Cheng et al. 2002, not referenced in the DOE handbook, point out that for particles in simulated lung fluids, less than 1% of the tritium was dissolved after 215 days, and the long-term dissolution half time was 4.28×10^5 days. This data raises a strong argument that the use of Type S for the ICRP 66 and 71 Model, as shown in Figure 5 of their report, does not come close to the measured dissolution rate of the hafnium tritide. Cheng et al. 2002 noted the following:

> *The current understanding of metal tritide and its radiation Dosimetry for internal exposure is limited, and ICRP publications do not provide the tritium Dosimetry for hafnium tritide.*

Strom et al. 2002 states the following:

> *For cells less than about 7 μm away from the surface of a metal tritide, the primary dose component is due to electrons. However, bremsstrahlung radiation may deposit some energy tens, hundreds, or even thousands of micrometers away from the surface of a tritide particle.*

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) states in Section 5.3.1.1, page 16, that, “Limited information is available on the metal tritides to which workers could have been exposed.” In interviews conducted by SC&A staff of health physicists from the facility, concerns were expressed for tritium and tritide exposures, especially concern for potentially high exposures in the early years. It was stated that exposures occurred while workers were passing things in and out of the gloveboxes or fume hoods. They stated that hafnium tritides were relatively insoluble, and that tritides were considered “bad characters.” One of the health physicists commented that he didn’t have any good answers on whether these tritides were being monitored or not, and if they are insoluble just can’t be detected. This problem has been addressed by SC&A in the reviews of a couple of other Site Profile reviews, in particular those of RFP and LANL, and is exacerbated in the case of Mound by the potential risks to significant portions of the worker population to insoluble tritide exposures within numerous areas of the facilities.

Further documentation on this issue at Mound comes from the 1990s, in particular in a 1999 *Draft Mound Technical Basis Document for Stable Tritiated Particulate and Organically Bound Tritium* (this Mound STP TBD was not found during the SC&A review). A Babcock and Wilcox of Ohio (BWO) memorandum dated June 17, 1999 (BWO 1999), with its attachment dated April 30, 1999, entitled: “Final Draft 2,” reports on the stable metal tritides history and chronology at Mound (see Attachment 7)**,** and is indicative of even more concern over the potential exposures of workers to SMTs and STPs without adequate means of detecting exposures or even monitoring for them properly in the times before 1999. The "Final Draft 2" (BWO 1999) points out the use of hafnium tritide and SMT in gloveboxes in SW-10, SW-13, SW-142, SW-150, SW-219, SW-8, SW-9, and R-108, and recirculating systems in SW-12, SW-231, SW-150, SW-152, and SW-240. Many of these gloveboxes and systems were removed in the 1970s and 1980s, and it appears that much of the monitoring that was done was the same as that for HT and HTO, which cannot be applied to SMTs.

Technological shortfalls were identified in 1999 in the DNFSB March 26, 1999, Staff Report (DNFSB 1999). This DNFSB Staff Report pointed out that workers during the days of production in SW, R, and T Buildings, and during the deactivation and decommissioning activities of these areas, were not properly monitored, and proper work controls were not in place to protect the workers (DNFSB 1999). There were various DNFSB and DOE comments and reviews in 1999 that pointed out weaknesses in the Draft STP TBD that would still leave remaining facilities not properly covered, even after the problems of SMTs/STPs were recognized. Many incidents of exposure and potentials for exposure are noted throughout the review of site documents.

The Babcock and Wilcox memorandum of June 17, 1999, with its attached Final Draft 2 dated April 30, 1999 (BWO 1999), provided the following conclusion about stable metal tritides at Mound (see Attachment 7):

> *Hafnium tritide and to a lesser extent other SMTs are potential contaminants in gloveboxes in SW-13 (Struers Box), SW-150/152/240, SW-8 (old recovery box only), R-108 and SW-9. The glovebox recirculation systems in SW-231 and R-108 and any piping that remains of the glovebox purification system in SW-12 have the potential for SMT contamination. Inaccessible surfaces in SW-13 and to a lesser extent SW-150 may have SMT contamination due to the 1972 glovebox breach and 1993 tracking event. Ventilation exhaust in SW-13 and to a lesser extent SW-150 may also be SMT contaminated. Iron oxide tritoxide may be found in the carbon steel TD-column feed tanks in SW-8 and to a lesser extent in the ICI fixed tube trailer and the ERS and TERF surge tanks.*

The DNFSB review of Mound in 1999 (DNFSB 1999) found the following regarding the Miamisburg Environmental Management Project (MEMP):

> *Deactivation and decommissioning activities at MEMP are expected to involve work in areas suspected of being contaminated with stable metal tritides (SMTs)… The dose resulting from a given intake of a particular type of SMT may be many times greater than that for tritium oxide (HTO). Therefore, a radiation protection approach somewhat different from that traditionally used for elemental tritium (HT) and HTO is needed for work with SMTs.*

The DNFSB listed the following shortfalls in the Mound monitoring programs (DNFSB 1999, pg. 2):

- *Past characterization efforts to identify and locate SMT contamination were limited. As of the time of the staff review, a rigorous characterization program had not yet been fully developed; however, it was indicated to the staff that efforts are being made to improve the program.*

- *The Basis for Interim Operations (BIO) does not address deactivation and decommissioning activities in a detailed manner. The BIO also does not adequately address SMTs.*

- *The technical bases for radiation program measures associated with SMTs were under development or incomplete. In some cases, the technical bases communicated during the review were excessively qualitative.*

- *Development of an integrated radiation protection program addressing SMTs had not been completed.*

Section 5.3.1.1, Metal Tritides, of the TBD (Millard 2004) states that a lung clearance class of S should be assumed for all metal tritides other than lithium. Interviews by SC&A with site experts found that former workers considered these metal tritides, especially hafnium tritides, to be very insoluble. It was also noted in these interviews that many small accidents with exposures to tritium occurred **all the time**, with an example of 3 cases occurring in one weekend and that tritium was ubiquitous in a number of operations and existed in many areas of the plant. It was also noted that tritium sampling was performed regularly and usually confirmed low levels of tritium present. Thus, if an individual worked at Mound for any length of time in tritium areas, they would likely have had recorded low levels of chronic tritium exposure without any credit for potential metal tritide exposure.

A paper by G. T. McConville and C. M. Woods in 1995 (McConville and Woods 1995) discussed the following concerns about metal tritides:

> *Tritium in the form of metal tritides particles presents a peculiar problem for the calculation of internal dose. Standard calculations indicate that just a few 3 to 5 micron sized particles appears to lead to a very large dose. There are very few data on which calculations can be based.*

A BWX Technologies, Inc., letter of July 13, 1998, includes an Attachment 1 dated July 9, 1998, which is a white paper on metal tritides at Mound (BWXT 1998, Attachment 1, pp. 1–3) that further describes technological shortfalls that existed in 1998 regarding worker health protection and management. These are summarized below:

- Air monitoring techniques used flow-through ionization chambers as the major monitoring technique for identifying tritium in air. These instruments can measure tritium in its elemental form (HT), oxide form (HTO) or any other gaseous compound form (tritiated methane, ammonia, etc.). However, these same instruments cannot be used to measure a particulate, because filters and electronic precipitators have been purposely incorporated into the system design.

- It may not be possible to accurately monitor for surface and skin contamination when dealing with stable metal tritides.

  Liquid scintillation counting (LSC), the primary method used to measure tritium from a surface (floor, skin, etc.), provides a determination of the number of pulses of light emitted from the beta particle produced when the tritium atoms decay and strike a liquid medium containing phosphors. In forms of tritium that rapidly disassociate, the quantity of light pulses is directly proportional to the quantity of tritium present. Stable metal tritides present a unique challenge when attempting to monitor for surface and skin contamination. Since these materials are in particulate form, many of the tritium atoms associated with the particle are interior to the surface of the particle. As a result, the counting technique will show a tritium activity that is too low since the beta particle from tritium within the metal tritide particle cannot escape the particle.

- Characterization of metal tritides by specific location within a room or building was not initiated until 1992. The project was initiated to systematically identify specific locations where tritides were handled. A "sticking" wipe survey was used to grab the particles that were then analyzed in an Energy Dispersive X-ray Spectroscopy (EDS) analyzer and a Scanning Electron Microscope (SEM) as the analysis tools for evaluation. Prior to this, no such detailed location analysis had been done.

- Characterization of particle size and solubility was also needed, and was useful in determining a conversion from liquid scintillation counting to actual quantity of material present. Particle size also determines the respirable fraction of the stable metal tritide and the extent to which the stable metal tritide is trapped in the lung. Even in 1998, a detailed facility characterization and determination of particle sizing and solubility had not been completed.

- When performing urine bioassay for stable metal tritides, it is not possible from a single urine sample to determine if the exposure was to metal tritides or to gaseous forms of tritium.

- In 1998, there was no National Council on Radiological Protection and Measurements (NCRP)- or International Council on Radiological Protection (ICRP)-accepted dose model for metal tritides, due to inadequate biological and solubility information.

Mound workers, prior to the realization of their significant potential for uptakes of metal tritides in the mid to late 1990s were not adequately monitored for metal tritide exposure. The means of detecting and doing bioassays for metal tritides, as noted above, were still evolving in the 1999 timeframe. NIOSH should, therefore, develop a methodology to estimate metal tritide dose for workers in locations noted in the quote above (BWO 1999) and paragraph 3 of this issue.

With these concerns in mind, SC&A does not feel the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) does an adequate job of addressing potential doses from uptakes of these insoluble tritides or from high-fired oxides. This TBD (Millard 2004) acknowledges that on page 16 that:

> *Limited information is available on the metal tritides to which workers could have been exposed.... Halfnium tritides were also used at Mound primarily in SW, R and T buildings. A lung clearance class of S should be assumed for metal tritides other than lithium. A lung clearance class of S should be assumed for halfnium tritides.*

The tritium recommendations provided in the TBD Occupational Internal Dosimetry (Millard 2004) on page 17, do not appear sufficient for many cases that most likely involved significant doses to SMTs and STPs, and do not acknowledge worker exposures to SMTs and STPs during the D&D operations from 1995 to present. The TBD (Millard 2004) recommends the following:

> *The corrected upper 95 percentile dose of 340 mrem should be assumed in assigning annual doses to unmonitored workers from 1947 to 1956. When the Mound records from 1957 to 1995 only include dose without any concentrations, equations 5-4 should be used to correct reported Mound doses to ICRP 68 doses. Tritium doses reported as blanks from 1957 to 1995 should be reconstructed by assuming a 6 μCi per liter urine concentration reporting limit. Otherwise, all actual recorded bioassay results should be used. Doses reported at or below detection or as zeros should be corrected using the applicable MDAs given in Table 5-4. Doses should not be assigned to any administrative or other non-radiological workers.*
>
> *Dose reconstructions should assume that tritium source term was constant because reliable air data was not available from 1947 to 1957 and effluent records starting in 1959, which precluded any evaluation of tritium source terms during the period of missing urinalysis.*

There does not appear to be documentation of personnel monitoring or adequate area monitoring for SMTs that would make it possible to be able to do dose reconstruction for claimants exposed to metal tritides. This is borne out in the reviews and comments in BWXT 1999 and DOE 1999a, and the comments provided by the DNFSB (1999), regarding the *Draft Mound Technical Basis Document for Stable Tritiated Particulate and Organically Bound Tritium*. The guidance provided by NIOSH in OCAS-TIB-002 (OCAS 2003) does not adequately address these specific problems with SMTs and STPs.

SC&A has concern with the NIOSH-suggested use of the default exposure values in the absence of measured SMTs. These default exposure values have been demonstrated by Cheng, et al. 1997 to be inadequate for metal tritides, because they are so insoluble and have a very slow dissolution, particularly with regard to hafnium tritides.

The use of Type S for dose calculation may not represent the degree of insolubility that hafnium tritides exhibit. However, research published by Zhou and Cheng (Zhou and Chen 2004) suggests the use of Type S. The ICRP 66-corrected deposition fraction (ICRP 1994) did give similar CED values taken from animal studies. The DOE Radiological Control Coordinating Committee (RCCC) also looked at the tritides issue and in their November 2000 meeting (RCCC 2000) made reference to the upcoming DOE Handbook (DOE 2004), which was referenced earlier in this issue. The RCCC also noted that RESRAD calculations appear to give very little dose consequence when levels of 10,000 dpm/100 cm^2 contamination were used in the calculation. The relatively low dose consequence from SMT contamination is supported by the recent statement by SC&A (SC&A 2006) that intake of metal tritides will typically produce annual dose to most organs of a few mrem, and about 10 mrem to the lung. SC&A recommends that NIOSH use an approach similar to that used at the SRS. In the SRS approach, the surface contamination limit for tritium in accessible spaces is used with a conservative resuspension factor (50%) to derive an daily intake value of particulate tritium. This can be used to assign a claimant-favorable absorption type (either S or M) to bound the maximum potential exposures that a worker may have received over the years from the very insoluble metal tritides. This is particularly that of hafnium tritides, while recognizing that the overall doses to workers may not be increased greatly by the contribution from metal tritides (SC&A 2006).

4.3 ISSUE 3: INTERNAL DOSE TO WORKERS FROM RADON EXPOSURES MAY NOT HAVE BEEN RECORDED

ORAU-TKBS-0016-5 (Millard 2004) acknowledges radon as an internal dose concern in SW-19 (due to exhalation into the building area from radium and thorium processing wastes from the “Old Cave”), and relies upon limited air-monitoring data from 1979–1980, coupled with a more comprehensive characterization study conducted in 1989 (UNC Geotech 1990), which is summarized in a June 2000 BWXT report (BWXT 2000) for its assumed building-by-building Rn-222 dose reconstruction assignments in Table 5-14. However, the air-sampling measurements from 1979–1980 were limited in location, and do not necessarily reflect potential radon air concentrations in various parts of the SW Building complex, nor can it be assumed they reflect concentrations that existed in previous years when radon exhalation was potentially much higher. From interviews with former RCTs, it was understood that considerable radon exhalation was experienced through foundation cracks in the SW buildings (they indicated that alpha meters would “peg out”); concentrations of radon in such areas would be expected to be elevated over other locations. Furthermore, the rate of radon exhalation into buildings, and therefore, the ambient indoor concentration, would increase considerably whenever negative pressure hoods were used in SW Building, which was relatively frequent. The TBD (Millard 2004) does not present substantiated radon characterization data for the SW process areas prior to the venting of the underlying cave and tunnel areas in 1980; the limited 1979 spot-air measurements and much later site-wide characterization do not provide a technically plausible basis to reconstruct radon dose for that earlier period. It is likewise not clear how the stated GSD of 3 is considered sufficient to offset the uncertainty regarding radon concentrations prior to 1980.

The TBD (Millard 2004) points out the measurements in building SW-19 of Rn-222 near an employee's desk ranged from 67 to 160 pCi L^{-1} in 1979, and concentrations in the tunnel were measured at 88,000 pCi L^{-1} Rn-222, 28,000 pCi L^{-1} Rn-220, and 640,000 pCi L^{-1} Rn-219. Table 5-14 provides Rn-222 levels to be used in dose reconstruction for all the buildings on site. This may be reasonable for the Rn-222 exposures to site personnel, however, there appears to be variability of exposure potential within areas, and this was borne out in interviews with site experts. These interviewees pointed out that radon was pulled out of basement floor cracks by negative pressure draw, when negative pressure hoods were used in SW Building (See Attachment 2). A 1980 Monsanto Research Corporation memorandum (Monsanto 1980) discussed elevated radon levels in SW-19, and pointed out the following regarding the June 1979 to May 1980 timeframe:

> *When the problem in SW-19 was discovered, the Radon Group was just getting established and did not have adequate equipment or techniques established to do a first rate job of quantifying the levels… Our efforts then turned to identifying the source of the radon, which we now believe is the tunnel under that area of SW. At the same time, the hole in the floor of SW-19 and cracks along the baseboards were sealed. This reduced the radon concentrations in the room somewhat.*

A 1982 Monsanto Research Corporation memorandum (Jenkins 1982) also pointed out that when sealing the base of the east wall of SW-19, the base of the partition that had not been sealed had the following air-sampling levels:

> a. *The air near the base of the partition continues to have a concentration of Rn-219 decay products roughly 10 times greater than the concentration at the normal breathing rate.*
>
> b. *Only trace quantities of Rn-222 decay products were observed in the samples. This is due to normal background.*

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004, pg. 29) mentions a DOE radon study conducted from December 12–15, 1989, and provides the following summary:

> *A DOE study was conducted from December 12 to 15, 1989, to measure radon in various Mound buildings (UNC Geotech 1990). The majority of the buildings had radon concentrations below 1.0 pCi/L^{-1} ^{222}Rn, except SW and Old SD Buildings. In June 2000 a radon study summary report was issued based on 1990 and 1999 measurements (BWXT 2000). Mound site radon background was reported to be 0.5 pCi/l^{-1} with a range of 0.1 to 2.1 L^{-1}. SW-19 was the only building at Mound identified as an area of potential occupational exposure to ^{222}Rn and ^{220}Rn.*

The Occupational Internal Dosimetry TBD also provides the results of various radon surveys done at Mound (Millard 2004, Table 5.13, pg. 28).

In 1991, however, a DOE Indoor Radon Study (UNC Geotech 1991, pp. 70–75) showed that even though most building readings at Mound were now in the range of 0.4 to 1.3 pCi/l, there were still areas were radon levels exceeded this average range:

Building	Radon pCi/l		Room	Comment
Bldg 21	161.1	125.8	Above Air Sampler	Wet – Old thorium storage
Bldg 21	115.7		Above Air Sampler	Wet – Old thorium storage
SW	4.8		19 Mid East Wall	History of Elevated Levels
48	3.2		114 B Closet On Sprinkler Pipe	
19	2.6		Room 1	
Old SD Bldg	2.4		Basement Right Cabinet	
55	2.1		1 Below thermostat on E. wall	
57	1.9		Room 1	
87	1.5		143	
998 Fire Station	1.4		Room 002 Equipment Room with SUM	

There is also the fact that other isotopes were involved throughout the operations that are not addressed, such as thoron and actinon. Review of reports, documents, and site expert interviews with regard to radon exposures to workers are rather extensive, with the worst conditions existing in SW Building and entrances in and around the "Cave" area.

Attachment 5D.7 of the Occupational Internal Dosimetry TBD (Millard 2004) states the following:

> *Information on the location and use of radioactive gases was primarily only available for ^{222}Rn (radon) from 1979 to the present. Very limited information was available for ^{220}Rn (thoron) and ^{219}Rn (actinon), and the measurements were questionable due to excessive decay times before analysis.*

The Occupational Internal Dosimetry TBD further states the following (Millard 2004, Attachment 5D.7):

> *The lack of data for the presence of thoron and actinon inside buildings at Mound could cause a large degree of uncertainty in actual worker exposures. Radon, thoron, and actinon in particular could have caused substantial worker exposure inside buildings before implementation of proper ventilation controls in 1980. Lung dose commitments from actinon could have been significant due to a very short actinon half-life of 4.0 s and direct deposition of actinon daughters on respiratory tract tissues.*" The following statement is made without support, "*Uncertainty from lack of radioactive gas information could underestimate*

> *worker doses by a factor of at least 10. However use of an assumed GSD of 3 compensated for this uncertainty.*

SC&A does not believe this position is sufficiently supported to provide claimant-favorable doses from the unmonitored gaseous radionuclides, such as thoron, actinon, and radon. SC&A is concerned that NIOSH is recommending the use of characterization data from the 1980s–1990s be used to define exposures for workers in earlier plant operations. SC&A questions whether the spot-sampled areas were representative of in-plant radon concentrations, particularly in the SW Building complex, as well as periods of operation involving negative pressure ventilation.

4.4 ISSUE 4: POTENTIAL DOSES FROM HIGH-FIRED PU-238 AND TH-232 ARE NOT SUFFICIENTLY ADDRESSED

It has been found that plutonium that has been exposed to extreme temperatures (e.g., in excess of 1000°C) undergoes metallurgical reactions, and upon inhalation, exhibits a very long retention time in the lungs that exceeds the default absorption types specified by the current ICRP lung model. While this so-called "Super S" type of plutonium already has been addressed in ORAUT-OTIB-0049 (OCAS 2006) for RFP, it is not clear how this empirical model would apply to Pu-238 microspheres at Mound (there is no current ICRP treatment of the biokinetics of Pu-238). These microspheres were formed through high-temperature plasma heating processes, and were designed for use in thermal generators. The Occupational Internal Dosimetry TBD (Millard 2004) notes that "in general, Pu-238 compounds are more soluble than Pu-239 due to greater specific gravity and therefore a greater energetic alpha recoil for Pu-238," but does not substantiate this claim, or provide a definitive solubility range for high-fired Pu-238, including the likely insoluble microspheres. The TBD (Millard 2004) assumes a solubility class "S," based on a 1995 King report, without addressing the implications of plutonium high-firing on this assumption.

[Note: The potential for exposure to high-fired oxides was present in several processes: According to the Energy Department:

> *In the microsphere process, the powder was fed through a plasma torch, producing microspheres of uniform size that went directly to the hot press facility. In the shard process, the powder was sieved for size and placed in a controlled atmosphere furnace at an atmosphere of oxygen-16. The material was heated to 1,600°C for 2 to 4 hours. This step produced a sintered plutonium-238/ oxygen-16. The sintered oxide was then transferred to the hot press facility where a sphere was fabricated. The die body was sprayed with colloidal graphite and then charged with plutonium dioxide particles. The die was loaded into the press, and the hot press chamber was evacuated. With a force of 2,500 pounds per inch and a temperature of 1,480°C, a sphere of plutonium dioxide was formed. The plutonium dioxide sphere was removed from the die, weighed, and gauged. The sphere was placed in a controlled atmosphere furnace and treated with oxygen-16 at 700°C for 1 hour. Next, the sphere was placed in a vacuum furnace and was allowed to outgas for 30 minutes at a temperature of 1,200°C and a vacuum of*

> *1 x 10^{-5}. The sphere at this point underwent calorimetry for specification testing. Now ready for encapsulation, the sphere was transferred to the R Building. Encapsulation involved welding a machined metal cover over the sphere. Encapsulation materials included iridium, graphite, tantalum, titanium, and hastelloy (an alloy of cobalt, molybdenum, chrome, tungsten, and iron).*
> (DOE Undated)

The TBD (Millard 2004, Section 5.3.1.4, pg. 24) states that the plasma torch process was used primarily in SM-39, resulting in PuO_2; the use of plasma torch plutonium has been demonstrated to produce the high-fired oxide of plutonium.

Dose reconstruction guidelines need to be more specific and have more instructions and backup materials to enable claimant-favorable estimates of high doses from insoluble high-fired oxides for workers with job assignments and in work areas that had the potential for higher exposures.

An analysis discussed in the SC&A *Rocky Flats Plant Site Profile Review* (SC&A 2005) showed that the incidental acute intake of insoluble plutonium compound in the first 20 years may be difficult to identify because of several factors, including the relatively high MDA (0.01 Bq), the low fraction of activity intake excreted through the urine (10^{-6} Bq), and historic delay in or lack of performing post-incident urinalysis or fecal analysis. It was found that the contribution of chronic intake in urinary activity increases over the time of exposure, obviating the detection of incidental intakes, unless the activity is extremely high or the chronic exposure is very low or undetectable. This analysis took into account chronic inhalation of Type S plutonium compound at 15 Bq/day and 100 Bq/day with acute intake of high fired-oxide, both with annual and quarterly urinalysis sampling respectively, and chronic inhalation of Type S plutonium at 100 Bq/day, plus acute intake with urinalysis sampling on day after acute intake.

Particle size also plays an important role in the potential for higher dose from Pu-238 high-fired oxides. The Mound Occupational Internal Dosimetry TBD (Millard 2004, pg. 12) states the following:]

> *…much of the reported particle size distribution information from the site was qualitative in nature and could not be verified by evaluation of quantitative particle size study results. In addition, it is not clear whether actual breathing zone particle sizes were based on reported estimates of process particle size distributions.*
>
> *Due to the limitations, the default particle size distribution AMAD from ICRP Publication 66 (ICRP 1994) of 5 μm should be used for all processes, as indicated in Table 5A-1. The default AMAD of 5 μm should be used to estimate intake and dose with an associated geometric standard deviation of 2.5 or the default value given in IMBA.*

Based on direction provided by 42 CFR Part 82, a default 5 μm AMAD particle size is only applicable in cases where there is no information on particle sizes available. SC&A recommends that the particle sizes should be reviewed, and the probability of exposure to particle sizes smaller or larger than 5 μm should be calculated before adopting the default parameter of 5 μm.

It is important to note that unless workplace indicators alert the staff of an exposure condition, it is very unlikely that an exposure to a high-fired Pu-238 oxide will be detected, measured, or noted until quite some time after the event. This is due to the fact that the highly insoluble high-fired Pu-238 oxide will not be detectable in the urine, and because of the lack of penetrating photons from the Pu-238, it will not be detectable through lung counting with any reasonable MDA sensitivity. Thus, very significant unknown exposures may have occurred and remained undetected for months. This becomes an even more significant issue in light of the policy described in the TBD (Millard 2004) of discontinued monitoring of workers after they were moved to other projects, and the fact that administrative personnel and support personnel were not monitored routinely.

The TBD (Millard 2004) does adequately address potential high doses from uptakes of these insoluble high-fired oxides. It is a fact that many of these insoluble radionuclides cannot be seen, and the uptakes quantified through urinary excretion and accurate assessments by *in-vivo* techniques, such as lung counting for transuranics, which has poor sensitivity and a high uncertainty associated with the measurements, particularly in the first year or so. The TBD points out that the reported MDAs in 1990 ranged from 69.6 to 73.7 nCi for plutonium and 0.18 nCi for americium (Millard 2004, Section 5.4.2, pg. 39). These values are fairly typical for most facilities, therefore leading to a potentially high missed dose and uncertainty in the estimated uptake.

In 1996, one Mound radiation safety staff member alerted Mound management in a memorandum (Robertson-DeMers 1996) that there were high-fired oxides present in some locations at Mound R Building that could lead to considerable contamination problems, and that effective bioassay and other detection techniques were not yet in place to adequately quantify dose:

> *….. I have considerable concerns about the D&D of R-140. After having several conversations with the production technicians who worked in the room and studying the process history, I have discovered that this room contains high-fired plutonium oxide. The glovebox removal could potentially lead to considerable contamination problems. This is evident by the contamination levels resulting from glovebox leaks and glove failures. In addition, I have also recorded contamination of the same isotopes as seen in R-140 in neighboring R-142 on the window behind Glovebox #2.*
>
> *My primary concern has been that current bioassay methods used at Mound are not sufficient to detect high-fired oxide. The reason for this is that the high-fired oxide does not go into solution adequately both in the body and in the radiochemical process for analysis of urine for plutonium. The bioassay and dosimetric difficulties of analyzing for high-feed oxide have been documented by both Hanford and Rocky Flats. In my discussions with experts on high-fired oxide, I have been told*

> *that the most effective way of determining intake of high-fired oxide is a lung count for identification of Am-241. In addition, there are improved urinalysis techniques for detection of this material including Fission Track Analysis and Mass Spectroscopy. I encourage you to develop an appropriate method of bioassay prior to additional work in R-140 and other areas identified as having high-fired oxide.*

In the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5, the statement is made, “In general, Pu-238 compounds are more soluble than Pu-239 due to greater specific activity, and therefore, a greater energetic alpha recoil for Pu-238 (Millard 2004, Section 5.3.1.4, pg. 23).” It appears this statement is based on observation of two human exposures; (1) at the SRS, “…in which a Pu-238-oxide inhalation case appeared to exhibit biokinetic behavior more characteristic of a class D material” (Carbaugh 2003), and (2) at LANL, in which “There was… considerably less activity in the respiratory tract than would be expected on the basis of current models... ” (USTUR 1995). However, this may be insufficient substantiating evidence upon which to reduce the margin of conservatism necessary for dose reconstruction involving high-fired Pu-238 oxide particles. By contrast, the Energy department does not accept the position stated in the TBD (Millard 2004), and has adopted Type S lung absorption for high-fired oxides of plutonium isotopes, as part of its dose reconstruction guidance (DOE 2004b).

In this context**,** the assumption in the TBD (Millard 2004) must be viewed very carefully, because while the Pu-238 high-fired oxide may be slightly more soluble than the Pu-239 high-fired oxide, the former can be considered still highly insoluble. High-fired Pu-238 oxides in microsphere forms were generated as products of production, in addition to the plasma torch operations and other operations that could have produced some of these high-fired oxide forms of Pu-238. It appears that high-fired Pu-238 oxides were present in numerous areas throughout the processes at Mound. Studies at LANL demonstrated the initial extreme insolubility of Pu-238 microspheres in lungs (James 2003). This was followed months later by a slightly more rapid dissolution of the Pu-238 high-fired oxide than seen with Pu-239 high-fired oxide. The TBD (Millard 2004) needs to address the Super Type S form of Pu-238 high-fired oxide and any modifications to modeling that might be required by the dose reconstructors.

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004, Section 5.3.1.4, pg. 24) states the that plasma torch process was used primarily in SM-39, resulting in PuO_2, the use of plasma torch around plutonium has been demonstrated to produce the high-fired oxide of plutonium.

Given these uncertainties, NIOSH/ORAU should use the more claimant-favorable approach for high-fired Pu-238 oxides, as adopted by the DOE in its dose reconstruction guidance. NIOSH-ORAU should also reconsider their approach to dose reconstruction considering the non-detectability of exposures to high-fired forms of Pu-238 below 70–75 nCi or more in the lungs and only detectable in urine months after an event, if monitoring was done at that time.

With respect to high-temperature processing of Th-232 feed material, ORAUT-TKBS-0016-5 observes that “the caustic treatment was likely to have been a high-temperature process that would have resulted in such refactory and highly insoluble thorium compounds as thorium dioxide." However, Attachment 5A of this TBD, which provides the lung clearance class for each compound handled in the Mound facilities, lists thorium isotopes from thorium refining as Class "M," as opposed to Type S, or perhaps more appropriately, "Super S." Apart from this seeming contradiction, it is not clear what the implications are of worker exposure to such high-fired thorium compounds.

4.5 ISSUE 5: USE OF 1949–1959 DOSE DATA FOR MODELING EARLIER YEARS (1943–1948) IS QUESTIONABLE.

The Site Description TBD (ORAUT-TKBS-0016-2), the Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004), and other documents illustrate how the Dayton/Mound sites in the early years were rapidly changing and exploring new, unknown technologies, especially in the area of radioisotopes. The first era was during 1943–1948, when research and development (R&D) and limited production was conducted at several make-shift sites. The second era was around 1949–1959, when a new facility was used to start production and further R&D. The physical facilities, working conditions, and radiation exposures of the two eras were necessarily different. Additionally, information gathered during the first era (at Dayton and other institutions) could start to be used to control radiation exposures during the second era. Therefore, the doses to the workers during 1949–1959 would decrease, compared to the workers of 1943–1948.

However, the second era was not, itself, without health physics (HP) problems. Page 9 of the Occupational External Dosimetry TBD (Proctor and Algutifan 2004) mentions that Mound never had a well-documented quantitative study of its external dosimetry programs, and on page 10, it states that the record on historical dose limit standards is ambiguous and a great deal must be inferred. A modal dose of 50 mrem/wk for neutrons and 50 mrem/wk (n/p = 1:1) for photons from 1949–1959 is recommended on pages 14, 22, 50, and 51 of the TBD (Proctor and Algutifan 2004) for dose assignment for workers during 1943–1948. There is no data provided to support the 50 mrem/wk dose value. The 50 mrem/wk equates to 2.5 rem/year. This is comparable to today's standards, but is much less than the allowable limits of 26 rem/year, and later 15 rem/year, as allowed in 1943–1949 (Proctor and Algutifan 2004, Table 6-3, pg. 11). Therefore, a worker could have received 6–10 times the proposed assigned dose and still have satisfied the guidelines.

The current Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) does not address some important issues that could lead to an underestimate of doses to workers when using the modal dose from 1949–1959 to assign doses to the 1943–1948 workers. Some of these issues are as follows:

- Different facilities: Many of the older facilities were not intended for use with radioactive material (surface decontamination, controlled areas, ventilations, etc).

- Different working conditions: Earlier workers did not benefit from established production operations and infrastructure as later workers did.

- Accidents/incidents: For example, the two that occurred in 1944 (as described in an article by L.B. Silverman (Silverman 1962)) are not captured by assigning later cohort doses.

- The later years had the benefit of experience from the earlier years; therefore, a lower modal dose would be expected during the later period.

- Early era dose limits were based on staying below regulatory limits, not necessarily on individual accumulative doses. Using modal doses from a period that controlled individual exposure does not correctly reflect the doses received by earlier workers where such controls did not exist.

Considering the differences between the two eras, it does not appear to be technically sound or claimant favorable to use the 1949–1959 modal recorded doses to back-establish doses for workers from the first era of Mound operations. Other methods are needed to address this issue.

4.6 ISSUE 6: HISTORIC BETA EXPOSURES ARE NOT SUFFICIENTLY CHARACTERIZED

Beta dose reconstruction is not sufficiently covered in the Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004). Periods when reliable beta dose and extremity dose records are not available need to be identified. Beta skin doses from contamination and organ and/or extremity doses from handling beta-emitting materials close to the body and hands need to be further addressed. Table 6-23 on page 35 of the TBD (Proctor and Algutifan 2004) provides a list of numerous beta-emitting isotopes that presented external dose hazards at the Dayton/Mound facilities from 1943 to 2000. While the TBD (Proctor and Algutifan 2004) provides some information concerning beta/low-energy photon dosimetry for this period, it appears scattered and incomplete. Without dose records available for analysis, it is not possible to determine if and when skin doses were recorded, or how LOD, zero, and blank readings were handled. The potential for underestimating beta dose is not sufficiently covered in the present TBD (Proctor and Algutifan 2004).

As early as 1944, it was known that the beta fields were intense around the irradiated material, because workers had to use lead gloves and tongs to handle them, and in 1956, beta activity in 1 lambda of water saturated the beta counter. In 1957, a bismuth shipment contained beta-contaminated water. The Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) and other documents also state that many beta-decay radioisotopes accompanied the bismuth/polonium irradiation, separation, and handling process, and Table 6-23 on page 35 provides a list of numerous beta-emitting isotopes that presented external dose hazards at the Dayton/Mound facilities from 1943 to 2000. The TBD (Proctor and Algutifan 2004) outlines some historic information concerning beta/low-energy photons dosimetry; such as on page 25:

- *1946–1952: No low-energy photon doses measured.*

- *1953–1977: Skin dose – Started reading OW in 1953 per pg. 25, but 1960 per pg. 23).*
- *1972: Began routine extremity dosimetry.*
- *1979: First beta calibration of dosimetry.*
- *1978–2006: Skin dose = skin gamma + neutron + beta (if measured).*
- *1995: Limit of detection (LOD) for beta was 53 mrem/qtr (pg. 36).*

Without a clear delineation of in-plant practices and for what periods of time reliable records exist of beta exposure, there is insufficient guidance for the dose reconstructor from the characterization information provided in the TBD (Proctor and Algutifan 2004) to ensure claimant-favorable dose reconstruction. Areas that need to be addressed are as follows:

- Periods when reliable beta dose and extremity dose records are not available need to be identified.

- Methods are needed to assign beta doses for periods when dose records are not available.

- Beta doses to organs and/or extremities from handling beta-emitting materials close to the body and hands need more investigation.

- The magnitude of beta skin doses from contamination needs to be determined.

- It needs to be determined how zeros, blanks, and LOD values were handled in recording the beta dose values, and how they will be handled during dose reconstruction.

In summary, the subject of beta exposure has not been sufficiently developed in the present TBD to ensure that workers will be assigned claimant-favorable beta doses.

4.7 ISSUE 7: ASSESSMENT OF PERSONNEL BADGING DURING THE EARLY YEARS NEEDS FURTHER REVIEW

Pages 11 and 15 of Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) indicate that all *radiation* workers were badged during 1949–1962. However, according to a report of January 1961 (Mathew 1961), roughly only 15%–20% of the employees were badged during 1947–1959. This could have resulted in some workers not being monitored during a period when all the radiation hazards were not recognized and, therefore, those workers were not considered radiation workers at the time. The TBD (Proctor and Algutifan 2004) is not clear concerning who was monitored and when. The term “radiation worker” has not been defined, and it is not certain how this was used at Mound Laboratory at the time to assign badges. Table 6-4, page 11 (Proctor and Algutifan 2004), lists some information on who was badged in the ‘Comments’ column. From this information, it is not clear for what time periods certain workers were badged; i.e., was everyone inside the plant area (security, crafts, maintenance, janitorial, etc.) considered “radiation workers,” or just those who routinely handled radioactive materials? There are some concerns that not all workers who needed to be monitored were monitored when they needed to be, as supported by statements made in the Occupational External Dosimetry TBD (Proctor and Algutifan 2004), as follows:

- ***Maintenance and engineering staff –*** Table 6-2, page 10, states that night maintenance staff in Building P started to be routinely monitored for neutrons in 1963, and that some hourly engineering staff members were starting to be routinely monitored for neutrons in 1966.

- ***Maintenance staff*** – Page 23 instructs the dose reconstructor to assign maintenance staff 38 mrem/2-wk periods or 1 rem/yr for unmonitored periods before March 22, 1966 [Maintenance workers often performed many different functions at different locations and under different situations, and are being assigned much lower doses than are listed on pages 50 and 51 (Proctor and Algutifan 2004) for base and missed (neutron plus gamma) doses of 2 to 7 rem/y.]

- ***Other workers –*** It appears that other workers (such as those involved in decontamination and decommissioning activities, roving workers, janitorial staff, etc.), who may have had the potential to be exposed to higher than average radiation doses, may not have been considered for monitoring, especially during post-1990 when operations stopped and D&D was performed. For example, Building 59 (Proctor and Algutifan 2004, pg. 34) could present radionuclides of concern, such as U-235 and Fe-59, in the form of rust during building demolition.

It is not apparent from the TBDs if incidents and accidents were recorded for unbadged workers, and if these will be used for individual dose reconstruction.

NIOSH needs to address the following:

- Determine how Mound Laboratory defined "radiation workers" during 1949–1962.

- Determine if these radiation workers were badged for neutron and beta, as well as photon, radiation, and if all doses were recorded.

- Examine the Mound badging policy and dose records to determine what criteria was used to assign badges; for example:

    - Were all workers who were expected to receive above a certain exposure badged?
    - Were supervisors allowed to select the workers who were badged?
    - Was badging random within a selected group of workers to be badged?
    - Were the maximum exposed workers continuously badged; if so, how can it be ascertained that they were the maximum exposed?

Much of this information can be derived from a detailed review of annual dose records. The answers to these concerns are important in order to determine whether workers who were potentially exposed to radiation were adequately monitored, and which workers need doses assigned based on co-worker radiation exposures. Workers who were unbadged, or whose individual doses were not recorded, cannot be assigned missed doses based on LOD values and still be ensured that the doses are technically sound. This issue needs further investigation and clarification.

4.8 ISSUE 8: PROBLEMS WITH NTA FILM NEUTRON DOSES

It is not clear from the present TBD (Proctor and Algutifan 2004) if or when the neutron dose records for **badged** workers are being corrected for the low-energy response and fading of NTA film (especially at low neutron energies), and for what years, and if and how the neutron-photon values are being used in neutron dose reconstruction. As at other nuclear facilities, Mound became aware of the NTA film under-response to neutrons below 0.8–1.0 MeV in the 1960s. However, it is not obvious that the dose reconstructor has sufficient detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy at the numerous facilities at Mound that produced neutron exposures throughout the years. Other issues of internal consistency were noted in the TBD (Proctor and Algutifan 2004), including inconsistencies in given neutron-to-photon ratios for various operational periods, neutron flux to DCFs used in 1947–1969, and NTA film fading in the 1950s and 1960s.

The use of NTA film to monitor neutron doses at Mound Laboratory raises several areas of concern as outlined below.

NTA film neutron energy threshold – As at other nuclear facilities, Mound became aware of the problem of the under-response of NTA film to neutrons of less than around 0.8–1.0 MeV in the 1960s. It is stated on page 17 of the TBD (Proctor and Algutifan 2004) that in 1963, the average energy of the neutrons measured in SM Building was 0.75 MeV, and again in 1969, an average neutron energy close to 0.75 MeV was measured; but that Mound dosimetrists thought it conservative to assume the higher energy of 1.3 MeV. The real danger in assuming a higher energy neutron field than that to which the worker is really exposed is that the NTA film practical threshold is around 1 MeV and, therefore, lower energy neutrons could go undetected. This was mentioned on page 19 of the TBD (Proctor and Algutifan 2004), but not sufficiently addressed. An adjustment to missed or under-reported doses is recommended on pg. 30 of the TBD (Proctor and Algutifan 2004), Table 6-17, in footnote (d), which recommends using a 14% correction factor obtained from the SRS for neutrons in the range of 0.1 to 2 MeV.

Correction factors for poor low-energy response depend to a large extent on the facilities' operating conditions, and should be determined for each site and location within a given site. Neutron sources in hydrogenous shielding and process streams quickly degrade to lower-energy neutrons. A missed dose of 14% for all neutrons that fall below the 1-MeV threshold of NTA film, considering the varied missions at the Mound Site, appears to be very small and could result in missed dose. In general, NTA film misses around 1/4 to 1/2 of the neutron dose around moderated neutrons. A multiplication factor of 2 (i.e., 1/2 go undetected) is stated for 1970–1976 on page 21 of the TBD (Proctor and Algutifan 2004).

It is not obvious from the current TBD (Proctor and Algutifan 2004) that the dose reconstructor has sufficiently and consistently detailed correction factors and instructions available to correct for unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy. The following areas need to be investigated to ensure complete neutron dose assignment:

- Determine in what buildings and time periods lower-energy (PoLi, PoF, PuO_2, PuF_4, etc.) or heavily moderated higher-energy (PoBe or PuBe) neutrons sources were present.
- Determine what neutron source(s) were used for NTA film calibration during these time periods.
- Determine if all exposed workers' neutron dose records were appropriately corrected for NTA film lower-energy response for each year (such as multiplying by a factor of 2, as stated on page 21 for 1970–1976) for the exposure and calibration conditions that existed.

[The above information is also useful for correcting for track fading, especially at lower-neutron energies.]

- Resolve the apparent conflicting concept of multiplying dose records by a factor of 2, as stated on page 21 for 1970–1976, as opposed to using a correction factor of 1.14, as stated in footnote (d) of Table 6-17 on page 30 to correct for missed dose because of poor low-energy response.

Neutron/photon ratios are not consistent – The Occupational External Dosimetry TBD (Proctor and Algutifan 2004, Section 6.6.3.4, pg. 37) states that the neutron-to-photon ratio at Mound was 2:1. However, Tables 6A-1 and 6A-2 both list the ***same*** imputed base dose for neutrons and photons of 2,600 mrem/y for the years 1943–1949 (i.e., n/p = 1.0). The first paragraph on page 50 (Proctor and Algutifan 2004) lists the base annual dose for 1947–1977 as the cohort dose **or** the modal dose for 1949–1959 of 2,600 mrem/yr for neutrons and 1,040 mrem/yr for photons (i.e., n/p = 2.50). A modal dose of 50 mrem/wk neutron and 50 mrem/wk photon is stated for 1949–1959, and recommended for dose reconstruction during 1943–1948; this is a n/p = 1.0.

Variation in neutron QF – Page 16 of Occupational External Dosimetry TBD (Proctor and Algutifan 2004) lists possible reasons why the neutron flux required to equal 300 mrem/wk varied between 30 and 150 n^o/cm^2-s in the period of 1947–1969. However, the two reasons suggested (longer than a 40-hr work week or decreased energy of the neutron sources) would not account for these drastic changes. Even a 60-hr work week would only decrease it by 33%. Changing back and forth between 5 MeV and 1 MeV neutrons would only change it by a factor of 2 (ICRP 1991; Proctor and Algutifan 2004, pg. 17). No feasible explanation was provided for the changes in the conversion factors.

NTA film fading – Page 20 of Occupational External Dosimetry TBD (Proctor and Algutifan 2004) discusses NTA film track fading, and states that it became important in 1968 and corrections were made from that time forward. It also states that Meyer (Meyer 1951) noted film fading as early as 1951; but he must have not considered it important, and no corrections were apparently made until July 15, 1968. If fading resulted in under-recorded doses in 1968, it also could be a problem back to 1949, when NTA film was first used at Mound. This is of concern especially when lower-energy neutrons from (alpha, n) reactions are present, such as those from PuO_2, PoF, PuF_4, or PoLi, etc, because of the more pronounced fading of lower energy tracks in NTA film.

Some aspects of neutron dose reconstruction for **missed** dose is provided on page 30 of the TBD (Proctor and Algutifan 2004), but it is not clear from the present TBD if the neutron dose records for **badged** workers are being consistently and appropriately corrected for the low-energy response and fading of NTA film (especially at low-neutron energies), and if and how the n/p values are being used in neutron dose reconstruction.

4.9 ISSUE 9: THE DECONTAMINATION AND DECOMMISSION (D&D) ERA OF MOUND OPERATIONS IS NOT SUFFICIENTLY ADDRESSED

Monitoring practices, particularly internal dosimetry, are not specified in the TBD for the D&D period (1992–2003) at Mound. Other contemporaneous sites undergoing D&D, such as RFP, conducted urinalysis on D&D workers, including subcontractors who entered radiological control areas and had Rad Worker II training. They also reportedly employed lapel samplers among other air samplers as a means to trigger special bioassays, as needed. One site expert indicated that Mound sent a team of workers to RFP in the early 1990s to study and emulate the RFP approach to radiation monitoring of D&D workers. However, according to this worker, the resulting D&D monitoring program applied lapel samplers and DAC-hour analysis as the primary, not secondary, dosimetry, as reported for RFP. (This assertion was also made by an RFP former D&D worker and is currently under review.) There are also concerns related to the adequacy of bioassay during the D&D period at Mound for specific radionuclides, as noted in Issue 1 (Section 4.1) of this report.

A number of questions present themselves that are not addressed by the existing Mound Site Profile. What specific external and internal monitoring program was established for D&D operations, and how effectively was it implemented? With the use of first-, second-, and third-tier subcontractors, to what extent were these workers “captured” in the site’s dosimetry program, and are their records maintained in the Mound database? How would the co-worker dose model be applied for unmonitored workers located adjacent to D&D operations; was resuspension of radioactive particulates an onsite issue during D&D?

There is a lack of sufficient environmental monitoring data to fully characterize source terms to which workers were exposed during waste disposal and D&D demolition procedures, particularly as production began to cease in the early 1990s. Many of the radionuclides that researchers were working with were often unknown to radiation safety personnel. Buildings at Mound were engineered during their construction to provide ventilation systems, fumehoods, and gloveboxes to help minimize inhalation uptakes by workers. As demolition workers began to remove walls and dividers, and to remove these contaminated fumehoods, gloveboxes, and ventilation systems, these engineering controls were breached and no longer became effective in minimizing inhalation uptakes. Contamination within the ventilation ductwork would have been an additional source of uptakes. Not always being aware of the mix of radionuclides present in specific demolition areas and/or researcher-handling areas made it difficult to adequately prevent, monitor, and detect uptakes of these radionuclides.

Over the years, occasional D&D at Mound Laboratory was a part of normal operations. However, there were two main eras when most of the D&D occurred at the overall Dayton Project facilities. The first was around 1948, when the older units were removed, such as Units I-IV, Site Description TBD (Vollmer 2004b, pg. 10), and the second in the 1990s, when the Mound facilities (Unit V) underwent D&D. The more recent D&D operations (1974–2001) at Mound are mentioned briefly in the Site Description TBD (Vollmer 2004b, pp. 9, 18, 19, 26, and 31) in the contents of building numbers and dates, but not with specific operations or dose details. The only reference to dose was on page 22 of the Site Description TBD (Vollmer 2004b), where it refers to Meyer as stating that the highest neutron doses were in D&D operations in Building PP, where the neutron doses were about 30 mrem/2 weeks. This was in the context of the fading of the thermoluminescent dosimeter (TLD) signal and not to workers' doses, in particular. The Site Description TBD (Vollmer 2004b, pg. 6) states that it was DOE's plan to close the Mound facility in 2006; and on page 34, it mentions that Building 59 could present radionuclides of concern, such as U-235 and Fe-59, in the form of rust during building demolition. The end of the table on page 9 (Vollmer 2004b) refers to some cleanups, and it states on page 31 that Building 123 was deconstructed in 2001, although no potential worker exposures or dose details are provided. In summary, this is the full extent to which this final era of radiological operations is mentioned in the various TBDs of the Mound Site Profile.

One of the Mound RCTs did address D&D activities during his SC&A interview, and his radiation exposure experience is provided in Attachment 2. As he pointed out, particular dose reconstruction attention should be considered for the open-processing areas of SM Building and PP Building (also known as Building 38), particularly in the late 1980s and early 1990s when the critical clean-up evolutions were underway. There was also some uranium work done in SM Building, whereas PP Building was primarily Pu-238 with potential for high-fired oxide exposures. Later in PP Building, there were many orphan sources handled. Some were encapsulated, but even these became leaky. As T Building was being torn down, all walls and cubicles were gutted, and there was only one cavernous area with many untested changes in the engineering controls. There were some very different and uncommon radioisotopes used in A-line operations. There was also significant potential for exposure to neutrons from Pu-238 operations. In most cases, Pu-238 contamination was effectively quantified and controlled, but there were instances when contamination leaked out of the D&D tents unexpectantly, and personnel may have had uptakes, since respirators were not always required for such work.

> *One Mound interviewee indicated that a small breathing zone (BZ) air monitoring program was implemented in 1989 (See Attachment 2). Once a month, workers were selected in certain production areas to wear lapel air samplers for measuring breathing zone (BZ) air concentrations. One worker remarked that it seemed to him that the BZ sampler was always given to the "cleanest" worker, i.e., the one with the least likelihood of high airborne readings, because elevated*

> *levels above certain criteria could shut a particular job down. According to the worker, a full-fledged breathing zone program was implemented in 1998.*

In most D&D activities, workers have to cut or otherwise breach the system during the removal process. This lends itself to multiple radionuclides used by researchers at Mound, but is a particular concern when such environmental exposures involve SMTs and STPs. In the BWX Technologies, Inc., letter providing responses on a draft TBD for STPs, BWX responded to questions regarding SMTs by stating the following (BWXT 1999):

> *Pre-job characterization surveys will be performed, but the tritium results will not be analyzed to differentiate forms of tritium. Further characterization is not necessary, since we are assuming that all tritiated materials on a survey or lapel sample are Stable Tritiated Particulates (STPs). Using the Dose Conversion Factors (DCFs) for observed counts has shown to be fairly independent on particle type and size, therefore reducing the impact that additional characterization data would have.*

According to a BWO response (BWO 1991), Mound attempted to monitor STPs:

> ….[by taking] *more accurate air monitoring results, which are used to assign dose… Urine bioassay is no longer considered to be a usable approach to assign dose. To the best of our knowledge the methodology for STP fecal bioassay analysis is not currently available; therefore the shortfall associated with the final methodology cannot be discussed. In a recent teleconference with DOE Headquarters regarding the TBD, they indicated that they intend to pursue development of a fecal bioassay methodology for STPs; however no timeline has as yet been established. Nonetheless, worker protection can be effectively achieved without a fecal bioassay process.*

In the same BWX Technologies, Inc., document (BWXT 1999), a question was raised about the potential use of the results of the individual lapel air sampling in assigning individual doses, what the sample validation process would be, and whether a sample validation process was referenced in Mound's existing procedures. It was also asked if Mound used lapel sampling results for assigning doses in the past. BWX responding by stating the following:

> *The following process will be used to validate lapel air sampling analysis background and a check source count will be run with each set of lapel samples as an indication that the instrumentation is functioning properly. In addition, the instrument is verified operational on a daily basis through the use of control charts using a predetermined background and a tritium check source. These processes are documented in MD-I 03 79, Health Physics Counting Laboratory Manual. A review of the lapel sample data will be performed by Count Lab health physicists before it is submitted to Internal Dosimetry for use in assigning individual doses. To the best of our knowledge, Mound has not used lapel sampling results for assigning doses in the past.*

Decontamination and decommissioning is not addressed in any detail in the documents reviewed to date on the "O" drive concerning external doses. In revisions to the TBDs, NIOSH should devote a section to D&D operations, and find ways to quantify dose for workers involved in D&D and demolition operations that produced dust levels with potentially high internal uptakes, and with worker exposure to radioactive debris that might have resulted in a significant potential for external dose. It is not apparent from the TBDs if recent D&D was performed on any large scale and, if it was completed, what specific operations were conducted. The TBDs should provide information by building decontaminated or demolished, and if not yet demolished, at what stage of D&D key facilities stand. This should include information that describes if the building was just decontaminated or completely removed, and if all the contaminated soil and material was removed. Health physics procedures needed for these D&D operations were also not addressed in the TBDs. No external dose monitoring, precautions, unusual conditions, or incident tracking during D&D is mentioned. All D&D workers in the radioactive areas should have been badged for ***photons, beta, and neutrons.*** It is not clear if this was done or if workers always wore respiratory protection during such evolutions. Buildings and materials could contain radioactive materials that emit neutrons from (alpha, neutron) reactions, such as PuBe contamination. This could present external and internal neutron exposures that are not normally encountered in D&D operations. Additionally, high concentrations of beta emitters (hot particles) could present unusual skin and internal exposures, if present.

The period from the end of operations to complete closure of the site appears to be missing from the TBDs reviewed to date. It is not possible to evaluate the external dose issues during this period without additional information on the D&D operations, health physics and monitoring procedures, and dose data results.

4.10 ISSUE 10: OCCUPATIONAL MEDICAL EXPOSURE IS NOT ADEQUATELY DEFINED AND ASSESSED

The current guidelines, as presented in Kathren and Shockley (2005), go a long way in ensuring that all occupational medical exposures are reasonably included in determining the overall dose estimations for claimants. Unfortunately, the interpretation of these guidelines, to date, by the contractor (ORAU) has not been applied conservatively to be claimant favorable. The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) assumes an interpretation of what constitutes an occupational medical x-ray examination, which also has been considered and applied at other sites, such as the RFP and LANL. To this extent, the assumption that medical procedures are limited to only one pre-employment chest x-ray and chest x-rays which are part of routine physical exams may substantially underestimate worker medical exposure when evaluating occupational medical exposure.

In the current guidelines document, ORAUT-OTIB-0006, Revision 3 (Kathren and Shockley 2005), it is concluded that other examinations should be included, such as special job exams (e.g., respiratory protection, beryllium workers, asbestos workers, etc.) and termination exams. The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) does not recognize this change from the previous Revision 2 of OTIB-0006 (Kathren and Shockley 2005), and also assumes that special chest radiography for respirator certification, beryllium and asbestos workers, and food handlers are accomplished as part of the annual physical, if these jobs are defined as "at-risk" workers. This is not documented in the TBD (Algutifan et al. 2006). Another factor not discussed in the TBD (Algutifan et al. 2006) is the potential for and impact of x-ray procedures utilized by medical authorities to do special screenings.

The TBD (Algutifan et al. 2006) makes the conclusion that one chest examination of a PA view per year should be limited to a small group of "high-risk" workers after 1980 and smokers after 1989, as documented in Table 3.1 of the Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006). The only differential noted is that women who underwent breast augmentation surgery after 1988 also had a chest LAT x-ray performed. To the contrary, there is ample evidence that chest x-rays were often provided on a voluntary basis to nearly all workers. The majority of workers had chest x-rays as a routine at DOE sites until the mid-1980s, when Federal guidelines warning against routine screening were first being enforced.

After discussion with NIOSH personnel, it became clear that it was their decision to limit occupational medical exposure to those chest exams described above, and to conclude all other exposure should be part of worker background. SC&A believes such an interpretation is not claimant favorable to those most at risk. Our concern is that specified "high-risk" workers, i.e., those most likely exposed to radiation and beryllium, would be at risk of having an incomplete dose assessment, if not all radiation associated to medical diagnoses for job-related activities were included. Since, all radiation provides some risk, and arguably, is cumulative, workers warrant consideration of all forms of work-related x-ray exposure to be claimant favorable. SC&A believes NIOSH should review its interpretation of included medical exposure, and should reasonably adopt a broader interpretation of occupational medical dose, as provided in the most recent version of OTIB-0006 (Kathren and Shockley 2005).

4.11 ISSUE 11: POTENTIAL MISSED DOSE

SC&A has concern with the TBD (Millard 2004) as it presently reads regarding the potential for large missed dose in the early days. Section 5.1.3, page 10, 2nd paragraph of the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) states the following:

> *Individuals identified as being involved in an internal exposure incident or had urinalysis results in excess of the* ***reporting limits listed in Table 5-7*** *were required to submit additional urine 24-hr samples for analysis. Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed.*

In the case of protactinium, Table 5-7 of the TBD (Millard 2004) lists "**Detection limit (dpm)"** for protactinium, also noted as the "MDA" in the caption preceding the table**.** The above statement from the TBD thus implies that the action level and reporting limits are the same. If this is the case, then the missed dose (those not resampled and unmonitored administrative personnel) would include all those having urine samples less than 2.2 cpm 24hr^{-1}, which also equates to 300 mrem wk^{-1} or 15 rem yr^{-1}. This could be a very significant missed dose, where no follow-up sampling would have been done for those administrative personnel, maintenance personnel, and for those who may have had exposure just prior to discontinuation of work on the project.

This is further exacerbated by the statements in the Occupational Internal Dosimetry TBD (Millard 2004), Attachment 5D.0 on Uncertainty Assessment, which states the following:

> *Uncertainties in estimating worker dose commitments from bioassay data result from uncertainty in monitoring measurements and assessment of intake (ICRP 1998). Uncertainties for the bioassay measurements were not stated in the records.*

SC&A has concern with the TBD (Millard 2004) as it presently reads regarding the potential for large missed dose in the early days. When monitoring for Pa-231, it is stated that monitoring was done for, "…only those workers conducting research to separate and purify protactinium," and "…Individuals identified as being involved in an internal exposure incident or had urinalysis in excess of the reporting limits listed in Table 5-1."

These limits were based on the 300 mrem wk $^{-1}$ MPC to the target organ at that time. This would indicate that any value less than the dose limit, equivalent to15 rem per year, may be missed.

The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004) goes on to point out that the practice was that, "Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed."

This, likewise, would lead to potentially significant missed doses, as described above for these workers.

There is also the issue of contamination reported in several documents for "T" Building in the early 1950s. Report MLM-MU-51-69-0024, September 15, 1951 (Mound 1951), addresses *T Building Contamination Problem in the Process and Electrolysis Lines*. The report mentions "levels of activity in the high risk corridors," and that "one of the greatest sources of contamination comes during trash collection." It is pointed out that about 300,000 counts per minute are contributed to the total weekly air count of a high-risk corridor during collection of trash. This level was significant and produced potential internal exposure risk to all workers in "T" Building using these corridors. Individuals using these corridors may not have been on any monitoring program for the contaminants that may have been present; the site profile TBDs are unclear on this.

In the early years, much was unknown about the potential exposure to other radionuclides, as pointed out by the Mound Phase II Final Report, Appendix C (MJW 2002a, pg. 7):

> *Many difficulties were encountered in attempting to interpret the available bioassay records and reports of the other radionuclides. Some of the results were*

> *not associated with a name, social security number (SSN), or health physics number (HPNO). Oftentimes, there were no units associated with a result. In many cases, there were results for an element such as radium or thorium, but it was unclear which isotope was intended. There was no information on the age, solubility, or chemical form of the elements. Also, there was no information concerning incidents, known intakes, or details concerning the work activities of any of the workers for whom there are results.*
>
> *The intake and dose assessments for the "other" radionuclides done during this project are based on limited, and on occasion conflicting, information. In some cases, it appears that the same bioassay results were repeatedly reported for two, or sometimes three, different radionuclides. For example, a person may have identical results for protactinium and thorium-232. In other cases, urine samples may have been analyzed for radium/actinium/thorium by differential decay analysis of the radium fraction. The same urine sample may have also been analyzed for Th-232 by doing a Ra-Th separation. The results of the differential decay analysis appeared to conflict with the Th-232 analysis in that the dominant radium isotope is Ra-223 whereas Ra-224 would be expected. This would seem to indicate that the thorium results should have been interpreted as Th-227.*
>
> *Because there is very little information available, it was necessary to take a holistic and somewhat flexible approach to each individual's assessment, rather than design a "one-size-fits-all" procedure. Also, the interpretation that would yield the most conservative estimate of dose was used. A set of default assumptions based on fundamentals of the Mound Internal Dosimetry Program were used primarily to limit the number of decisions that had to be made, the basis of which may be tenuous at best.*

The state of the art of the Mound internal dosimetry program did not reach a much improved status until about the early 1990s. A draft internal dosimetry upgrade summary plan in June 1990 (Mound 1990) had this to say about the Mound internal dosimetry program prior to 1990:

> *The lack of a consolidated, comprehensive Internal Dosimetry Program at Mound has led to the present situation involving many areas of noncompliance with internal dosimetry monitoring specified in DOE Order 5480.11. Mound has no unified, technically based performance requirements for bioassay and in vivo monitoring and action levels for prompt dose assessment and remedial actions. The new DOE Order 5480.11 and the draft DOELAP Accreditation Program for Internal Dosimetry provides the incentive for developing a new Mound Internal Dosimetry Program Manual which establishes the technically based performance criteria for all internal radiation exposure monitoring requirements…Presently, supervisors are responsible for assuring that their employees, visitors, or contractors receive the appropriate personnel dosimetry monitoring for the areas which they will encounter while at Mound. Although guidance in the form of policy and recommendations is available in several manuals and procedures,*

> *information and technical assistance is not consolidated or readily available. Supervisors are not provided with a single point of contact for obtaining technical or administrative guidance to fulfill their responsibilities associated with personnel dosimetry. An especially confounding problem is knowing whether construction contractors are provided with adequate personnel monitoring services to comply with internal dosimetry requirements.*

Beyond the compliance issues, it is clear that even as late as the early-1990s, Mound did not have a coherent dosimetry program, apparently relied upon supervisors for monitoring decisions, and was initially struggling with assuring adequate bioassays for D&D construction workers.

4.12 SECONDARY ISSUES

4.12.1 Secondary Issue 1: Lack of Available Dose Data Details

The Occupational External Dosimetry TBD, ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) recommends using cohort dose data to assign doses to unmonitored workers. Some statistical analysis needs to be provided concerning the cohort data. For example, how many workers were badged during each year for neutrons and for photons, and what was the dose range and number of zeros in each dose set? What is the justification for applying this dose data to unmonitored workers? Will dose reconstruction be performed on a building or job title basis, or will the one dose be used for all workers, as is recommended for the 1943–1949 groups? Column 2 of Tables 6A-1 and 6A-2 recommends using the cohort dose; will this be on a yearly basis, or averaged over the time period listed in Column 1? Additionally, it is not clear from the TBD if adjustments (for fading, thresholds, etc.) to the recorded doses have been made in the past or if these adjustments will be made to the worker's dose during the dose reconstruction process. In view of the lack of complete dose records for all workers, it is certainly necessary to explore in some detail the data that is available and its applicability to unmonitored workers.

Some of the previously stated external dosimetry issues stem from the lack of available dose data details in Occupational External Dosimetry TBD, ORAUT-TKBS-0016-6. More details are needed concerning the 1949–1959 dose data and the appropriateness of using the modal dose of 50 mrem/wk neutron and 50 mrem/wk photon for dose reconstruction, especially in view of Section 6.6.3.4, page 37 of the TBD that states that the n:p ratio was 2:1. The TBD needs to provide a technically sound basis for using 50 mrem/wk modal doses and the applicability of the use of cohort data as suggested in Tables 6A-1 and 6A-2. Some tabular information is needed concerning the individual workers' dose data to include: year, ID number, job tile and/or department number and/or building number, neutron penetrating dose, photon penetrating dose, total penetrating dose, skin or non-penetrating dose.

Some statistical analysis needs to be provided. For example, how many workers were badged during each year for neutrons and for photons, and what was the dose range and number of zeros in each dose set? What is the justification for applying this dose data to unmonitored workers?

Will dose reconstruction be performed on a building or job title basis, or will the one dose be used for all workers, as is recommended for the 1943–1948 group?

Column 2 of Tables 6A-1 and 6A-2 recommends using the cohort dose; will this be on a yearly basis, or averaged over the time period listed in Column 1?

The Occupational External Dosimetry TBD does not make it clear if the "dose of record" for the workers has been modified with the necessary adjustments or not. These adjustments would include tantalum shielding of 60 keV gammas; NTA film track fading and low-energy threshold; TLD signal fading; and decreased response at high-neutron energies. The TBD provides a lot of information concerning adjustments to the "Missed" dose calculations based on LOD, but very little information concerning the worker's dose of record and its adjustments for use during dose reconstruction. In view of the lack of complete dose records for all workers, it is certainly necessary to explore in some detail the data that is available and its applicability to unmonitored workers.

4.12.2 Secondary Issue 2: Discrepancies in Definitional Terms

There is confusion throughout the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004) in the use of and definitions of MDA, Reporting Level, Decision Level, Decision Limit, and Action Level. This is illustrated on pages 10, 11, and 22 of the TBD (Millard 2004). It would appear that the terms "decision level" and "decision limit," and "MDA" are used by the author interchangeably. On pages 10 and 11, the equations 5-1 and 5-2 approximately define decision level (D_L) and minimum detectable activity (MDA).

Confusion is further added in the TBD (Millard 2004) on page 22, where it states, "Table 5-7 lists reported background count rates given in Section 4, Bigler's Annual Monitoring Reports by time period and **MDAs** derived using Currie's equation 5-2 (Meyer and Reeder 1992)." This is followed by Table 5-7 that lists the last column as **Detection limit.** Is this column D_L or MDA, as stated in the sentence preceding the Table 5-7?

It is SC&A's view that NIOSH needs to review this section for technical accuracy.

4.12.3 Secondary Issue 3: Problems with Recovery of Po-210 and Pu-238,239 Could Affect Dose

The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), goes into detail describing the problems discovered in the 1980s and 1990s, and discussed at length by Meyer (1992) *History of Mound Bioassay Programs*, regarding the recovery problems with metabolized Po-210 prior to 1964 and the poor recoveries of Pu-238,239 prior to 1960. In the Meyer (1992) report he states:

> *If we were to do dose commitment calculations today, we would consider the recovery efficiency of polonium from all past urinalyses to be just 10%. This would make a very significant change in the dose commitment calculations that*

> *we have done on a limited basis in the past and will do for a comprehensive study in the future.*

NIOSH in the TBD (Millard 2004) is to be commended for recognizing and dealing with these corrections for years prior to 1964. However, SC&A is not sure the full content of the Meyer report, quoted above, has been applied or considered. Meyer states that this recovery efficiency of polonium from **all past urinalyses be just 10%** and would make a significant change in the dose commitment calculation done on a limited basis in the past and will be done in the future. NIOSH is suggesting in Section 5.3.1.2, page 21, that this correction be applied to the data **prior to 1964. Data reported after 1963 should be normalized to 86% and corrected for a 63% chemical recovery** based on analysis by (Fellman 1989), a study done 3 years prior to the Meyer historical documentation. The difference is explained by NIOSH in the TBD (Millard 2004) on page 19 as being due to 10% recovery from the presence of metabolized polonium in raw undigested or unoxidized urine and from 1964 to 1973 a 63% correction factor based on ashed sample results duplicating methods used previously at Mound with a 2-hr spontaneous plating time conducted at room temperature.

4.12.4 Secondary Issue 4: Revised Body Burdens and Resultant Organ Doses May Need Further Evaluation

Kenneth R. Heid at the U.S. Transuranium Registry reported the results of a Pu assessment study done in 1983. Mr. Heid's April 11, 1984, letter to Mr. W. A. Bigler at Monsanto Research Corporation (Heid 1984) provided the results for the six participating laboratories who took part in a coordinated laboratory intercomparison study for bioassay of Pu-238. In that letter (Heid 1984), he pointed out the following:

> *The results reported showed good agreement between the participating laboratories. Results are shown in Table 1 and Figure 1. For most of the cases in the study the difference between the highest and lowest estimates reported was a factor of two or three. For two cases the difference was nearly a factor of ten with an average slightly over four for all 17 cases. This may not be too different from what might be expected if one laboratory had made all the assessments using a different person to make the assessment each time.*

The estimated systemic burdens (nCi plutonium) for Mound Laboratory, Lab C in Table 1 (Heid 1984), showed that the estimated body burdens that Mound results study were lower by almost one-half when compared to the other five DOE laboratories. Thus, the recorded Pu-238 estimated systemic burden data at Mound needed a correction factor to make up for the missed dose. It appears from Lab C results, shown on a different page (Heid 1984), that Mound was given an opportunity to redo their samples and provided revised nCi plutonium systemic burden estimates for 17 cases. NIOSH needs to ensure that previous Pu-238 systemic burden estimates were multiplied by about two and corrected in individual worker dose reconstruction files for Pu-238 doses recorded prior to April 1984.

On May 10, 1985, Dr. Ken Scrable from Lowell University did an internal dosimetry review of Mound's Health Physics Office (HPO) internal dose evaluation program, air sampling methods for plutonium, the HPO training program, and other aspects of the HPO operations. In a memorandum from Meyer, H. E. to Neff, R. A. dated May 16, 1985 (Meyer 1985), this review was discussed. Bob Robison revised the methodology used at Mound in past years to calculate the internal systemic burden of Mound employees to Pu-238. It is noted that Bob Robison found some errors in the Mound program, and that there would be significant ramifications in revising upward the body burden estimates for Mound employees. At a review closeout meeting on May 10, Dr. Scrable agreed with Bob Robinson's calculations that an upward revision of Mound employee systemic burdens was appropriate. In this memorandum (Meyer 1985), Dr. Scrable recommended that Mound go beyond the mere revision of the Mound body burden estimates to one of calculating radiation dose to specific organs, such as lung, liver, and bone. NIOSH needs to ensure that Mound did such calculations, and that the revised body burdens and resultant internal dose was entered into personnel files or, if not, that NIOSH has included such a provision in its Mound site-specific dose reconstruction guidance.

A Status Review Visit to EG&G Mound, July 8–10, 1991 (Runkle 1991), provides a status of the plutonium reconstruction project, the polonium reconstruction project, the Mound DOELAP program, the upgrade of the lung counting lab, and an addendum to the Blush Incident Report. Mound was required to ensure that all urinalysis results were in pCi for each Mound worker by October 20, 1991. The Polonium Reconstruction Committee was required to reach a consensus on the parameters to be used for dose calculations. The Mound Dosimetry Coordinator was required to ascertain that all personnel working in areas where internal exposures were possible were included in the urinalysis (in-vitro) bioassay program. NIOSH needs to ensure that workers who received doses prior to this 1991 review visit had necessary adjustments made to their dosimetry records to reflect any possible increase in dose for recommended adjustments in dose from these dose reconstruction projects, and that improvements in detection capabilities resulted in more accurate recorded or reconstructed dose.

A report prepared by Herbert Meyer and Dianne Reeder (Meyer and Reeder 1992) provided further information on the need to use raw data to rebuild the personal files of Mound's plutonium workers by stating the following:

> *Of primary concern was Mound's historical dosimetry program. One activity in this program, involving some 59,000 urinalysis records, yielded estimates of individual plutonium <u>body burdens</u>. The new standards require recording and reporting committed doses. Also, it was found that Mound's bioassay records misidentified a number of employee's urine samples in early years of operations because health physics identification numbers of terminated employees had been assigned to subsequently hired employees. The development of reliable records would require a complete reconstruction of plutonium bioassay results using only original records of raw data to rebuild the personal files of Mound's plutonium workers.*

The Phase II Final Report prepared by MJW Corporation describes what was done on behalf of Mound workers (MJW 2002b, Executive Summary):

> *Due to concerns raised by workers at Mound in 1996, the Department of Energy committed to make several improvements to the Mound Radiological Safety Program. One of those commitments was to perform internal dose assessments for all individuals who were estimated to have received equal to or greater than 20.0 rem Committed Effective Dose Equivalent (CEDE) from intakes of radioactive material received prior to 1989.*
>
> *The contract to perform the work was awarded to the MJW Corporation on April 23, 1997 and was broken down into two distinct phases. In Phase I, data in all formats (paper and electronic) was gathered and entered into an electronic database using a detailed QA process and screened for the potential to exceed 20.0 rem internal exposure prior to 1989 using very conservative assumptions. The screening resulted in data for 1553 individuals (approximately 500,000 data points) being screened for inclusion in the Phase II portion of the project. Thirty-one of the Phase II candidates were not assessed due to various problems with their data.*
>
> *In Phase II, the data for individuals who met the Phase I screening criteria of 20.0 rem were assessed and assigned dose using standardized processes and procedures describing, in detail, the method, software and assumptions used for each radioisotopic case. The Phase II process resulted in assessment of 2327 radioisotopic intakes for 1522 individuals. This information was then entered into the Mound MESH database for formal documentation of the dose received.*

On page 1 of 6 of the Phase II Final Report (MJW 2002b), the following summary is provided on the dose assessment work that was done for plutonium (non-DTPA) workers:

> *A total of 850 non-DTPA plutonium assessments were completed as part of the Phase II work. The isotope Pu-238 was involved in 788 of the assessments, while Pu-239 was involved in 210 of the assessments. Both isotopes were assessed for 148 assessments… A total of 40 original plutonium assessments were reworked due to the discovery of raw data in the files that in some significant way changed the original assessment.*

Page 2 of 6 of the same document (MJW 2002b) reported the following findings on plutonium workers who received DTPA therapy:

> *Mound employees who received or who were believed to have received significant intakes of plutonium were administered the chelation agent DTPA in an attempt to bind and eliminate the plutonium taken into the body and thereby reduce the dose received. A total of 63 individuals were on record as receiving DTPA therapy. After careful review of all bioassay records for these individuals, it was*

> *determined that one of the individuals fell outside the scope of the Pre-1989 Dose Assessment Project in that he had been chelated after December 31, 1988. Therefore, no plutonium dose assessment was performed for this individual.*

All plutonium dose assessments were performed by MJW and were based on information in a plutonium position paper, Section 6, Appendix (La Bone 1994). Polonium dose assessment for Mound workers was also completed. The Phase II Final Report (MJW 2002b) on page 3 of 6 states the following:

> *Once all of the above tasks were complete, polonium dose assessment work was initiated in October of 1999. A total of 1147 polonium assessments were performed as part of the Phase II work. As in the case of plutonium, a polonium position paper has been prepared to detail the thought processes used to accomplish this work.*

In regards to Mound workers dose assessment for "Other" radionuclides, the Phase II Final Report, Appendix C (MJW 2002a), states the following on page 3 of 6:

> *The "other" radionuclides consisted of all of the nuclides used for various experiments at the Mound other than plutonium and polonium. The nuclides used to varying degrees consisted of actinium-227, protactinium-231, radium-226 and 228, thorium-228, 230 and 232 and uranium-233, 234, 235 and 238… and were broken down by nuclide as follows: actinium (82), protactinium (17), radium (44), Th-228 (81), Th-230 (57), Th-232 (60) and uranium (28).*

The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), spends little time addressing this plutonium assessment effort. It is unclear if current NIOSH dose reconstruction processes go beyond the mere revision of the Mound body burden estimates to one of calculating radiation dose to specific organs, such as lung, liver and bone. NIOSH should clarify how the plutonium reassessment doses are being used and what the procedures are for determining organ doses. This should be addressed in the revisions to the next Mound Occupational Internal Dosimetry TBD. If this has not been done, it could result in plutonium doses that are not claimant favorable.

4.12.5 Secondary Issue 5: Lack of Environmental Monitoring and Survey Data Limits Accurate Dose Estimation at the Dayton Facility

The Occupational Environmental Dose TBD ORAUT-TKBS-0016-4 (Hysong et al. 2004) states that the principal contaminant at the Dayton facilities, which contributed to environmental dose, was Po-210. Dayton facilities involving the use of radioactive materials included Units I, III, and IV, which operated from late 1943 through late 1948, at which time operations shifted to the Mound facility in Miamisburg, Ohio. Most activities involving the release of Po-210 occurred at Units III and IV from October 1943 through 1948.

The TBD indicates that environmental monitoring data is very limited in the form of progress reports in 1945, monthly health reports in 1947, and additional monthly health reports in 1948. No environmental data was found for 1943, 1944, and 1946. Based upon the data available, the TBD suggests that Unit I contributed little to the dose, and Units III and IV contributed most to the environmental dose and had similar effluent levels. SC&A agrees that the operational records show negligible contribution to the dose results from Unit I; however, the data viewed on Units III and IV is too limited to suggest they are equivalent within reasonable certainty. In fact, a 3-year period is not adequate to suggest comparability.

The conclusion in the TBD is that, since the weekly outdoor perimeter data for Unit III in December 1947 was the highest they noted, it could be applied to both Units III and IV for the entire 3-year period. SC&A notes that this approach cannot be considered statistically sound, as no evidence exists of other comparisons. For example, the TBD does not address whether a cross-comparison to operational and production schedules was performed to further test that the assumption of highest effluents occurring in December 1947 could be validated.

4.12.6 Secondary Issue 6: Atmospheric Dispersion Models are not Correlated to Offsite Data

Atmospheric dispersion models based upon effluent (Stack) data are used to determine onsite airborne concentrations. NIOSH has not attempted to correlate these onsite airborne concentrations to the results from offsite monitoring data.

The Occupational Environmental Dose TBD, ORAUT-TKBS-0016-4 (Hysong et al. 2004), in the absence of onsite monitoring results prior to 1971, uses stack samples and dispersion analyses to determine and estimate onsite airborne concentrations. The TBD recognizes that the stack results are limited, and are not available for some operational periods and episodic events. There is no documentation of metrological data to test or validate the dispersion calculations. Contrary to what occurred at the Dayton facilities, there was significant offsite environmental airborne monitoring at Mound during the late 1940s, 1950s, and 1960s. The TBD indicates the author chose not to use the offsite monitoring results to estimate airborne concentrations, due to gaps in data and monitoring stations frequently being moved, as some monitoring was performed using mobile truck-based samplers. SC&A believes that when offsite locations are known and comparable stack effluents exist, a back calculation using the offsite monitoring data could reasonably test the validity of the dispersion calculation.

4.12.7 Secondary Issue 7: Missing Dose within Annual Dose Records for 1947–1977

The Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004, pg. 50) states that only annual dose records are available for 1947–1977, because the weekly, monthly, or quarterly records were lost. If a complete year of dose information is not available, some form of dose assignment may be appropriate. But the dose reconstructor does not know if a given year in a worker's dose record includes monitoring for the complete year. Perhaps, the dose record only contains information for a part of a year. Given the fact that Mound did not have any type of policy for recording dose due to lost or damaged dosimeters, the

TBD effectively compounds this problem. A worker's dose record may appear complete for a given year, but in reality it lacks dose information for the amount of time that the worker's dose was not monitored or recorded. It appears that this would go uncorrected if the dose reconstructor follows the current recommended procedure. Assigning a missed dose based on LOD is not acceptable for unbadged workers or for lost, damaged, or unreturned badges, because it may not reflect the actual dose received. Assignment of dose based on adjacent readings is possible, if there are no incidents/accidents (such as fires) during the unmonitored periods to create abnormal exposures. A method for ensuring that the entire year of exposure is accounted for is needed for each worker for each year employed.

4.12.8 Secondary Issue 8: Assumed Techniques and Protocols used in the TBD could increase Uncertainty of DCFs

The assumed techniques and protocols used in the TBD could increase the uncertainty of dose correction factors (DCFs) that are listed in the Occupational Medical Dose TBD, ORAUT-TKBS-0016-3 (Algutifan et al. 2006). Sections 3.2 and 3.3 of the TBD fail to adequately describe information upon which to adequately establish beam quality for x-ray units in use from 1946 to 1980. In 1980, the site installed a single phase Eureka unit. There is documentation to show that the TWX-235/Eureka 125, in use from 1980 through 2003, had 3.3 mm Al of added filtration, as first measured by the State of Ohio after 1988. However, in the absence of definitive tube output measurements prior to 1980, the TBD directs the use of default values and DCFs derived from ICRP Report No. 34 (ICRP 1982). These values are then applied to determine organ doses using Tables A.2 through A.8 of ICRP Report No. 34 (ICRP 1982). An issue of concern is that the DCFs are derived using a default HVL of 2.5 mm Al for Type 1 units, in use from 1946–1980. The TBD does not document the measure of any HVL for units in use prior to 1980. Another issue is that the unit, in use from 1980–2003, had added filtration of 3.3 mm Al, which is different from the default value from NCRP Report 102 (NCRP 1989).

The TBD likewise provides little documentation to support the use of assumed techniques and protocols applied to calculate the dose, which is also mainly derived from NCRP Report 102. NIOSH has acknowledged that the lack of verifiable protocols and beam measurements are a generic problem at many sites, has planned to search all available records, and will include pertinent records and references in any future revision of this section of the TBD.

4.12.9 Secondary Issue 9: The Frequency and Type of X-ray Exposure is Uncertain

The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) relies on a very limited historical review (Mound 2002) to establish x-ray frequency assumptions. The assumption of one chest radiograph (PA) per year is not reasonably conservative, in that workers could essentially request an x-ray, or be subject to special screening exams. The frequency of screenings, and number and type of workers receiving x-rays does vary from site to site.

The TBD, in Section 3.2, provides no documentation or references to support the assumption that only a limited group of workers received annual x-ray exams after 1959. To the contrary, up until about 1985, most DOE sites performed chest x-rays almost on a voluntary basis. DOE medical program reviews documented during the early 1990s showed many sites still used chest radiography as a general screening exam. Most workers accepted chest x-rays, even though the job did not require it. Also, the assumption that workers in special exposure categories, such as beryllium workers, were given chest x-rays only as part of their annual physical is not well-documented. The TBD applies no conservative assumption to cover specialty screening exams.

The TBD, in Sections 3.2, states that photofluorography (PFG) units, although generally available up to the late 1950s at most DOE sites, were not used at Mound. The undocumented absence of PFG units at Mound clearly has significant dose implications to workers who may have been given much higher doses from PFG units. The PFG unit provides a dose to the worker greater by a factor of 5–6, more than that delivered by conventional radiography. The TBD fails to document the type of equipment in use at Mound prior to 1980. SC&A believes it is not claimant favorable to instruct dose assessors to use kerma (dose) values of 200 mrem and 100 mrem for chest radiography, prior to 1970 and 1970–1979, respectively. To be fully claimant favorable, it would be appropriate to instruct dose assessors to use an annual dose of 3.0 rem per year for chest radiographs, in accordance with guidelines set forth in OTIB-0006 (Kathren and Shockley 2005).

4.12.10 Secondary Issue 10: The Use of Medium of Onsite Monitoring Results from the Period 1971–2003 May Not be Claimant Favorable

The Occupational Environmental Dose TBD (Hysong et al. 2004) states that to calculate environmental doses, it used a median value of onsite monitoring results for the isotopes that would most contribute to environmental dose. SC&A is concerned that, depending on where the air monitoring stations are located relative to worker occupancy determinations, the use of "median" value may not be claimant favorable. In the absence of accurately being able to estimate worker occupancy and frequency rates for the higher known concentration locations, it may be more appropriate to use the "mean" value, plus two standard deviations, to assure that estimations of environmental dose are claimant favorable.

4.12.11 Secondary Issue 11: Environmental Gamma Measurements at Mound do Not Correlate to Prior Dayton Estimates

There is no correlation between aerial direct gamma measurements at Mound when compared to control badge measurements at Dayton. The Occupational Environmental Dose TBD (Hysong et al. 2004) documents that an aerial survey performed at Mound in 1976 reported gamma estimates that ranged from 20.5 to 23.5 µR/h. If this were the case, the annual estimated environmental direct gamma dose at Mound would be approximately 40–50 mrem. When compared to the 1,800 mrem for 2,000 hours ambient dose rate mentioned in the TBD on page 15, the estimates of occupational exposure in the µR/h range do not seem claimant favorable. In the TBD (Hysong et al. 2004, pg. 15), the µR/h estimates were apparently calculated by assuming that the control badge was representative of the ambient dose outside the Dayton facilities. This draws attention to the possibility that Dayton environmental dose estimates are probably in error. The production rates and source terms at Mound always exceeded those at Dayton. Residual materials and waste products at Mound exceeded Dayton by several orders of magnitude. There are no known sources at either site during the years of Mound operations to cause elevated levels of gamma, beyond a few tens of mrem per year. NIOSH may want to revisit Dayton estimates as being unreasonably high.

4.12.12 Secondary Issue 12: Other Potential Medical Exposures have Not been Identified

The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) does not address the potential use of other forms of x-ray exposure other than routine chest x-rays. Workers were exposed to other x-ray examinations to support medical injury diagnoses. This may have involved the use of isotopes, sealed sources, etc.

The Occupational Medical Dose TBD does not discuss the use of portable radiography to perform screenings. Interviews with past medical staff do suggest that portable x-ray units were not used. This is potentially an issue relatively to the potential use of a PFG unit, which was often van-mounted at other sites. Additionally, the TBD fails to document that available x-ray units were not operated at greater than 80–90 kVp. To the contrary, Table 3-3 of the TBD indicates that the kVp after 1988 was set at 110 kVp when performing LAT chest exams.

The conclusion is that the TBD does little to reasonably document the variety of medical occupational exposures, and the lack of documentation on the type of equipment and the maintenance records does little to assure that a conservative and claimant-favorable estimation of dose is possible. This circumstance would suggest the need to reconsider a worst-case approach to establishing dose. NIOSH should revisit and update Sections 3.2 and 3.3 of the TBD, as needed.

4.12.13 Secondary Issue 13: There are Other Additional Factors that May Contribute to the Uncertainties of Medical Occupational Dose

The Occupational Medical Dose TBD (Algutifan et al. 2006) does not consider dose impacts due to less than optimal use of technology, such as using screens, grids, or bucky systems, nor does it consider these elements as potential contributions to uncertainty.

The TBD does consider the potential contribution to dose that may have resulted in less than optimal use of collimation at least prior to 1980, as stated in Section 3.2 of the TBD, and offers substitute DCFs for use by Dose Reconstructors (DRs) for selected exams, as presented in Tables 3-4 and 3-5.

Uncertainty is defined in the TBD as being due to measurement error and variations in kilovoltage, tube current, timers, and the skin-to-surface distance (SSD). This approach is quite similar to the uncertainty analyses documented in other DOE site profiles. The conclusion in the TBD, and others, is that an uncertainty factor of +30% should be used by dose reconstructors.

SC&A agrees that the TBD conservatively estimates these essential aspects of an uncertainty review. Unresolved is the contribution to uncertainty in dose, due to other errors introduced by lack of quality controls in processing equipment and lack of adherence to established standard operating procedures (SOPs). A reasonable estimate of these contributions to uncertainty would be an evaluation of retake rates, per examination type. NIOSH should revisit the potential for significant retake rates and evaluate its potential effect on dose as part of future revisions of the TBD.

4.12.14 Secondary Issue 14: Mound Classified Document Shipments

An activity of Non-nuclear Reconfiguration (FY1991–FY1993) included the shipment of 458 boxes (1 box equals 1 cubic ft) of Mound classified documents to LANL. These boxes represented the entire Mound Inactive (meaning they were no longer routinely used and were boxed and sent for storage) classified records. Due to the storage location (T-Bldg.), radiological surveys were required before the boxes could be removed from the building. These surveys produced positive results, which caused the collection to be shipped as a classified, contaminated collection. The boxes were never formally inventoried at the folder or document level, but a brief description of the box contents was provided to LANL at the time of the shipment. Generally speaking, this collection contained classified research and development records, and classified financial and programs records, and bioassay records. During the SC&A, NIOSH, and ORAU conference call (see Attachment 4), it was learned that MJW conducted a classified review in the late 1990s of the Mound classified records in this contaminated collection, and did retrieve the logbooks containing the bioassay data. The researcher's lab notebooks were primarily filled in during the 1950s and 1960s. These boxes were shipped to the LANL at the direction of the DOE Albuquerque Weapons Quality Division, where they were to be imaged and the originals destroyed as contaminated, classified waste. Subsequently, approximately 40 boxes of the contaminated, classified laboratory notebooks were returned to Mound to be scanned and made part of the final shipment of Mound classified document shipments that were sent in May 2003 to the National Nuclear Security Administration (NNSA) Classified Records Service Center, Sandia National Laboratory in Albuquerque, New Mexico, and to the DOE Office of Scientific and Technical Information (OSTI) center at Oak Ridge, Tennessee.

Our review identified an unclassified records file at the Dayton Federal records center and a classified file being maintained at LANL. The classified records being held at LANL were considered particularly important to address a number of site profile issues, e.g., metal tritides, Pu-238, etc., for which data was found to be lacking in the unclassified files in Dayton. Arrangements were made to meet with the LANL records manager to arrange access, wherein he notified us that all of these records had been disposed of the previous year (2005) at the direction of LANL management. He also indicated that "notifications" had been sent to pertinent parties to determine any objections to this disposal. He indicated that an inventory had been taken of the disposed records, which he would make available to SC&A. This inventory will be transmitted in the near future, but at the time of release of this report, the inventory is being delayed awaiting final review and approval.

The provision by DOE and LANL of an inventory of the buried records will help determine what original records are not now available for site characterization and dose reconstruction, and what implications that may have. It is also clear that MJW in its 1990s dose reconstruction for Mound workers had reviewed these records and has apparently retrieved considerable information. This retrieved data should be compared with the inventory when it is available to ascertain whether the relevant and important radiological information is accessible through this alternate source. It should also be ascertained whether this MJW-retrieved data and the Mound dose reconstruction data, in general, is readily available in the public domain for use by the Advisory Board and its support contractor. Finally, given the implications of the destruction of such a large amount of potentially relevant worker radiological information, it will be important to determine how the disposal of these historic records occurred.

Non-nuclear Reconfiguration of specific DOE sites in the United States was a Presidential mandate and affected weapons production facilities such as RFP, Pinellas, Mound, and Fernald. LANL was to image the classified, contaminated collection so that it could be electronically available, with the intent to ensure these Mound records were transferred from the contaminated record block onto contamination-free electronic records. LANL apparently never received the funding from DOE to image the collection. In approximately 2004, the DOE Ohio Field Office Chief General Counsel received a request from LANL for approval to destroy the collection. Discussions between SC&A team members who went to LANL for a classified record review in April 2006 and the LANL Records Manager verified that this block of Mound Inactive contaminated classified records were disposed of at an undisclosed burial site in 2005.

As a separate effort, the Mound Classification Office was responsible for the managing of the Active classified records. In 1999, a large-scale effort was intiated to consolidate numerous classified safes and repositories located all over the site, which resulted in >73,000 documents coming to a centralized location. This collection included additional individual lab books that were issued to Mound researchers to keep their personal notes of the research they were conducting. There were also financial data, technical reports, research papers, Safety Analysis Reports (SARs), Final Safety Analysis Reports (FSARs), litigation records, classified drawings, and other documents.

Several projects were performed simultaneously involving the now-consolidated Active classified collection. First, a records inventory was performed to separate records from non-records. All non-records were destroyed with approval of the DOE Ohio Field Office. Second, an imaging project was initiated to convert the records (paper) collection into electronic format, thus further reducing the security area footage. Third, DOE required that DOE facilities and laboratories provide a copy to the Office of Scientific and Technical Information (OSTI) of any formal report released. A part of the 73,000 documents included formal reports that had not been provided to OSTI, per the DOE Order. In the 2001 timeframe, DOE required that Mound conduct a review of all classified formal reports and forward to OSTI any formal reports that had not been previously submitted. OSTI provided an inventory listing of all formal reports they already had and Mound compared that list to the current holdings. Any Mound formal documents that had not already been sent to OSTI were sent at this point. OSTI received 28 boxes of hardcopy documents, 7 boxes of microfiche, and 7 boxes of microfilm that are purported to include all of the Mound formal document collection.

Once the imaging project was complete, Mound contacted DOE Albuquerque about taking the newly imaged classified collection. DOE Albuquerque agreed to accept the classified collection.

On April 8, 2003, Mound shipped by Medlar Trucking to the Sandia's National Nuclear Security Administration (NNSA) Service Center, Albuquerque, New Mexico, all of the remaining Mound classified documents. Mound has a DOE F 5635.3 record receipt form signed by a representative of the Sandia NNSA Service Center on April 15, 2003, that verified receipt of the classified shipment.

Mound believes that all exposure records needed for dose reconstruction are included in the Mound Radiological Laboratory records. Mound Radiological Lab records are unclassified and include the individual radiation personal file; personal incident reports filed by incident number and by incident itself by year by date; and in Mound incidence and accident reports. The personal incident file can be accessed by HP number or name or incident number. Sometimes this data was put into an individual's medical record, but when done represented a duplicate of what was included in the incident file. According to Mound Records personnel, this duplication was not always done.

4.12.15 Secondary Issue 15: Occupational Medical Exposure is Not Adequately Defined and Assessed

The current guidelines, as presented in the *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* (ORAUT-OTIB-0006, Kathren and Shockley 2005), go a long way in ensuring that all occupational medical exposures are reasonably included in determining the overall dose estimations for claimants. Unfortunately, the interpretation of the guidelines to date by the contractor (ORAU) has not been applied conservatively enough to be claimant favorable. The interpretation in the TBD (ORAUT-TKBS-0016-3, Algutifan et al. 2006), wherein medical procedures are assumed to be limited to only one pre-employment chest x-ray and other chest x-rays that are part of routine physical exams, may substantially underestimate worker medical exposure when evaluating occupational medical exposure. This overly restrictive interpretation also has been considered for and applied at other sites, such as RFP and LANL.

5.0 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 evaluation of specific issues of 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.

5.1 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—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 Mound represents an adequate accounting of the "core" polonium and Pu-238 handling operations, and dosimetry history of the Mound site, but falls short in fully characterizing a number of key underlying issues that are fundamental to guiding dose reconstruction. In some cases, these issues may impact other site profiles. Many of the issues involve lack of sufficient conservatism in key assumptions or estimation approaches, or incomplete site data or incomplete analyses of these data. Section 6.0 summarizes the key issues. Detailed evaluation of these issues is provided elsewhere in the report.

5.1.1 Objective 1: Completeness of Data Sources

The breadth of data sources used as a basis for the Mound site profile is evident in the 411 reports for Mound Laboratory and 30 reports for Monsanto Chemical Company, Dayton, Ohio, available in the Site Profile Research Database. Three hundred and fifty-two (352) of these reports were cited in the site profile references, while others served to provide confirmatory information. The ORAU team included health physics personnel with long histories at Mound, who have extensive knowledge of key dosimetry historical processes and personnel monitoring data.

There are additional sources of data, however, that have not been fully reviewed, and it is unclear to what depth the classified records have been reviewed. There is significant concern related to the content of the Mound classified, contaminated records disposed of at LANL. These records dated from the early days up through 1993 (see Secondary Issue 15). Although MJW did capture much of this important bioassay data from bioassay logbooks during their review of Mound classified documents at LANL in the late 1990s, there were still many additional classified documents for potential additional review that have been lost. When notified of the burial of these records during the conference call, MJW staff involved in the LANL data captures expressed concern regarding the disposal of these records and their importance to dose reconstruction efforts. LANL has located the inventories pertaining to these records and is in the process of reviewing the information for security purposes. Upon completion of this review, the inventory will be released to SC&A. That inventory will provide some insight into what kind of records have been lost. Additional classified records sent to Sandia National Laboratory have not been reviewed to evaluate their usefulness in dose reconstruction. Many boxes of Mound MLM reports are still sitting in boxes at the Mound Museum that have not been inventoried and applied to addressing missed dose and gaps in radiological monitoring that could be useful in doing claimant-favorable dose reconstructions. The daughter of a claimant has recently scanned many of these documents, and has 4 drawers containing about 1,300 documents (Jerison 2006). There are 135 boxes of documents at the Mound Museum that have not been previously reviewed. SC&A recommends that NIOSH should review this new source of Mound data to ensure these boxes of records do not contain important dose-related information for Mound workers.

The Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004, pg. 50) states that only annual dose records are available for 1947–1977, because the weekly, monthly, or quarterly records were lost, and recommends that the model dose be used for missed dose information. Occupational external dosimetry data is very limited in the 1943–1948 time period. This first era of research and development was conducted at several makeshift sites. This was a period when Dayton/Mound were exploring new, unknown technologies using many multiple, and not very adequately characterized, radioisotopes. The TBD's (Proctor and Algutifan 2004) use of 1949–1959 external radiation exposure data is questionable. It is unlikely that doses during 1949–1959, when radiation monitoring coverage was improved, adequately characterizes the external dose to workers in the 1943 to 1948 early period. Even in the later period of 1949–1959, Mound never had a well-documented quantitative study of its external dosimetry programs. Only 15%–20% of the employees were badged during 1947–1949 (Matthew 1961). It is not even clear for what time periods certain workers were badged; i.e., was everyone inside the plant area (security, crafts, maintenance, janitorial, etc.) considered "radiation workers," or just those who routinely handled radioactive materials? If a complete year of dose information is missing, some form of dose assignment may be appropriate. But the dose reconstructor does not know if a given year in a worker's dose record includes monitoring for the complete year.

There is a lack of sufficient environmental monitoring data to fully characterize source terms to which workers were exposed during waste disposal and D&D demolition procedures, particularly as production began to cease in the early 1990s. Many of the radionuclides that researchers were working with were often unknown to radiation safety personnel. Buildings at Mound were engineered during their construction to provide ventilation systems, fumehoods, and gloveboxes to help minimize inhalation uptakes by workers. As demolition workers began to remove walls and dividers, and to remove these contaminated fumehoods, gloveboxes, and ventilation systems, these engineering controls were breached and no longer became effective in minimizing inhalation uptakes. Contamination within the ventilation ductwork would have been an additional source of uptakes. Not always being aware of the mix of radionuclides present in specific demolition areas and/or researcher handling areas made it difficult to adequately prevent, monitor, and detect uptakes of these radionuclides.

5.1.2 Objective 2: Technical Accuracy

NIOSH, in the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004), is to be commended in recognizing and dealing with corrections necessary to take into account recovery problems with metabolized Po-210 prior to 1964, and the poor recoveries of Pu-238,239 prior to 1960, and for making these corrections for years prior to 1964 and 1960, respectively.

It is not clear from the present TBD (Proctor and Algutifan 2004) if or when the neutron dose records for **badged** workers are being corrected for the low-energy response and fading of NTA film (especially at low-neutron energies) and for what years, and if and how the neutron-photon values are being used in neutron dose reconstruction. As at other nuclear facilities, Mound became aware of the NTA film under-response to neutrons below 0.8–1.0 MeV in the 1960s. However, it is not obvious that the dose reconstructor has sufficiently detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy at the numerous facilities at Mound that produced neutron exposures throughout the years.

The radionuclide-specific application of detection limits and minimal detectable activities criteria as cited in ORAUT-TKBS-0016-5, Occupational Internal Dosimetry TBD (Millard 2004), do not include treatment of historic issues related to inadequate bioassay techniques and procedures that may have led to significant under-reporting and missed dose at Mound. This is particularly true for the pre-1990s, before these were more adequately addressed and documented during the D&D era of the 1990s. A more comprehensive list of these deficiencies in provided in Vertical Issue 5.1.

The Occupational Internal Dosimetry TBD (Millard 2004, pg. 16) indicates, “Limited information is available on the metal tritides to which workers could have been exposed.” The TBD (Millard 2004, pg. 16–17) does provide some guidance on tritides when it states the following:

> *Halfnium tritides were also used at Mound primarily in SW, R. and T buildings. A lung clearance class of S should be assumed for all metal tritides other than lithium. A lung clearance class of S should be assumed for halfnium tritides… Intake of lithium tritides should be estimated by assuming exposure to HTO. Exposure to all other tritides including halfnium should assume class S clearance.*

In the TBD (Millard 2004, pp. 47–48), Table 5A-1 does provide recommended lung clearance types for the site process activities for the buildings noted above. In addition, Table 5B-1 (pp. 51, 53, 54, 55, 59, and 60) does provide specific comments on tritide use in specific buildings and rooms, and comments on the activities ongoing there. These are only mentioned, however, as secondary to other radionuclides (pg. 51 – Ac-227; pg. 53 – Ra-223, Ra-224, and

Ra-226; pg. 54 – Rn-226 and Rn and progeny; pg. 55 – Th-228, Th-229, Th-230 and Rn and progeny; and pp. 59 and 60 – U-235, U-238, and U-239). This aspect is more complete that any other site profile where tritide exposure is an issue. However, the TBD (Millard 2004) does not probe deep enough into the impact of specific operations and activities that are known to have the potential for significant radiation exposure and address recommendations to the dose reconstructor on how these should be handled to develop a claimant-favorable tritide dose. Dose reconstruction guidelines need to be more specific and have more instructions and backup materials to enable claimant-favorable estimates of high doses from insoluble tritides for workers with job assignments and in work areas that had the potential for higher exposures. The TBD needs to address more up-to-date information on tritides by Cheng et al. (1997) and incorporate these considerations into the dose reconstruction instructions; the use of type S may not be adequate for hafnium tritides.

Dose reconstruction parameters and a generic dose assignment of a corrected 95th percentile dose of 340 mrem of workers exposed SMTs and STPs from 1947 to 1956 was provided in Section 5.3.1.1 of the TBD (Millard 2004). In SC&A's opinion, these procedures fall short in dealing with many significant exposures to SMTs and STPs at Mound that likely far exceeded these generic guidelines.

In regard to dose reconstruction for Pu-238 high-fired oxides, the TBD (Millard 2004) does not probe deep enough into the correct models to use to do claimant-favorable dose reconstructions. These Pu-238 high-fired oxides have a much longer retention time in the lungs that exceeds the default adsorption types specified by the current ICRP lung model. NIOSH has tried to address the so-called "Super S" type of plutonium in ORAUT-OTIB-0049 (OCAS 2006) for RFP. It is not clear, however, how this empirical model would apply to Pu-238 microspheres at Mound (there is no current ICRP treatment of the biokinetics of Pu-238 for these Mound operations). It is important to note that unless workplace indicators alert the staff of an exposure condition, it is very unlikely that an exposure to Pu-238 high-fired oxide would have been detected, measured, or noted until quite some time after the event. The TBD (Millard 2004) needs to address some of the literature available on highly insoluble (high-fired ceramic particles) Pu-238 by James et al. (2003), Guilmette et al. (1994), Cheng e. al. (2004), and Hickman et al. (2003). There is a difference in the way the body appears to handle and excrete Pu-238 from that of Pu-239.

The TBD (Millard 2004) does not go far enough in addressing the potentially high radon doses in SW Building. Air-sampling measurements from 1979–1980 were limited in location and do not necessarily reflect potential radon air concentrations in various parts of the SW Building complex, nor can it be assumed they reflect concentrations that existed in previous years when radon inhalation was potentially much higher. The TBD (Millard 2004) does not present substantiated radon characterization for the SW process areas prior to the venting of the underlying case and tunnel areas in 1980; the limited 1979 spot-air measurements and much later site-wide characterization do not provide a technically plausible basis to reconstruct radon dose for that earlier period. Likewise, it is not clear how the stated GSD of 3 is considered sufficient to offset this uncertainty regarding radon concentrations prior to 1980.

5.1.3 Objective 3: Adequacy of Data

The Occupational Internal Dose TBD ORAUT-TKBS-0016-5 (Millard 2004) does not adequately cover the dose potential from D&D activities that have been ongoing since the end of the weapons component production period in 1995. The Occupational Internal Dose TBD (Millard 2004) provides limited direction to dose reconstructors on the process and assumptions that should be used to calculate internal dose for the D&D activities. The TBD (Millard 2004) provides limited guidance for the assessment of missed dose for unmonitored workers.

NIOSH/ORAU have made extensive use of the Wayne King report on radioisotopes by location (King 1995), which provides credibility to the tables provided in the Site Description TBD, ORAUT-TKBS-0016-2 (Vollmer 2004b) that in most cases nicely covers what workers would have been exposed to in each building and room at Mound Laboratories.

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) provides a very useful Table 5-1 on page 9, which lists primary bioassay programs with reported radionuclide action levels in counts per minute for a urine sample, workers who were monitored, and frequency of monitoring.

Section 5.3.1, pages 14–27 of the TBD (Millard 2004), provides an effective summary of the primary radionuclides handled by workers at Mound. In addition, Section 5.3.2, pages 27–36 of the TBD (Millard 2004), provides a nice overview of the secondary radionuclides used at Mound. Table 5.20 (page 38) in the TBD (Millard 2004) also provides a most useful summary of analytical methods and detection limits (MDAs) that assists in the proper evaluation of bioassay data, as well as a means to assign missed dose.

5.1.4 Objective 4: Consistency Among Site Profiles

An extensive comparison was performed by SC&A to compare and contrast the methodologies used in the Mound and other site profiles reviewed to date 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 POC for individual claimants.

ORAUT-TKBS-0016-5 (Millard 2004) describes the default assumptions for occupational internal dose at Mound. The assumptions were derived from historical records relating to the in-vivo and in-vitro monitoring programs. The procedures used for assignment of missed internal dose is derived from ORAUT-OTIB-0002, *Technical Information Bulletin, Maximum Internal Dose Estimates for Certain DOE Complex Claims* (Rollins 2004), and ORAUT-OTIB-0018, *Internal Dose Overestimates for Facilities with Air Sampling Programs* (Brackett and Bihl 2005), as indicated in a conference call with NIOSH/ORAU (see Attachment 5). These procedures are similar to those used for other site profile dose reconstructions.

Mound, SRS, and LANL each had operations that involved exposure to SMTs and STPs. The Mound TBD (Millard 2005) and the LANL Occupational Internal Dose TBD ORAUT-TKBS-

0010-5 (Argall 2004) have identified operations involving metal tritides. The Mound TBD has gone one step further by providing solubility classes. The SRS TBD (Scalsky 2005) acknowledges the existence of special tritium compounds; however, it neglects any potential dose from these compounds. All three TBDs fall short in providing specific guidance to the dose reconstructors on how best to do claimant-favorable dose reconstructions for metal tritides. NIOSH has yet to develop a consistent approach for handling of stable metal tritide dose reconstructions.

5.1.5 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 TBDs 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.

6.0 USABILITY OF SITE PROFILE FOR INTENDED PURPOSE

SC&A has identified seven criteria that reflect the intent of the EEOICPA 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 Mound 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 POC 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.

6.1 AMBIGUOUS DOSE RECONSTRUCTION DIRECTION

Page 10 of Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) points out that the record of historical dose limit standards is ambiguous and a great deal must be inferred.

From the current Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004), it is not obvious that the dose reconstructor has sufficiently detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy at the numerous facilities at Mound that produced neutron exposures throughout the years, or the necessary information and dose records for beta-dose and extremity-dose assessments.

6.2 INCONSISTENCIES AND EDITORIAL ERRORS IN THE SITE PROFILES

Page 16 of Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) should read $n^o/cm^2\text{-}s$; not $n^o/s/cm^2$.

6.3 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues were identified that are common in the Mound and other site profiles reviewed to date 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 Mound and previous site profile reviews that in SC&A's view 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 often be 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 D&D 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.

(9) A consistent methodology for assessing exposure to metal tritides should be developed and applied to all sites where these chemical forms are identified.

Dose reconstruction for occupational medical exposures remains incomplete. NIOSH needs to reconsider the definition to include all forms of radiation medical exposure, to ensure its considerations are claimant favorable.

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ATTACHMENT 1: TECHNICAL DOCUMENTS CONSIDERED DURING THE REVIEW

Technical Basis Documents

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ATTACHMENT 2: SITE EXPERT INTERVIEW SUMMARY

Interviews were conducted with 17 operations, RCTs, radiological control (RadCon) and, internal dosimetrists, crafts and maintenance, and radiation waste and decontamination and decommissioning (D&D) personnel. Current workers represented about one-third of the interviewees, with the remainder being retirees who had previously worked at Mound. An attempt was made with the retirees to interview previous workers who had been employed at Mound for at least 20 years. Joseph Fitzgerald and R. Thomas Bell conducted the interviews jointly. "Q"-clearance was not required, since all Mound's classified documents had been sent in May 2003 to Sandia, National Nuclear Security Administration (NNSA) Service Center, Albuquerque, NM and the Office of Scientific and Technical Information (OSTI), Oak Ridge, Tennessee. An older block of Mound classified records (458 boxes) was residually contaminated and was sent to LANL in 1993. In 2005, that collection of Mound classified documents could not, reportedly because of cost, be copied to non-radioactive media and was buried as radioactive waste. This is discussed in more detail in Secondary Issue 6, Section 1.3 of this report. Therefore, there were no classified documents on the Mound site or at the Dayton Ohio Federal Records Center.

The purpose of these interviews was to receive first-hand accounts of past radiological control and personnel monitoring practices at Mound and better understand how operations were conducted. Health physics and radiological control personnel were interviewed on February 15, 2006. Production operations interviews were conducted individually on February 15 and 16, 2006. The interviews with retired Mound Laboratory internal dosimetrists were conducted individually on February 16, 2006. Radiological technicians currently working at Mound Laboratory were interviewed in groups of 2–3 on both February 15 and 16, 2006. Interviews with maintenance and crafts workers were conducted on February 15 and 16, 2006. Interviews with those workers knowledgeable about radiation waste and D&D work were conducted on February 16 and 17, 2006. Interviewees were selected so as to represent a reasonable cross-section of production areas and job categories. Time was also spent reviewing unclassified health physics records and reports, conversing with records staff, and reviewing documents at the Dayton Ohio Federal Record Center.

Workers were briefed on the purpose of the interviews, and background on the EEOICPA dose reconstruction program and site profiles, and asked to provide their names in case there were follow-up questions. Participants were reminded that participation was strictly voluntary and that all interviewer notes would be reviewed for classification following the interview even though the interviews were to be done as unclassified interviews. Interviewees were cautioned not to discuss any topic that they might feel could be classified.

Mound Laboratory facilities represented included by the site experts interviewed included Buildings B, G. T, SW, WD, WD Annex, R, R (Tritium Recovery Laboratory), R (Plutonium Processing), DP, SM, PP, Fire Department, A6 Assembly Building, BS, SD, SW-19 (Old Cave) and SW-22 (New Cave). The job categories represented included:

- H-3 Recovery
- Pu Heat Sources
- Pu Solubility Studies
- Maintenance and Testing of Cylinders
- H-3 Contamination Control in Air Conditioning Systems
- Ultrasonics
- Radiometric Calorimetry
- Research Related Work
- Decontamination
- Radiation Waste Disposal
- Building Demolition
- D&D
- Analytical Chemistry
- Waste Characterization
- Environmental and Waste Management
- Po-210 Trigger Fabrication
- Pu-213 Encapsulation and Assembly Fabrication
- Cotter Concentrate Handling
- Carpenter/Demolition Work
- Health Physics
- Internal Dosimetry
- Bioassay
- Computer Analysis
- Statistical Analysis
- Experimental Design
- Separation and Purification of Po-210
- Separation and Purification of Pu-238

Individuals interviewed were given the opportunity to review the documented interview for accuracy and completeness. This is an important safeguard against missing key issues or misinterpreting some vital piece of information.

All interviews have been documented and summarized below. The information provided is not a verbatim discussion, but is a summary of information from multiple interviews with multiple individuals. Individuals have provided this information based on their personal experience. It is recognized that these former worker recollections and statements may need to be further substantiated before adoption into the six Mound technical basis documents (TBDs). However, they stand as critical operational feedback. These interview notes are provided in that context; former worker input is similarly reflected in our discussion and, with the preceding qualifications in mind, has contributed to our findings and secondary issues.

[NOTE: The following represents a summary of former worker recollections of Mound operations and radiological issues that have not been necessarily substantiated for factual accuracy in the course of this site profile review].

Production/Operations

In the early days, things were not as well understood. There was a high frequency of minor incidents in T Building. Spills of Po-210 were frequent. There was no environmental program in the beginning. A Union representative who did not have much training for what they were doing did the early environmental study program. One interviewee drove around in a truck and run his air sampler to take his air samples at each location. As the environmental program matured, Mound radiation monitoring personnel started looking for radionuclides in the river and took soil samples off site. Even when environmental monitoring was fully in operation, there were never any major releases, nor was anything appreciable found on roofs of buildings. Even when trying to find an air sampler with the highest reading, the contamination found was still below discharge limits and clean air guidelines.

In the beginning years at Mound, Po-210 was the major isotope handled. It had a short half-life, as well as a short shelf life. It was used initially in the fabrication of nuclear triggers. Because of the short half-life, Mound started looking for a substitute to polonium and settled on Pu-238. Most of the early operational work was done in R Building.

Initial production of nuclear triggers involved the use of Po-210. Polonium-210 was produced from bismuth slugs. This bismuth slugs were taken out of a pool and put into a small loading container. Then it was put into long glass tubes. The bismuth slugs were in aluminum containers or aluminum jackets, as they called them. The bismuth in its aluminum jacket was dissolved in acid. The resulting fluid was emptied into casks. As it was processed, it was not pure, but had all kinds of fission products. Cobalt-60 was leached out of the aluminum during the process. Monitoring was crude in the early 1960s. Workers did have pocket dosimeters and the radiation safety personnel were observing the operations. Everyone who needed monitoring received such monitoring with the best radiation safety equipment technology at that time. The workers used special 2-piece clothing, but did not wear respirators. The health physics staff was only worried about gamma dose and nothing was done to determine if they had any uptakes. One good thing about Po-210 was that it had a very short half-life and it was eliminated very quickly.

Protactinium-231 was handled at Mound as early as 1956. At one time, 99% of the work in R Building did involve Pa-231, but over the years the R building was involved in many projects, and many isotopes. Building WD and WD Annex (WDA) were not as hot. When they tapped into the filter banks in WD Annex, they found high levels of contamination. There was a potential for an alpha/beta soup of isotopes. Waste management in the early years had less engineering controls in place. One worker pointed out that Mound had the largest batch of Pa-231 in the world at that time. There was continued interest in collecting the Pa-231, which was used in general research.

By 1960–1962, work with Pu-238 was begun. They extracted or milked U-234 out of the Pu-238. Mound sent the extracted U-234 to the isotope pool at Oak Ridge.

When Pu-238 processing started up in the early 1960s, and they were processing Pu-238 in PP Building and SM Building, large amounts had a gamma component. Some workers had to be pulled from work due to their burnout mainly due to the gamma exposure. Substitute workers were then sent in to replace those workers that had to stop work because of burnout. The burned out worker would then be allowed to go back to work in the next quarter, since they were complying with quarterly dose limits. This happened mostly in the production area. The bulk of the people were very conscientious about complying with the quarterly limits. Burnout with neutrons also occurred in some work areas. The neutron source in this case was the milking of U-234 from the aged U-238. Some neutrons were triggered and leached out of light materials, which created some alpha/neutron reactions.

In the process of fabricating the assemblies, Pu was encapsulated and then assembled in glove boxes or hoods. In R-149, workers were building heat sources. They would encapsulate the Pu-238 in a cylinder with a sealed bottom and then would weld the top in place. This was done in a hood. When the encapsulation was complete, the radiation safety personnel would decontaminate the hood. The hoods got highly contaminated during the process, and the air vents from the hoods were all tied into a HEPA filter bank in the penthouse, thus precluding the release of contamination into the environment.

Many workers chose to work an 8-hour workday or one shift in R Building. In PP Building and SM Building, work was done on a two-shift basis. More recently Mound went on a 4 day, 10-hours/day work schedule. Operational and maintenance personnel were often badged similarly. The type of work they were doing dictated whether they needed extremity dosimeters and had the need to get a WBC done. One HP was asked to compare the 1960s with the 1990s and he indicated that air monitoring did not improve that much, particularly since the continuous air monitor (CAMs) and instrument got older over time. When one health physicist was asked what he would do differently if he could change something that had caused the greatest problem, he said he would have made sure that Pu and alpha emitters were reported in dpm from the start, instead of the early use of cpm.

A lot of special processing was done in T Building in the early years. There were a number of Po-210 issues that needed to be evaluated. There were even some deaths caused by the acid vapors. Many procedures were developed on a trial by error basis. Another RCT, however, never heard of any such associated deaths on the Mound site.

When you look back, there were certain isotopes that couldn't be seen. You had to often wait for documentation of a worker exposure to a specific radionuclide before radiation safety could develop techniques and methods to document such exposure effectively. This often hinged on the radiation monitoring equipment at the time and its sensitivity and effectiveness in recording cpm, dpm, or mr/hr. During some periods in the 1970s, cpm was recorded, when it would have been far better to record meter response in dpm. There were gross alpha counters that were effective in monitoring for Pu-238, Am-240 and Th-230. Workers at Mound were instructed to provide nose wipes in any situation when intakes were suspected. However, if a worker was a mouth breather, nose wipes could easily miss a significant uptake.

Mound was generally a safe site in most cases. There were a lot of burnouts in SM building though. When handling the fuel cells and the SNAP-27 heat sources, workers would have to rotate them periodically every 2-½ degrees. This involved a lot of handwork to do this, with resultant extremity and whole body dose.

In the early days of the cold war in the 1940s, Mound supervisors had a paranoia that Russia was going to nuke the site. AEC decided to buy a piece of land in Marion Ohio and built a genuine duplicate of T Building (i.e., a redundant facility in case of emergency) in case the main plant in Miamisburg was ever bombed and they needed to shift to a secondary backup plant. Mound never used chemicals or radionuclides at the Marion Ohio site, but they would have one person go over to the site each week to check the site. The local residents thought that the plant facility was real. Many years later, a cancer cluster was detected at Marion Ohio. There is public concern, to this day, that the mock T Building played a role in their development of cancer.

Mound kept pretty much up to date on their radiological monitoring instrumentation. They used the old snowball with the moderator on top for neutrons, and the cutie pie for alpha counting. Pocket ionization chambers (PICs) were used routinely up until 1966, but continued to be used for some applications after that timeframe. The only problem with PICs is that, if you drop them, they go back to zero and any dose on the PIC is lost. Before the mid-1960s, the bioassay process at Mound was a bit shaky. The T-289s were considered a good instrument. The T-290s were not as good. Mound felt they had a very good monitoring capability especially when they compared themselves with other sites. Argonne National Laboratory, in particular, had a much less effective program.

High-fired oxide microspheres using plutonium and uranium were produced in R-140. Higher exposures were possible from the vaporization of the compounds. An argon torch was used in rooms R-145 and R-147. Workers would put the Pu, along with cladding material from around the heat source, in a ceramic crucible to determine how soluble it was with heating. It was then put into jars of water in the analytical laboratory to see how much was going into solution.

In PP-13 Building in the 1980s, they never had a situation that involved a positive high-fired oxide nose wipe. These operations in PP-13 were buttoned up around 1975. Things, however, were scary in the early years. There was need for a lot of scrubbing down. In Building SM, the hoods had Plexiglas, which was installed to reduce exposure mostly from Pu-238 neutrons.

Super high-fired Pu oxides were produced when Pu was heated above about 850°C. You get a very insoluble form of high-fired oxides when the Pu is heated from 1,200° to 1,600°C. During this process, oxygen is given off which will brittle up the cladding. You get an orange glow during the process. After a long period of time, a person's urine counts will tell you something about the solubilities of the plutonium compounds inhaled.

There were quite a few Pu-238 heat sources in T Building, which delivered a lot of direct radiation to workers if they got too close. These heat sources were generally locked up to prevent this.

Mound also had concrete retention ponds, much like the big sanitary sewage concrete ponds. Workers would precipitate out the alpha emitters and the sludge was then placed in drums and shipped to the Nevada Test Site (NTS) for burial. Also, beta emitters (basically H-3) were mixed with concrete and placed in a small burial drum. That small drum was then placed inside another larger drum. These were also sent to NTS.

The old x-ray machines used for autoradiographs had a tube type that generated 18 to 200 keV. There were also Co-60 isotopic sources used. In R building, there was a 267 Ci Co-60 source. T Building has medical x-ray units and Co-60 was used for industrial autoradiography. The non-destructive testing (NDT) equipment was a Co-60 source with a 1.2 MeV range. An Ir-192 source was also used; it had a half-life of 75 days and put out 440 keV. There were four ranges in the spectrum. Mound had x-ray machines that generated 18 keV and 300 keV. Mound also had a Neutron Facility with a neutron generator. It had a californium CFX multiplier with U-235 plates that kept it at the subcritical level.

The Mound accelerator had an 18 keV tube.

Mound made calibration sources for the nuclear submarines. Neutron sources had a bad name, since their handling them could result in significant dose to workers. The RadCon staff had to watch folks carefully when they were handling tritium sources. A rule of thumb, used at Mound, was that every 4 fast neutrons were equivalent to about 1 mrem of dose potential.

Radiological Control (RadCon) and Health Physics Aspects

In this early period, workers didn't get routine Pa-231 bioassay; workers were, however, monitored. Urine samples (24-hour) were analyzed by collecting a phosphate carrier precipitate. This procedure collected most of the heavy alpha emitters. At first, the counting was gross alpha counts; later alpha pulse height counting was done. One time they attempted to try to monitor for Pa-231 by urinalysis, but this turned out to be an exercise in futility. The solubility was so low that it could not be seen in the urine. They sent these urinalysis samples out to a contractor, but they really should have been taking and analyzing fecal samples. It appears that urinalysis for Pa-231 stated in 1955. By 1959, they were able to detect Pa-231. There was a gut feeling that actinium might be around, but cases did not readily show up. It may only be a problem for less than 6 people. If Pa-231 bioassay was done, it would have been done by sending samples out to contractors for analysis. Protactinium-231 and Th-230 were components in Cotter Concentrate, which was a byproduct of uranium milling of Belgium Congo ore. "Monazite sand" (thorium ore) was very low in Th-230, and 40–60 drums were the stored outside on the hillside. These thorium ore drums had a history of leaking and required periodic redrumming. "Cotter Concentrate" was different and was always stored inside at Mound.

At one point, there was a flap about actinium. Workers were doing some digging in a corridor and Ac-227 contamination was found. It appeared that previously radium had been irradiated and had produced actinium. Actinium is also a predecessor of Pu. Actinium is a "bad actor." Some 25 to 50 grams of Ra-226 came in when they were ready to make Ac-227. Sometimes Ac-227 sat around in refrigerators for a couple of years before it was realized that it was there.

Actinium is a weak beta emitter; it is hard to detect, and even harder to separate. If you weren't in an area where actinium was handled, you were not monitored. The only areas in SW Building where actinium monitoring might have been done were in the old radium caves and the new radium caves (SW-19, Old Cave) and (SW-22, New Cave). Some areas of R Building also had similar actinium exposure potential (R corridor – Room 111). Sometimes the only way it was determined that workers were being exposed to actinium was from environmental samples that detected it. It was routine to have contamination surveys show the presence of actinium.

When alpha pulse height analysis was first started, the techniques were not much different that they have been over the past 10 years or so. However, today, the recoveries are up and the backgrounds are down. There has never been a problem with determining solubilities. There was never anything out of the ordinary regarding capturing the source term, determining the activity, or the radioisotope being analyzed.

In R Building, there were large amounts of primarily Pu-238 contamination. There was also some Pu-239 contamination in R-140. In the early days, workers wore respirators on their hip. At some points, workers went in without their respirators. Later, workers had full face respirators donned when they entered any area when loose surface contamination was known or suspected. If a CAM went off, the workers would put on their respirators. If it was needed, HP could determine exposure from real time air samplers. If static air samplers were around, this helped. The CAMS, for the most part, worked quite well. The CAM would go off within 2 seconds, if there were a lot of contamination around. Sometimes the sensitivity of the CAMS was too sensitive, and they would alarm repetitively even in low contamination areas. It this case, the sensitivity was adjusted slightly upward so as to alarm at a more significant contamination level.

There were several processes that produced Bi-210 slugs in production reactors, including Bi-210, itself. The slugs were shipped to Mound for the extraction of polonium. The beta activity of 1 lambda of water from each cask was reported to be too high to count. Because of the quantity of bismuth processed, there are a number of contaminating isotopes that provided the potential for beta dose at Mound through the decommissioning and cleanup of polonium operations in 1971. One HP advised that they used gamma doses to develop ratios of what beta exposure might be expected. The issue of a high mysterious beta problem was discussed, but the HP thought that this was probably not work related, but instead was the result of natural uranium in the well water or other naturally occurring radionuclides.

A lot of radon gas was found in SW Building in the 1970–1980 timeframe especially when working in SW and adjacent areas. Radon was discovered in SW-140 when a high alpha sample was found. This area of SW-140 had been expanded to include an area for the handling of Cotter

Concentrate. Rad Safety set up grab samplers, pulled 10–15 ml air samples, and put the filter in a gross alpha counter. The health physics staff was amazed to find how much radon was there. Remedial actions were taken by drilling down into the concrete floor and putting a tube that was vented to a stack. Later, it was common to leave a spot sample once a month for analysis. In the labs, spot samples were taken twice a day, once in the morning and once later in the afternoon.

Radon and tritium exposure in the 1970s became a problem when it was thought that the Power Plant in the valley was sending up air that was carried by the wind to the Mound site area. Health physics personnel thought this was the cause. Later it was realized that the old radium cave was the origin of the radon exposure. The Old Cave had been used for some Ra-226 work.

Exposure to high-fired oxides was an issue of concern to the HP staff. It is hard to get these high-fired oxides into solution. Counting was done in an attempt to calculate the quantity, in pCi, that would be encountered in several of the operations where this might be a problem. Analysts would look at the records, noted the trends, and try to come up with body burden estimates. Since high-fired oxides have such low insolubility, they stay in the lungs and do not come out into the urine in high enough concentrations to be detected. If workers were in the area when the Pu oxides were heated to high degrees, then they had a potential for inhalation.

High-fired oxides were recognized as a problem as far back at the early 1960s at the time that Pu-238 was beginning to be handled and processed. In dealing with high-fired oxides, it is important to know the minimum detectable levels (MDAs) since different forms of high-fired oxides may have different MDAs. If exact MDAs were not known, it complicated being able to determine dose from high-fired oxides. With the advent of more powerful computers in the 1990s, the MDAs could be calculated. But in the early days, lack of knowledge of the backgrounds could mess up the determination of the MDA. There were rules on how high a background could be tolerated. When asked about problems with spikes with Pu high-fired oxides, one HP indicated that they tended not to worry much about it in the early bioassay program. If an incident was suspected, they would do more frequent sampling and health physics personnel would decide who should be followed, and if fecal sampling needed to be done. If fecal samples were taken, the analytical staff would be warned that fecal planchets were in the batches provided.

Plutonium high-fired oxides were handled in R Building, Room R-142. Workers were required to leave fecal samples when they started working in the area as a baseline and when they completed work and did not plan to return to that area. In high-fired oxide areas, routine fecal sampling was done at least twice a year. For special high-fired jobs, it was required to provide a fecal before and after the specific job. Some of this was still occurring as late as 3–4 years ago during recent D&D operations. A-line in Building 38 in Room 5A, which was in the basement, had some workers that had to be removed from work based on the specific tasks they had been doing. Some of the tasks that involved uptakes was removing ductwork and taking down the old conveyers. These parts had to be taken down and taped up in plastic bags. Workers were in full plastic suites and full-face respirators. One RCT remembered finding tools that had been left on top of the duct, which were covered with a lot of dust and when swiped, were found to be heavily contaminated.

One RCT didn't recall seeing any of his doses from Pu high-fired oxides until late in the 1990s. He had looked at 1989 dose data and found that it did not include dose from Pu high-fired oxides. Lung counts would have shown it, but they couldn't help in quantifying high-fired oxide dose. A dosimetrist from Fernald (previously a Mound worker who did the lung counting) ran the lung counter and he could see the signature but couldn't quantify it. It wasn't until the advent of the germanium detectors in the late 1990s that quantification of high-fired oxides was possible. Health physics personnel at Mound felt there was a population of Mound workers who were exposed to high-fired oxides. The ones most likely to receive dose to high-fired oxides were those in the Pu-238 programs. This was also true for workers who cleaned up facilities during the D&D phase. Monitoring regimens for high-fired oxides did not really come fully into being until the mid 1990s.

Large hard cover urinalysis logbooks were used to record urinalysis results. They were maintained by the HP Staff. Later, these data were entered on a computer mainframe. Then it became possible to choose samples, sum then up, and calculate means and high exposures for radioisotopes sampled. With this old system, it was necessary to type in the parameters to set up the computation, and put data into the appropriate bins. All along, there was concern that the data was being captured properly. About 1955, the computer system became old and the DOE people worried about the computer system crashing. It wasn't until 1993, that an interim computer system was put in place when money was made available for a brand new system. With the new system, it was then possible to calculate sigmas. Now it is possible to keep track of the last 20 background counts and the last 20 spikes and do an analysis with the package that came with the computer system.

In regard to reporting zero dose, when one HP was asked about whether it was common practice to record a dose just below MDA as zero or MDA or non detectable, he stated they usually recorded the exact count. If below MDA, they still used the exact count. When it was possible with more modern computers to do calculations on multiple samples, someone else would determine the MDA. It was easier to do this with long-lived radioisotopes. It was not as easy with Po-210, since it has a 138-day half-life. Most of this was picked up when counting environmental samples. Their requirements were not as low and would usually be run on chambers with higher backgrounds.

Fixed air samples were taken in front of the glove boxes and these air samples were picked up daily. The filters in R Building were changed daily. Starting in 1966, and continuing until 1975, workers worked in controlled areas, and health physics surveys were conducted in these controlled areas.

Field Radiological Control

Early on, the air monitoring program was not real effective. RCTs tried to determine the direction of air flow in the Building spaces and made an attempt to place the CAMs along a route that was believed to be most effective to spot elevated airborne contamination levels. Sometimes walls would be torn out to more favorably allow for exit of air so as to minimize personnel exposure. This continues to be a problem for the site even today, as buildings are gutted and demolished. This kind of problem has occurred for virtually every building in the complex increasing worker potential exposure.

In any lab where production work was ongoing, Mound workers were monitored by some means. This was particularly true for workers in the Pu-238 production areas. However, in the early days, no formal radiation work permit (RWP) process was in place. The health physics staff and line supervisors monitored the areas with significant exposure potential and instituted procedures to minimize dose when it was found to be needed. If a worker worked in an area where uptakes were possible, the routine urine bioassay was enforced. Building SW had its own independent radiation safety program where it was important to utilize procedures for tritium analysis. If they did run into Pu, then a different bioassay process was used.

Prior to the 1996 timeframe, there really was no formal work planning. Starting in 1996, both Job Specific Work Permits (SWPs) and Routine Radiation Work Permits (RWPs) were put into use. The Radiological Records Organization had a collection of permits that extend a number of years in the past. The farther you go back, the less complete the set of permits is.

Radiation Work Permits were written by a combination of the Radiological Engineer and the RCT Supervisor. The field radiation operations supervisors determined the personnel monitoring requirements and personnel protective equipment. During the 1994 to 1996 timeframe, the Internal Dosimetry Technical Basis Document was under development, so it was not available for reference by the field. The PPE was tied to the postings of the area and the type of activity. For example, you could enter a contamination area with shoe covers, gloves, and a lab coat if you were going in a room to change air samples. For repacking drums, a bubble suit was required. I suspect the field supervisors were using personal experience and the Wayne King (King 1995) document. There were sign-in sheets associated with RWPs.

The gamma spectroscopy lab processed mainly soil from remediation activities. Occasionally, the Radiological Control Organization would send smears, air samples, and other items for isotopic characterization by the lab. For example, large area smears were taken in the hood in R-140 and sent it to the laboratory for isotopic analysis. There have been gamma spectroscopy capabilities for quite some time. It was pointed out that this is a good source of information on soil concentrations during remediation for verification of isotopic characterizations and ratios. There was a separate environmental monitoring section. These samples actually went through radiochemistry.

Radiological Engineering included, in their standard procedures, the use of glove boxes, hoods, and negative pressure. When there was no ventilation in a building, maintenance personnel would build tents and use portable ventilation systems to get negative pressure in the tent. There were two failures in the engineering controls during 1994–1996. There was a glove box in R-140 that contained a furnace. In the adjacent room there was a window where the carbon arc equipment shot a beam through the window into the glove box in R-140. Contamination was found around the window, indicating leakage from the back of the R-140 glove box.

The second situation involved a tent constructed to open drums, and recover material from the drums. The tent was based on a three-zone concept, and had ventilation, which exhausted out the window of the building. There was a tritium sniffer that was used to measure tritium off gassing when drums were opened. Workers were required to wear bubble suits due to the tritium airborne potential. The radionuclides of concern in these drums were not limited to tritium. There were situations were tritium leaked through the walls of the tent. In addition, the Radiological Control Organization identified tritium outside the building under the area where the tent was being exhausted. This project also resulted in a contamination incident in R-Building while transporting smears to the R-Building count room. The hallway became contaminated with tritium. The smears had very high levels of tritium on them.

Egress monitoring was improved as a result of the union lawsuit sometime after 1996. While working in the field, workers were required to do their own self-survey out of areas, with a portable alpha meter (PAM). In the case of WD Building, there should also have been a self-survey for beta/gamma.

There was a difference of opinion on what constituted a "high contamination area" verses a "contamination area" between some Field Radiological Control Staff. Some of the Radiological Control staff assumed that you could apply an average contamination level over the room to determine which posting was necessary. Others felt that, if there was an uncontained location in a room greater than 2,000 dpm/cm^2, it should be posted as a high contamination area until it was decontaminated. The level of posting influenced the amount of personal protective equipment (PPE) and the kind of respiratory protection that was worn by each individual that entered into an area.

During the mid-1990s, a significant effort was underway to evaluate the air sampling program of the time. This included an air sampling needs analysis based on radionuclide inventory, and containment in particular rooms. In addition, airflow studies were completed to verify the positioning of both continuous air monitors, tritium monitors, and fixed air sample heads. This documentation, if located, would give a contemporary idea of radionuclides present during the mid-1990s.

There was a feeling among the workers that some workers would sometimes bypass radiation safety protocols. Also, Mound radiation safety personnel sometimes did not tell you that you were being exposed or what the results of the monitoring showed. Radiation safety personnel in general did make sure that individuals were so advised. Some bioassays and fecal samples were taken and then never analyzed. Technicians would sometimes not record the needed radiation monitoring data. This happened a lot until about 1995. The 1970s was the worst time for these problems.

Radon was a concern at Mound. They worked with Ra-226 in the Cave. During early operations, they used to perform Radon Breath Analysis. Radon was often a bad actor for inhalation dose. If thoron daughter products were around, they often would go gaseous and then back to particulates. When they took pipes out of the ground around RW Building, this caused resuspension of particulates. But doses were usually less than 10 mrem/month for workers.

They did study dose especially if it dealt with Ac-227. Dave Abbott was involved in these studies. By 1994–1995, workers in SW Building did begin to wear respirators. They were told that this was because of the potential for radon inhalation.

Internal Dosimetry

Radon dose was considered by workers to be "the joker in the deck" at Mound. In Building R and SW, radon exposure trumped all other dose contributions. It was pointed out that, if you took samples of the soil under R Building, you would really get a good idea of the extent of the radon exposure problem by the amount of Ra-226 you would find. Mound did have health physics personnel supervising the taking of core samples to monitor the radon problem, and these personnel were often in bubble suits.

A number of strange types of radionuclides were used at Mound. Some of these unusual radionuclides were: Sb-128, Sb-121, Bi-210, Ac-227, Pa-231, Th-232. Thorium-232 was a huge problem in legacy waste stored at Mound, especially when it came to leaking drums. These radionuclides were ubiquitous and moved all over the site and you would find them in the most unexpected places.

Mound had to do a lot of bioassays since the greatest exposure potential was internal dose. To ensure that Mound had the best techniques to do this, it was reported that Mound borrowed their procedures from Oak Ridge where these techniques were first developed and refined. One RCT felt that Mound perfected the techniques and adapted them to suit the bioassay needs at Mound.

If the Pu-238 got into your lungs, it was hard to detect since the high-fired oxides were very insoluble, and could not be detected in the urine or by using the lung counter. Lung counting for high-fired Pu-238 oxide, however, was no different than doing normal lung counts for Pu-238 at Mound. The lung counter could not differentiate between routine samples containing Pu-238 and samples containing high-fired Pu-238 oxide. During the 1980s, if positive readings were detected on the lung counter, it usually meant that a worker had received a dose of at least 40 rem or so. This detection level improved greatly with the introduction of more sensitive lung counters in the 1990s.

Plutonium was hard to detect in the early days, when it was used most. It was easy, however, to detect H-3. The old scintillation counters were sensitive enough to detect tritium. With Pu-238 on the lung counters, there was not as good a signature. All you could do is detect if it was present, but you could not quantify it.

Solubilities were all over the place. Once radionuclides got into the lung, you could see many of them by using the alpha spectrometers and chest counters. High-fired oxides, on the other hand, were so insoluble, that they could not be detected after an uptake. Dosimetry personnel were able to pick up the weak 40 kVp x-ray. There was a lot of work in the 1960s and 1970s to take current measurements, and try to infer what the update might have been in the early days. They worked with phantoms, and the chest counters, to attempt to get the data needed for back extrapolation. Dosimetry personnel tried to correct for the person's geometry, i.e., whether the worker was thin or heavy set. Some of the air sampling was farmed out to contractors. Mound was responsible for making sure it was done correctly and that the data was quality data and received on planned schedules.

Nose wipes were used to try to detect any Pu uptakes. Fecal samples were used at Mound, at least as early as 1995, for the detection of the high-fired oxides. High-fired oxide sampling and tritium sampling were done on a more frequent basis, within hours of exposure, when such exposures were suspected.

Fecal samples were only done if health physics personnel became interested in possible uptakes of significance. Urine sampling was done routinely on a monthly basis. When working in glove boxes, in situations where gloves were punctured, these workers were referred to medical where medical excision of wounds was considered, if needed. Whole body count (WBC) results were placed in the individual's personal medical record.

The high-fired oxides are so insoluble that, for purposes of detection, they seem to come out of the lung very slowly. The practice was to take nose wipes in those operations involving any Pu exposures, including high-fired Pu oxides. Radiation safety personnel did do checks to see if personnel were providing nose swipes and cautioned those who were not to provide them. Periodic urine samples were taken on workers who were involved in operations in the Pu areas.

The lung counter was able to detect a wide spectrum of gamma energies down to about 40 keV. The lung counter, however, had difficulty sometimes detecting the very low energy gamma associated with Pu-238.

Most workers were good about providing urine samples when it was called for. The health physics staff made sure that the urine samples were turned in. Most workers in production area knew this was for their own good, and health physics staff did their best to keep on top of this. Urine samples were given twice weekly in the 1970s for Po-210 and for H-3.

Tritium (H-3) recovery from recycled materials became an important operation at Mound. This process was done by heating the materials under a vacuum. Metal hydrides were used in the release of the H-3. The released H-3 was collected in such things as mole sieve and activated charcoal, and then purified. The work was done in stainless steel glove boxes. In the early years, there was a greater potential for the H-3 to get out. There was good room monitoring and this worked well. There were multiple "drops" which was a way to collect the air. It wasn't until the 1970s, that a double containment system was developed and used. There were not only filters in each glovebox exhaust air vents, but all the glovebox exhaust air passed through a second room exhaust air filter bank. There was no apparent problem with blow back. It was rare if the differential between the room and the fume hoods failed to function properly. If it did, air would come pouring through the cracks.

When it came to inhalation dose in the early days and even up until the 1960s workers were given a 500 mrem exemption dose. If it was less than this, health physics personnel often did not record it at all. There were no alpha CAMS in the1950s. The air sample results from exposure to these particulates were known. They did have work level monitors. In the 1960s, a lot of this work was done in the Old Cave and the New Cave areas.

By the 1980s, the MDA for Pu was getting better. Lots of workers worked with metal tritides while doing catalyst reactions in gloveboxes. Tritides were handled in SW, R, and T Buildings. Tritides must be heated up to 800°C to disassociate the H-3. Uranium tritides, when exposed to air, give off H-3. Lithium tritides result in the production of HTO. These exposures occurred while workers were passing things in and out of the gloveboxes or fume hoods. Uranium tritides would react with the moisture in the air. The tritides were considered to be "bad characters." One of the health physicists didn't have any good answers on whether these tritides were being monitored or not. The problem is you just can't detect them if they are insoluble. This is, of course, true of the Pu high-fired oxides as well. The Mound internal dose TBD (TBD-0010-5) does not seem to do an adequate job of addressing potential high doses from uptakes of these insoluble tritides and high-fired oxides.

Exposure to H-3 was common at Mound; so common that in the early days the doses were not as likely to be closely followed. Workers often accepted working around H-3 just as part of doing their job. In time, the health physics staff became stricter. Research was done in cooperation with staff from LANL. LANL was handling H-3 in their fume hoods. Mound handled the H-3 in stainless steel enclosures.

There were H-3 exposures in SW-208. The recovery system caught most of the H-3, but there was an incident in the late 1980. Two individuals received significant tritium doses. These doses were usually received as they were passing things in and out of the glove boxes. Instances of high doses, such as these, occurred as consequences of accident situations in which large quantities of tritium were suddenly released. This contrasts with chronic exposures occurring during normal during daily activities.

There were three cases of H-3 exposure reported in one weekend, on one occasion. Tritium (H-3) was ubiquitous, and was found in many areas. There were small accidents, like this, all the time, with a few big ones from time to time. Constant sampling was done to detect potential H-3 exposure. These usually confirmed low levels of H-3 present. So if you worked at Mound for any length of time in H-3 areas, you would likely have received low level chronic H-3 exposure.

The respirators were not very effective in the early days. If uptakes were expected, then bubble suits were worn. Bubble suits were used for planned maintenance operations. The operations folks didn't have much input into the decision to wear bubble suits. Respirators were particulate filters and, as such, were not designed to trap gaseous materials like HTO and H-3.

In the Mound Occupational Internal Dosimetry TBD (Millard 2004), it was noted that in Table 5B-1 on page 51 that Room R-128 should have been listed as a location where Po-210 as handled. Another example was pointed out where the discussion of Room R-142 did not mention H-3. It was pointed out that the Wayne King report (King 1995) was very effective in overviewing total inventories, but may not always have the needed specific information on the exact locations of specific radionuclide use locations. It was reported that radiation monitoring personnel picked up millions of counts that came out of the cracks in the floor in Room R-218. In the King report (King 1995), there was no mention that there was a radium/radon problem. The cave was under the foundation of the Building R and Building SW complex. Under R and SW Buildings, radiation monitoring personnel found 19,000 dpm down in the manholes. These manholes were infrastructure utility manholes located outside R and SW buildings. This was in the late 1980s. They made the measurements for radon using gross alpha counters. Apparently, there was a water leak, it seeped through the floors, and they were able to detect high radon contamination levels.

It wasn't until the 1990s that it was realized that radon was a big player in internal dose. Radon sampling was not performed in the 1960s and 1970s. Until the 1990s, it was thought that radon was just part of natural airborne radon elevated, during times of inversions, when air was trapped closer to the ground. One internal dosimetrist had personal experience with the radon in R Building. The fume hood was not always closed. Wall samplers would not detect that. The radon decayed out before it got to the wall samplers. They counted the filter paper from the air sampler with a scintillation detector, and often got millions of counts. This was especially a problem when the fume hoods were left open, were sucking air out of the room, and creating a negative air pressure void that the radon was pulled into. When it was discovered that radon was around, radiation safety personnel would place proportional counters over the cracks, while the fume hoods were operating and creating a negative air pressure. This is when they found that large quantities of radon and thoron were being sucked from the cracks into the building, especially in basement areas. It was discovered, that in one case, an office was right over this area of high radon levels and corrective measures were taken to reestablish the office to a new location.

The workers put too much faith in the fact that they were wearing their respirators. Some workers didn't submit urine samples when they were supposed to. Not only were some urine sample submittals not made, but also the bioassay group did too little monitoring and for too few isotopes. Mound was a research facility under a code of silence that transcended good common sense. The dosimetry group most often made the calls on frequency of monitoring, along with input from RadCon data. The dosimetry group was not always willingly to accept requests by the worker for additional monitoring. This did not foster an environment for open honest exchange. It became a ripping point of contention between the Site and the Union workers at one point. It was always a five-alarm issue when a request for additional monitoring came up. The frequency also for the monitoring program was so haphazard. There were times when catching the discharge of certain key isotopes may simply have gone undetected. The underlying causes were (1) workers were not monitored, so they would have been stripped out by the labs processing for the requested isotopes; (2) the frequency was not monitored properly; and (3) no one knew that certain isotopes could be a key contributor and the area in question had only the elite few lab scientist that would have been even aware of such potential exposure or uptake. Researches often kept such exposure potential concealed due to the classification nature of its use and keep that information under lock and key. Hence, workers were potentially exposed without the knowledge that certain radionuclides were present.

There appeared to be two separate sets of books on bioassay results at Mound, one set of urine bioassay data by the contractor and another by urine bioassays done on the Mound site. The contactor results took longer to come back. At one point, there was no process at Mound to monitor for Ac-227 and samples had to be sent out to the University for analysis. These dual processes were not good and led to a lot of misinformation. A study was done on a list of samples that had been collected over a 3-year period to review problems in this process. Some of the samples were stacked elbow high. It almost led to a Class A or Class B investigation, but Jack Clark worked out corrective measures that satisfied preliminary inquiries by DOE on this. Thus, it was evident that Mound did not have a good technical process for documenting Ac-227 exposure. There were a lot of errors in the process that could result in false positives. It was also hard to detect the thoron daughters of actinium.

From one interviewee's experience, starting around 2001, urine bioassay analyses were being done for mixed alpha (annual, 24 hour sample), which encompassed monitoring for americium, plutonium, uranium, thorium and tritium (twice monthly). Monitoring requirements evolved constantly as technology and state of the art advanced.

Lunches were often eaten in the H-3 lab, but not in the Pu labs.

The internal dosimetrists that were interviewed were asked to comment on the following statement from the Mound Internal Dose TBD (Millard 2004), Section 5D.7 on page 64:

> *Information on the location and use of radioactive gases was primarily only available for ^{222}Rn (radon) from 1979 to present. Very limited information was available for ^{220}Rn (thoron) and ^{219}Rn (actinon), and measurements conducted in the underground tunnel in 1979 confirmed the presence of ^{222}Rn at 88,000 pCi/L, ^{220}Rn at 28,000 pCi/L, and ^{219}Rn at 640,000 pCi/L. These concentrations clearly indicate the potential for indoor worker exposure to these inert radioactive gases…. Uncertainty from lack of radioactive gas information could underestimate worker doses by a factor of at least 10. However, use of an assumed GSD of 3 compensated for this uncertainty.*

The two internal dosimetrist interviewees felt that this was not sufficient to develop a claimant favorable radon dose for those workers working in R and SW Buildings. One of the internal dosimetrist interviewees said it was "bias" and another operations interviewee used the term "swag", since it seemed too generic to work in areas of high radon exposure.

In the Mound Occupational Internal Dosimetry TBD (Millard 2004) in Section 5.3.2.1 on page 29 in the second paragraph it was stated the following:

> *A DOE radon study was conducted from December 12 to 15, 1989, to measure radon in various Mound buildings (UNC Geotech 1990). The majority of the buildings had radon concentrations below 1.0 pCi L^{-1} ^{222}Rn, except SW and Old SD buildings.*

One internal dosimetry interviewee felt that this was not valid. There were more areas and buildings than just SW. In the Old SD buildings, work going on in hood would draw air and create a negative pressure, and pull the radon right out of the ground. 1984 was the only year that had an active program to try to alleviate radon exposure for Mound workers.

It was reported by one health physicist interviewee that they would assume that an individual was there at the point of the highest hot spot for air and water based on sampling. Then they would calculate the individual's dose. The calculated dose was always below even the EPA guidelines. Some Pb-210 was found on roofs, which likely was the result of radon decaying down to lead. Also, DP&L Hutchins stations set off alarms at Mound. The radon off the airborne coal soot was likely responsible. This was seen even more in the 1990s to present, with the new sophisticated low level detectors. Mound had some environmental fixed station monitors, but in the early days these were not very sophisticated.

There are known cases of tritium uptakes from organically bound tritium and/or stable metal tritides. Terry McConville published a paper on determining the dose to three workers from uptakes of this material (McConville and Woods 1995). It pointed out the following:

> *Tritium in the form of tritide particles presents a peculiar problem for the calculation of internal dose. Standard calculations indicate that just a few 3 to 5 micron sized particles appears to lead to a very high dose.*

There were approximately sixty individuals chelated at Mound. There were also others with significant uptakes that were not offered chelation therapy. Dr. Reagan was responsible for administering the DTPA. There is a list of individuals who were chelated, available through the Internal Dosimetry department.

An interviewee reported that, in brief conversations with the individual who ran the lung counter, that a positive lung count during her tenure had not been seen. The exception was a former worker who was involved in response to many incidents. The lung counter operator and the interviewee were both surprised when they saw the positive Am-241 in this individual's lung count. Due to the calibration, the result obtained was more of a qualitative than quantitative value. Incidentally, the initial *in vivo* counts of the individuals involved in the glove box explosion at Mound were negative.

Internal dose was modified, as new models were developed by the ICRP. Initially, internal dose was tracked in body burdens per ICRP 2. A second set of calculations was performed with the change to Annual Effective Dose Equivalents (AEDE). Finally, doses were calculated in terms of Committed Effective Dose Equivalent (CEDE). If the bioassay samples were less than the minimum detectable concentration, the dose was assigned as zero.

In the Mound Occupational Internal Dosimetry TBD (Millard 2004) in Section 5.3.1.4 on page 23 of 65, the following statement was made: "In general, Pu-238 compounds are more soluble than Pu-239 due to greater specific activity and therefore a greater energetic alpha recoil for Pu-238." One Mound internal dosimetrist did not agree with this statement. In fact it was a flat out "No." He points out that high-fired Pu-238 remains very insoluble. He said there is no basis for that statement.

In the Mound Occupational Internal Dosimetry TBD (Millard 2004) in Section 5.3.1.5 on page 24, it is stated that, "A particle size of 5 μm should be assumed for plutonium, and all other alpha emitters in the R Building at Mound in the absence of specific information on actual particle size distributions (King 1995)." One of the internal dosimetrists interviewed did not agree with this. He stated that they had all kinds of particle sizes in R Building. He felt this needed a better basis to back this up. He pointed out that, when working with some heat source fuel, particle sizes of 50–250 μm are possible. Gel processes and torch processes also produced higher micron particle sizes. When the "fines" got through the filters, they also had larger particle sizes.

The Mound internal dosimetrist also pointed out that pocket ionization chambers were still used after 1966, especially when working with lots of materials to keep track of exposure levels. He felt the statement on in the Mound Occupational External Dosimetry TBD (Proctor and Algutifan 2004) at the beginning of Section 6.1.3.1 on page 10 should be modified to reflect this.

The same Mound dosimetrist found fault with another statement made it the Mound Occupational External Dosimetry TBD (Proctor and Algutifan 2004), in Section 6.6.3.1 on page 37. It was stated in the second paragraph that:

> *For the manufacture of radioisotope thermoelectric generators (RTGs) for spacecraft, Mound selectively used plutonium and* ^{18}O*, the highest atomic mass of oxygen, to minimize neutron emissions from the RTGs.*

Mound later found by doing in rate kinetic range studies that O-16 was more effective in minimizing neutron emissions. Mound, therefore, stopped using the process of using O-18 to prevent the alpha/neutron reaction. Don Plymel did the studies and found it was correct to minimize neutrons by using O-16 but not O-18. The internal dosimetrist pointed out that the O-18 (and O-17) content were reduced to lower the (alpha, neutron) production reaction. This is a basic nuclear physics truth and was not something revealed by Mound studies. The internal dosimetrist further stated that this statement in the Mound Occupational Environmental Dose TBD (Hysong et al. 2004) is incorrect. The Mound studies mentioned that O-18 was used to determine exchange rate constants, and to facilitate the plutonium O-16 fuel production. The large neutron increase using O-18 was just easier to measure than the somewhat lower decrease attainable by removing the O-18. The concentration of O-18 in natural oxygen is ~0.2% (2000ppm). So neutron reduction, by removing 0.2%, is much smaller than a neutron increase by using high concentrations (>50%) of O-18 in the mentioned study.

Contamination Control

WD Building was the worst facility at the Mound site when it came to potential for radiation exposure. Radiological Control Technicians did monitor this facility carefully. Workers drummed waste with different kinds of chemicals to remove alpha and beta contaminants from the wastewater from contaminated building areas such as in Buildings R, T, WD and PP. Off gassing of the drums in the basement was an operation that led to personnel exposure. There were only 8 workers and two RCTs in the building. The lunchroom was in the middle of the production area. Personnel were instructed and signs were posted to monitor their hand, feet and clothing prior to entering the lunchroom. For monitoring, the radiation safety personnel only had an alpha meter and used hand and foot survey meters. It was determined by previous surveys and smears that there was no beta or gamma emitting contaminants that egressed from the building. In the late 1980s, there was one room (WD-A-10) that had an old glovebox that was heavily contaminated. The floors and walls and other hoods (anything in that room) were highly contaminated and they painted over the floors to fix the contaminants. This was only done after washing down operations could not bring levels down to acceptable standards. Eventually, after successful fixing, personnel sometimes did not wear a respirator when entering this room. These area, however, were revisited from time to time to ensure that no fixed contaminants had bled through the painted surfaces. Workers wore disposable blue paper suits. They did change and shower as they left the area.

There was a lot of loose Pu-238 contamination in Buildings 38, and in SM and PP Buildings. Workers were monitored and if they received an uptake or were thought to have received an uptake, they were asked to provide a urine sample and were put on restriction until their urine sample could be evaluated. CAMs and other instruments were used to monitor potential exposures and the workers wore half-face respirators. One RCT pointed out that half-face respirators were not worn they were dawned around the neck for potential emergency egress only. Half-face masks were not considered acceptable PPE in my days from 1990 to present, only full face were worn as official PPE. This was true even of workers that were working outside if they were working in an area where uptakes might occur. Lynn Knowles, Reeves Dudley and Bob Michigan were the ones that set up the radiation work permits (RWPs).

Contamination at Mound was first reported in cpm. It should have been reported as dpm. After about 5–6 years of using cpm, it was decided to try to convert the cpm reading to dpm. The early portable alpha meter read out in cpm. Since the sensitivity of the instrument is not known, there may have been some error in this conversion process, and the accuracy of the early cpm readings may be in question. They initially worked to keep contamination below 100 cpm, which is about equivalent to 200 dpm.

When property was to be released, the MDAs were not always used as the basis for release. Also the calibration of some of the radiation monitoring equipment was not always well documented. This was particularly true in the 1950s and 1960s. Stacks were not well monitored. Some contamination was found close to the golf course. WD Building discharged and contributed to some ground seepage into the river. This, however, was not the only such likely source. A similar problem existed from liquid seepage emanating from the SM/PP Hill area, Buildings 38 or PP, and SM Buildings. Also it could not be ruled out that the R/SW/T complex could have been a contributor to the golf course problem but it was SM/PP that was the closest to the golf course area with alpha particulate production work being carried on there. There are documented plumes in the 1970 time frame that would have been the likely contributor to that area's contamination problem from that group of building on site. Alpha contamination was the issue.

It was discovered at the golf course area as well as what was referred to as the new property. This new property area was a 40-acre plot purchased in the 1970s or early 1980s with justification being that this land was lightly contaminated due to production fall out. The golf course contamination may not have been well documented. The land purchase adjacent to the golf course is most likely a matter of record. That land has recently been released to the public in the site closure process.

Much of the contamination on site, that arises now or arose previously, arises from decontamination and decommissioning (D&D) activities, and is the consequence of redruming operations. Thoron was corrosive, and ate though the barriers. The waste storage drums started to leak. The contamination was not the result of any massive release. These drums were left out in the rain, and eventually began to corrode. Tons of Cotter Concentrate was involved. Mound finally built a special wooden building to house this Cotter Concentrate. The building was sort of like a gigantic coal bin like the ones that were used years ago in personal residences that had coal-burning furnaces. There was one incident where a drum leaked while sitting on a railroad car, which had come from WD waste disposal operations. Surveys showed that the radionuclides involved were all alpha or beta emitters.

Mound at one point, had 3000 drums of Cotter Concentrate stored on site. They finally got rid of these and shipped them off to Nevada Test Site (NTS) for burial. Even after these shipments, there was some soil contamination. Tritium waste was also stored in the basement of SW Building in a separate room to allow them to off gas. Building WD also had some drum storage. At one point, these drums started to bulge on the top and it was decided to monitor them regularly with a tritium sniffer.

Building 38's A-lines through F-Lines had some high readings during and after production work, but the front gloveport side generally was not contaminated. The backside of the lines, however, was generally much more contaminated. The readings were up in the millions of dpm from Pu-238 contamination. In the 1985 timeframe, Mound brought in Ken Scrable from Lowell University. Dr. Scrable reviewed Mounds internal dose evaluation program, air sampling method for Pu, Mound's HPO training program and other aspects of the HPO organization. Dr Scrable recommended to Mound that they go beyond the mere revision of the Mound body burden estimates, to one of calculating radiation dose to specific organs such as lung, liver, and bone. Mound's analysis of Pu in the urine was found to be lower than most other DOE labs or facilities. Dr Scrable agreed that Mound was underestimating the amount of Pu in the urine.

In the basement of PP Building, one interviewee mentioned that he had been involved in taking hot spots out of the walls with a jackhammer. They would then have to patch up the holes with filler material. This process had the potential to create a lot of radiologically hot dust. The interviewee asked the radiation safety personnel if he should be wearing a mask for this evolution and was told that it was not necessary; that contamination levels were so low that they were below the minimum detectable level (MDA). They did wear blue paper suits and did shower and change when they left the job.

Additional areas of contamination occurred in WD Building where there were strange gas smells, but this work was classified. It was hard to do a good job of quantifying the contamination levels there. There was a lot of waxing done in R Building. In 1983, while taking trash out, some of the material had to be chopped up and activity got on the mops. During clean up, the contamination ended up on floors and this was waxed over to fix it. Protactinium and actinium were also in the WD Building, so they had to do a lot of painting and waxing in the 1980s.

External Dosimetry

In the early days, there was worry about properly assessing beta dose for workers who fabricated the Po-210 nuclear triggers. To try to assess this, health physics personnel would evaporate down a urine sample on a planchet. Since Po-210 has a spontaneous fission, the analysis was done by gross alpha counting. Urinalysis results in the hundreds or even thousands were not of particular concern in these early days. When shipments came in, health physics personnel had radiation meters they used to monitor for beta exposure. One health physicist interviewed recalls a big tank, like a swimming pool, in which in the incoming casks were stored. They used manipulators and tongs to handle the casks.

In terms of monitoring processes in the early days, pocket ionization chambers (PICs or pencil dosimeters) were used to monitor for gamma and x-ray dose. When the PICs started to be phased out, the readings from film badges became the official record of dose. When the plastic film badge began to be used, it was then possible to differentiate beta and different energy neutrons. Mound used Room Monitors and PAC Dome proportional counters to monitor spaces. Liquid scintillation came in during the mid-1970s.

In the early days, there was not much concern about extremity exposure. Most doses, close in, were monitored by pocket dosimeters. External readings were taken in the glovebox area when operations were underway. This was done a couple times a week. When working with SNAP, there was often a high dose rate, so the gloveboxes were posted to indicate possible exposure to gamma and neutrons. Health physics personnel would watch what workers were doing to make sure that the workers were not doing anything wrong. When a higher level was detected, additional measurements were made in front of the gloveboxes and health physics personnel checked for any elevated neutron levels. As the neutron sources started to get bigger, the use of Plexiglas was instituted. Radiation safety personnel used PNC-1s and PNC-45s to monitor at the surface of the gloveboxes. Around the gloveboxes was the highest area of exposure.

Beta was not much of a problem at Mound. The most likely beta sources at Mound were Sr-90 and Co-60 and Cs-137. There was no air monitoring for beta. 99% of air monitoring was done for alpha. There may have been some beta work in Building 59 that was known at the Star Wars Building near Post 5. Work was done in glove boxes, but what they did was on a need-to-know basis only. This work was conducted in the late 1980s. In the high-fired oxide waste farms, it was reported that contamination crept up the walls. There was monitoring by RCTs and they did find contamination on the walls. The RCTs did not have information on the level of this contamination. The furnace was the worst contributor to dose.

When asked about a mysterious beta exposure problem that is sometime heard about, one RCT indicated that it might have come from Sr-90. Strontium-90 has a high enough energy beta that it can be distinguished from H-3.

There were some neutron exposures in R Building, so they had to control the flux carefully. NTA film was used and it could not detect below 100 mrem. There were also byproducts in Building 38 (neutron dose) and the old SM Building. The health physics staff was understaffed, but those present were good technicians. It was just hard for only a few RCTs to cover all the areas adequately. In the early days, very few people were formally trained in health physics. They just learned it on the job as they assisted in the monitoring efforts.

Neutron monitoring was done with neutron balls. Calcium was used to moderate the neutrons so that it was everywhere in the spaces where neutron heat sources were handled and produced. Some of the labs in Building 38 and in WD Building had pump lines in them that had to be checked with a Fiddler, and scans were done on boxes before they were shipped out.

There was a correction process used for NTA film due to its under-response to neutrons. They took a look at the neutron/gamma ratios and tried to correct the neutron dose based on the gamma photon dose. Ron Daily and Mike Hall did a lot of studies on this and they discussed their findings with the dosimetry group leader. Although the data was developed, the women, who ran the dosimetry group, wrote this all down. If it didn't appear that workers were exceeding the regulatory limits, nothing much was done with this use of neutron/gamma ratios. Jack Fix was asked to come into to look into it. After this visit, Plexiglas was installed on the hoods. The Plexiglas and the changes in the dimensions of the rooms resulted in changes in these neutron/gamma ratios and the ratios corrections came more into use. The Plexiglas caused thermalization of the neutrons. Mark Murphy from Hanford visited and assisted Mound RCTs in doing neutron spectral analysis for doses associated with: (1) the RCTs, (2) the F line work, and (3) the Building 35 Calibration Facility. They found good agreement on efforts to verify the dose received from californium.

Control of radiation sources used for calibration of radiation monitors was poorly enforced in the early days. The need for improved equipment technology was always a problem and hinged on the availability of funding for updated equipment.

Some areas presented a greater potential for external dose. There was exposure from sources that were sitting out in air and not shielded. The SNAP sources had a lot of thermal energy. The health physics personnel would take dose rates at differing distances. Ra-226, used in the production of actinium in the early days, was shipped in casks. Such doses did show up on the early pocket dosimeters used. When they shipped in the Pu-238 raw material they found that the Pu-238 was a heat source. They also had large calibration sources that were used to calibrate instruments. Radium-226 calibrations sources were common. Most workers, however, got small doses from this. Workers wore their film badges at mid chest. In the early days workers often did not wear their film badge. This was not true for PP Building and SM Building where close in work made it essential that workers wear their film badge. Workers often donned lead aprons during high exposure jobs. Most work in R Building, however, was not close in work and the potential for external exposure was less. Beta emitters were few and far between.

Dosimetry readings may have been significantly lower in some work areas than the actual doses being received by the workers. In any lab that had direct frontal exposures, such as when facing gloveboxes or hoods, there were angular dependence problems for situations were the source of exposure was no longer a point source. For instance, in PP-13 Building there were 18 gloveboxes in a line. Often, there was work ongoing in areas across the line from the gloveboxes or hoods on countertops, where workers were faced away from the gloveboxes, and were they were working on their paperwork. In this case, the geometry would have individuals receiving dose from behind, or to the side, when the film badge was worn on the chest on the front of the body. Workers generally had their hands in the gloves of the gloveboxes only about 10% of the time, and spent the other 90% of the time working on tasks on countertops with their backs to the gloveboxes. In the tritium areas, for the most part, this was not a problem.

Building 45 was a neutron flux measurement facility. A leaker in that facility, on one occasion had to be re-encapsulated. Non-Destructive Testing (NDT) was used to verify the quality of the weld. Sometimes Ir-192 sources were used and were handled and used correctly.

One RCT offered that even into the 1980s and 1990s, workers would sometimes work without their film badges. This was often due to badge storage location and being hassled by the plant dosimetry team and site administrative staff. Storage locations were not conducive to work locations and badges were not policed by RCTs to enter an area, even though the RWP have it listed and workers may have responded yes that they planned to wear their film badge.

Environmental Monitoring

Mound did Annual Environmental Reports and provided inputs into the Annual Site Environmental Reports (ASER), which were initiated in the mid to late 1980s.

Mound stacks are primarily on the west side of Mound. One bank of stacks took their air from R Building and T Building, which was just across the street. Buildings SM/PP, SW and B also had stacks.

In regard to stack monitoring, EPA never came to the Mound site until about 1986–1987. Finally, the Defense Nuclear Facilities Safety Board (DNFSB) came out and decided that a $30,000 probe should be installed in the stacks. One week later, the probe was installed. In the early 1960s in the SM Building, and later in WD-A building in the early 1970s, single stack monitors were used. Usually there were to absolute filter banks and a dust stop filter bank in front of the absolute filter banks. From the early 1980s, the stacks had multiple air sampling monitors that ensured that the filter banks were working effectively in reducing environmental releases. Therefore, from this time forward, there were no workers who would have gotten a significant exposure from any of the stack plumes. Monitoring personnel did find “stuff” (i.e., contaminants) though at the bottom of the stacks.

There was some run-off of tritium from the Mound site that flowed over the hill and into the woods. It was resolved by flooding the area with water so that the tritium seeped down below the water table. When monitored, it was later found to be below the EPA ground water standard.

Environmental monitoring personnel went off site in the Middletown area of Dayton and Miamisburg Park areas and they found some Pu-238. From a Pu study in 1974 that looked at water samples from the canal, it was determined that Pu-238 did reach there, and soil samples also showed the presence of Pu-238. They decided to cover some of the river area bottom with silk to try to keep the contamination stabilized at the Miami River bottom. They also did sampling in the Ohio River. Although no longer a flowing water canal, samples were also taken in the dried up Miami-Erie Canal bed. The health effects of all this were nil, but this was a seminal point in the Mound environmental program. From that point forward, Mound constructed retention basins to hold the water until contaminants settled out. The water was held in the basin until it met environmental release criteria to ensure that contaminants did not get off site. Air monitoring stations were established on the Mound site and in the community surrounding the Mound site. They used flow proportional samplers to collect hourly samples. CAMs and Bubblers were used. They established an inner ring for air sampling and an outer ring for sampling. Gamma surveys done off site were rare, and were usually done only if an accident had occurred. Health physics staff did do some gamma surveying inside the fence.

It has been reported that environmental samples were often collected. They were either duplicated or spilt in half to allow for duplicate sampling, and set aside with the intent to have them analyzed. Then later, sometimes years later, it would be discovered that these samples were still there in the sample collection area and had never been analyzed. RadCon staff did take their job seriously, but even then, some analysis did not get done. One health physicist said he had faith in the quality of the data coming from sample analysis, and he never saw anyone try to purposely suppress data. He stated that Mound alpha procedures were the best in the country. Since Am is an alpha emitter, it could be detected by the alpha pulse height analyzer, so that you could see it easily. This was also true for Pu, U and Th.

Mound still has responsibility for the Dayton area environmental sampling program, but its all remediation work at present. From the 1970s until present, annual environmental reports have been published and were/are made available to the public and interested environmental groups. During the 1970s until 2003, Mound held annual public community meetings to discuss the annual environmental reports and to answer any questions. To further alleviate public concern, DOE asked the Army Corps of Engineers to set up an independent air and soil monitoring system that is still ongoing to the present.

One internal dosimetrist said he disagreed with the statement in the Mound Occupational Environmental Dose TDB (Hysong et al. 2004) in Section 4.2.1 on page 19 of 113 that: "Consequently, the offsite data cannot be used to infer onsite airborne radionuclide concentrations." Also on page 20 of 113, he did not agree that it was claimant favorable to do the following:

> *For years in which the air monitoring data were unavailable (prior to 1971) and effluent data was available, empirically derived onsite atmospheric dispersion factors (plutonium, polonium particulars and hydrogen gas/vapor χ/Qs were used to estimate the intake air concentrations.*

He stated that he did not believe that this could be justified. He offered that a better way was to use inventory reports to see the ups and downs, when you are trying to derive a concentration. You could determine the average, and do a log normal plot to get the highest dose atmospheric dispersion factors. This is still not enough, and in accident situations you should use the 99th percentile, and even that may not be legitimate.

Miamisburg Environment, Safety and Health (MESH) activists were against the way Mound was doing their off site assessment. They claimed the air settled down to the ground causing more deposit of airborne radionuclides on the ground. So what was released came down to ground level. But Mound did sampling on cars in the parking lot and on people there, and found very few positive readings. It was pointed out that you might see something, if there had been a recent resuspension event on Mound site.

In the Mound Occupational Environmental Dosimetry TBD (Hysong et al. 2004) in Section 4.2.1 on page 23 of 113, the following statement was made:

> *Polonium production and research at Mound were discontinued in the early 1970s (DOE 1993b). Polonium effluent discharge data are available only for 1953, 1973 and 1974; as a result, the ratio of ^{210}Po to ^{238}Pu observed in environmental air samples has been used to infer the ^{210}Po effluent release rate from 1967 through 1979.*

It was pointed later in the text on page 23 of 113 that "…the 1974 polonium effluent data and air monitoring results shown in Table 4-16 were not used in the χ/Q derivation for polonium."

In regard to HTO release rate from the stacks at Mound, the Mound Occupational Environmental Dose TBD (Hysong et al. 2004) at the top of page 27 states:

> *For HTO, the data from 1971 through 2001 are based on the medium, onsite annual environmental air sampling results. Beginning in 1959-1970, the data are based on reported tritium effluent source terms (Table 4-15) combined with derived atmospheric dispersion factor derived for tritium in Table 4-16 to infer onsite environmental concentrations. From 1951 through 1958, it is assumed that the HTO release rate decreased 10% each year from that for 1959 (31,527 Ci/yr). From 1954 through 1958, the HTO annual effluent source terms were combined with derived atmospheric dispersion factor for tritium to infer onsite median environmental concentrations.*

One Mound internal dosimetrist took issue the 10% each year for the HTO release rate correction factor. He felt that the 10% correction factor was not a sufficient adjustment and that it should be reviewed to incorporate a percentage greater than 10%. He pointed out that this was based upon only three data points for effluents out of the stacks. The 10% factor in environmental concentrations is a decrease going backwards in time from 1958, or a corresponding increased amount going forward in time from 1954.

Radiation Waste and Decontamination and Decommissioning

DP originally had responsibility for the site. EM later assumed management responsibility at Mound for D&D but this is currently transitioning to LM in 2006 even though EM is still providing the funding until 2007...

Up until April 30, 2006, there were two DOE Facility representatives. The Miamisburg Closure Project (MCP) was one of these and the ES&H organization was the other. As of May 1, 2006, all offices were transitioned into one legacy management office under management control of LM.

A lot of repackaging of waste started in 1983, when it was decided to get rid of old legacy waste that had built up over the years. In the restoration process, they started seeing gold and antimony, and it was not clear from where this was coming. A lot of this odd stuff was from the Mound research applications.

When handling waste in WD and SW buildings, workers used bubble suits. The health physics staff did a good job of monitoring these operations.

There are records of Ac-227 coming in. An exhaustive survey of records was completed, and it was determined that Ac-227 could, indeed, be accounted for as leaving Mound. This was the basis for abandoning Mound's plans to robotically demolish SW-19, "Old Cave."

In SW Building, reservoirs were dismantled, and in SW-19 they worked on the components and dismantled the whole package. There was some experimental work with Pu-239. These experiments were small, but sometimes involved whole weapons, as opposed to just the reservoirs.

The total accumulative dose for D&D workers over the last few years is 5 rem or less. 85% of this dose is internal dose.

Officially, all production work was to have stopped at Mound by 1994, but researchers continued to try to finish studies even after they were told to cease their work. This went on until 2000.

Even though there was no production going on after about 1994, airborne levels of contaminants was an issue during the D&D phase of the project for the SM/PP Buildings. The contamination levels at times during removal of key areas of the building were extreme and special previsions were taken to count the air samples because they were so hot they could not be processed in the laboratory in the early 1990s. Sacrificial instrumentation was supplied in the area to count the air samples. This process did claim a few pieces of equipment so that they had to be disposed of as radioactive waste. Many chemicals were handled in these buildings as well. Many of the lines used Pu combined with acids. The combination made clean up even that more of an environmental and health issue. Many people were exposed to acid Pu, as well as airborne particulates. Such acid Pu could penetrate the skin layers much more readily. There were documented cases of workers that were sprayed with acid Pu during line removal.

Because Mound work was done by many independent researchers, their classified work and the isotopes they were using were often only known to them. Janitors and other maintenance workers, who had to access their spaces, often did not know of the radiological hazards present, and were not monitored.

Although Mound made an attempt to bioassay for the 9 or so prominent radioisotopes used in Mound production work, the huge number of other radionuclides used at Mound, represented a potential for external dose and internal uptakes without bioassay techniques to quantify and record personnel radiation exposures in many cases.

According to one interviewee, particular dose reconstruction attention should be considered for the open processing areas of SM Building and PP Building (also known as Building 38), particularly in the late 1980s and early 1990s when the critical clean-up evolutions were underway. There was also some uranium work done in SM Building whereas PP Building was primarily Pu-238 with potential for high-fired oxide exposures. Later in PP Building, there were many orphan sources handled. Some were encapsulated, but even these became leaky. As T Building was and is being torn down, all walls and cubicles were gutted and there is now only one cavernous area with many untested changes in the engineering controls. There were some very different and uncommon radioisotopes used in A-line operations. There was also significant potential for exposure to neutrons from Pu-238 operations. Many times Pu-238 contamination was effectively quantified but there were times when contamination leaked out of the tents, when not expected, and personnel may have had uptakes since the need for respirators was not as evident in these situations.

Protactinium-231 and Ac-223 were found in B Building and also in G Building as well as throughout the SW/R/T Building complex. When they tore down B Building during the D&D process, RCTs had to set up a spreadsheet for potential areas for Ac-227 exposure. Actinium-227 couldn’t be monitored by the CAMs and the RCTs never got an onsite procedure to detect it. Spills were occurring in certain areas. Studies were even done in the Old Cave areas using an Alpha-6 survey meter and health physics personnel tried to find a good way to look out for peaks, but it did not tell them much about the Ac-227 levels.

During the 1990s, when D&D began in great earnest, building walls, cubicle areas and box lines were removed and the changes in ventilation and engineering controls were violated. This degradation of engineering controls was a significant problem during these D&D operations and increased the odds of accidental exposure during the ongoing dismantling process. When the buildings were built, these engineering controls were carefully developed and tested to minimize personnel exposures. There were no definitive studies done to reevaluate the impact of loss of the engineering controls and to potential for increased external or internal dose due to the lack of these controls. During D&D, the multiple radioisotopes represented a significant source of potential exposure without much attention to dose impacts from less commonly monitored radioisotopes.

There has been a lot of open-air demolition as old buildings were torn down. Some of this is still ongoing. It was hard to keep the dust down during these building demolitions and the potential for significant uptakes of radionuclides was possible in situations where air monitoring was not always possible to do. One interviewee had done demolition work on R and WD Building where this was a problem. He mentioned that he was also involved in high radiation exposure areas in R, SW, and PP buildings. In these cases, workers wore bubblesuits with respirators on their hips and they would don their respirator when they entered the radiation area. Nose wipes were routinely done early on, but as the nasal wipes often did not show the presence of contaminants, it became a practice that was not as closely followed as years went along. This relaxation in the use of nasal wipes presented the potential for undetected uptakes.

During the tear down of SW Building in 2005, workers were not adequately monitored for the many less prevalent radioisotopes, and thus had a potential for both external dose and internal dose that could not be quantified and placed in the worker's radiation exposure file.

It was common to see Cs-137 in many buildings at Mound, and it was commonly found during radiological surveys. Although much of this was in encapsulated sources, it was also used in non-encapsulated form by researchers in situations where radiation work permits may have been in place and personnel exposure possible. This was a particular problem in R Building and WD building in the process of handling radioactive wastes from many of these classified research related studies.

Because of the classified nature of researchers work, radiation safety personnel often were not aware of the need to monitor or quantify the many exotic radioisotopes present.

Stable tritides were handled in the 2003–2004 timeframe.

In order to detect exposure to high-fired Pu oxides, fecal samples were taken until the year 2000.

Decontamination of R and SW buildings was conducted in 2004. During those operations there were some positive bioassays. There, however, have been no individual external radiation doses recorded for the past 11 years.

T Building is the last building to be cleaned up. It is underground with a hill on top of it. It has 17-ft concrete walls. During the T Building decontamination, lead sheeting was removed from the floor in a couple of rooms. The lead was apparently put in place to shield radiation from Co-60, Bi-207, Bi-210m, Cs-137, and Ag-108m remaining in the floor following earlier decontamination efforts. During decontamination in 2004–2005, some of these areas were posted as Radiation Areas from time to time, after the lead had been removed. T Building is now gutted. They are in the final process of the close out survey.

In the process of cleaning up and disassembling T Building, soil contamination was a problem. Roughened or "scabbled" concrete dust was also a source of exposure in T Building. However, there have been no radiation areas at these decontamination sites for the past two years. The only way to receive a radiation dose would be if a worker chose to stand on top of the waste drums, but this was not often done.

Incidents/Unusual Occurrences:

The ORPS Occurrence Reporting started in 1991 to report accidents and unusual occurrences. Prior to that incident/accident reports were written up and maintained by the Health Physics Office. Copies of these incident/accident reports are maintained by Mound to the present and are provided as part of a claimant's file, when requested from NIOSH.

An incident occurred in R-140 involving Pu-238 oxide. A Teflon o-ring melted, and there were a lot of moderated neutrons produced that resulted in a high reading. It was important to keep the Pu-238 away from the fluorine. They were using a carbon rod and they got some high-fired oxides. Things were flying all over the place inside the glovebox. The interior of the glovebox was contaminated with Pu, but not the outside. There was a white paper developed regarding the incident... It is a Radiological Control Organization document dated December 12, 1996, EG&G Mound, Weaver R. (wpin/drp/whitepap.fin).

In 1956, one worker had an uptake when he was working with a PuBe source used for oil wells. It was determined that he inhaled 10^{12} pCi. And yet, later, the records showed his dose as zero. The lung counter was used to determine that he had a chronic whole body dose of 81.3 rem.

In the late 1960s or early 1970s, there was an explosion in a glovebox in the Pu handling area. All the alarms went off, and everyone was told to go outside. The glovebox blew out and some workers did get uptakes of Pu-238. Some of these individuals got body burdens of Pu. These folks with body burdens were transferred to non-nuclear work areas.

In January 1969, near the waste disposal (WD) Building operational area, there was an accident involving a big release of Pu-238. There was a break in a pipeline. Alpha waste liquid was in the process of being transferred from SM Building at the top of one of the Mound hills to WD Building at the top of the other Mound hill. This was done through a pipeline that ran by gravity feed downhill from SM Building to the valley below to a pump station. The pump station then pumped the alpha waste liquid uphill to WD Building. Bubbles were noticed coming out of the ground. It was necessary to dig up the ground at the pipeline break site. This was being done during the January thaw period, and rain was pouring down a significant portion of the time that this digging was underway. They took environment water samples during the cleanup to ensure that nothing was running off site. When the cleanup was completed, environmental water samples were filtered through filter papers, and the water was analyzed for Pu-238. The water was found to be free of Pu-238, and it was, therefore, assumed that nothing got off site. But it was later discovered, when they analyzed the filter papers, that Pu-238 had adhered tightly to the soil particles in the water. The Pu-238 was retained on the soil that had adhered to the filter paper, and thus, there had been some Pu-238 in the environmental water samples taken. It was, therefore, realized that things were not okay.

One worker that got a dose of over 100 rem in SM buildings in the late 1970s. He was later transferred to R Building. The worker was asked to follow up with quarterly urine samples. Several workers were concerned about the Pu-238 urinalysis results. Each time the worker received his urinalysis results, they were quite similar. The worker felt they were "dry labbing" it. On one occasion, the worker decided to have his wife (no known uptakes) give a urine sample in place of his. The urinalysis results were nearly identical to his previous Pu-238 urinalysis sample. When confronted with this, the lab personnel claimed that they had gotten his urine samples mixed up with someone else. Another example of "dry labbing" was when Mound RadCon personnel collected fish samples out of a local body of water. Later it was found that the samples were never analyzed, even though reports showed data based on these fish samples.

There were accidents where workers did get higher dose. There was explosion in the SW Building where they were handling H-3. The H-3, however, was eliminated quickly.

In the Building 38 neutron facility, there was an explosion in the neutron generator. The calcium that was used to control the neutrons that got hung up, the generator went sub critical, and there was a high neutron flux produced. This was an error make by the worker. The worker assumed the brunt of the criticism for the incident. Workers did receive some dose as a result of the explosion.

Another event involved a SNAP-27 source that was being developed for missions going to the moon. These were one-man expendable sources. GE wasn't really ready on their end of the project, and tried to slow down work progress by disputing Mound's film readings and ultrasound inspections. GE was so insistent that, at Valley Forge, GE cut one SNAP 27 open and inspected the welds in a metallurgical lab, by cross sectioning the welds. Although GE was trying to prove that Mound's film readings and ultrasound inspections were not done well, the GE inspection of the SNAP-27 welds showed that Mound had produced quality welds and had, indeed, done their film readings and ultrasound inspections correctly. This resulted in a big shakeup in the GE management. During this operation, there were some unscheduled processes that caused exposure. When handling SNAP-27 sources, they took their ring badges and whole body badges off prematurely so that they could collect their dosimeters early. They were near the allowable exposure limit, and there is speculation that their film badges were removed so that they could get the work done.

One Mound worker got over 1 rem dose, because he did not wet wipe his facemask when taking it off in a contaminated area. He was wearing a full-face respirator, and was working in an area of contaminated dust. He got the 1 rem internal dose when he took off his uncleaned mask. A co-worker got a dose of 2 rem as a result of the incident. The Mound worker was fired due to his negligence.

One incident of high radon exposure occurred in SW Building (cave area in SW-140) when a blower motor venting the radon burned out. When the high levels of radon were detected, the blower motor was replaced, venting was resumed, and radon levels were again minimized.

An accident occurred in R Building, Room R-149. The front of a glovebox was blown off. When such accidents occurred, contamination levels were quite high. Some workers had concerns about these possibly high levels of contamination. Sometimes health physics personnel would downplay an incident, but the actual readings were recorded by health physics personnel and reported in incident reports.

Ac-227 was processed from Ra-226 in the Old Cave area. One of the hot drains containing Ac-227 liquid went the wrong way, and the hot stuff got into the cold drain. A report on this incident was written up. The health physicists in the 1950s got very interested in this. When this kind of attention developed, you knew something bad had happened. Millions of dollars were subsequently spent adding containment barriers and installing remote handling systems. Health physics personnel were not sure where the Ac-227 was coming from. In the 1950s, decontamination and decommissioning (D&D) was done on the Old Cave. The problem was just too much to solve. In the late 1950s, the Old Cave was buried. Later SW Building was built on top of the Old Cave.

In the old caves section of Building SW (SW-19), the CAMS worked generally quite well. One RCT remembered only 2–3 times when CAMS went off due to gross alpha counts. Individual workers might be exposed to 8–9 pCi/l when the average around Ohio is about 4 pCi/l. The CAM location is also important. CAM readings are usually not treated as occupational dose. Overall, Mound was not in bad shape. One RCT took issue with this. He claimed that Cams went off more frequently than this. This was sometimes due to unknown reasons. He conjectured that perhaps radon or short bursts of other radionuclide airborne release caused the frequent CAM alarms. In other situations, it may have been due to loss of material in mass. The RCT Teams themselves could not say for sure, at that moment in time due to instrument limitations, what the root problem of the CAM alarms was.

While repackaging the Th-232 Cotter Concentrate into smaller packages in Building 21, the RCTs were sent out to take air samples. They used the PAC 1SA to monitor smears and the instrument pegged. It was discovered that the fans had been turned off and the higher levels detected were due to the lack of ventilation. The packages did leak and they had to be repackaged. It turned out that workers probably received more dose from radon in the drum storage area.

One worker dropped a vial containing Pa-231. Most work with Pa-231 was done in the biological research area of B Building. It was necessary to monitor here for both Pa-231 and Ac-227.

One time RCTs found a hole in one of the high-level filter banks. As a result, the wall in that area was found to be highly contaminated. Fortunately, this was not in a highly occupied area.

There have been reports that individuals used to put their badges under the lip of the hoods to get out of doing hot work. As a result, dosimetry personnel did not trust the data when badges came back totally black. One individual indicated that he was working in a hood with high dose rates, and was assigned a zero dose. He requested that External Dosimetry personnel investigate his results that did not seem to match with the field survey data. This request was made in the presence of another RTC who said such an investigation was not completed while that interviewee was still at Mound.

In PP Building, there was one contamination exposure incident that occurred while drilling holes in the masonry floors, where removal contamination became a problem. One worker reported that the health physics staff knew how bad the contamination was. The workers would drill a hole, put a metal plate at the bottom, and then refill the hole with gook. During this process, contaminated concrete dust was resuspended. They also had to do "scabbling," which was a process like roughening up a concrete road surface prior to repaving. It took the top surface off the concrete causing resuspension of the concrete dust. Some of these were hot spots, and the work was done under a Radiation Work Permit.

There was an incident in R Building in Room R-130 that occurred while workers were digging a hole. They were in one-half face respirators and radiation safety personnel were on the shift. Some workers may have been working in plastic bubble suits with an independent air supply while others were in paper suits taped up around the ankles and wrists. Their masks were smoked tested, but no x-ray fit test was done to check on the mask fit. There was no indication during the morning that workers had been exposed. The only way the uptake was discovered was by a routine nose swipe taken on one of the workers on Friday. The nose swipe was read on Monday and a reading of 43,000 or 48,000 cpm was noted. A Rad Tech pulled the worker off to the side on Monday and told him about the finding. He, however, said not to say anything, as he was not supposed to tell him. A senior Rad Con staff member told the Rad Tech not to tell the worker about the uptake. Two days later, the worker was transferred to SM building. The worker had strong words with the senior Rad Con staff member about trying to keep this positive exposure incident from him. In SM Building, the worker was later exposed to Pu and Am as he had the job of busting up concrete where he got even more exposure. The worker was later transferred to the Fire Department and noted that there was never any follow up as to his possible exposure to Am or Pu. The worker also worked around Pu in PP Building from 1984 to 1985. He worked the Fire Department from 1986–1999. He was also told that there was some Rn-222 in R Building, that it would not hurt him, and that he should not worry about it. The Mound medical doctor told him that everything was fine on his annual physical, and that his exposure was within applicable DOE standards. The worker did not like the Mound doctor. He felt the doctor wasn't square with him and didn't give him straight answers. The worker worked in R Building from 1983 to 1985. In 1988, he developed shortness of breath and in 1990 he was diagnosed with Chronic Pulmonary Disease (CPD). In 1996, it finally came out in the news that workers in R Building had been exposed to Am.

Records

The operational records have some information on source data that can be used in a generalized way to get an idea of what radioisotopes were handled at Mound. The Health Physics (HP)

Monthly Progress Reports monitored all the work that was done with radioisotopes. These are not the MLM reports. They eventually became quarterly reports. These were started in the 1948 to 1950 timeframe. HP Daily Logs were also maintained. These were different than the HP Monthly Progress Reports. The HP Daily Logs had detailed information about wipes on containers, alarm incidents, incident investigation, faulty alarms, and release criteria when the alarms went off, etc.

There were also some outstanding summaries known at the Operating Unit 9 (OU9) reports that have a lot of good information on waste management issues.

458 boxes, representing the entire Mound Inactive (meaning they were no longer routinely used and were boxed and sent for storage) classified records, were shipped to LANL in the 1993 timeframe. Due to the storage location (T-Bldg.), radiological surveys were required before the boxes could be removed from the building. These surveys produced positive results, which caused the collection to be shipped as a classified, contaminated collection. The boxes were never formally inventoried at the folder or document level, but a brief description of the box contents was provided to LANL at the time of the shipment. Generally speaking, this collection contained classified research and development records and classified financial and programs records. The researcher's lab notebooks were primarily filled in during the 1950s and 1960s. They are not believed to be the kind of files that would have recorded radiation exposure information in them, but instead dealt with the details of their particular research project progress. The LANL Records Manager has verified that in 2005, this contaminated record block was buried as contaminated waste.

Classified records are no longer at the Mound Site, and are not at the Dayton Record Center. These classified records were sent away off site in 2003 to Sandia, NNMC Security Center, Albuquerque NM and the Office of Technical and Scientific Information (OSTI) in Oak Ridge Tennessee. For more information on these shipments see Secondary Issue 16 in Section 1.3 of this report.

Mound believes that all exposure records needed for dose reconstruction are included in the Mound Radiological Lab records. Mound Radiological Lab records are unclassified, and include: the individual radiation personal file; personal incident reports filed by incident number and by incident itself by year by date, and in the Mound incidence and accident reports. The personal incident file can be accessed by HP number or name or incident number. Sometimes this data was put into the individual's medical record but when done was a duplicate of the incident file. According to Mound Records personnel, this duplication was not always done.

There was an effort in the mid-1990s to consolidate survey, air sampling data, work permits, and personnel monitoring data into a Radiological Records Center. This records center use to be located in R-Building that does not exist anymore. Some of the records available for dose reconstruction include the following:

- Dosimetry Microfilm Data
- Radium Urinalysis Logbook

- Radon Breath Analysis Logbook
- Fecal Sampling Logbook
- Thorium Urinalysis Logbook
- Personnel Monitoring Files for Po-210
- Incident Files
- Air Sampling Records
- Permits
- Dosimetry Algorithm Data.

Records that you might find in a Personal Radiation Exposure File include the following:

- Personnel Exposure Questionnaire (O-35)
- Radiation Urinalysis Report (Form 1053)
- Mound Laboratory Radiation Exposure Record (Form 1015)
- Pocket Dosimeter Dose Record for YYYY (Form 1333)
- Referrals to incident files
- Periodic Annual Radiation Exposure Reports
- Radiological Work Restrictions.

Much of the plutonium urine data has been computerized.

Annual reports had been issued to workers in some form since the 1980s. An explanation was not provided with the reports, and many workers did not understand them. In the mid-1990s, formal reports were required by 10 CFR 835. These reports were issued to employees, subcontractors, visitors, and individuals that requested records. The initial reports did not include internal dose, in most cases, since they were not calculated yet in terms of CEDE.

HP reports are on microfiche. Also external dose records and extremity doses were placed on microfiche or microfilm. These records used to be kept in the dosimetry office.

Dr. Ken Skrable from Lowell University was called in to review the Pu monitoring program in 1985. Mound had previously participated in a Hanford Intercomparison Study on Pu monitoring using urine bioassay techniques. Mound was found to have significantly lower results that most of the other DOE facilities and Labs that participated. Dr. Scrable recommended that Mound go beyond the mere revision of the Mound body burden estimates to one of calculating radiation dose to specific organs such as lung, liver and bone. Apparently Dr. Skrable and Mound agreed that it would be best to wait for the publishing of ICRP 30 prior to making that decision. The Mound RCTs were asked if Dr. Skrable's recommendations were later implemented and if so, did Mound do the calculations and was the new data entered into personnel files. One RCT recalled that Henry Spitz was the senior Mound representative that discussed this with Dr. Skrable during the 1988 timeframe. They discussed the data from the notebooks and as a result there was some reentering of data where it seemed to be needed. Gene Runkle for DOE came in later and told Mound that the re-evaluation of Pu doses would be done at Mound in a more global way. Mound health physicists were set to work on reviewing these Pu doses. In some cases, the doses were changed. By 1991, all the reassessment work on the Pu doses was completed.

It was hard to get Mound health physicists to do calculations prior to 1992. In the early days they had an in vivo monitoring program, but it was not very effective in determining body burdens. Until germanium detectors came in, quantification of Pu-238 dose was difficult. The older phoswich detectors could only tell you that Pu-238 was there, but the lung counters technology at that time could not quantify what was there. Henry Spitz is very knowledgeable about the limitations of phoswich detectors. MJW later came in and did a great job of reconstructing doses. LANL was even asked to come in and help with needed dose reconstructions. But Mound Laboratory never seemed happy with these dose reconstructions.

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An additional conference call was held on June 21, 2006, with Mound former workers at their request. This was not a formal interview in the vein of the previous discussions in this section, but was more of an informal exchange of viewpoints on historic sources of exposure at Mound, the dosimetry available for measurement at the time, and the treatment of these issues in the site profile TBDs. The following is a summary of this conference call.

Participants

Mound Worker Representatives: Paige Gibson, Deb Jerison, Mike Ball, Eric Parker

SC&A: Joe Fitzgerald, Robert Bistline, Ron Buchanan, Tom Bell

Date of Call: June 21, 2006

Introductory Comments:

SC&A: We appreciate your willingness to talk with us today. We have had two site expert interviews and gone through many documents. These interviewees have been most helpful in shaping our report. SC&A then provided a brief overview of emerging issues in its ongoing site profile issue.

Beyond what we see as these emerging issues, we have two issues, which we believe are particularly pertinent for any input you can provide:

Data Integrity – Our interviews had brought up a 500 mrem inhalation dose, if below that it was not recorded in the early 1950s and 1960s.

1997 Allegations – “dry labbing” – Urinalyses taken and results were not analyzed and yet the results showed up in the worker’s record. We have antidotal information on data integrity where workers were assigned doses in radiation areas that didn’t reflect their dose. Any additional information you have would be most helpful.

2nd Issue: Once you got beyond the 12 primary nuclides, there wasn't established a program to effectively monitor the secondary exotic nuclides and Mound did handle them. The King report did handle most of these, but it still leaves the question as to how well this was handled. Cs, Ac and Pa are the ones that keep coming up. Until you have alpha spectrometry, this wasn't done particularly well.

Reps: We agree with your analysis. We are having trouble finding records on incidents. An explosion in SM Building is not documented in the Site Profile (Major incidents that happened), nor is available in individual claimant medical files.

Tom: Mound may have the ability to pull up incidents by individual.

Reps: When they had NTA badges in the 1960s, the film would be black and was not counted. It was not used as an assumed dose.

Joe – That was one of the comments received in earlier former worker interviews regarding data integrity. They assumed that the badges were put in hoods and had turned black from gross exposure.

Paige – Some left them in their lockers.

Mike – Most people wore their badges faithfully, but some did not.

Joe – Was this ever addressed in an investigation?

Deb – There was one whole bank of badges that were found to have been exposed together?

Joe – We didn't come across that this happened in the records.

Mile – I was an RCT in the 1960s and there were some who were caught without their badges.

Deb – There are 135 boxes that have not been gone through at the Mound Museum.
A lot of information may be coded in report numbers. I do not know what is in them.

Joe– SC&A will add this information in our report in the "completeness" section.

Joe – Is there anything else you want to bring up? Were workers recorded zero doses and yet were in areas where they should have received a dose and yet the record showed zero?

Deb – Father was exposed to Po-210 Rn-226, but his urine and feces samples did not show anything.

Joe – We haven't been able to find documentation that could be used to emphasize this issue. This is sometimes a systemic issue.

Deb – There are some files from the 1970s on.

Paige – We are running into the same roadblocks. They [Mound radiation dosimetry program] have nose wipes and fecal samples and yet there is no dose recorded. No one was told they had an uptake. Other than word of mouth – there is no documentation.

Paige – Alpha spectrometry – It was a supervisor's call as to who would be monitored. They often did not use a wide spectrum. Selection of worker to be monitored may have been too narrow and not done at frequent enough intervals to detect the exposure.
If you did not know that a building demolition involved Pa or Th, and then it was would not have been monitored.

Paige – Management determined who was badged and was the decision was based on money.

Joe: One site expert indicates that Mound's D&D program was patterned after RFP, and it, like RFP, relied upon lapel samplers and DAC hours to determine the need for follow-up bioassay.

Paige – The issue is who was the person with the lapel monitor and how did that lapel reading relate to the other co-workers working with them? Sometimes the RCT would wear the lapel monitor and his lapel monitor may not have been representative of the other workers around him.

Joe – This is an important point to emphasize in our report. When bioassay was cut back, did the air sampling really capture dose?

Reps: No, because a worker was selected at random to be lapel sampled and often that individual was clearly not the maximally exposed worker on the job. Sometimes the RCT, themselves, wore the lapel samplers and they were not even involved with the work evolution, itself.

Paige – Did you find sufficient documentation of actinium internal dose for 1957 to 1997?

Ron – We have identified the investigation and note that NIOSH has used mixed terminology for terms like, action levels, MDAs, reporting levels etc. It is unclear how these were used.

Ron – On Cohort badging – Do you have evidence of cohort badging in the 1950s to 1970s? Did they just badge on person and then uses it for others? Do you have documentation on who was badged?

Paige – It was a management decision on who was badged or who received internal dose monitoring.

Bob B. It is not clear that maintenance workers, janitors, security personnel were covered.

Paige – Maintenance and support workers moved around. They moved back and forth between facilities. In particular, the monitoring of maintenance workers was problematic. They may move from one alpha radiation environment to another that likewise had high alpha radiation.

Ron – People might be transferred to other areas and not followed after let's say having had potential exposure to Pu in their first work location.

Paige – We found this to be true, too. People were taken out for chelation shots on the other side of the Hill and taken off SM.
Joe: One issue – The TBD relies heavily on the King report; are their other critical sources of information on radiation sources at Mound?

Tom: The Floyd Hertwerk report might help on this.

Deb: I have this report and it could be put on a disk to you, if needed.

Joe: One thing that surprised me was the presence of high-fired thorium that comes about during Th-232 refining using the monazite process. I had not heard about this at other sites. In the TBD, it assigns high-fired thorium a solubility of class M instead of class S. Are you familiar with the high-fired thorium issue or questions regarding the presence of "other" such radionuclides?

Eric – Bldg 38 did Pu, but started with Th first. Some were pilot studies and if you can't find the report compiled by the investigators, you would not know that this was the case. In SW-19, a lot of personal scientific work was going on that is not documented and led to situations where exotic radionuclides are being handled without everyone else's knowledge.

The SC&A report should be available in the next 3 weeks. We will develop an issues resolution matrix that will used to summarize SC&A findings, which activates a process for NIOSH and SC&A to go back and reexamine these issues and achieve closure on them.

We appreciate your help on this. I think the Conference Call has been most beneficial.

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

SITE DESCRIPTION (ORAUT-TKBS-0016-2)

(1) ***Contamination at subcritical assembly –*** On Page 26, concerning Building 59, it states the following:

> *However, all fission products were sealed in aluminum containers, so the probability of contamination is remote. The water surrounding the containers inside the assembly is constantly monitored and contamination has been observed.*

This statement seems to contradict itself. Was contamination observed? Was this a source of external/internal personnel exposure?

(2) ***Need details on subcritical assembly –*** On Page 26 statements are made concerning a subcritical assembly in Building 59. But it is not clear what isotopes were sealed and what radioactive material/contaminates perhaps were not sealed. Could some more details, and dates, be provide on this subject?

OCCUPATIONAL MEDICAL DOSE (ORAUT-TKBS-0016-3)

(1) The introduction to TBD (ORAUT-TKBS-0016-3) states that, "medical x-rays administered in conjunction with routine or special physical examinations…are a valid source of occupational exposure." The TBD draws upon (ORAU 2003), which is Revision 2 of OTIB-0006. Current Revision 3 of the OTIB-0006 (ORAU 2005) states that special exams, even from illness and injury from incidents on the job are deemed occupational exposures. The entirety of the subject TBD addresses only dose considerations from PA and LAT chest x-rays. How does NIOSH/ORAU intend to resolve the necessity to consider other forms of diagnostic x-ray exposure beyond chest radiography?

(2) In Section 3.2 of the TBD, it indicates that LAT chest radiography was only required after 9/19/88 for women who underwent breast augmentation surgery. What was the medical basis for this policy and did the women getting LAT chest x-rays also receive a PA chest exam? There is no indication whether any other LAT chest exams were performed on anyone other than this select group either before or after 1988. Please clarify. If so, what was the frequency of LAT chest x-rays, as it is not specified in the TBD?

(3) In the TBD on Table 3-1, it lists frequency of PA chest x-rays provided at Mound. The table suggests that chest x-ray frequency varied with age and time. However, review of historic support documentation suggests that SOPs provided for voluntary chest x-rays to

all workers who suffered a respiratory complaint, no matter what age. Can NIOSH/ORAU validate how many voluntary chest x-rays occurred, and is that information noted in individual medical records? The TBD indicates that after 1980, only asbestos and other non-defined "at risk" workers are provided annual chest x-rays. Can NIOSH/ORAU better define "at risk" workers beyond the example of welders?

(4) The TBD in Table 3-1 indicates that smokers of all ages after 1989 received chest x-rays. Our review of historic documents finds a mention of smokers after age 45 being "at risk." Can NIOSH/ORAU further clarify the dates from which Mound provided chest x-rays to all workers who were smokers and considered "at risk"?

(5) The TBD only lists one x-ray unit at Mound since 1980. No documentation exists prior to 1980, to establish what was used prior to 1980, yet x-ray exams occurred. Can NIOSH/ORAU justify its assumption that the entrance kerma values listed in Table 3-2, prior to 1995, are truly conservative and claimant favorable, given they are derived only from ORAU (2003)? It appears that NIOSH/ORAU has not conclusively ruled out the potential existence of photofluorography (PFG) units at Mound. Has NIOSH/ORAU been able to substantiate that all films found in medical files of claimants prior to 1980 are of the 11x17 inch variety?

(6) The TBD in Section 3.3 states that organ doses prior to 1988 are derived using default values from ORAU (2003) and the application of ICRP Publication 34 (ICRP 1982). Since we do not know the equipment type, the procedure (technique), filtration, or HVL for any procedure prior to 1980, does NIOSH/ORAU believe it is claimant favorable to use assumptions based on ORAU (2003) and ICRP Report 34, which are based on known equipment type, technique, filtration, etc., and if so, why?

(7) The TBD states that organ dose estimates after 1988 are derived from in air measurements, made by the State of Ohio. Review of historic records suggests that Ohio only made such measurements in 1995, 1997, and 2000 for this x-ray unit. Table 3-2 would appear to suggest that Mound made its own measurements from 1988–1994. Can NIOSH/ORAU substantiate if physical measurements are available for review?

(8) In Section 3.4 of the TBD, it provides a prospective that delineates "uncertainty" as those things that may affect the beam output and therefore the dose. Not to be included, and so stated, as not being part of the uncertainty analysis, are other factors, including improperly used screens, grids, film speed, and film development, which ultimately affect dose. The SC&A reviewer agrees with the extent that uncertainty was reviewed and states that a 30% factor is reasonable and conservative. However, the TBD does not consider the other factors mentioned above, nor does it estimate their potential collective impact. These errors will result in retakes that need to be included as extra dose to the claimant review. Has NIOSH/ORAU reviewed these impacts, and estimated their potential affect on dose? Has NIOSH/ORAU been able to estimate and substantiate a retake rate on a yearly basis?

(9) In Section 3.5 of the TBD, it recommends that dose assessors should review each claimant medical file to establish if the frequencies listed in Table 3-1 are appropriate or need to be adjusted. NIOSH should advise the dose reconstructor to include all other exams noted in the file, as that instruction would be appropriate under ORAU (2003), and given that Table 3-1 covers chest x-ray frequency only.

(10) SC&A review finds that the proposed multiplier of a 2.5 factor for a LAT, as opposed to the PA, is appropriate for chest radiography, however, NIOSH should make dose assessors aware that a correction factor of 2.5 is not appropriate for other exams, such as an AP and LAT c-spine. Has NIOSH considered establishing factors for other exams, as historic procedures manuals from Mound files show many other procedures beyond chest radiography were envisioned?

OCCUPATIONAL ENVIRONMENTAL DOSE (ORAUT-TKBS-0016-4)

(1) The TBD states that no onsite environmental monitoring occurred at either Dayton or Mound prior to 1971. It appears that TBD authors derived pre-1971 inhalation doses, using total stack effluent data, and empirically derived atmospheric dispersion factors. Has NIOSH explored the possibility of comparing these empirical determinations to offsite concentrations of target nuclides, which were measured at various off-site locations during the early years?

(2) The Dayton site does not have environmental survey results for 1943, 1944, and 1946. The TBD utilizes comparable results from 1945, 1947 and 1948, as the basis to use December 1947 (highest recorded) to estimate inhalation doses. Has NIOSH compared the operations and production records for all these years, especially for Dayton Unit III, to ensure that perimeter measurements in December 1947 do represent a worst case?

(3) The TBD estimates that inhalation of Po-210 and soil ingestion resulted in environmental doses at Dayton Units III and IV, to less than 1 mrem annually. These doses are due to submersion, and external exposure to contaminated soils. However, the TBD estimates that external environmental gamma exposure from the facilities could be as high as 1800 mrem per year of operation. This assumption is based upon one control badge result during May 1944. The estimate is further based upon a 2000 hr per year occupancy factor. How does the estimated 1800 mrem/year, outside the facility, compare to inside measurements noted on worker wrist film badges?

(4) The TBD utilizes the same approach to derive intakes for dose reconstruction for Mound facility, as chosen for Dayton, for the period prior to 1971. However, significant offsite airborne monitoring was performed at Mound after 1948. Has NIOSH/ORAU made an attempt to compare results of offsite monitors to the results from the atmospheric dispersion approach results, displayed in the TBD?

(5) The TBD indicates that for the years 1971–2003, an <u>average</u> of onsite monitoring stations was used to determine environmental intakes. Has NIOSH reviewed the onsite

monitoring data for all stations and determined if the use of the highest monitoring site would be more claimant favorable?

(6) The TBD indicates that no general area direct gamma measurements were made for Mound, with an exception of an aerial survey in July 1976, which reported gamma estimates ranging from 20.5 to 23.5 µR/hr. Was the aerial survey corrected for ground level elevation? The levels stated would result in 40–50 mrem per year, as compared to 1800 mrem estimated for the Dayton Unit III and IV. How does the TBD author correlate this difference, given the source terms at Mound far exceeded Dayton source terms?

OCCUPATIONAL INTERNAL DOSE (ORAUT-TKBS-0016-5)

(1) Can NIOSH update the Internal Dosimetry TBD (ORAUT-TKBS-0016-5) so that there is more consistent and appropriate use of the terms: detection limits, reporting limits, and action levels? The author of the TBD has NOT done a very effective job of this. The terms are used interchangeably throughout the document. A good example is on page 22 of 65 of the TBD, in the sentence preceding Table 5-7 where it states "…MDAs derived using Currie's equation 5-2…" and the table providing protactinium detection limits provides values in the last column as 'Detection limit (dpm).'"

(2) Can NIOSH provide more detail on how a reasonable dose reconstruction can be done prior to 1981 when the following statements are made in historical documents? The following statements can lead to large possible missed doses.

> *…. erratic recoveries from 6% to 85% were observed for metabolized plutonium in urine due to plating.* (Meyer and Reeder 1992)

The gross alpha results were reported as Pu-239 for workers in R Building and Pu-238 for SM and PP Building workers until 1980…. The precision of Pu-239 analysis was reported in 1981 as 6.7% at a concentration of 3.2 dpm kg^{-1} in urine with a large counting error of 73% in Section 3, Bioassay Data Quality Assessment/Control (Meyer and Reeder 1992).

(3) How is internal dose calculated for those employees that worked in areas that were not monitored or were monitored only during the time they worked in that area and then discontinued? Likewise, how is internal dose calculated for those monitored, but whose recorded doses results are less than the reporting limits in Table 5-1? The TBD on page 10 of 65 states:

> *Individuals identified as being involved in an internal exposure incident or had urinalysis results in excess of the reporting limits listed in Table 5-1 were required to submit additional urine 24-hr samples for analysis. Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed.*

For example, Pu-239 reporting limits appear to be the Action Level of 3.5 cpm 24 hr^{-1}. This equates to 300 mrem wk^{-1}, or 15 rem yr^{-1}, which is a very high missed dose level.

(4) Are there any estimates of the number of unmonitored employees for the various isotopes over the years that may have had unmonitored exposures? (For example, the TBD states "…only those workers conducting research to separate and purify protactinium were monitored monthly for Pa-231." Nose swipe data were considered secondary information and were not evaluated. Air-sampling data was also considered secondary information contingent upon demonstration that measured concentrations were representative of breathing zone concentrations. Were breathing zone samples done and are the data available for dose reconstruction personnel? The TBD does not make this clear on page 40, section 5.4.3.

(5) Who determined the need for special bioassay sampling and what indicators were used to trigger required special bioassay samples?

(6) Was DAC-hr tracking ever done at Mound for chronic exposure control of any of the many radioisotopes used? Is there air monitoring data available?

(7) Historically, what was the basis for determining who was put on a bioassay program? Were these only the hands-on researchers or workers? How were maintenance workers, janitorial staff, ventilation workers, pipefitters, and occasional visitors to the areas handled?

(8) What triggered generation of incident reports? What were the indicator levels required? Were all incidents reported somewhere with the personnel involved identified? Information that we have been provided on polonium incidents alone does not support the number noted on page 17 of the TBD.

(9) Is there a list of the major incidents that have occurred at the Mound facility?

(10) How can you justify the two final paragraphs of section 5.2.1 on page 12 of the TBD as claimant friendly? Considering the previous discussion in the text of plasma torch operations, etc., this assumption does not seem reasonable.

(11) What is the basis upon which NIOSH makes the statement in the TBD in the paragraph below Table 5-10, that many of the plutonium compounds are highly soluble and are ICRP type M? SC&A questions if this is the case. Only the nitrate and chloride compounds of plutonium in normal industrial processes are soluble enough to be classified as type M. NIOSH may want to review with the author his knowledge of the chemistry and biology of plutonium considering this statement and the discussions of particle size and solubility of plutonium throughout the document.

(12) In equation 5-10 on page 26 of the TBD, shouldn't the 85% be in the denominator of the equation? Since the recovery was 85%, then the daily excretion would seem to be the dpm value corrected for the efficiency and recovery values.

(13) How were the less than detection level bioassay values recorded? On page 16 of the TBD, second paragraph, it states that values of 0.0 were used for non-detection results for tritium. Was this true for all other radioisotopes?

(14) How were urine sample results handled for individuals having chelation therapy? There is some explanation in the Phase II Final Report Appendix A "Plutonium Position Paper on Dose Assessments Performed for the Mound Pre-1989 Dose Assessment Project" (MJW 2001), but, there is little, if any, explanation in the TBD for internal dosimetry.

(15) How is the dose reconstruction going to be handled for those employees that had potential exposures to multiple radioisotopes and for whom gross alpha counting was used to analyze their urine excretion? Examples include the plutonium isotopes, americium, uranium (including U-233), radium, thorium, etc. The TBD identifies numerous assumptions throughout the discussions of these radioisotopes.

(16) Is NIOSH sure that the ratios for weapons grade plutonium used in the TBD are correct? On page 35 of the TBD, first paragraph of section 5.3.2.6, there is a wrong table reference for weapons grade plutonium and the ingrowth rate for Am-241 in weapons grade plutonium is approximately 20 ppm per month.

(17) Is the MDA for Pu-238 and Pu-239 fecal listed in section 5.4.1 **really** better that the MDA for Pu-238 and Pu-239 urine? This MDA for plutonium fecal can only be approached within the first week after an incident.

(18) Based on the current and past decision levels and the fact that no uncertainties for the bioassay measurements were stated in the records (Attachment 5D.0 in the TBD), what is the estimated potential missed dose in the records data?

(19) Can you please explain the separate, and very different, MDA values for Pu-240 and Pu-239 chest counting in Table 5-22 on page 40? Was Pu-240 really monitored?

(20) During SC&A's review of the TBD and the Phase II Final Report (Plutonium Position Paper on Dose Assessments Performed for the Mound Pre-1989 Dose Assessment Project Phase II Final Report) (MJW, 2002b), SC&A notes that there is a lack of proper information to calculate MDAs or LDLs for the bioassay data (defaulting to a "Level of Significance"). There also appears to be totally insufficient chemistry data for recovery and gross alpha determinations (See page. 30 of 65 of the TBD). In light of this, how does NIOSH plan to provide a reasonable or appropriate dose reconstruction for plutonium exposures of the Mound population?

(21) What energies were analyzed in the spectrums for lung counting/whole body counting for the various radionuclides? Of particular interest are the transuranic isotopes. It does not appear that there was very good detection capability or consistency in the results at Mound or at the other sites that tried to monitor workers from Mound.

(22) Were there workers that had exposures up through at least the 1970s that were missed as a result of poor *in vivo* counting sensitivity?

(23) Can you explain in more detail the discussions of particle size and solubility on page 63, of Attachment 5D.5 and 5D.6 in the TBD? The statement "Alpha emitters with larger 5-µm particles and lung clearance types S or M tend to have smaller inhalation effective dose coefficients than do smaller 1-µm particle" only holds true for certain organs.

(24) What areas and processes at Mound are considered potential for high-fired oxides of radionuclides such as uranium and plutonium?

(25) How were intakes of highly insoluble materials determined prior to *in vivo* counting.

(26) Have there been any comparison studies done at Mound between air concentration data and bioassay data? If so, what were the results?

(27) How did you account for intakes of the various radionuclides used at Mound prior to the establishment of bioassay techniques to monitor for them?

(28) What were/are the background levels of uranium and thorium in urine and fecal samples for the geographical area around Mound?

(29) Have there been any recorded incidents of tampering with urine bioassay or dosimeter badges at Mound?

(30) What shortfalls, through audits, assessments, or investigations, have been identified in the Mound internal dosimetry program?

OCCUPATIONAL EXTERNAL DOSE (ORAUT-TKBS-0016-6)

(1) ***Beta radiation –*** As early as 1944 it was known that the beta fields were intense around the irradiated material because workers had to use lead gloves and tongs to handle them and in 1956 beta activity in 1 lambda of water maxed out the counter (Pages 6 and 36). The TBD and other documents also state that many beta-decay radioisotopes accompanied the Bi/Po irradiation, separation, and handling process. However, according to the TBD, they did not always consider beta radiation of concern and did not routinely monitor/calibrate for it until later years (1979?) (Page 24 and Page 37). They apparently assumed that beta monitoring was not needed when working around Po (Page 28, last paragraph) and if beta dose was monitored, it was not always recorded or was not recorded with worker's identification (Page 10).

a. What years were reliable beta doses recorded?
b. What can be done to provide dose reconstructor (DRs) with some reliable beta exposure information for dose calculations when beta radiation was present, but not monitored/read?

(2) ***Use of 1949–1959 data for earlier years –*** The TBDs and other documents illustrate how the Dayton/Mound sites in the early years were rapidly changing and exploring new, unknown, technologies, especially in the area of radioisotopes. The first era was during 1943–1948 where R&D and limited production was conducted at several makeshift sites. The second era was around 1949–1959 when a new facility was used to start production and further R&D. The physical facilities and working conditions of the two eras were necessarily different. Additionally, information gathered during the first era could start to be used to control radiation exposures during the second era. However, the second era was not itself without health physics (HP) problems. As stated in a letter to Dr. J.H. Roberson of the AEC in July 1952 (Burbage, 1952):

> *…thus far leads us to the conclusion that we are facing a serious health physics problem in the handling of quantities of actinium. At the present time 40 or 50 Mound Laboratory employees receive unknown exposures several times a week to a chain of radioactive materials whose parent has an unknown toxicity and metabolism. For this reason it becomes necessary for us to point out the need of immediate action in the fields of health physics…*

Page 9 of the TBD mentions that Mound never had a well-documented quantitative study of its external dosimetry programs and on Page 10 it states that the record on historical dose limits standards is ambiguous and a great deal must be inferred. Considering the differences between the two eras (and that the second era was not without problems) it does not appear to be technically sound to use the 1949–1959 modal recorded dose to establish doses for the first era workers.

Is the TBD (e.g., Page 50 and 51) recommending using the modal dose from the workers that were badge during 1949–1959 as the assigned dose for workers during 1943–1948? Additionally, how could incidents/accidents that resulted in individual exposures above the average (such as noted in the first paragraph on Page 12 of the TBD and incidents such as the two that occurred in 1944 as described in an article by L.B. Silverman (Silverman 1962) be included in a worker's DR if the modal dose is used?

(3) ***Clarification of badging –*** Table 6-2, Page 10, shows that night-maintenance staff members in Building P were starting to be routinely monitored for neutrons in 1963 and that some hourly engineering staff members were starting to be routinely monitored for neutrons in 1966. Table 6-4, Page 11, lists some information on who was badged in the 'Comments' column. From this information, it is not clear when what groups were badged. According to a report of January 1961 (Mathew, 1961) roughly only 15%–20% of the employees were badged during 1947–1959. Could you provide more details on

who was badged, and when? Was everyone inside the plant area (security, crafts, maintenance, janitorial, etc.) considered "radiation workers," or just those routinely handling radioactive materials (RAM)?

(4) ***Missing dose within annual dose records 1947–1977 –*** Pages 12 and 24 states that only annual dose records are available for 1947–1977 because the weekly/monthly/quarterly records were lost. Pages 50 and 51 recommend that the modal dose be used for missed dose information. If a complete year of dose information is missing, this may work. But how does the DR know if a given year in a worker's dose record includes monitoring for the complete year? Perhaps the dose record only contains information for a part of a year. The fact that Mound did not have any type of policy for recording dose due to lost or damaged dosimeters (Page 12 of the TBD) compounds this problem.

(5) ***Incidents –*** Page 12 states that each incident at the plant was documented. Was the incident and the associated estimated dose recorded in each worker's file that was involved in an incident? What records exist for unbadged workers involved in radiation accidents/incidents?

(6) ***Work hour details –*** Page 13 states that the DR should adjust the worker's neutron dose if the worker worked greater than a 40-hr workweek. Is the number of hours each worker worked each week contained in their records and available to the DR?

(7) ***Variation in neutron QF –*** Page 16 lists possible reasons why the neutron flux, that was required to be equal to 300 mrem/wk, varied between 30 and 150 n^o/cm^2-s in the period of 1947–1969 (note: it should read n^o/cm^2-s not $n°/s/cm^2$). However, the two reasons suggested (longer than a 40-hr workweek or decreased energy of the neutron sources) would not account for these drastic changes. Even a 60-hr workweek would only decrease it by 33%. Changing back and forth between 5 MeV and 1 MeV neutrons would only change it by a factor of 2 as noted in ICRP 60 (ICRP 1991) and on Page 17 of the TBD. Could it be more likely that Mound personnel were not sure of the measurement methods, energies of the neutron fields, and the correct neutron flux-to-dose equivalent conversion factors to use during this period of development?

(8) ***NTA film neutron energy threshold –*** Assuming higher energy of neutrons (e.g., 1.3 MeV instead of the more likely value of 0.75 MeV on Page 17 of the TBD) is not always claimant favorable. Using the old NBS #63 (NBS 1957, Figure 13, Page 62) may show a slight claimant advantage using 1.3 MeV instead of 0.75 MeV neutrons (approximately a 15% reduction in allowed neutron flux per 300 mrem/wk), but using the ICRP 60 (ICRP 1991) continuous function shows that the weighting factor for 0.75 MeV neutrons is greater than for 1.0 MeV neutrons and if you use the step function, they are the same. But the real danger in assuming a higher energy neutron field than what the worker is really exposed to is that the NTA film practical threshold is around 1 MeV and therefore lower energy neutrons could go undetected. This was mentioned on Page 19 of the TBD, but not sufficiently addressed. Page 30 of the TBD, Table 6-17 Footnote (d), uses a 14% correction factor obtained from the SRS for neutrons in the range of 0.1 to 2 MeV. This

correction factor depends to a large extent on the facilities' operating conditions and should be determined for each site and locations within a given site. A missed dose of 14% for all neutrons that falls below the 1 MeV threshold of NTA film, considering the varied missions at the Mound Site, appears to be very small and could result in missed dose. Neutrons sources in hydrogenous shielding and process streams quickly degrade to lower energy neutrons. In general, NTA film misses around 1/4 to 1/2 of the neutron dose around moderated neutrons. Some situations could result in the majority of neutrons below the NTA threshold so that the NTA film dose does not record a significant dose and the missed dose cannot be calculated from ratios. Is the DR process going to address this issue further?

(9) ***NTA film fading –*** Page 20 discusses NTA film track fading and states that it became important in 1968 and corrections were made from that time forward. It also states that Meyer (Meyer 1951) noted film fading as early as 1951, but he must have not considered it important and no corrections were apparently made until 15 July 1968. If fading resulted in under recorded doses in 1968, it also did so back to 1949 when NTA film was first used at Mound. How is this under-recorded neutron dose due to NTA film fading during 1949–1968 being handled by the DRs?

(10) ***Percent NTA film fading –*** Page 20 states, in the next to the last paragraph, that Meyer (Meyer 1994) in his 1967 appendices recommends an evaluation error of approximately 9% per week for plutonium-fluoride sources. However, elsewhere on this page (Table 6-11) the percent fading for PuF_4 is listed as 36%/1 wk and 56%/2 wk. Why the difference? Which was actually used in the dose records? Should PoBe be stated instead of plutonium-fluoride in the next to the last paragraph concerning Meyer's conclusion note?

(11) ***Thermal and low-energy energy neutrons –* Comment concerning Page 21, first paragraph.** If there are neutron sources, then there are thermal and low energy neutrons in the environment around these sources that NTA film would not detect, but Li-7 photon monitors could detect. Also, the 2.5 MeV peak in Figure 6-2 most likely belongs to the B^{10} reaction, not the Li^6 reaction.

(12) ***Maintenance staff –*** Page 23 states that the dose reconstructor should assign maintenance staff 38 mrem/2-wk periods or 1 rem/yr for unmonitored periods before March 22, 1966. Maintenance staff often perform many different functions at different locations/situations and are being assigned much lower doses than are listed on Pages 50 and 51 of TBD for base/missed doses (2 to 7 rem/y neutron plus photon). How can we know that the lower dose of 1 rem/y can be representative of the doses maintenance workers received?

(13) ***Short-time area monitoring –*** Page 23 states that the dose reconstructor should assign workers in buildings T, R, SM, and SW missing doses from area-monitoring results performed during a short time (5/25/63 – 6/8/63). How can it be assured that the radiation fields remained the same after this short 2-week period that the surveys were taken? How long of a period after 6/8/63 is this to be applied to?

(14) ***Skin correction factor of x1.20 –*** Page 26 recommends that the skin gamma dose be calculated by multiplying the results by a correction factor of 1.20 because of the over response of the chip at low energies. However, if the chip over responded, shouldn't the dose be divided by 1.20 rather than multiplied?

(15) ***Neutron factors of x0.4 and x0.739 –*** Page 27 uses multiplication factors of 0.4 and 0.739 for neutron dose calculations. Are these empirically derived values for the TLD system? If so, did they stay the same for 1977–1991 and 1991–2006?

(16) ***Tantalum shield on TLDs –*** Page 29, and Table 6-2 on Page 10, mentioned the problem of the tantalum shield on the photon TLDs causing decreased response below about 200 keV, and zero response below about 110 keV (which included the 60 keV gamma from Am-241). It was recommended in 1977 by Anderson that this be corrected for, but mentions that there were no records showing that it had been acted upon. Page 51, Footnote (e) assigns a value of 572 mrem/yr as the maximum missed dose. How was this value arrived at?

(17) ***Wall and floor radiation –*** Page 34 lists the two sources of radiation in the facilities as Process Radiation Fields and Cumulative Radiation Sources. It then goes on to state that it will only address the Process Radiation Fields using AP-body geometry and will not address the Cumulative Radiation Sources that consist of sources of radiation deposited on wall, floors, etc., in the facilities. Has it been determined how significant this source of dose to the workers might be?

(18) ***Neutron/photon ratios –*** Page 37, Section 6.6.3.4, states that the neutron to photon (dose equivalent?) ratio at Mound was 2:1. However, Tables 6A-1 and 6A-2 both list the ***same*** imputed base dose for neutrons and photons of 2,600 mrem/y for the years 1943–1949 (i.e., n/p = 1.0). The first paragraph on Page 50 lists the base annual dose for 1947–1977 as the cohort dose **or** the modal dose for 1949–1959 of 2,600 mrem/yr for neutrons and 1040 mrem/yr for photons (n/p = 2.50). Can you please explain this apparent conflict?

(19) ***Assigning both Base and Missed doses –*** Page 50, Table 6A-1, lists a Base neutron dose and a Missed neutron dose. I can see adding a missed dose when there is not a dose of record or cohort dose available. However, why is it necessary to add a missed dose when a base dose of 2,600 mrem/yr has already been assigned for the Period of 1943–8/1949? The same question applies to Table 6A-2, Page 51, for photon dose.

(20) ***Corrected photon dose –*** Page 51, first paragraph, states that the base and missed photon dose are multiplied by the photon correction factors to obtain the corrected photon dose and that Table 6A-2 lists the corrected photon doses. However, Table 6A-2 does not list any corrected doses. Where are the photon correction factors and corrected dose presented?

(21) ***Base dose of 2600 vs. 1040mrem/y –*** Page 51, Table 6A-2 list the Base dose as 2,600 mrem/yr imputed for the Period of 1943–1/1949 (from the modal photon dose of 9/1949–

1959). However, the first paragraph of Page 50 states that the base dose of 1040 mrem/yr for photons for the period of 1947–1977 comes from the modal dose for 1949–1959. Why the difference base doses of 2,600 and 1040 mrem/y?

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11. ORAU, 2005, Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures, ORAUT-OTIB-0006, Revision 3 PC-1, December 21, 2005, Kathren, R. L. and Shockley, V. E. Oak Ridge Associated Universities, Oak Ridge, Tennessee.

12. ORAUT-TKBS-0016-1, Rev. 00, September 9, 2004, *Technical Basis Document for the Mound Site – Introduction,* Volmer, J. S., Oak Ridge Associated Universities, Oak Ridge Tennessee.

13. ORAUT-TKBS-0016-2, Rev. 00, March 30, 2004, *Technical Basis Document for the Mound Site – Site Description*, Volmer, J. S., Oak Ridge Associated Universities, Oak Ridge Tennessee.

14. ORAUT-TKBS-0016-3, Rev 01 PC-2, March 31, 2006, *Technical Basis Document for the Mound Site – Occupational Medical Dose*, Algutifan F., Shockley, V. E., and Kathren, R. L., Oak Ridge Associated Universities, Oak Ridge Tennessee.

15. ORAUT-TKBS-0016-4, Rev. 00, October 6, 2004, *Technical Basis Document for the Mound Site – Occupational Environmental Dose*, Hysong, R., Orthen, R, and Lombardo, A., Oak Ridge Associated Universities, Oak Ridge Tennessee.

16. ORAUT-TKBS-0016-5, Rev. 00, September 9, 2004, *Technical Basis Document for the Mound Site – Occupational Internal Dosimetry*, Millard, J., Oak Ridge Associated Universities, Oak Ridge Tennessee.

17. ORAUT-TKBS-0016-6, Rev. 00, August 11, 2004, *Technical Basis Document for the Mound Site – Occupational External Dosimetry*, Proctor, C. W., Algutifan, F., Oak Ridge Associated Universities, Oak Ridge Tennessee.

18. Silverman, L.B., 10 April 1962, letter to Warren, S.L., MD, "*A short History of the Health and Safety Program at the Dayton Polonium Project of Manhattan Engineering District During World War II*" (Doc #030000248 scanned 5/3/04).

ATTACHMENT 4: NIOSH REPONSES TO SC&A KEY QUESTIONS

Responses to SC&A Questions
Site Description ORAUT-TKBS-0016-2

(1) ***Contamination at subcritical assembly* –** On Page 26, concerning Building 59, it states:

> *However, all fission products were sealed in aluminum containers, so the probability of contamination is remote. The water surrounding the containers inside the assembly is constantly monitored and contamination has been observed.*

This statement seems to contradict itself. Was contamination observed? Was this a source of external/internal personnel exposure?

This will be corrected to: The water surrounding the containers inside the assembly was constantly monitored and no contamination had been observed.

(2) ***Need details on subcritical assembly* –** On Page 26 statements are made concerning a subcritical assembly in Building 59. But it is not clear what isotopes were sealed and what radioactive material/contaminates perhaps were not sealed. Could some more details, and dates, be provide on this subject?

Californium-252 and enriched uranium encapsulated sources were used for irradiation. Some activation products were produced such as iron-55, iron-59, and cobalt-60. A start up date has not been found; however, the building has not been operational since 1990.

Draft Response to SC&A Questions
ORAU-TKBS-0016-3
Occupational Medical Dose

(Revision of this TBD dated March 31, 2006 has minor adjustments to skin dose in Tables 3-6, 3-7, and 3-8.)

(1) The introduction to TBD (ORAUT-TKBS-0016-3) states that, "medical x-rays administered in conjunction with routine or special physical examinations…are a valid source of occupational exposure." The TBD draws upon (ORAU 2003), which is Revision 2 of OTIB-0006. Current Revision 3 of the OTIB-0006 (ORAU 2005) states that special exams, even from illness and injury from incidents on the job are deemed occupational exposures. The entirety of the subject TBD addresses only dose considerations from PA and LAT chest x-rays. How does NIOSH/ORAU intend to resolve the necessity to consider other forms of diagnostic x-ray exposure beyond chest radiography?

NIOSH could not find the statement referenced above in Revision 3 of ORAUT-OTIB 0006 (ORAU 2005). 42 CFR 81 and 82 require the dose from x-ray screening procedures to be included in dose reconstruction, while excluding dose from x-rays performed for injuries sustained on the job. The files that we have reviewed for Mound do not define any other procedures than PA and lat chests for medical screening at Mound. Another subcontractor has reviewed and summarized the x-ray program files for Mound and they have not identified any other procedures. We plan one final data capture of the Mound files and we will incorporate any additional information. If a claimant identifies any additional examinations and evidence is found to support that these examinations were performed for medical screening, then other dose estimates will be developed.

(2) In Section 3.2 of the TBD, it indicates that LAT chest radiography was only required after 9/19/88 for women who underwent breast augmentation surgery. What was the medical basis for this policy and did the women getting LAT chest x-rays also receive a PA chest exam? There is no indication whether any other LAT chest exams were performed on anyone other than this select group either before or after 1988. Please clarify. If so, what was the frequency of LAT chest x-rays, as it is not specified in the TBD?

The medical basis is related to the obscurity of lung tissue by superimposed breast implants, and the physician required the additional projection on these workers. A PA chest would have been performed as well, as it is usually performed first in a series of chest projections. No frequency has been specified. If evidence of lateral projections is included in the individuals' files, they should be included in the dose reconstruction.

(3) In the TBD on Table 3-1, it lists frequency of PA chest x-rays provided at Mound. The table suggests that chest x-ray frequency varied with age and time. However, review of historic support documentation suggests that SOPs provided for voluntary chest x-rays to

all workers who suffered a respiratory complaint, no matter what age. Can NIOSH/ORAU validate how many voluntary chest x-rays occurred, and is that information noted in individual medical records? The TBD indicates that after 1980, only asbestos and other non-defined "at risk" workers are provided annual chest x-rays. Can NIOSH/ORAU better define "at risk" workers beyond the example of welders?

There are no records of the quantity of voluntary chest x-rays that might have been performed, and voluntary chest x-rays (for example for respiratory complaint) would not be eligible for inclusion in dose reconstruction as medical screening under 42CFR 81 and 82. Those considered at risk were smokers, and workers with past and current exposures to asbestos, silica, and beryllium. Generally they were x-rayed every five years below age 30, every two years from age 35 to 45, and annually thereafter. This could be supplemented with claimant provided information.

(4) The TBD in Table 3-1 indicates that smokers of all ages after 1989 received chest x-rays. Our review of historic documents finds a mention of smokers after age 45 being "at risk." Can NIOSH/ORAU further clarify the dates from which Mound provided chest x-rays to all workers who were smokers and considered "at risk"?

The Mound records do not identify the start date for smoker x-rays. However, the first Surgeon General's Report was released in 1964 and that would be a reasonable start date.

(5) The TBD only lists one x-ray unit at Mound since 1980. No documentation exists prior to 1980, to establish what was used prior to 1980, yet x-ray exams occurred. Can NIOSH/ORAU justify its assumption that the entrance kerma values listed in Table 3-2, prior to 1995, are truly conservative and claimant favorable, given they are derived only from ORAU (2003)? It appears that NIOSH/ORAU has not conclusively ruled out the potential existence of photofluorography (PFG) units at Mound. Has NIOSH/ORAU been able to substantiate that all films found in medical files of claimants prior to 1980 are of the 11x17 inch variety?

Page 20 of ORAUT-OTIB 006 (ORAU 2003) provides default values that are conservative and claimant favorable, and its stated purpose is use when no other site-specific information has been located. There is information available from 1960 on that PFG was not used. PFG use might be assumed prior to that year.

(6) The TBD in Section 3.3 states that organ doses prior to 1988 are derived using default values from ORAU (2003) and the application of ICRP Publication 34 (ICRP 1982). Since we do not know the equipment type, the procedure (technique), filtration, or HVL for any procedure prior to 1980, does NIOSH/ORAU believe it is claimant favorable to use assumptions based on ORAU (2003) and ICRP Report 34, which are based on known equipment type, technique, filtration, etc., and if so, why?

The assumptions within ORAUT-OTIB 006 (ORAU 2003) are very conservative and claimant favorable, and based on contemporaneous literature. The assumptions include minimal *collimation, little filtration, and a conservative ESE. It is appropriate to use default values from this document in the case of Mound, or other DOE sites, when site-specific information has not been located.*

(7) The TBD states that organ dose estimates after 1988 are derived from in air measurements, made by the State of Ohio. Review of historic records suggests that Ohio only made such measurements in 1995, 1997, and 2000 for this x-ray unit. Table 3-2 would appear to suggest that Mound made its own measurements from 1988–1994. Can NIOSH/ORAU substantiate if physical measurements are available for review?

The TBD is correct in that in air measurements were made in 1988; however, in-house health physics staff, not the State of Ohio, made them. These in house measurements include a variety of performance tests, but no entrance skin exposure information. The measurements made in 1995, 1997, and 2000 were made by the Department of Health and Human Services Food and Drug Administration, and do include entrance skin exposure estimates from phantom measurements. The TBD will be clarified on these details.

(8) In Section 3.4 of the TBD, it provides a prospective that delineates "uncertainty" as those things that may affect the beam output and therefore the dose. Not to be included, and so stated as not being part of the uncertainty analysis, are other factors, including improperly used screens, grids, film speed, and film development, which ultimately affect dose. The SC&A reviewer agrees with the extent that uncertainty was reviewed and states that a 30% factor is reasonable and conservative. However, the TBD does not consider the other factors mentioned above, nor does it estimate their potential collective impact. These errors will result in retakes that need to be included as extra dose to the claimant review. Has NIOSH/ORAU reviewed these impacts, and estimated their potential affect on dose? Has NIOSH/ORAU been able to estimate and substantiate a retake rate on a yearly basis?

A retake rate was not estimated in OTIB-0006. Many different factors can produce a poor film ranging from positioning and movement through misjudgment of body thickness. Most of the x-rays taken at Mound were standard PA chest films and one would expect a low retake rate. Especially since 1984, quality assurance improvements have been promoted by the Conference of Radiation Control Program Directors (state regulators) and the Food and Drug Administration's Center for Devices and Radiological Health. Retake rates cannot be reproduced for Mound. Some nation-wide basis might be developed but it is likely to be low.

(9) In Section 3.5 of the TBD, it recommends that dose assessors should review each claimant medical file to establish if the frequencies listed in Table 3-1 are appropriate or need to be adjusted. NIOSH should advise the dose reconstructor to include all other exams noted in the file, as that instruction would be appropriate under ORAU (2003), and given that Table 3-1 covers chest x-ray frequency only.

NIOSH does not agree that dose from all x-ray procedures in the claim file should be included, as this is inconsistent with the intent of 42 CFR 81 and 82. 42 CFR 81 and 82 require the dose *from x-ray screening procedures to be included in dose reconstruction, while excluding dose from x-rays performed for injuries sustained on the job. The claims files may include both types of x-ray procedures, those performed for medical screening, and those performed on an as needed basis for that individual, such as for work-related accident.*

(10) SC&A review finds that the proposed multiplier of a 2.5 factor for a LAT, as opposed to the PA, is appropriate for chest radiography, however, NIOSH should make dose assessors aware that a correction factor of 2.5 is not appropriate for other exams, such as an AP and LAT c-spine. Has NIOSH considered establishing factors for other exams, as historic procedures manuals from Mound files show many other procedures beyond chest radiography were envisioned?

The files that we have reviewed for Mound do not define any other procedures than PA and lat chests for medical screening. Another subcontractor has reviewed and summarized the x-ray program files for Mound and they have not identified any other procedures.

Response to SC&A Questions
Mound Occupational Environmental Dose (ORAUT-TKBS-0016-4)
April 5, 2006

(1) The TBD states that no onsite environmental monitoring occurred at either Dayton or Mound prior to 1971. It appears that TBD authors derived pre-1971 inhalation doses, using total stack effluent data, and empirically derived atmospheric dispersion factors. Has NIOSH explored the possibility of comparing these empirical determinations to offsite concentrations of target nuclides, which were measured at various offsite locations during the early years?

Yes. However the offsite data was not suitable for dispersion modeling for onsite concentrations and doses. Locations changed and sampling periods were varied and intermittent. This was discussed in section 4.2.1 of this TBD.

(2) The Dayton site does not have environmental survey results for 1943, 1944, and 1946. The TBD utilizes comparable results from 1945, 1947 and 1948, as the basis to use December 1947 (highest recorded) to estimate inhalation doses. Has NIOSH compared the operations and production records for all these years, especially for Dayton Unit III, to ensure that perimeter measurements in December 1947 do represent a worst case?

Limited quantities of material were used at Mound during 1943 and 1944, and it would not be appropriate to assume 1947 levels for those years. Available records showed the highest concentrations in 1947. A further review of more recently acquired records will be used to *verify that the 1947 levels were the highest.*

(3) The TBD estimates that inhalation of Po-210 and soil ingestion resulted in environmental doses at Dayton Units III and IV, to less than 1 mrem annually. These doses are due to submersion, and external exposure to contaminated soils. However, the TBD estimates that external environmental gamma exposure from the facilities could be as high as 1800 mrem per year of operation. This assumption is based upon one control badge result during May 1944. The estimate is further based upon a 2000 hr per year occupancy factor. How does the estimated 1800 mrem/year, outside the facility, compare to inside measurements noted on worker wrist film badges?

The lower distributions of external dosimetry measurements are questionable and cannot be used for this kind of assessment. For example, one file showed an individual who had accumulated only 18 mrem in two years. If the monitored period had weekly exchanges, the 1800 mrem/yr would be 35 mrem/wk. This is below the dosimeter sensitivity at that time and any data around those levels would not be sufficiently reliable for analysis. The 1800 mrem/yr is the best available data.

(1) The TBD utilizes the same approach to derive intakes for dose reconstruction for Mound facility, as chosen for Dayton, for the period prior to 1971. However, significant offsite airborne monitoring was performed at Mound after 1948. Has NIOSH/ORAU made an

attempt to compare results of offsite monitors to the results from the atmospheric dispersion approach results, displayed in the TBD?

Yes, but as noted in the response to Question 1. above, the data were not suitable for that purpose.

(2) The TBD indicates that for the years 1971–2003, an average of onsite monitoring stations was used to determine environmental intakes. Has NIOSH reviewed the onsite monitoring data for all stations and determined if the use of the highest monitoring site would be more claimant favorable?

The TBD used onsite air sample data when available and otherwise used atmospheric dispersion of stack effluent source terms. The approach was summarized in the second paragraph of section 4.0. The balance of the TBD developed each step for each facility that ultimately produced the Table 4-20 Site Wide Maximum Annual Intakes at Mound.

(3) The TBD indicates that no general area direct gamma measurements were made for Mound, with an exception of an aerial survey in July 1976, which reported gamma estimates ranging from 20.5 to 23.5 μR/hr. Was the aerial survey corrected for ground level elevation? The levels stated would result in 40–50 mrem per year, as compared to 1800 mrem estimated for the Dayton Unit III and IV. How does the TBD author correlate this difference, given the source terms at Mound far exceeded Dayton source terms?

The aerial survey exposure rates are corrected to a height of one meter above the surface. A number of locations have been "calibrated" for reference including an area on the Temple Bar at Lake Mead (Nevada). The aerial survey was a "snapshot" of the exposure rate during July 1976. As developed in the TBD there was significant contribution to the external exposure rate from sources other than the soil surfaces.

Responses to Key Questions for NIOSH/ORAU Regarding Mound Site Profile Review Documents by Sanford Cohen & Associates

January 19, 2006

Occupational Internal Dose (ORAU-TKBS-0016-5)

(1) Can NIOSH update the Internal Dosimetry TBD (ORAUT-TKBS-0016-5) so that there is more consistent and appropriate use of the terms: detection limits, reporting limits, and action levels? The author of the TBD has NOT done a very effective job of this. The terms are used interchangeably throughout the document. A good example is on page 22 of 65 of the TBD, in the sentence preceding Table 5-7 where it states "…MDAs derived using Currie's equation 5-2…" and the table providing protactinium detection limits provides values in the last column as 'Detection limit (dpm).'"

In reviewing the Mound records, three terms were used to express sensitivity. They are the Minimum Detectable Activity (MDA), the Decision Level, and the Detection Limit. Four terms were used to indicate some reporting or follow up action. The four are Reporting Limits, Action Levels, Reporting Levels and Notification Levels. During the 60 years, the bases of the definitions were not consistent. The TBD is being revised to clarify the meaning or meanings of the respective terms and their significance for dose reconstruction. The bases for the values are being verified. (5.1.5 Detection Limit has been changed to Decision Level). Chest count MDAs were revisited and the variation is better managed with fitted exponential equations for four characteristic radionuclides related to the weight of the person being counted.

The MDA appears to be consistent and corresponds to Currie's treatment of a dual distribution; that is the statistical variance of the background combined with the statistical variance of the analytical value above the background. The specific formulae are slightly varied because Currie's successive publications had formulae that varied slightly depending upon the type of analysis. The term detection limit was used rather loosely. In most cases, the detection limit was identical to the MDA. However, other less defined detection limits were also applied. For example, an early principle investigator gave detection limits that were, in his judgment, the level that had a value that was ± 100 percent.

Action Levels were initially applied for in-vitro monitoring and were defined as the indication of a burden corresponding to a dose rate of 300 mrem wk^{-1}. A more recent Action Level was any in-vivo chest count that exceeded the MDA. Reporting Levels, Reporting Limits and Notification Levels varied based upon the application. These were not necessarily dose based but they will be presented in that context.

(2) Can NIOSH provide more detail on how a reasonable dose reconstruction can be done prior to 1981 when the following statements are made in historical documents? The following statements can lead to large possible missed doses.

> *...erratic recoveries from 6% to 85% were observed for metabolized plutonium in urine due to plating.* (Meyer and Reeder 1992)

"The gross alpha results were reported as Pu-239 for workers in R Building and Pu-238 for SM and PP Building workers until 1980….The precision of Pu-239 analysis was reported in 1981 as 6.7% at a concentration of 3.2 dpm kg^{-1} in urine with a large counting error of 73% in Section 3, Bioassay Data Quality Assessment/Control" (Meyer and Reeder 1992).

We will do the best that we can given the nature of the information available. We cannot improve the historical data.

For example, for the metabolized plutonium in urine we recommended increasing the reported urine sample results by a factor of 8.5. The analysis assumed 85 percent recovery and we estimated that a 10 percent recovery was reasonable.

The second paragraph above was misquoted. The paragraph is:

The observed overall precision for measuring Pu-239 concentration at 3.2 dis/min/kg in urine was 6.7 %; however the error due to counting a sample at this concentration of Pu-239 was greater than 73% of this value.

It is clear in Appendix II of Section 3that the 73 % refers to a counting error of 73 % of the precision value or a 4.9 % counting error which is reasonable.

Application of a log-normal σ_g *of three, as is done in dose reconstruction, is sufficiently large to account for the quoted precision and counting errors, as well as other uncertainties in internal dose reconstruction.*

(3) How is internal dose calculated for those employees that worked in areas that were not monitored or were monitored only during the time they worked in that area and then discontinued? Likewise, how is internal dose calculated for those monitored, but whose recorded dose results are less than the reporting limits in Table 5-1? The TBD on page 10 of 65 states:

> *Individuals identified as being involved in an internal exposure incident or had urinalysis results in excess of the reporting limits listed in Table 5-1 were required to submit additional urine 24-hr samples for analysis. Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed.*

For example, Pu-239 reporting limits appear to be the Action Level of 3.5 cpm 24 hr^{-1}. This equates to 300 mrem wk^{-1}, or 15 rem yr^{-1}, which is a very high missed dose level.

(Table 5-1 lists Action levels and not reporting limits.)

The 300 mrem $week^{-1}$ *was the limit early in the history of Mound. The report will be revised to show specific dates and time periods to account for potential missed doses.*

A coworker internal dose analysis is in progress for Mound. The TBD gives direction on how to interpret information but does not give guidance on how to reconstruct a dose. Missed dose is assigned when an individual's results are less than the MDA or reporting level.

The Action Level for ^{239}*Pu should not be confused with the MDA. Table 5-12 on p. 27 lists the urine MDAs with the corresponding periods. These are the recommended levels for determining any potential missed doses.*

(4) Are there any estimates of the number of unmonitored employees for the various isotopes over the years that may have had unmonitored exposures? (For example, the TBD states "…only those workers conducting research to separate and purify protactinium were monitored monthly for Pa-231." Nose swipe data were considered secondary information and were not evaluated. Air-sampling data was also considered secondary information contingent upon demonstration that measured concentrations were representative of breathing zone concentrations. Were breathing zone samples done and are the data available for dose reconstruction personnel? The TBD does not make this clear on page 40, section 5.4.3.

Estimates of unmonitored employees can be made however there is no essentially no information that can identify a number of unmonitored individuals that were exposed. Limiting the monitoring for ^{231} *Pa to those who were working with the radionuclide seems reasonable.*

Nose swipe data can show that radioactive material has been inhaled but the data cannot be used to estimate dose.

Breathing zone air samples are likely to be more representative of potential inhalation exposure compared to area or fixed location air samples. The records show that lapel air samplers were in use during 1996 and that more were requested (Memo Dated February 5, 1997 from Ken Sirois to Al Ogurek Subject: Internal Dosimetry Group Perspective on the Use of Lapel Samplers). However we can find no data on any lapel air sampling measurements.

(5) Who determined the need for special bioassay sampling and what indicators were used to trigger required special bioassay samples?

It is not clear what the comment is referring to as "special" samples. Work restriction and follow up sampling was triggered when action levels were exceeded (e.g. Table 5-1).

Samples were collected when any incident occurred that suggested internal deposition.

(6) Was DAC-hr tracking ever done at Mound for chronic exposure control of any of the many radioisotopes used? Is there air monitoring data available?

No DAC-hr tracking data have been found. This approach was recommended in the Feb. 5, 1997Memo cited in 4. above.

(7) Historically, what was the basis for determining who was put on a bioassay program? Were these only the hands-on researchers or workers? How were maintenance workers, janitorial staff, ventilation workers, pipe fitters, and occasional visitors to the areas handled?

The basis seemed to be common sense. When work entailed potential intake the individuals were placed into the appropriate bioassay program.

(8) What triggered generation of incident reports? What were the indicator levels required? Were all incidents reported somewhere with the personnel involved identified? Information that we have been provided on polonium incidents alone does not support the number noted on page 17 of the TBD.

No specific criterion for incident reporting was found. Action Levels given in Table 5-1 were in the nature of administrative limits. Follow-up sampling and possible work restriction would prevent any one from exceeding the annual regulatory limits. One basis was 300 mrem/wk to the critical organ given the annual limit of 15 rem. Incidents were reported and in many cases the names of the individuals involved. But we have not found the specific dose records for the individuals involved. Probably the most severe accident was the explosion in the Pu-238 glove box that occurred at 2:00 PM on April 3, 1968. The three exposed employees were followed closely and the results were published in Health Physics, *(Vol. 18, June 1970, pp. 631–639)*

The 12 polonium-210 incidents cited on page 17are from Mound documents. From the Pre-1989 Dose Assessment by MJW, we know that 63 people received CaDTPA therapy. The question implies that there were many more polonium-210 incidents. If the incident information that you were provided supports this implication we would be interested in reviewing it to determine if an update to our site profile is warranted.

(9) Is there a list of the major incidents that have occurred at the Mound facility?

Mound Site Radionuclides by Location Technical Manual (*King 1995) lists incidents by Bldg and room number. Cited references include names of the individual(s) involved. It does not seem reasonable to include such a list in the TBD.*

(10) How can you justify the two final paragraphs of section 5.2.1 on page 12 of the TBD as claimant friendly? Considering the previous discussion in the text of plasma torch operations, etc., this assumption does not seem reasonable.

The wording of this section is misleading. Although some of these operations do produce submicron particles, they also produce larger respirable particles, and except for the Po-210 operations, it is believed that the adoption of the 5 µm AMAD default assumption is reasonable.

The assumption of a smaller particle size is not claimant favorable in all situations: it will depend upon the organ of interest, among other factors. For Po-210, starting with bioassay results, although the intakes are different, the doses are identical for 1 and 5 µm AMAD intakes. The single exception is the ET_1 *region.*

(11) What is the basis upon which NIOSH makes the statement in the TBD in the paragraph below Table 5-10, that many of the plutonium compounds are highly soluble and are ICRP type M? SC&A questions if this is the case. Only the nitrate and chloride compounds of plutonium in normal industrial processes are soluble enough to be classified as type M. NIOSH may want to review with the author his knowledge of the chemistry and biology of plutonium considering this statement and the discussions of particle size and solubility of plutonium throughout the document.

When a TBD advises that multiple material types were present, the Dose Reconstructor is to use the type that is claimant favorable for the cancer organ.

The term "highly soluble" would befit Type F and is not accurate for Type M. Use of the term soluble would be more appropriate.

(12) In equation 5-10 on page 26 of the TBD, shouldn't the 85% be in the denominator of the equation? Since the recovery was 85%, then the daily excretion would seem to be the dpm value corrected for the efficiency and recovery values.

The purpose of this equation is to modify the previously assumed recovery (85 %) to the newly assumed recovery. This would result in an increase in activity by a factor of 8.5 (85%/10%).

(13) How were the less than detection level bioassay values recorded? On page 16 of the TBD, second paragraph, it states that values of 0.0 were used for non-detection results for tritium. Was this true for all other radioisotopes?

Recording of results less than "detection levels" depended upon the period, the analyte and the analytical method.

(14) How were urine sample results handled for individuals having chelation therapy? There is some explanation in the Phase II Final Report Appendix A "Plutonium Position Paper on Dose Assessments Performed for the Mound Pre-1989 Dose Assessment Project" (MJW 2002a), but, there is little, if any, explanation in the TBD for internal dosimetry.

The methods used by Mound to assess doses to individuals who were chelated are not relevant to this project. We will assess them using current models. Thomas LaBone, an expert on this subject, will provide input as needed.

(15) How is the dose reconstruction going to be handled for those employees that had potential exposures to multiple radioisotopes and for whom gross alpha counting was used to analyze their urine excretion? Examples include the plutonium isotopes, americium, uranium (including U-233), radium, thorium, etc. The TBD identifies numerous assumptions throughout the discussions of these radioisotopes.

Radionuclide exposure may be identified by the work location and history. The MJW 2002 analysis included the radionuclide distribution associated with irradiated radium-226. The dose reconstructor will review files for any available information.

(16) Is NIOSH sure that the ratios for weapons grade plutonium used in the TBD are correct? On page 35 of the TBD, first paragraph of section 5.3.2.6, there is a wrong table reference for weapons grade plutonium and the ingrowth rate for Am-241 in weapons grade plutonium is approximately 20 ppm per month.

The reference to table 5-8 will be changed to Table 5-9.

Weapons grade plutonium needs to be relatively pure (about 93 percent plutonium-239) so the production reactor irradiations are relatively short with low burn up. Irradiation also produces plutonium-241 (14-year half life), which decays to americium-241. Hence the gradual increase of americium-241 with age which enhances chest counting sensitivity.

Comparison of Table 5-9 to some more recently reported data from Savannah River Plant shows.

Nuclide	***Table 5-9 Weight Percent***	***Savannah River Weight Percent***
Pu-239	*93.2*	*95.0*
Pu-240	*5.7*	*4.2*
Pu-241	*0.33*	*0.8*

With the Savannah River data about 25 percent of the dose is due to plutonium-241.

(17) Is the MDA for Pu-238 and Pu-239 fecal listed in section 5.4.1 **really** better that the MDA for Pu-238 and Pu-239 urine? This MDA for plutonium fecal can only be approached within the first week after an incident.

Fecal sample analyses are particularly important for insoluble forms that cannot be adequately monitored by urine analysis. First samples need to be collected within eight to 72 hours due to *the rates of upper respiratory and GI clearance. A new search of the records did turn up the MDAs for plutonium. This was derived from a large data set of analytical results.*

Nuclide Form	***MDA pCi/Sample)***
Pu-238	*0.02*
Pu-238 High-fired Oxide	*0.05*
Pu-239/240	*0.02*
Pu-239/240 High-fired Oxide	*0.05*

Of course, the MDA is not a function of time after exposure and dose.

(18) Based on the current and past decision levels and the fact that no uncertainties for the bioassay measurements were stated in the records (Attachment 5D.0 in the TBD), what is the estimated potential missed dose in the records data?

Calculation of missed dose is based on an individual's bioassay data and the period of exposure, and may also include consideration of exposure to associated radionuclides that were not directly monitored. If no bioassay data are available, estimation of doses depends on the potential for exposure and may be based on coworker data.

(19) Can you please explain the separate, and very different, MDA values for Pu-240 and Pu-239 chest counting in Table 5-22 on page 40? Was Pu-240 really monitored?

The different MDAs cannot be explained. However, chest count data were reviewed and the MDAs were fitted to exponential equations related to the weight of the individual being counted. Those results are:

Americium-241	$y = 3.0E\text{-}05\ e^{0.0229X}$	$R^2 = 0.8029$	*(~1.0 – 7.0E-04 µCi)*
Plutonium-239	$y = 2.7E\text{-}03\ e^{0.057X}$	$R^2 = 0.915$	*(~0.04 – 4.5 µCi)*
Plutonium -238	$y = 1.0E\text{-}03\ e^{0.0572X}$	$R^2 = 0.9086$	*(~0.02 – 4.5 µCi)*
Thorium-234	$y = 3.0E\text{-}04\ e^{0.0204X}$	$R^2 = 0.8763$	*(~0.5 – 4.5E-03 µCi)*

Where y = *MDA (µCi)*
X = *Weight (kg)*

The above are based upon 1994 data. The counting system at that time was a six detector array of intrinsic Ge detectors. These were initiated in 1992. Prior counts utilized a Phoswich detector and those MDAs in the first and second columns of Table 5-22. This section is being revised.

(20) During the SC&A review of the TBD and the Phase II Final Report (*Plutonium Position Paper on Dose Assessments Performed for the Mound Pre-1989 Dose Assessment Project Phase II Final Report*) (MJW, 2002), SC&A notes that there is a lack of proper information to calculate MDAs or LDLs for the bioassay data (defaulting to a "Level of Significance"). There also appears to be totally insufficient chemistry data for recovery and gross alpha determinations (See page. 30 of 65 of the TBD). In light of this, how does NIOSH plan to provide a reasonable or appropriate dose reconstruction for plutonium exposures of the Mound population?

We believe that there is sufficient information to estimate MDAs. Use of the "level of significance", which is larger than reported MDAs for the time, will generally result in claimant favorable assessments because the MDA is used to calculate the missed dose.

(21) What energies were analyzed in the spectrums for lung counting/whole body counting for the various radionuclides? Of particular interest are the transuranic isotopes. It does not appear that there was very good detection capability or consistency in the results at Mound or at the other sites that tried to monitor workers from Mound.

After 1992, the low energy photons from plutonium-238 and plutonium-239 were counted. The 59.5 keV gamma ray from americium-241 was more readily measured. The earlier Phoswhich detector focused on the 17 keV x-ray from plutonium-239.

(22) Were there workers that had exposures up through at least the 1970sthat were missed as a result of poor *in-vivo* counting sensitivity?

With all monitoring methods there is always the potential for "missed" exposures; there is no instrument that can measure down to zero. Missed doses are assigned based on the sensitivity of the monitoring methods, so a less sensitive instrument will yield a larger missed dose. However, when multiple monitoring techniques were used, all are considered in the analysis.

(23) Can you explain in more detail the discussions of particle size and solubility on page 63, of Attachment 5D.5 and 5D.6 in the TBD? The statement "Alpha emitters with larger 5-µm particles and lung clearance types S or M tend to have smaller inhalation effective dose coefficients than do smaller 1-µm particle" only holds true for certain organs.

The discussions in these sections are not site specific and do not belong in the TBD. The y will be removed when the TBD is revised.

(24) What areas and processes at Mound are considered potential for high-fired oxides of radionuclides such as uranium and plutonium?

We have some of that information from King 1995 and Meyer 1992. If a specific claimant relationship cannot be established then the most favorable assumption can be made based upon the cancer type and site. The Mound records will be reviewed to assure the best information is available regarding high-fired oxides and locations.

(25) How were intakes of highly insoluble materials determined prior to *in vivo* counting?

What is relevant is how we would determine this, not how Mound might have, as we do not use their dose assessments. We would use available bioassay date and air monitoring results where available. If information is not available and there was the potential for highly insoluble materials in a particular area, the appropriate solubility type yielding the largest dose to the organ of interest would be assigned.

(26) Have there been any comparison studies done at Mound between air concentration data and bioassay data? If so, what were the results?

We have specifically looked for this kind of information but have not found records to this effect.

(27) How did you account for intakes of the various radionuclides used at Mound prior to the establishment of bioassay techniques to monitor for them?

In most cases, later bioassay can be used t estimate intakes from earlier periods.

(28) What were/are the background levels of uranium and thorium in urine and fecal samples for the geographical area around Mound?

Area specific uranium and thorium background levels in urine and feces have been located. This project does not subtract background so the information is not important unless results are known to have a significant background subtracted.

(29) Have there been any recorded incidents of tampering with urine bioassay or dosimeter badges at Mound?

No specific records have been found that document such incidents. One would expect that any significant tampering would have been dealt with at the time of discovery. There were some unexplained uranium urinalysis results for a Mound employee in recent years that gave rise to a concern that the sample might have been tampered with. This incident is well documented.

(30) What shortfalls, through audits, assessments, or investigations, have been identified in the Mound internal dosimetry program?

Review of audits or investigations was not a principle part of this initial survey of the records. Where shortfalls were obvious, such as in the radiochemical recoveries, those weaknesses were reported in the TBD along with recommendations to increase the calculated doses.

Responses to SC&A Questions
Occupational External Dose (ORAUT-TKBS-0016-6)

(1) ***Beta radiation*** **–** As early as 1944 it was known that the beta fields were intense around the irradiated material because workers had to use lead gloves and tongs to handle them and in 1956 beta activity in 1 lambda of water maxed out the counter (Pages 6 and 36). The TBD and other documents also state that many beta-decay radioisotopes accompanied the Bi/Po irradiation, separation, and handling process. However, according to the TBD, they did not always consider beta radiation of concern and did not routinely monitor/calibrate for it until later years (1979?) (Page 24 and Page 37). They apparently assumed that beta monitoring was not needed when working around Po (Page 28, last paragraph) and if beta dose was monitored, it was not always recorded or was not recorded with worker's identification (Page 10). What years were reliable beta doses recorded?

Beta radiation to the hands was recorded from the beginning of the polonium alpha-neutron research in 1943 with the Dayton Project. There are several weeks and fragmentary months of finger ring beta dose measurements from the Dayton Project but the results were considered unreliable because of difficulties in calibration.

The beta dose does not come from handling the polonium-210 per se. It comes from the remaining fraction of parent lead-210 and activation impurities in the bismuth slugs which were irradiated and from which the polonium was chemically extracted.

In the report of March 8, 1944, Capt. Ferry states: "The tolerance dose for beta radiation has been set at 0.5r per 8-hr. day." The report of March 30, 1944, elaborates on the beta dose limits. Capt. Ferry writes: "The tolerance accepted by the Medical Section for beta radiation to the hands is 0.5 R/8 hours or 3.5 R/week. The entire dose of beta radiation may be received in one day, if the person exposed does not receive any beta radiation for the rest of the week, but the entire exposure for any length of time greater than one week cannot be acquired in concentrated doses without causing irreversaible (sic) tissue changes." We could use these dose limits as a first cut to assign dose.

In his October 30, 1944 report entitled <u>Report On Medical Considerations of Work with Polonium at Monsanto</u>, Capt. John L. Ferry writes: "The beta radiation from the bismuth slugs is sufficient that the use of lead gloves and tongs in handling them was considered imperative." Once the polonium had been extracted and the activation impurities chemically removed there was no beta dose because polonium is a pure alpha emitter.

According to the extant reports the quality of the beta extremity dose monitoring improved in 1944. In addition, there are very careful statements of the dose limits, both whole body photon and extremity beta, which were applied during those years.

The Tolerance Dose published by the Atomic Energy Commission on January 5, 1945 indicated a skin dose limit of 0.1 rep/day measured by an ion chamber with a 10 mg/cm^2 wall.

We could derive a beta extremity dose for each year from 1944 through 1948 by a careful study of the extant records. More records have been uncovered since the TBD was written. It might be necessary to go with some fraction of the maximum permissible dose for the years 1949 through 1959.

> What can be done to provide dose reconstructor with some reliable beta exposure information for dose calculations when beta radiation was present, but not monitored/read?

The dosimetry records are fragmentary but there are enough of them that an average beta extremity dose, possibly with a standard deviation, could be derived for most of the years from 1944 through 1948. Some assumptions would have to be made to cover the data gaps but it would be a reasonable dose for assignment. A few more Dayton Project records have been uncovered since the TBD was written which might help close some dosimetry gaps. It might be necessary to go with some fraction of the maximum permissible dose for the years 1949 through 1959.

In 1954 NBS Handbook 54 (Protection against Radium, Cobalt-60 and Cesium-137) first considered the skin as a critical organ and set the permissible dose at "0.6 R/wk at a depth of 7 mg/cm^2." On Jan. 8, 1957, the NCRP (Statement No. 2) gave a Maximum Permissible Dose of 10(N-18) rems and the dose in any 13 consecutive weeks could not exceed 6 rems.to the skin.

We have very recently regained access to the Mound files and have spent several days for data capture. We now have additional information on shallow dosimetry but we need to evaluate the information for potential application.

(2) ***Use of 1949–1959 data for earlier years –*** The TBDs and other documents illustrate how the Dayton/Mound sites in the early years were rapidly changing and exploring new, unknown, technologies, especially in the area of radioisotopes. The first era was during 1943–1948 where R&D and limited production was conducted at several makeshift sites. The second era was around 1949–1959 when a new facility was used to start production and further R&D. The physical facilities and working conditions of the two eras were necessarily different. Additionally, information gathered during the first era could start to be used to control radiation exposures during the second era. However, the second era was not itself without health physics (HP) problems. As stated in a letter to Dr. J.H. Roberson of the AEC in July 1952 (Burbage, 1952):

> *…thus far leads us to the conclusion that we are facing a serious health physics problem in the handling of quantities of actinium. At the present time 40 or 50 Mound Laboratory employees receive unknown exposures several times a week to a chain of radioactive materials whose parent has an unknown toxicity and metabolism. For this reason it becomes necessary for us to point out the need of immediate action in the fields of health physics…*

Page 9 of the TBD mentions that Mound never had a well-documented quantitative study of its external dosimetry programs and on Page 10 it states that the record on historical dose limits standards is ambiguous and a great deal must be inferred. Considering the differences between the two eras (and that the second era was not without problems) it does not appear to be technically sound to use the 1949–1959 modal recorded dose to establish doses for the first era workers.

Is the TBD (e.g., Page 50 and 51) recommending using the modal dose from the workers that were badge during 1949–1959 as the assigned dose for workers during 1943–1948? Additionally, how could incidents/accidents that resulted in individual exposures above the average (such as noted in the first paragraph on Page 12 of the TBD and incidents such as the two that occurred in 1944 as described in an article by L.B. Silverman (Silverman 1962) be included in a worker's DR if the modal dose is used?

The 1952 letter to the AEC was concerned about the internal deposition and dose from actinium. By 1952 the external dosimetry program was capable of monitoring personnel exposure to the penetrating radiations emitted from actinium.

While Mound did not mount a broad scope assessment of the earlier dosimetry systems in use, it did rely on methods that were developed by reliable organizations including Oak Ridge National Laboratory and the Nevada Test Site.

Footnote b. explains that the Base Dose for the period 1943–8/1949 assumes the modal neutron dose experience recorded from 9/1949 through 1959.

It is assumed that a claimant that was subjected to unusual exposure due to an incident would be assigned a dose based on his or her recorded monitoring results. If those records are not available, then a graded approach would be used to establish conditions leading to an estimate of the dose. Relatively few individuals were involved in any incidents. It would not be reasonable to assign a higher dose based upon exposures due to incidents.

After this document was drafted, more dosimetry data from the 1943–48 era has been uncovered. They might allow interpolation to better estimate the exposures for periods lacking data such as 1947. Dose estimates could now be developed from what actual data is available.

(3) ***Clarification of badging –*** Table 6-2, Page 10, shows that night-maintenance staff members in Building P were starting to be routinely monitored for neutrons in 1963 and that some hourly engineering staff members were starting to be routinely monitored for neutrons in 1966. Table 6-4, Page 11, lists some information on who was badged in the 'Comments' column. From this information, it is not clear when what groups were badged. According to a report of January 1961 (Mathew, 1961) roughly only 15%–20% of the employees were badged during 1947–1959. Could you provide more details on who was badged, and when? Was everyone inside the plant area (security, crafts,

maintenance, janitorial, etc.) considered "radiation workers," or just those routinely handling radioactive materials (RAM)?

Table 6-2 on p. 10 summarizes the assignment policies. We have not found any more explicit guidance or specific information.

(4) ***Missing dose within annual dose records 1947–1977 –*** Pages 12 and 24 states that only annual dose records are available for 1947–1977 because the weekly/monthly/quarterly records were lost. Pages 50 and 51 recommend that the modal dose be used for missed dose information. If a complete year of dose information is missing, this may work. But how does the DR know if a given year in a worker's dose record includes monitoring for the complete year? Perhaps the dose record only contains information for a part of a year. The fact that Mound did not have any type of policy for recording dose due to lost or damaged dosimeters (Page 12 of the TBD) compounds this problem.

There is a method for assigning missed dose when the number of zero measurements is unknown and used by the dose reconstructors for Mound records from 1947–1977. This method is based on Section 2.1.2.3 OCAS-IG-001 (OCAS 2002a), and discussions with NIOSH. Briefly, this method consists of estimating the maximum, median, or minimum number of potential zeros considering available information, multiplying by the limit of detection (LOD) or the LOD/2, and treating the result as the 95th percentile of a lognormal distribution. The specific details depend on whether the approach to dose reconstruction is to underestimate, overestimate or provide a best estimate of the dose to determine the probability of causation.

(1) ***Incidents –*** Page 12 states that each incident at the plant was documented. Was the incident and the associated estimated dose recorded in each worker's file that was involved in an incident? What records exist for unbadged workers involved in radiation accidents/incidents?

There were reports written of each and every radiation incident. We have recently recovered reports of all significant incidents, but not all reports included estimated doses from the incident. Since most of these accidents occurred in the research laboratories where only badged personnel were allowed to go, it is not likely that there were unbadged people involved in these incidents. The energy employee's dose from incidents is expected to be included in their dose records (they are cross-referenced with the incident files per the Mound records organization). If the energy employee (badged or unbadged) states that he/she was involved in an incident(s) in a telephone interview and there are no records in the claim file, an additional data request is made to Mound to attempt to verify the verbal information.

(2) ***Work hour details –*** Page 13 states that the DR should adjust the worker's neutron dose if the worker worked greater than a 40-hr workweek. Is the number of hours each worker worked each week contained in their records and available to the DR?

It is likely that an interview with the worker or his immediate surviving family could provide an estimate of the overtime.

(3) ***Variation in neutron QF*** **–** Page 16 lists possible reasons why the neutron flux, that was required to be equal to 300 mrem/wk, varied between 30 and 150 n^o/cm^2-s in the period of 1947–1969 (note: it should read n°/cm^2-s not n°/s/cm^2). However, the two reasons suggested (longer than a 40-hr workweek or decreased energy of the neutron sources) would not account for these drastic changes. Even a 60-hr workweek would only decrease it by 33%. Changing back and forth between 5 MeV and 1 MeV neutrons would only change it by a factor of 2 as noted in ICRP 60 (ICRP 1991) and on Page 17 of the TBD. Could it be more likely that Mound personnel were not sure of the measurement methods, energies of the neutron fields, and the correct neutron flux-to-dose equivalent conversion factors to use during this period of development?

We believe that the Mound health physicists knew the neutron energy spectrum. Prior to 1991, they were not using ICRP 60 but were likely to refer to NBS Handbook 63 Protection against Neutron Radiation up to 30 MeV (Nov. 1957). It would probably be sufficient for the DR to use 100 keV to 2.0 MeV energy range. Page 17 of the TBD shows a variation by a factor of five: i.e. the equivalent of 300 mrem/wk ranged from 30 n/cm^2*-s to 150 n/*$cm^{2\text{-}s.}$

(4) ***NTA film neutron energy threshold*** **–** Assuming higher energy of neutrons (e.g., 1.3 MeV instead of the more likely value of 0.75 MeV on Page 17 of the TBD) is not always claimant favorable. Using the old NBS #63 (NBS 1957, Figure 13, Page 62) may show a slight claimant advantage using 1.3 MeV instead of 0.75 MeV neutrons (approximately a 15% reduction in allowed neutron flux per 300 mrem/wk), but using the ICRP 60 (ICRP 1991) continuous function shows that the weighting factor for 0.75 MeV neutrons is greater than for 1.0 MeV neutrons and if you use the step function, they are the same. But the real danger in assuming a higher energy neutron field than what the worker is really exposed to is that the NTA film practical threshold is around 1 MeV and therefore lower energy neutrons could go undetected. This was mentioned on Page 19 of the TBD, but not sufficiently addressed. Page 30 of the TBD, Table 6-17 Footnote (d), uses a 14% correction factor obtained from the SRS for neutrons in the range of 0.1 to 2 MeV. This correction factor depends to a large extent on the facilities' operating conditions and should be determined for each site and locations within a given site. A missed dose of 14% for all neutrons that falls below the 1 MeV threshold of NTA film, considering the varied missions at the Mound Site, appears to be very small and could result in missed dose. Neutrons sources in hydrogenous shielding and process streams quickly degrade to lower energy neutrons. In general, NTA film misses around 1/4 to 1/2 of the neutron dose around moderated neutrons. Some situations could result in the majority of neutrons below the NTA threshold so that the NTA film dose does not record a significant dose and the missed dose cannot be calculated from ratios. Is the DR process going to address this issue further?

There were three distinct neutron energy spectra at Mound. One was the fission spectrum (e.g. critical assembly). The second was the higher energy (two to five MeV) neutrons from the manufactured alpha-neutron sources. The third was the lower energy incidental environmental alpha-neutron interactions (e.g. α-O and α-F) with plutonium-238 used for the RTGs.

Given the previously mentioned research, it is likely that we will be able to characterize three neutron spectra to provide a better basis for the neutron doses.

(5) ***NTA film fading –*** Page 20 discusses NTA film track fading and states that it became important in 1968 and corrections were made from that time forward. It also states that Meyer (Meyer 1951) noted film fading as early as 1951, but he must have not considered it important and no corrections were apparently made until 15 July 1968. If fading resulted in under recorded doses in 1968, it also did so back to 1949 when NTA film was first used at Mound. How is this under-recorded neutron dose due to NTA film fading during 1949–1968 being handled by the DRs?

It seems reasonable to apply the same fading from 1949 on. That is the weekly fading rate of 33 percent can be assumed or otherwise the biweekly fading rate of 56 percent. It is important to note that on March 15, 1976 direction was given to double previously recorded neutron doses from 1970 to 1976.

(6) ***Percent NTA film fading –*** Page 20 states, in the next to the last paragraph, that Meyer (Meyer 1994) in his 1967 appendices recommends an evaluation error of approximately 9% per week for plutonium-fluoride sources. However, elsewhere on this page (Table 6-11) the percent fading for PuF_4 is listed as 36%/1 wk and 56%/2 wk. Why the difference? Which was actually used in the dose records? Should PoBe be stated instead of plutonium-fluoride in the next to the last paragraph concerning Meyer's conclusion note?

Further review of the empirical data shows that the fading with PuF_4 is 29.7 ± 0.80 percent per week (95% confidence). This is the value that will be used.

(7) ***Thermal and low-energy energy neutrons* – Comment concerning Page 21, first paragraph.** If there are neutron sources, then there are thermal and low energy neutrons in the environment around these sources that NTA film would not detect, but Li-7 photon monitors could detect. Also, the 2.5 MeV peak in Figure 6-2 most likely belongs to the B^{10} reaction, not the Li^6 reaction.

The rhetoric on page 20 is confusing and will be improved. The bottom line is that the neutron energy spectrum must be known in order to determine the dose due to higher energy neutrons while the dosimeter responds primarily to low energy neutrons.

Extensive studies by Mound, completed in February 1978, included neutron spectrometry with Bonner spheres and also intercomparisons of film and TLD calibrations. The studies revealed that neutron dosimetry determinations from 1970 through 1976 may have been low by as much as a factor of two. A March 15, 1978 memorandum from W.A. Bigler announced the adjustment of personnel neutron doses by a factor of two for that period.

(8) ***Maintenance staff –*** Page 23 states that the dose reconstructor should assign maintenance staff 38 mrem/2-wk periods or 1 rem/yr for unmonitored periods before March 22, 1966.

Maintenance staff often perform many different functions at different locations/situations and are being assigned much lower doses than are listed on Pages 50 and 51 of TBD for base/missed doses (2 to 7 rem/y neutron plus photon). How can we know that the lower dose of 1 rem/y can be representative of the doses maintenance workers received?

This question will be further evaluated.

(9) ***Short-time area monitoring –*** Page 23 states that the dose reconstructor should assign workers in buildings T, R, SM, and SW missing doses from area-monitoring results performed during a short time (5/25/63 – 6/8/63). How can it be assured that the radiation fields remained the same after this short 2-week period that the surveys were taken? How long of a period after 6/8/63 is this to be applied to?

The period 5/25/63 to 6/8/63 was when the Eberline service was started. Area monitoring continued for years.

(10) ***Skin correction factor of x1.20 –*** Page 26 recommends that the skin gamma dose be calculated by multiplying the results by a correction factor of 1.20 because of the over response of the chip at low energies. However, if the chip over responded, shouldn't the dose be divided by 1.20 rather than multiplied?

Yes. This is from a 1981 procedure and the dose calculation included dividing by 1.2. Multiplying by 1.2 is not correct. However, the reported doses already took this into account.

(11) ***Neutron factors of x0.4 and x0.739 –*** Page 27 uses multiplication factors of 0.4 and 0.739 for neutron dose calculations. Are these empirically derived values for the TLD system? If so, did they stay the same for 1977–1991 and 1991–2006?

These were empirically determined during the major study that was completed at the end of 1976. They would likely be adjusted for different batches of dosimeters through empirical measurements attending quality controls and subsequent calibrations. Page 27 shows the algorithms used.

(12) ***Tantalum shield on TLDs –*** Page 29, and Table 6-2 on Page 10, mentioned the problem of the tantalum shield on the photon TLDs causing decreased response below about 200 keV, and zero response below about 110 keV (which included the 60 keV gamma from Am-241). It was recommended in 1977 by Anderson that this be corrected for, but mentions that there were no records showing that it had been acted upon. Page 51, Footnote (e) assigns a value of 572 mrem/yr as the maximum missed dose. How was this value arrived at?

There is no footnote (e) on page 51 however the question is likely in reference to footnote (e) on page 31. This is being further evaluated.

(13) ***Wall and floor radiation –*** Page 34 lists the two sources of radiation in the facilities as Process Radiation Fields and Cumulative Radiation Sources. It then goes on to state that it will only address the Process Radiation Fields using AP-body geometry and will not address the Cumulative Radiation Sources that consist of sources of radiation deposited on wall, floors, etc., in the facilities. Has it been determined how significant this source of dose to the workers might be?

It is not significant. Only the Old Cave area had wall and floor contamination that was sufficient to be a significant and distinct source of exposure. The Cave was concreted over and abandoned. We have not found information regarding the dose rate or of the concentrations that might be used to model the dose rate. However, the AP component was monitored by personnel dosimeters. NIOSH project direction is to model the AP configuration.

(14) ***Neutron/photon ratios –*** Page 37, Section 6.6.3.4, states that the neutron to photon (dose equivalent?) ratio at Mound was 2:1. However, Tables 6A-1 and 6A-2 both list the ***same*** imputed base dose for neutrons and photons of 2,600 mrem/y for the years 1943–1949 (i.e., n/p = 1.0). The first paragraph on Page 50 lists the base annual dose for 1947–1977 as the cohort dose **or** the modal dose for 1949–1959 of 2,600 mrem/yr for neutrons and 1040 mrem/yr for photons (n/p = 2.50). Can you please explain this apparent conflict?

The statement that the ratio of neutron to photon dose was 2:1 was a rough estimate by Anderson (1981 and 1985) and might be better omitted from this TBD. It is likely that the dose is as defined in ICRP 30 (1979).

There is disagreement that will be resolved. The text of Attachment 6A gives that the 1949 – 1959 doses could be assumed to be 2,600 mrem/yr for neutrons and 1040 mrem/yr for photons. This does not agree with the footnoted values below Tables 6A-1 and 6A-2. The issue will be resolved.

(15) ***Assigning both Base and Missed doses –*** Page 50, Table 6A-1, lists a Base neutron dose and a Missed neutron dose. I can see adding a missed dose when there is not a dose of record or cohort dose available. However, why is it necessary to add a missed dose when a base dose of 2,600 mrem/yr has already been assigned for the Period of 1943–8/1949? The same question applies to Table 6A-2, Page 51, for photon dose.

Will be resolved. See answer to question 18, above.

(16) ***Corrected photon dose –*** Page 51, first paragraph, states that the base and missed photon dose are multiplied by the photon correction factors to obtain the corrected photon dose and that Table 6A-2 lists the corrected photon doses. However, Table 6A-2 does not list any corrected doses. Where are the photon correction factors and corrected dose presented?

Table 6A-2 lists the corrected photon doses per the footnote.

(17) ***Base dose of 2600 vs. 1040mrem/y –*** Page 51, Table 6A-2 list the Base dose as 2,600 mrem/yr imputed for the Period of 1943–1/1949 (from the modal photon dose of 9/1949–1959). However, the first paragraph of Page 50 states that the base dose of 1040 mrem/yr for photons for the period of 1947–1977 comes from the modal dose for 1949–1959. Why the difference base doses of 2,600 and 1040 mrem/y?

Will be resolved. See 19. and 18., above.

ATTACHMENT 5: SUMMARY OF CONFERENCE CALL ON SC&A QUESTIONS PROVIDED TO NIOSH

Draft Conference Call Notes, June 8, 2006
Mound Issue Resolution Call, SC&A and NIOSH/ORAU

Dates: May 8, 2006 Occupational Internal Dosimetry BD
May 8, 2006 Occupational External Dosimetry TBD
May 8, 2006 Occupational Medical Dose TBD
May 8, 2006, Occupational Environmental Dose TBD
May 8, 2006, General Questions and Site Description TBD

Participants

NIOSH:	John J. Johnson
ORAU:	Stan Waligora, Liz Brackett, Tom Labone, Jack Fix, Elyse Thomas, Karin Jessen, Monica Harrison Maples
SC&A:	Joe Fitzgerald, Robert Bistline, Ron Buchanan, Robert Alvarez, Harry Pettengill, Tom Bell

Introductory Comments:

SC&A: We appreciate you arranging this call. It is important to do this prior to putting things on paper. We will take notes so that we can acknowledge what has expired. This is coming late, but it will help to validate our findings and will help to ensure that we are not off on the wrong track. If there are new OTIBs or changes to TBDs, it would be helpful to know this. We are pretty far along, but this will be useful to us. We propose we go from TBD to TBD in our review today and save general comments to the end. I would like to have Bob Bistline start things off on internal dosimetry.

GENERAL COMMENTS

SC&A:

Key Issues:
- Metal Tritides
- Radon Exposures at Mound
- Pu-238 High-fired oxides
- Use of 1949–1959 data for the 1943 to 1948 period
- Neutron Dose Correction for Under Response and Fading of NTA film

OCCUPATIONAL INTERNAL DOSE (ORAUT-TKBS-0016-5)

Question 3: Internal dose calculations for unmonitored workers.

SC&A: In regard to Question #3 on co-workers, I'm still hung up on how you would do your dose reconstruction. Regarding Pa-231, the TBD recommends that an MDA of 0.3 dpm should be assumed for all exposures that occurred from 1954 to August 17, 1955. Table 5.17, pg 22 (Millard 2004) also points out that the detection limit for this period was 0.3 dpm and footnote b of the table states that this should be used when there are no bioassay data available. It is still unclear to me how internal dose is calculated for those employees that worked in areas that were not monitored or were monitored only during the time they worked in that area and then discontinued their work. I don't understand how this correlates with the action levels given for Pa-231 of 2.2 cpm 24 hr-1 for research workers in Table 5-1 on page 9 (Millard 2004).
2.2 cpm $24hr^{-1}$, equates to 300 mrem wk^{-1} or 15 rem yr^{-1}. Isn't, then, the 0.3 MDA equivalent to 15 rem/year?

ORAU: Missed dose is based on ½ of the MDA. If the site did not record anything, then we use the reporting level; otherwise we use MDA.

Question 5: Who determined the need for special bioassay sampling?

SC&A: Your above explanation makes it clearer to me how you are doing this.

SC&A: Were zeros recorded on the basis of MDAs? The historical basis for entering a zero was that you used zero if it did not go above the MDA, but if you use the detection level there could be a 50% difference. Are there missing doses for those that have zero?

ORAU: We use the larger of the MDA or the detection level and the larger of the two is used to assign missed dose.

Question 7: What was the basis for determining who was put on a bioassay program?

SC&A: It still bothers me. Were individuals put into a bioassay program when the radiation safety personnel suspected that the worker had the potential to receive an uptake? My concern is that there may be a group of people that were there that are not usually given bioassay. For example, maintenance workers, security personnel, janitors etc. Are these a missed population of people that were not sampled?

ORAU: **(ACTION ITEM #1)** For Mound, we are preparing a co-worker OTIB and the guidelines in that OTIB will be applied. We realize the problem and it is a matter that is being considered.

SC&A: Do we need to go into emerging issues?

SC&A: Let's just cover them in general. Some questions were on co-workers. So it's good to know that an OTIB is being considered for Mound co-worker dose.

Key Issue: Metal Tritides

SC&A: A key issue is how will NIOSH deal with insoluble metal tritides? How will NIOSH handle this? Sampling for water and HTO does not cover metal tritides. What will be the approach and how will NIOSH assign dose for workers exposed to metal tritides? You appear to plan to use Type S. In more recent literature, Chang 2002 included a graph that shows that 99.2% of the metal tritide activity was in an insoluble form. There is no data in the early days and this was true even up into the 1990s. For halfnium tritides, this is an even bigger concern. There are no NCRP or ICRP models to deal with this effectively. How is NIOSH going to provide claimant favorable doses for Mound workers who were exposed to metal tritides?

ORAU: We plan to look at the source term and see if we can find data on the highest contamination levels recorded. We will then use a 10^{-4} to 10^{-5} resuspension factor to calculate the most probable highest dose. We can also correlate this with the lapel monitor data that we have.

SC&A: At SRS, they used a similar process and assumed a worker claimant contamination level; assumed that it was resuspended; and developed bounding calculations. They assumed Class S for everything except lithium. It these cases, there is a very low solubility for the metal tritides. It is very similar to high-fired Pu-238 oxides.

ORAU: At SRS, they would have to have a source term of sufficient quantity and then try to bound it by calculations.

SC&A: Something of this order needs to be done at Mound. There is a lack of characterization of this at Mound and it is uncertain as to where the metal tritides might be. The biokinetics is also uncertain. To deal with the insolubility, it will be necessary to find a model that will bound the dose. There is a strategy at the SRS. You will need to emulate this at Mound. Halfnium is the biggest problem. This is also true for the heavier metals.

ORAU: If you know the metals, it helps.

SC&A: Yes, it's a similar problem to Pu-238.

ORAU: **(ACTION ITEM #2)** I don't know what was done in the Mound TBD, but we will review this.

Key Issue: Radon Exposure

SC&A: The issue here is how will NIOSH handle dose for radon for Mound workers exposed to high radon levels, such as those observed in SW Building? Characterization was spotty and was only done many years later. Use of 1990s radon survey data for the earlier exposure periods leaves me cold when hoods were running and radon levels were high. It does not appear that many workers at Mound were monitored for radon exposures in many of these operations areas.

ORAU: We did not see this concern in your list of questions.

SC&A: We did some interviews and talked with some of Mounds RCTs during our site expert interviews. The TBD does address the radon problem in SW Building. Radiation safety personnel would put their alpha monitors over the cracks and they would peg out. This has been documented for SW-19. Our concern is the variations from building to building levels and the limited air sampling available. 15 years later, better air samples were taken, but this was after better ventilation was installed. There were high levels under the processing areas that came through cracks in floor prior to 1980. The 160 pCi/L radon level recommended in Figure 5-14 on page 29, for use by the dose reconstructor for SW-19, was only a grab sample taken at only one location (Millard 2004). This may not be characteristic of actual values. It is not clear if the inhalation rate was normalized and if the data is representative of radon levels before remediation was done.

Key Issue: Pu-238 High-Fired Oxides

SC&A: This is an issue that has been beaten around a lot at other sites. It involves the Pu-238 high-fired oxide exposures to Mound workers and how this is addressed in the Occupational Internal Dose TBD (Millard 2004). More work is being done at other sites that will play into this Mound effort to develop claimant favorable dose reconstructions for Mound workers exposed to Pu-238 high-fired oxides.

ORAU: Pu-238 does not fit the Super S model. It's Pu-239 that needs to be considered as having a Super S solubility.

ORAU: The Super S OTIB that has been developed is more for Rocky Flats. There is also a worse insoluble problem when dealing with ceramics at LANL, but this is not as much of a problem with weapons grade materials handled.

SC&A: We are more concerned with the encapsulated stuff. There isn't anything definitive regarding Pu-238 high-fired at Mound and there are no curves. The OTIB is for weapons grade where it doesn't become soluble. Is there a model for Pu-238 at Mound?

ORAU: There were some Mound cases that deal with eventual increasing solubility of the Pu-238 high-fired oxides that eventually come out in the urine. But these individual cases are still to be done and it's not yet addressed in the TBD (Millard 2004).

SC&A: The TBD does assign a Class S. There is data, but it is not laid out in the TBD.

SC&A: Has there been a review of excretion curves?

SC&A: There was a Pu-238 explosion in the 1960s with a number of Mound workers were exposed to the Pu-238 high-fired oxides. Is there information to model specific cases?

ORAU: Yes, there are models, but this is not discussed in the TBD. We have found some additional references that should also help.

SC&A: Could you provide these references to us?

ORAU: **(ACTION ITEM #3)** Yes. Is it Bob Alvarez who is requesting that we provide the references?

SC&A: Yes, Bob Alvarez would like to receive these additional references.

SC&A: Can I go back to Question #3 for a moment. When I was employed in the DOE, there was a problem with the definition of the MDAs. It is not clear what NIOSH/ORAU is doing to address the issue of reporting limits required under 10CDR35. SC&A has a concern regarding whether the dose estimates derived from bioassay by DOE and contractors at Mound, and all other sites, was used or not. The use of a minimum detectable activity (MDA) equation might result, depending on the radionuclide, in a substantially larger dose. To what extent have these corrections been made in the Mound bioassay data to address this MDA issue?

ORAU: MJW did a recalculation of the MDA when they worked on Mound internal doses. The MDA values used were developed by modern methods. There were some periods when they were unclear. There is a problem with setting the MDA at a higher level. It can also be a problem with you set the MDA too low.

ORAU: There was a threshold of 20 rem committed dose that dictated when there was a need for full dose reconstruction. If a claimant's dose was below 20 rem committed dose, and they were below that; then full dose reconstructions were not done. Previous dose reconstructions done by MJW at Mound corrected this problem, but only for workers who had recorded doses above 10 rem. These were based on the use of the MDA equation. For workers who did not exceed this 10 rem threshold, no corrections were made. I don't think they assigned an MDA of zero. We do this based on the bioassay data at face value.

SC&A: Did you go back to logbooks? Yes, when MJW conducted a review of the Mound records at LANL in the late 1990s, considerable information from these old Mound logbooks was retrieved.

ORAU: Yes.

SC&A: There does, however, seem to be an inconsistent use of the term “action level.”

ORAU: **(ACTION ITEM #4)** Yes. There will be changes in the next update of the TBD to clean some of this up.

SC&A: There is also a lack of proper estimates of the number and data for gross alpha surveys in areas where there were many other alpha emitters present.

SC&A: Po-210 and Pu-238 recovery was talked about by Herb Meyer. There was poor recovery.

ORAU: The use a 10% recovery was used to try to bound it. We think this covers it pretty well.

SC&A: When you calculate radiation dose to specific organs, did you multiply those doses by the factor of 2 that was recommended and was referred to in the TBD?

ORAU: Yes, this was done by MJW during their review of doses in the Phase II process. But these will not be used. We will use original urine data to determine the organ doses.

ORAU: There is an OTIB on internal dosimetry being developed that will address how to incorporate site-specific data or co-worker data. It will be a generic OTIB that will help this.

SC&A: We are glad to hear that this is being developed. This will be a big help.

OCCUPATIONAL EXTERAL DOSE (ORAUT-TKBS-0016-6)

Question 1: What is the extent of beta radiation and monitoring dose for beta at Mound?

SC&A: One of our main concerns is the potential for intense beta exposure to Mound workers who worked around irradiated materials as early as 1944 using lead gloves and tongs to handle them. The Occupational External Dosimetry TBD (Proctor and Algutifan 2004) states that many of the beta-decay radioisotopes accompanied the Bi/Po irradiation, separation, and handling processes. They did not always consider this a concern until years later (1979?). Po-210 did not have beta, but others did. More records were found. NIOSH may have to go to some maximum dose calculations to provide claimant favorable doses. Do you have new data?

NIOSH: Yes, we do have new data and a great deal of new information.

SC&A: Does this include names and doses?

NIOSH: **(ACTION ITEM #5)** Yes. We will revise the TBD as soon as we determine the impact of the new data.

SC&A: For what periods have you found data?

NIOSH: We found new data for every year.

SC&A: Is there calibration for these records?

NIOSH: We can't answer that at this point.

SC&A: In regard to dose to extremities and organs, does NIOISH think that beta dose will be significant compared to gamma?

NIOSH: The slugs were irradiated by neutron bombardment and the Bi-209 was transmuted into Po-210. When the Mound facility opened in 1948, the bismuth was cast into slugs that were then inserted into aluminum cans, which were welded shut. The canned bismuth was then irradiated at the Hanford facility and shipped to Mound in lead casks. This resulted in finding a combination of lead and Po-210.

SC&A: What year did they stop doing that?

NIOSH: I can't recall. They used Bi-209 to get Po-210.

SC&A: I believe that the Po-210 work was stopped sometime around 1959.

Questions 2: How claimant favorable is the use of 1949–1959 data for the earlier years?

SC&A: We have a concern regarding the use of the 1949–1959 data for the 1943–1948 period. Where did the 50 mrem/week for neutron and protons come from?

NIOSH: Is this in regard to Question 2?

SC&A: Yes.

NIOSH: It came from the review of the data. I can get more specific, if it is needed.

SC&A: I believe that this was a NBS limit at the time. NBS was recommending that doses be held to below a 0.1 R/day. But they were very skeptical at the time that this was adequate. A Robert Stone paper in 1946 discussed the monitoring and was skeptical about the use of this limit. This was also discussed in an AEC Biology and Medicine memo.

NIOSH: **(ACTION ITEM #6)** There was a threshold of 50 mrem/wk. We can look at this.

SC&A: In table 6A-1 and 6A-2, of the TBD (Proctor and Algutifan 2004) provides the corrected neutron dose for specific periods.

SC&A: In the cover letter, it would be helpful to have background data on this.

SC&A: I would like to request a clarification of badging described in the TBD (Proctor and Algutifan 2004). The TBD doesn't seem to adequately define radiation workers. Was that everyone who entered a fenced in area or just those that were expected to handle radioactive materials?

NIOSH: I have no idea at this point. It was when they were working in controlled areas.

SC&A: This was not the case in the early Manhattan Project days.

SC&A: In Table 6-14 on page 23 (Proctor and Algutifan 2004), does it include maintenance workers? If it is only those working with radioisotopes, then there could be many maintenance workers, security guards and janitorial workers that could have missed dose.

SC&A: Robert Stone did write this up as to who were to be monitored.

SC&A: Is there anything hard on what the badging policy really was at Mound? NIOSH did a lot of research to try to determine this. If there is any body of information on this that NIOSH could share, this would be helpful. Is there anything more than what we have seen?

NIOSH: We have tried hard to discern who radiation workers were at Mound. It is also difficult to determine who the non-radiation workers were and if they were or were not monitored. It appears it was a local radiation safety decision as to who would be issued a film badge, especially in the early days. We don't know who got radiation safety training. This might be one additional way to determine who would have been badged.

SC&A: We are most interested in the co-worker model that will become available in the new Mound related OTIB. The distribution would be different for unmonitored population. How workers were badged and how co-worker dose could be used to assign dose to unmonitored workers in the same general area is important and should be more thoroughly developed in the TBD (Proctor and Algutifan 2004), when it is revised.

ORAU: I'm not sure that an external co-worker study is going to be done.

Question 4: How much missed dose is there within annual dose records 1947–1977?

SC&A: We are concerned about missed dose within annual dose records 1947 to 1977. My concern is how will ORAU dose reconstructors know that a worker didn't get badged or if he was only badged for part of a badging period. How will ORAU know if the badge reading was for an acute exposure all at one time and not over the whole year? There may have been times during the year when they weren't badged. The recorded film badge results could represent only one quarter or do they could reflect the dose for a whole year; there is no way to discern which is true?

SC&A: Could NIOSH do a sensitivity distribution to see what fraction of the whole year is represented?

NIOSH: **(ACTION ITEM #7)** Yes, this might be possible. In addition, there are individual or group incident files for the several thousand incidents that happened at Mound. These incident files included: what happened; who else was there; survey data swipes and; other related data. These incident reports go back to 1943.

Question 5: Individual documentation of each incident. What records exist for unbadged workers involved in radiation accidents/incidents?

SC&A: Are incident reports found in the individual claimant's personal file?

NIOSH: Yes, we have a good handle at Mound on what data can be obtained.

ORAU: Yes, at Mound they do include the incident report in the individual's personal file.

SC&A: Yes during our visit at Mound, we too found that the incident file was routinely included in the individual's personal file. Mound can also cross reference these incidents via use of the related computer databases.

Question 6: Work hour details – pg 13 states 40-hour weeks. Is the number of hours worked per week in the claimant's file?

SC&A: Does the claimant's personnel record document the number of hours that workers worked per week? Is there any specific data?

ORAU: We don't get personnel records. We get radiation records and sometimes medical records. The CATI might help in this regard.

ORAU: For bioassay purposes, you would not have to take into account hours unless you are trying to assign dose for environmental exposures.

SC&A: If a security guard worked 60 hours/week, would he get more credit for this?

ORAU: There is an assumption that the integrity of record is complete.

ORAU: The Occupational External Dose TBD (Proctor and Algutifan) was written in 2004. Since them we have found a lot of new material.

SC&A: Then we can assume that there is no correction for number of hours worked.

Key Issue: Neutron Dose Correction for Under Response and Fading of NTA film.

SC&A: We have a major problem with the TBD (Proctor and Algutifan 2004) in its handling of whether neutron doses have been properly corrected for under response and fading and that the correct neutron dose has been entered into the claimant's radiation exposure record. The TBD (Proctor and Algutifan 2004) addressed neutron dose correction, but we cannot tell from the

TBD text whether the claimant can be sure that his records have been corrected for the low response of the NTA film. Were the fading corrections put in previously by Mound or by MJW? Or does ORAU now have to put these corrections in as they are doing the claimant's dose reconstruction?

ORAU: The dose reconstructors make a number of conservative assumptions to adjust the neutron dose. It is not adjusted specifically for fading or the under response of NTA film, but the conservative assumptions used allow for these corrections. There are certain aspects of the TBD (Proctor and Algutifan 2004) that need to be redone. There is new data since 2004 and this will be used update the TBD when it is revised.

SC&A: Do you have an idea of how many missed doses are out there?

ORAU: I don't know that much about Mound, although I have been there a number of times.

NIOSH: One major adjustment was made during reevaluation. Recalibration was done. There was an edit in the records that indicated that the neutron doses were doubled during the appropriate time that this was an issue.

SC&A: The TBD indicated that this was done for fading.

NIOSH: We would have to look at this on a case-by-case basis.

SC&A: Was there was an appreciation of α/η reactions. Has this been addressed?

NIOSH: Yes, this was taken into account.

Question 17: How extensive was radon exposure to Mound workers from floor and wall contamination and is there important missed dose due to lack of monitoring for radon?

SC&A: At Mound there were α/η reactions. Contamination was produced by these α/η reactions that got on walls and floors. This contamination could irradiate workers well after the initial α/η reactions ceased. Not only were high radon levels found on the floors, but also on the floors in the basement of SW Building. How significant were these exposures during the Old Cave work? Could this have been a source of neutrons? Do you have any details?

SC&A: At LANL in the reactor areas, Na-24 was used to assess dose. Was there an analysis for Na-24 at Mound?

NIOSH: We have not seen this at Mound. It takes a large flux to get any significant measurable neutron dose. We haven't seen any situations that would result in significant doses at Mound.

OCCUPATIONAL MEDICAL DOSE (ORAUT-TKBS-0016-3)

SC&A: General comment. We are trying to get an understanding of what the totality of the medical x-ray dose was at Mound and what should be included as occupational medical x-rays. Clearly, medical screening for diseases, illness or injury should not be included. But some injuries may be job related and it is possible that some occupational disease (such as exposure to beryllium) should be considered as an occupational screening.

ORAU: Doesn't that relate to Q3? It involves those that are at risk in the occupational setting.

Question 3: What is the extent of records on the quantity of voluntary chest x-rays that might have been performed at Mound?

SC&A: Has NIOSH looked carefully at the definition of occupational x-ray screening at Mound? Have you come back to this issue and tried to redefine what represents occupational x-ray screening?

ORAU: It is difficult to define what was done for occupational medical screening. We would like to find the physician's order. That is a good source of information on what was defined as an occupational medical screening procedure. Individual x-ray files can help on this. The individual x-ray might give us a clue that a particular x-ray may have been done for and whether it was for occupational medical screening purposes. There is also a regulatory issue here that prescribes the kinds of procedures that might fall under the definition of occupation medical screening. You have to differentiate between other x-rays done for personal medical reasons and not for occupational medical exposure.

SC&A: Generally we know this encompasses pre-employment chest x-rays, routine annual chest x-rays and termination of employment chest x-rays. But there is a secondary part that this standard definition does not cover. It doesn't pick up on the procedures and protocols related to physician's prescription for occupational medical screening. When the dose reconstructor goes to personal file, they may not find information on types of x-rays that were given.

ORAU: When the dose reconstructor tries to determine what dose from x-rays should be assigned, he needs guidance. To answer which x-rays are included, he would need to know what type of dose reconstruction is being done.

SC&A: But what about chest x-rays done for fit testing of respirators or for beryllium? These may be part of the occupational medical x-ray mix that is not easily identified.

Question 2: Is there good data to determine the frequency of LAT chest x-rays?

SC&A: LAT x-rays to women who had breast augmentation were unique to Mound. Was there a written policy for chest augmentation?

NIOSH: Yes.

SC&A: Would they usually take the LAT chest x-ray first?

ORAU: The file would dictate if they got the LAT or PA chest x-ray first. Women who have had breast augmentation would probably have had the PA chest x-ray first followed by a LAT. I would expect this group to be small, however.

Question 4: Can NIOSH provide clarification on the dates and frequency that Mound provided chest x-rays to smokers?

SC&A: At Mound, have you found that the medical records clarify which Mound workers were smokers and might have the need for more frequent chest x-rays.

ORAU: Yes, smokers were identified and followed. For some workers we know that information, but we do not know that for all workers.

ORAU: Claimants are only required to send information to us on smoking if they have lung cancer. So we would not have had that information for non-lung cancer claimants unless the site recorded it.

ORAU: If the dose reconstructor were tying to overestimate the dose, then all x-rays would be included.

ORAU: **(ACTION ITEM #8)** We could start requesting this information for smokers who have not developed lung cancer. We will try to find out more about that.

Question 5: Is there documentation of the one x-ray unit at Mound and the possible use of photofluorography (PFG) machines?

SC&A: This comes up a lot at the various sites for the early years. It appears from the TBD (Algutifan et al. 2006) that you were not able to find much documentation on the pre 1980 period. When you go to Version 3 of OTIB-0006 (Kathren and Shockley 2004), it references the 1982 NCRP report. But this was based on equipment at that time, not equipment in the earlier period. Can we assume this is claimant favorable?

ORAU: Yes. The NCRP 1982 report had some generalization about earlier filtration for equipment in the 1940s, 1950s and 1960s that makes it conservative enough.

SC&A: But in NCRP 1982, this is usually based on an assumed 2.5 mm Al filtration. I have seen some cases with 6.5 mm Al filtration. It seems you would have had to have made some claimant favorable assumptions to include this possibility.

ORAU: These are documented in OTIB-0006 Version 3 (Kathren and Shockley 2005) and are for DOE sites in general. These conservative estimates are used when we don't have site-specific data.

SC&A: PFGs were mentioned in OTIB-0006 as being typical in use prior to 1958. It is most likely that PFG was not used after about 1958. Since you don't have any substantiated declarations before 1960, how do you conclude it wasn't used at Mound?

ORAU: We might look at this more closely. It might be more claimant favorable to assume PFGs were used at Mound prior to 1958.

ORAU: Is SC&A recommending that we do this?

SC&A: Yes, if you can't find any data to prove or disapprove the use of PFGs at Mound. A thorough review of medical records of claimants for the use of the PFG film would be a good giveaway.

NIOSH: **(ACTION ITEM #9)** We will look into it.

Question 7: What is known about the physical measurements on the x-ray unit in 1995, 1997, and 2000 made by HHS?

SC&A: There was a contract with the Food and Drug Administration (FDA) in 1988 to do these x-ray equipment measurements.

ORAU: **(ACTION ITEM #10)** Yes, the TBD (Algutifan et al. 2006) does need to clarify this. There were all kinds of information on the performance and measurements of the machine. But you can't make the link from these measurements to the possible individual dose. The data is insufficient.

Questions 8: Has NIOSH been able to substantiate the retake rate on a yearly basis and the uncertainty is might contribute to dose estimation?

SC&A: Was there a determination of the site-specific retake rates at Mound?

ORAU: We haven't found this for all sites, but particularly not at for Mound. This would have to be a part of our uncertainty analysis.

SC&A: If they had an optical density devise as part of their x-ray unit, which was used say after 1985, that would help a lot. You should focus your review of retakes prior to the use of optical density devices.

Question 10: Has NIOSH looked into the use at Mound of "other" x-ray exams beyond chest radiography?

SC&A: Should other exams be included besides chest radiography?

ORAU: We have not found evidence of any other screening exams at Mound. We will address them if we find them or if SC&A can provide evidence of them.

OCCUPATIONAL ENVIRONMENTAL DOSE (ORAUT-TKBS-0016-4)

Question 1: TBD authors derived pre-1971 inhalation doses using total stack effluent data and empirically derived atmospheric dispersion factors. Has NIOSH considered comparing these empirical determinations with offsite concentrations?

SC&A: No onsite environmental monitoring was done at Mound pre-1971. Did NIOSH derive its inhalation dose for claimants based on total stack effluent data and empirically derived atmospheric dispersion model? Was there an attempt made to look at off site sampling for specific stack release data and could that be used to validate your dispersion calculation?

ORAU: We are not sure that was available at Mound. There isn't any analysis data to compare the two to our knowledge.

Question 2: There are no environmental survey results at the Dayton site for 1943, 1944 and 1946. How can the NIOSH verify the use of 1947 levels determine environmental levels for 1943–1946?

SC&A: Have you looked at perimeter data in the missing years to verify 1947 levels?

ORAU: **(ACTION ITEM #11)** Yes, we have some additional records that will help on this. This is under review.

Question 3: Inhalation of Po-210 and soil ingestion at Dayton Units III and IV is less than 1 mrem/year? How does this compare with external gamma doses as high as 1800 mrem/year and with inside measurements noted on the worker's wrist badges?

SC&A: A May 19th control badge showed that Po-210 is quite low. It is reasonable to use 1800 mrem/year as the best way to do this.

ORAU: Yes. We do not have a better approach.

Question 5: Has NIOSH reviewed the onsite monitoring data for all stations and determined if the highest monitoring site would be more claimant favorable?

SC&A: This has to do with using an average instead of the highest level. Could you use an average with 2 standard deviations?

ORAU: **(ACTION ITEM #12)** Yes. We could look at that.

Question 6: Aerial surveys estimated 40–50 mrem/year as compared to 1800 mrem/year for Dayton Unit III and IV – How does NIOSH correlate the difference?

SC&A: The answer provided in the NIOSH responses appears to be reasonable.

General Comments

SC&A: To what extent has NIOSH accessed the LANL files for Mound?

ORAU: When MJW did classified records searches for Mound records at LANL in the late 1990s, we searched them for polonium logbooks. Now there are no missing Po logbooks. Yes, they were looked at from the internal dose standpoint. MJW did retrieve considerable information from these old Mound logbooks.

SC&A: We have learned that LANL disposed of the pre-1993 Inactive contaminated classified records in 2005 as classified waste by burying them.

ORAU: I didn't know that. There were some interesting records in that collection.

SC&A: This is an issue that could be quite important. We have requested an inventory of those Mound records at LANL that were disposed of as classified waste. It is probably just Mound's pre-1993 Inactive classified records, but we won't know for sure until we get the inventory.

ORAU: Anything that was in there in the late 1990s would have been incorporated into the MJW internal dose evaluation. We had to suit up in order to be able to look at the records. They were still contaminated.

SC&A: Yes, we understand that they were still contaminated, but not at a very high level. If the data in the logbooks and other associated records were not fully retrieved in the late 1990s by MJW, there could be important information lost regarding Mound worker doses associated with exposure to metal tritides, recycled uranium, and Pu-238 high-fired oxides. We will be notifying the Advisory Board of the destruction of these classified records at the upcoming Advisory Board meeting.

SC&A: We hope to have SC&A's report out for review in a couple of weeks. We appreciate all of your help on assisting us today in going over the points that we have raised. It has been most helpful.

Summary of Action Items:

(1) ORAU will soon release a Co-worker OTIB for Mound to be used for internal dose reconstruction.

(2) ORAU will review the Occupational Internal Dose TBD (Millard 2004) to ensure that the TBD addresses the assignment of dose for metal tritides.

(3) ORAU is to provide Bob Alvarez with the references that relate to information to model specific cases for the number of Mound workers exposed to Pu-238 high-fired oxides from the Pu-238 explosion at Mound in the 1960s.

(4) ORAU will make changes to the Occupational External Dosimetry TBD (Proctor and Algutifan 2004) to resolve the inconsistent use of action levels.

(5) NIOSH will incorporate new data on beta exposures at Mound into the Occupational External Dosimetry TBD (Proctor and Algutifan 2004).

(6) NIOSH will review the threshold value of 50 mrem/week for protons and neutrons.

(7) NIOSH will consider doing sensitivity distributions to see what fraction of the ORAU will review if it is now desirable to request smoking histories for Mound workers, even though they have not yet developed lung cancer.

(8) NIOSH will look into the possibility of assigning PFG doses to Mound workers pre-1958, if there is no confirmation that PFG was used at Mound.

(9) ORAU will provide clarification in the Occupational Medical Dose TBD (Algutifan et al. 2006) about the FDA contact in 1988 to do calibrations and testing on Mound x-ray equipment.

(10) ORAU will provide SC&A with environmental survey perimeter data that is to be used to verify the use of 1947 levels for determining environmental levels for 1943–1946.

(11) ORAU will look into the use of 2 standard deviations if environmental on site monitoring data is not sufficient to determine the highest potential releases at some of the environmental monitoring stations.

ATTACHMENT 6: OVERVIEW OF NIOSH RECOMMENDED DOSE RECONSTRUCTION PROCEDURES FOR MOUND LABORATORY

The following is a brief summary, with some notes, of how it appears that NIOSH presently plans to perform DR for **monitored** and **unmonitored** workers at the Mound Labs for 1943–2006. This was derived from studying the Occupational External Dosimetry TBD, ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) and other Mound related documents.

<u>Monitored workers with dose records available</u>

1943–1949: No individual records available for neutron, photon, or beta doses during this time (see unmonitored workers).

1949–1951: (All *radiation* workers badged with photon and neutron NTA film.)

- Photon – Dose of record[1] + 442 mrem/yr possible missed dose due to LOD of 34 x 26/2.
- Neutron – Dose of record[1] + 6956 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[2]
- Nonpenetration – No beta or skin photon doses determined.

1951–1960: (All *radiation* workers badged with photon and neutron NTA film.)

- Photon – 1951–1957: Dose of record + 442 mrem/yr possible missed dose due to LOD of 34 x 26/2.
- Photon – 1957–1960: Dose of record + 130 mrem/yr possible missed dose due to LOD of 10 x 26/2.
- Neutron – Dose of record + 4353 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[3]
- Nonpenetration – 1953–1960: Skin dose of record = low-energy gamma (OW) + neutron.

1960–1968: (All *radiation* workers badged with photon and neutron NTA film.)

- Photon – 1960–1963: Dose of record + 130 mrem/yr possible missed dose due to LOD of 10 x 26/2.
- Photon – 1963–1968: Dose of record + 390 mrem/yr possible missed dose due to LOD of 30 x 26/2.
- Neutron – Dose of record + 5142 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[4]
- Nonpenetration – Skin dose of record = low-energy gamma (OW) + neutron.

1968–1973: (Some workers were badged, depending on work area, with photon and NTA film.)

- Photon – 1968–1970: Dose of record + 390 mrem/yr possible missed dose due to LOD of 30 x 26/2.
- Photon – 1970–1973: Dose of record + 78 mrem/yr possible missed dose due to LOD of 13 x 12/2 or 26 mrem/yr for 13 x 4/2.
- Neutron – Dose of record + 5142 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[4]
- Nonpenetration – Skin dose of record = low-energy gamma (OW) + neutron.

1974–1976: (Some workers were badged, depending on work area, with photon and NTA film.)

- Photon – 1974–1975: Dose of record + 78 mrem/yr possible missed dose due to LOD of 13 x 12/2 or 26 mrem/yr for 13 x 4/2.
- Photon – 1976: Dose of record + 572 mrem/yr maximum possible missed dose due to LOD of 20 x 12/2, fading = 40, and Ta shield loss = 312, and 26 exchanges.[5]
- Neutron – Dose of record + 6123 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[6]
- Nonpenetration – Skin dose of record = low-energy gamma (OW) + neutron.

1977–2006: (Some workers were badged, depending on work area, with TLDs.)

- Photon – 1977: Dose of record + 572 mrem/yr maximum possible missed dose due to LOD of 20 x 12/2, fading = 40, and Ta shield loss = 312, and 26 exchanges.[5]

- Photon – 1978–1981: Dose of record + 572/2wk, or 456/mo, or 376/qtr mrem/yr possible missed dose due to LOD of 20, fading, and Ta shield loss.[5]
- Photon – 1981–1991: Dose of record + 260/2wk, or 120/mo, or 40/qtr mrem/yr possible missed dose due to LOD of 20.
- Photon – 1992–2006: Dose of record + zero (0) missed dose.
- Neutron – Dose of record + 554, or 264, or 220, or 88 mrem/yr possible missed dose; corrected for fading and MDL.[7]
- Nonpenetration – Skin dose of record = low-energy gamma (OW) + neutron + beta (if measured. Beta calibration started in 1979. LOD for beta = 53 mrem/qtr in 1995).

[1][TBD-6 does not make it clear if the "dose of record" for the workers have been modified with the necessary adjustments or not. These adjustments would include Ta shielding of 60 keV gammas; NTA film track fading and low-energy threshold; and TLD signal fading and decreased response at high neutron energies. TBD-6 provides a lot of information concerning adjustments to the "Missed" dose calculations based on LOD, but none concerning the worker's dose of record and its adjustments for use during DR.]

[2][Based on weekly exchange; fading = 33% of MDL; MDL = 50 mrem; and low-energy threshold missed 14% (based on SRS) of MDL; all corrected by ICRP-60 dose factors for different neutron energy ranges; 25% and 75%. See pg. 30 and 50 of TBD-6.]

[3][Based on biweekly exchange; fading = 56% of MDL; MDL = 50 mrem; and low-energy threshold missed 14% (based on SRS) of MDL; all corrected by ICRP-60 dose factors for different neutron energy ranges; 25% and 75%. See pg. 30 and 50 of TBD-6.]

[4][Based on biweekly exchange; fading = 56% of MDL; MDL = 50 mrem; and low-energy threshold missed 14% (based on SRS) of MDL; all corrected by ICRP-60 dose factors for different neutron energy ranges; 50% and 50%. See pg. 30 and 50 of TBD-6.]

[5][It is not clear from pg. 28 of TBD-6 how this is calculated.]

[6][Based on biweekly exchange; fading = 56% of MDL; MDL = 50 mrem; and low-energy threshold missed 14% (based on SRS) of MDL; all corrected by ICRP-60 dose factors for different neutron energy ranges; 75% and 25%. See pg. 30 and 50 of TBD-6.]

[7][Missed dose depends on exchange freq. MDL = 10 mrem. No correction for TLD's lower response at higher neutron energies. ICRP-60 correction factor = x2.2 (all below 2.0 MeV).]

Zeros and blanks in original dose data for 1949–1977: It is not known how zero and blank entries in the original dose data for 1949–1977 will be accounted for during DR for badged workers because their available dose data is only a summary of each year and does not contain details for each badge exchange period.

Unmonitored/undermonitored workers

(These procedures do not include exposures from incidents or acute exposures, or any exposures above the norm unless separately accounted for in other records.)

1943–1949: (No individual dose records, all workers potentially exposed to radiation will be assigned the following doses.)

- Photon – 2600 mrem/y imputed base dose[a] + 1040 mrem/y possible missed dose[b].
- Neutron – 2600 mrem/y imputed base dose[c] + 6955 mrem/y possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[d]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from 1953–? TBD-6 does not address unmonitored workers' skin dose. No beta doses recorded for this period.

1949–1951: (All *radiation* workers badged with photon and neutron NTA film.)

- Photon – Cohort dose[e] (or 50 mrem/wk)[f] + 442 mrem/yr possible missed dose due to LOD of 34 x 26/2.
- Neutron – Cohort dose[e] + 6956 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[2]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from 1953–? TBD-6 does not address unmonitored workers' skin dose. No beta doses recorded for this period.

1951–1960: (All *radiation* workers badged with photon and neutron NTA film.)

- Photon – 1951–1957: Cohort dose + 442 mrem/yr possible missed dose due to LOD of 34 x 26/2.
- Photon – 1957–1960: Cohort dose + 130 mrem/yr possible missed dose due to LOD of 10 x 26/2.
- Neutron – Cohort dose + 4353 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[3]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from 1953–? TBD-6 does not address unmonitored workers' skin dose. No beta doses recorded for this period.

1960–1968: (All *radiation* workers badged with photon and neutron NTA film.)

- Photon – 1960–1963: Cohort dose + 130 mrem/yr possible missed dose due to LOD of 10 x 26/2.
- Photon – 1963–1968: Cohort dose + 390 mrem/yr possible missed dose due to LOD of 30 x 26/2.
- Neutron – Cohort dose + 5142 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[4]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from each year? TBD-6 does not address unmonitored workers' skin dose. No beta doses recorded for this period.

1968–1973: (Some workers were badged, depending on work area, with photon and NTA film.)

- Photon – 1968–1970: Cohort dose + 390 mrem/yr possible missed dose due to LOD of 30 x 26/2.
- Photon – 1970–1973: Cohort dose + 78 mrem/yr possible missed dose due to LOD of 13 x 12/2 or 26 mrem/yr for 13 x 4/2.
- Neutron – Cohort dose + 5142 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[4]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from each year? TBD-6 does not address unmonitored workers' skin dose. No beta doses recorded for this period.

1974–1976: (Some workers were badged, depending on work area, with photon and NTA film.)

- Photon – 1974–1975: Cohort dose + 78 mrem/yr possible missed dose due to LOD of 13 12/2 or 26 mrem/yr for 13 x 4/2.
- Photon – 1976: Cohort dose + 572 mrem/yr maximum possible missed dose due to LOD of 20 x 12/2, fading = 40, and Ta shield loss = 312, and 26 exchanges.[5]
- Neutron – Cohort dose + 6123 mrem/yr possible missed dose; corrected for fading, MDL, threshold, and ICRP-60.[6]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from each year? TBD-6 does not address unmonitored workers' skin dose. No beta doses recorded for this period.

1977–2006: (Some workers were badged, depending on work area, with TLDs.)

- Photon – 1977: Cohort dose + 572 mrem/yr maximum possible missed dose due to LOD of 20 x 12/2, fading = 40, and Ta shield loss = 312, and 26 exchanges.[5]
- Photon – 1978–1981: Cohort dose + 572 mrem/yr maximum possible missed dose due to LOD of 20 x 12/2, fading = 40, and Ta shield loss = 312, and 26 exchanges.[5]
- Photon – 1981–1991: Cohort dose + 260/2wk, or 120/mo, or 40/qtr mrem/yr possible missed dose due to LOD of 20.
- Photon – 1992–2006: Cohort dose + zero (0) missed dose.
- Neutron – Cohort dose + 554, or 264, or 220, or 88 mrem/yr possible missed dose; corrected for fading and MDL.[7]
- Nonpenetration – Cohort (low-energy gamma + neutron dose) from each year? TBD-6 does not address unmonitored workers' skin dose. Some beta doses recorded for this period. Beta calibration started in 1979.

[a] [Based on badged workers' modal photon dose data of 50 mrem/yr for 1949–1959.]

[b] [Based on film LOD; 40 mrem/wk x52/2 = 1040.]

[c] [Based on badged workers' modal neutron dose data of 50 mrem/yr for 1949–1959.]

[d] [Based on weekly exchange; fading = 33% of MDL; MDL = 50 mrem; and low-energy threshold missed 14% (based on SRS) of MDL; all corrected by ICRP-60 dose factors for different neutron energy ranges; 25% and 75%. See pg. 30 and 50 of TBD-6.]

[e] [TBD-6 does not provide any details concerning the calculation of cohort doses; i.e., statistics, handling of zeros and blanks, etc.]

[f] [TBD-6, last part of first paragraph on pg. 50, does not state when the DR is to use the cohort dose and when to use the modal dose of 50 mrem/wk. Additionally, it states to use 1040 mrem/yr as a base dose (from the 1949–1959 dose data), but in Table 6A-2 of pg. 51, it list 2600 mrem/yr as the photon base dose.]

Zeros and blanks in cohort dose data for 1949–2006: It has not yet been demonstrated how zeros and blanks in the dose records may have been handled in the compiling the recommended cohort doses or the modal dose of 50 mrem/wk obtained from the 1949–1959 dose data.

Some questions and issues/concerns concerning the present DR procedures

(1) The Occupational External Dosimetry TBD (Proctor and Algutifan 2004) does not make it clear if the "dose of record" for the workers have been modified with the necessary adjustments or not. These adjustments would include Ta shielding of 60 keV gammas; NTA film track fading and low-energy threshold; and TLD signal fading and decreased response at high neutron energies. The Occupational External Dosimetry TBD (Proctor and Algutifan 2004) provides a lot of information concerning adjustments to the "Missed" dose calculations based on LOD, but none concerning the worker's dose of record and its adjustments for use during dose reconstruction.

(2) The Occupational External Dosimetry TBD (Proctor and Algutifan 2004) does not address unmonitored workers' skin dose, and is not clear on monitored workers' skin doses.

(3) It is not known how zero and blank entries in the original dose data for 1949–1977 will be accounted for during dose reconstruction for badged workers because their available dose data is only a summary of each year and does not contain details for each badge exchange period.

(4) It has not yet been demonstrated how zeros and blanks in the dose records may have been handled in the compiling the recommended cohort doses or the modal dose of 50 mrem/wk obtained from the 1949–1959 dose data.

(5) It is unusual that the cohort modal dose for neutrons and photon are both exactly the same, 50 mrem/wk, for 1949–1959; especially if the n/p value is normally 2:1 as stated on pg. 37 (Proctor and Algutifan 2004).

ATTACHMENT 7: STABLE METAL TRITIDE HISTORY/CHRONOLOGY

B&W of Ohio

Memo

To: Sandy Baker

From: P.J. Bums Jr.

Date: 06/17/99

Re: Stable Metal Tritide History/Chronology

Please find attached a process history of Stable Metal Tritides at Mound which will become part of the Technical Basis Document used during Safe Shutdown activities involving Stable Metal Tritides.. Also attached is a chronology of events starting in July 1998 that have occurred in our efforts to pave a path forward to complete work in areas that have been identified as possibly containing Stable Metal Tritides. Paperwork has also been provided in most cases for each significant event that has taken place in the last year.

We continue to update our Technical Basis Documents based upon peer review and anticipate having a much clearer path forward after the Special Session of Health Physics Society for Internal Dosimetry for Inhalation of Stable Metal Tritides scheduled the week of June 27, 1999. Shortly after this meeting, we will schedule the Independent Verification necessary to approve our methods. This review is anticipated to be in early August 1999.

Presently we are preparing a response to the latest DNFSB staff request received June 15, 1999. The crosswalk, which was developed addressing the Defense Board Staffs concerns after their visit in March, will be the basis for the response. The Independent Verification Team from LLNL will provide the agenda for their review.

April 30, 1999

Process Historv/Technical Basis

Mound history Of SMT Usage – Mound has been handling metal tritides for more than 40 years in R&D applications. The following table is a list of metal tritides that have been handled at Mound.

Lithium tritide
Vanadium tritide
Palladium/Rhodium tritide
Yttrium tritide
Nickel Zirconium tritide
Niobium tritide
Beryllium tritide
Europium tritide
Zirconium tritide
Plutonium tritide
Scandium tritide
Lutetium tritide
Erbium tritide
Rhodium tritide

Vanadium/Niobium tritide
Barium tritide
Lanthanumckel tritide
Titanium tritide
Iron Oxide tritide
Uranium tritide
Iron/Titanium tritide
Palladium tritide
Lanthanum/Nickel/Aluminum tritide
Hafnium tritide
Calcium tritide
Platinum/Rhodium tritide
Magnesium/Nickel tritide
Tantalum tritide

Many commonly used metal tritides, such as uranium and palladium, rapidly release tritium to air/water. The tritium released from these unstable metal tritides behaves very much like HT and/or HTO in the body. The metal tritides shown in bold lettering, however, are considered stable in air, water and body fluid. These Stable Metal Tritides (SMTs) behave much differently if inhaled and are not as well understood biokinetically as HT and HTO forms.

Recent Meetings To Review Stable Metal Tritide Usage – Fortunately, many individuals who have handled SMTs at Mound continue to work at Mound. There have been several meetings within the last six months to establish the potential location of SMT contamination at Mound. The SMT of most concern at Mound is hafnium tritide. These meetings were attended by personnel who worked with SMTs as early as the 1960s, and included several knowledgeable of the hafnium tritide contamination event of 1972. The chemist who synthesized the hafnium tritide, and most other tritides in SW-150; the chemist who last handled hafnium tritide in SW-13 and R-108; the individual who supervised the SMT work in SW-13 during the 1972 event; and the RCT who worked in SW-13 during the 1972 event attended a meeting on 11/11/98 to discuss historical SMT usage and the potential locations for contamination. As a result of this meeting and subsequent meetings and tours, it was determined that individual gloveboxes in SW-8, SW-9, SW-13, SW-150, SW-152, SW-24, and R-108 have the potential for SMT contamination. Because of the handling-techniques used for processing the SMTs within the glovebox and the extensive cleaning of these boxes in subsequent years, there is little real potential for any significant quantity of SMTs to be present in these gloveboxes.

History Of Mound SMT Usage – With the exception of iron oxide tritoxide, stable metal tritides were synthesized directly or indirectly as part of a R&D project, program or experiment. The syntheses of these tritides was carried out inside process equipment inside inert atmosphere gloveboxes to reduce the potential for contamination (02, N2, H2O etc.) of the tritide. These synthesis reactions were carried out in SW-10, SW-13 , SW-142 and SW-150. All gloveboxes, except one in SW-150, used in the synthesis of SMTs at Mound were physically removed from the site in the 1970s and 1980s. The metal tritides were analyzed in SW-13 or SW-219. One SW-13 glovebox remains, but all gloveboxes/fumehoods in SW-219 were removed in the late 1980s. After use, the metal tritides were processed for recovery of the tritium in SW-8 (prior to 1978) or R-108 (after 1978). The primary waste from the recovery process was a welded can with the reduced metal inside. The recovery glovebox in SW-8 was deactivated in the late 1970s; but remains to be removed and boxed for burial. The R-108 process continues to recover tritium from safe shutdown uranium and palladium beds. The glovebox in SW-9 was used briefly in the mid-1970s to handle hafnium tritide contaminated hardware and may remain slightly contaminated.

In 1972 a glove failure on a single box in SW-13 contaminated the room with hafnium tritide. The cleanup/decontamination of the room took several weeks during which two persons were exposed to hafnium tritide. Because of this incident, surfaces not readily available for decontamination in 1972 or in subsequent years have the potential for hafnium tritide contamination. These formerly inaccessible surfaces may become accessible during the safe-shutdown process. The glovebox involved in the 1972 event, although relocated, remains in SW-13 and may still contain hafnium tritide contamination. The contents of this box were removed, the box cleaned and the windows replaced in the mid 1980s. This box now contains a Struers thin sectioning saw and is referred to as the “Struers Box.”

A small amount of work, with hafnium tritide, was performed about 1970 in the California fumehood that remains in the NW corner of SW-13. Since this fumehood exhausts to the room ventilation system, there is the possibility that a small quantity of halfnium tritide migrated into the SW-13 exhaust ventilation system and that parts of that system remain contaminated. The SW-13 exhaust system was HEPA filtered inside the room during the time hafnium tritide was handled.

There was a minor tracking incident in SW-150 in 1993 (Tritium Contamination Tracking Incident, EGGMAT01-006). This tracking incident identified hafnium tritide in the NW fumehood in SW-150. The source of this contamination was traced to an old secondary container that may have been used to transport SMT contaminated samples. The fact that this fumehood was found to be contaminated with hafnium tritide in 1993, indicates the potential for the exhaust ductwork downstream of the fumehood to also be contaminated.

The inert atmosphere SMT synthesis and handling gloveboxes in SW-13 and SW-150 were processed by recirculating gas cleanup systems in SW-12 and SW-231 respectively. These gas cleanup systems recirculated the glovebox atmosphere through “deoxo” beds, reactors and molecular sieve dryer beds to remove oxygen, tritium and moisture. The SW-12 recirculation system was removed in the mid-1980s, however, parts of the piping manifold remain and are potentially contaminated with SMTs. Only the “Struers Box” remains of those that utilized this recirculation system. There are three recirculation systems in SW-231, one of which remains in service. These systems recirculated gas to many gloveboxes in SW-150, SW-152 and SW-240. While the reactors and molecular sieve beds that comprise the cleanup systems would serve to “filter” any SMT particles, the removal would not be complete and some SMTs may have been recirculated back to the remaining gloveboxes in SW-150, SW-152 and SW-240. The recirculation path to the gloveboxes in SW-240 was very convoluted and characterization to exclude SMTs should be straight forward. Only the “South Gas System Box” and the “Function Test Box” in SW-150, which were never connected to the SW-231 recirculation system, are not expected to contain SMT residual contamination.

The glovebox recirculation systems in SW-231 and R-108, as well as any remaining piping from the recirculating system in SW-12, have the potential for SMT contamination. Since there was a major SMT contamination event in SW-13 in 1972, the "old" ventilation systems in the room as well as any inaccessible surfaces have the potential for SMT contamination. To a lesser extent, inaccessible surfaces and ventilation systems in SW-150 have the potential for minor SMT contamination due to a very limited tracking event in 1993.

Tritiated rust (iron oxide tritoxide) has been identified at other tritium handling sites as a potntial problem during safe-shutdown/D&D. Mound has occasionally found contamination that exhibits the characteristics of tritiated rust. This condition is thought to occur primarily inside carbon steel vessels that have a relatively long history of high tritium partial pressure. Historically Mound has utilized stainless steel for tritium containment, with few exceptions. The best opportunity to find significant quantities of tritiated rust at Mound is in the old Thermal Diffusion Column feed tanks in SW-8. These tanks, installed in the late 1950s or early 1960s, are carbon steel and processed 10%–15% tritium at several atmospheres for many years. Of secondary concern is the "fixed" tube trailer south of M-17. This trailer was used to store the regeneration gas from the HH-17 carbon traps. Of tertiary concern are the ERS and TERF surge tanks. These tanks are carbon steel, but have always operated below atmospheric pressure and rarely contained gas with more than a few ppm of tritium.

EDX/SEM Surveys For SMTs – The Energy Dispersive X-Ray/Scanning Electron Microscope (EDS/SEM) was first used for identification of SMTs following the 1993 tracking event. Hafnium tritide was identified in the NW fumehood in SW-150 and on the container handled in the event. After the 1993 tracking event a systematic survey of the building using the EDS/SEM was initiated. This effort was terminated prior to its conclusion due to funding limitations. In 1998, there was a minor contamination event in the NW fumehood in SW-150. In this case the container, that had been contaminated with hafnium tritide in the 1993 event, was removed from the NW fumehood and placed in a waste drum. The EDS/SEM analysis of the fumehood in 1998 indicated no SMT contamination. Repackaging of hardware, suspected of SMT contamination, was completed in 1998 in R-130. The EDS/SEM was use to analyze Fixed Air Sampling Head (FASH) samples and smears with no evidence of SMT contamination. As a follow-up to the repackaging in R-130, samples were taken in R-108 to establish PPE and bioassay requirements for handling the hardware repackaged in R-130. No SMT contamination was found in the room or in the fumehood that was to be used. Additional samples were taken in SW-13 around the "Struers Box" and on limited access surfaces near the "Struers Box." This included EDS/SEM samples on pipes and flanges above the north end of the central glovebox as well as on the top of the "Struers Box" fumehood and exhaust trunk line. These samples were all analyzed with the EDS/SEM with no indication of hafnium. Two samples taken from between floor tiles in SW-13 have indicated hafnium tritide contamination.

Conclusion – Hafnium tritide and to a lesser extent other SMTs are potential contaminants in gloveboxes in SW-13 (Struers Box), SW-150/152/240, SW-8 (old recovery box only), R-108 and SW-9. The glovebox recirculation systems in SW-231 and R-108 and any piping that remains of the glovebox purification system in SW-12 have the potential for SMT contamination. Inaccessible surfaces in SW-13 and to a lesser extent SW-150 may have SMT contamination due to the 1972 glovebox breach and 1993 tracking event. Ventilation exhaust in SW-13 and to a lesser extent SW-150 may also be SMT contaminated. Iron oxide tritoxide may be found in the carbon steel TD-column feed tanks in SW-8 and to a lesser extent in the ICI fixed tube trailer and the ERS and TERF surge tanks.