Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF REVISION 03 TO THE SITE PROFILE FOR NUCLEAR MATERIALS AND EQUIPMENT CORPORATION, APOLLO AND PARKS TOWNSHIP, PENNSYLVANIA

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ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
ALARA	as low as reasonably achievable
Am	americium
AWE	Atomic Weapons Employer
B&W	Babcock & Wilcox
BWXT	Babcock & Wilcox Technologies
BZ	breathing zone
Co	cobalt
Cs	cesium
CWT	chest wall thickness
DOE	U.S. Department of Energy
dpm	disintegrations per minute
DR	dose reconstruction
DWE	daily weighed (average) exposure
ER	evaluation report
FFTF	Fast Flux Test Facility
FP	fission product
GA	general air (sample), general area
GM	geometric mean
GSD	geometric standard deviation
HASL	Health and Safety Laboratory
HEU	high-enriched uranium
ICRP	International Commission on Radiological Protection
keV	kiloelectron volt
LANL	Los Alamos National Laboratory
MDA	minimum detectible activity
MeV	mega-electronvolt
NIOSH	National Institute for Occupational Safety and Health
n:p, n/p	neutron-to-photon dose ratio
NRC	U.S. Nuclear Regulatory Commission
NTA	nuclear track emulsion, Type A

NUMEC	Nuclear Materials and Equipment Corporation
ORAUT	Oak Ridge Associated Universities Team
p/n	photon-to-neutron dose ratio
PNC	Japan's Power Reactor and Nuclear Fuel Development Corporation
Pu	plutonium
RU	recycled uranium
Sr	strontium
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document
TLD	thermoluminescent dosimeter
U	uranium
UK	United Kingdom
WG	Work Group
ZPPR	Zero Power Plutonium (later Physics) Reactor
ZPR-III	Zero Power Reactor

1.0 INTRODUCTION AND BACKGROUND

In accordance with direction provided by the Advisory Board on Radiation and Worker Health (the Advisory Board) at the July 19, 2016, meeting of the Uranium Refining Atomic Weapons Employers (AWEs) Work Group (the Work Group, or WG) (NIOSH 2016b), this report reviews Revision 03 to ORAUT-TKBS-0041, *Site Profile for Nuclear Materials and Equipment Corporation, Apollo and Parks Township, Pennsylvania*, dated August 25, 2016 (NIOSH 2016c; also referred to as the technical basis document, or TBD), to assess if it adequately addresses the findings on the TBD that SC&A had developed since its initial publication in 2008 (NIOSH 2008). The work site description section of the National Institute for Occupational Safety and Health (NIOSH) website for the Nuclear Materials and Equipment Corporation (NUMEC) provides a detailed compendium of the entire review and publication process (http://www.cdc.gov/niosh/ocas/numec.html).

Some of the most pertinent recent events and reports related to the findings are as follows:

- *NIOSH Responses to SC&A Review of ORAUT-TKBS-0041, Rev. 02: Site Profile for Nuclear Materials and Equipment Corporation, Apollo and Parks Township, Pennsylvania*, Revision 0-A, National Institute for Occupational Safety and Health, Cincinnati, Ohio, May 14, 2015 (NIOSH 2015b)
- *SC&A Assessment of Selected NIOSH Responses to SC&A NUMEC Site Profile Findings*, SC&A, Inc., Vienna, VA, August 14, 2015 (SC&A 2015)
- *White Paper on NUMEC Issues and Feasibility of Coworker Model*, Revision 0, National Institute for Occupational Safety and Health, Cincinnati, Ohio, June 23, 2016 (NIOSH 2016a)
- July 19, 2016, WG meeting.

All findings were resolved "in principle" during the July 19, 2016, WG meeting, pending review of Revision 03 to the TBD, which was issued August 25, 2016, and some responses by NIOSH. The objective of this report is to assess whether Revision 03 to the TBD does, in fact, contain the information and revisions agreed upon during the WG meeting, thereby allowing the WG to close the findings at a future meeting. The format used to present SC&A's review of the TBD is to briefly summarize each of the 21 findings, outline how they were resolved in principle during deliberations by the WG, identify any unresolved issues, and assess the degree to which the findings were adequately addressed in Revision 03 to the TBD or otherwise clarified by NIOSH.

Each section of this report (1) uses the NIOSH white paper of June 23, 2016 (NIOSH 2016a), as its starting point for convenience, as that paper systematically lists each finding and its status; (2) adds material on NIOSH's position for that finding; (3) adds any comment SC&A may have expressed about that finding; and (4) evaluates whether that finding has been adequately addressed in Revision 03 to the TBD or otherwise addressed by NIOSH. The material in italics is excerpted directly from NIOSH 2016a. As indicated in SC&A's August 2015 report (SC&A 2015), at that time, of the original 21 SC&A findings developed during the NUMEC site profile

review process, 11 were closed and 10 remained in progress. As described in more detail in the sections that follow, this current report concludes the following:

SC&A recommends closing all 21 findings except Findings 6, 10, and 12.

2.0 ASSESSMENT OF FINDING RESOLUTIONS

The following subsections present the status of each of the 21 findings in turn. The italicized paragraphs are quoted from NIOSH 2016a, followed by SC&A's evaluation and recommendation to the WG for disposition of the finding. Note that, for convenience in referring to the findings, SC&A has given each finding a short, descriptive subsection title.

2.1 FINDING 1: PARKS TOWNSHIP SITE OPERATION PERIOD

> ***Finding 1:*** *Clarification is needed regarding the start and end dates of Parks Township Site operations.*
>
> *Proposed NIOSH resolution: Tables will be updated with new information and values possibly corrected.*
>
> *August 2015 WG discussion:* ***Closed****, if change is included in TBD revision.*
>
> *NIOSH update June 2016: Change included in draft ORAUT-TKBS-0041 Rev. 03-B.*

SC&A Evaluation: SC&A first raised **t**his issue in SCA-TR-SP2013-0038, *Review of the NIOSH Site Profile for Nuclear Materials and Equipment Corporation Park Township and Apollo Sites*, April 19, 2013 (SC&A 2013), which states that Section 2.2.1 of the site profile (at the time) indicates that the site was not authorized to begin work until 1961, but Table 2-4 of the site profile indicates that many of the locations were operational in 1960. Additionally, Section 2.2.3.3 indicates that Building C was not used from construction until 1973, and Section 2.2.5 states that all operations in Building C ceased in 1978, yet Table 2-4 indicates that operations in Building C began in 1969 and lasted till 1980. This issue was closed during subsequent deliberations but needed to be confirmed once Revision 03 to the TBD was issued.

Inspection of Table 2-3 in Revision 03 to the TBD indicates that it has been revised to indicate that no facilities were operational before 1961.

SC&A Recommendation: SC&A recommends closing this issue.

2.2 FINDING 2: LEVEL OF URANIUM ENRICHMENT FOR URINE BIOASSAY RESULTS EXPRESSED IN UNITS OF µg/L

> ***Finding 2:*** *The site profile should provide guidance about what level of uranium enrichment should be assumed for those urine bioassay results that are expressed in units of µg/L.*

Proposed NIOSH resolution: NIOSH will add a section to TBD with guidance on enrichment assumption if no other information is available (assume highly enriched since it is claimant favorable and was used at Apollo).

*August 2015 WG discussion: **Closed**, if guidance is included in TBD revision.*

NIOSH update June 2016: Change included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: SC&A first raised this issue in SC&A 2013 regarding TBD Section 4.4.1, which states that for those urine analysis results expressed in terms of μg/L, no guidance is provided regarding what level of enrichment should be assumed. NIOSH claimed to have resolved this issue with a revision to the TBD that states that the dose reconstructor should use the claimant-favorable assumption that the uranium is enriched if no other information is available.

Inspection of Section 5.2.2.4 of Revision 03 to the TBD does, in fact, state: "*If the enrichment is not known, then an estimate of activity that is favorable to the claimant can be made by assuming the material to be HEU* [high-enriched uranium] *(93%).*"

SC&A Recommendation: SC&A recommends closing this issue.

2.3 FINDING 3: GUIDANCE ON DOSE RECONSTRUCTIONS PRIOR TO 1959, AND APPROACH FOR MISSED AND UNMONITORED EXPOSURES

***Finding 3:** Some guidance is needed on how to perform dose reconstructions prior to 1959, and what approach to use for missed and unmonitored exposures.*

Proposed NIOSH resolution: None. Pre-1959 dose reconstruction is infeasible per SEC [Special Exposure Cohort].

*August 2015 WG discussion: **Closed**.*

SC&A Evaluation: SC&A concurs with NIOSH's proposed resolution; i.e., if there is no technical approach that can be used to reconstruct doses to workers who are not covered by the SEC, no dose reconstruction can or should be performed.

SC&A Recommendation: SC&A's review of Revision 03 to the TBD does not alter the basis of the August 2015 WG decision to close the finding.

2.4 FINDING 4: URANIUM INHALATION RECOMMENDATIONS FOR THE APOLLO SITE

***Finding 4:** Uranium inhalation recommendations for the Apollo Site need to consider the method discussed by Davis and Strom (2008) for dealing with uncertainties in DWE* [daily weighted (average) exposure]. *This technique was evaluated and found to be appropriate in the site profile review for the Fernald Feed Materials Production Center (Fernald).*

Proposed NIOSH resolution: Davis and Strom (2008) evaluated several HASL [Health and Safety Laboratory] *reports and concluded that the daily weighted exposures have a lognormal distribution with a geometric standard deviation of 5. HASL data is available for the Apollo site and has been used to evaluate exposure concentrations. As discussed in Finding 18, the air concentration used for the beginning of the residual period has been re-evaluated and is now based on General area (GA) monitoring rather than daily weighted average exposures (see response to Findings 5 and 18 below). The geometric standard deviation (GSD) for the revised air concentrations has been set to 5.0 based on Davis and Strom (2008).*

August 2015 WG discussion: The discussion during the work group meeting moved from the question of using the HASL data in dose reconstructions to the more general issue of whether it was possible to develop co-worker models for uranium intakes. Based on the Apollo Evaluation Report, internal doses from uranium bioassay can be reconstructed when data are available for an individual claim. SC&A questioned if NIOSH has any claims with uranium bioassay where internal uranium dose was not assigned. SC&A would like to investigate more to find workers who were exposed to U [uranium] *and not had internal U assigned. NIOSH was tasked to review and evaluate if a coworker model is needed.* ***Issue 4 was closed****; however, NIOSH committed to assess the possibility of a coworker model. Dr. Neton pointed out that the SEC decision does not mean that every single feasibility and infeasibility was evaluated (meaning, just because the finding for the Apollo ER* [evaluation report] *was that internal uranium dose reconstruction are feasible when data exist for a given claim does not necessarily mean that a coworker model can be developed for this data). Any coworker model that is developed would have to hold up to the standards of the coworker implementation guide.*

NIOSH update June 2016: During the initial discussion, there was some misunderstanding in NIOSH's part on the focus of this issue. The original issue addresses Section 5.4 of the TBD, which provides guidance to assign internal doses based on fixed BZ [breathing zone] *air data for uranium workers during 1959-1961. Upon further consideration of the guidance and the data, this section using HASL BZ data will now be removed from the TBD in accordance with the findings presented in the Apollo SEC evaluation report that internal doses cannot be reconstructed during that time period except when uranium bioassay are available. HASL BZ data were collected for specific projects and operators during a limited operating time and do not reflect the range of uranium activities carried out and NUMEC.*

As for the coworker model discussion, it is not expected that the available data can be used to develop coworker models that would adhere to the guidelines expected from such a model. Please see detailed analysis below.

SC&A Evaluation: This issue has a complex history, as described in NIOSH 2016a. The important conclusion made by the NIOSH paper is that it is not expected that the available data can be used to develop coworker models that would adhere to the guidelines expected from such a model. This revised strategy for dose reconstruction makes this issue moot.

Therefore, SC&A concurs with this position, and the matter is considered adequately addressed in Revision 03 to the TBD.

SC&A Recommendation: SC&A recommends closing this issue,

2.5 FINDING 5: INADEQUATE INFORMATION IS GIVEN TO REPLICATE NIOSH'S DETERMINATION OF MEDIAN INHALATION CONCENTRATION OF URANIUM

Finding 5: *Inadequate Information is given to replicate NIOSH's determination of median inhalation concentration of uranium. The NIOSH result could not be replicated, and it appears that relevant information has been omitted from the HASL studies reported in Appendix A to the site profile.*

Proposed NISOH resolution: No data from the HASL reports cited have been omitted, but the calculation approach has been revised since the previous TBD was issued and is now based on GA data.

August 2015 WG discussion: NIOSH should provide more guidance how the revised approach is to be used for partial dose reconstructions. This analysis was done to get to a starting point for levels to be used in the residual period. For the operational period, BZ samples are used if they are available. SC&A voices concerns that there were significantly higher intakes in the ceramics plant than other areas and whether those would be represented in the median intakes.

NIOSH update June 2016: See response to Finding 4.

SC&A Evaluation: The publication record and Section 7.4 of Revision 03 to the TBD state that Table 7-3 has been revised to use general air sampling data rather than breathing zone data as the basis for intakes of residual uranium.

SC&A Recommendation: SC&A recommends closing this issue.

2.6 FINDING 6: ASSUMED PLUTONIUM MIXTURE

Finding 6: *The site profile would benefit from a discussion demonstrating that the Hanford fuel-grade mix, as opposed to the weapons-grade or commercial-grade plutonium, is limiting for the full range of plutonium mixes and ages that were used at NUMEC. In addition, given the complexity of this subject, a review of actual dose reconstructions would provide greater insight into how this matter is actually being addressed.*

Proposed NISOH resolution: Table will be updated with recently captured information on the fuel types used at NUMEC to represent more accurately the mixes that were handled.

August 2015 WG discussion: SC&A wants to review response in detail and provide comment on the response. SC&A was tasked with providing an additional response.

SC&A Response after WG discussion: Other possible Pu mixes that may have been present at NUMEC should be investigated (such as Japanese fuels and fuels from the UK [United Kingdom]*).*

NIOSH update June 2016: This issue was not pursued further. Additional data capture is not considered to be a productive option for NUMEC. The currently available data can be used for a reasonable claimant-favorable assumption to assign partial internal dose. It would not be reasonable to speculate on additional Pu mixtures to complete partial dose reconstructions for non-presumptive cancers. Any reported Pu bioassay will be used at face value. No adjustments for other contaminants are available.

SC&A Evaluation: As indicated in Section 1.1 of SC&A 2015, NIOSH provided extensive additional information about the plutonium-grade mix handled at NUMEC by compiling applicable information from the Hanford TBD, and committed to include this new information in the next revision of the TBD. SC&A agreed that this new information essentially resolved this issue. However, as stated in the SC&A report, several additional questions needed to be addressed:

- NIOSH's May 14, 2015, report (NIOSH 2015b) does not appear to address all the possible sources and mixtures of plutonium that might have been present at NUMEC over the years. While it presents new information about Japanese and Zero Power Physics Reactor (ZPR-III, located at Argonne National Laboratory-West on the Idaho National Laboratory site) fuels produced in the 1960s, it does not discuss possible United Kingdom fuel or other fuels. SC&A requested that NIOSH address these specific categories of fuel, as was done for the other categories of fuel.
- The report (SC&A 2015) asked if NIOSH will run all combinations of grades and ages of plutonium that might apply and use the limiting scenario to envelope the actual dose. If so, will NIOSH develop a workbook that can be used under these circumstances?
- Additionally, SC&A suggested that NIOSH include Hanford Table 5-5, "Activity Composition of Hanford Reference Commercial Power Fuel-Grade Plutonium Mixture" (in addition to Tables 5-3 and 5-4), in the site profile for convenience to the dose reconstructor.

NIOSH's response was reiterated at the July 19, 2016, Uranium Refining Atomic Weapons Employers WG meeting (NIOSH 2016b). NIOSH stated that they do not have any more data and that what they "*currently have can be used to make a reasonably claimant-favorable assumption for partial dose reconstructions and anything else would be more or less speculation…We do not*

expect that any additional data capture is possible at this site." NIOSH also repeated its previous commitment to revise the appropriate section in Revision 03 to the TBD with the addition of Pu mix information for three other Pu-240 weight percentages (as presented in NIOSH 2015b), and to supply more guidance to the dose reconstructor; e.g., to ensure that the most claimant-favorable mixture is chosen by running a few different cases. SC&A accepted NIOSH's strategy in general but reserved making a recommendation to the Work Group before seeing Revision 03 to the TBD.

Inspection of Revisions 02 and 03 to the site profile reveals the following with respect to the degree to which issues related to Finding 6 are now fully addressed. Revision 02 (NIOSH 2012a) notes that there are three types of plutonium mixtures, reactor grade (27 weight percent Pu-240), weapons grade (6 weight percent), and fuel grade (12 weight percent), with Table 5-3 containing specific activities by isotope and different fuel aging times for only the fuel-grade mixture ("Hanford reference-grade plutonium," which was supplied to the Fast Flux Test Facility [FFTF]). Table 5-3 of Revision 03. However, Revision 02 presents specific activities for those three mixes as well as for 8.5 weight percent, U.S. Department of Energy (DOE) plutonium, for a total of four mixes ranging from 6 to 27 weight percent Pu-240 in the plutonium matrix.

Revision 03 contains an expanded discussion of the different types of plutonium-based fuels encountered at NUMEC as well as guidance for the dose reconstructor, which is reproduced here for convenience:

> *Fuel-grade plutonium was used for FFTF fuel fabrication and most of the ZPPR fuel fabrication (11,500 plates). However, commercial reactor-grade plutonium was also used for some ZPPR* [Zero Power Plutonium (later Physics) Reactor] *fuel fabrication (700 fuel plates) starting in April of 1969. For work in the FFTF fuel fabrication, lacking specific information on the actual composition of the processed plutonium, the composition of Hanford fuel-grade plutonium can be used because this was the source of plutonium for FFTF fuel fabrication (Author unknown 2004). The site also used Hanford 6% weapons-grade plutonium for some mixed-oxide fuel fabrication. An 8.5% plutonium mix was used for a contract with Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC) and for ZPR-III fuel. The activity compositions for the four grades of plutonium are listed in Table 5-3 for fuel aged up to 20 years (*[NIOSH] *2010b, 2015*[d]*). The age of plutonium to assume for a given analysis depends on the radionuclide measured in the bioassay analysis. When gross alpha,* ^{238}*Pu, or* ^{239}*Pu is measured, the dose is maximized by assuming longer decay times (20 years). When* ^{241}*Am is measured and the intake is estimated using ingrowth of* ^{241}*Am from decay of* ^{241}*Pu, the dose is maximized by assuming a short (5-year) decay time. If the actual age of the fuel is known (such as from an incident investigation report), that age can be used in the intake and dose analysis. If the exposure occurred only in FFTF fuel fabrication, then the Hanford fuel-grade composition can be used. If the work location is not known (such as for plutonium scrap recovery), then use of the Hanford 6% weapons-grade plutonium will provide a dose estimate that is favorable to the claimant.*

While reviewing NIOSH's response to this finding, SC&A also became aware that a recent NIOSH report, DCAS-RPT-005, Revision 0, *Alternative Dissolution Models for Insoluble Pu-238,* (NIOSH 2016d). NIOSH 2016d lists NUMEC as one of the sites where workers could be exposed to special Pu compounds (i.e., unencapsulated, insoluble Pu-238), and that the lung model parameters derived for Los Alamos National Laboratory (LANL) should be used. The document explains that the special dissolution type for Pu-238 (Super-S, or SS) should be used in addition to Types M and S, and that the dissolution type that results in the highest dose to the organ of interest should be used for the final dose assignment. SC&A confirmed that Revision 03 to the TBD addresses this issue in Section 5.1, as follows:

> *The dose reconstructor should use the solubility type that results in the highest dose.*
>
> …
>
> *In general, plutonium oxides, carbides, and hydroxides are absorption type S; nitrates and other compounds are type M (ICRP 1995, p. 328–329). Older materials, even when starting out as soluble, can have a tendency to oxidize when left in contact with air. Oxides, metals, and old contamination should be treated as type S. If nothing is known about the chemical form of plutonium, either type M or S can be used to maximize the dose to the organ of concern. In addition, because highly insoluble forms of plutonium might have been present, guidance in ORAUT-OTIB-0049, Estimating Doses for Plutonium Strongly Retained in the Lung (*[NIOSH 2010c]*), should be followed for the evaluation of highly insoluble (type SS) plutonium. Americium-241 is a component of plutonium contamination and should be modeled in the lung the same as the plutonium matrix in which it has grown. In other words, the americium should be treated as absorption type S if the plutonium is type S (ORAUT 2015). If the plutonium is type SS, follow guidance in* [NIOSH 2010c] *for assignment of the* ^{241}*Am solubility type.*

Notwithstanding the above, SC&A suggests that for completeness and to provide a full discussion, NIOSH should supplement Section 5.1 of the TBD by noting that ORAUT-OTIB-0049 (NIOSH 2010c) is applied only to doses resulting from intakes of plutonium for which the activity isotopic ratio of Pu-(239+240) to Pu-238 is greater than one. When this condition is met, Type SS behavior applies to all isotopes in the plutonium mixture. In addition, when workers are exposed to basically pure, insoluble Pu-238, special dissolution models should be used in dose reconstruction, as specified in DCAS-RPT-005, Revision 0 (NIOSH 2016d). According to this report, NUMEC workers could have been exposed to significant quantities of unencapsulated, insoluble Pu-238. The alternative dissolution model for Pu-238, with parameters defined in NIOSH 2016d, should be tested against the standard Pu-238 types to define which lung model results in the highest dose to the organ of interest. NIOSH should add an additional special dissolution type to TBD Section 5.1 for sources of almost pure insoluble Pu-238, as defined in DCAS-RPT-005, Revision 0.

SC&A is satisfied that Revision 03 to the TBD adequately responds to the original concerns of Finding 6, but not to the additional issue of the solubility type.

SC&A Recommendation: SC&A recommends that this issue remain open pending further discussion of the solubility class for almost pure insoluble Pu-238.

2.7 FINDING 7: THE MINIMUM DETECTABLE ACTIVITIES FOR Am-241 LUNG COUNTING ARE VERY LOW, AND THE COUNTING METHOD SHOULD BE FURTHER EXPLORED TO GIVE THEM CREDIBILITY

Finding 7: *The MDAs* [minimum detectable activities] *for Am-241 lung counting are very low, and the counting method should be further explored in order to give them credibility.*

Proposed NIOSH resolution: NIOSH will add some additional guidance to the draft TBD.

August 2015 WG discussion: NIOSH has addressed some of the MDA issues and added some more reasonable values, but SC&A's concerns remain. Dr. Neton agrees in that the MDA numbers for Pu look somewhat low, the Am MDA looks ok. The Pu MDA values are very much dependent on chest wall thickness. SC&A was tasked with providing additional assessment.

SC&A response after WG discussion: SC&A believes that the MDA value for in-vivo monitoring of Am-241 and Pu-239 are not reliable, that very limited data is available, and that the low reported values for MDAs for Am-241 in-vivo lung monitoring need to be further developed. The values for Pu-239 are not credible, due to the 17 keV X-rays being measured directly.

NIOSH update June 2016: NIOSH has discussed and evaluated the chest counting data that was supplied by Babcock and Wilcox. Many of the reported results have a reported MDA when a non-detectable amount is reported. The MDAs appear to be lower than what might be reported today, but it would be difficult to come up with an alternate value. Most measurements were done at the University of Pittsburg and the NUMEC in-vivo program was overseen by a person who was highly regarded in the field. The lower MDAs could be the result of the calibration phantoms used at the time. Until the advent of the Livermore realistic phantom in the late 1970's, the phantoms in use did not provide a sophisticated representation of human anatomy and tissue equivalency. It was eventually discovered that the earlier phantoms tended to overestimate counting efficiency, especially for low-energy emitters like Pu and Am. Unfortunately, there does not seem a straightforward way to adjust the earlier values retroactively, to comport with what might be reported today.

There are too many unknown variables involved, including the exact design and configuration of the detectors used, the position of the detectors over the lungs (i.e., measurement geometry), and the chest wall thickness (CWT) for each subject counted. Even if the CWT is known for a person, the manner in which it was measured or calculated can lead to large differences in the

value. Given all this, NIOSH intends to use the detection limits as reported for each original measurement. While there may be some negative bias associated with using these values, it seems that this is preferable to making adjustments that would largely be based on conjecture. This approach would be consistent with performing partial dose reconstructions for non-presumptive cancers using "data that may be included in an individual's file (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures)" to support a partial internal dose reconstruction for non-presumptive cancers and/or cases that have less than 250 working-days of employment.

SC&A Evaluation: SC&A believes that NIOSH has thoroughly investigated this issue and has adopted a reasonable strategy for implementing this strategy, as indicated in the above excerpt from Revision 03 to the TBD. It is also noteworthy that the protocol proposed by NIOSH is a means for assigning at least some dose to workers who would otherwise not be assigned any dose under the SEC.

Hence, SC&A believes that NIOSH has made every reasonable effort to assign a reasonable dose to uncovered workers.

SC&A Recommendation: SC&A recommends closing this issue.

2.8 FINDING 8: AIR SAMPLING DATA TO RECONSTRUCT INTERNAL PLUTONIUM EXPOSURES

Finding 8: *The site profile would benefit from a more thorough discussion of the possible use of air sampling data to reconstruct internal plutonium exposures and to take into consideration the additional data provided by Crosby 1967 and NUMEC 1967.*

Proposed NIOSH resolution: None. Internal dose reconstructions are partial and done only in cases where bioassay is available.

August 2015 WG discussion: ***Closed****.*

SC&A Evaluation: SC&A concurs with NIOSH's position on this matter because air sampling data are not used for dose reconstruction and, therefore, this issue becomes moot.

SC&A Recommendation: SC&A's review of Revision 03 to the TBD does not alter the basis of the August 2015 WG decision to close the finding. Revision 03 to the TBD does not rely on air sampling data to reconstruct internal dose, and, therefore, the TBD need not address this issue.

2.9 FINDING 9: ORAUT-OTIB-0054 APPLICABILITY

Finding 9: *It does not seem appropriate to use ORAUT-OTIB-0054 (*[NIOSH] *2007a) to reconstruct the internal exposure of workers at NUMEC who might have been exposed to mixed fission products. ORAUT-OTIB-0054 states that its guidance "does not apply to determination of intakes where radionuclides have*

been purposely extracted and concentrated as for heat generation sources, medical uses, or waste handling operations that caused significant alteration to the source term to which workers were exposed." For example, see Table 5-1 of the site profile. Also, the fission product mix given in ORAUT-OTIB-0054 does not contain the same radionuclides as the fission product mixes given for the NUMEC Laundry in the 1975 effluent release report (SRDB #20081) and for in-vivo count results in SRDB #19970. The NUMEC mixes include Co-60, which the ORAUT-OTIB-0054 mix omits.

Proposed NIOSH resolution: The use of OTIB-0054 ([NIOSH 2015a]*) is appropriate when the source of activity is from reactors. As indicated in this finding, the NUMEC laundry processed materials from many sources in addition to the commercial reactor laundry. The site profile will be modified to remove guidance on use of OTIB-0054 for evaluation of dose from associated fission products and activation products. The guidance will indicate that doses are to be evaluated only for the radionuclides included in the bioassay results*

*August 2015 WG discussion: **Closed**, if new guidance is included in TBD revision.*

NIOSH update June 2016: Change included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: At the Work Group meeting of August 3, 2015, the Advisory Board members requested that SC&A evaluate some of NIOSH's responses to SC&A's findings in NIOSH's May 14, 2015, report (NIOSH 2015b), but did not include Finding 9, noting that the finding should be closed if NIOSH provided appropriate revised guidance in Revision 03 to the TBD. Hence, SC&A's subsequent report of August 14, 2015 (SC&A 2015), did not contain an assessment of NIOSH's response to Finding 9.

NIOSH responded to various NUMEC issues raised by SC&A in a June 23, 2016, white paper (NIOSH 2016a). Its section on Finding 9 reiterates the statement contained in NIOSH 2015b and notes that the change was made in the draft TBD Revision 03.

Discussions at the July 19, 2016, WG meeting covered several of the findings, but not Finding 9.

SC&A reviewed the portion (Section 5.2.4, "Mixed Fission Products") of Revision 03 to the TBD applicable to Finding 9 to assess how it addresses the issues that were raised. As promised by NIOSH, all references to OTIB-0054 that were present in Revision 02 of the TBD were removed in Revision 03. After noting radionuclides that could have been encountered at either the Apollo site (where the Laundry Building was located) or the Parks Township site, the revised TBD states:

Urine bioassay data for mixed FPs [fission products] *should be used, if included in the case files, to estimate intakes of FPs. The mixed FP urine bioassay results do not indicate if the measurements are based on beta or gamma analysis, so the*

intake should be based on ^{90}Sr as a representative beta emitter and ^{137}Cs as a representative gamma emitter and the analysis providing the highest dose should be used.

SC&A is satisfied that Revision 03 to the TBD adequately responds to the concerns of Finding 9 and recommends that the WG close the finding.

SC&A Recommendation: SC&A recommends closing this issue.

2.10 FINDING 10: INTERNAL DOSE RECONSTRUCTIONS FOR RU INTAKES

Finding 10: *Internal dose reconstructions performed for NUMEC personnel might need to be revisited in light of changes to the Fernald site profile (*[NIOSH] *2004) with respect to RU* [recycled uranium]. *Also, additional direction is needed with respect to which workers or operations should be assigned RU intakes.*

Proposed NIOSH resolution: Some language will be added to the revised NUMEC TBD regarding assigning RU doses for NUMEC.

August 2015 WG discussion: Discussed whether any additional sources of information regarding the uranium composition were reviewed. ***Closed*** *if NIOSH adds guidance on assigning RU doses to the TBD revision.*

NIOSH update June 2016: Change included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: As indicated in the Publication Record of Revision 03 to the TBD, revised Section 5.2.5 indicates recycled uranium contaminants should be included in the evaluation of the material solubility type that gives the highest internal dose. A review of that section of the TBD reveals that the NIOSH states that: "*The intake of RU contaminant radionuclides can be estimated using the guidance in Section 5.3.2 and activity fractions in Tables 5-33 and 5-34 of ORAUT-TKBS-0017-5,* Technical Basis Document for the Feed Materials Production Center – Occupational Internal Dose *(*[NIOSH 2016e; i.e., Revision 01]*).*"

The Fernald site profile was recently revised (NIOSH 2016f; i.e., Revision 02), which, in part, corrected the RU values that were recommended in Table 5-34 of Revision 01 to the Fernald site profile. Section 5.3.2.1 of Revision 02 to the Fernald site profile acknowledges that "*concentration of contaminants in RU changed with time, so default values for dose reconstruction are defined for discrete time intervals*." The recommended RU contaminant mass concentrations for use in dose reconstruction at Fernald are provided in Table 5-10. Two sets of values are provided; one set for 1961–1972 and a second set for 1973 to the present. Accordingly, Revision 03 to the NUMEC site profile should: (1) be revised to refer to RU values in Revision 02 to the Fernald site profile (as opposed to Revision 01), and (2) also provide guidance with respect to which RU time periods in the Fernald site profile should be used. Finally, a review of Revision 02 to the Fernald site profile, with respect to RU, reveals that many aspects of RU at Fernald are quite complex because of RU-containing plutonium that was out of specification. Accordingly, Section 5.2.5 of Revision 03 to the NUMEC site profile also needs to

address issues related to the unique aspects of RU at Fernald and the degree to which they apply to NUMEC.

SC&A Recommendation: SC&A recommends that this issue remain open until these concerns are resolved.

2.11 FINDING 11: HELGESON CHEST COUNT DATA CONCERNS

Finding 11: *NIOSH should explain whether the concerns expressed in the Pantex site profile (*[NIOSH 2007b]*) about the Helgeson chest count data might also apply to chest count data at NUMEC performed by Helgeson for NUMEC workers.*

Proposed NIOSH resolution: The in vivo counting at NUMEC was performed by Helgeson only during 1968, 1971, and once in 1975. The Helgeson counts included primarily plutonium-239, with a few results for uranium and fission products. The majority of in-vivo counting was performed at the University of Pittsburg hospital. The issue with Pantex was that the counts for uranium were biased high and represented false positives (Brake 1989). The current Pantex internal dose TBD has eliminated all reference to Helgeson in-vivo measurements. Using the Helgeson results for uranium at NUMEC is favorable to the claimant, because any bias would be high. There was no issue identified related to Helgeson in-vivo counting for fission products, plutonium, or americium.

August 2015 WG discussion: SC&A wants to look into this issue more. SC&A will review the issue and provide findings to NIOSH.

SC&A response after WG discussion: SC&A remains concerned about the values used for MDA for in-vivo counts, as some are listed as 63 µg and some are listed as 80 µg for U-235. SC&A would like to see clarification and DR [dose reconstruction] *examples to ensure the correct value is used.*

NIOSH update June 2016: NUMEC used the Helgeson mobile whole body counter for Pu and Am counts, and also some U-235. The MDA reported for U-235 in 1968 using the Helgeson unit is 80 µg. NUMEC mostly did whole body counts at the Low Level Radiation Monitoring Facility at the University of Pittsburg, which, on many count results, report a MDA value of 63 µg for U-235. A clarifying statement could be added to the TBD, but since generally the MDAs seem to be reported with the respective result, for a non-presumptive cancer, the MDA respective to the analysis would be used. As outlined for item 7, NIOSH has not located any information that would allow for a critical assessment and correction of reported MDA values that are perceived low by SC&A. The issue with Pantex was that the counts for uranium were biased high and represented false positives (Brake 1989). The current Pantex internal dose TBD has eliminated all reference to Helgeson in vivo measurements. Using the Helgeson results for uranium is not to the

detriment to the claimant, since it would lead to a positive bias. No additional research is proposed at this point by NIOSH.

SC&A Evaluation: SC&A accepts the NIOSH 2016a explanation because the use of the Helgeson mobile whole body counter at Pantex was of concern with respect to measuring plutonium and americium, but likely overestimated doses from uranium. As such, the use of Helgeson data is claimant favorable as applied to NUMEC, where it was used to estimate uranium body burdens.

SC&A Recommendation: SC&A recommends closing this issue.

2.12 FINDING 12: REVISION OF TABLE 6-2 AND ASSOCIATED TEXT IN SECTION 6.3.2 OF THE SITE PROFILE

Finding 12: *Table 6-2 and the associated text in Section 6.3.2 of the site profile should be reviewed and modified as needed to correct any oversights, inconsistencies, or errors.*

Proposed NIOSH resolution: The indium foil criticality dosimeters were not included in Table 6-2 because they were not used for routine workplace exposures. They were included only to determine dose from a criticality in the event that a criticality occurred. No criticality incidents were reported at the NUMEC facilities. The text was reviewed as suggested and the information in the text is consistent with information provided in Tables 6-2 and 6-3.

August 2015 WG discussion: SC&A insists there is still an error in the table. How are data from multi component badges handled? SC&A to elaborate further.

SC&A response after WG discussion: More information is needed regarding how the data from the neutron detection devices will be used to reconstruct neutron doses. For example, Table 6-2 describes the method for deriving the fast neutron dose that involved subtraction of the thermal dose, but it is not clear if this was determined from a cadmium-filtered film badge or not. The Landauer "Z1" dosimeter contains a neutron sensitive CR-39 component, but this is not mentioned in the table or text. Both the text and table are unclear and inconsistent regarding the use of CR-39. Table 6.2 indicates that Z1 badges are used (for beta/gamma), but nowhere does it say that they contain a CR-39 neutron component. The text in section 6.3.2 mentions the use of NTA [nuclear track emulsion, Type A]*, then states that, after 1968, neutron monitoring was performed with TLDs* [thermoluminescent dosimeters]*. Table 6-2 does say that other types of neutron dosimeters (not mentioned in the body of the text) did contain CR-39 components. NIOSH needs to revisit this section and ensure that both the table and text agree with each other and with the dosimetry practices of the period*

> *NIOSH update June 2016: The available guidance is suitable for assigning neutron doses for partial dose reconstruction of external neutron dose. NIOSH will clarify any outstanding questions from SC&A during the upcoming work group discussion.*

SC&A Evaluation: It is important to document as accurately as possible the types and capabilities of dosimetry utilized throughout the site history. Two issues remain unresolved, especially about neutron dosimetry. The first is to accurately reflect historical practice in the site profile prose descriptions and summary tables. The second is to address the practices that were followed by the dosimetry service providers and NUMEC for determining the recorded dose where multiple neutron dosimetry components were utilized for a given individual. As the technology changed, so did energy response thresholds, minimum and maximum reportable doses, and overlap between devices detecting differing portions of the neutron spectrum. This needs to be laid on top of a complex site with changing processes, personnel, and facilities.

The site utilized the entire wide-ranging arsenal of Landauer neutron dosimetry capabilities, which is an indication that there were complex neutron measurement issues and that radiation safety personnel were attempting to do the best possible job. Technologies provided by Landauer included cadmium filtered film for thermal neutrons, TLD 600 and 700, CR39 track etch, NTA film, and electrochemically etched polycarbonate. In addition, neutron-sensitive TLD 100 or insensitive 700 chips were incorporated into photon dosimeters depending on whether a neutron field was anticipated. In some cases, more than one of these neutron dosimeters were worn at the same time in the same holder and, thus, it is important to understand how records were maintained to ensure that doses were not duplicated or missed. It is also important to understand the rules that both Landauer and NUMEC used in determining which dosimeters were utilized and how multiple neutron components assessing differing parts of the neutron spectrum were recorded. Likewise, rules for missing or inconsistent component results should be identified.

In cases where Landauer provided a single dosimeter to measure whole body dose, then the recordkeeping was probably standard. However, if multi-component neutron whole body dosimeters were worn, then care needs to be exercised in examining the record to ensure that the appropriate results were documented. In some cases in Table 6-2, it is not clear how this issue is handled; indeed, it is not mentioned. For example, a Landauer "Z" dosimeter is designed to measure photon, beta, and neutron radiations. The table omits mention of the neutron capability entirely. The Landauer "K" dosimeter is similar to the Z, but without neutron capability. However, the K dosimeter was intended for use where neutron fields were not anticipated, so standard TLD 100 chips were used. As the Z badge was intended for neutron fields and contained a CR39 component, TLD 700 was used for gamma monitoring to prevent neutron sensitivity. Obviously, it is important to document exactly the dosimeters used or dose reconstruction and audit personnel may be lead to false conclusions. Section 6.3.2 of Revision 03 to the site profile is incorrect, or inconsistent with Table 6-2, as it fails to mention CR39 and electrochemically etched polycarbonate dosimetry:

> ***6.3.2 Neutron Dosimeters***
>
> *Workers were monitored for neutron exposures with nuclear track emulsion, Type A (NTA) film from commercial vendors until about 1968 and with TLDs*

thereafter. In addition, criticality dosimetry monitoring was done with an array of area critical assemblies that fed into a central system. This system existed from at least 1963; in September 1963, each visitor and employee was issued an indium foil criticality dosimeter as part of each security badge (NUMEC 1963).

No mention is made of CR39 or electrochemically etched dosimeters. If dose reconstruction personnel read this paragraph, they will be confused as to actual practices on the sites. One is left to draw the conclusion that the (admittedly very wide) selection of dosimetry that was in use is not fully appreciated. Compare this with Table 6-2, excerpted here in Table 1:

Table 1: Neutron Dosimeters – WB

Period	Monitoring Technique	Dosimeter Description
1957–05/1968	NTA film badge	Film badges using NTA films: Fast neutrons undergoing elastic collision with content of emulsion or cellulose acetate base material produce recoil protons, which are recorded as photographic tracks in emulsion. Track density is a linear function of dose. Developed image exhibits tracks caused by neutrons, which can be viewed using appropriate imaging method (i.e., oil immersion) and 1,000-power microscope or projection capability.
06/1968–1995	Landauer Neutrak Extended Range dosimeter (types 18, I1, or RI)	Combined TLD albedo neutron monitor with track recoil device [CR-39 (allyl diglycol carbonate)] that responds to neutron radiation through proton recoil events. The dosimeter is responsive to a neutron energy range of about 0.0001 to 10 MeV. Dosimeter response to thermal neutron radiation was subtracted to yield fast neutron dose. The Neutrak ER has an albedo element with above-described elements. Qualitative relationship was derived to determine ratios of neutrons of various energies. The RI badge was capable of monitoring beta, X-ray, gamma, and neutrons.
07/1991–12/1991	Teledyne Isotopes TLD badge	Combined gamma, beta, and neutron TLD (BWXT 1991). Details of the dosimeter are not available, other than detection limits.

Note: excerpted from Table 6-2 of NIOSH 2016c.

Given the above, it is recommended that the TBD be modified to provide a more complete picture of the neutron dosimetry program and to address how to handle a wide range of potential anomalies and exceptions.

SC&A Recommendation: SC&A recommends that this finding remain open until a more complete picture of the neutron dosimetry program is provided and the TBD addresses how to handle a wide range of potential anomalies and exceptions.

2.13 FINDING 13: BETTER DEVELOP DESCRIPTION OF THE SOURCES AND CIRCUMSTANCES RESPONSIBLE FOR EXTERNAL EXPOSURES

Finding 13: *Given our understanding that it is NIOSH's position that external exposures at the Parks Township Site can be reconstructed with sufficient accuracy, it appears that the description of the sources and circumstances responsible for external exposures need to be better developed, if possible.*

Proposed NIOSH resolution: External dose can be evaluated only when dosimetry records exist. There was one dosimetry department for all NUMEC facilities that provided dosimetry for both the Parks Township and Apollo facilities. The limitations stated for the Apollo facilities also apply to the Parks Township facilities (see response to Finding 16).

August 2015 WG discussion: NIOSH to issue response on whether an external coworker model is feasible.

NIOSH update June 2016: It is not expected that the available data can be used to develop a coworker model that would adhere to the guidelines expected from such a model. Please see detailed analysis below.

SC&A Evaluation: SC&A reviewed the attachment to NIOSH 2016a with respect to being able to construct an external dosimetry coworker model and notes that it provides a detailed description of the quality and completeness of both the internal bioassay and external dosimetry data. SC&A agrees with NIOSH's conclusion that the available external dosimetry data cannot support the development of an external dosimetry coworker model. Section 6.0 of Revision 03 to the TBD states that external doses will be assigned to workers to the extent that external dosimetry was provided for a given worker.

SC&A Recommendation: SC&A recommends closing this issue.

2.14 FINDING 14: NUCLEAR TRACK EMULSION TYPE A (NTA) FILM ADJUSTMENT FACTORS FOR NEUTRON EXPOSURES

Finding 14: *The site profile should provide justification for why adjustment factors are not required for neutron exposures estimated using nuclear track emulsion type A (NTA) film, considering that it appears that the neutron energy spectrum likely extended to well below 1 mega-electronvolt (MeV). For example, Table 6-8 of the site profile indicates that the energy range of neutron exposures extended from 0.1 to 2 MeV.*

Proposed NIOSH resolution: A n:p [neutron-to-photon dose ratio; also "n/p"] *approach was developed from available data.*

August 2015 WG discussion: SC&A states that NIOSH response is thorough, but is not sure it makes technical sense. SC&A is to provide a response after additional review.

SC&A response after WG discussion: While the n/p methodology that NIOSH is proposing for NUMEC has been used at other AWE and DOE sites, the dose data used to derive the n/p values suggested by NIOSH for NUMEC are not comprehensive or robust. NIOSH may want to consider adopting a bounding n/p ratio that ensures that the neutron doses are not understated for circumstances where the available n/p data are limited.

NIOSH update June 2016: NIOSH has reviewed the suggested approach, and agrees that the data are limited; however, NIOSH is not aware of any additional data that may exist and that would allow for refining the currently proposed approach in any way. The proposed approach was included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: NIOSH 2015b states that NUMEC used NTA film to monitor for neutron exposure until approximately June 1968, when TLDs were introduced at the site. NIOSH explains that a study was performed in 1975 using TLDs to determine the photon and neutron doses while working in the FFTF fuel fabrication area of the Parks Township plutonium facility. Additionally, dosimeters were placed at various fixed locations. The NIOSH study resulted in the following estimate of neutron-to-photon ratio (Author unknown 1977; also, BWTX 1975, BWTX 1981, and BWTX 1982), shown in Table 2.

Table 2. Neutron-to-Photon Ratios on Personnel Dosimeters

Geometric Mean	0.34
GSD	1.71

Source: Table copied from the Finding 14 section of NIOSH 2015b.

This ratio is supported by the Health and Safety ALARA Reports BWTX 1981 and BWTX 1982, which indicate that neutron-to-photon ratios (n/p) varied from 0.23 to 0.42 from 1979 to 1981, with an average of 0.33. The geometric mean (GM) n/p value of **1.00** for glovebox workers was obtained from BWTX 1975 (Table 6, PDF page 27) from the 42 reported 1975 photon-to-neutron dose ratio (p/n) values (converted to n/p values).

Table 3. Neutron-to-Photon Ratio Glovebox Dosimeters

Geometric Mean	1.00
GSD	1.49

Source: Table copied from the Finding 14 section of NIOSH 2015b.

In addition, NIOSH stated that information was obtained from a September 1968 event in which a worker involved with manufacturing neutron sources had a neutron-to-photon ratio of 2.33 (determined using estimated neutron dose values) (Caldwell 1968). A review of neutron-to-photon ratios from neutron sources was evaluated and a broad range of ratios were found. Without additional information to indicate otherwise, NIOSH adopted a ratio of 2.33.

On this basis, NIOSH proposed that NUMEC workers, prior to 1969 and with neutron dosimetry, receive a neutron dose assigned using the ratio most appropriate for their work and job location (i.e., use a ratio of **0.34** for typical workers, a ratio of **1.00** for glovebox workers, and a ratio of **2.33** for workers involved with manufacturing sources). This dose would be assigned using a lognormal distribution with the GSD provided, except for the manufacturing source ratio, which would be applied as a constant. If the worker's recorded neutron dose is higher than the neutron dose calculated from applying the ratio to the photon dose, the recorded neutron dose should be assigned. NIOSH indicated that this is the approach it will use to reconstruct neutron doses for workers prior to 1968, the time period when NTA film was used, and the revised TBD will incorporate this new information.

During the WG meeting in August 1015, SC&A expressed some concern regarding the sources and robustness of the data used to derive the n/p ratios. Given this background information, SC&A reviewed Revision 03 to the TBD to determine the degree to which NIOSH fulfilled its commitments.

SC&A's review of Section 6.5.2.4 reveals that NIOSH did, in fact, incorporate the new material discussed in theory in the white paper and during WG meetings. In addition, SC&A reviewed the source documents upon which NIOSH based its recommended n/p ratios as used in Revision 03 to the TBD and found the following:

1. **n/p = 0.34:** The n/p GM value of **0.34** was derived from averaging the gamma and neutron TLD data in the three columns in Table 1, page 26, of BWTX 1975. These data consisted of recorded neutron and gamma doses for 17 operators and associated workers for three different months in 1975.
2. **Supporting recommendation of n/p = 0.34:** To support the recommended n/p value of 0.34, NIOSH showed that other data provided a similar n/p value of 0.33, derived from the n/p values of 0.23 to 0.42, with an average of 0.33. These data were obtained from BWTX 1981, which lists the 1979 average n/p value as 0.42 and the 1980 average n/p value as 0.35, and BWTX 1982, which lists the 1980 average n/p value as 0.35 and the 1981 average n/p value as 0.23. The overall average n/p values would be (0.42 + 0.35 + 0.23)/3 = 0.33.
3. **n/p = 1.00:** The GM n/p value of **1.00** for glovebox workers was obtained from BWTX 1975, Table 6, PDF page 27, from the 42 reported 1975 p/n values (converted to n/p values). SC&A calculated an n/p GM value of 0.94 and an average n/p value of 1.08, which closely matches NIOSH's recommended value of 1.00.
4. **n/p = 2.33:** The source worker's n/p value of **2.33** was obtained from one worker involved with manufacturing neutron sources in 1968 (Caldwell 1968). SC&A found that this n/p value was derived from the first quarter exposure results for 1968 for a worker who has a 1.309 rem photon TLD dosimeter reading and a total neutron dose of 3.054 rem calculated from a combination of time-in logs and area neutron surveys (n/p = 3.054/1.309 = 2.33).

SC&A's research into the source documents used by NIOSH to derive the n/p ratios reveals that they appear to be scientifically sound. However, since all the values were obtained from snapshots in time, we are concerned whether they are representative of the complex operations and long period of time that workers at NUMEC may have experienced neutron exposures. For example, both NUMEC locations performed a variety of handling and fabrication operations with uranium and plutonium, from reactor fuels to (alpha, n) neutron sources, with some work conducted in gloveboxes. These varied operations present a challenge in reconstructing neutron doses, especially compared to an AWE facility that only performed routine fuel processing. While the n/p methodology that NIOSH is proposing for NUMEC is plausible, the dose data used to derive the n/p values suggested by NIOSH for NUMEC are not as robust as would be desired, for the following reasons:

1. The **n/p = 0.34** value to be applied to <u>typical</u> workers was derived from one 3-month study conducted in 1975 for 17 workers at one location (Table 1 of BWXT 1975). This

would only provide a snapshot in time of the n/p value and would not necessarily be representative of all the typical workers' locations and time periods where NTA film was used (1950s and 1960s) at the two NUMEC locations.

2. The **n/p = 1.00** value to be applied to glovebox workers was derived from one 3-month study conducted in 1975 for personnel working near 20 gloveboxes (Table 6 of BWXT 1975). This would only provide a snapshot in time of the n/p value and would not necessarily be representative of all the typical gloveboxes and time periods where NTA film was used (1950s and 1960s) at the two NUMEC locations.
3. The **n/p = 2.33** value to be applied to workers involved in **manufacturing neutron sources** was derived from one 3-month gamma TLD dosimeter reading and area neutron surveys using neutron survey instruments and a time log for one worker in 1968 (Caldwell 1968). Details of the processing situation (gloveboxes, shielding, etc.) were not provided. This would only provide a snapshot in time of the n/p value and would not necessarily be representative of all the neutron source manufacturing exposures and time periods where NTA film was used (1950s and 1960s) at NUMEC.

In order to evaluate the degree to which the n/p ratios are reasonable as applied to NUMEC operations, SC&A reviewed n/p ratios from two other DOE sites that performed similar operations processing uranium and plutonium. The following is a summary of our investigations:

1. **Rocky Flats Plant** – ORAUT-TKBS-0011-6, Revision 03, *Technical Basis Document for the Rocky Flats Plant* (NIOSH 2010a), Table 6-21, lists n/p values for the period 1970–1976 that range from 0.67 to 1.61, with an average n/p value of 1.05. Additionally, Table 6-22 lists n/p values for the period 1977–2000 that range from 0.26 to 0.61, with an overall n/p value of 0.42.
2. **LANL** – ORAUT-TKBS-0010-6, Revision 03, *Technical Basis Document for the Los Alamos National Laboratory – Occupational External Dose* (NIOSH 2013), lists the following n/p information:
    - Table 6-16 lists n/p values from a 1972 study that range from 1.33 to 3.98 for the depleted plutonium site.
    - Table 6-18 lists n/p values from a 1968 study that range from 0.67 to 2.8 as a function of distance from a critical assembly.
    - Table 6-22 lists overall recommended LANL n/p values for various facilities/operations at LANL that range from 0.7 to 3.9.
    - Table B-1 lists an overall n/p value of 1.04 for 1950–2008 from LANL recorded dose data.
    - Table B-2 lists overall n/p values ranging from 0.53 to 2.66 for the time period 1957–1968 from LANL recorded doses.

With the additional reference information provided in the revised NUMEC TBD, SC&A was able to derive n/p values as recommended by NIOSH for NUMEC and obtain more details concerning their sources and applicability. While the NUMEC n/p data set is not as robust as desired because it is limited to providing only a snapshot of the situation in time and location, the

derived NUMEC n/p values are not out of line with other DOE facilities that handled uranium and plutonium.

SC&A Recommendation: SC&A recommends closing this issue.

2.15 FINDING 15: NON-PENETRATING DOSE ASSIGNMENTS USING FILM BADGE DOSIMETERS

Finding 15: *The markedly different photon energies associated with the operations at NUMEC would indicate the possible need for adjustment factors for the results of film badge dosimeters, which are not provided in the site profile.*

Proposed NIOSH resolution: Film badge dosimeters, while over responding to radiation recorded in the open window, may under respond to low energy photons (16 keV and 59 keV photons are a particular concern) (Wilson et al. 1990). Although the films and filters at NUMEC were different than the dosimeters discussed in the reference, a reasonable comparison between the film dosimeters is expected (AEC 1955). The site acknowledged this deficiency in a 1966 report (Caldwell and Judd 1966) and made corrections to the dosimetry to account for this under response. Prior to the report being issued (i.e. prior to 1966), to account for under response of film dosimetry to low energy photons, the result in the open window should be assigned as <30 keV photons for workers at plutonium facilities while the deep dose response is assigned in accordance with the worker location.

August 2015 WG discussion: Auger electrons are very low energy and would not penetrate skin; therefore, part of NIOSH response does not address this issue. Also, do we assign these low energy betas for all alpha emitters at other sites? NIOSH wants to check this answer and get back, but WG decided that this is an SC&A action item for now – SC&A is to provide additional information on this finding.

SC&A response after WG: NIOSH concurred that the site profile needs to be revised to account for possible over- and/or under-responses of dosimeters under some circumstances. The decision to modify the site profile approach for situations where low-energy photons and betas are present seems appropriate by assuming <30 keV photons for plutonium workers for open window results. However, NIOSH should endeavor to gather more information on the differing film badges and the protective coverings to enable a better assessment of situations where low-energy photons or betas were under-reported or missed entirely.

NIOSH update June 2016: The initially proposed guidance was added to the draft ORAUT-TKBS-0041 Rev. 03-B. Additional data capture is considered to be unproductive, but additional review in available NUMEC files continues.

SC&A Evaluation: SC&A reviewed Section 6.5.2.1 and Table 6-5 of Revision 03 to the TBD, and NIOSH does, in fact, recommend assigning non-penetrating dose as <30 keV photons for plutonium workers and as >15 keV electrons for other workers as per ORAUT-OTIB-0017, Revision 01, *Interpretation of Dosimetry Data for Assignment of Shallow Dose* (NIOSH 2005). SC&A's additional observation that it is unclear what the authors intended by describing all beta energies for Am-241 as being >15 keV, as Am-241 and U-233 are alpha emitters, is also resolved.

SC&A Recommendation: SC&A recommends closing this issue

2.16 FINDING 16: NUMEC COWORKER MODEL

> ***Finding 16:*** *NIOSH should consider developing a universal coworker model based on NUMEC claimant records, or specify a more consistent basis for assigning external doses beyond the medical x-rays associated with the site.*
>
> > *Proposed NIOSH resolution: A coworker model for non-presumptive claims is not expected to be feasible.*
> >
> > *August 2015 WG discussion: NIOSH is tasked to do a formal review to see if a coworker model is feasible.*
> >
> > *NIOSH update June 2016: It is not expected that the available data can be used to develop a coworker model that would adhere to the guidelines expected from such a model. Please see detailed analysis below.*

Following discussion of the 21 findings in NIOSH 2016a, NIOSH provides its rationale for determining that it is not feasible to develop a coworker model for workers with non-presumptive cancers at NUMEC. Internal exposure to uranium at Apollo and external exposures at Parks Township are of particular interest. The white paper investigated this matter by researching the extent to which uranium bioassay data were available for workers at Apollo and external dosimetry data that were available for workers at Parks Township. NIOSH found that some non-covered workers had such data available, and those data were used to reconstruct partial dose reconstructions for those workers, where feasible. However, NIOSH determined that the amount, completeness, and quality of the data did not meet NIOSH's criteria for developing coworker models as set forth in NIOSH 2015c.

NIOSH 2016a provides an extensive discussion of the types of data that are available as well as those that are not available. For example, the white paper explains that the uranium bioassay data that are available do not provide information regarding the location of the worker (e.g., Apollo versus Parks Township). With respect to Parks Township, NIOSH 2016a compiles and presents the external dosimetry data that are available (i.e., 28,000 lines of data). The white paper explains that data are missing for some years, some of the data were for workers involved in commercial operations, some data lacked job and location indicators, and some workers clearly worked in areas where the potential for exposures existed but were not monitored. On the bases of these findings, NIOSH 2016a concluded that the data have many deficiencies and could not be used to construct an external dosimetry coworker model.

This subject was discussed at the WG meeting on July 19, 2016 (beginning on page 25 of the transcript). The key point that emerged in this discussion begins on page 118 of the transcript. The point is made that although there are considerable external dosimetry data, there are data gaps that indicate that some of the high exposures might be missing. The basis for this judgment is that many workers were monitored for internal exposures but did not have external dosimetry. It is then reasonable to conclude that, without assurance that high-end exposures were captured, it might not be possible to develop an external coworker model. In addition, the point was made that in many cases it cannot be determined if the data apply to workers at Apollo or Parks Township.

An important policy discussion followed that SC&A believes should be documented here. As described in the WG transcript beginning on page 130, although there might be a fairly large external dosimetry data set for a given year, if there is some question that the data set does not capture the upper bound or that the locations of the exposures are not known, the data set does not meet the criteria for building a coworker model. As articulated by Mr. Katz (the Designated Federal Officer), it has long been NIOSH's policy that minimal exposures are not to be assigned when developing coworker models. It is essential that the coworker model be used to assign realistic or at least plausible bounding exposures. It is clear that the external dosimetry data at Parks Township do not meet this test, and, on this basis, it would not be appropriate to try to construct an external coworker model.

SC&A Evaluation: SC&A accepts the above NIOSH response that it is not feasible to construct a coworker model for non-presumptive cancers.

SC&A Recommendation: SC&A recommends closing this issue.

2.17 FINDING 17: NON-PENETRATING DOSES FROM BETA EMITTERS ASSOCIATED WITH RESIDUAL PERIOD SURFACE CONTAMINATION

Finding 17: *The site profile should include guidance for deriving non-penetrating doses to skin and other organs from beta emitters associated with surface contamination during the residual period.*

Proposed NIOSH resolution: Additional information was included in the draft of the revised TBD.

August 2015 WG discussion: ***Closed****.*

SC&A Evaluation: Section 7.1 of Revision 03 to the TBD addresses the reconstruction of doses during the residual period. Table 7-1 and its supporting text provides detailed guidance regarding the reconstructing of external dose from surface contamination, including skin doses from beta contamination.

SC&A Recommendation: SC&A recommends closing this issue.

2.18 FINDING 18: GENERAL AIR SAMPLES TO RECONSTRUCT RADIONUCLIDE INTAKE RATES DURING THE RESIDUAL PERIOD

***Finding 18**: General air (GA) samples, as opposed to breathing zone (BZ) samples, should be used as the starting point for reconstruction of radionuclide intake rates during the residual period.*

Proposed NIOSH resolution: The air concentration value that is favorable to claimants to use for the residual period is represented by the maximum median value of 222 dpm/m^3. The maximum estimated GSD for all data sets is 6.95 for the HASL GA data. Therefore, the residual activity will be based on a lognormal distribution with a median of 222 dpm/m^3 and a GSD of 5.0. This represents a slight increase in median air concentration from the previous concentration of 210 dpm/m^3 and GSD of 7.91.

August 2015 WG discussion: Some BZ samples are higher than some of the GA samples. Why is that? Possibly there are some process samples that were added to the GA sample set. The data need to be reviewed to make sure there are no inconsistencies.

NIOSH update June 2016: The data were reviewed and corrected if necessary and the revised approach was included in draft ORAUT-TKBS-0041 Rev. 03-B. The results from these measurements and the HASL reports indicate an air concentration value that is favorable to claimants to use for the residual period is represented by the maximum median value of 329 dpm/m^3.

SC&A Evaluation: Inspection of Section 7.4.1 of Revision 03 to the TBD reveals that NIOSH plans to use the maximum median air concentration of uranium of 328 dpm/m^3 as the median concentration, with a GSD of 6.95, as the starting point for deriving the uranium intake rate for workers during the residual period. This is a reasonable bounding airborne uranium dust loading as the starting point for reconstructing internal doses during the residual period because it is based on measurements made at several locations at the facility during operations. Hence, it represents an upper bound as applied to the residual period. This value is used to derive the concentration of uranium deposited on surfaces, which is used to estimate airborne dust loading using a resuspension factor of 10^{-5}/m, along with other assumptions described in ORAUT-OTIB-0070, Revision 01, *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities* (NIOSH 2012b). The entire protocol is in accord with all previously approved procedures for reconstructing doses during the residual period at facilities that handled uranium.

SC&A Recommendation: SC&A recommends closing this issue.

2.19 FINDING 19: RESUSPENSION FACTOR DURING THE RESIDUAL PERIOD

***Finding 19:** SC&A recommends that NIOSH use a resuspension factor of about 1E-5 per meter to derive the airborne dust loading for the beginning of the*

residual period, or perhaps simply assume that the average general air dust loading observed during the residual period is applicable to the beginning of the residual period.

Proposed NISOH resolution: Resuspension factor for Apollo was changed, but not for Parks, because of cleanup activities.

*August 2015 WG discussion: **Closed**, if the guidance is included in the TBD revision.*

NIOSH update June 2016: The change was included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: See Finding 18 and SC&A's associated response and recommendations.

SC&A Recommendation: SC&A recommends closing this issue.

2.20 FINDING 20: RADIONUCLIDES OTHER THAN URANIUM DURING THE RESIDUAL PERIOD AT APOLLO

***Finding 20:** The site profile makes no reference to radionuclides other than uranium during the residual period at Apollo*

Proposed NISOH resolution: Suggestion for adding thorium and progeny to approach.

*August 2015 WG discussion: **Closed**, if the thorium guidance is added to the TBD revision.*

NIOSH update June 2016: The change was included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: Section 5.2.3, "Thorium Exposures," of Revision 03 to the TBD explains that thorium was processed at NUMEC at both Apollo and Parks Township sites beginning in the early 1960s, and that some thorium bioassay data are available. However, the TBD explains that not all workers who should have been monitored for thorium were in fact on a routine thorium monitoring program, nor are there adequate data characterizing the airborne concentrations for thorium. Therefore, the TBD concludes that it is not possible to construct a coworker model for thorium exposures. However, the TBD explains that, for workers who have thorium bioassay data, the internal doses to those workers from the intake of thorium will be reconstructed.

SC&A Recommendation: SC&A recommends closing this issue.

2.21 FINDING 21: GUIDANCE ON TREATING AGED PLUTONIUM MIXTURES DURING THE RESIDUAL PERIOD AT PARKS TOWNSHIP

***Finding 21:** There is conflicting guidance on how aged plutonium mixtures should be treated during the residual period at Parks Township.*

Proposed NIOSH resolution: add guidance to TBD

*August 2015 WG discussion: **Closed**, if guidance was added to the TBD revision.*

NIOSH update June 2016: The change was included in draft ORAUT-TKBS-0041 Rev. 03-B.

SC&A Evaluation: The Publication Record of Revision 03 to the TBD states that revised Section 5.1 and Table 5-3 address this issue. Inspection of the TBD reveals that Table 5-3 provides detailed guidance on the mix of plutonium isotopes that should be assumed for different grades and ages of plutonium.

SC&A Recommendation: SC&A recommends closing this issue.

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