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ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

SC&A'S EVALUATION OF REVISIONS TO PANTEX TECHNICAL BASIS DOCUMENTS RELEVANT TO SITE PROFILE AND SEC ISSUES

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ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
AP	anterior-posterior
cm	centimeter
DOE	(U.S.) Department of Energy
DR	dose reconstructor
eV	electron volt
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
keV	kiloelectron volt
L	liter
LANL	Los Alamos National Laboratory
µCi	microcurie
MCNP	Monte Carlo n-particle
MDA	minimum detectable activity
MeV	megaelectron volt
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
n/p	neutron-to-photon
NTA	Neutron Track Emulsion, Type A (film)
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
PA	posterior-anterior
$^{238}PuO_2$	plutonium-238 oxide
$^{238}PuF_4$	plutonium-238 tetrafluoride

TBD	technical basis document
SEC	Special Exposure Cohort
WG	Work Group

1.0 INTRODUCTION AND BACKGROUND

Four of the Pantex Plant site profile [and corresponding Special Exposure Cohort (SEC)] issues identified by SC&A (SC&A 2008, 2009) and discussed during the Pantex Plant Work Group (WG) meetings were to be resolved by the National Institute for Occupational Safety and Health (NIOSH) making revisions in the Pantex technical basis documents (TBDs). The applicable documents were as follows:

- ORAUT-TKBS-0013-3, *Pantex Plant—Occupational Medical Dose*, Revision 02, February 1, 2007, superseded by Revision 03, March 20, 2014.

- ORAUT-TKBS-0013-4, *Pantex Plant—Occupational Environmental Dose,* Revision 01, June 22, 2007, superseded by Revision 02, January 3, 2014.

- ORAUT-TKBS-0013-5, *Pantex Plant—Occupational Internal Dose*, Revision 01, June 22, 2007, superseded by Revision 04, June 1, 2015.

- ORAUT-TKBS-0013-6, *Pantex Plant —Occupational External Dose*, Revision 01, June 22, 2007, superseded by Revision 02, November 24, 2015.

Additionally, NIOSH released ORAUT-OTIB-0086, *Pantex External Coworker Model*, in 2015 (ORAUT 2015; referred to as “OTIB-0086” in this report). This document addresses the Pantex external coworker model and also replaces the neutron-to-photon (n/p) method for assigning neutron dose with the recorded neutron dose, modified by an overall adjustment factor of 2.9 for Neutron Track Emulsion, Type A (NTA) film. SC&A evaluated OTIB-0086 and provided a report to the Pantex WG in October 2015 (SC&A 2015). That review is applicable to the evaluation of ORAUT-TKBS-0013-6, Revision 02, because ORAUT-TKBS-0013-6 uses the methodology developed in OTIB-86 for assigning neutron doses from recorded NTA film.

SC&A evaluated the relevant revisions to the latest editions of the Pantex TBDs, compared to the editions that were available when the issues were identified, to determine if the changes instituted by NIOSH provided for adequate issue resolution. SC&A did not evaluate the technical aspects of the entire revised TBDs, as that is outside the scope of this task; only the sections relevant to resolving the TBD and SEC issues were evaluated. There were no issues to be addressed by revisions in the occupational medical dose TBD, ORAUT-TKBS-0013-3, or the occupational environmental dose TBD, ORAUT-TKBS-0013-4.

The four site profile issues (and their corresponding SEC issues) that were to be resolved by NIOSH making changes in the Pantex TBDs were as follows:

- **Site Profile Issue #1 (SEC Issue #6): Interpretation of external dosimetry data**. NIOSH was to provide clarification of “zero” entries in the electronic database beyond 1976.

- **Site Profile Issue #2 (SEC Issue #7): Data do not support assumption that 95th percentile neutron-to-photon ratio is bounding for all exposure scenarios.** NIOSH issued a different neutron dose reconstructor (DR) approach in the revised ORAUT-

TKBS-0013-6 (Revision 02, November 2015) and OTIB-0086 (August 2015), "Evaluation of the Pantex External Coworker Model." SC&A reviewed OTIB-0086 in October 2015 (SC&A 2015).

- **Site Profile Issue #3 (SEC Issue #8): Completeness and interpretation of historic radiological exposure sources.** NIOSH agreed to add information in the revised TBDs to inform DRs of this history.

- **Site Profile Issue #4 (SEC Issue #15): Exposure from tritium.** NIOSH agreed to revise Tables 5-1, 5-2, and 5-3 and the corresponding guidance from ORAUT-TKBS-0013-5, Revision 01, to reflect the actual Pantex minimum detectable activity (MDA) values. These proposed changes will be provided in a note or memo to the WG, followed by a subsequent revision of ORAUT-TKBS-0013-5.

In the following sections SC&A presents its evaluations of whether or not the current revisions to the TBDs adequately resolve the outstanding issues.

1.1 SITE PROFILE ISSUE #1 (SEC ISSUE #6): INTERPRETATION OF EXTERNAL DOSIMETRY DATA

ORAUT-TKBS-0013-6, Revision 02, *Occupational External Dose*, was released on November 24, 2015. SC&A evaluated NIOSH's recommendations about dose record entries containing zeros, blanks, or marks in this revision and also in OTIB-0086 (ORAUT 2015).

1.1.1 NIOSH's Recommendations on Dose Record Entries

Revised ORAUT-TKBS-0013-6

SC&A could not find that the issue of dose record entries containing zeros, blanks, or marks was addressed in Revision 02 of ORAUT-TKBS-0013-6.

OTIB-0086 recommendations

OTIB-0086 makes the following recommendations:

- **Recorded "0" –** This entry is assumed to mean that the dosimeter was issued and processed, and that no exposure or dose was detected in excess of the dosimeter limit of detection.

- **Blanks –** Indicates that no dosimeter was issued during this exchange cycle, or that the dosimeter was lost or damaged, or a processing error occurred.

- **Marks –** Dash, slash, or hash marks indicate that no dosimeter was issued during this exchange cycle, or that the dosimeter was lost or damaged, or a processing error occurred.

According to page 5 of OTIB-0086 (ORAUT 2015), the DR will assign dose before[1] 1988 as follows:

> *In such cases for years before 1988, NIOSH intends to apply (after consideration of the worker's job title and the totality of the monitoring record), either:*
>
> *(1) Unmonitored dose based on external coworker data*
>
> *(2) Missed dose*
>
> (3) *Ambient dose.*

The DR will assign dose after 1988 as follows:

> *After 1988, all personnel who entered the operational areas of the plant were required to wear a dosimeter as a condition for entry. The absence of a listed result, or the presence of a dash, slash, or hash mark for a given dosimeter exchange cycle in 1988 and later years, should be interpreted to mean that the worker was not monitored because he or she was not present in the operational areas. Therefore, ambient dose should be assigned for those exchange cycles.*

1.1.2 SC&A's Evaluation

Revised ORAUT-TKBS-0013-6

SC&A could not find that the issue of dose record entries containing zeros, blanks, or marks for the period 1976–1988 was addressed in Revision 02 of ORAUT-TKBS-0013-6. Therefore, it appears that this issue remains unresolved.

OTIB-0086 recommendations

It is not clear if the DR is to take into consideration the job title and totality of the monitoring records only for blanks, dashes, and hash mark entries, or if this consideration applies to entries with zeros also. If the consideration does apply to entries with zeros, then SC&A concurs with NIOSH's recommendation. However, if it does not, then SC&A recommends that the consideration should be applied to entries with zeros after 1976, because the original issue was that the electronic database may have inserted zeros if a worker was not monitored, requiring the DR to evaluate if the worker should receive missed dose, coworker dose (which may be greater), or environmental dose.

[1] According to ORAUT-TKBS-0013-6, Revision 02, Section 6.4, page 13, starting in 1989, all personnel entering the operational areas were required to wear a dosimeter; therefore, the terms "before 1988" should be changed to "before 1989" and "in 1988" should be changed to "in 1989" in this section of OTIB-0086 (ORAUT 2015).

1.2 SITE PROFILE ISSUE #2 (SEC ISSUE #7): DATA DO NOT SUPPORT ASSUMPTION THAT 95TH PERCENTILE NEUTRON-TO-PHOTON RATIO IS BOUNDING FOR ALL EXPOSURE SCENARIOS

ORAUT-TKBS-0013-6, Revision 02, was released on November 24, 2015. SC&A evaluated NIOSH's recommendations concerning neutron dose in the revised ORAUT-TKBS-0013-6 and in OTIB-0086, Attachment B (ORAUT 2015). The proposed neutron dose assignment method does not use the n/p values; instead, it uses the recorded neutron dose and applies adjustment factors to the NTA film results for both individual dose reconstruction (i.e., ORAUT-TKBS-0013-6, Revision 02, pages 34, 43, and 46), and to create the neutron coworker model dose results for 1960–1977 in Table 7-2, page 10, of OTIB-0086.

1.2.1 NIOSH Recommendations Concerning Neutron NTA Film

NIOSH recommends using the original recorded neutron dose from NTA film, multiplied by a correction factor of 2.9, which was derived from an energy response factor of 1.4, an angular response factor of 1.33, and a track fading factor of 1.56 (i.e., $1.4 \times 1.33 \times 1.56 = 2.9$). ORAUT-TKBS-0013-6, Revision 02, page 34, refers to OTIB-0086 (ORAUT 2015) for the details of these correction factors. According to OTIB-0086, these factors were derived as follows:

1. **Energy response –** NIOSH used its Monte Carlo n-particle (MCNP) model generated for Mound Laboratory of an observer located at 240 centimeters (cm) from a glovebox (shielded with 4 inches of moderator) located in a concrete room. In this model, the NTA film would miss 29% of the dose equivalent because of the NTA film's 500 kiloelectron volt (keV) neutron energy threshold. The correction factor would be $1/(1 – 0.29) = 1.4$.

2. **Angular response –** NIOSH used the angular correction factor of 1.33 for NTA film from Kathren et al. (1965) for anterior-posterior (AP) geometry neutron exposures.

3. **Track fading –** NIOSH used the NTA film track fading correction factor of 9% per week (Kahle et al. 1969) for a total of $4 \times 0.09 = 0.36$ per month, to result in a derived track fading factor of $1/(1 – 0.36) = 1.56$.

ORAUT-TKBS-0013-6, Revision 02, Table 6-2, pages 34, 43, and 46 indicate that NTA film was used through 1976. However, this is less clear in OTIB-0086 because it is uncertain if the 2.9 factor applies to all recorded neutron doses through 1977. Page 7 of OTIB-0086 recommends that it be applied for 1960 through 1977, but Table A-1, page 17, of OTIB-0086 lists NTA film used through 1975. This point needs to be clarified and consistent dates used.

1.2.2 SC&A's Evaluation of NTA Film Correction Factors

The following summarizes SC&A's evaluation of the NTA film correction factors as recommended by NIOSH in ORAUT-TKBS-0013-6, Revision 02, and OTIB-0086. The details were provided in SC&A's evaluation of OTIB-0086 (SC&A 2015).

1. **Energy response –** OTIB-0086 uses the term "THERMAL NEUTRONS" on page 21; however, SC&A assumes that this is a general term that refers to neutrons with energy below 500 keV, since thermal neutrons are defined as 0.025 electron volts (eV) in energy.

In evaluating the recommended energy correction factor of 1.4, SC&A does not find that the MCNP model generated for Mound Laboratory of an observer located at 240 cm from a glovebox with 4 inches of moderator necessarily represents the situation and neutron energy fields for a worker at Pantex with potential exposure to multiple neutron sources (such as in a bay, cell, etc.). This is especially true for situations where a Pantex worker was exposed to posterior-anterior (PA) geometry neutron sources, because the Mound model was for AP geometry neutron sources. Additionally, SC&A could not find that NIOSH had performed an MCNP model particular for Pantex, as implied in the following statement on page 21 of OTIB-0086 (ORAUT 2015):

> *A Monte Carlo n-particle (MCNP) model was developed to determine the amount of dose that was missed due to a sensitivity threshold of 500 keV for the conditions likely to have been encountered by workers who received neutron doses at Pantex (LANL 2003).* [Emphasis added.]

SC&A found that NIOSH apparently applied the MCNP model for Mound to Pantex. SC&A also found that the reference to LANL 2003 in the above quoted statement was to the LANL MCNP program in general, which was not specific to either Mound Laboratory or Pantex.

2. **Angular response** – The angular correction factor of 1.33 for NTA film from Kathren et al. (1965) was derived for only AP geometry exposures. However, personnel at Pantex were potentially exposed to multiple sources of neutrons, which could include PA geometry. Neither NTA film calibration nor the AP angular correction factor address PA geometry for neutron exposure.

3. **Track fading** – OTIB-0086 used the moderated plutonium-238 oxide ($^{238}PuO_2$) [average energy of 0.9 megaelectron volts (MeV)] exposed NTA film track fading correction factor of 9% per week (Kahle et al. 1969) for a total of 4 × 0.09 = 0.36 per month, resulting in a derived track fading factor of 1/(1 – 0.36) = 1.56. However, the same referenced article (Kahle et al. 1969) also provides data that show that a plutonium-238 tetraflouride ($^{238}PuF_4$) neutron source (average energy of 1.3 MeV), under identical exposure conditions, produced a fading factor of 33% after one week and 56% after two weeks. ORAUT-TKBS-0013-6, Revision 02, does not provide information about the timing of the neutron calibration cycle (i.e., if it was performed at the beginning, middle, or the end of the badging cycle; although Table 6-8 states "*Midcycle calibration minimizes overall uncertainty*," it does not state this was performed for Pantex NTA film). However, Table 6-13, page 37, of ORAUT-TKBS-0013-6, Revision 02, does recommend using a neutron energy range of 0.1–2 MeV; hence, both the 0.9 MeV $^{238}PuO_2$ and the 1.3 MeV $^{238}PuF_4$ neutron source fall in that energy range. There does not appear to be any supporting evidence to select the lower fading factor of 9%. NIOSH's Mound white paper (NIOSH 2010) states the following (page 4):

> *NIOSH continues to support the fading values of 33% in the first week after exposure and 56% after two weeks. This fading correction is to be applied independent of other corrections such as angular response or energy response.*

Therefore, it is not obvious why the value of 9% fading per week was selected to be applied at Pantex.

The issues identified by SC&A in evaluating OTIB-0086 (ORAUT 2015) are applicable to this issue because Revision 02 of ORAUT-TKBS-0013-6 (November 2015) uses the methodology detailed in OTIB-0086 (August 2015) to assign neutron dose from recorded NTA film. Additionally, the coworker neutron dose for 1975 is approximately ten times larger than those of other years (ORAUT-TKBS-0013-6, Revision 02, page 71, Table A-2, and OTIB-0086, Table 7-2, page 10).

1.3 SITE PROFILE ISSUE #3 (SEC ISSUE #8): COMPLETENESS AND INTERPRETATION OF HISTORIC RADIOLOGICAL EXPOSURE SOURCES

1.3.1 NIOSH

To resolve this issue, NIOSH agreed to add information in the revised TBDs to inform DRs of the history of potential sources of exposure for Pantex workers.

1.3.2 SC&A's Evaluation

SC&A found that Section 5.1.4, page 10, and Section 5.1.6, page 14, of ORAUT-TKBS-0013-5, Revision 04 (June 2015), and Section 6.1.4, page 10, of ORAUT-TKBS-0013-6, Revision 02 (November 2015), added additional information about Pantex's history and workers at other Atomic Energy Commission (AEC)/U.S. Department of Energy (DOE) facilities, which may require the DR to require additional records. SC&A finds that this issue has been sufficiently addressed.

1.4 SITE PROFILE ISSUE #4 (SEC ISSUE #15): EXPOSURE FROM TRITIUM.

1.4.1 NIOSH

NIOSH agreed to revise Tables 5-1, 5-2, and 5-3 and corresponding guidance in ORAUT-TKBS-0013-5, Revision 04, to reflect the use of actual Pantex MDA values, instead of program limits. These proposed changes will be provided in a note or memo to the WG, followed by a subsequent revision of ORAUT-TKBS-0013-5, Revision 04.

1.4.2 SC&A's Evaluation

SC&A compared ORAUT-TKBS-0013-5, Revision 04 (June 2015), paragraph by paragraph to ORAUT-TKBS-0013-5, Revision 01 (June 2007), and found the following:

- It appears that Table 5-1 of Revision 04 is the same as Table 5-1 of Revision 01.
- It appears that Table 5-2 of Revision 04 is the same as Table 5-2 of Revision 01, except that, when the job title of Machinist is listed, the "*Possibility for intake*" was changed from "*See Section 5.2.2.4*" to "*1*[a]."

- Table 5-3 of Revision 04 (maximum and mode of tritium intakes/doses for 1956–1990 and 1991–present) is completely different that Table 5-3 of Revision 01 (which contains tritium dose data for 1972–2004). Figure 1 provides a reproduction of Table 5-3 of ORAUT-TKBS-0013-5, Revision 04:

Figure 1: Table 5-3 of ORAUT-TKBS-0013-5 (2015)

Table 5-3. Internal dose for missed and unmonitored tritium intakes.

Year	Maximum undetected individual annual tritium dose (mrem)[a]	Maximum annual undetected intake (µCi)	Mode of the annual undetected individual annual tritium dose (mrem)	Mode of the annual undetected intake (µCi)
1956–1990	42	619	21	309
1991–present	12	167	6	83.5

a. Calculated based on 1 month of chronic exposure assuming detection limits of 0.500 µCi/L through 1990 and 0.135 µCi/L for 1991 through the present, and normalized for annual intake using the ICRP Publication 68 dose coefficient of 0.067 mrem/µCi (ICRP 1995). Note that these values exceed any recorded doses or intakes the site reported for any year of operation, including 1989 when a major tritium released occurred.

SC&A evaluated Table 5-3 of ORAUT-TKBS-0013-5, Revision 04 (2015) and verified the values listed. These values were derived as follows:

- NIOSH's search of the individual claimant files indicated that the largest MDA value recorded for the period 1956–1990 was 0.500 microcuries per liter (µCi/L), and for the period 1991–present, the largest MDA value recorded was 0.135 µCi/L.

- The full MDA values (because this was a maximum calculation for triangular distribution) were used in the Integrated Modules for Bioassay Analysis (IMBA) program to derive the maximum annual undetected intake, in µCi, (as listed in Column 3 of Table 5-3). The following parameters were used in the IMBA program:

    - 30 days chronic intake (because of monthly tritium bioassays)

    - Type F, inorganic tritium

    - 42 L body fluid

- In Column 5, the mode intake values, in µCi, are one-half the maximum intake values.

- In Column 2, the maximum values of the undetected individual annual tritium dose, in millirem (mrem), were derived by multiplying the maximum intake values, in µCi, by 0.067 mrem/µCi (ICRP 1995).

- In Column 4, the mode values of the undetected individual annual tritium dose, in mrem, are one-half the maximum dose values.

SC&A did not search all the claimant files to verify the maximum MDA values that NIOSH recommended, because this would have been a very large and resource-intensive task; SC&A did verify the resulting intakes and dose recommendations as appropriate, including Table 5-3 and Attachment C of ORAUT-TKBS-0013-5, Revision 04 (2015). However, it appears that while the last sentence in footnote a to Table 5-3 of Revision 04 is correct for the period 1991–present, it is incorrect for the period 1956–1990. The sentence states,

> *Note that these values exceed any recorded doses or intakes the site reported for any year of operation, including 1989 when a major tritium released occurred.*

During the period 1956–1990, the maximum dose in Table 5-3 (ORAUT-TKBS-0013-5, Revision 04) is 42 mrem. However, according to Table 5-3 (ORAUT-TKBS-0013-5, Revision 01), during the period 1972–1990, there was a maximum recorded individual tritium dose of 114 mrem in 1980, 122 mrem in 1981, and 1,180 mrem in 1989. Therefore, it would not appear that using the values in Table 5-3 of ORAUT-TKBS-0013-5, Revision 04, would necessarily bound all recorded tritium doses at Pantex.

Additionally, it is not obvious why the periods of 1956–1990 and 1991–present were selected when the SEC period is through 1991; i.e., why were the periods not 1956–1991 and 1992–present?

2.0 SUMMARY AND CONCLUSIONS

SC&A's review of the revised Pantex TBDs indicates the following:

- **Site Profile Issue #1 (SEC Issue #6): Interpretation of external dosimetry data**. SC&A could not find that NIOSH addressed the issue of recorded zeros (or other markings) in the records before 1989 in the revised ORAUT-TKBS-0013-6 (Revision 02). From reviewing OTIB-0086 (ORAUT 2015), SC&A recommends that the DR consider the worker's job titles and dosimetry records in totality when evaluating recorded zeros (as well as blanks, dashes, and hash marks) for deciding whether to assign coworker, missed, or environmental external dose, because the electronic database may have inserted zeros for unmonitored workers after 1976.

- **Site Profile Issue #2 (SEC Issue #7): Data do not support assumption that 95th percentile neutron-to-photon ratio is bounding for all exposure scenarios.** From reviewing the revised ORAUT-TKBS-0013-6 (Revision 02) and the related document, OTIB-0086 (ORAUT 2015), SC&A found that instead of using the n/p method, NIOSH recommends using the recorded neutron dose, with the NTA film results adjusted for energy response, angular response, and track fading. As previously summarized, and detailed in SC&A's review of OTIB-0086 (SC&A 2015), SC&A does not find the neutron adjustment factors to be claimant favorable for Pantex workers.

- **Site Profile Issue #3 (SEC Issue #8): Completeness and interpretation of historic radiological exposure sources.** SC&A found that sections had been added to ORAUT-TKBS-0013-5, Revision 04 (2015), and ORAUT-TKBS-0013-6, Revision 02 (2015), with information concerning Pantex's history and workers at other AEC/DOE facilities that resolves this issue.

- **Site Profile Issue #4 (SEC Issue #15): Exposure from tritium.** SC&A found that Revision 04 to ORAUT-TKBS-0013-5 (mainly Table 5-3) provides for tritium dose assignments based on recorded MDA values and also simplifies tritium dose assignment for the DR and allows for consistence in dose assignments. SC&A found this issue to be addressed, except for the statement in the footnote to Table 5-3 of ORAUT-TKBS-0013-5, Revision 04 (2015), concerning the maximum intake and dose, and the reason for using the period 1956–1990 instead of 1956–1991.

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