MEMORANDUM

TO: Pantex Work Group
FROM: SC&A, Inc.
DATE: October 19, 2016
SUBJECT: Pantex TBD and OTIB-0086 Neutron NTA Film Correction Factor Issues

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Introduction and Background

As outlined in Pantex technical basis document (TBD) ORAUT-TKBS-0013-6, *Pantex Plant – Occupational External Dose*, Revision 02 (NIOSH 2015a, hereafter "TBD-6") for monitored external dose and in ORAUT-OTIB-0086, *Pantex External Coworker Model*, Revision 00 (NIOSH 2015b, hereafter "OTIB-0086") for coworker dose assignments, the National Institute for Occupational Safety and Health (NIOSH) recommends using the recorded results from neutron track Type A (NTA) film for assigning monitored and coworker neutron doses, with adjustment factors applied for lack of low-energy response (1.4), angular response (1.33), and track fading (1.56) for a total combined adjustment factor of 2.9. SC&A reviewed OTIB-0086 and issued a report in 2015 (SC&A 2015) that asked NIOSH to provide additional support for the selection of these individual NTA film adjustment factors. This request also applies to TBD-6 because it uses the same correction factors recommended in OTIB-0086.

Pantex Work Group Meeting – August 4, 2016

During the Pantex Work Group (WG) meeting of August 4, 2016, the individual adjustment factors for NTA film were discussed. NIOSH provided some additional references during the meeting, and the WG discussed the importance of NTA correction factors for the relatively small neutron doses at the Pantex facility during the Special Exposure Cohort period. The WG tasked SC&A to evaluate the additional support documents and the impact finer adjustments to the correction factors might have.

SC&A's Evaluation

SC&A reviewed the additional reference documents and some of the previous relevant documents. As discussed during the WG meeting, the exact adjustment factors cannot be determined; therefore, SC&A attempted to evaluate the recommended values in light of the possible ranges of values that might be plausible, and their impact on the final adjustment factor and neutron doses. The following is a summary of this evaluation.

1. **Neutron energy threshold adjustment factor –** NIOSH recommends a neutron energy threshold adjustment factor of 1.4 based on Monte Carlo N-Particle (MCNP) calculations using 4 inches of research department formula X (RDX) as a moderator in a room similar to that used for the Mound facility for determining the fraction of the dose that consisted of neutrons below

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the 0.5 mega-electron volt (MeV) threshold. SC&A evaluated this issue relative to methods used at other U.S. Department of Energy (DOE) facilities that had addressed similar issues. The values for Mound in NIOSH's 2010 draft paper (NIOSH 2010) list neutron energy threshold adjustment factors of 2.1, 1.7, and 0.8 for a plutonium-238 tetraflouride (^{238}Pu-F_4) neutron source with 4 inches of water moderations. This gives a range of adjustment factors of 0.8 to 2.1, with an average value of 1.53, compared to the recommended value of 1.4. In a Hanford paper (BNWL 1972, page 13), the average correction factor for NTA film compared to thermoluminescent dosimeter measured dose was 1.7. Therefore, the Pantex correction factor of 1.53 is in the same range as those used at other DOE facilities.

2. **Angular adjustment factor –** NIOSH recommends an NTA film angular adjustment factor of 1.33 based on the results from Kathren et al. (1965). In the Kathren et al. article, the response of NTA film as a function of incident angle was evaluated for the anterior-posterior (AP) geometry only (e.g., 0^o–90^o; Kathren et al. 1965, page 2). SC&A evaluated the geometry situation applicable to Pantex with potentially both AP and posterior-anterior (PA) exposures as follows:

   - Assume the operator's whole-body exposure was approximately 2 feet from the source in front (AP exposure) and 8 feet from an equal source in back (PA exposure).
   - By inverse square calculations, the operator would receive 6.25% of the neutron dose from the rear (PA) compared to the front (AP).
   - The maximum PA neutron dose not registered would be 6.25% of the AP neutron dose if the neutrons coming from the rear were not registered at all on the NTA film; therefore, the correction factor would be 1.33 × 1.06 = 1.41.
   - If the PA neutron dose was registered with the same efficiency as the AP neutron dose, then the correction factor would be 1.33 and applied to both the PA and AP registered neutrons (i.e., the total registered neutron dose).
   - The middle value of the angular correction factor would be 1.33 × 1.03 = 1.37 (i.e., half the PA neutron dose was not registered).

   Considering these possible scenarios for neutron track registration, the angular correction factor could range from 1.33 to 1.41, with a middle value of 1.37, which is not greatly different from NIOSH's recommended value of 1.33.

3. **NTA film fading adjustment factor –** NIOSH recommends an NTA film track fading adjustment factor of 1.56 based on a 9% per week fading rate for 4 weeks per cycle (i.e., 1/[1 - (4 × 0.09)] = 1.56), as reported in one of the Mound papers (Meyer 1994). However, Figure B-1, page 23, of OTIB-0086 shows the NTA film track-fading results for other measurements at Mound, which include 30% fading in 2 weeks for plutonium-238 oxide (^{238}Pu-O_2) neutrons and 56% fading in 2 weeks for ^{238}Pu-F_4 neutrons. It has not been established when the NTA film calibration was performed during the monthly exchange cycle at Pantex (i.e., beginning, middle, or end). Therefore, it will be assumed that the NTA film was calibrated in the middle of the exchange cycle. The following summarizes the potential fading correction factors:

   - Low fading factor – 9%/week for 2 weeks = 1/[1 - 0.18] = 1.22

- Middle fading factor – 30% for 2 weeks = 1/[1 - 0.30] = 1.43
- High fading factor – 56% for 2 weeks = 1/[1 - 0.56] = 2.27

The middle value of 1.43 from these possible fading factors compares favorably to NIOSH's recommended value of 1.56.

Table 1 summarized the potential individual adjustment factor values and the combined correction factor (CF).

Table 1. Potential Adjustment Factor Values

Adjustment Factor	Low	Middle	High	NIOSH
0.5 MeV Threshold	0.8	1.53	2.1	1.4
Geometry	1.33	1.37	1.41	1.33
Tack Fading	1.22	1.43	2.27	1.56
Combined CF	1.30	3.02	6.72	2.90

Summary and Conclusions

The results of this brief study indicate that the overall NTA film correction factor does not vary widely when the range of potential variables is applied. The middle value (3.02) is consistent with NIOSH's value of 2.90.

SC&A's conclusions are based on the following:

- The lower energy neutrons (<0.5 MeV) do not contribute greatly to the total neutron dose (e.g., see OCAS-IG-001, pages 63–76, neutron flux-to-dose equivalent conversation factors as a function of neutron energy internal).
- TBD-6, page 32, indicates that the energy of neutrons in the workplace at Pantex was predominately in two ranges: 0.1 to 2 MeV and/or 2 to 20 MeV.
- Neutrons did not contribute a large amount of dose at Pantex, e.g., Table 7-2, page 10, of OTIB-0086.
- The appropriate correction factors for each worker would vary with weapon type, working conditions, and time; therefore, they cannot be determined precisely.

From this evaluation, SC&A found that the NTA film correction factor of 2.9 is reasonable, and that there are no physical measurements to suggest otherwise.

References

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