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RESOLUTION OF SC&A FINDINGS DEVELOPED DURING REVIEW OF DCAS-TKBS-0006, REVISION 00

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AWE	Atomic Weapons Employer
CEDE	Committed Effective Dose Equivalent
cm	centimeter
cm^2	square centimeter
DCAS	Division of Compensation Analysis and Support
dpm/m^3	disintegrations per minute per cubic meter
GM	geometric mean
GSD	geometric standard deviation
hr/yr	hours per year
m^2/hr	square meter per hour
m^3/hr	cubic meter per hour
mg/day	milligrams per day
mR/hr	milliroentgen per hour
mR/yr	milliroentgen per year
mrad	millirad
mrem/hr	millirem per hour
mrem/yr	millirem per year
NIOSH	National Institute for Occupational Safety and Health
NRC	(U.S.) Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission Regulation
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
rad	a unit of absorbed dose of ionizing radiation
rem	Roentgen equivalent man
SC&A	S. Cohen and Associates
SRDB	Site Research Database
TBD	Technical Basis Document
U	uranium
UF_4	uranium tetrafluoride

This draft white paper presents the status of findings made by SC&A (SC&A 2011) during its review of Rev. 00 of DCAS-TKBS-0006, *Technical Basis Document for the DuPont Deepwater Works Deepwater, New Jersey* (DCAS 2011), against a new baseline established by Rev. 01 (DCAS 2013) of that document.

CHRONOLOGY

- 2/14/2011 – NIOSH issues DCAS-TKBS-0006, *Technical Basis Document for the DuPont Deepwater Works Deepwater, New Jersey* (DCAS 2011). This TBD was intended to eliminate reliance on TBD-6001 (Battelle 2006), which had been withdrawn.
- 8/12/2011 – SC&A delivers site profile review of DCAS-TKBS-0006 (SC&A 2011).
- 9/7/2012 – NIOSH is requested by AWE Work Group to provide response to SC&A's site profile review.
- 3/18/2013 – NIOSH provides response to site profile review (Neton 2013).
- 6/6/2013 – SC&A provides critique of March 2013 NIOSH response (SC&A 2013).
- 10/16/2013 – Anderson provides status report to ABRWH on DuPont Deepwater (Anderson 2013).
- 12/12/2013 – NIOSH issues Rev. 01 to DCAS-TKBS-0006 (DCAS 2013).

BACKGROUND

In its August 2011 review of DCAS-TKBS-0006 (DCAS 2011), SC&A made the following seven findings:

Finding	SC&A Review
Finding 1	The site profile should discuss the degree to which the air sampling data, which was collected in 1944 and 1945, can be used to reasonably bound doses in the earlier years of operation (e.g., 1942–1943).
Finding 2	We would request that the site profile discuss the levels of surface contamination at the facility and explain that, at these levels, the default ingestion rate of 0.5 mg/day, which is inherent to OCAS-TIB-009 [OCAS 2004], applies to this facility. NIOSH should also describe how the ingestion intake in Table 1 was calculated.
Finding 3	It appears that uranium metal was produced at the site using the UF_4 to U magnesium bomb reduction process, which, because of the Putzier effect, could have produced uranium ingots that were associated with external beta radiation fields that were 10 to 20 times greater than those adopted in the site profile.
Finding 4	There seems to be a substantial disparity between the explanation of how the annual photon doses to operators were derived and the actual values employed in the site profile.
Finding 5	There seems to be a substantial disparity between the explanation of how the annual contact doses to operators were derived and the actual values employed in the site profile. In addition, justification should be provided as to why TBD-6000 default values should not be used at DuPont since no site data are available for external exposure during the operating period.
Finding 6	Assuming 50% of the beta/gamma dose rate measured at 3 ft from a surface is 50% from gamma and 50% from beta does not appear to be appropriate. In addition, beta dose cannot contribute significantly to whole-body dose.
Finding 7	The development of the photon dose is convoluted and not scientifically sound. A simpler approach would be to assume the deep dose rate was 0.05 mrad/hr, based on measurements at 3 ft from contaminated surfaces, and pro-rate this dose rate between beta and gamma based on Table 3.10 of TBD-6000.

Source: SC&A 2011

Based on the NIOSH responses (Neton 2013) and AWE Work Group discussions, Findings 1 and 3 were closed. Based on Work Group discussions, there was general agreement on how to resolve the other five findings, but final resolution could not be achieved until a revised TBD was issued by NIOSH. Accordingly, Rev. 01 to DCAS-TKBS-0006 (DCAS 2013) was published by NIOSH on December 13, 2013. The present white paper addresses the question of whether Rev. 01 of TKBS-0006 provides a satisfactory resolution to the open findings.

RESOLUTION OF OPEN FINDINGS

Finding 2. As described in DCAS-TKBS-0006, Rev. 1:

> *A total of 252 air samples were collected. These air samples were analyzed by assuming they fit a lognormal distribution. The geometric mean of that distribution was 181 dpm/m3 with a geometric standard deviation of 5.73.*

The ingestion dose for the operating period was assumed to be constant at the 95th percentile. From these data, one can calculate that the 95th percentile airborne concentration is 3,198 dpm/m^3. NIOSH used the procedure presented in OCAS-TIB-009 (OCAS 2004) to estimate the ingestion dose from the airborne concentration, namely, "The amount of activity ingested on a daily basis can be approximated by assuming it to be 0.2 times the activity per cubic meter of air." Using this methodology, the ingestion dose would be 640 dpm/day (3,198 × 0.2), which needs to be adjusted from work days to calendar days (640 × 300/365 = 526 dpm/calendar day. This value is 20% higher than the value of 438 dpm/day[1] reported in Table 1 of DCAS-TKBS-0006. As a check on how the adjustment from work days to calendar days was made, Table 1 cites a daily <u>inhalation</u> intake of 25,245 dpm/day for an operator (3,198 dpm/m^3 × 1.2 m^3/hr × 8 hr/work-day × 300 work-days/365 calendar-days). The check calculation suggests that two different methods were used to convert work days to calendar days. SC&A is satisfied that the correct basic methodology is used to calculate operator ingestion doses (i.e., it is the same as TIB-009), but questions whether the ingestion exposures have been properly adjusted to a calendar-day basis. This issue had been raised previously, but not resolved. While the difference between ingestion exposures of 438 dpm/day and 526 dpm/day for the operational period is not significant from a health effects standpoint, the issue should be resolved consistent with established procedures.

NIOSH pointed out previously (Neton 2013) that the methodology of OCAS-TIB-009 (OCAS 2004) had been approved by the Procedures Review Subcommittee and SC&A concurred with that decision. NIOSH also pointed out that the methodology for calculating ingestion doses during the residual period based on TIB-009 was incorrect and would be revised when DCAS-TKBS-0006 was revised. This was done with ingestion doses during the residual period being increased from 0.00685 dpm/day (in Rev. 00) to 30.1 dpm/day (in Rev. 01). For the residual period, NIOSH used an approach documented in NUREG/CR-5512 (NRC 1992), where the annual ingestion dose is calculated as follows:

> CEDE for Ingestion = Exposure Duration for Occupancy × Effective Transfer Rate for Ingestion × Ingestion Dose Factor × Average Surface Activity per Unit Area

[1] A value of 438 dpm/day is obtained by assuming 250 work days per year, which is not the correct assumption for the early days of the Manhattan Engineer District.

As stated in DCAS-TKBD-0006, Rev. 01:

> *As with the airborne estimate, the fixed contamination will be assumed to be transferable to the point of causing inadvertent ingestion intakes. Again, the 500 dpm/100cm^2 value will be used and combined with a value of 1.1E-4 m^2/hr (NRC 1992) to estimate an ingestion rate. This results in an estimated ingestion rate of 30.1 dpm/day.*

For an exposure duration of 8 hours per work-day, a surface concentration of 500 dpm/100 cm^2, and 250 work-days/365 calendar-days, the calculated exposure is 30.1 dpm/calendar-day in agreement with the value quoted by NIOSH for ingestion in Table 10 of DCAS-TKBS-0006, Rev. 01.

ORAUT-OTIB-0070 (ORAUT 2012) provides an alternative approach to estimating ingestion during the residual period. The geometric mean (GM) air concentration during operations was 181 dpm/m^3. Per OTIB-0070, this can be assumed to decrease exponentially during the residual period based on a rate constant of 0.00067/day. As stated in Section 3.6 of OTIB-0070:

> *If inhalation intakes are calculated from air concentrations, ingestion intakes are to be considered. The ingestion rate, in terms of disintegrations per minute (dpm) for an 8-hour workday, can be estimated by multiplying the air concentration in dpm per cubic meter by a factor of 0.2 (NIOSH 2004)* [OCAS 2004]. *To adjust this to ingestion intake per calendar day, the calculated ingestion rate is multiplied by 250 workdays per year and divided by 365 d/yr.*

The following table uses this methodology and the factors taken from Table 4-2 of OTIB-0070 (ORAUT 2012) for an alternative calculation of ingestion during the residual period.

Year	**Factor**	**Air conc. (dpm/m^3)**	**Ingestion (dpm/workday)**	**Ingestion (dpm/calendar-day)**
1	1.00E+00	181	36.2	24.8
2	7.83E-01	1.42E+02	28.3	19.4
3	6.13E-01	1.11E+02	22.2	15.2
4	4.80E-01	8.69E+01	17.3	11.9
5	3.76E-01	6.81E+01	13.6	9.3
6	2.94E-01	5.32E+01	10.6	7.3
7	2.31E-01	4.18E+01	8.3	5.7
8	1.81E-01	3.28E+01	6.5	4.5
9	1.41E-01	2.55E+01	5.1	3.5
10	1.11E-01	2.01E+01	4.0	2.8
11	8.67E-02	1.57E+01	3.1	2.1
12	6.79E-02	1.23E+01	2.4	1.7
13	5.32E-02	9.63E+00	1.9	1.3
14	4.16E-02	7.53E+00	1.5	1.0
15	3.26E-02	5.90E+00	1.2	0.8
16	2.55E-02	4.62E+00	0.9	0.6
17	2.00E-02	3.62E+00	0.7	0.5
18	1.56E-02	2.82E+00	0.5	0.4
19	1.23E-02	2.23E+00	0.4	0.3
20	9.60E-03	1.74E+00	0.3	0.2
21	7.51E-03	1.36E+00	0.3	0.2

Year	Factor	Air conc. (dpm/m^3)	Ingestion (dpm/workday)	Ingestion (dpm/calendar-day)
22	5.88E-03	1.06E+00	0.1	0.1
23	4.61E-03	8.34E-01	0.1	0.1
24	3.61E-03	6.53E-01	0.1	0.1
25	2.83E-03	5.12E-01	0.1	0.1
26	2.21E-03	4.00E-01	0.1	0.1
27	1.73E-03	3.13E-01	0.0	0.0
28	1.36E-03	2.46E-01	0.0	0.0
29	1.06E-03	1.92E-01	0.0	0.0
30 on	8.32E-04	1.51E-01	0.0	0.0

For Year 1, the ingestion exposure is similar to that calculated based on the NUREG transfer rate, but after that, due to the assumed exponential decay, the ingestion exposure drops off rapidly.

With consistent adjustment of the ingestion dose during the operational period for calendar-days, SC&A considers this finding closed.

Finding 4. In Rev. 01 to the TKBS-0006, NIOSH changed the methodology for calculating photon exposure to operators. In Table 6, NIOSH calculated the photon exposure rate to operators as a function of distance from drums of various sizes containing uranium compounds. The exposure rate, including Bremsstrahlung at 1 meter from a 55-gallon drum, was calculated to be 0.28 mR/hr (DCAS 2013, Table 6). This value was assumed to be the median of a lognormal distribution with a geometric standard deviation (GSD) of 5 to account for uncertainty in the source-to-object distance. Based on a 2,400-hour work-year, the GM operator photon exposure rate was 672 mR/yr. This value is reported in Table 7 of TKBS-0006, Rev. 01. However, it should be noted that value of 672 mR/yr is based on work-days, not calendar-days. Adjusting to a calendar-day basis would reduce the GM exposure rate to 552 mR/yr (i.e., 672 × 300/365).

SC&A finds that this approach is consistent with prior discussions and agreements and is appropriate for dose reconstruction. The assumptions regarding photon doses in Rev. 01 are more claimant-favorable that those in Rev. 00 (GM of 672 mR/yr versus 519 mR/yr)

Fiinding 5. NIOSH presented data in Figure 1 of DCAS-TKBS-0006, Rev. 01 showing the measured decay of beta dose as a function of distance from a yellowcake source. The yellowcake measurements were made 100 days after processing the yellowcake from uranium ore to insure build-up of Th-234 and Pa-234m to peak levels (NRC 2002). NIOSH then determined that the beta dose from Figure 1 could be approximated by a lognormal distribution with a GSD of 5 and a median value of 1 mrem/hr at 100 cm from the source as shown in Figure 2 of TKBS-0006, Rev. 01. It was assumed that the operator spends a portion of his time at a distance of 100 cm from the source and the balance at 1 foot from the source. For the period of time at 1 foot from the source, it was further assumed that for half of that time, the operator had his hands in contact with the source. Based on the photon exposure rate spatial distribution and the lognormal behavior, it can be calculated that 17% of the time, the operator would be at 1 foot (30 cm) from the source and 8.5% of the time, his hands would be in contact with the source. The contact beta dose rate per Table 5 of TKBS-0006, Rev. 01, is 233 mrem/hr. Thus, the beta dose would be:

Contact: 2,400 hr/yr × 0.085 × 233 mrem/hr = 47,500 mrem/yr
At 1 foot: 2,400 hr/yr × 0.085 × ca. 2 mrem/hr = 408 mrem/yr
At 100 cm: 2,400 hr/yr × 0.83 × 1 mrem/hr = 1990 mrem/yr
Total beta dose: 50,000 mrem/yr
Beta dose to skin other than hands and arms: 2,400 mrem/yr (408 mrem/yr + 1990 mrem/yr)

These doses are the same as reported by NIOSH in Table 7 of TKBS-0006, Rev. 01. The dose to the hands and arms is characterized as a bounding dose, rather a dose with an assigned distribution.

SC&A was able to verify most of the modeling assumptions used by NIOSH. However, we could not easily duplicate the assumed lognormal function that NIOSH presented in Figure 2. More details should be provided as how that curve was developed. In addition, as noted in the findings table above, SC&A questioned why the approach to calculating external dose used in TBD-6000 (Battelle 2011) was not used for DuPont. DCAS-TKBS-0006, Rev. 01, does address this issue. We note in TBD-6000 that an operator is assumed to spend 50% of the time with his hands in contact with a uranium source, as compared to the assumption at DuPont Deepwater that the operator spends only 8.5% of his time with his hands in contact with a uranium source. Thus, the annual contact dose for an operator at DuPont is 47,500 mrem compared to 276,000 mrad in TBD-6000. Similarly, the annual other skin dose is 2.4 rem at DuPont as compared to 25 rad in TBD-6000. Discussion should be provided by NIOSH to reconcile these significant differences.

Finding 6. As discussed in Finding 5, the photon exposure in Rev. 01 is based on the calculated exposure at 100 cm from a 55-gallon drum of uranium (0.28 mR/hr), and is assumed to be the median exposure for a lognormal distribution with a GSD of 5. The beta exposure is based on taking measured values at various distances from a yellowcake source and approximating this measured distribution by a lognormal distribution with a GM of 1 mrem/hr (at 100 cm) and assuming a GSD of 5. The revised approach in Rev. 01 addresses prior concerns and is acceptable.

Finding 7. As discussed under Findings 4 and 6, the photon exposure rate was based on MicroShield calculations (adjusted to include Bremsstrahlung), assuming that the operator was at various distances from a 55-gallon drum of uranium during the work day. The GM distance from the source was 100 cm. The approach used to develop the photon exposure is a significant improvement over that in Rev. 00 and is scientifically sound.

SUMMARY

- NIOSH should ensure that all dose reconstruction parameters are clearly identified as to whether they are on a work-day or calendar-day basis. In addition, NIOSH should ensure that inhalation and ingestion exposure parameters are presented on the same basis.
- To provide transparency in DCAS-TKBS-0006, Rev. 01, NIOSH should describe how the lognormal curve in Figure 2 was developed.
- NIOSH should provide a rationale as to why the beta doses to the hands and arms are substantially higher in TBD-6000 than in DCAS-TKBS-0006, Rev. 01.

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