Draft

ADVISORY BOARD ON RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF THE NIOSH SITE PROFILE FOR THE HOOKER ELECTROCHEMICAL COMPANY

Battelle-TBD-6001, Appendix AA

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ACRONYMS AND ABBREVIATIONS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AMAD	Activity Median Aerodynamic Diameter
AWE	Atomic Weapons Employer
Ci	curies
cm^3	cubic centimeter
DOE	U.S. Department of Energy
dpm	disintegrations per minute
Electro-Met	Electro Metallurgical Company
EU	enriched uranium
g	gram
g/cm^3	grams per cubic centimeter
GM	Geometric Mean
gpm	gallons per minute
GSD	Geometric Standard Deviation
HASL	Health and Safety Laboratory
HCl	hydrochloric acid
m	meter
m^3	cubic meter
MCNP	Monte Carlo N-Particle
MED	Manhattan Engineer District
mg	milligram
mR	milli roentgen
mrad	milliradian
mrem	millirem
mrep	millirep
m/s	meters per second
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
pCi/d	picocuries per day
pH	measure of acidity

RU	recycled uranium
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
TBD	Technical Basis Document

1.0 STATEMENT OF PURPOSE

The purpose of this report is to provide a critical review of Battelle-TBD-6001, Appendix AA, Hooker Electrochemical Corporation. In this report, we assess the merit and technical basis of the data and guidance to be used for dose reconstruction. This review was authorized by the Advisory Board on Radiation and Worker Health (ABRWH) at its May 2010 meeting in Niagara Falls, New York.

At about the same time, the National Institute for Occupational Safety and Health (NIOSH) issued a review of Special Exposure Cohort (SEC) Petition SEC-00141 covering Hooker Electrochemical (NIOSH 2010). SC&A was not tasked with a review of the petition evaluation report; however, as we have done in the past in similar situations (e.g. our review of the United Nuclear Corporation site profile), we provide some initial impressions regarding possible SEC issues, based on reading the petition and the evaluation report. A more detailed review of the petition and evaluation report will be performed if so authorized by the ABRWH.

2.0 INTRODUCTION

On June 15, 2007, NIOSH issued Appendix AA to Battelle-TBD-6001, which provides data and guidance for dose reconstruction of workers employed at an Atomic Weapons Employer (AWE) site—the Hooker Electrochemical Company (Hooker) in Niagara Falls, New York. This facility processed uranium-bearing (C-2) slags from July 11, 1944, to January 15, 1946. The operations at the Hooker facility involved treatment of C-2 slag from the nearby Electro Metallurgical Company (Electro-Met) with hydrochloric acid (HCl) to recover uranium. The C-2 slag from Electro-Met was a byproduct of the bomb reduction process, in which uranium tetrafluoride was reacted with magnesium to produce uranium metal. The HCl was excess acid produced at Hooker under AEC contract as a byproduct from the non-radioactive P-45 process.

Slag from Electro-Met was shipped in wooden barrels to Hooker by rail (DOE 1977, MED 1944). Each barrel was filled with 500 lbs of slag (reduction bomb liners) with the nominal composition of 90% MgF_2 and 10% CaO, plus about 1 lb of natural U (0.2%) (MED 1944). It is assumed here that the barrels were unloaded from the rail cars and initially stored on a concrete pad at the rail siding. The barrels were then opened and dumped on a bucket conveyor, which carried the slag over a 20 mesh screen, with the undersize being conveyed to one of three wooden digestion tanks (MED 1944, although DOE 1985 says that 4 tanks were used). Oversize from the screening was drummed and returned to Manhattan Engineer District (MED) control.

After 40 barrels were loaded into a 13-ft diameter by 11-ft high wooden digester tank (Dowling 1944, p. 112), HCl was added and the pH was adjusted to 4.0 with water additions (MED 1944). Digestion of the agitated slurry continued for about 20 hours (MED 1944). Operators standing on platforms above the tanks then added lime from 100-lb bags to neutralize the slurry (MED 1944). The neutralized slurry was pumped to a plate and frame filter press, where the filtrate was collected and discharged into a sewer. The filter cake was then washed several times. The filter cake containing 5 to 10 lbs of U (per 500 lbs of residue or 1 to 2% U) was then re-drummed in wooden barrels and shipped by rail to MED control (MED 1944). The turnover rate for a digester tank was stated to be once every 2 days (MED 1944). The digester tanks, bucket elevator, and filter press were housed in a cinder block building specifically constructed for the process (Dowling 1944, p. 112). The other operations, such as handling of barrels, were conducted outdoors.

The volume of the slurry in a digester tank based on 20% free-board is about 1,200 ft^3. Assuming that the digester feed is MgF_2 with a density of about 187 lb/ft^3, the addition of 20,000 lbs of slag to a tank would produce a slurry initially containing about 10% solids. According to http://www.mine-engineer.com/mining/plate.htm, a 50 ft^2 plate and frame filter press can dewater 10% solids at 50 gpm. Accordingly, it would take about 3 hours to dewater the contents of a digester tank, and that operation would occur about every second or third day for each digester. It is not known how much time would be required to unload the press and transfer about 2,000–4,000 lbs of product into barrels and how much time would be spent in other routine operations around the filter press.

Magnesium fluoride has very low solubility in water, but its solubility is significantly increased in HCl solutions with a pH of 4 or less (Johnson et al. 1954). Based on a 10-ton charge into a digester, 8 tons of MgF_2 and CaO would need to be dissolved to achieve a concentration of 1% U in the product residue, or 9 tons dissolved for a concentration of 2% U.

Four operators handled the process that involved 200 manhours per week (MED 1944). The maximum production rate was 10 tons per month (MED 1944), and a total of 152 tons were produced from July 1944 through January 15, 1946 (Battelle-TBD 6001, Appendix AA).[1] Assuming that the filter cake contained 10 lbs of U (per 500 lbs of residue), then based on a production rate of 10 tons per month, 100 tons per month of slag would need to be processed. This would require 10 digester batches per month.

Before proceeding with the review, it should be pointed out that Appendix AA relies heavily on TBD-6001. SC&A reviewed TBD-6001, and a work group meeting was held to go over our findings. Attachment 1 presents the issues matrix for TBD-6001 as of April 14, 2010.

[1] Another source states that the plant was shut down in October 1945 (Young 1985).

3.0 REVIEW OF SECTIONS AA.2 THROUGH AA.6 OF APPENDIX AA: OBSERVATIONS AND/OR FINDINGS

Appendix AA of Battelle-TBD-6001 is a brief document consisting of 10 pages that include 5 pages of text and 4 tables. Our review follows the sequence of topics as presented in Appendix AA.

3.1 REVIEW OF SECTION AA.2 "SITE DESCRIPTION"

As discussed in more detail in Section 3.3, we question whether it is reasonable to assume that transfer of 400 barrels of slag to the digestion process could be accomplished in 1 day per month.

3.2 REVIEW OF SECTION AA.3 "OCCUPATIONAL MEDICAL DOSE"

Based on available information, NIOSH recommends that each worker be assumed to have had a pre-employment physical, and that exposures be based on guidance provided in ORAUT-OTIB-0006 (ORAUT 2005). As SC&A pointed out in its review of the Electro-Met SEC petition (SC&A 2010), estimates of occupational medical exposure should be based on photofluorography, unless there is evidence that this technique was not used at AWE sites and only at Department of Energy (DOE) sites.

Observation 1: NIOSH should clarify whether or not photofluorography was used at AWE sites.

3.3 REVIEW OF SECTION AA.4 "OCCUPATIONAL INTERNAL DOSE"

NIOSH assumed that an operator would spend 1 day per month, or 5% of his/her time, dumping slag from barrels onto the conveyor for screening and transfer to the digesters. As described in Section 2.0 above, if the process product contained 2% U and the monthly output was 10 tons, then 100 tons of C-2 slag would need to be processed monthly. This would require dumping of 400 barrels, assuming that all the material was minus 20 mesh. However, some unknown fraction was oversized, so more than 400 barrels would be dumped in a month to obtain the required amount of minus 20 mesh feedstock. It seems unlikely that an operator using a fork lift truck could open a barrel, move the barrel from the storage pad to bucket conveyor (or a feed hopper), dump the barrel, and place the empty barrel back on the storage pad in about 1 minute. In addition, time would be required to re-package the +20 mesh fraction and the leached product in barrels. Repackaging of the product should cause limited additional inhalation exposure, because the filter cake would be moist.

Finding 1: NIOSH should re-examine the assumption that dumping of barrels could be done in 1 day per month.

In Table AA.1, Internal Dose Pathways, NIOSH lists 156 pCi/d as the inhalation intake for an operator. According to NIOSH, this is based on Table 8.29 of TBD-6001, where a median inhalation intake rate of 2,920 pCi/calendar-day is quoted for a scrap recovery furnace operator (1951 and earlier) handling trays of scrap. NIOSH observed that the inhalation intake of 2,920 pCi/calendar-day was based on a geometric mean uranium concentration of 822 dpm/m^3, which translates to a total dust loading of 293 mg/m^3 (Appendix AA, Section AA.4). This very high dust loading might be expected from very dusty operations, such as dumping of slag from the barrels.

Using the NIOSH assumption that exposure to dust occurred 5% of the time, the calculated daily exposure for an operator would be 146 pCi/d (2,920 pCi/calendar-day × 0.05 exposure days/ calendar-day), a value similar to that in Table AA.1. However, this approach neglects the exposure from other operations involving the digester and the filter press, and underestimates the time required to handle the barrels of slag.

Since it is estimated that about 10 batches per month were processed through the digesters, and a digester was turned over once every 2 days, then one could assume that the balance of the operator's time during the month was spent in processing material through the digesters and filtering the acid-digested product. According to Table 8.29 of TBD-6001, a digest operator involved in scrap recovery prior to 1951 had an inhalation intake of 28.4 pCi/calendar-day (based on a 48-hr work week) and a filtration operator had an intake exposure of 10.7 pCi/calendar-day.[2] Assuming that the operator spent 75% of the time working around the digester and 20% of the time working around the filter press, this would add 23 pCi/calendar-day or about 15% to the operator's exposure (28.4 × 0.75 + 10.7 × 0.20).

Finding 2: NIOSH should account for all activities causing inhalation exposure, not just those involved in dumping barrels of C-2 slag.

NIOSH assumed that it was appropriate to use the median value from Table 8.29 of TBD-6001 as a bounding value for exposures at Hooker Chemical. NIOSH said that this approach was reasonable, since the data in Table 8.29 are based on exposures from uranium and/or its compounds, rather than material initially containing only 0.2% U. While there is no doubt that the uranium concentration in the dust from slag processing operations is significantly lower than from the scrap recovery operations characterized in Tables 8.24 and 8.29 of TBD-6001, it is not clear that reducing the measured data to the median and then assuming that the median is bounding is claimant favorable absent further analysis. For example, statisticians generally regard the arithmetic average as the expected value of a distribution. Thus, the expected value for the dust concentration experienced by furnace operators involved in scrap recovery is 3,000 dpm/m^3 (TBD-6001, Table 8.23), as compared to an estimated median of 822 dpm/m^3 (TBD-6001, Table 8.24). The assumption that 156 pCi/day is bounding for operators at Hooker is based on several factors, which may or may not be sufficiently conservative to account for uncertainties:

- The operator is exposed to uranium-bearing dust 5% of the time
- The median is the appropriate metric for the expected exposure
- The operator experiences no other exposure for the remaining 95% of his/her time

[2] The dust loadings in TBD-6001 are based on an extensive database of plant measurements summarized by Christofano and Harris (1960).

- The scrap material on which the analysis was based may not be solely uranium. As noted by Christofano and Harris (1960), "Scrap as it enters the recovery plant might be high-purity uranium metal (99%), low-grade ore, slag and dross from remelting operations, or thermite-reduction bomb linings." Thus, it may not be appropriate to reduce exposures by a factor of 500 based on the slag composition of 0.2% U.

An alternative approach that could be considered is to use data in TBD-6001 related to the digestion of uranium ore (TBD-6001, Table 8.2). The nature of the ore is better documented [it contains 20% to 50% U_3O_8, per Christofano and Harris (1960)], and the digestion process includes opening and dumping drums, digesting the concentrate in acid, and filtration, processes conceptually similar to those practiced at Hooker. Using the information from Table 8.2 precludes the need to assume a distribution of time spent among the various aspects of the acid treatment process and speculation on the uranium content of the scrap. Table 8.2 of TBD-6001 lists dust concentrations (average daily exposures in dpm/m^3) associated with ore digestion as follows:

Minimum	Maximum	Average
7	350	110

Equal contributions to alpha activity in the ore are made by U-238, U-234, Th-230, and Ra-226. Thus, the values from Table 8.2 must be reduced by a factor of two to account for uranium only. From this information, one calculates the parameters for a lognormal distribution using procedures described in Section 2.1.2.3 of Strom 2007 as follows:

GM = 24.7 dpm/m^3
μ = 3.21
σ = 1.26
GSD = 3.54

If one assumes that the 95th percentile is bounding, the limiting air concentration would be 198 dpm/m^3, which is equivalent to 704 pCi/calendar-day (198 dpm/m^3 × 1.2 m^3/hr × 8 hr/work-day × 6 work-days/week × 50 weeks /yr × 1 yr/365 calendar-days × 1 pCi/2.22 dpm). The uranium ore contains 20% to 50% U_3O_8 (Christofano and Harris 1960), so we will assume an average concentration of 35% U_3O_8 or 30% U. However, the C-2 slag processed at Hooker contains only 0.2% U, so the ore exposure must be reduced by a factor of 150 (30%/0.2%) to obtain an exposure representative of slag or 4.7 pCi/calendar-day. This value is substantially below the 156 pCi/calendar-day assumed by NIOSH in Table AA.3, indicating that the NIOSH approach is claimant favorable and bounding in spite of our concerns about some of the underlying assumptions.

One could also consider use of the data from concentrates in Table 8.2. In the case of concentrates, no adjustment is required for Th-230 and Ra-226, as these radionuclides would have been removed in the processing of ore to concentrates. Since the minimum, maximum, and average values for concentrates do not fit a lognormal distribution, Strom (2007, Section 2.1.2.4) recommends using the average and an assumed geometric standard deviation (GSD) of 5 to calculate lognormal parameters. This approach results in a 95th percentile value of 153 dpm/m^3, which is equivalent to an inhalation intake of 544 pCi/calendar-day. The concentrates contain an average of 80% U_3O_8 (Christofano and Harris 1960) or 68% U. Adjusting the concentrate exposure for the uranium content of the slag (68%/0.2%) results in an estimated inhalation intake of 1.6 pCi/calendar-day, providing another benchmark indicating that the NIOSH approach is conservative. The data selected by NIOSH from TBD-6001 were based on scrap recovery operations that are quite different from those practiced at Hooker and resulted in inhalation intakes that were higher by factors ranging from 30 to 100, as compared to those from other operations described in TBD-6001 that are more akin to the Hooker process. It is arguable that the selected approach, while claimant favorable, may not be plausible.

Finding 3: While SC&A does not agree with some of the underlying assumptions in their approach, the NIOSH approach appears to be bounding for dose reconstruction. However, our independent analyses indicate that the values for intake rate are unrealistically high.

3.4 REVIEW OF SECTION AA.5 "OCCUPATIONAL EXTERNAL DOSE"

Since no monitoring data were available, NIOSH used the median values from Table 7.3 of TBD-6001 for workers involved in scrap recovery. Values for whole-body dose from external exposure pathways are presented in Table AA.3. According to Section AA.5, the operator is assumed to spend 5% of the time exposed to both surface (floor) contamination (0.376 mR/ calendar-day) and exposure from handling barrels (0.528 mR/calendar-day), and 95% of the time exposed only to surface contamination, resulting in an external exposure of 0.402 mR/ calendar day ([0.376 + 0.528] × 0.05 + 0.376 × 0.95). However, as discussed by SC&A in its review of TBD-6001, Table 7.3 is lacking in transparency, making it difficult for the reader to trace the values in that table to their sources. For example, Table 7.3 lists the median exposure based on a 48-hr week for a scrap recovery operator from material handling as 0.528 mR/ calendar-day. Presumably this exposure rate is derived from information provided in Table 7.1. In Table 7.1, we find that the exposure from scrap recovery is 2.25 mR/8-hr work-day[3], which can be converted to 1.84 mR/calendar-day (2.25 mR/work day × 6 work-days/work week × 50 work weeks/yr × 1yr/365 calendar-days). If one assumes that this (i.e., 1.84 mR/calendar-day) is the arithmetic average for a lognormal distribution with a GSD of 5, then the geometric mean (GM) would be 0.504 mR/calendar-day, a value similar to 0.528 mR/calendar-day reported in Table 7.3 of TBD-6001. We believe that the difference may be due to the fact that the authors of TBD-6001 assumed 350 calendar-days per year, rather than 365 calendar-days per year. If we are correct in this interpretation of the values, such a description should be included in the TBD.

Observation 2: If conversion of external exposure to a calendar-day basis is based on 350 days per year, the basis for this assumption should be provided. In addition, NIOSH should provide example calculations to show how the values in Table 7.3 of TBD-6001 were derived.

Table 7.3 lists the median exposure to an operator standing on a contaminated surface as 0.376 mR/calendar-day. NIOSH provided information to assist SC&A in understanding the source of this exposure metric, since it could not be readily derived from the information in

[3] This value is traceable to MicroShield calculations summarized in Table 7.2 of TBD-6001. The exposure calculated by MicroShield assumes that the worker spends 100% of the time 1 m from a 55-gallon drum containing uranium compounds and was doubled to account for Bremsstrahlung radiation.

TBD-6001 (Allen 2010). The starting point was general area samples taken near a scrap processing furnace (TBD-6001, Table 8.23), which list average values of 900 dpm/m^3 (trays) and 200 dpm/m^3 (calciner), yielding an average value of 550 dpm/m^3. This was converted to a GM of 151 dpm/m^3, assuming that the data were described by a lognormal distribution with a GSD of 5. Assuming deposition for 1 year at a deposition velocity of 7.5E-04 m/s, the contamination factor is 2.37E+04 m and the annual areal deposition is 3.57E+06 dpm/m^2 (151 dpm/m^3 × 2.37E+04 m). From this, the exposure rate can be determined to be 0.002 mR/hr using the conversion factor in Table 3.10 of TBD-6001 of 5.61E-10 mR/hr per dpm/m^2. Due to spreadsheet error, the hourly exposure had been calculated to be a factor of 100 higher. This means that external exposure from contaminated surfaces has been overstated in Table AA.3 by a factor of about 30.

Finding 4: NIOSH should correct the external exposure rates in Table AA.3.

The values in Table AA.3 are based on the median and assumed to be constant. NIOSH argues that use of the median rather than the full distribution is appropriate for a bounding calculation because the uranium concentration in the slag is low (i.e., 0.2%). In contrast, the uranium source term for materials handling in Table 7.3 of TBD-6001 is based on exposure to 55-gallon drums containing loosely packed uranium (or U_30_8)[4] with a density of 1.6 g/cm^3 that has decayed for 100 days after refining. Based on the specific activity of natural uranium of 684 pCi/mg, the drum would contain 1.09E+06 pCi/cm^3. The equivalent U content in the C-2 slag would be 4.35E+03 pCi/cm^3 based on an MgF_2 density of 3.18 g/cm^3 (0.002g U/g MgF_2 × 3.18 g MgF_2/cm^3 × 684 pCi/mg U × 1,000 mg/g). The fact that the curie density in 55-gallon drums is about 2.5 orders of magnitude greater than in the C-2 slag supports the use of the median from Table 7.3 as the upper bound for materials handling exposures at Hooker. However, a more robust approach would be to calculate external exposures specific to Hooker by modeling barrels of slag with MCNP or MicroShield.

Finding 5: Rather than applying the values in Table 7.3 as default/bounding values, NIOSH should derive the correct external dose values using MicroShield or MCNP.

NIOSH provides information on skin doses in Table AA.4. (This is incorrectly labeled Table AA.3 in Appendix AA). The dose to the hands is based on Table 7.3 of TBD-6001. The median dose to the hands of a scrap recovery operator working 48 hours per week is listed as 219 mrem/calendar-day. Assuming that the operator's hands are in close contact with the slag for 5% of the time, the dose would be 11 mrem/calendar-day. Table AA.4 lists the dose as 11 mR/d.

Observation 3: For consistency with the TBD-6001 source document, the units in Table AA.4 should be specified as mrad or mrem/calendar-day rather than mR/calendar-day.

The source of the median dose to the hands in Table 7.3 appears to be based on Table 3.4 of TBD-6001. Table 3.4 lists the exposure to the hands in contact with a slab of uranium as

[4] Section 7.3 of TBD-6001 does not specify the material in the drums and should do so to improve document clarity.

233 mrad/hr, which in turn stems from measurements reported in DOE 2004. If one assumes that 233 mrad/hr is the average of a lognormal distribution with a GSD of 5, the median value is 64 mrad/hr. As modeled, the operator has his/her hands in contact with the uranium metal slab 50% of the work-day (TBD-6001, Section 3.3.1), resulting in a dose of 219 mrad/calendar-day as shown in Table 7.3 of TBD-6001 (64 mrad/hr × 0.5 × 8 hr/work-day × 300 work-days/ 365 calendar-days = 210 mrad/calendar day, a value similar to that in Table 7.3). Based on the assumption that barrel handling occurs on 5% of the calendar-days, the resulting exposure for Hooker is 11 mrem/calendar-day.[5]

The assumption that the worker had his hands in contact with a slab of uranium rather than a wooden barrel containing slag with 0.2% to 2% U is claimant favorable. The wooden barrels would provide a significant reduction in beta dose compared to direct contact with a solid uranium object. The assumptions that the worker exposure is based on the median (64 mrad/hr), rather than the average or expected value (233 mrad/hr), and that barrel handling occurs on 5% of the work-days, are not claimant favorable. The average value of 233 mrad/hr is based on measurements that would not have the uncertainty suggested by assuming a lognormal distribution with a GSD of 5.

As an alternative, NIOSH has suggested in its review of Petition SEC-00141 for Hooker that a value of 11.5 mrep/hr be used for shallow dose, based on measurements taken in 1948 at the top of a pile of C-liner slag at the St. Louis Airport Storage Site (NIOSH 2010). Estimates of exposure to the hands could then be based on the time spent per day with the hands in contact with the barrels of slag and the number of days per month that barrels were handled. However, as discussed above regarding photon exposure, the scientifically sound approach would be to calculate the shallow dose exposure using MicroShield or MCNP.

Finding 6: NIOSH should consider whether use of shallow dose estimates based on slag sampling is a more plausible approach than pro-rating exposures from a large uranium object. Alternatively, NIOSH could consider using a conservative estimate of the concentration of uranium in the barrel, and take into consideration self-shielding and the shielding from the barrel wall using MicroShield or MCNP.

3.5 REVIEW OF SECTION AA.6 "RESIDUAL CONTAMINATION"

The residual period is assumed to run from January 15, 1946 through October 11, 1976. The end date was established based on a radiological survey conducted by the Oak Ridge National Laboratory for DOE showing that no elevated contamination levels were detected during the survey (ORNL 1977).

[5] Since the 5% exposure estimate was based on work-days rather than calendar-days, for logical consistency, the exposure should be increased by the ratio of 365 calendar-days/300 work days, which would increase the exposure to the hands to 13 mrem/calendar-day (219 mrem/day × 0.05 × 365/300). However, given the fact that the worker is assumed to have his hands in contact with uranium 50% of the time, this correction is inconsequential.

3.5.1 Estimate of Inhalation Quantity from Residual Contamination

Per Table AA.1, NIOSH assumes an inhalation intake of 1 pCi/calendar-day for all workers during the residual period. NIOSH states the following in Section AA.6:

> *The internal dose rates are based on the average air concentration during operations (from section C.4) assumed to deposit throughout an entire work year with no removal. This deposited contamination is assumed to resuspend with a resuspension factor of 1E-06 m^{-1}.*

We presume that there is a typo in the above quotation and that the average air concentration during operations is obtained from **Section AA.4**, where the GM concentration is quoted as 822 dpm/m^3. (Average air concentrations are not mentioned in Appendix AA.) This dust concentration assumes pure uranium when, in fact, the slag contains 0.2% U. At this dust level, the adjusted uranium concentration would be 1.64 dpm/m^3. When dust from the slag handling is deposited for an entire work year at a terminal settling velocity of 7.5E-04 m/s, the resulting surface concentration is 3.9E+04 dpm/m^2 (0.002 × 822 dpm/m^3 × 7.5E-04 m/s × 3.15E+07 sec/yr). Based on the assumed resuspension factor of 1E-06/m, the resuspended dust concentration is 3.9E-02 dpm/m^3 or 1.8E-02 pCi/m^3. Using a breathing rate of 9.6 m^3/8-hr work day, the intake is 0.17 pCi per work day or 0.13 pCi per calendar day (for a 48-hr work week). This value is lower by a factor of 8 than that cited in Table AA.1.

We note that the intake would have been higher had a larger resuspension factor been used. SC&A has stated in several reports that a value of 1E-06/m is unrealistically low (e.g., SC&A 2008). With a resuspension factor of 1E-03/m, the inhalation intake would be 130 pCi/calendar-day. The approach taken in Appendix AA can, in principle, lead to claimant-favorable results, because the surface concentration is assumed to remain constant through the residual period. However, this is only true if the initial surface concentration and resuspension factors are properly justified.

Finding 7: NIOSH should provide an example calculation showing how they arrived at an inhalation intake of 1 pCi/calendar-day.

Finding 8: NIOSH should justify the use of a resuspension factor of 1E-06/m.

We further note that the method used here of assuming a constant surface concentration during the residual period based on deposition during the final year of the operational period combined with a resuspension factor of 1E-06/m is not one of the seven methods proposed in ORAUT-OTIB-0070 (ORAUT 2008). One method proposed in OTIB-0070 is to use the surface concentration at the end of the operation period, a resuspension factor of 1E-06/m and an assumed dust concentration decay rate of 1%/day. As pointed out by SC&A in its review of OTIB-0070, a resuspension factor of 1E-06/m is equivalent to a decay rate of 0.012%/day based on a room height of 5 m and one air change per hour (SC&A 2008). A decay rate of 1%/day is roughly equivalent to a resuspension factor of 1E-04/m. If one uses a higher resuspension factor, the initial dust concentration is higher, but the dust concentration falls much more rapidly over time. Figure 1 compares the dust concentration in the air at 100 days and 1,000 days after cessation of operations for resuspension factors ranging from 1E-06/m to 1E-03/m. It can be seen that after 1,000 days, the dust concentration is greater for a resuspension factor of 1E-05/m than for values above and below.

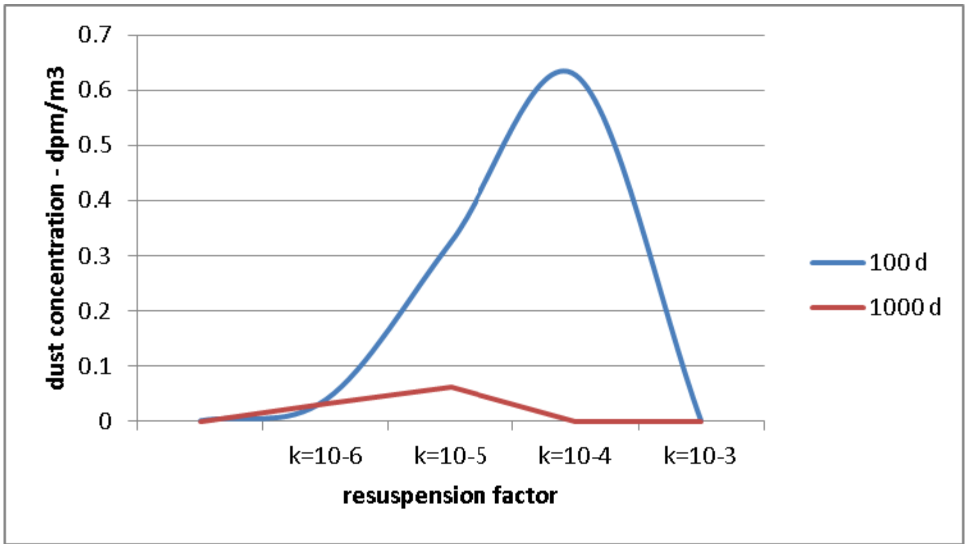

Figure 1. Effect of Resuspension Factors on Dust Concentrations

However, a higher resuspension factor does not necessarily result in a higher integrated inhalation intake. When sufficient time has elapsed, a worker will experience the same integrated intake regardless of the resuspension factor. For the case modeled here, the integrated intake is the same for resuspension factors of 1E-05, 1E-04, and 1E-03/m after 10 years. A considerably longer period is required to reach the same asymptotic value for a resuspension factor of 1E-06/m.

As an alternative, NIOSH could have used an approach where the initial dust concentration was based on surface contamination at the end of operations and an appropriate resuspension factor, and assumed that this decayed exponentially to some value below the detection limit at the end of the residual period.

Finding 9: NIOSH should justify that the approach taken to calculate inhalation exposures during the residual period is bounding, and take into consideration SC&A's review of ORAUT-OTIB-0070.

3.5.2 Estimates of External Dose from Residual Contamination

NIOSH used surface contamination exposures from Table 7.3 to estimate external exposures during the residual period. Thus, the median exposure for a scrap recovery operator standing on a contaminated surface is 0.376 mR/calendar-day based on a 48-hr work-week. As discussed in Section 3.4, this value is overstated by a factor of 100 and needs to be corrected. Even though the external exposure is trivial, NIOSH also needs to review the assumptions used in converting this exposure to pCi/calendar-day.

Finding 10: NIOSH needs to correct the calculation of external exposure during the residual period and revise the basis for converting this exposure to pCi/calendar-day.

4.0 USE OF SURROGATE DATA

In this section, we review the use of surrogate data in developing dose reconstruction guidance at Hooker, and how this usage comports with the surrogate data criteria recently approved by the ABRWH. As described in Section 3, the guidance for Hooker relies solely on TBD-6001, where surrogate data were used to calculate inhalation/ingestion intakes for both the operational and residual periods. In particular, NIOSH used data for scrap recovery operations based on measurements made by Christofano and Harris (1960) and summarized in Tables 8.23 and 8.24 of TBD-6001. The selected data were for the *average* exposure of a furnace operator handling trays of scrap prior to 1952. No information is available about the number and distribution of samples used to calculate the average exposure. This measured average exposure (3,000 dpm/m^3) was converted by NIOSH to a median exposure (822 dpm/m^3), assuming a lognormal distribution with a GSD of 5. The use of surrogate data is evaluated below against the ABRWH's criteria. It should be noted that the surrogate data criteria did not exist at the time that Appendix AA was written.

(1) Hierarchy of Data. In accordance with this criterion, the usual data hierarchy should be followed; for example, individual monitoring data are preferable to workplace monitoring data. The surrogate data used at Hooker were both individual monitoring data and general area samples. In addition, the criterion further requires that surrogate data be used to replace available data only if the surrogate data have some advantages over available data. At Hooker, there were no available data, thereby necessitating the use of surrogate data. Adjustments must be made to the surrogate data to account for uncertainty. This was achieved at Hooker by assuming that workers were exposed to uranium dust, when in fact, their exposure was to slag containing a low percentage of uranium. Based on these considerations, we believe that the hierarchy of data criterion was satisfied. However, as discussed below, the approach used by NIOSH, though bounding, might not reflect plausible circumstances.

(2) Exclusivity Constraints. This criterion requires that the use of surrogate data be stringently justified. Not only must the amount of surrogate data be considered, but also its quality and completeness. The Christofano and Harris (1960) dataset is comprehensive, covering the 60 complete evaluations made at 7 AEC uranium refining facilities over the 10-year period 1948 through 1957. The dataset included more than 20,000 dust samples taken both from the operators' breathing zone and the general work area. The measurements were made by AEC Health and Safety Laboratory (HASL), whose work was well-regarded. Unfortunately, the Christofano and Harris dataset does not provide information on the number and distribution of samples used to develop an average exposure. For example, as discussed above, the scrap recovery operator's exposure is given as 3,000 dpm/m^3, but no information is available on the underlying data from which the average was calculated. While lacking in transparency, the dataset is based on a large amount of high quality data. On this basis, we believe the exclusivity constraints criterion is satisfied.

(3) Site or Process Similarities. No AEC sites performed work identical to that at Hooker, i.e., leaching of uranium-bearing slag with HCl. However, as described in Section 3.3 above, some sites did perform acid leaching of ore and/or concentrates, which involved processing steps similar to those at Hooker, including drum handling, acid digestion, and filtration. Instead of choosing dust sampling results from these operations, NIOSH chose a more conservative and claimant-favorable approach to bounding worker exposures by selection of a furnace operator involved in scrap recovery as the basis for dose reconstruction. Thus, to insure that inhalation/ingestion exposures at Hooker were bounded, NIOSH selected data from a process that generated higher dust levels than the actual Hooker process. Such an approach is certainly claimant favorable, but it does raise question regarding process similarities and plausible circumstances.

(4) Temporal Considerations. It is desirable that surrogate data be obtained during the same general period for which doses are to be reconstructed. NIOSH used data prior to 1952 (TBD-6001, Table 8.23) to reconstruct doses for the period July 11, 1944, through January 15, 1946. We believe that these periods are reasonably contemporaneous and that this criterion is satisfied.

(5) Plausibility. This criterion addresses the reasonableness of the assumptions made, in terms of both scientific plausibility and workplace plausibility. Judging plausibility in the case of a bounding calculation such as at Hooker is highly subjective. On the one hand, selection of the bounding approach must not strain credulity to the point of being impossible. (Obviously, almost anything can be bounded.) On the other hand, the selected approach must insure that the results are indeed bounding to protect the claimant. At Hooker, NIOSH selected an aspect of the uranium scrap recovery operation that involved the highest exposure (furnace operator handling trays of uranium oxide) and applied it to processing slag—a product with a low uranium content (0.2%). We believe that information is available in TBD-6001 on processes that more closely approximate the operations at Hooker. Use of such data should be considered by NIOSH to better demonstrate the plausibility of the dose reconstruction guidance. We also note that in its review of Petition SEC-00141 (NIOSH 2010), NIOSH utilized data on C-2 slag handling at several AEC sites. Use of these data could also lead to more plausible guidance than use of the scrap recovery data from TBD-6001.

External operational exposures in Appendix AA and TBD-6001 from penetrating radiation during handling uranium-bearing materials were based on MicroShield calculations. External operational exposures from non-penetrating radiation were based on measured values taken from natural uranium slabs. As such, these exposures did not involve use of surrogate data.

5.0 SUMMARY, CONCLUSIONS, AND INITIAL IMPRESSIONS REGARDING THE SEC PETITION AND EVLAUATION REPORT

Appendix AA of Battelle-TBD-6001 provides guidance for the reconstruction of potential occupational exposures to Hooker Chemical Company workers from medical x-rays and internal, as well as external, sources during the 18-month operational period of July 11, 1946, through January 15, 1946. Thereafter, Appendix AA also provides guidance for the reconstruction of internal and external exposures associated with residual contamination through October 11, 1976.

Because worker-specific monitoring records for Hooker personnel are unavailable, NIOSH intends to assign default doses for occupational medical, external, and internal exposures during facility operation, as well as from residual contamination from 1946 through 1976. In total, our review identified 3 observations and 10 findings. A common element in our findings is that the default values contained in Tables AA.1 and AA.3 appear to reflect a combination of undocumented assumptions, errors in the underlying source document TBD-6001, and lack of traceability of some of the data. Attempts by SC&A to duplicate/validate NIOSH's default values were only partially successful.

Even though many of the models and assumptions and much of the data used to construct the co-worker model appear to be bounding, they represent circumstances that are not plausible for Hooker and for which a site-specific analysis needs to be performed.

In the process of reviewing Appendix AA, SC&A briefly examined the NIOSH report reviewing Petition SEC-00141. This review was only cursory, but a few observations are noted here:

- There is considerable confusion about the extent to which activities were conducted indoors versus outdoors. Despite recollections of workers interviewed during preparation of the Petition Evaluation Report, the *Completion Report – Construction of the Hooker Electrochemical Company P-45 Plant* (Dowling 1944) states that agitated tanks, plate and frame filter press, bucket elevator, pumps, motors and auxiliary equipment were housed in a specially constructed cinder block building. Therefore, it should be concluded that most of the processing was conducted indoors.

- In documenting its ability to adequately reconstruct internal exposures, NIOSH sited dust levels associated with slag handling at Fernald, Mallinckrodt and Electro-Met. Use of actual slag-handling data is superior to using generic scrap recovery data from TBD-6001. The highest average dust concentration observed during slag handling was 456 dpm/m^3 (at Electro-Met), while the <u>average</u> dust concentration used to develop Appendix AA guidance was 3,000 dpm/m^3. While clearly supporting the NIOSH contention that the approach taken in Appendix AA is claimant favorable, it also supports SC&A's concern that Appendix AA may be overly conservative.

- NIOSH used a similar approach to documenting external exposure in the Hooker Petition Evaluation Report, namely, use of measurements taken directly from slag. A photon dose of 1.6 mrep/hr was measured chest- high at the top of a large slag pile (Caplan 1949). In

Appendix AA, NIOSH calculated photon (plus Bremstrahhlung) exposure of 0.3 mR/hr at 100 cm from a 55-gallon drum. It is difficult to compare the two approaches. As noted above, a preferable approach would be to calculate the external exposure from barrels containing slag with either MicroShield or MCNP.

Before concluding, we would like to point out that it is difficult to provide our initial impressions regarding possible SEC issues, because the site profile is based primarily on surrogate data. A typical SEC petition/Evaluation Report review focuses on data completeness and adequacy, as collected and used at the facility under review. This is not possible here, because the dose reconstruction methods employed surrogate data. Hence, a review of the SEC petition and Evaluation Report will need to focus on surrogate data issues.

6.0 REFERENCES

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ATTACHMENT 1: ISSUES MATRIX FOR TBD-6001 AS OF JUNE 14, 2010

TBD-6001 Issues Matrix				
Finding or Observation	**SC&A TBD Review[a]**	**NIOSH Initial Response**	**SC&A Comments on NIOSH Response**	
Finding 1	It is not possible to judge whether the basic approach to developing inhalation doses in TBD-6001 is claimant favorable, based on the information presented in that document. However, based on analyses presented in this review, it appears that the average inhalation doses used in TBD-6001 are not claimant favorable, particularly for the period prior to 1948 (SC&A 2008, Section 8.1).			
Finding 2	TBD-6001 oversimplifies the process descriptions from Christofano and Harris (1960) and, as a result, may have missed or understated significant pathways for external and internal exposure (SC&A 2008, Section 4.0).			
Finding 3	The approach used in TBD-6001 to calculate the contribution to external exposure of contaminated dust settled on workplace surfaces is not appropriate. SC&A addressed the same issue in its review of TBD-6000 (SC&A 2007, Item 5). (See Section 3.1 in SC&A 2008 for basis of Finding 3.)	This issue has been resolved as part of the TBD-6000 Issue Resolution Process, based on the Battelle-TBD-6000 Issue 5 White Paper (Allen 2009). NIOSH demonstrated, based on data from Adley et al. 1952, that the median settling rate was 0.00023 m/s, as compared to 0.00075 m/s assumed in TBD-6000 and TBD-6001. The lower settling rate reduces external exposure from surface contamination and resuspended contamination. The assumption of a 7-day deposition period understates the expected total deposition, but the impact on external dose is trivial.	It would be helpful if NIOSH indicated why a deposition period of 7 days was used for calculating external dose from contaminated surfaces in TBD-6000 (Section 6.1.2), while a deposition period was used in TBD-6001 (Section 7.1.2).	
Finding 4	Summary Tables 7.1 and 7.3 in Section 7 of TBD-6001 that address external exposures require additional elaboration to understand the sources of the contained data and how the data			

TBD-6001 Issues Matrix

Finding or Observation	SC&A TBD Review[a]	NIOSH Initial Response	SC&A Comments on NIOSH Response	
	were derived (SC&A 2008, Sections 7.1 and 7.3).			
Finding 5	*The approach taken by NIOSH to develop year-specific correction factors to inhalation doses does not appear to be claimant favorable. Doses in the early years may be understated.* (SC&A 2008, Section 8.3)			
Finding 6	NIOSH did not consider radon exposures in developing inhalation exposure rates. Since pitchblende ore contains significant quantities of Ra-226 and its progeny, this omission significantly understates inhalation exposure rates for workers involved with operations at the front end (ore processing) of the refining process (SC&A 2008, Section 3.2).			
Observation 1	NIOSH states in Section 1 that the report provides the technical basis for reconstructing doses for AWE sites that refined uranium under government contract during the period 1942–1958; however, no basis is provided for selecting 1942–1958 as the relevant time period. We also note that NIOSH refers elsewhere to 1944 as the start date (pg. 4, second paragraph). NIOSH should document the basis for the dates and correct any inconsistencies.			
Observation 2	As noted in Section 2.0 of TBD-6001, Christofano and Harris (1960) do not present information on exposures from the solvent extraction unit operation. NIOSH notes in Section 8.2.2 that the air concentration data for solvent extraction are under development. NIOSH should provide the appropriate data.			
Observation 3	TBD-6001 should address possible exposures to Th-230 and Ra-226 for workers handling ore (SC&A 2008, Section 3.2).			

TBD-6001 Issues Matrix				
Finding or Observation	**SC&A TBD Review[a]**	**NIOSH Initial Response**	**SC&A Comments on NIOSH Response**	
Observation 4	TBD-6001 also does not address exposures to enriched uranium (EU) or recycled uranium (RU). In light of this, Section 1 of the report, titled "Purpose and Scope," should make it clear that this document should only be used for workers involved in the processing of uranium ores and concentrates, and that it does not provide direction regarding exposures to workers who might have handled EU, RU, or ores containing Th-232 (SC&A 2008, Section 3.2).			
Observation 5	Any use of a default air concentration for non-operational areas should provide some guidance as to what should be considered "non-operational areas of the plant." Use of a value of 7 dpm/m^3 would not be appropriate for all types of non-operational locations (SC&A 2008, Section 6.1).			
Observation 6	No information is provided as to how doses are apportioned to laborers, supervisors, and clerical staff in Table 7.3 of TBD-6001 (SC&A 2008, Section 7.5).			
Observation 7	It should be noted that in several of the TBD-6001 lognormal tables in Section 8, the reported GSD is less than 1, although the GSD for a lognormal distribution must be greater than 1. Hence, there appears to be an error here that needs to be corrected (SC&A 2008, Section 8.1).			
Observation 8	SC&A provided a list of minor clarifications and corrections that should be made to TBD-6001 (SC&A 2008, Section 9).			
Observation 9	Table 8.3 lists the GSD of the daily weighted average for ore as 4.939. Although not stated in TBD-6001, we presume that the GSD is calculated based on equations 3 and 10 of Strom 2007. Using these equations, we calculate the GSD to be 3.539. NIOSH should confirm what the correct value is for the GSD, and document the procedures used to calculate			

TBD-6001 Issues Matrix

Finding or Observation	SC&A TBD Review[a]	NIOSH Initial Response	SC&A Comments on NIOSH Response	
	median and GSD values in Section 8.0 of TBD-6001.			
Observation 10	NIOSH states in Section 3.5 of TBD-6001 that, "The dose reconstructor should use the default values shown above. The default values of ICRP-66 (ICRP 1994) should be used." This is very confusing. In one sentence, the dose reconstructor is advised to use Table 3.12 and in the next, he is advised to use ICRP-66. In addition to confusing instructions, we believe that the correct reference should be ICRP-68, Annexe F, Table F.1. There are similar problems with the introductory material at the beginning of Section 8.0 in TBD-6001.			
Observation 11	While the assumption of a 5-µm AMAD is often used for calculating inhalation doses, it is of questionable relevance when calculating surface contamination levels (SC&A 2008, Section 6.1, p. 20).			
Observation 12	In its review of TBD-6000, SC&A raised some concerns about the use of an air concentration of 7 dpm/m^3 for non-operational areas of a plant (SC&A 2007, Section 5). We further note here that exposures to workers in non-operational areas may be higher than that (SC&A 2008, Section 6.1, p. 20).			
Observation 13	NIOSH should explain why the calculations discussed in Section 8.4.2 are not done on the same basis as those in Section 3.4.2 (SC&A 2008, Section 8.2, p. 36).			

a – SC&A 2008. *Draft Review of Battelle-TBD-6001, Site Profiles for Atomic Weapons Employers That Refined Uranium and Thorium*, Revision FO Dated December 13, 2006, Contract No. 200-2004-03805, Task Order No. 1, SCA-TR-TASK1-0026.
Note: The "Observations" tabulated above are based on comments made by SC&A in the text of SC&A 2008, but not specifically delineated as "Observations."

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