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Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

A Review of NIOSH's Program Evaluation Report DCAS-PER-068, "Electro Metallurgical Company"

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AWE	atomic weapons employer
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
dpm	disintegrations per minute
DR	dose reconstruction
ER	evaluation report
GSD	geometric standard deviation
m^3	cubic meter
MDA	used in text to indicate detection limit of the time
MED	Manhattan Engineer District
mo	month
mrad	millirad
mrem	millirem
N/A	not applicable
NIOSH	National Institutes for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
Pa-234m	metastable protactinium-234
PER	program evaluation report
POC	probability of causation
R	roentgen
R&D	research and development
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document
Th	thorium
TWA	time weighted average
UC	Union Carbide
UF_4	uranium tetrafluoride
WG	work group
Zr	zirconium

1 Statement of Purpose

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) assembled a large body of guidance documents, workbooks, computer codes, and tools. In recognition of the fact that all supporting elements in DR may be subject to revisions, provisions exist for evaluating the effect of such programmatic revisions on the outcome of previously completed DRs. Such revisions may be prompted by document revisions due to new information, misinterpretation of guidance, changes in policy, and/or programmatic improvements.

A program evaluation report (PER) provides a critical evaluation of the effects that a given issue or programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact on the probability of causation (POC) of previously completed DRs with POCs less than 50 percent.

During a teleconference by the Advisory Board on Radiation and Worker Health (ABRWH, "Board") Subcommittee for Procedure Reviews on June 21, 2023, the Board tasked SC&A to review DCAS-PER-068, revision 0, "Electro Metallurgical Company" (NIOSH, 2016), pertaining to the Electro Metallurgical Company ("Electro Met," "Electromet"). In conducting a PER review, SC&A performs the following five subtasks, each of which is discussed in this report:

- **Subtask 1:** Assess NIOSH's evaluation and characterization of the issue addressed in the PER and its potential impacts on DR. Our assessment intends to ensure that the issue was fully understood and characterized in the PER.

- **Subtask 2:** Assess NIOSH's specific methods for corrective action. When the PER involves a technical issue that is supported by documents (e.g., white papers, technical information bulletins, procedures) that have not yet been subjected to a formal SC&A review, subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, subtask 2 will simply provide a brief summary and conclusion of this review process.

- **Subtask 3:** Evaluate the PER's stated approach for identifying the universe of potentially affected DRs and assess the criteria by which a subset of potentially affected DRs was selected for reevaluation. The second step may have important implications where the universe of previously denied DRs is very large and, for reasons of practicality, NIOSH's reevaluation is confined to a subset of DRs that, based on their scientific judgment, have the potential to be significantly affected by the PER. In subtask 3, SC&A will also evaluate the timeliness of the completion of the PER.

- **Subtask 4:** Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. (It is assumed that the Board will select the DRs and the total number of DR audits for each PER.)

- **Subtask 5:** Prepare a written report that contains the results of DR audits under subtask 4, along with our review conclusions.

2 Relevant Background Information Pertaining to Facility Operations, Potential Source Terms, and Worker Monitoring Protocols

2.1 Facility operations

The Electro Met technical basis document (TBD), DCAS-TKBS-0007, revision 01 (NIOSH, 2015), provides background information on the facility and its operations. Electro Met, a Union Carbide (UC) subsidiary located in Niagara Falls, NY, was an existing ferro-alloy manufacturing plant when it was selected to participate in the nuclear weapons program. The nuclear weapons program portion of the plant ("Area Plant") became operational in March 1943 under contract to the Manhattan Engineer District (MED), a predecessor of the U.S. Atomic Energy Commission (AEC); subsequent contracts were with the AEC. The uranium operations facility occupied a single purpose-built, fenced-off, 50 × 219 foot, single-story building on the larger UC site. The mission of the Area Plant was to convert uranium tetrafluoride (UF_4, also referred to as "green salt") into uranium metal. It received the UF_4 from the UC Linde Air Products Division Plant (Linde) in Tonawanda, NY, and sent the finished product and residues to several other nuclear weapons program sites. The final contract terminated on June 30, 1953, when Electro Met purchased the facility from the AEC. Under the terms of the termination contract, Electro Met decontaminated the site, and, after the final cleanup survey on August 14, 1953, the site was released.

The conversion process from UF_4 to uranium metal was accomplished by mixing the UF_4 with magnesium, putting the mixture it into a metal "bomb" lined with dolomite (a refractory material), and heating the bomb in a furnace to initiate a vigorous exothermic ("thermite") reduction reaction. When finished, the bomb was opened, the uranium metal separated from the magnesium fluoride slag, and both components removed. The uranium was then cast into 110–135 kilogram ingots, which were later recast in a vacuum reduction furnace into billets that were shipped off site for further processing. Electro Met also received uranium scraps from other facilities and remelted the scraps into ingots (DOE, 1986).

Table 2 of TBD revision 01 (NIOSH, 2015) shows the operational history of the Electro Met plant, divided into three operations periods and three standby periods, with start and stop dates and, where applicable, associated average monthly uranium metal production rates. Although the design capacity of the plant was 50 tons of uranium metal per month, the actual production rate was consistently less. The TBD notes that other nonradiological processes might have occurred during the standby periods. Table 2 of TBD revision 01 is adapted here for convenience as table 1.

Table 1. Electro Metallurgical operating history

Description	Non-uranium-related standby operations	Start date	Stop date	Approximate uranium metal production rates, tons/mo [a]
Operations 1	N/A	8/13/1942	8/31/1946	44
Standby 1	Calcium metal production	9/1/1946	9/30/1947	N/A
Operations 2	N/A	10/1/1947	9/30/1949	26 (10/1947–6/1948) 35 (6/1948–6/1949)
Standby 2 – overall period	N/A	10/1/1949	1/1/1951	N/A
Standby 2 – Zr period	Zr production during standby	4/1950	9/1950	N/A
Operations 3	N/A	1/1/1951	6/30/1951	Not provided (research quantities)
Standby 3	N/A	6/30/1951	6/30/1953	N/A

Source: Adapted from NIOSH (2015), table 2.

[a] Production average from AEC (1951), p. 38.

TBD revision 01 observes:

> Contemporaneous reports provide that some 50-70 persons operated the Area Plant, others also mention that others from the plant provided support as needed with an estimated 30 additional persons who are not recorded including electricians and pipe fitters. [NIOSH, 2015, p. 21]

When in an operational period, the Area Plant ran three shifts of workers to support production. NIOSH is unaware of any complete lists of all Electro Met personnel over time and notes that "construction workers from other companies completed work in the Area Plant during active operations" (NIOSH, 2015, p. 22).

2.2 Source terms

Since Electro Met was exclusively processing uranium, uranium isotopes and members of their decay chains (also referred to as "progeny" or "daughter products") were the only radioisotopes of concern. For example, uranium-238, with a 4.3 billion year half-life, has 13 radionuclides, with half-lives ranging from short to very long, in its decay chain, eventually ending in stable lead-208. TBD revision 01 states:

> No documentation was found indicating there were other sources of radiation beyond what has been described at Electro Metallurgical during the covered period between 1942 and 1953. Processes used in the Area Plant caused uranium progeny to be non-uniformly distributed and/or concentrated in the materials and equipment causing documented high beta doses to some workers. [NIOSH, 2015, p. 11]

2.2.1 Internal monitoring

Section 4.0 of the Electro Met TBD discusses internal dosimetry for the different operations and standby time periods (refer to table 1 of this report). Revision 1 of the NIOSH SEC-00136

petition evaluation report (NIOSH, 2012, p. 3) defines a class of Electro Met employees to be included in the Special Exposure Cohort (SEC) class based on internal dose considerations:

> NIOSH finds it is not feasible to estimate internal exposures with sufficient accuracy for all workers at the site from August 13, 1942 through December 31, 1947. Internal monitoring data, work area radiological monitoring data, and source term data are not sufficient to provide a sufficiently accurate estimate of the bounding internal dose during this early period at Electro Metallurgical.

As shown in table 1, the defined SEC period encompasses the entire first operations period (August 13, 1942–August 31, 1946), the entire first standby period (September 1, 1946–September 30, 1947), and part of the second operations period (October 1, 1947–September 30, 1949). TBD revision 01 (NIOSH, 2015, p. 16) notes:

> A small group of employees at the Area Plant have bioassay data available to NIOSH during this period [1942–1947]. These values should be used with standard dose reconstruction methods to assess intake rates of uranium during the period.

After the SEC period, two large air sampling campaigns were conducted by the AEC's New York Operations Office Health and Safety Laboratory in November 1948 (AEC, 1949a) and in August 1949 (AEC, 1949b). UC's Linde plant health physics personnel conducted some measurements at Electro Met as well (AEC, 1948), but "they appear to be ad hoc and without further write-up" (NIOSH, 2015, p. 16). The TBD reports:

> The time weighted average (TWA) values determined from these [August 1949] measurements was lower than reported from the November 1948 samples and this was attributed to some changes that occurred to the practices and ventilation as well as the fact that the facilities doors [and windows] were open in August [providing outside air ventilation to the facilities] unlike during the November measurements. [NIOSH, 2015, p. 16]

In a claimant-favorable approach, NIOSH decided to use the higher November 1948 sampling data (facility windows and doors closed) for DR. TBD revision 01, table 3, lists TWA multiples of the preferred level (70 disintegrations per minute per cubic meter (dpm/m^3)) for different employee job titles (NIOSH, 2015). Most of the titles had associated TWA multiples greater than 1.0, ranging up to 577.0 for a green salt room operator. In a claimant-favorable decision, NIOSH chose to use the green salt room operator TWA with an uncertainty of geometric standard deviation (GSD) of 3 as the assumed air concentration data for all operational periods. It then used those values to determine ingestion intakes, following the guidance of OCAS-TIB-0009, revision 0 (NIOSH, 2004), during both the operational and standby periods. TBD revision 01, table 4, summarizes the assumed uranium air concentrations and ingestion rates per day for the individual operations and standby periods.

TBD revision 01 notes that "substantial floor contamination was clearly present as sweeping up of residues generated air borne concentrations up to 97,000 dpm/m^3" (NIOSH, 2015, p. 17). During the standby periods, when the uranium inventory in the plant would have been reduced,

TBD revision 01 assigns intake rates based on the TWA for the highest nonoperational job title (3.0 for a repairman) to account for internal dose from uranium contamination.

Figure 3 of TBD revision 01 (NIOSH, 2015) shows a graph of the lognormal distribution of air sampling data at the Area Plant, plotting air concentration data (dpm/m^3) as a function of Z-score. Figure 4 shows a graph of uranium bioassay data (milligrams uranium per liter urine) as a function of time and operations period. Doses were calculated using either type M or type S solubility, and the highest of the two was used for dose determinations.

2.2.2 External monitoring

Electro Met's mission was to process the incoming green salt into uranium metal and then to ship that metal out to other facilities for further processing. As described in section 5 of the Electro Met TBD, revision 01 (NIOSH, 2015, p. 22ff), the external radiation exposures to workers arose from beta and gamma radiation (not from very short range, nonpenetrating alpha radiation) from uranium isotopes and their progeny as they decay.

External exposures were not uniform for all job titles. Some of the processing steps exposed workers to particularly high beta fields as they "concentrated uranium progeny on the surfaces of the metal and also surfaces and residues of the production process (e.g., molds and slag)" (NIOSH, 2015, p. 22). For example, AEC (1948–1953) reports furnace operators with film badge readings of approximately 500–700 millirem (mrem)/week and some nonpenetrating dose levels measured up to 1,900 millirad (mrad)/week; these are far in excess of the recommended maximum levels at that time. Wearing of contaminated gloves (measured exposures of up to 2 roentgen (R)/8-hour day in 1944 and continuing afterwards) also elevated the beta dose to workers. Laundry washed at Linde was contaminated as well (measurements up to 15 mrad/hr beta on coveralls). TBD revision 01 notes, "However, since doses are being based on measured photon doses [rather than on beta doses], the issue of the contaminated laundry will not affect the assignment of dose at Electro Met" (NIOSH, 2015, p. 22).

"Limited external dosimetry data was collected over the operating history of the Area Plant" (NIOSH, 2015, p. 22). In addition, the quality of the available data in the first operations period (August 13, 1942–August 31, 1946) is questionable, as many of the dosimeter films were fogged. External dosimetry improved during the second operations period (October 1, 1947–September 30, 1949), and NIOSH has data for 58 employees representing 21 job titles from June 1948 through September 1949. TBD revision 01 claims that "Analysis of this data set provides for a claimant favorable dose reconstruction method (all workers at the 95th percentile) as compared to [the] operator category of TBD-6000 [NIOSH, 2011b]" (NIOSH, 2015, p. 23).

Table 5 of Electro Met TBD revision 01 (NIOSH, 2015) shows all the external dosimetry data by title for 21 job titles. For each title, the columns list the number of measurements available, the number with gamma measurements <detection limit of the time (MDA), the number with beta measurements <MDA, the percentage with gamma measurements >MDA, and the percentage with beta measurements >MDA; the MDA over the period was 50 mrem/week gamma and 50 mrad/week beta.

In addition to film badge data, Electro Met TBD revision 01 (NIOSH, 2015) also remarks that several hundred ring dosimeter measurements (used to register doses to hands and forearms) are also available, but not useful, as

> they were without worker titles and offer little information about how they were worn (with or without protective gear). Furthermore, the ring badges were worn by only a fraction of the employees and only for a limited time. [NIOSH, 2015, p. 26]

3 Subtask 1: Identify the Circumstances that Necessitated DCAS-PER-068

3.1 Chronology of events

The following outlines the events that led to the revision of the Electro Met TBD, which prompted NIOSH to issue DCAS-PER-068, revision 0 (NIOSH, 2016), assessing the revision's effect on prior DRs; additional events are also included to provide appropriate background. Note that the six ABRWH TBD-6001/Uranium Refining Atomic Weapons Employers (AWEs) Work Group (WG) meetings listed in this section are those that included discussions on Electro Met. Many of the activities concerning Electro Met SEC-00136 are relevant to this PER-068 review, since the SEC review entailed examination of TBD revision 01 (NIOSH, 2015).

Battelle-TBD-6001 ("TBD-6001"), revision F0 (Battelle, 2006): The AEC employed many facilities, including Electro Met, as part of the effort to refine uranium from ore to a desired final state. TBD-6001 describes the typical processes and provides guidance applicable to DR.

Battelle-TBD-6001, Appendix C, revision 0 (NIOSH, 2007): This is the original Electro Met site description, included as Appendix C to the general TBD for uranium processing facilities (Battelle, 2006). It was later extracted as a standalone Electro Met TBD in NIOSH (2011a).

SEC-00136 petition evaluation report, revision 0 (NIOSH, 2009): NIOSH evaluated the SEC-00136 SEC 83.13-type petition for all workers in any area of Electro Met from April 1, 1943, through June 30, 1953 (note that the SEC-00132 petition was merged into the SEC-00136 petition). NIOSH concluded that DR is feasible for the designated period.

SC&A review of SEC-00136 petition evaluation report (SCA-TR-SEC2010-0010, revision 0) (SC&A, 2010): SC&A reviewed revision 0 of the NIOSH petition evaluation report for SEC-00136 (NIOSH, 2009) as requested by the ABRWH at its October 20–22, 2009, meeting.

ABRWH TBD-6000 WG meeting, July 7, 2010 (ABRWH, 2010a): The meeting included a review of TBD-6001 issues and SC&A's findings and observations. The Electro Met-specific portion of the meeting (transcript pages 158–249) was concerned with the SEC-00136 petition evaluation report, revision 0 (NIOSH, 2009), and was organized around discussions of SC&A's findings.

ABRWH TBD-6001 WG meeting, November 4, 2010 (ABRWH, 2010b): The Electro Met portion of this meeting is found on pages 158–207 of the transcript. The discussion primarily continued that of the July 7, 2010, meeting (ABRWH, 2010a) concerned with the SEC-00136 petition evaluation report, revision 0 (NIOSH, 2009), especially the question of who is defined as a covered employee according to the U.S. Department of Labor (DOL): everyone in the entire Electro Met plant or only those in the much smaller Area Plant (the only portion that did uranium work)? NIOSH mentioned that it was in the process of canceling TBD-6001 and replacing its Appendix C on Electro Met with an updated individual site profile of its own.

Electro Met TBD, revision 00 (NIOSH, 2011a): As stated in the Record of Issues/Revisions section of the TBD: "Changes Battelle-TBD-6001 Appendix [C] to a standalone document.

Change is primarily format only. Does not incorporate review comments" (p. 2). This was basically a reformatting that does not change the technical material.

SC&A review of SEC-00136 petition evaluation report (SCA-TR-SEC2010-0010, revision 1) (SC&A, 2011): SC&A revised its earlier evaluation (SC&A, 2010) of revision 0 of the NIOSH petition evaluation report for SEC-00136 (NIOSH, 2009).

ABRWH Uranium Refining AWEs WG meeting, May 16, 2011 (ABRWH, 2011a): The Electro Met-specific discussion is included on pages 210–239 of the transcript. That discussion included all of SC&A's 17 findings (SC&A, 2011) on the NIOSH SEC-00136 petition evaluation report, revision 0 (NIOSH, 2009).

ABRWH Uranium Refining AWEs WG meeting, August 16, 2011 (ABRWH, 2011b): The WG received a brief update from NIOSH on its data-gathering efforts and progress on responding to SC&A's findings on the SEC-00136 petition evaluation report (NIOSH, 2009).

ABRWH Uranium Refining AWEs WG meeting, November 21, 2011 (ABRWH, 2011c): NIOSH stated that it had reassessed its SEC-00136 petition evaluation report (NIOSH, 2009) and concluded that it could not adequately reconstruct doses from 1942 to 1947 using back-extrapolation from the post-1947 period (due primarily to process improvements in the latter period, which marked a change from conditions in the former period). NIOSH proposed adding an SEC class from 1942 to 1947. NIOSH maintained that they can still reconstruct doses from 1948 through 1952.

SEC-00136 petition evaluation report, revision 1 (NIOSH, 2012): In its 2012 revision to its 2009 petition evaluation (NIOSH, 2009), NIOSH reevaluated the available information and concluded that it is not feasible to estimate internal doses with sufficient accuracy for the designated period due to inadequate bioassay, work area monitoring, and source term data. This is a change to its earlier (NIOSH, 2009) conclusion that these were feasible. However, external doses can be reconstructed. The revised report also changed the start date of the SEC period to August 13, 1942, to coincide with the start date of the MED. The end date of the SEC period, June 30, 1953, coincides with the end date of the facility's contract with the AEC (the successor to the MED).

ABRWH Uranium Refining AWEs WG meeting, February 14, 2012 (ABRWH, 2012): The WG continued to discuss SEC-00136. Based on a preliminary analysis, SC&A believed that NIOSH might be able to adequately reconstruct internal doses for the 1942 to 1947 time period, which is at odds with NIOSH's conclusion. The WG decided to wait until this issue is resolved before making recommendations to the Board.

SCA-TR-SEC2012-0010, revision 0 (SC&A, 2012): SC&A produced an addendum to its previous review (SC&A, 2011) of NIOSH's petition evaluation report for SEC-00136, revision 0 (NIOSH, 2009), in response to NIOSH's revised petition evaluation report (revision 1; NIOSH, 2012). This SC&A report is characterized as a "partial review" of the revised NIOSH petition evaluation report, reflecting the limited amount of time SC&A had to review the new material and produce a report on the NIOSH revision to support a request by the AWE WG (details of the timeline of reports supporting WG requests appear in SC&A (2012), page 4). The SC&A

addendum noted two overarching issues: (1) "the ability to identify and differentiate employees who worked in the Area Plant where . . . [AEC and MED] activities were conducted as compared to employees who worked in the commercial operations that constituted the majority of the activities at Electro-Met" and (2) "the ability to calculate bounding doses for the 'early operations' from August 13, 1942 through December 31, 1947." Attachment A to the 2012 SC&A report is an updated issues matrix consisting of the 17 findings of SC&A (2011).

Electro Met TBD, revision 01 (NIOSH, 2015): This was a major revision of the original Electro Met TBD, including greatly expanded sections on DR guidance and incorporation of the SEC designation for the early days of the plant. The issuance of this revised TBD prompted NIOSH to investigate the effect on prior DRs and to issue DCAS-PER-068 (NIOSH, 2016).

DCAS-PER-068, revision 0 (NIOSH, 2016): NIOSH issued this PER, which this current SC&A report is assessing, to evaluate the effect of revision 01 of the TBD (NIOSH, 2015) on the previously completed DRs and to present a plan for corrective actions.

3.2 SC&A's comments

SC&A reviewed each of the documents leading to changes incorporated into revision 01 of the Electro Met TBD (NIOSH, 2015). SC&A agrees with NIOSH that these changes and their impacts on Electro Met worker doses mandate the need for DCAS-PER-068 (NIOSH, 2016).

There are no findings pertaining to subtask 1.

4 Subtask 2: Assess NIOSH's Specific Methods for Corrective Action

NIOSH produced DCAS-PER-068 (NIOSH, 2016) to report on its evaluation of the effects on its prior DRs of revising the Electro Met TBD to revision 01 (NIOSH, 2015) and to present its plan for any required corrective actions. Although SC&A has not formally reviewed Battelle-TBD-6001, revision 0 (NIOSH, 2007), DCAS-TKBS-0007, revision 00 (NIOSH, 2011a), or revision 01 of the TBD (NIOSH, 2015), it has tangentially examined these revisions during its SEC-00136 evaluation. Since the WG has not asked SC&A to perform a full TBD review, this report conducts a limited review focusing on DCAS-PER-068.

4.1 Overview of SC&A's previous review of Electro Met SEC-00136

Since revision 01 of the Electro Met TBD (NIOSH, 2015) was largely motivated by the papers of NIOSH and SC&A and the discussions at WG meetings regarding SEC-00136, it would be useful to this review to begin with a brief discussion of the relevant issues raised; section 3.1 of this report is a chronology of those events.

NIOSH issued its SEC-00136 petition evaluation report in 2009 for all workers in any area of Electro Met (not just the relatively small Area Plant, where all uranium processing was done) from April 1, 1943, through June 30, 1953 (NIOSH, 2009). SC&A evaluated this petition in April 2010 (SC&A, 2010), and potential issues were identified and discussed at subsequent WG meetings (ABRWH, 2010a, 2010b, 2011a). Following additional interviews, SC&A produced a revised evaluation in 2011 containing 17 findings, summarized on pages 6–8 of the executive summary (SC&A, 2011).

Following further WG discussions (ABRWH, 2011b, 2011c), NIOSH revised its SEC-00136 petition evaluation report (rev. 1) in January 2012 (NIOSH, 2012), where, notably, it (1) changed the SEC period to August 13, 1942, through June 30, 1953, and (2) changed its determination of the feasibility of internal DR during the SEC period from feasible to not feasible due to inadequate bioassay, work area monitoring, and source term data. The revised SEC petition evaluation report was discussed at the February 2012 WG meeting (ABRWH, 2012). SC&A produced, also in February 2012, an addendum to its previous review report in response (SC&A, 2012). The 2012 SC&A evaluation report review contains an updated issues matrix of the 17 findings, including SC&A comments; SC&A (2011) has a detailed discussion of the findings.

For convenience in this report, table 2 is a summary of the findings and their status, taken from SC&A (2011) and WG discussions in ABRWH (2011a); the accompanying page numbers are the starting points of the discussions on the findings from the ABRWH meeting transcript. SC&A also examined the later WG meeting transcripts (ABRWH, 2010b, 2011c, 2012) and noted that, although certain issues were discussed, there was no systematic review of the 17 findings. Although there was frequent agreement on a finding (e.g., that it is resolved, not pertinent to an SEC evaluation, or that NIOSH needs to do further work), as far as SC&A could find in the transcripts, the WG did not classify any of them as either closed, open, or in abeyance: hence, they are all formally still open, or at least in progress. Note that these 17 findings are based on reviews and discussions of revision 00 of the TBD (NIOSH, 2011a), not the latest revision 01 (NIOSH, 2015), and that SC&A has not been tasked with reviewing revision 01 to see if it satisfactorily resolves all the findings made on revision 00.

Table 2. Summary of SEC-00136 findings based on Electro Met TBD revision 00

No. (page number [a])	SC&A finding	Status [b]
1 (p. 210)	NIOSH should discuss the issue of access controls explicitly in the ER to justify the basis for including all workers at Electro Met, rather than just those who worked in the Area Plant.	NIOSH requested worker location clarification from DOL.
2 (p. 215)	R&D work with uranium ores was not mentioned in NIOSH (2009). While the information reviewed here does not indicate that significant quantities of uranium-bearing materials other than green salt were used by Electro Met, NIOSH should address the scope of work that might actually have been done at Electro Met (and in which facilities).	R&D was conducted for a short period using small quantities of low-grade African ore. SC&A is satisfied.
3 (p. 216)	NIOSH should review the start and end dates for the operational period to ensure that all relevant documentation has been evaluated.	Start and end dates should be revised to be consistent in the ER and the TBD to reflect those of the MED and AEC contracts.
4 (p. 217)	The NIOSH assumption that the uranium metal reduction process and associated industrial production and industrial hygiene conditions were unchanged from 1943 to 1949 may not be correct. The changes that appear to have been made in 1947 would need to be investigated before this assumption can be used to implicitly back-extrapolate post-October 1947 data to the 1943–1946 period. (Refer also to finding 17.)	Open
5 (p. 222)	NIOSH should clarify the text to remove what appears to be an inconsistency regarding the availability of internal exposure data during standby periods.	NIOSH modified text in revised ER. Minor issue that was resolved between SC&A and NIOSH at the Feb. 2012 WG meeting.
6 (p. 223)	NIOSH should take into account the difference between fixed head samplers, process samplers, and general area samplers and actual intake, and the uncertainties this creates for estimating bounding intakes.	Finding relates to how DRs are performed; not an SEC issue. Issue was resolved between SC&A and NIOSH at the Feb. 2012 WG meeting.
7 (p. 224)	NIOSH needs to establish that job titles corresponded to the jobs actually done for the period of employment. NIOSH's job title consolidation scheme would not produce bounding estimates for all workers in the proposed class in the absence of such an analysis.	SC&A and NIOSH agreed at the Feb. 2012 WG meeting that this finding relates to how DRs are performed; not an SEC issue.
8 (p. 225)	We note that the graphical method used by NIOSH in Appendix C of TBD-6001 (NIOSH, 2007) to calculate the inhalation intakes for operators results in the lowest estimate of the 95th percentile among possible alternative calculational approaches. Arguably, in this case, the graphical method is not claimant favorable.	SC&A and NIOSH agreed at the Feb. 2012 WG meeting that this finding relates to how DRs are performed; not an SEC issue and also a global issue.

No. (page number [a])	SC&A finding	Status [b]
9 (p. 230)	The site-specific values for inhalation intakes for Electro Met from Appendix C are significantly more claimant favorable than the generic intakes proposed in table 8.29 of TBD-6001, rev. F0 (Battelle, 2006), which raises questions as to whether TBD-6001 is appropriately conservative for its intended purpose. This is noted for the record, but it is not an Electro Met finding.	SC&A and NIOSH agreed at the Feb. 2012 WG meeting that this is moot since TBD-6001, rev. F0 (Battelle, 2006), is no longer applicable.
10 (p. 230)	Given the high frequency of blowouts at other facilities using the same equipment, NIOSH should reexamine the possibility that blowouts occurred at Electro Met.	Additional reviews have not uncovered evidence of blowouts.
11 (p. 232)	NIOSH should address residual exposures in the SEC-00136 petition evaluation report.	Since the Area Plant was an AEC facility, evaluation of exposures during the residual period is not required.
12 (p. 232)	NIOSH should provide more detailed information to support their position in section 7.2.3 of NIOSH (2009) that, “considering the intake scenarios established in Battelle-TBD-6001 Appendix C, the calculated urinary excretion of uranium from these intakes was compared to actual data and was found to be bounding in each case” (p. 26). Independent calculations by SC&A do not support this conclusion on the bounding nature of the intakes in Appendix C, table C.2.	The Electro Met TBD and the revised ER eliminated discussions about comparing actual and calculated excretion rates. NIOSH will investigate further.
13 (p. 234)	The approach taken to bound external photon exposure values in table C.4 of TBD-6001, Appendix C, appears to be reasonable for the operating period beginning June 1948. However, NIOSH must demonstrate that this approach is bounding for the earlier operating period, when essentially no film badge data are available. In addition, NIOSH should explicitly define in Appendix C how to proceed with DR when the job description is uncertain or unknown.	Not resolved.
14 (p. 235)	NIOSH should state in the petition evaluation report for SEC-00136 and in Appendix C of TBD-6001 that 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 DOE sites. This is a DR issue, not an SEC issue.	DR, not an SEC issue, and photofluorography was practiced only at larger AEC facilities. Not resolved.
15 (p. 236)	SC&A independently developed a database for annual beta and found that the 95th percentile value was in excellent agreement with that developed by NIOSH for table C.5. However, 50th and 95th percentiles were somewhat higher, based on the SC&A analysis. Consequently, it is possible that the dose to Supervisor/Laborers could be understated by about 40% and the dose to Others by about 80%.	DR, not an SEC issue, but should be investigated.

No. (page number [a])	SC&A finding	Status [b]
16 (p. 237)	Use of 95th percentile exposures, as proposed in tables C.4 and C.5 of TBD-6001, Appendix C, adequately accounts for enhanced exposures from high surface concentrations of Th-234 and Pa-234m produced during melting and casting of uranium ingots, except for exposures to the hands and arms. Table C.5 is specific to "Other Skin." Guidance should be added to Appendix C to specifically address exposure to the hands and arms.	Dose reconstruction, not an SEC issue.
17 (p. 238)	NIOSH needs to provide convincing arguments that 95th percentile values based on 1948/1949 data are bounding for the period prior to December 1947.	Not resolved.

[a] Page numbers refer to meeting minutes from the May 16, 2011, WG meeting (ABRWH, 2011a).

[b] As far as SC&A can determine, the WG has not assigned a status to any of the findings; hence, they are all considered in progress.

SC&A was not tasked with reviewing revision 01 of the TBD but performed a cursory comparison of revision 01 (NIOSH, 2015) to revision 00 (NIOSH, 2011a) to see how it might affect calculated doses. The Records of Issue/Revisions section of TBD revision 01 summarizes the changes made from revision 00:

> Revision to incorporate Special Exposure Cohort designation information throughout the document. Added and revised information throughout the document regarding a correction in the start date for MED work. Substantial update of the document with re-analysis of the external and internal dosimetry data. Constitutes a total rewrite of the document. [NIOSH, 2015, p. 2]

Section 2.0 of DCAS-PER-068 (NIOSH, 2016, p. 1) notes an increase in external dose estimates for all claims using information in revision 01 of the TBD ("The external dose from Table 7 shall be used to determine dose for all Electro Met employees" (NIOSH, 2015, p. 29)) compared to those using revision 00 (table 3; NIOSH, 2011a, p. 7). Internal dose data are summarized in table 4 of TBD revision 01 (NIOSH, 2015, p. 19) and in table 2 of revision 00 (NIOSH, 2011a, p. 6).

4.2 SC&A's comments

TBD revision 01 (NIOSH, 2015) is a substantial revision of TBD revision 00 (NIOSH, 2011a), which was only a repackaging of Appendix C to Battelle-TBD-6001, revision 0 (NIOSH, 2007). TBD revision 01 added material on the granted SEC-00136, incorporating many more monitoring and other data, and updating and expanding its methods and guidance. Absent a full review of the TBDs, SC&A believes that revision 01 of the TBD is an improvement on what came previously. For example, as reported about internal monitoring in section 2.2.1 of this report, NIOSH made several very claimant-favorable assumptions in determining air concentrations and, therefore, resulting inhalation and ingestion doses: It adopted the November 1948 air sampling dataset and chose air concentration data for a green salt room operator for all operational periods, which was many multiples of the TWA.

Section 2.0 of DCAS-PER-068 (NIOSH, 2016, p. 1) discusses external dose rates:

> The revision [NIOSH, 2015] also incorporated a re-evaluation of data and information as a result of the SEC review process. One change in the revision was an increase in the external photon dose rates for all years. That change resulted in an increased external dose estimate for all claims completed using an earlier version.

In light of this statement, SC&A examined NIOSH's approach to assigning external doses found in section 5.0 of the TBDs, comparing the approach in revision 01 (NIOSH, 2015) to that in revision 00 (NIOSH, 2011a). (Note that, as stated elsewhere in this report, SC&A's PER review is not intended to be a detailed assessment of the TBDs.) The first obvious observation is that the revised external dose section contains much more information and guidance, expanding from about 1 page to about 13 pages. The revised section now contains lengthy discussions of operations that affected external dose, available data, a table showing external dosimetry monitoring by job title (table 5), and a separate section providing detailed information on how external dose is assigned. Some highlights of the latter are (NIOSH, 2015, p. 29):

- *Item 2:* "Photon and Beta dose during operations was determined using the 95th percentile of all badged worker data."
- *Item 3:* "Photon dose during standby was determined using the geometric mean of all badged worker data."
- *Item 4:* "Non-penetrating dose to other skin is assigned based on the recommended 10 times the photon dose to account for incorrectly worn badges."
- *Item 5:* "Beta doses to the hands and forearms during standby periods are determined using whole body skin doses (10 times the GM of photon dose)."
- *Item 6:* "The annual dose values shall be assigned as the geometric mean for that period with an uncertainty equal to a GSD of 3."

Assigned annual external doses are given in table 3 of TBD revision 00 (NIOSH, 2011a) and table 7 of TBD revision 01 (NIOSH, 2015). TBD revision 00 assigns doses to three job categories: operators, supervisors/laborers, and others. TBD revision 01 assigns doses to all workers based on the guidance of items 2 and 3 in the preceding list. The resulting external doses are summarized here in table 3, illustrating that TBD revision 01 assigned doses are substantially greater than those for TBD revision 00, and hence are claimant favorable.

Table 3. Comparison of TBD revision 01 and revision 00 external dose assignments

TBD revision, period	Photon whole-body dose, mrem/year	Nonpenetrating dose to other skin, mrad/year	Nonpenetrating dose to hands and forearms, mrad/year
Rev. 00, Operations	Operators: 3,934 Supervisors/Laborers: 1,003 Others: 256	Operators: 21,030 Supervisors/Laborers: 3,221 Others: 493	N/A
Rev. 01, Operations	All: 4,403	All: 44,030	All: 276,000
Rev. 00, Standby	All: 256	All: 493	N/A
Rev. 01, Standby	All: 1,356	Al: 13,560	All: 13,560

Sources: TBD revision 00 (NIOSH, 2011a), table 3; TBD revision 01 (NIOSH, 2015), table 7).

5 Subtask 3: Evaluate the PER's Stated Approach for Identifying the Number of DRs Requiring Reevaluation of Dose

5.1 NIOSH's selection criteria

Section 3.0 of DCAS-PER-068 describes the process NIOSH used to evaluate the effect that the introduction of TBD revision 01 (NIOSH, 2015) might have had on already-completed DRs. Since the number of previously completed DRs was small, NIOSH was able to examine all claims with a POC of <50 percent, which amounted to 63 cases. NIOSH then deleted from consideration 25 of those cases that qualified for inclusion within the SEC. After performing new DRs on the remaining 39 cases, NIOSH found that 19 of those still had POCs <45 percent and 20 had POCs >52 percent.

5.2 SC&A's comments

The selection criteria used by NIOSH for previously completed DRs that require reevaluation under DCAS-PER-068 are valid; i.e., NIOSH evaluated all noncompensated claims not included in the SEC. There are no findings associated with subtask 3.

6 Subtask 4: Conduct Audits of a Sample Set of Reevaluated DRs Mandated by DCAS-PER-068

Previous sections of this report described changes introduced in revision 01 of the Electro Met TBD (NIOSH, 2015) that increased the dose assigned for the operational periods. NIOSH identified 63 previously completed claims with a POC <50 percent, eliminated 25 that are within the SEC designation, and performed a new dose estimate on the remaining 39 claims using revision 01 of the TBD. This process resulted in 19 of those claims with POCs <45 percent but 20 claims with POCs >52 percent.

SC&A recommends the Board select for additional evaluation two DRs with POCs still <45 percent after NIOSH reworked them, for production workers covering the operational periods.

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