Draft

ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF NIOSH PETITION EVALUATION REPORT FOR PETITION SEC-00136 DATED JULY 21, 2009, ELECTRO-METALLURGICAL CORPORATION

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Prepared by

William C. Thurber
S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, Virginia 22182

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

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Project Manager: _________________________ Date: ___________ John Mauro, PhD, CHP	Reviewers: Arjun Makhijani John Mauro

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LIST OF ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AWE	Atomic Weapons Employer
dpm	disintegrations per minute
DOE	U.S. Department of Energy
DWA	daily weighted average
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
GA	general air
GM	geometric mean
GSD	geometric standard deviation
IMBA	Integrated Modules for Bioassay Analysis
MAC	maximum air concentration
MED	Manhattan Engineer District
Mg	magnesium
MLE	maximum likelihood estimate
mr	milli-roentgen
mrad	millirad
NIOSH	National Institute for Occupational Health and Safety
NYOO	New York Operations Office
OCAS	NIOSH Office of Compensation and Support
ORAUT	Oak Ridge Associated Universities Team
pCi	picocurie
pdf	portable document format
PFG	photofluorography
R&D	Research and Development
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document

EXECUTIVE SUMMARY

The Advisory Board on Radiation and Worker Health (ABRWH) requested that SC&A review the Special Exposure Cohort (SEC) Petition Evaluation Report, Petition SEC-00136, for the Electro-Metallurgical Corporation (Electro-Met) prepared by the National Institute for Occupational Safety and Health (NIOSH) (NIOSH 2009). This report presents SC&A's review of the SEC-00136 Petition Evaluation Report and related documents. Beginning in 1943, the Electro-Met received uranium tetrafluoride (UF_4), or green salt, from the Linde Division of Union Carbide in Tonawanda, New York, and processed this salt into uranium metal. The uranium metal was recast into ingots suitable for fabrication and shipped to a variety of locations for further processing.

A petition was filed on behalf of a former employee at Electro-Met requesting that Electro-Met employees who worked on atomic weapons during the period from April 1943 through June 1953 be added to the SEC. NIOSH reviewed the petition and concluded that it had sufficient information to estimate bounding radiation doses, or to estimate doses more precisely than the maximum dose, and therefore the Electro-Met employees should not be added to the SEC.

To some extent, the current review is also a review of certain aspects of Battelle-TBD-6001 and its Appendix C, since these documents provide the basis for NIOSH's assumed ability to calculate bounding doses. In the course of its review, SC&A made a number of findings that are summarized below.

Finding 1: *NIOSH should discuss the issue of access controls explicitly in the Evaluation Report to justify the basis for including all workers at Electro-Met, rather than just those who worked in the Area Plant.*

Finding 2: *Research and Development (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).*

Finding 3: *NIOSH should review the start and end dates for the operational period to insure that all relevant documentation has been evaluated.*

Finding 4: *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. (See also Finding 17.)*

Finding 5: *NIOSH should clarify the text to remove what appears to be an inconsistency regarding the availability of internal exposure data during standby periods.*

Finding 6: 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 7: 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.

Finding 8: We note that the graphical method used by NIOSH in Appendix C of TBD-6001 (Battelle 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.

Finding 9: 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 (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.

Finding 10: Given the high frequency of blowouts at other facilities using the same equipment, NIOSH should re-examine the possibility that blowouts occurred at Electro-Met.

Finding 11: NIOSH should address residual exposures in the SEC-00136 Petition Evaluation Report.

Finding 12: NIOSH should provide more detailed information to support their position stated 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." Independent calculations by SC&A do not support this conclusion as to the bounding nature of the intakes in Appendix C, Table C.2.

Finding 13: 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 dose reconstruction when the job description is uncertain or unknown.

Finding 14: 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.

Finding 15: 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 5th 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%.

Finding 16: 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.

Finding 17: NIOSH needs to provide convincing arguments that 95th percentile values based on 1948/1949 data are bounding for the period prior to December 1947.

Revision 0 of this report (April 12, 2010) included one worker interview in Appendix E. Since Revision 0 was issued, we have conducted additional interviews and have, accordingly, revised Appendix E to summarize all of the worker interviews.

1.0 INTRODUCTION

At the October 20–22, 2009, meeting of the Advisory Board on Radiation and Worker Health (ABRWH) in Port Jefferson, New York, the ABRWH requested that SC&A review the SEC Petition Evaluation Report, Petition SEC-00136, Electro-Metallurgical Corporation,[1] prepared by the National Institute for Occupational Safety and Health (NIOSH) (NIOSH 2009). This report presents SC&A's review of the SEC-00136 Petition Evaluation Report and related documents.

At various times during the period from April 1, 1943, through June 30, 1953, the Electro-Metallurgical Corporation (Electro-Met) received uranium tetrafluoride (UF_4), or green salt, from the Linde Division of Union Carbide in Tonawanda, New York, and processed this salt into uranium metal. The uranium metal was recast into ingots suitable for fabrication and shipped to a variety of locations for further processing. A petition was filed in December 2008 by the survivor of one of the employees at Electro-Met requesting that a group of Electro-Met employees be added to the Special Exposure Cohort (SEC). NIOSH reviewed the petition and determined that (NIOSH 2009, p. 3):

> *Per Energy Employees Occupational Illness Compensation Act of 2000 (EEOICPA) and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to (1) estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class; or (2) estimate radiation doses of members of the class more precisely than an estimate of maximum dose. Information available from the site profile and additional resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the evaluated class under plausible circumstances during the specified period.*

In the particular case of Electro-Met, NIOSH has chosen the approach of estimating the maximum, or bounding, dose.

In the following sections, SC&A presents its independent review of the SEC petition, the NIOSH Petition Evaluation Report, and related dose reconstructions.

[1] At the beginning of the Manhattan Engineer District work in 1943, the Electro-Metallurgical Company, the National Carbon Company, and the Linde Air Products Company were all units of Union Carbide and Chemical Corporation. Successor organizations included the Metals Division, the Carbon Products Division, and the Linde Division of Union Carbide Corporation.

2.0 REVIEW OF PETITION SEC-00136

A petition to add "All workers who worked in any area at the Electro-Metallurgical Corporation facility, for the period from August 13, 1942 through December 31, 1953" was received by NIOSH on December 2, 2008, and qualified on March 12, 2009. The basis for the petition, as stated on Form B, Section F.1, of the SEC Petition was that only limited data on the range of air concentrations were available for dose reconstruction. Because uranium processing did not begin until April 1943 and the contract with the AEC ended in June 1953, NIOSH modified the proposed class definition to include "All workers who worked in any area at the Electro-Metallurgical Corporation for the period from April 1, 1943 through June 30, 1953."

A second petition (SEC-00132) was received on November 14, 2008. This petition was merged with SEC-00136. According to Form B, Section E, the proposed class definition in Petition SEC-00132 was all workers who worked in the entire building (50 × 217) from September 29, 1952, through August 31, 1959. The petitioner indicated in a letter dated January 7, 2009 (CCR 2009), that it was acceptable to change the covered period to 1942–1953 and reaffirmed that the petition was "on behalf of all employees who worked in the Electro-Metallurgical facility (one 50 × 219 building)." This is significantly different from the NIOSH proposed class of "all workers who worked in any area at the Electro-Metallurgical Corporation." One definition includes the entire industrial plant whose main function was to produce commercial metallurgical products for steel-making and other heavy industries, while the other definition includes only the facility specifically constructed for Manhattan Engineer District (MED)/ Atomic Energy Commission (AEC) work. Given the differences in the size of one building versus the entire plant, the ambiguity in the area covered by the petitions needs to be clarified, perhaps through additional interviews and data capture efforts.

The SEC-00132 petition includes a February 27, 2008, letter from Union Carbide discussing the energy employee's employment history with that company. It is stated in the letter that, "It appears that he spent his entire career with the Carbon Products division." The Carbon Products Division of Union Carbide (see footnote 1) operated several plants at Niagara Falls. Thus, it is possible that the presumed energy employee worked for Carbon Products, rather than Electro-Met. Again, whether the Atomic Weapons Employer (AWE) operations of concern to this petition include a limited number of buildings or the entire Electro-Met plant is critical, not only to the definition of the class, but also to the reconstruction of doses to AWE workers.

We note in Section 5.1 of the Petition Evaluation Report (NIOSH 2009) that MED and the successor AEC contracted with Electro-Met to build a special facility for the weapons work—the Area Plant. The Area Plant was fenced in and housed all the operations required under the government contract. The plot plan in Appendix C provides the reader with some idea as to the physical separation of the Area Plant from other facilities on the Electro-Met site. However, an interviewee (see Appendix E) states that initial work was performed at the Research Building, which apparently is separate from the Area Plant. More than one building in the plot plan (Appendix C) has the term "Research" in it. It is not clear to SC&A whether the work was in one of these two buildings, or whether another building was meant by the interviewee. Some discussion of this area is needed in order to ensure a full understanding of the AWE activities that took place at Electro-Met. SC&A is doing some follow-up in this regard, and will provide any new information in a supplemental report.

The Petition Evaluation Report does not establish whether workers may have been assigned to both the Area Plant and the other Electro-Met facilities at different time periods. However, information in Blatz 1949 (pdf p. 32) indicates that about 30 workers provided intermittent services to the Area Plant. Intermittent services ranged from electricians, who worked about 2 days per month, to pipe fitters, who worked 2 or 3 days per year. The Area Plant Plot Plan (Appendix D) indicates that the uranium facility was gated; [redacted] guards were part of the Area Plant work force. In response to written questions, one former worker indicated that there was a chain link fence around the Area Plant with a guarded gate. Workers were required to show a badge to obtain entry. Details are provided in Appendix E. In addition, TBD 6001 Appendix C states that, "[a]vailable information indicates that all uranium operations (including the business office lunchroom and shipping areas) were conducted within a single building" (Battelle 2007, Appendix C, p. 1).

The issue of access control to the Area Building and the scope of employees covered should be further explored through additional employee interviews with those who were actually involved with MED/AEC work. If there were other buildings, such as the Research Building, where substantial AWE activities were carried out during one or more periods, access control evaluations would also be relevant for these buildings. An exploration of the issue, which is not discussed in the Evaluation Report, is warranted, since NIOSH has included all workers at the entire Electro-Met in the facility, even though it appears that only a small fraction of the total workforce did AEC-related work. Most of the AEC work was done in the Area Plant, where there is evidence of access controls.

<u>Finding 1</u>: NIOSH should discuss the issue of access controls explicitly in the Evaluation Report to justify the basis for including all workers at Electro-Met, rather than just those who worked in the Area Plant.

3.0 REVIEW OF NIOSH PETITION EVALUATION REPORT FOR SEC-00136

3.1 DESCRIPTION OF ELECTRO-MET ACTIVITIES RELATED TO ATOMIC WEAPONS PRODUCTION

All uranium production operations were carried out in the Area Plant, which was specifically built by Electro-Met for the required work under Contract W-7405-Eng-14. The Area Plant was situated in a fenced-in area on land owned by Electro-Met (ElectroMet 1946a, pdf p. 5). The location of the Area Plant in relation to other nearby Electro-Met facilities is shown in Appendix C.

Operations at the Area Plant involved the reduction of UF_4 (green salt) to uranium metal, and recasting the metal into ingots suitable for further fabrication by rolling or extrusion. Green salt was shipped to Electro-Met from Linde. The green salt mixed with magnesium was packed into a metal bomb lined with a refractory material (e.g., dolomite). The bomb was placed in a furnace and heated to a temperature sufficient to initiate an exothermic reduction reaction. When the reaction was complete, the bomb was opened and the uranium metal was separated from the MgF_2 slag. The resultant uranium biscuits weighed between 110 and 135 kg. The biscuits were cleaned by chipping away any adhering slag, and then remelted and recast in a vacuum induction furnace. The recast ingots were shipped offsite for further fabrication. Electro-Met also received uranium scrap from other contractors and remelted this scrap into ingots. Electro-Met shipped process residues, including dolomite slag, crucible dross, and uranium chips, offsite for storage, disposal, or uranium recovery (DOE 1986).

The design capacity of the plant was 50 tons of uranium metal per month as billets;[2] actual production was lower, averaging 44 tons/month from April 1943 through August 1946, when the plant was placed on standby. The plant began restart operations during the last week of November 1947 (AEC 1947, pdf p. 30). Table 5-1 of NIOSH 2009 indicates that restart occurred in October 1947, and production for Fiscal Year (FY) 1948 was about 26 tons/month. The average production rate in FY 1949 was about 35 tons/month (NYOO 1951, pdf p. 38). According to the New York Operations Office of the AEC (NYOO 1951), the plant was shut down in October 1949, and the report makes no mention of further activities prior to issuance of the NYOO report on May 22, 1951. The plant was given a "thorough vacuum cleaning and washing of the entire area" after shutdown (NYOO 1951, pdf p. 52). The staff included 70 employees (NYOO 1951, pdf p. 52).

The MED contract also provided for research and development (R&D) work. Apparently, some work was done under this contract provision from April through October 1945. "The exact nature of the work is not known, but it may have involved low- or high-grade uranium ores" (DOE Undated). A March 17, 1945, letter from the War Department to Electro-Met discusses R&D work specifically on uranium extraction from low-grade ores (Kelley 1945). Another indication of R&D activities is a letter from the War Department (Corps of Engineers) to

[2] According to SRDB 59225, the capacity was 30 tons/month, and according to SRDB 9036, the production rate was 45 tons/month.

Electro-Met, dated October 7, 1943 (War Department 1943), describing problems with reactivity of Product 65 (UO_2) supplied by the Laboratories to Harshaw Chemical Company compared to Product 65 from other suppliers. The letter requested that the Laboratory prepare a 6,000-lb sample of Product TC (UO_3) and send half to Mallinckrodt for reduction to Product 65. The other half was to be reduced at the Laboratories. The basic processes at Harshaw involved the conversion of UO_2 to UF_4 (Product O-71) and conversion of UF_4 to UF_6 by reaction with F_2. According to AEC 1949, Mallinckrodt supplied Harshaw with its UO_2 feedstock. Thus, it is not known to what extent the Electro-Met laboratories supplied UO_2 to Harshaw. It is possible that only experimental quantities were involved. A search for information related to Harshaw on the NIOSH secure web site did not reveal any use of feedstocks from Electro-Met. It should also be noted that the Corps of Engineers request was directed to the Electro-Met laboratories on Royal Avenue. As shown on the site plan in Appendix C, the Area Plant was a separate facility from the research laboratories building.

We have uncovered no evidence that the Area Plant contained the requisite equipment to convert ore into UO_2; the Area Plant received green salt from Linde and processed it into uranium billets. Processing of ore to UO_2 requires digester tanks, filter presses, driers, precipitation tanks, and hydrogen reduction furnaces. The absence of ore processing equipment is supported by the equipment list in the *Completion Report for the Construction of Electro Metallurgical Company Area Plant* (Electro-Met 1946a), which includes vacuum induction furnaces and bomb heating furnaces, but none of the items needed for ore processing.

Indication of other R&D activities is a letter from the Corps of Engineers to the Linde Air Products Company, dated February 17, 1944, advising Linde to ship 25 lbs of high-grade ore to Electro-Met for experimental work (War Department 1944). In addition, according to War Department 1945 (pdf p. 6), 2 lbs of uranium tetrachloride, 3 lbs of uranium tetrafluoride, and 1 lb of UO_2F_2 were shipped to Electro-Met in the second quarter of 1945 for experimental use. It was noted in a progress report on R&D projects, dated March 15, 1945 (Unknown 1945, pdf p. 14), that Electro-Met had started small-scale casting of rods in graphite. This work was done in anticipation of a possible process change from casting billets to casting rods.

The processing of ores, and notably of high grade ores, would have introduced radionuclides other than uranium-234, -235, and -238, and the short-lived decay products of uranium-238 (Th-234 and Pa-234m). Specifically, the ores would contain thorium-230 and radium-226, with the latter causing radon emissions. Furthermore, raffinate streams would have concentrated thorium-230 and radium-226, for which uranium urinalysis would not provide a satisfactory basis for dose reconstruction. The presence of these radionuclides would make the use of TBD-6001 Appendix C inappropriate, since this document does not cover radionuclides other than uranium. Given that the dose conversion factors for thorium-230 are more than 2 orders of magnitude larger than those for U-234 (the reference uranium radionuclides used in dose reconstruction) for the bone surface and the red bone marrow, and more than an order of magnitude larger for several other organs and the whole body, it is important to identify the specific activities that were carried out, and explore the relevance of the available data to be used to put a scientifically plausible upper bound on doses.

<u>Finding 2</u>: Research and Development (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).

Uranium processing began in April 1943 and continued until September 1949, except for the period from September 1, 1946, through September 30, 1947. The start date is attributed by NIOSH (2009, p. 14) to NYOO (1951, p. 31). However, the weekly report to the District Engineer for the period December 26, 1942, through January 1, 1943, states that Electro-Met experimentally cast 175 pounds of uranium during the week. This material was referred to as "crude metal," which required recasting elsewhere (Crenshaw 1943). Uranium processing ceased in September 1949, when the Area Plant was again placed in standby. From April until September 1950, the plant was reactivated to cast zirconium sponge, and then again returned to the standby mode. From January through June 1951, the Area Plant was used for an R&D contract with the AEC to study metal forming techniques that would reduce finishing operations and reduce waste. Although the contract was not specific, DOE presumed that the contract involved uranium metal (DOE 1986). But, as noted above, NYOO makes no mention of additional production activities after shutdown in October 1949 (NYOO 1951). It is stated in DOE 1986 that, "AEC involvement at the site ended when Contract W-7405-Eng-14 expired on June 30, 1953." However, DOE (1986, pdf p. 4) is ambiguous about the end of AEC involvement.[3] In the sentence prior to that quoted above, DOE states that, "Later, just prior to demolition, the building was also apparently used for titanium processing (contract number unknown)." This is important, because it creates an opportunity for exposure to residual radioactivity between June 30, 1953, and the time of building demolition.

<u>Finding 3</u>: NIOSH should review the start and end dates for the operational period to insure that all relevant documentation has been evaluated.

After the contract expired, the Area Plant was purchased by Electro-Met. Electro-Met decontaminated the plant and equipment using washing, vacuuming, and, in some locations, removing concrete floors and wooden platforms (DOE 1986). The plant was then surveyed by the Health and Safety Division of the AEC in August 1953. Alpha counting of smear samples is reported in Smear Results 1952–1953. The maximum alpha count observed on 28 samples was 711 dpm/sample (arithmetic mean - 158 dpm/sample). This maximum was higher than for a December 1952 pre-decontamination survey involving 164 samples, where the maximum was 300 dpm/sample (Smear Results 1952–1953). Based on the August 1953 survey, the AEC recommended in September 1953 that the facility be released to the purchaser (DOE 1986).

The Area Plant was demolished in 1957 (DOE 1986). Debris and uranium processing wastes were transferred to another AEC location (the Lake Ontario Ordnance Works). NIOSH reported that Electro-Met subsequently processed uranium and thorium ores for commercial purposes under radioactive materials license 950-0139 issued by the State of New York (NIOSH 2009,

[3] According to information included in SRDB 9036 (pdf p.166), Contract W-7405-Eng14 was closed out with Amendment 28 on November 27, 1953.

p. 16). From August 1965 through April 1972, 505 tons of slag containing 9,212 pounds of ThO_2 and 1,293 pounds of uranium oxide was generated (DOE undated).

To assist in dose reconstruction, film badge data, air sampling data, surface smear samples, direct radiation measurements on surfaces and equipment, and bioassay samples are available for various time periods, as summarized in Table 1.

Certain broad features of the available data in relation to the periods and types of production discussed above are noted here:

(1) There are no internal or external dosimetry data for the late-1942–early-1943 period of experimental uranium production. We note that in Petition SEC-00136, the petitioner-requested start date was August 13, 1942, but that NIOSH changed the start date to April 1, 1943. NIOSH stated in their Petition Evaluation Report that a contract for the construction of the Area Plant was issued in November 1942, but that uranium processing did not begin until April 1943 (NYOO 1951). However, the discussion related to Finding 3 above indicates that experimental uranium production was being done in late 1942.

(2) There are no internal or external data for 1945, when experimental ore processing might have occurred and when radium-226 and thorium-230 may have been introduced into the site as part of ore processing.

(3) There are almost no external dose (film badge) data for 1944 ([redacted] badge results in all) when radium-226 may have been introduced into the site.

(4) Extensive air sampling and film badge data are available during the 1948–1949 operating period

In the ensuing paragraphs, the headings are generally the same as those in the Petition Evaluation Report (NIOSH 2009); the NIOSH 2009 paragraph numbers are indicated in parentheses. Since the Petition Evaluation Report relies heavily on information in Battelle-TBD-6001 (referred to subsequently as TBD-6001), and more specifically Appendix C of that report, this review is also a limited critique of those NIOSH documents to some extent.

Table 1. Availability of Monitoring Data at Electro-Met

Period	Operational Status	Air Samples	Film Badges	Bioassays	Smear Samples (alpha)	Direct Radiation Measurements
April 1, 1943–December 31, 1943	Operating	4 (ElectroMet 1943)	0	0	0	0
January 1, 1944–December 31, 1944	Operating	15 (Dust Samples June 1944, Dust Samples July 1944, Dosimetry Results 1944)	[redacted] (Dosimetry Results 1944)	67 (Dosimetry Results 1944)	0	0
January 1, 1945–December 31, 1945	Operating	0	0	0	0	0
January 1, 1946–August 31, 1946	Operating	0	0	0	0	0
September 1, 1946–December 31, 1946	Standby	0	0	0	0	[redact] – beta (ElectroMet 1946b)
January 1, 1947–September 30, 1947	Standby	0	0	0	0	11 – beta (Hayden 1947)
October 1, 1947–December 31, 1947	Operating	>10 (Dust Sample Results 1947–1948)	0	0	0	0
January 1, 1948–December 31, 1948	Operating	164 (Dust Sample Results 1947–1948, Dust Sample Results 1948–1949, Urinalysis Results 1949)	1156 (Dosimetry Results 1948–1949)	0	0	0
January 1, 1949–September 30, 1949	Operating	215 (Dust Samples 1948–1949, Dust Samples 1949, Urinalysis Results 1949)	884 (Dosimetry Results 1948–1949, Dosimetry Results 1949)	0	0	0
October 1, 1949–December 31, 1949	Standby	0	0	43 (Urinalysis Results 1949)	0	0
January 1, 1950–December 21, 1950	Standby	0	0	0	0	0
January 1, 1951–June 30, 1951	Operating	0	0	0	0	0
July 1, 1951–June 30, 1953	Standby	0	0	0	164 (Smear Results 1952–1953)[a]	192 (Smear Results 1952–1953)
July 1, 1953–?? 1957	Shutdown	11 (Dust Samples 1953)	0	0	28 (Smear Results 1952–1953)	53-beta/gamma (Harris 1953)

a – This December 10–12, 1948, survey also included contract radiation measurements for α, β, and γ for the many of the same items on which smear samples were taken (Blatz 1949).

3.2 ELECTRO-METALLURGICAL PLANT AND PROCESS DESCRIPTIONS (5.1)

The authors of NIOSH 2009 state the following in Section 5.1:

> *NIOSH did not locate any documentation indicating that the uranium reduction process initiated in April 1943 was modified or altered during the course of operations (i.e., the same process steps were employed during uranium handling operations over the entire history of AEC involvement at the site).*

While the process steps may have remained unchanged over the course of the operations, we believe that it is inappropriate to equate this statement with the corollary that radiation exposures remained unchanged over time without further documentation. This statement is particularly important to the NIOSH approach to dose reconstruction, since the vast majority of the data are from 1948 and 1949. Effectively, any validation of the dose values in TBD-6001 using these data involves an implicit back-extrapolation that air concentrations were generally the same in the 1943–1946 operating period. However, there is some doubt as to whether the NIOSH assumption of unchanged process is correct. Specifically, in its semi-annual report to Congress, dated December 1, 1947, the Uranium-Thorium Branch of the AEC noted that, "A thorough health survey was made before operations were [re]started and many changes were made as recommended by the Medical Division" (Harris 1953, pdf p. 75). Due to the date of the report, we presume that this AEC report to Congress refers to the restart on October 1, 1947 (see Table 1). This issue will be discussed further in Section 3.7.

<u>Finding 4</u>: *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.*

3.3 INTERNAL RADIOLOGICAL EXPOSURE SOURCES FROM ELECTRO-MET OPERATIONS (5.2.1)

NIOSH notes in this section that, "NIOSH found no information pertaining to exposure conditions during the standby periods shown in Table 5-1." However, NIOSH notes in Section 6.1 that, "With the exception of the 11 results from 1953 (during the last standby period), 135 air samples were collected during Electro-Met operational periods." Hence, there appear to be 11 results during the standby period.

<u>Finding 5</u>: *NIOSH should clarify the text to remove this apparent inconsistency regarding the availability of internal exposure data during standby periods.*

3.4 AVAILABLE ELECTRO-METALLURGICAL INTERNAL MONITORING DATA (6.1)

In Section 6.1, the NIOSH list of available dust sampling references is incomplete. Additional references are included in the reference list in Section 10.0, but are missing from this section of the report. In addition, NIOSH did not note that there are a large number of dust samples tabulated in Urinalysis Results 1949 (pdf pp. 64–77). The cover letter transmitting the sample data to the Kettering Laboratory, dated December 30, 1959, states that the dates covered range from November 1948 through August 1949. However, examination of the individual sample records suggests that the period may have been from August 18, 1948, through February 22, 1949. Data are provided on 78 general air (GA) and operator samples, plus 16 process samples from various exhaust stacks.

A summary of air sampling results is provided in Table 2. The number of available air samples listed in Table 2 is significantly more than those listed in Table 6-1 of the NIOSH Petition Evaluation Report (see Table 3 below). Particularly noteworthy are four air samples taken from May/June 1943, since these measurements were made soon after start-up (Electro-Met 1943). The maximum observed air activity was about 48,300 dpm/m^3 for an "Operator" filling a bomb with green salt and Mg. This operation typically produced the highest exposures. Based on the descriptions of the sampling locations on the data sheets, we believe that the sampling was at fixed head stations near a worker, rather than lapel sampling. This can make a major difference in the intake. Furthermore, while sampling times are given (10 minutes), the task times are not provided. The sample results are summarized in Appendix D, Table D-1. Table D-1 provides information on sampling locations that were taken near various operations, with the sampling head located 4.5 ft off the ground. It is not possible to tell whether these should be construed to be process samples, breathing zone analogs, or GA samples.

Table 2. Summary of Air Sampling Results at Electro-Met

SRDB Reference	Sampling Date	Number of Samples (excluding controls)	Alpha Concentration Range (dpm/m^3)	Comments
5809	May/June 1943	4	188 (GA), 642 to 43,800[b] (Operator)	GA and operator samples
8887	April 5, 1944	6	273 to 4,094[b]	GA samples
7726	May 16, 1944	4	317 to 664[b]	GA samples
7727	July 26, 1944	5	98.6 to 379[b]	GA samples
8917	December 24, 1947	Unknown, only averages provided, but more than 10 samples were taken.	106 to 6,145[a]	Measurements converted to daily weighted averages. See Table 4 below.
8917	March 30, 1948	8	77.6 to 9,840	Mixed GA and operator?
8912	April 5, 1948	10	8 to 180 (GA), 32,700 to 97,000 (Operator)	
8917	May 14, 1948	18	38.8 to 57,300	Mixed GA and operator?
35738	August 18, 1948	8	0 to 810 (GA), 240 to 3,250 (Operator)	
8912	November 3–4, 1948	120	12 to 2,490 (GA), 0 to 480,000 (Operator)	Measurements converted to daily weighted averages. See Table 4 below.
8912	January 12, 1949	13	8 (GA), 0 to 72,000 (Operator)	
35738	January 26, 1949	13	16 to 3,500 (GA), 4,400 to 140,000 (Operator)	
35738	February 2, 1949	14	141 to 680 (GA), 250 to 3,040 (Operator)	

Table 2. Summary of Air Sampling Results at Electro-Met

SRDB Reference	Sampling Date	Number of Samples (excluding controls)	Alpha Concentration Range (dpm/m^3)	Comments
35738	February 7, 1949	16	63 to 520 (GA), 60 to 4,400 (Operator)	
35738	February 16, 1949	11	130 to 1,100 (GA), 500 to 128,500 (Operator)	
35738	February 22, 1949	16	0 to 3,000 (GA), 2,700 to 60,600 (Operator)	
8930	August 17–19, 1949	132	Individual sample data illegible. Average of [redacted] samples for green salt loaders was 92,700 dpm/m^3	Prior to standby on September 30, 1949. Measurements converted to daily weighted averages. See Table 4 below.
8889	August 14, 1953	11	1.2 to 24.7	After shutdown and decon

a – range of averaged values
b – converted to dpm/m^3 based on specific activity of natural U of 6.84E+02 pCi/mg

Table 3. Comparison of Number of Available Air Samples

Year	NIOSH 2009, Table 6-1	This Review
1943	0	4
1944	5	15
1945	0	0
1946	0	0
1947	7	>10
1948	29	164
1949	82	215
1950	0	0
1951	0	0
1952	0	0
1953	11	11

During air sampling campaigns in 1947, 1948, and 1949, daily weighted average (DWA) exposures associated with various job descriptions were determined. Results of these DWA exposures are presented in Table 4.

Table 4. Daily Weighted Average[a] Air Samples (Alpha) Based on Breathing Zone Samples and General Air Samples in Areas Frequented by Workers in Each Job Description

Job Description	December [redacted], 1947 (dpm/m^3)	November [redacted], 1948 Samples (dpm/m^3)	August [redacted], 1949 Samples (dpm/m^3)
Green Salt Loader	1,136.6	40,400[c]	15,300[c]
Repairman – Furnace Parts		2,240	1,310
Head Electric Furnace Remelt Operator and Assistant	263.2	882	440
Back Saw Operator	151.5	284	368
Topper		355	308
Jolter Operator	1,759.9	N/A	229
Plant Guard		200[b]	218
Utility Man/Laborers		1,185	142
Laboratory Handyman		1,793	138
Reaction Furnace Operator	194.5	384	133
Shift Foremen/Foreman		243*	93
Technician		71.5	101
Repair Man and Handyman		178*	72
Janitor		189	30.4
General Foreman		218	26.5
Storekeeper and Attendant		53*	30
Guards		180	30
Chemists		53	18
Office Personnel		30	16

a – Based on 515 minutes per day, including 20 minutes in lunch room and 15 minutes in locker room, except for “guards” who worked 495 minutes with no lunch break, “chemists” who worked 500 minutes with no locker room time, and “office personnel” who worked 480 minutes with no lunch or locker room time
b – Estimated from Figure 1 in Dust Samples 1949
c – See Appendix A for details
* – Weighted average of two job categories

The DWA results were based on analyses performed by the AEC Health and Safety Division. Additional insight into the number of samples used to calculate the DWAs for the August 1949 sampling period (Table 4, Column 4) is provided in Table 5. The table indicates the number of workers involved with each job description, the number of time-weighted operations included in the DWA, and the total number of air samples averaged for all of the sampled operations. Details of the DWA calculations for the green room operator for the surveys of November [redacted], 1948, and August [redacted], 1949, are included in Appendix A.

Table 5. Summary of Air Concentration Measurements from August 1949 Survey at Electro-Met (Dust Samples 1949)

Job Description	No. of Workers	Operations Sampled[1]	Total Air Samples for All Tasks	Daily Weighted Air Concentration (dpm/m^3 - alpha)
Green salt loader	[redacted]	6	19	15,300[a]
Repair man – furnace parts	[redacted]	6	21	1,310
Head electric re-melt furnace operator and assistant	[redacted]	7	23	440
Hack saw operator	[redacted]	4	15	368
Topper	[redacted]	6	28	308
Jolter operator	[redacted]	6	26	229
Plant guard	[redacted]	3	22	218
Utility men and laborers	[redacted]	10	59	142
Laboratory handyman	[redacted]	5	12	138
Reaction furnace operator	[redacted]	4	16	133
Shift foreman	[redacted]	5	50	93
Technician	[redacted]	5	50	101
Repair man and handyman	[redacted]	4	48	72
Janitor	[redacted]	4	8	30.4
General foreman	[redacted]	5	N/A	26.5
Storekeeper and attendant	[redacted]	5	11	30
Guards	[redacted]	3	46	30
Chemists	[redacted]	2	4	18
Office personnel	10	2	2	16

1 – Includes 15 minutes in locker room, 20 minutes in lunch room, and 480 minutes at other tasks for each job category except the guards, for whom no lunch room time was assigned, and chemists/office personnel, for whom no locker room time was assigned.

a – See Appendix A for details.

One cannot add the samples in Column 4 of Table 5 for each job category to obtain the total number of air samples taken during the August 1949 survey, because in several cases, the same average for a task was assigned to several operators working in the same area. The total number of air concentration measurements quoted in Dust Samples 1949 is about 132. (The detailed air sampling sheets in Appendix C of Dust Samples 1949 are somewhat illegible, but a count of the number of samples is possible.)

The approach used to calculate internal exposure presented in Appendix C of TBD-6001 is based on taking the data from the surveys of November 1948 and August 1949 summarized in Table 4 above, and dividing the job descriptions into three groups:

- Operators – workers who routinely handled uranium or operated uranium processing equipment
- Supervisors/Laborers – foremen, guards, maintenance personnel, chemists, janitors, lab technicians, etc.
- Other – office personnel, storekeepers, storeroom attendants, etc.

Using the daily weighted averages for the job descriptions in each group, the 95th percentile of an assumed lognormal distribution for each group was then calculated. This metric was recommended to calculate the inhalation intake for each group during the various operating periods. During standby periods, it was recommended that inhalation intakes for the "Other" group be used (TBD-6001, Appendix C, Section C.5).

We divided our comments on the use of air sampling data into five parts:

(1) The type of air sampling data

(2) Consolidation of many worker categories into just three types with very different assigned intakes

(3) The statistical analysis that NIOSH has performed on the data

(4) Accidents, specifically blowouts

(5) Residual contamination

(1) Type of air sampling data

The sample sheets from 1943 indicate that the sampling may not have been using lapel samplers, but rather fixed head samplers close to the worker concerned. There can be a considerable difference between a worker's actual intake and that indicated by a fixed head sampler. See above discussion regarding Table D-1.

Finding 6: 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.

(2) Job categories

NIOSH has not discussed the mobility of workers in practice between job types. Was the Area Plant a union shop with strict work rules, or was mobility between jobs permitted? It is not clear, for instance, whether laborers may also have done jobs that had exposures closer to those of operators. The constancy of jobs as done in practice needs to be established before the job consolidation scheme that NIOSH proposes can be used in the context of estimating bounding dose in an SEC context.

Finding 7: 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.

(3) NIOSH approach to estimating intakes from air sampling data

NIOSH did not use the limited daily weighted average data from December 1947 (Table 4, Column 2) for this analysis. With the exception of the bomb room activities, which we assume here were comparable to the job description for the jolter operator, the December 1947 data were lower than the data used by NIOSH in calculating bounding values. Inclusion of these data would have reduced the proposed bounding values, so the approach taken by NIOSH is claimant favorable. Inspection of the other air sampling data in Table 2 not used in the bounding calculation, because they were not reduced to DWAs, suggests that these values are generally encompassed by the range of values used to calculate the DWAs. Some exceptions to this generalization will be discussed elsewhere.

NIOSH did not provide sufficient documentation to permit an audit of 95th percentile calculations by job description described in Section C.5, Appendix C, of TBD-6001. They also did not provide any reference to the data underlying the statement, "Air samples were collected in various areas of the plant in 1948 and 1949." However, to assist in the current review, NIOSH provided a spreadsheet and list of supporting documentation to SC&A (Allen 2009).

NIOSH used a graphical method for estimating the parameters of lognormal distributions needed for estimations of inhalation intakes. This method is particularly useful when the data include non-detect values (missing values that are below the minimum detectable level). However, the graphical method is not the method that generally would be used to estimate parameters of a lognormal distribution if there were no missing values. The most commonly recommended approach is to use the maximum likelihood estimate (MLE) method. The MLE method is applied by taking logarithms of the data, then calculating the parameter estimates using the standard formulas for the normal distribution.

The parameter *mu* is estimated using the average of the logarithms. The MLE is also an unbiased estimate of *mu*. The parameter *sigma* is estimated using the MLE for the standard deviation of the logarithms. The MLE for sigma is obtained by dividing the sum of squared deviations for *mu* by the factor N. Another common approach is to use an unbiased estimate for *sigma*. This estimate is obtained by dividing the sum of squared deviations by the factor N-1. The three methods for estimating lognormal parameters are shown in Table 6.

The three methods often yield very similar results when the sample size is over 30. For small samples, the three methods may yield different results. In the case of operator exposures, the sample size is N=13, a relatively small sample. The results of applying the three methods in this case are shown in Table 7. The three methods yield substantially different results for the 95th percentile, ranging from 60,661 dpm/calendar day for the NIOSH graphical method shown in Figure 1 up to 83,721 dpm/calendar day for the unbiased method. The MLE method yields a value in between, at 75,203 dpm/calendar day. The differences between the three methods are due to the different weight assigned to the two highest values. The unbiased estimate yields the highest estimate for sigma, because of the large magnitude of the squared deviations for these two extreme values. For the supervisors/laborers and other workers categories, agreement among the three approaches is much better, since the results are not significantly affected by extreme high-end values. The MLE method is generally preferred by statisticians over other methods if there are no missing values.

Table 6. Three Methods for Estimating Lognormal Distribution Parameters

	Method of Estimation		
Parameter	**NIOSH**	**SC&A**	
Mu	Graphical Method	Maximum Likelihood	Maximum Likelihood
Sigma	Graphical Method	Maximum Likelihood	Unbiased
		S2/N	S2/(N-1)

Table 7. Comparison of Numerical Results for Operators Using Three Methods of Estimation (N=13)

	Numerical Results by Method of Estimation			
Parameter/	**NIOSH**	**SC&A**		
Statistic	**Graphical Method**	**Maximum Likelihood**	**Unbiased**	**Units**
Mu	8.615	8.600	8.600	
Sigma	1.458	1.597	1.663	
Geometric Mean	5,516	5,433	5,433	dpm/calendar day
Geometric Standard Deviation	4.3	4.9	5.3	
95th Percentile	60,661	75,203	83,721	dpm/calendar day

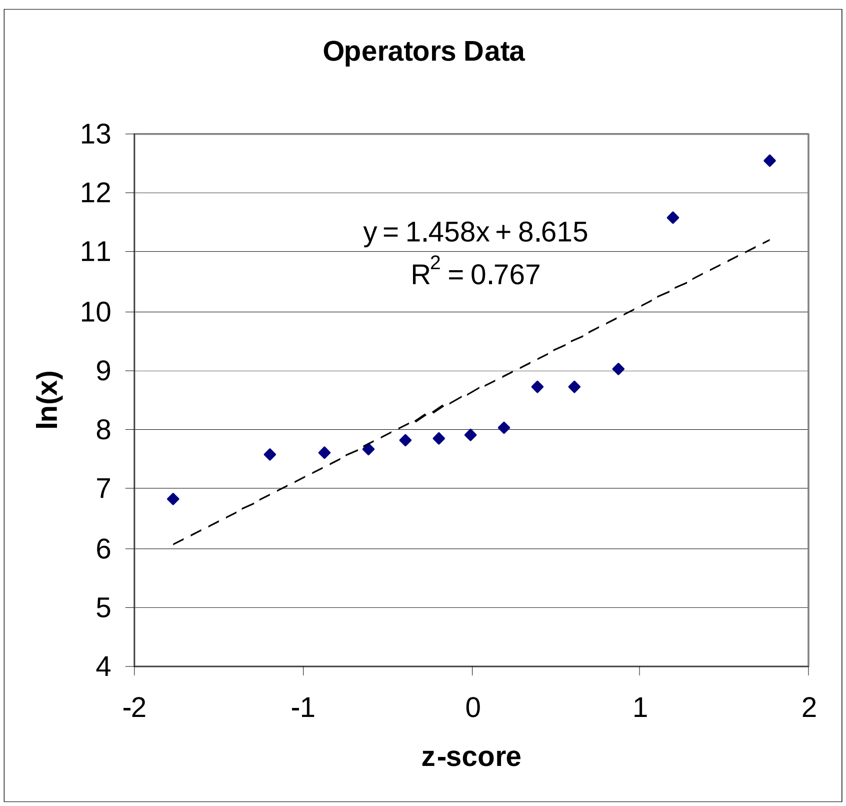

Figure 1. Normal Score Plot of Operator Data

<u>Finding 8</u>: We note that the graphical method used by NIOSH in Appendix C of TBD-6001 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.

It is instructive to compare the generic inhalation intakes for some of the operations listed in Table 8.29 of TBD-6001 with those specific to Electro-Met in Table C.2, Appendix C of TBD-6001. Tasks listed in Table 8.29 that are comparable to the operator tasks in Table 4 are summarized in Table 8. The reader is referred to Appendix B for a discussion of the data sources and problems with interpretation of some of the data in Table 8.29.

The 95th percentile of the values in Table 8 is 4,986 dpm/calendar-day, demonstrating that the site-specific approach in Appendix C (Table C.2) of TBD-6001 is clearly more claimant favorable than the generic approach embodied in Table 8.29 of TBD-6001 (i.e., 60,661 dpm/calendar-day versus 4,986 dpm/calendar-day). This raises concerns as to the whether the generic approach in TBD-6001 is claimant favorable. While a detailed review of this issue probably lies within the scope of the TBD-6001 Work Group, we note the issue here for the record.

Table 8. Inhalation Exposures for Job Descriptions in Table 8.29 of TBD-6001 that are Comparable to Operator Jobs at Electro-Met

Operator Job Description	Inhalation Exposure[a] (pCi/calendar-day)
Bomb preparation (prior to 1952)	711
Reduction (prior to 1952)	243
Bomb breakout (prior to 1952)	693
Recasting – crucible loading (prior to 1951)	130
Recasting – recasting (prior to 1951)	1,990
Recasting – crucible burnout (prior to 1951)	41.5
Recasting – billet cleaning (prior to 1951)	97.8
Recasting – crucible assembly (prior to 1951)	678

a – Assumed geometric mean (GM) for lognormal distribution with a gerometric standard deviation (GSD) of 5, based on 40-hr workweek.

<u>Finding 9</u>: 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, 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.

(4) Blowouts

The petitioner has stated that the process used at Electro-Met typically resulted in blowouts. NIOSH's response in its Evaluation Report is that there is no specific Electro-Met evidence indicating blowouts at the plant. NIOSH noted on page 19 of NIOSH 2009 that, "Electro-Met documentation recognized that an uncontrolled reaction could result in an explosion of the bomb (ElectroMet 1946a, p. 6)." In its Petition Evaluation Report, NIOSH stated that neither of the two persons interviewed had any knowledge that such events occurred. As described in Appendix E, SC&A also interviewed a former Area Plant worker employed in the 1940s, who stated that he and his coworkers were never involved in an accident, contamination spill, fires, or other incidents, and that he was unaware that any blowouts or bomb explosions had occurred. SC&A reviewed all the documentation available on the O-drive and other materials, and could find no evidence of blowouts. However, as summarized below, the occurrence of blowouts from the same process at other sites is well documented.

Workers at Ames Laboratory, where the UF_4 reduction process was invented, were acutely aware of the possibility of blowouts; indeed, they occurred frequently. Only some are documented, but there is an instance of at least six on a single day (Payne 1992, p. 133). As another example, the Fernald plant, which was built as a more modern facility in the early 1950s, continued to have blowouts for many years after the start of operations. For instance, one document shows that dozens of blowouts occurred in a single 10-day period (there were several reduction furnaces at Fernald).

Clearly, the AEC was very concerned about the consequences of blowouts. It is therefore surprising that, if blowouts had occurred at Electro-Met, there would be no documentation of that fact, especially since their occurrence was well-documented at other facilities. It would also be surprising if there were no blowouts at Electro-Met, given the frequency of blowouts in the same period and in the same type of equipment at Ames, and given that later facilities also had blowouts for long periods after Electro-Met ceased producing uranium metal. If Electro-Met knew how to prevent blowouts, it is puzzling that the lessons were not applied elsewhere then or later. This is an issue that also needs further investigation.

<u>*Finding 10*</u>*: Given the high frequency of blowouts at other facilities using the same equipment, NIOSH should re-examine the possibility that blowouts occurred at Electro-Met.*

(5) Residual contamination

Results of final air sampling data taken in August 1953 after the Area Plant had been shut down and decontaminated are shown in Table 9.

Table 9. Post-Decontamination Air Sampling Measurements Made on August 14, 1953, at Area Plant

Sample Number	Alpha Concentration (dpm/m^3)
N400	24.7
N401	13.7
N402	1.2
N403	15.5
N404	1.5
N405	117
N405	2.7
N407	9.8
N408	2.4
N409	3.9
N410	8.6

Source: AEC 1953 (pdf p. 2)

The geometric mean (GM) and geometric standard deviation (GSD) of the data in Table 9 are 7.1 dpm/m^3 (about 0.1 MAC) and 3.9, respectively. We note that NISOH does not consider any residual contamination period in the SEC-00136 Petition Evaluation Report; rather, they assume that there was no exposure after the AEC contract expired on June 30, 1953. It is possible that workers were exposed to residual contamination from July 1, 1953, until 1957, when the Area Plant was demolished. Based on the post-decontamination air sampling results in Table 9 and the limited time period between plant shutdown and demolition, we expect that exposures would be low, but, for completeness, they should be documented.

Finding 11: NIOSH should address residual exposures in the SEC-00136 Petition Evaluation Report.

3.5 URINALYSIS DATA (7.1.1.1)

NIOSH states that a total of 111 urinalysis samples were taken in 2 years—1944 and 1949—from 48 employees, and that about half of the results were 0. We note that the 1949 sampling was done in October through December 1949, which was after the Area Plant was placed on standby on September 30, 1949. The 1949 samples were collected from 11 to 63 days after shutdown. Some decline in the quantity of uranium in urine would occur during the shutdown period, so the use of measurements made in the fourth quarter of 1949 would be understated, as compared to those for the period prior to shutdown. The fall-off is significantly greater for Type M as compared to Type S absorption.

Since NIOSH assumes in the SEC-00136 Petition Evaluation Report that operations did not change substantively over time prior to the institution of extensive monitoring programs in 1948 (see Section 3.2 above), SC&A examined the two sets of urinalysis data to determine if the results were statistically similar for 1944 and 1949.

The normal score plots and regression lines in Figure 2 look similar for the 1944 and 1949 datasets. The regression coefficients provide estimates of the lognormal parameters *mu* (μ) and *sigma* (σ) for each year. The estimated lognormal distributions have similar means and 95th percentiles, as shown in Table 10. The other lognormal parameters show larger differences. The largest differences for GM and GSD have opposite signs, indicating that these are offsetting differences. The differences between the two distributions are large enough to require further investigation, as described below.

The approximate 95% confidence intervals for the regression coefficients are shown in Figure 3. The smaller size of confidence region in 1949 is due to the larger number of samples over the limit of detection. The actual confidence intervals for the regression coefficients have an elliptical shape, similar to the examples shown in Figure 4, stretching from the upper left corner to lower right corner of the rectangular regions shown in Figure 2. The negative slope of the major axis of the ellipses in Figure 3 indicates that there is a negative correlation between estimates of the slope and intercept of a regression line. This negative correlation accounts for the opposite signs of the differences between 1944 and 1949 for the GM and GSD noted in Table 10.

The slight overlap of the approximate 95% confidence intervals for the 2 years in Figure 3 provides statistical evidence that the regression lines for 1944 and 1949 are not significantly different.

Table 10. Comparison of Lognormal Distributions for 1944 and 1949

Lognormal Parameter	Urinalysis Results 1944	Urinalysis Results 1949	Units	Percent change 1944 to 1949
GM	0.018	0.010	mg/L	-46%
GSD	4.14	5.72		38%
Mean	0.050	0.045	mg/L	-10%
85th	0.080	0.061	mg/L	-24%
95th	0.190	0.175	mg/L	-8%
99th	0.499	0.574	mg/L	15%

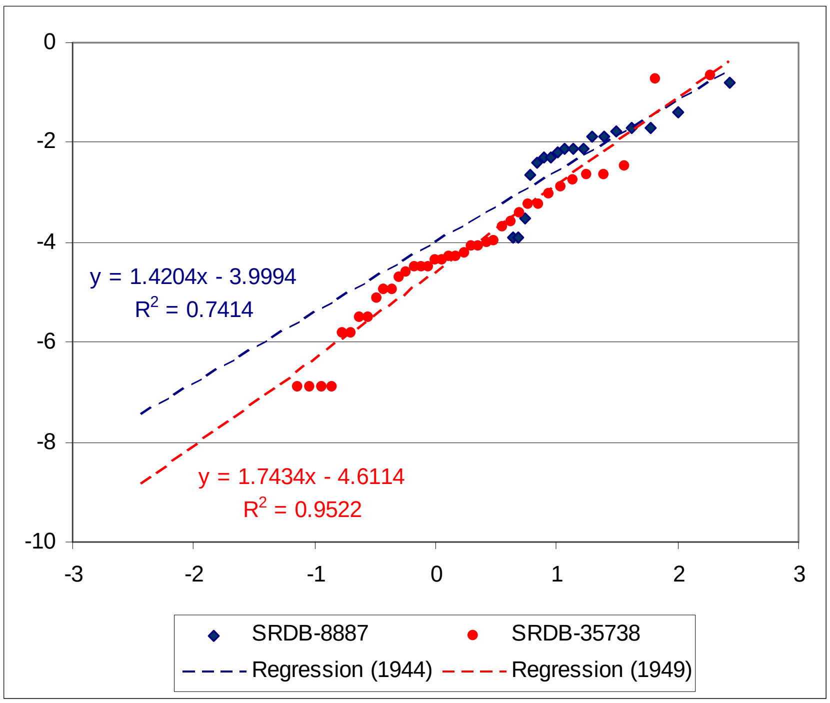

Figure 2. Normal Score Plots for 1944 and 1949 with Regression Lines

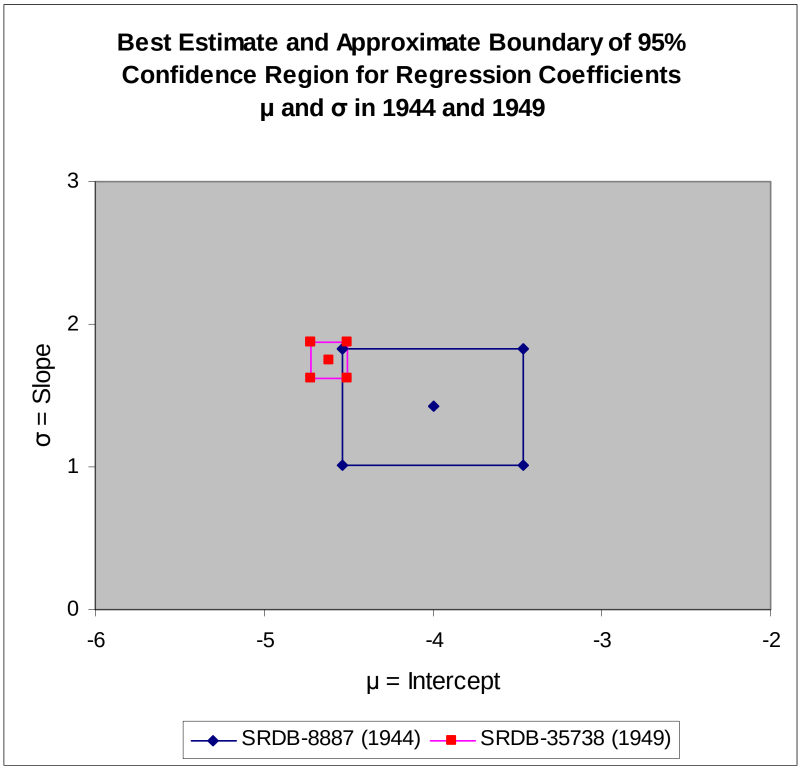

Figure 3. Best Estimate and Approximate 95% Confidence Region for the Intercept (μ) and Slope (σ) of the Regression Lines for 1944 and 1949

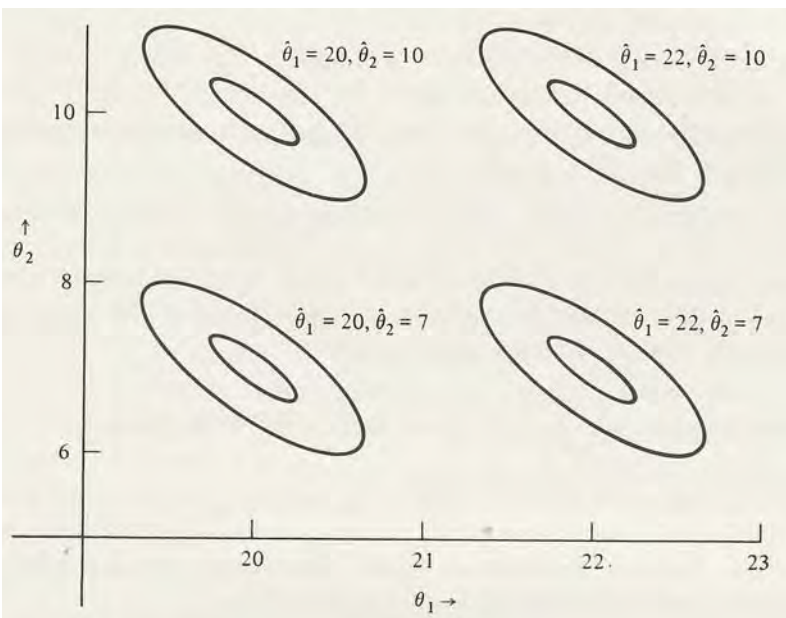

Figure 4. Examples of the Elliptical Shape of Confidence Intervals for the Intercept and Slope of Regression Lines

(Source: Box and Tiao 1973)

3.6 METHODS FOR BOUNDING OPERATIONAL INTERNAL DOSE AT ELECTRO-METALLURGICAL (7.2.3)

NIOSH reports that they used the uranium inhalation intake data from Appendix C of TBD-6001 and calculated the uranium urinary excretion. The calculated excretion was compared to the actual urinalysis measurements. NIOSH observed that calculated excretion exceeded the actual measurements in every case, substantiating that the intakes in Appendix C were bounding. However, NIOSH provides no documentation to support this position.

SC&A used the inhalation intake limits proposed in Table C.2 of Appendix C of TBD-6001 and calculated the excretion rates using IMBA. These excretion rates were then compared to measured rates from Urinalysis Results 1949 (pp. 82–83). Only a portion of the 1949 urinalysis measurements were identified by job description and none of the 1944 measurements. However, the maximum observed value from all sampling was for an "Operator" (0.510 mg/L). The maximum reported value for the Supervisors/Labors category was a [redacted] (0.487 mg/L), while the maximum for the "Other" category was an [redacted], with an exposure of 0.033 mg/L. Results of the comparison between measured and calculated excretion rates are summarized in Table 11.

Table 11. Comparison of Measured and Calculated Uranium Excretion Rates from Urinalysis

Job Description	Intake[a] (dpm/day)	Intake (pCi/day)	Excretion – Type M[c] (pCi/day)	Excretion – Type S[c] (pCi/day)	Max. Measured Excretion (mg/L)	Max. Measured Excretion (pCi /day)[b]
Operators	60,661	27,325	1.844E+03	1.347E+02	0.510	4.82E+02
Supervisors/Laborers	8,159	3,675	2.478E+02	1.812E+01	0.487	4.66E+02
Other	473	213	1.437E+01	1.050E+00	0.033	3.16E+01

a – Bounding values from Table C.2, Appendix C, TBD-6001

b – mg/L converted to pCi/day as follows: mg/L × 1.4L/day × 6.83E+02 pCi/mg per ORAUT-TKBS-0025 (ORAUT 2006)

c – IMBA input assumptions: collection period – 1 day; sampling date – 10/11/1949; chronic exposure to natural U from 4/1/1943 to 6/30/1953

It can be seen from Table 11 that intake assumptions for Supervisors/Laborers and Other job descriptions in Appendix C.2 do not appear to be bounding, when compared to maximum measured urine excretions reported in Urinalysis Results 1949. For the Supervisors/Laborers, the maximum measured excretion rate of 466 pCi/day exceeded the calculated excretion rate of 248 pCi/day for Type M absorption and 18.1 pCi/day for Type S. For the "Other" job description, the maximum measured excretion rate of 31.6 pCi/day exceeded the calculated values of 14.4 and 2.05 for Type M and Type S absorption, respectively For the Operators, the calculated excretion is bounding for Type M, but not for Type S, absorption. However, it should be pointed out that the particular worker sampled was an "Operator," whose exposure was more likely to have been Type S (UO_2/U_3O_8), rather than Type M (UF_4).

<u>Finding 12</u>: NIOSH should provide more detailed information to support their position stated 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." Independent calculations by SC&A do not support this conclusion as to the bounding nature of the intakes in Appendix C, Table C.2.

3.7 METHODS FOR BOUNDING OPERATIONAL PERIOD EXTERNAL DOSE (7.3.4.1)

3.7.1 Photon Dose

NIOSH states that the photon dose can be bounded using guidance provided in Appendix C of TBD-6001 (NIOSH 2009, p. 28). The guidance in Section C.4 of Appendix C is based on film badge data over a 16-month period, from June 1948 through September 1949, which include both beta and gamma measurements. The population of badged workers included operators, foremen, janitors, laborers, storeroom attendants, etc. It did not include chemists, guards, and office personnel. The entire population of film badge measurements was assigned a lognormal distribution. The calculated GM and GSD for the population were calculated to be 20.06 mr/week and 2.30, respectively. NIOSH assumed that operators were exposed to an annual dose based on the 95th percentile (3,934 mr/yr), supervisors/laborers at the 50th percentile (1,003 mr/yr), and other workers at the 5th percentile (256 mr/yr). These job categories are the same as those described in Section 3.3 above. NISOH did not provide a specific reference to the film badge data in Appendix C, but we presume, based on references in the NIOSH 2009, that the film badge data were extracted from Dosimetry Results 1948–1949 (SRDB 11547) and Dosimetry Results 1949 (SRDB 11548).

SC&A independently developed a spreadsheet, based on the data in Dosimetry Results 1948–1949 and Dosimetry Results 1949, and calculated lognormal statistics using the graphical method (see Table 6 above). We believe that NIOSH generally uses the graphical method, as well. This method is better adapted to datasets where there are a large number of measurements below the limit of detection, as is the case here. Using the graphical method, SC&A calculated that the GM and GSD were 23.76 mr/wk and 2.21, respectively. A comparison of the annualized exposures from the two calculations is presented in Table 12.

Table 12. Comparison of Annual Photon Exposures

Job Description	Percentile	NIOSH Appendix C (Table C.4) (mr)	SC&A Graphical Analysis of SRDB 11547 and 11548 (mr)
Operator	95th	3,934	4,375
Supervisor/Laborer	50th	1,003	1,188
Other	5th	256	325

The graphical method as implemented by both NIOSH and SC&A yielded comparable results.

As a check on the bounding annual operator exposure (i.e., the 95th percentile exposure) of 3,934 mr proposed by NIOSH, SC&A calculated the annual exposure for the particular worker [Supervisor/Laborer] with the highest annual exposure amongst all the badged population. Based on 45 weekly measurements above the assumed limit of detection of 50 mr/wk, the [Supervisor/Laborer] was exposed to 3,294 mr of gamma radiation during a 50-workweek year. This [Supervisor/Laborer] also received the highest single weekly exposure (690 mr), which contributed 21% of his annual exposure. A [Operator] with no significant outlier in his exposure pattern received a similar annual exposure of 2,881 mr, based on 59 weekly measurements above the limit of detection. These measurements support the NIOSH position that the 95th percentile in Appendix C, Table C.4, of 3,934 mr/yr is bounding for gamma exposure. However, Appendix C is silent as to how workers with unknown job descriptions should be evaluated. We believe that Appendix C should specifically state that, when the job description is uncertain or unknown, the worker should be considered to be an operator. Otherwise, NIOSH cannot say that the results are bounding.

It should also be emphasized, as shown in Table 1, that there are virtually no film badge data prior to June 1948. Thus, NIOSH needs to clearly demonstrate that the results are bounding for earlier years during the operational period.

<u>*Finding 13*</u>*: 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 dose reconstruction when the job description is uncertain or unknown.*

3.7.2 Medical X-rays

This section of the Petition Evaluation Report indicates that x-ray doses can be bounded by assuming that the energy employee receives a pre-employment x-ray, an annual x-ray during employment, and a post-employment x-ray, and refers the reader to ORAUT-OTIB-0006 (ORAUT 2005) for details. TBD-6001, Appendix C, provides the same guidance in Section C.3. In principle, this approach should be bounding. However, we note an apparent ambiguity in OTIB-0006 with regard to the use of exposures from photofluorography. For the pre-1970 period, three default exposures are listed in Table 3-4 of that report; PA chest, lateral chest, and photofluorographic chest. The report goes on to state the following (ORAUT 2005, p. 21):

> *It is reasonable to presume that at least some of the occupational medical diagnostic chest x-rays with the DOE and its predecessor organizations were accomplished by PFG and in the absence of data to the contrary, the use of PFG should be assumed to ensure claimant favorable dose reconstructions.*

The report is silent on whether this presumption is limited only to DOE organizations, or includes AWE organizations as well. In order to insure that a bounding calculation is made in dose reconstruction, NIOSH should explicitly state that photofluorography should be assumed for dose reconstruction at Electro-Met, or clarify ORAUT-OTIB-0006 to state that it does not apply to AWE sites.

We note in SRDB 8897 (Wolf 1949, pdf p. 33) that the Medical Director referred to x-ray examinations and x-ray equipment. It is not possible to deduce from the correspondence whether x-ray equipment was a generic term embracing photofluorography or not.

Finding 14: 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.

3.7.3 Beta Dose

NIOSH states that, similar to the photon dose, the beta dose can be bounded using guidance provided in Appendix C of TBD-6001 (NIOSH 2009, p. 28). The guidance in Section C.4 of Appendix C is based on film badge data over the 16-month period from June 1948 through September 1949, which included both beta and gamma measurements. The entire population of film badge measurements was assigned a lognormal distribution. The calculated GM and GSD for the population were calculated to be 64.43 mr/week and 3.13, respectively. NIOSH assumed that operators were exposed to an annual dose based on the 95th percentile (21,030 mr/yr), supervisors/laborers at the 50th percentile (3,221 mr/yr), and other workers at the 5th percentile (493 mr/yr) (Battelle 2007, Table C.5). These exposures are to the skin other than the hands and arms.

SC&A analyzed beta exposures using the same graphical method discussed above for photon exposures and determined that the GM was 88.69 mr/wk, with a GSD of 2.64. Percentiles from this distribution are compared with those from Table C.5 of TBD-6001 in Table 13.

Table 13. Comparison of Annual Beta Exposures

Job Description	Percentile	NIOSH Appendix C (Table C.5) (mr)	SC&A Graphical Analysis of SRDB 11547 and 11548 (mr)
Operator	95th	21,030	21,845
Supervisor/Laborer	50th	3,221	4,434
Other	5th	493	900

Values at the 95th percentile for the two sets of calculations are in excellent agreement. Values for the 5th and 50th percentiles are lower in Table C.5 than those calculated by SC&A.

As a check on the bounding annual operator exposure (i.e., the 95th percentile exposure) of 21,030 mr proposed by NIOSH, SC&A calculated the annual exposure for the particular worker [redacted] with the highest annual exposure amongst all the operators. Based on 57 weekly measurements above the assumed limit of detection of 50 mr/wk, the [redacted] was exposed to 17,053 mr of beta radiation during a 50-workweek year. This result supports the NIOSH position that the 95th percentile in Appendix C, Table C.5, is bounding for beta exposure. (This estimate is conservative, since it assumes a weekly exposure rate of 50 mr for those weeks where the reported results are less than the lower limit of detection.)

Finding 15: 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 5th 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%.

3.7.4 Doses from High Surface Concentrations of U-238 Progeny[4]

High beta radiation levels have been observed at sites where melting and casting of uranium was done. The phenomenon was described in a document authored by Edward Putzier (1982), formerly Health Sciences Manager at the Rocky Flats Plant, who observed that the surface beta dose from as-cast uranium ingots was about an order of magnitude greater than from a clean uranium surface in equilibrium with Th-234 and Pa-234m daughters of U-238. For convenience, this phenomenon will be referred to here as the Putzier effect. As quoted by Putzier (1982):

> *In the earlier years in handling large quantities of depleted uranium, and to some extent this is true in more recent years, we did have a significant beta radiation control problem in Building 444. This was not experienced so much in the machining areas but in the part of the foundry operations we called burnout and breakout. Castings were removed by breaking them out of the molds. This operation and the recovery of the material from the casting and handling the molds themselves resulted in very high beta radiation levels. There was an extremely high level of beta radiation associated with this because the first two daughters of ^{238}U are beta emitters and during the molten state of the uranium there is a tendency for these two daughters to flow to the top and also to show up at the interface of the uranium and the mold itself thereby enhancing the amount of beta radiation coming off from the chunk of the material. We used to use as a rule of thumb that clean uranium metal in equilibrium with at least its first two daughters would give off on the order of 200 mrad per hour beta radiation at the surface of a piece of the metal. This went up by at least an order of magnitude and probably more than that. We can say that we saw readings as high as 2000 to 3000 mrad/hr on castings of depleted uranium that were in the foundry area. Then, too, the dusts which were generated in the burnout and breakout process settled on various pieces of equipment and from that there were additional beta radiation fields generated.*

Evidence of high surface concentrations of beta emitters has been observed on equipment used in uranium casting operations at Electro-Met (AEC 1949). The authors of AEC 1949 state the following:

> *A similar separation occurs in the processes at Mallinckrodt Chemical Works Plant 4 and Electro Metallurgical Company. In these plants, uranium metal, with UX_1-UX_2 in approximate equilibrium, is purified by vacuum recasting at a temperature which volatilizes various impurities in the metal, including the UX_1-UX_2. These impurities condense on the cooler surfaces of the furnace interior and this deposit is the source of intense beta exposure during charging, discharging, cleaning and repair of the furnaces.*

It is clear that operators at Electro-Met involved in the melting and casting of uranium ingots would have experienced high doses caused by the Putzier effect. As described above, beta and gamma exposures defined in Tables C.4 and C.5 of TBD-6001, Appendix C, were based on

[4] This subject was not included in the SEC-00136 Petition Evaluation Report (NIOSH 2009).

about 2,000 film badge measurements made at Electro-Met in 1948 and 1949. The monitored population involved those workers with the highest exposure potential, including furnace operators. Thus, the film badges would have captured any abnormal exposures from high surface concentrations of Th-234 and Pa-234m. Use of the 95th percentiles of the film badge measurements for operator exposures per Tables C.4 and C.5 of Appendix C should provide reasonable assurance that high exposures resulting from the Putzier effect would be accounted for in dose reconstruction.

However, there is one caveat that must be considered in using the values in Table C.5 of Appendix C for dose reconstruction; these exposure values are specific to the skin other than the hands and arms. Exposure to the hands and arms would be higher, since film badges are worn at a considerable distance from these extremities. One possible approach to addressing exposures to the hands and arms is to use a factor developed by NIOSH in OCAS-TIB-0013 (OCAS 2005). That document describes a modeling approach to estimate correlations between film badge exposures and exposures to other body parts. They determined that the hands-to-badge ratio was to 3.65.

Finding 16: 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.

3.8 A CRITICAL QUESTION

A critical question regarding the SEC-00136 Petition Evaluation report is this:

- Was the process sufficiently constant from 1943 (when very little monitoring data are available) to 1948/1949 (when extensive monitoring data are available) that the 95th percentile exposures based on 1948/1949 monitoring would adequately represent the earlier times?

The information in Section 3.2 above is repeated here to consolidate all of the information relevant to this question in one place.

The authors of NIOSH 2009 state in Section 5.1 that:

> *NIOSH did not locate any documentation indicating that the uranium reduction process initiated in April 1943 was modified or altered during the course of operations (i.e., the same process steps were employed during uranium handling operations over the entire history of AEC involvement at the site).*

The items below address the available information.

Item 1

While the process steps may have remained unchanged over the course of the operations, it would be inappropriate to equate this statement with the possible corollary that radiation exposures remained unchanged over time. In its semi-annual report to Congress, dated December 1, 1947, the Uranium-Thorium Branch of the AEC noted that, "A thorough health survey was made before operations were [re]started and many changes were made as recommended by the Medical Division" (Harris 1953, pdf p. 75). We presume that the AEC report refers to the start-up on October 1, 1947 (see Table 1).

Item 2

An MED cover letter for July 26, 1944, air sampling (Dust Sample Results 1944) states:

> *These samples indicate that the use of the portable vacuum cleaner has reduced radioactive dust concentrations in the general plant atmosphere as compared to what it was in the report from this office to the Tonawanda Area Engineer, ????[5]-34 dated 7 June 1944 …*

Additional information on the efficacy of the vacuum cleaner is provided in MED 1944 (pdf p. 8).

While June 7, 1944, sampling results have not been retrieved, results from prior sampling in April 1944 are available in Dosimetry Results 1944 (see Table 2). The GM and GSD for the April 1944 GA samples were 892 dpm/m^3 and 2.86, respectively. By comparison, the GM and GSD for the July 1944 GA samples were 253 dpm/m^3 and 1.72, respectively.

An analysis similar to that described Section 3.4 for the urinalysis data was conducted to determine if the July 26, 1944, GA samples were statistically lower than the April 5, 1944, air samples. The lognormal parameters for the two datasets are compared in Table 14, which clearly indicates the magnitude of the changes that occurred between April and July of 1944.

Table 14. Comparison of Lognormal Parameters for Air Samples Taken Before and After Use of Portable Vacuum Cleaner

Lognormal Parameter	SRDB-8887[a] 4/5/1944	SRDB-8887[a] 7/26/1944	Units	Percent Change 4/5 to 7/26/44
GM	891.964	252.749	dpm/m^3	-72%
GSD	2.74	1.61		-41%
Mean	1482.252	283.287	dpm/m^3	-81%
85th	2535.146	414.646	dpm/m^3	-84%
95th	4680.729	554.476	dpm/m^3	-88%
99th	9302.703	767.796	dpm/m^3	-92%

a – Dosimetry Results, Aug. 1944

[5] ???? – text illegible.

To further demonstrate that the two datasets are statistically different, the 95% confidence regions are compared in Figure 5. The large separation of the two confidence regions provides additional evidence that the two datasets are statistically different. This evidence does not support the NIOSH hypothesis that the process did not change over time prior to 1948. We recognize that this conclusion is based on small samples, but they represent all of the available information.

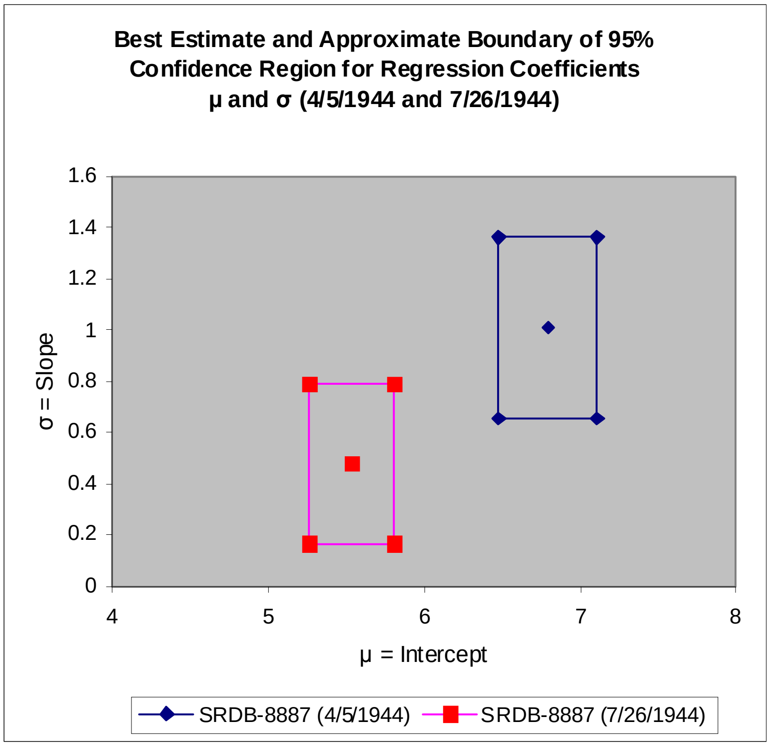

Figure 5. Comparison of 95% Confidence Regions for General Air Sample taken on April 5, 1944, and July 26, 1944

Item 3

In Section 3.4 above, SC&A compared the results of uranium concentrations in urine samples taken in 1944 and 1949. Based on the statistical comparison, one cannot say that the two datasets are different.

Item 4

Three beta exposure measurements were made on August 28–29, 1944 (Dosimetry Results 1944), with results ranging from 125 to 180 mrem per 8-hour day. Converted to a weekly basis, the range would be 626 to 900 mr/wk. This range may be compared to the lognormal statistics for a much larger population of measurements made in 1948 and 1949, as discussed under "Beta Doses" in Section 3.7. For the 1948/1949 measurements, the median and 95th percentile values based on NIOSH calculations were 64.4 and 421 mr/wk, respectively. Based on the limited sample from 1944, use of the 95th percentile value from film badge measurements made in 1948/1949 is not bounding for beta exposures in the earlier years.

In some instances, workers wore leather gloves to reduce exposure to the hands. Five measurements taken on April 5, 1944, from the **inside** lining of gloves worn by a [redacted] operator ranged from 150 to 200 mrem per 8-hr day. These results are similar to the film badge measurements of August 28–29, 1944.

Item 5

Seven beta measurements were made on October 22, 1946, when the Area Plant was in a standby mode (Electro-Met 1946b). There were three non-zero measurements ranging from 24 to 220 mr per 8-hr day. These data are not particularly useful in answering the over-arching question.

Item 6

The daily weighted average air samples for operators taken on December [redacted], 1947, are lower than the comparable DWAs for operators taken on November [redacted], 1948, and August [redacted], 1949 (see Table 4). This comparison indicates that use of the 95th percentile from the November 1948 and August 1949 air samples, as proposed in Table C.2 of Appendix C, TBD-6001, would be a prudent estimate, at least forward in time from December [redacted], 1947.

Item 7

The approach used by NIOSH to develop generic guidance in TBD-6001 differs from the specific guidance for Electro-Met provided in Appendix C of that report. As described above, in Appendix C, NIOSH used DWA data for operators, based on air sampling campaigns of November 1948 and August 1949 (see Table 4), and selected the 95th percentile from the combined results as the bounding metric. This upper 95th percentile was assumed to apply to all operating periods between 1943 and 1953. On the other hand, in TBD-6001, NIOSH proposed that the process-specific data (e.g., metal reduction and recasting) from Christofano and Harris 1960 be adjusted by a year-specific factor. Year-specific factors are listed below (Battelle 2006, Table 8.28):

- 1948 and before – 6.89
- 1949 – 0.897
- 1950 – 0.325
- 1951 – 0.485
- 1952 – 0.116
- 1953 – 0.0656

Since Christofano and Harris reported no measurements prior to 1948, NIOSH proposed assuming that the factor for 1948 be extended to earlier years. However, use of the year-specific factors does not work for much of the data in TBD-6001, because for many of the operations in

Section 8, there are two sets of process data for different times, and it is not possible to determine which of the process-specific dust levels against which to apply the year-specific factors.

Item 8

As noted in Section 3.3, an air sample near an "Operator" loading a bomb with green salt in May/June 1943 measured 69,100 dpm/m^3. The average of four air samples near an "Operator" performing a similar operation in November 1948 was 264,250 dpm/m^3 (see Appendix A). Obviously, these data should not be construed as saying that environmental conditions deteriorated with time, but they do suggest that the situation in the earlier years was captured by the 95th percentile exposures in later years.

Summary of Evidence Related to the Over-Arching Question

There is conflicting evidence as to whether the process at Electro-Met remained essentially unchanged from start-up on April 1, 1943, until June 1948, when significant and regular monitoring was undertaken. The following bullets summarize the items discussed above:

- AEC correspondence indicates that process changes were made prior to restart of operations on October 1, 1947
- Comparison of **general air** sampling results made in April and July 1944 show significant improvements in July, presumably associated with use of a portable vacuum cleaner
- It is not possible to show that results of urinalysis sampling in 1944 and 1949 are statistically different
- Daily weighted air sample for process operators measured in December 1947 are lower than for comparable jobs in November 1948 and August 1949
- A limited number of beta samples (3) taken in 1944 are higher than the upper 95th percentile of a large population of film badge measurements made in 1948/1949
- It is not obvious how to apply the generic inhalation approach proposed in TBD-6001 to the years prior to 1948 at Electro-Met
- Air samples taken near a green room operator loading a reduction bomb were no worse in 1943 than in 1948

<u>Finding 17</u>: NIOSH needs to provide convincing arguments that 95th percentile values based on 1948/1949 data are bounding for the period prior to December 1947.

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APPENDIX A: EXAMPLE DAILY WEIGHTED AVERAGE CONCENTRATIONS OF URANIUM IN AIR SAMPLES

Green Room Operator
1 man per shift – 3 shifts per day – total, 3 men
Measurement Date – November [redacted], 1948

Operation	No. of Minutes	No. of Times per Shift	Total Time (Minutes)	Alpha Concentration if d/m/m^3	Alpha Concentration Times Total Time
Charging bomb and cleaning out mixer.	3.4	12	41	264,250 (Average of 4 samples) (High – 319,000 Low – 212,000)	10,800,000
Dumps UF_4 and magnesium into mixer	1.5	12	18	290,800 (Average of 4 samples) (High – 480,000 Low – 91,000)	5,220,000
Removing funnel from bomb. Works UF_4-magnesium mixture down with tapered rod. Smooths and packs with tamp and mallet.	4.8	12	58	66,950 (Average of 4 samples) (High – 111,500 Low – 44,100)	3,880,000
General air magnesium room. Sampling and riffling magnesium.	–	–	60	106 (Average of 3 samples) (High – 180 Low – 80)	6,300
General area.	–	–	294	250 (Average of 6 samples) (High – 360 Low – 189)	75,250
Sweeping up UF_4 from the floor.	–	–	6	97,000	582,000
Removing and cleaning 3 trays from mixer and replacing.	–	–	3	32,700	96,100
Lunch room	–	–	20	109 (Average of 3 samples) (High – 203 Low – 52)	2,180
Locker room	–	–	15	122 (Average of 5 samples) (High – 289 Low – 52)	1,830
			515		20,663,660

$$\text{Average alpha concentration} = \frac{20{,}663{,}660}{515} = 40{,}400\ \text{d/m/m}^3.$$

Assuming 10 cubic meters of air per day

Daily concentration = 40,400 × 10 = 404,000 d/m/day.

Note: Operators wear masks while working in green salt room.
Source: SRDB 8912

Green Salt Loader

1 man per shift – 3 shifts per day – total, 3 men

Measurement Date – August [redacted], 1949

Operation	Time (Min.)	No. of Times per Shift	Total Time (Min.)	Alpha Concentration in Alpha dpm/m^3	Concentration Times Time
Wheels bomb into enclosure, stops mixer, loads mix into bomb, reloads mixer.*	6	14	84	92,700 Average of 4 samples	7,800,000
Fills containers with weighed amount of magnesium.	60	1	60	1,050 1 sample	63,000
Cleans up green salt loading area.	18	1	18	640 1 sample	11,500
General air, green salt area.			318	72 Average of 9 samples	22,900
Lunch room.			20	97 Average of 2 samples	1,940
Locker room.			15	21 Average of 2 samples	315
			515		7,899,655

$$\text{Average weighted exposures} = \frac{7{,}899{,}655}{515} = 15{,}300 \text{ alpha dpm/m}^3.$$

$$\text{Multiple of preferred level} = \frac{15{,}300}{70} = 219.$$

* Operator wears dust mask.

Source: Dust Samples 1949 (SRDB 8930)

APPENDIX B: COMMENTS OF DATA REDUCTION IN TBD-6001

In Table 8 of this report, we extracted inhalation limits from Table 8.29 of TBD-6001 and used that data as a basis of comparison with the Electro-Met-specific inhalation limits included in Appendix C (Table C.2) of TBD-6001. The relevant data in Table 8.29 for metal reduction and casting are, in turn, traceable to Tables 8.16 (Lognormal Distributions of Parameters for Metal Reduction) and Table 8.19 (Lognormal Distributions of Parameters for Metal Recasting). The input data to calculate the lognormal parameters were originally reported in Christofano and Harris (1960). Christofano and Harris provided the minimum, maximum, and average values of the "weighted average" concentrations for each job category, based on air samples taken from 1948 through 1958 at seven uranium refining plants. The relevant data used to calculate the lognormal parameters are summarized in Tables 8.15 and 8.18 in TBD-6001.

NIOSH presumably used guidance in Battelle-TIB-5000 (Strom 2006) to calculate the lognormal parameters. Specific guidance provided in Section 2.1.2.4 of that document states:

> *The average value is generally a more robust statistic than minimum or maximum values, which can be outliers. The preferred default assumption is to ignore the minimum and maximum values, use the average (arithmetic mean) value, and assume a lognormal distribution with*
>
> - *A GSD of 5 for data describing a single process (e.g., a series of air samples), or*
> - *A GSD of 10 for data describing an entire site, plant, or factory.*
>
> *The basis for assuming these GSDs derives from analyzing data from many facilities. The median (GM) x_{50} is computed from the average (arithmetic mean) × using*
>
> $$x_{50} = x \exp(-\sigma^2/2) \qquad 13$$
>
> *where $\sigma = \ln(GSD)$.*

NIOSH used this approach (i,e., equation 13 from Strom 2006) and an assumed GSD of 5 to calculate some of the medians in Tables 8.16 and 8.19. In other cases, NIOSH calculated the median using the following equation (Equation 8 from Strom 2006):

$$x_{50} = \sqrt{x_{min} x_{max}}$$

This equation assumes that x_{min} and x_{max} are symmetrical about the median. Table B-1 compares the calculated medians. Highlighted values in Columns 2 and 3 indicate the values selected for inclusion in TBD-6001. For all but two operations, the median was based on the square root of the product of x_{min} and x_{max}.

Table B-1. Calculated Median Values for Operations in Tables 8.16 and 8.19 of TBD-6001(Units – dpm/m^3)

Operation	Median Weighted Average from Equation 13	Median Weighted Average from Equation 8	Median Weighted Average Reported in Tables 8.16 or 8.19
Bomb preparation	831	240	240
Reduction operations	355	82	82
Bomb breakout*	234	139	234
Crucible loading	14	44	44
Recasting	301	672	672
Crucible burnout	14	50	14
Billet cleaning	13	33	33
Crucible assembly	99	232	232

*- Based on general area sample

Observation: NIOSH does not provide a rationale in TBD-6001 for the approach taken to calculate the GM from the Christofano and Harris (1960) data. In most cases, they did not use the more robust method described in Section 2.1.2.4 of TIB-5000. NIOSH should document the basis for their decision-making.

SC&A also examined the basis for the GSD calculations in the same sets of tables. Although not specifically mentioned in TBD-6001, we assume that σ [i.e., ln(GSD)] was calculated using Equation 9 (the companion equation to Equation 8) from Strom 2006:

$$\sigma^2 = 2\ln x - \ln x_{min} - \ln x_{max} \qquad (9)$$

The values of σ were calculated using Equation 9, converted to GSDs, and compared to the values listed in Tables 8.16 and 8.19 of TBD-6001. The comparison is presented in Table B-2.

Table B-2. Comparison of Calculated Geometric Standard Deviations for Selected Operations with Values Reported in Tables 8.16 and 8.19 of TBD-6001

Operation	GSD Calculated Using Equation 9	GSD Reported in Tables 8.16 or 8.19
Bomb preparation	1.381	5
Reduction operations	Sigma is negative number	5
Bomb breakout*	3.596	5.145
Crucible loading	1.731	1.351
Recasting	2.700	2.683
Crucible burnout	1	5
Billet cleaning	2.280	1.972
Crucible assembly	2.549	2.4

*- Based on general area sample

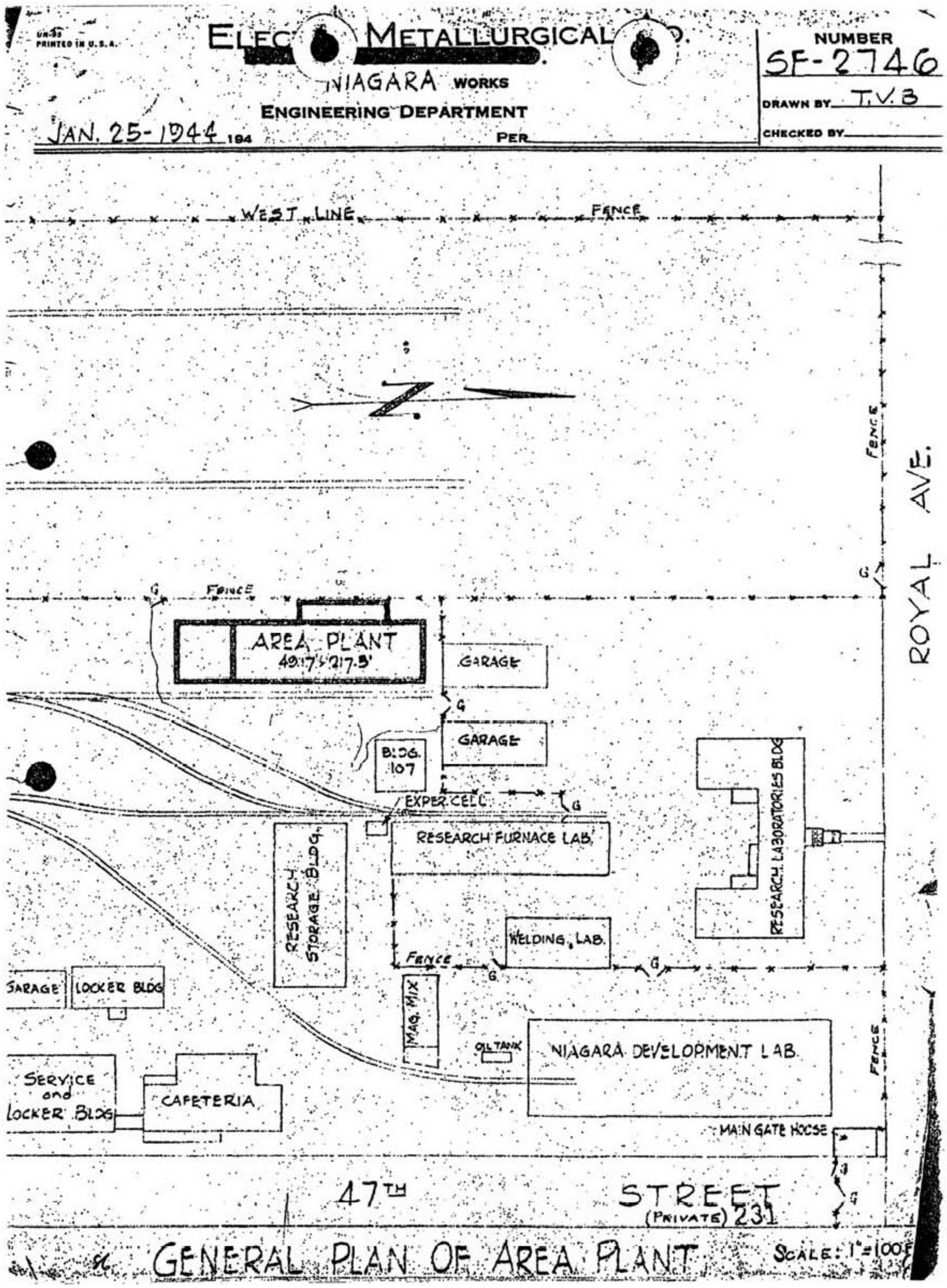
It is not always apparent why NIOSH chose the default GSD value of 5 in some cases and not in others. It is also not clear why the GSD values calculated using Equation 9 from TIB-5000 do not closely agree with the values reported in Tables 8.16 and 8.19 of TBD-6001.

Finding: NIOSH should document in TBD-6001 the basis for selecting when the default GSD was used, and how the GSD was calculated when the default value was not used.

References

Strom D.J. 2006. *Default Assumptions and Methods for Atomic Weapons Employer Dose Reconstruction*. Battelle TIB-5000 Rev. 00-A.14, Battelle, Richland, Washington.

APPENDIX C: AREA PLANT PLOT PLAN



Source: ElectroMet 1946a (SRDB 59225)

APPENDIX D: AIR SAMPLING RESULTS

Table D-1. Air Sampling Results from May/June 1943

Sample	Operation	Sampling Location	Total Dust (mg/m^3)	Uranium Dust[a] ($\mu g/m^3$)	Alpha Activity[b] (dpm/m^3)
601	Filling bomb with green salt and Mg	4.5 ft from floor, 1 ft from bomb loading, 3 ft from mixer	51.7	31,800	48,300
602	Emptying bombs with sledge hammer	4.5 ft from floor, 5 ft from bomb	9.4	2,350	3,570
603	Lining bomb with dolomite	4.5 ft from floor, 1.5 ft from 2 bombs	4.7	423	642
604	General test – above shipping platform	4.5 ft above shipping platform, 1.5 ft from steps	1.17	188	285

a – X material
b – Based on specific activity of natural uranium of 684 pCi/mg and 2.22 dpm/pCi
Source: ElectroMet 1943 [SRDB 5809]

Table D-2. Air Sampling Results from April 5, 1944

Sample	Operation	Total Dust (mg/m^3)	Uranium Dust[a] ($\mu g/m^3$)	Alpha Activity[b] (dpm/m^3)
5	8 ft from packing of dolomite	2.47	400±10%	607
6	5 ft in front of burners whole metal is being burned out of crucibles	6.47	380±10%	577
7	5 ft from chipping operation	4.23	1,700±10%	2,850
8	Center of the floor to test general conditions	2.82	330±10%	501
9	2 ft from where charge is dumped into bomb	4.7	180±10%	273
10	4 ft from green salt mixing (not mixing all the time)	8.81	2,700±10%	4,100

a – X material
b – Based on specific activity of natural uranium of 684 pCi/mg and 2.22 dpm/pCi
Source: Dust Sample Results, April 1944 [SRDB 16247, pdf p. 6]

Table D-3. Air Sampling Results from May 16, 1944

Sample	Operation	Total Dust (mg/m^3)	Uranium Dust[a] ($\mu g/m^3$)	Alpha Activity[b] (dpm/m^3)
11	4 inches in front of crucible	2.47	437	664
12	8 feet from chipping bench	0.47	209	317
13	Center of room in front of remelt furnace	2.23	437	664
14	5 feet from operator of crushing machine	16.6	361	548

a – X material
b – Based on specific activity of natural uranium of 684 pCi/mg and 2.22 dpm/pCi
Source: Dust Sample Results, June 1944 [SRDB 7726]

The authors of Dust Sample, June 1944 (SRDB 7726), observed that "dust concentrations in the chipping room had been cut down to a safe value…" However, because the other dust samples were well above the tolerance level of 150 $\mu g/m^3$, "it is recommended that steps be taken to keep the dust contamination down."

APPENDIX E: MASTER INTERVIEW SUMMARY

INTRODUCTION

As a technical support contractor to the Advisory Board on Radiation and Worker Health (Advisory Board), SC&A has been tasked with reviewing NIOSH's SEC Petition Evaluation Report for the Electro-Metallurgical Corporation facility (Electro-Met). One component of SC&A's review is a series of interviews with site experts, including former site workers, a petitioner, and a petitioner's representative. The purpose of these interviews was to obtain information on past radiological control and personnel monitoring practices, and to better understand how operations and safety programs were implemented at the site over time. Interviewees were identified through petitioners and other interviewees. This report summarizes the results of those interviews.

SC&A interviewers Kathryn Robertson-DeMers and Lynn Ayers conducted telephone interviews or communicated in written form with the interviewees between February 22 and August 16, 2010. Former workers, one petitioner, and one petitioner representative participated in these interviews. All of the former workers were employed at the site during the contract period (1942–1953), with one continuing employment at Electro-Met beyond that time. The workers represent laboratory and maintenance personnel. The petitioner and petitioner representative speak for deceased energy employees who worked at Electro-Met during the atomic weapons contract.

SC&A explained that the interviews were being conducted on behalf of the Advisory Board as part of their review of the National Institute for Occupational Safety and Health's (NIOSH's) Special Exposure Cohort (SEC) petition evaluation report. Participants were told that the interviews were unclassified, and that they should not disclose any classified information. Summaries from each interview were prepared and provided to the interviewees for review. All of the interviewees provided responses to SC&A, have reviewed and approved their written summaries, and their responses are represented in this master summary.

This summary report is not a verbatim presentation of the material contained in the interview notes, nor is it a statement of SC&A's findings or opinions. It is a consolidated summary of statements, opinions, observations, and comments that the interviewees communicated to SC&A. The sole intent of this summary document is to communicate to the Advisory Board and other interested parties the information that the interviewees communicated to SC&A. Where conflicting observations and statements have been received, both perspectives have been retained in this summary report. Any comments inserted by SC&A for the purpose of clarification are designated by brackets.

Information provided by site experts is invaluable in helping SC&A to better understand the operations at Electro-Met. Information provided by the interviewees was based entirely on their personal experience with Electro-Met. It is recognized that the site experts' recollections and statements may need to be further substantiated; however, they stand as critical operational feedback and reality reference checks. The interview summaries are provided in that context.

With the preceding qualifications in mind, this summary has contributed to SC&A's understanding of issues raised in the Electro-Metallurgical Corporation SEC petition.

PRODUCTION AND ANALYTICAL OPERATIONS

[The interviewees, collectively, provided their characterization of radiation-related facilities and work, as follows.]

Facilities

The plant was located at 47th and Royal in Niagara Falls, New York. It was known as Electro-Met and Union Carbide (now Dow Chemical).

There was one building that supported work for the Manhattan Project; it was knocked down in about 1957. The "Area" Plant, Building 166, was a cinder block, single-story building about the size of two garages. It was a substantive building for that time. According to the petitioner, [the Area Plant] was a small building, only 50 feet by 217 feet, but it housed the lunch room, offices, shipping and receiving, the furnace area, etc. With so much going on in such a small building, it doesn't seem possible that any worker who was in there could have avoided contamination and exposure. The analytical laboratory was on one end, and the production area and furnaces were on the other end. They had one or two furnaces in that building for the uranium project. There were fans and hoods in the lab area. The production area had its own ventilation. The furnace room was dusty and very hot.

There were also other furnaces in two or three other buildings where a variety of other metal products were made. They had a total of 13 furnaces at Electro-Met. Electro-Met made stainless steel—that was a main product. They also made welding rods for an electric welding process, including rods for underwater welding. Electro-Met developed this technology. The Navy used welding rods like the ones they made at Electro-Met to repair buckling metal while the ship was at sea.

The uranium building was behind the Union Carbide Research Building. Workers were interviewed, hired, and had training at the Research Building. There was quite a bit of space between the buildings, but workers could go between the buildings easily. Interviewees' estimates of the distance to neighboring buildings ranged from 50–100 feet to at least 100 yards. They did not have a lunch room in the uranium facility, so they ate outside or went off-site for lunch.

Some radiological work was done in the Research Building off Royal Avenue before the new lab in the Area Plant was operational. When the plant was first starting up in late 1942, there was an area in the Research Building where they did analysis on uranium metal to help the workers get acquainted with the procedures. Sometime in 1943, the analytical laboratory was moved to the new uranium facility [Building 166].

Interviewees were not aware of radiological work being done in any other buildings on site. When asked if there were radioactive materials outside of Building 166 [e.g., in the yard], they did not know.

Work Force

The uranium work was sponsored by the Manhattan Engineering District (MED); it was before the Atomic Energy Commission (AEC). The uranium project workers and the research lab workers technically worked for Union Carbide Research Lab at the time.

There was no shift work in the lab. There may have been shift work in the production area. People worked very hard at the time; they didn't watch the clock in those days.

Interviewees estimated that about 50–75 people worked in the uranium facility at a time. There were 8–10 individuals in the laboratory. There were at least 5 or 6 people on the engineering side of the house. There were about 15–20 people working in the production area of the uranium shop on each shift.

The entire Electro-Met facility had about 2,000–3,000 people. There was an entire building with administrative office workers. New construction was hired from the local union halls.

It was important to keep the process going. On one occasion, there was so much snow on the ground, they weren't sure if people could get to the plant through the snow. A [redact] got to work and turned out to be the senior professional on site for the day. He was worried that if the workers were sent home and couldn't get back to the plant, there wouldn't be enough individuals to run the process. Since this was the case, he had to keep the people at the plant who were already there for overtime (24–48 hours). They were treated well, and the professional in charge made sure they got fed at the cafeteria during this time.

Production Operations

The plant mission was to take uranium tetrafluoride [UF_4] and convert it to uranium metal. The uranium metal was forwarded to other areas in the Manhattan Project.

They handled natural uranium in the form of uranium tetrafluoride, and also dolomite, high-fired dolomite, and high-purity magnesium. The uranium material came in as green salt (UF_4). They used only natural uranium, not enriched uranium, at Electro-Met. They only reduced the uranium to metal—other facilities did shaping/fabrication of the fuel. There were no other [radioactive] projects at Electro-Met.

The process [used at Electro-Met] was developed at Iowa University at Ames, Iowa. It was similar to the Mallinckrodt Chemical Works (MCW) process, but Electro-Met refined it a little bit. Electro-Met had a bit of an advantage over MCW, which started the process. By the time Electro-Met started the project, they knew what would work, so they were able to make improvements.

The reaction chambers [used in production] were metal containers (steel, lined with dolomite). The material was prepared with care and thoroughness—using dolomite, magnesium, and UF_4. They used a furnace to initiate the reaction. It operated at high temperature—the reaction is exothermic. After cooling, they would disassemble the chamber to get the metal plugs or buttons out of the reaction container.

After the reduction reaction, the uranium metal button was like a large doughnut sitting at the bottom of the chamber. They had to clean the product before working on it further; they wanted the billets to be pure. [The metal plugs or buttons] were gathered, melted, and cast into cylindrical forms as billets. Casting was done in graphite—under vacuum—by radio frequency induction heating. After casting, the graphite was broken away and the metal was cleaned. Billet samples were taken for laboratory analysis.

To the best of the interviewee's knowledge, they did not handle thorium at the Electro-Met Building. An interviewee is not aware of Electro-Met receiving any scrap uranium metal from outside. The metal that came in was magnesium.

Packaging and Shipping

Incoming material was packaged in drums, bags, and barrels. Material was unloaded by tow-motors and brought into the facility; the same process was used for outgoing material. Workers and furnace operators handled the material. An individual who worked in the furnace area was also involved in shipping and metals; he would package the metals that were produced and ship them to the companies that ordered the material.

Uranium was packaged and shipped in a different building than where the material was processed. The product didn't hang around for long. The billets were shipped out by train in boxcars; a track went right by the plant. They were put in wooden boxes of the correct dimension; each billet was handled separately. The boxes were nailed shut and moved onto the trains that came to pick them up. They would go into the boxcars. There was some element of reasoning for placement—they designated how to arrange them in the car—the worker didn't know why at the time.

One interviewee said the incoming and outgoing trains were guarded. Another worker said there was no security escort.

Analytical Operations

In the Chemistry Laboratory, workers determined the purity and density of the uranium metal that was processed in the plant. The material was handled manually. A chemist would take a piece of the metal for analysis. The metal was dissolved and analyzed for specific impurities. The analysis involved wet chemistry, use of spectroscopic methods, and use of colorimetric methods. They observed the valence change and oxidation state in solution during the dissolution process.

Analytical samples were prepared from samples taken from uranium billets. Laboratory workers were responsible for collecting the billet samples [from the production area] and analyzing the metal. A worker who collected samples would go in and out of the production area; he visited often. The sample taken from the billet was approximately 3 inches in diameter and approximately ¼-inch thick. Laboratory workers used a hacksaw to cut the samples. An interviewee said pieces were broken off to perform chemical analyses. Some workers recalled that they used a vise and a rasp file to remove black residue from the outer surface. Another laboratory worker does not remember cleaning magnesium metal off the uranium metal; the uranium metal was cleaned by people in the production area before they arrived in the laboratory.

Density of uranium analysis was performed on each billet sample. The sample was sawed in half. One half was filed smooth to remove black residue on the outside. The half-moon sample was hung by platinum wire on an analytical balance and weighed. It was weighed again while immersed in a glass beaker containing distilled water. The difference in the two weights was recorded to determine the density of the metal sample.

Uranium samples were heated in furnaces to determine how much carbon and hydrogen and total solids were contained in the uranium. Uranium was dissolved in acid and heated to perform analyses for iron, nitrogen, and boron content.

Analysis of uranium for carbon and hydrogen was done by combustion. The exit of the combustion tube was packed with asbestos that had been soaked in a solution of silver nitrate and dried. Ascarite [a product used to absorb carbon dioxide] was also used. The sample burned at high temperature. The silica combustion tube would not melt at this temperature, but it often cracked from the heat. This was time-consuming, because the worker had to start over with a new tube and a new sample. A laboratory worker said one reason he left Electro-Met was that he was tired of dealing with cracked tubes.

Laboratory personnel filled out forms for each billet that they analyzed (nickel, boron, cadmium elements). They had to report the analysis for each billet; that was standard.

MAINTENANCE AND CRAFTS

[The interviewees with maintenance and crafts experience, collectively, provided their characterization of their radiation-related work in various onsite facilities, as follows.]

A dust collector was a big metal or wooden framework that held a screen and a bag. One end of the frame was open, and one end had a screen. It was as big as a room. They took a lot of metal dust out of the air. Normally, they changed out the bags in the dust collectors about every 3 months, but sometimes they got busy and went a little longer between changes. Maintenance also replaced dust bags when they broke open or got plugged up. As soon as the dust collectors started getting plugged, they would send a maintenance group in to change/replace them. If you didn't keep the dust collector working right, the furnace could overheat.

To change the dust bag, maintenance would pull out the old bags or filters. Sometimes a maintenance worker had to climb into the unit to put the filters and bags back in place. Sometimes going into the dust collector was like going into a fog—you couldn't see or breathe. It looked like pictures of old steelwork areas.

Maintenance workers had to repair furnaces as necessary when they blew out. They would shut off the furnace, cut damaged sections out, fabricate replacement pieces, repair the crack or hole, and get it back up and running. This required them to go inside the furnace when it was cooled down.

There was a sheet metal shop at the plant. The Area Plant had a repair shop for fixing things that broke down, in addition to the uranium processing area.

Janitors assigned to the Uranium Plant were assigned only to the Uranium Plant. They were responsible for keeping things clean. They were definitely in the laboratory and possibly in the production area.

SECURITY

[The interviewees, collectively, provided their characterization of security practices, as follows.]

There was a fence around the entire Electro-Met plant, with a guard at the gate. There were two entrances to the plant; (1) off Pine Avenue, and (2) at Royal and 47th Street. Family members who drove workers to the site would let the workers off before the gate to the plant. The workers would pass through the gate; the family members who were not Electro-Met employees were not allowed to go beyond the gate.

An interviewee does not remember [an additional] fence or guard at the Research Building when radiological work was done there. All he had to do was to walk into the building.

[There are some discrepancies in former workers' recollections of access controls specific to the Area Plant.]

- Laboratory workers recalled that uranium operations areas were restricted to workers who were directly involved in these operations.
    - An interviewee does not remember the details of security, but the uranium building was not open to everybody. It was a wartime thing, and it was important. The worker never discussed anything with anyone outside the building. It was kept very hush-hush.
    - Some workers recalled that there was a second enclosure fence around the uranium facility [Building 166]. The gate was guarded, and workers had to show a badge to the guard to gain entry.

- Another worker did not recall any additional barrier separating the Uranium Shop from the rest of the Electro-Met facility, but he thinks they had special identification to enter the Area Plant and that guards would prevent people from coming in without proper identification.

- A maintenance worker does not remember an additional fence or security checkpoint at the uranium area. They had Security at the main gate. Once you got inside the plant, you could go into any building. All the plant was pretty wide open to the workers. Nothing prevented workers who were not assigned to the uranium program from gaining access to the uranium work areas. Anyone could go from building to building.

The chemists had access to the operations area, but they did not go there every day. Laboratory workers didn't participate in the production activities directly, because it was pretty restricted.

Workers never mentioned their work on the Manhattan Project [to their family]. Individuals were sworn to secrecy. A worker described a situation that illustrates the level of secrecy about the project at the time. When a doctor evaluating an unusual health problem asked if he worked with a heavy metal, the worker said, "I can't answer that question." They were working in a wartime situation—the doctor knew enough to ask, and the worker knew enough to say, "I can't answer."

RADIOLOGICAL CONTROLS

[The interviewees, collectively, provided their characterization of radiological control activities at the Electro-Met facility, as follows.]

A laboratory worker did not think the work he did at Electro-Met was particularly hazardous. Uranium emits an alpha, which can be stopped by a sheet of paper. There was nothing particularly deleterious about the work they did with uranium; it was a lot like working with lead, another heavy metal. It wasn't considered a serious hazard, at least not for the time. People have gotten a lot more concerned about hazards over time. For example, a chemist using a Bunsen burner often used a screen that contained asbestos; that was just what you did. Now, everyone avoids asbestos.

A worker does not recall a formal Radiation Safety Program.

When asked about interactions with the New York Operations Office (NYOO), an interviewee said they may have been involved with the higher ups. Laboratory workers knew when the big shots were coming in, but didn't interact with them. It was their job to keep the laboratory clean.

Surveillances

They took precautions, even in those days. The detection limits have improved over time. Methods of detection of radiation have improved to the point where things can be detected at very low limits. The detection levels just weren't there at the time. They did the best they could at the time.

Workers were not required to survey their clothing, hands, or feet with radiation detection instruments for radioactive dust when they left production areas to go to non-radiological areas of the building (office, break room, etc.). They were not required to survey when they left the buildings where uranium work was conducted. One individual said they may have changed shoes, but he was not certain.

A worker was assigned by management to collect air samples to check for uranium dust in the air. The air samples were taken in the general area of the room or at the hood. This was being done with some routine frequency—not sporadically—for some time before the summer of 1946. They pulled air through a filter and sent the filter out for analysis. The interviewee doesn't remember the details, where they sent it, or who he gave the samples to. Samples were probably collected from both the production area and the analytical lab. Management encouraged professionals to take the credit and the responsibility for the work they performed. The lab worker took it to the supervisor, and he said "You did the work, you sign it."

Contamination Control

The analytical work was done in hoods. They had the usual hoods at Electro-Met that were used in an analytical lab. Gloveboxes were not available and were not used for this time period; they emerged slowly over time. There were separate hoods and design systems for the lab. Consult the engineering drawings for the remainder of the plant.

They tried to keep the production area clean. It was a metallurgical process area—what does clean really mean? They were meeting the standards of the time as they knew them. This was an embryonic thing; they didn't know a lot about things at this time.

Interviewees did not know if uranium could have been tracked from the uranium shop to other areas of the Electro-Met facility; they did not recall any specific issues with uranium tracking. Material might have gotten out by mistake, maybe on someone's clothing. It could be tracked to other areas on shoes. There was no difference going from building to building. There were no special practices unique to the uranium building.

Showers were available; the interviewee is not sure how often people showered. A laboratory worker did not have to shower after going into the production area; he does not know if the production workers were required to shower. A maintenance worker was not required to shower after working in the uranium shop. He did shower and change clothes at the end of the workday. He took a shower on his own time after work.

A worker said eating, drinking, and smoking were permitted in "safe areas" (e.g., offices). One worker said they were allowed to eat and drink in the chemistry laboratory, and another lab worker said they were not. Laboratory workers did some mouth pipetting; this was a routine practice at the time. They did not have vacuum suction devices to use in pipetting.

An interviewee doesn't know how effective the controls were or how well the material was contained. If you did get it on your clothes and walk around with it, you didn't know. The lack of controls would never be acceptable today in the U.S.

Personal Protective Equipment (PPE)

Maintenance wore regular work clothes they bought at the store, no matter where they were working. The company did not provide work clothing and did not have a laundry facility. The worker had two or three sets of work clothes. Some personnel left their work clothes at the shop unless they were dirty; they brought them home to get washed once or twice a week. Workers in the chemistry lab could wear white coats.

Workers wore hard hats most of the time out in the plant areas. They used safety glasses, goggles, gloves (including asbestos gloves for furnace work). Maintenance had no special PPE for changing bags in the dust collector; although, they may have chosen to wear a respirator as needed for low oxygen, due to the heavy dust levels. In general, dust masks and respirators were worn in the furnace room or wherever the dust was bad. The boss was not around telling you to wear particular safety gear; a worker used their own judgment and wore what was appropriate for the job conditions. Not everyone wore a respirator.

The respirator was a mask that covered the face; there was a regulator on the back of the neck. There was a multiple-use policy; the respirator would be left in the area for the next guy to use. All PPE—hard hats, gloves, glasses, respirators, etc.—was made available in an area and was worn by multiple users. The equipment was not issued or assigned to a particular worker.

When laboratory workers cut and filed uranium billet samples, the filings fell on the floor or on the vise used to hold the sample. Workers wore eye protection, but no gloves or respirators during this process. On occasion, workers saw sparks when they swept up filings. A worker held his breath to avoid inhaling the fumes (smoke from the sparking uranium). One interviewee wore a face mask when handling and preparing uranium samples; he does not recall where they were stored when not in use.

Environmental Monitoring

An interviewee does not remember them conducting any analysis of the ground around Electro-Met while he was there. Uranium is found in soil. Rare earths are also prevalent in the soil naturally.

EXTERNAL MONITORING

[The interviewees, collectively, provided their characterization of how external monitoring was performed historically at the Electro-Met facility, as follows.]

[Recollections about external monitoring were variable.] Of the workers interviewed, some did not recall whether or not they wore badges or dosimeters at Electro-Met. One interviewee "did not have the pleasure" [of wearing a monitoring device], and one interviewee stated that film badges were used at Electro-Met.

INTERNAL MONITORING

[The interviewees, collectively, provided their characterization of how internal monitoring was performed historically at the Electro-Met facility, as follows.]

[Submittal of bioassay reported varied by interviewee.] One interviewee recalls submitting urine for bioassay. Other interviewees did not recall submitting urine bioassay. Another recalls that Electro-Met First Aid nurses collected a blood sample once a month. Urine samples were given during yearly or semi-annual physicals.

INCIDENTS

[The interviewees, collectively, provided their recollection and understanding of what incidents occurred at the facility and how they were handled, as follows.]

[Different recollections were presented in regard to "blow-outs" or "bomb explosions."]

- There were no high energy explosions at Electro-Met. Sometimes—not frequently—there might be a leak if the seal didn't get sealed all the way.

- You could get blow-outs in the cradle [the bomb or reaction vessel]. These blow-outs would include anything from cracks to holes in the cradle.

An interviewee is not aware of any official documents for documenting blow-outs or other incidents. Your boss would tell you to fix the problem.

Small chemical explosions sometimes happened in the laboratory hoods as a result of a perchloric dehydration process. Dust and condensate accumulated in the [ventilation] ducts as a normal part of the analytical lab process. Heat could set off the dust, but this was a normal thing. There would be a pop, and the workers had to stop and clean the area. It happened periodically—more than once over a 3-year period.

MEDICAL

[The interviewees, collectively, provided their characterization of how medical monitoring was performed historically at the Electro-Met facility, as follows.]

An interviewee recalled that medical services were located in a neighboring building, separated from the Area Plant. A nurse was routinely available; an interviewee thinks they had one right there in the Area Plant. There was a nurse assigned to the area also. Workers saw them quite frequently. A worker saw the doctor more at Electro-Met than at his later workplaces.

A physical examination was required once or twice a year with x-rays (chest). Workers submitted urine samples during this physical.

[Electro-Met extended a high level of care for a worker with a chronic condition.] The doctor at Electro-Met sent the worker to a prominent medical facility in an effort to diagnose the problem. The doctor sent him there and Electro-Met paid him while he was gone. There was a care that was expressed, even though they didn't figure it out at that time.

RADIOLOGICAL RECORDS

Interviewees were not aware of any documents or records related to the historical operations and potential exposure conditions at Electro-Met. The Medical Department may have kept records.

An individual was involved with the claims process for at least five Energy Employees or their survivors. They were not able to retrieve any of the radiation records for these individuals. Records were destroyed, inadequate, or unavailable.

WASTE MANAGEMENT

[The interviewees, collectively, provided their characterization of how radioactive and hazardous waste was handled historically at the Electro-Met facility, as follows.]

Cleaning of the surfaces may have generated some waste. There was no waste in the sense of lousing the material up.

Acid solutions of uranium were collected in a container. They were neutralized to pH 7, and the precipitate was filtered. The uranium was in the precipitate. The small amount of waste handling was done at the lab sink. The interviewee does not remember if the liquid went into the sink or was poured into another container, but does recall filtering it.

They had a dump area outside Niagara Falls going toward Lockport; it was less than half a mile from the plant. The waste from the uranium processing was dumped there, as well as waste from other operations. Another dump was located near Lake Ontario. There were railroad tracks running right up by the building. Waste was put on flatbeds and sent to the dump—the one behind the plant or the one on Lake Ontario. This is where they dumped all this stuff. The facilities are still there where they dumped the waste.

They tried to keep the piles separate, in case they might need to go back and use it again. They thought it didn't have a use at the time, but they have dug up a lot of material from the waste dumps. Sometimes waste was reprocessed for other uses.

SEC PETITIONERS' COMMENTS

Basis for Petition

One petitioner chose to include the entire Electro-Met population in the petition, rather than only those individuals who worked in the Area Plant. Electro-Met was a very small plant, and workers were walking into areas with uranium even if they didn't work there all the time. For example, maintenance was in and out of the building where uranium was processed. They would walk around the furnace areas. The petitioner felt that everyone who was exposed should be included in the SEC group.

The original timeframe for Petition SEC-00132 was from 1952 to 1959, based on an employment record provided by Dow Chemical for the survivor. When discussing the time period with NIOSH, they said to limit the petition to the time when they were actually doing the [uranium] work. They recommended a cutoff date of December 1953. In the evaluation report, they cut it off in June 1953. The contract ended in June 1953, so NIOSH's timeframe does not allow for any cleanup period beyond the end of the contract period. If there was a cleanup effort, the contamination would be stirred up, perhaps even more than it was during production.

There was no evidence that there was a period of cleanup. There was certainly residual contamination. In fact, in the evaluation report, NIOSH indicates that there were contamination surveys in August 1953 and contamination was present. Ending the class in June 1953 does not make sense. Workers should be given at least some time beyond the contract because of the residual contamination.

Petitioners have referenced an article that was published in *USA Today*. The article indicated that the Electro-Met facility was lacking meaningful records and had dust concentration levels at many times the limit of the time. Another document, called "The Legacy of the Manhattan Project at Niagara Falls," was also provided to the Department of Labor (DOL). "The Legacy of the Manhattan Project" mentions that Electro-Met reprocessed filings from Simonds Saw and Steel, including uranium filings and thorium. There was a series of articles called the "The Bomb that Fell on Niagara." It included an article on Human Radiation Experiments. These articles mentioned a dump site near the Pine Avenue area. There was a permanent dump site, which is the only hill in Niagara.

A petitioner's information about the absence of records and monitoring was specific to [a family member's] case. General information about work conditions and monitoring came from *USA Today* articles and similar types of information.

A primary basis for the petition is lack of records. No dosimetry records are available for an individual who was stationed in the uranium facility. The individual either did not wear a dosimeter or [the records] were destroyed.

For supporting documentation, a petitioner had letters from the retirement service stating that [the Energy Employee's] records had been destroyed. There were no existing records whether the Energy Employee had ever worn a dosimeter or not. NIOSH asked a petitioner if [the Energy Employee] had ever worn a dosimeter. The petitioner wrote a letter to Dow Chemical requesting [the worker's] dosimeter records. They wrote back saying the records were destroyed. The petitioner had to write to Dow Chemical a second time requesting dosimetry records and was told there were none.

There are errors and details missing from the worker's employment record from Dow Chemical. For example, the worker's time at two other facilities was not on the record. The petitioner was able to locate a coworker of [the family member] who verified that he worked at another facility for a period of time.

Even NIOSH has acknowledged that there were not a lot of records. There were air sampling records for 1948 and 1949, and limited records for other periods of time. NIOSH says the data are sufficient enough to render a decision. How, with such a limited amount of records, can they assign a dose? How does one explain the cancers that occurred?

The articles referenced in the petitions indicate there was a lack of any real meaningful ventilation system. Documentation states that Electro-Met failed to even vacuum work areas, despite being "persistently instructed" by the AEC to do so. When AEC medical officials suggested that the AEC could pay for new ventilation, the higher-ups balked at the time. It was felt that it would only be a few more years before federal facilities would be built to take over the work done at Electro-Met, and that the system was cost prohibitive.

Even when the operation was on standby, there was exposure to residual contamination. There was a focus on production. The area was not cleaned up properly. The buildings looked like old factories; the windows were black and it was awful. Even in 1952–1953, according to the evaluation report, significant uranium surface contamination was present. The area was definitely not cleaned up to perfection, leaving some material behind. Nowadays, if you view the site from the fence, it looks like a pile of rubble with a metering hose and vent pipes.

As discussed in a letter related to the SEC petition for another AWE facility, a reform to the SEC program is needed. How can you use limited data or incomplete data and a computer program to come up with an exposure?

The burden of proof is so difficult unless you are a scientist. The claimants have an insurmountable burden of proof, since they do not have access to the records they need. The records and reports put out by NIOSH are difficult to analyze, technically complex, and not understandable. You need to be a scientist to understand and come up with proof. The burden of proof has clearly been placed on claimants and petitioners. The burden of proof should be on the government instead.

Claims Process

Individual people are not being listened to, and individual situations are not taken into account. Individual claims don't seem to be handled on an individual basis. No one seems to be interested in the specific circumstances of an individual worker. They just put information (like a job title) into the computer and get a result out.

It is not claimant favorable to assume that a worker was not exposed based on a job title. [The Energy Employee] is not here to speak for himself and tell you what he did. [Survivors] don't know exactly what he did. Did administrative workers have to go into [radiological] work areas to collect time cards and deliver paychecks? Did they have to go into areas and ask workers about vacation? Were they asked to sweep dust off the floor because it needed to be done?

Details like this would affect an individual’s exposure, and there is just no way to know the information.

There are a lot of assumptions being made in dose reconstruction. NIOSH doesn’t address monitoring or exposure to the support staff who intermittently visited the uranium area. Were there air concentration measurements for other areas of the plant [outside the Area Plant]?

It is very difficult to get the medical/hospital records to support a claim, particularly for survivors. For example, an Energy Employee went to see the plant doctor, the Union Carbide doctor in Niagara Falls, for care related to his cancer. The [Electro-Met] plant was taken over by another company after Union Carbide. The employee’s survivors contacted the new company to request the Energy Employee’s medical records; however, they indicated his records were no longer available.

If a cancer is considered secondary or metastatic, NIOSH/DOL does not consider it in dose reconstruction. [Given the scarcity of medical records], how do they know the cancer didn’t start there?

An individual has been involved with several claims for family members and friends. Two of the claimants died of [redact] cancer, and they received full compensation after partial dose reconstructions. Two other claimants, who worked in the same departments for much longer periods of time, were denied compensation for other cancers. One worker who was compensated for [redact] cancer only worked there for [redact] months. The interviewee does not understand why one family member, who worked at Electro-Met for a few years, was assigned over 100 rem, while another family member, who worked in the same departments through the entire covered period and beyond, was assigned less than 10 rem.

It seems if a worker had [redact] cancer, it doesn’t matter when, where, or for how long the individual worked at the site, the worker receives compensation. For other cancers, including bladder, colon, and liver cancer, the workers are not being compensated. And bladder cancer is on the list of 22 cancers for an SEC.

In one family, one sibling was compensated as a survivor, but another sibling was not compensated, because he was not under the age of 18 when his father died.

[The process of filing a claim and a petition] was extremely frustrating and confusing. The process has been going on for 8 years, since the time the claim was originally filed. Why does it take years to go through the process? What takes so long? Why is it so difficult? The claimant/petitioner has been made to jump through all sorts of hoops. It seems like they send you on wild goose chases just to keep you busy, and then the information they asked for isn’t important when you get it. It is difficult to find the correct person to talk to. It feels like NIOSH tries to wear you down so you give up and quit.

Initially, a claimant/petitioner was asked to provide Medical Records. Last year, they just noted that there was a [health condition that had not been addressed previously]. They asked for additional medical information associated with this condition. Because they waited 7 years to request these records, the doctor was no longer available and the medical records (now over 10 years old) had been destroyed. If they had asked for the additional records when the claim was first filed, the medical records would have been available.

When a second cancer was discovered in the medical file, [a claimant] was told they were going to redo the dose reconstruction. The second dose reconstruction had a much lower probability of causation (POC)—it was about one-fourth of the value from the previous dose reconstruction. The claimant asked NIOSH about the reduction in the POC. They were told that the second dose reconstruction was a more realistic way of doing it, so the new numbers were more accurate. The interviewee doesn't think it is claimant favorable to ever lower the dose reconstruction dose. It feels like the numbers are being manipulated to control the outcome (POC).

Petition Process

A petitioner doesn't think there have been any Worker Outreach meetings for Electro-Met. There are none listed on the website for Electro-Met.

A petitioner is aware of the petition areas on the NIOSH website and believes the petition on the website is complete. There were no worker affidavits associated with the petition.

There was a particular woman at NIOSH that was very helpful to a petitioner navigating the process. She told them what to do and said she was available to answer any questions. She made sure they had the right forms.

NIOSH did not interview the petitioners when they evaluated the petition. No one called during the evaluation process to discuss the petition. A petitioner received notice by FedEx that they approved the petition for review.

Upon completion of the petition evaluation report, petitioners received a written report. No one spoke with them about it. A petitioner received a letter from NIOSH with the evaluation report attached. [NIOSH] indicated that the evaluation report had been completed and was being submitted to the Advisory Board. In the letter, it indicated that they would contact the petitioner at a later date to explain the details in the report, but there had been no additional contact. NIOSH did not explain the method for assigning a bounding dose and what this means.

The [petition evaluation] report is difficult to read. It seems to go back and forth. It seems to go in one direction that favors the petition (e.g., agreeing that they don't have monitoring records), but then it changes gears (e.g., badge data for a similar job title is sufficient). There are lots of "but" and "however" statements.

NIOSH responded to concerns about blow-outs (mentioned in the petition) by saying there were no records supporting the occurrence of blow-outs.

The Advisory Board denied a request to postpone the presentation [of the evaluation report] on Electro-Met, but assured the individual that there would be additional opportunities to provide information. Individuals could call in during the meeting and provide comments. During the comment period, a caller asked why the petition was denied. The Advisory Board indicated that it would be a while before the petition was considered, because they were going to have an independent agency look at it. The caller was told that additional information could still be submitted.

A petitioner was listening in on a meeting when a representative from NIOSH said that only a small percentage of cancers are caused by radiation. This overlooks the fact that workers didn't even know they were working with radiation or chemicals. Doctors questioned [a family member] about his risk factors for multiple myeloma. The only factors he had were being male and working with radiation (which he didn't know). How can science figure out the causes and risk factors when the patients themselves don't have knowledge of their exposure?

MISCELLANEOUS COMMENTS

- Initially, a laboratory worker didn't know what they were working with. They were given the procedures and followed them like a cake recipe. They found out what they were working with when the bomb went off in Nagasaki.

- Another interviewee said that the analytical chemists had the training to know the basic hazards of the material and to know the proper ways to handle it. They did not know all of the dangers, but they were trained as chemists and worked willingly.

- There is lot of variation among people regarding the sensitivity of their bodies and their fear of radiation. No one really understands how it all works. It's very difficult to look back—that was now almost 70 years ago—and decide if something back then caused a problem that's happening now.

- An interviewee said they were trained well at Electro-Met. Some well-known people in the field were involved with the Electro-Met projects. They had a very experienced and well-known metallurgist.

- There were some chemicals in the analytical laboratory. Bunsen burners were used to heat stuff. Some of the gauzes that were used to handle samples had asbestos. That was a normal practice at the time for chemistry labs, even in high school and universities. That was before we knew about mesothelioma. Not all forms of asbestos result in mesothelioma.

- An interviewee indicated all coworkers died from cancer at a young age.

- Stainless steel hoods and gloveboxes were developed later. They learned from the experience of the milk industry that had to maintain sanitary conditions.