
Draft

**ADVISORY BOARD ON
RADIATION AND WORKER HEALTH**

National Institute for Occupational Safety and Health

**REVIEW OF THE NIOSH TECHNICAL BASIS DOCUMENT
FOR THE HOOKER ELECTROCHEMICAL COMPANY,
DCAS-TKBS-0009**

**Contract No. 200-2009-28555
SCA-TR-SP2013-0034, Rev. 0**

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S. COHEN & ASSOCIATES: <i>Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program</i>	Document No. SCA-TR-SP2013-0034
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ACRONYMS AND ABBREVIATIONS

Advisory Board, ABRWH, or Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AMAD	activity median aerodynamic diameter
AWE	Atomic Weapons Employer
BZ	breathing zone
CaO	calcium oxide
CFR or C.F.R.	<i>Code of Federal Regulations</i>
DCAS	Division of Compensation Analysis and Support
dpm/m ³	disintegrations per minute per cubic meter
DWA	daily weighted average
ElectroMet	Electro Metallurgical Company
ER	Evaluation Report
FGR	Federal Guidance Report
g/cm ³	grams per cubic centimeter
g/L	grams per liter
GM	geometric mean
GSD	geometric standard deviation
HCl	hydrochloric acid
Hooker	Hooker Electrochemical Company
ICRP	International Commission on Radiological Protection
keV	kilo electronvolt
kg	kilogram
LOOW	Lake Ontario Ordnance Works
m	meter
m ³ /hr	cubic meter per hour
MCNPX	Monte Carlo N-Particle eXtended
MCW	Mallinckrodt Chemical Works
MED	Manhattan Engineer District
Mg	magnesium
MgF ₂	magnesium fluoride
MgO	magnesium oxide

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mR/hr	milliRoentgen per hour
mrem	millirem
mrep/hr	millirep per hour
m/s	meter per second
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
pCi	picoCuries
pH	- log H ⁺ concentration
R or r	roentgen
rem	Roentgen equivalent man
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	Technical Basis Document
U	uranium
UF ₄	uranium tetrafluoride
μm	micrometer

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1.0 STATEMENT OF PURPOSE

The purpose of this report is to provide a critical review of the National Institute for Occupational Safety and Health (NIOSH) *Technical Basis Document for Hooker Electrochemical Company*, DCAS-TKBS-0009 (NIOSH 2011b). In this report, we assess the merits and technical basis of the data and guidance to be used for dose reconstruction. This review was authorized by the Advisory Board on Radiation and Worker Health (Advisory Board or ABRWH) Subcommittee on Procedures Review at its January 2013 meeting.

In this report, SC&A also provides a critique regarding whether or not NIOSH has appropriately addressed in NIOSH 2011b findings from an earlier SC&A review of the original Hooker site profile, Appendix AA of TBD-6001 (SC&A 2010), and the Special Exposure Cohort (SEC) Petition Evaluation Report (ER) for Hooker (NIOSH 2010). Review of the ER findings is equally relevant, since many of SC&A's findings on the ER were also tied to Appendix AA.

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2.0 INTRODUCTION

In 2007, NIOSH issued the original site profile for the Hooker Electrochemical Company in Niagara Falls, New York (Battelle 2007) as Appendix AA to Battelle-TBD-6001, *Site Profiles for Atomic Weapons Employers that Refined Uranium and Thorium* (Battelle 2006). As an appendix to TBD-6001, the Hooker site profile relied heavily on the parent document for dose reconstruction guidance. Based on a May 2010 request by the Advisory Board, SC&A performed a review of Appendix AA and reported 10 findings (SC&A 2010). These findings are summarized in Section 4.0, along with a discussion regarding the extent to which these original findings have now been resolved. It should be noted that several of these findings related to problems with the parent document TBD-6001 upon which much of Appendix AA was based. TBD-6001 was subsequently cancelled by NIOSH and alternate modeling approaches were used in revising Appendix AA.

At about the same time as the Advisory Board made its request to SC&A to review Appendix AA, NIOSH issued an ER on Hooker Electrochemical Petition SEC-00141 (NIOSH 2010). SC&A was not initially tasked with reviewing the ER on Petition SEC-00141; however, as noted in its review of Appendix AA (SC&A 2010):

SC&A was not tasked with a review of the petition evaluation report; however, as we have done in the past in similar situations (e.g., our review of the United Nuclear Corporation site profile), we provide some initial impressions regarding possible SEC issues, based on reading the petition and the evaluation report. A more detailed review of the petition and evaluation report will be performed if so authorized by the ABRWH.

Subsequently, at the TBD-6001 Work Group Meeting held in Cincinnati, Ohio, on November 4, 2010, SC&A was requested by the Work Group to prepare a focused review of the NIOSH Petition Evaluation Report for the Hooker Electrochemical Atomic Weapons Employer (AWE) site (NIOSH 2010). Since the ER contained new information developed since Appendix AA was issued in 2007, the Work Group felt that a focused review of this new information was needed. In response to this tasking, SC&A provided the focused review of the ER in January 2011 (SC&A 2011a). SC&A had nine findings based on its review of the Hooker ER. These findings are also summarized in Section 4.0, along with a discussion addressing the extent to which these nine ER findings have also been resolved.

After the 2010 SC&A review, NIOSH converted Appendix AA to a stand-alone site profile or technical basis document (TBD) published on April 4, 2011 (NIOSH 2011a) and issued a revision to that document on June 17, 2011 (NIOSH 2011b). The changes made, according to NIOSH 2011a, were:

Changes Battelle-TBD-6001 Appendix to a standalone document. Revises dose models to eliminate dependence on Battelle-TBD-6001. Provides more detailed description of dose models. Incorporate [sic] review comments.

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Similarly, with regard to NIOSH 2011b:

*Revision initiated to correct errors in Tables 2, 3, and 6 [of NIOSH 2011a].
Renummer tables after Table 4. Added language on page 10 to indicate the 95th
percentile of the airborne values was used. Corrected typographical error on
page 7 and 14.*

In the ensuing sections of this report, SC&A documents its review of the *Technical Basis Document for Hooker Electrochemical Company*, Rev. 1 (NIOSH 2011b) and discusses the extent to which prior findings regarding NIOSH documents related to Hooker have been adequately addressed.

Since NIOSH 2011b uses surrogate data, the appropriateness of this usage, as judged against the criteria developed by the ABRWH, is discussed in Section 5.0.

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3.0 REVIEW OF HOOKER ELECTROCHEMICAL TECHNICAL BASIS DOCUMENT, DCAS-TKBS-0009

During the course of this review, SC&A uncovered some new information, which was not considered by NIOSH and presents a somewhat different picture of what could have occurred at Hooker. The new information is a February 1944 report describing laboratory work done at Hooker to develop the C-2 slag concentration process and size process equipment for the leaching operation that began in July 1944 (Thomas 1944). In the discussion that follows, SC&A contrasts the process information based on the laboratory work (Thomas 1944) with the process information derived from MED 1944. As will be described, the information in MED 1944 is ambiguous regarding the uranium content of the slag and the processing rate through the acid leaching operation. SC&A's review here follows the sequence of topics as presented in the Hooker Electrochemical TBD (NIOSH 2011b).

3.1 REVIEW OF SECTION 3.0 "PROCESS DESCRIPTION" AND SECTION 3.1 "URANIUM CONCENTRATION"

The Hooker Electrochemical Company (Hooker) in Niagara Falls, New York, processed C-2 slag from July 11, 1944, to January 15, 1946 (NIOSH 2011b, Section 2.0). The operations at the Hooker facility involved treatment of C-2 slag from the nearby Electro Metallurgical Company (ElectroMet) with hydrochloric acid (HCl) to increase the uranium content. The C-2 slag from ElectroMet was a byproduct of the bomb reduction process, in which uranium tetrafluoride was reacted with magnesium (Mg) to produce uranium metal. Dolomite was used as the bomb liner at that point in time (NIOSH 2011b).¹ The dolomite was high-fired or fused, resulting in a product with the approximate formula CaO·MgO. The HCl was excess acid produced at Hooker under an Atomic Energy Commission (AEC) contract as a byproduct from the non-radioactive P-45 chemical process.

In the bomb reduction process, several different "slags" were apparently produced. The bomb liner was fused dolomite, which was tamped into the bomb between the inner surface of the bomb and a mandrel. After the mandrel was withdrawn, the charge of Mg plus UF₄ was inserted into the cavity. During the reduction process, both reaction products (U and MgF₂) were molten and separated by gravity into distinct layers. The products were the uranium derby, the MgF₂ slag, and the decomposed liner slag, which were physically separated from one another. Obviously, the separations were imperfect, so each product would be contaminated by the other two products. The spent liner was referred to as C-liner or C-slag. According to Thomas (1944), the reaction slag was divided into two parts; (1) C-1 slag, which was +4 mesh lumps containing 5%–10% U, and (2) C-2 slag, which was the -4 mesh material containing 0.5%–3% U. ORAUT 2005 (Table 4) mentions C-1 scrap, but provides no insight into its origin or composition. It is also not clear whether or not MgF₂ slag and C-1 slag are somehow related.

C-2 slag from ElectroMet was shipped to Hooker by rail in wooden barrels (DOE 1977, MED 1944). Each barrel was filled with 500 lbs of slag (reduction bomb liners) with the "approximate" composition of "90% MgF [sic] and 10% CaO, plus 1% X" (MED 1944, p. 29).

¹ After 1949, recycled MgF₂ was used as the bomb liner.

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We note that the correct chemical formula for magnesium fluoride is MgF_2 and that “X” was used as code for uranium.

The barrels were opened and the contents were dumped onto a 20-mesh screen,² with the undersize being conveyed by a bucket elevator to one of three wooden digestion tanks (MED 1944, although DOE 1985 says that 4 tanks were used). Oversize (+ 20 mesh) material from the screening operation was drummed and returned to Manhattan Engineer District (MED) control. According to Thomas (1944), the oversize contained 8 times as much uranium as the -20 mesh fraction and accounted for about 20% of the as-received slag.

After the undersize from 40 barrels of slag was loaded into a 13-ft diameter by 11-ft high wooden digester tank (Dowling 1944, p. 112; MED 1944, p. 30), HCl was added and the pH was adjusted to 4.0 with water additions (MED 1944).³ Digestion of the agitated slurry continued for about 20 hours (MED 1944). Operators standing on platforms above the tanks then added lime from 100-lb bags to neutralize the slurry (MED 1944). The neutralized slurry was pumped to a plate and frame filter press, where the filtrate was collected and discharged into a sewer. The filter cake was then washed several times, and was re-drummed and shipped by rail to MED control (MED 1944). The turnover rate for a digester tank was stated to be once every 2 days (MED 1944).

There is some uncertainty as to the uranium content and composition of the slag. As noted above, the uranium content is stated on page 29 of MED 1944 as 1%. However, on page 30 of MED 1944, it is stated that, “slag is concentrated from about 1 lb to 5 or 10 lb by weight.” If the barrel contained 1 lb of uranium in 500 lbs of slag, then the initial composition would be 0.2% (as assumed in NIOSH 2010, NIOSH 2011a, NIOSH 2011b, and SC&A 2010), not 1%, as stated in MED 1944 (p. 29).

NIOSH (2011b) addressed the question as to whether the slag contains 0.2% U or 1% U, since both values appear in MED 1944. NIOSH notes that similar slag produced at Mallinckrodt Chemical Works (MCW) during the time when dolomite was being used as a bomb liner contained 0.3% U. NIOSH also argued that:

Lastly, if the incoming material had a uranium concentration of 1%, the Hooker process description does not appear to make sense. A 1% concentration would equate to 5 pounds of uranium in 500 pounds of slag. If that were true, the mention of one pound of uranium in the description makes no sense. Also stating that the slag was concentrated to 5 pounds would make no sense.

However, Thomas (1944) states that the C-2 slag obtained from ElectroMet for Hooker process development contained 0.84% U, a value similar to the 1% X cited on page 29 of MED 1944. Thomas further states that the wet filter cake contained 5%–6% U and about 40% moisture. Given this information, the statement in MED 1944 that “slag is concentrated from about 1 lb to 5 or 10 lb by weight” can be interpreted as meaning **lbs of U per 100 lbs** or concentration from

² Screen opening – 0.0335 in.

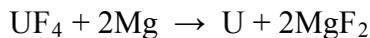
³ We note that the September 12, 1944 *Outline for Operating C-2 Slag Plant* states that the pH was adjusted to 5. See Appendix B.

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1% to 5%–10% U. With this interpretation, the compositions on both page 29 and page 30 of MED 1944 are consistent within that document and with Thomas 1944.

The information in Thomas 1944 also brings into question whether the nominal slag composition of “90% MgF [sic] and 10% CaO, plus 1% X” is correct. Thomas (1944) states that the “bulk of the C-2 slag is magnesium oxide and calcium oxide.” The goal of the Hooker process was to increase the uranium content in the slag by dissolving away some of the unwanted constituents. According to the September 12, 1944, *Outline for Operating C-2 Slag Plant*, “the fines are dissolved in acid to remove lime.” If the feed stock contained only 10% CaO, it would not be possible to increase the uranium concentration from 1 lb to 5 to 10 lbs by weight through acid leaching of the CaO (and MgO) alone. It is possible that some of the MgF₂ might also be dissolved during digestion in HCl. However, the solubility of MgF₂ is reported to be only 3 g/L at pH 4 and 25°C (Johnson et al. 1954). At this solubility limit, less than 2% of the MgF₂ could be removed. If the solution pH was 5, consistent with the conditions stated in the September 12, 1944, *Outline for Operating C-2 Slag Plant*, the solubility of MgF₂ is even lower – about 1 g/L. Johnson et al. 1954 also observed that the solubility of MgF₂ decreased in the presence of Ca⁺² ions.

To increase the uranium concentration from 0.2% to 1% (or from 1% to 5%) would require that 80% of the mass of the C-2 slag be dissolved, which means that the incoming slag would need to contain at least 80% CaO+MgO. Is this composition reasonable or possible? Consider the simplified chemical reaction:



Each kilogram of U produced will also produce 0.52 kg of MgF₂ and consume 1.32 kg of UF₄. The mass ratio of liner to UF₄ can be estimated from Spedding et al. 1945 to be 0.54 (see Appendix C), so the mass of liner per kg of U produced is 0.71 kg. Assuming that the C-2 slag contained 20% MgF₂, the mass of slag (liner plus 20% MgF₂) would be 0.89 kg per kg of U produced and would contain 80% CaO+MgO.

As previously noted, Thomas (1944) states that the “bulk of the C-2 slag is magnesium oxide and calcium oxide” and there is some evidence that separation of the MgF₂ from the balance of the slag was practiced. At MCW, “derby slag was scalped or cut off the derby and separated into an MgF₂ part and a C-liner part” (ORAUT 2005, Table 4).

Spedding et al. (1945) provided additional contemporaneous information on the separation of MgF₂ and liner. They note in Section 2.7:

The bomb was removed from the cooling spray to a room equipped with a pit in the floor covered with grating made of ¼” steel bars separated by ¼” spaces. The pit was vented from the bottom by ducts leading to the main exhaust fan of the building. In emptying the bomb the cover was removed from the bomb, the side wall chipped down by a pneumatic chisel similar to a concrete chipper, the loose material dumped on the grating. The bomb was placed mouth downward on a pneumatic jolter and jolted until the ingot of metal was loosened and fell to the

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floor. The remaining wall or liner material was chiseled loose and all liner material and slag were swept onto the grating which acted as a sieve permitting the 1/4" and finer material to pass into the barrel or drum below the screen. This product consisted chiefly of liner material, CaO or MgO, poor in both fluorine and uranium. Larger pieces, including most of the slag or MgF₂, were removed to a chute in the cover of an adjacent pit and dropped into a second container. This product contained most of the unrecovered uranium

If this type of separation was practiced at ElectroMet or if -20 mesh fraction from the screening at Hooker was enriched in CaO+MgO, then the digester feed could contain sufficient acid-soluble components.

Based on the information presented here, it is plausible to assume that the concentration of uranium in the incoming slag and in the resultant concentrate is at least five times higher than assumed in the TBD.

Another factor to consider is estimating the external dose from slag handling. The +20 mesh fraction, which was not subject to acid digestion, but did require handling, amounts to about 20% of the slag mass and contains 9% U (Thomas 1944). The contribution from this higher uranium content material needs to be included in the external exposure estimate.

Finding 1. NIOSH should review the assumptions regarding the composition of the incoming slag and the outgoing concentrate in light of the new material provided in Thomas 1944.

According to MED 1944, the barrels of feedstock contain about 500 lbs of slag, while Thomas (1944) uses a value of 275 lbs. If the bulk of the slag is CaO+MgO, a 50-gallon barrel⁴ would contain about 310 lbs of slag, assuming a bulk density of 55 lbs/ft³ for dolomitic lime (http://www.lime.org/documents/lime_basics/lime-physical-chemical.pdf). Barrels with lower slag content would result in lower external exposures per unit time, but exposures times would be longer due to increased barrel handling, so the net result should be about the same regardless of the barrel mass loading.

3.2 REVIEW OF SECTION 3.2 "MONTHLY PRODUCTION RATE"

NIOSH (2011b) cites data sources indicating that the monthly production rate was 10 tons per month (MED 1944), and that total production was 152 tons over the life of the Hooker project (Mears 1946), but notes that some ambiguity exists as to whether these quantities refer to incoming slag or outgoing concentrates. NIOSH estimated that ElectroMet could have produced 777 tons of slag through the end of 1945. Of this tonnage, some was apparently shipped to the Lake Ontario Ordnance Works (LOOW) for storage, and any oversized slag shipped to Hooker would not have been put through acid leaching. They note that, if the 10 tons per month referred to concentrate rather than slag, then 50 tons per month of slag would need to have been processed to increase the uranium content from 1 lb to 5 lbs. Over 18 months, this would require more feedstock (i.e., 900 tons) than was produced by ElectroMet. On this basis, NIOSH

⁴ Mallinckrodt used 50-gallon whiskey barrels to package C-2 scrap (ORAUT 2005, Table 4).

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concluded that the documented production rates and quantities referred to slag rather than concentrates.

The ElectroMet slag production estimate of 777 tons made by NIOSH appears to be low. From April 1943 through August 1946, the average rate of uranium production at ElectroMet was 44 tons/month (NYOO 1951). Since the Hooker work ended in January 1946, the maximum amount of C-2 slag available for processing at Hooker (April 1943 through December 1945) would have been 1,031 tons (33 months × 44 tons U/month × 0.71 tons slag/ton U), or about 33% more than estimated by NIOSH. Assuming that the 152 tons cited by Mears (1946) was concentrate rather than incoming slag, the average concentrate production over the 18-month life of the Hooker project would be 8.4 tons/month. If the uranium concentration increased from 1% in the C-2 slag to 5% in the concentrate, then the monthly slag feed to the process would be 42 tons/month, or 760 tons over the project life. Since we estimate that 1,031 tons of slag was available from ElectroMet, allowing for 20% oversize that was not acid-leached would leave 825 tons. Thus, there should be sufficient C-2 slag to supply a 42-ton/month requirement, cover removal of oversize from processing, and provide for some slag storage at LOOW.

The Hooker facility included three digester tanks, and the turnover rate per digester was about 2 days (MED 1944). Thus, the plant had the capacity to process about 45 batches per month. It is puzzling why a plant of this size would be built if the processing rate was only one batch per month. In addition, we note from the September 12, 1944, *Outline for Operating C-2 Slag Plant* (Appendix B) that:

IT IS MOST IMPORTANT THAT ALL THE DISPOSAL ACID BE USED FOR C-2 SLAG. Each hour that acid runs to the lime pit is wasted time for the slag plant. The work SHOULD be planned with this in mind.

It can be inferred from this quotation that there was little storage capacity for HCl at Hooker and, if the acid could not be used promptly to treat slag, it was sent to a neutralization pit. This information suggests that the Hooker plant was intended to handle considerably more than one batch of slag per month.

Information in Thomas 1944 supports the idea that the input to the Hooker process was more than 10 tons per month. Thomas notes that the availability of HCl at Hooker was sufficient to concentrate 65 to 80 tons of slag per month. In addition, equipment was sized for an 80-ton per month acid leaching plant at Hooker.

Finding 2: NIOSH should re-examine its position that external exposures were based on slag input to the leaching process of 10 tons per month. It is possible that external exposures are understated by a factor of about 5.

3.3 REVIEW OF SECTION 4.0 “INTERNAL DOSE”

Since there were no air monitoring data from Hooker, NIOSH collected surrogate data on C-2 slag handling from ElectroMet, MCW, and Fernald. These data are summarized in Table 1 of the TBD. NIOSH fit these data to a lognormal distribution and determined that the geometric

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mean (GM), geometric standard deviation (GSD), and 95th percentile values were 187.7 dpm/m³, 2.43, and 806 dpm/m³, respectively. SC&A verified these metrics.

The data in Table 1 of NIOSH 2011b were selected from a larger dataset developed by NIOSH and summarized in Tables 6-1, 6-2, and 6-3 of NIOSH 2010. NIOSH eliminated some of the data from the NIOSH 2010 tables in creating Table 1, based on judgments as to the relevance to Hooker of some of the surrogate slag handling data. SC&A reviewed the available data and concluded that some of the data excluded by NIOSH should be added to the Hooker dataset. Using this revised dataset (see Appendix A), SC&A determined that the GM was 95.1 dpm/m³, with a GSD of 3.53, and the 95th percentile was 759 dpm/m³. These values are similar to those calculated by NIOSH using a different dataset. Based on this analysis, it appears the TBD values needed to estimate internal dose are reasonable and claimant favorable.

As discussed above, NIOSH assumed that slag handling occurred 5% of the time and assumed that the operators were exposed to the 95th percentile dust levels (i.e., 806 dpm/m³). For the remainder of the working time each month, it was assumed that the worker was exposed to dust levels representative of filtration of uranium concentrates. Christofano and Harris (1960) cite a range of 17 to 100 dpm/m³ for the daily weighted average (DWA) exposure when acid-digesting uranium concentrates (avg. 68% U). Using the upper limit of 100 dpm/m³ DWA and scaling this to a 2% concentrate results in a DWA exposure from processing C-2 slag of 2.94 dpm/m³ for 95% of the working period. The average airborne concentration was determined to be 43.1 dpm/m³ ($806 \times 0.05 + 2.94 \times 0.95$). This general approach for establishing dust levels is reasonable, assuming that slag handling occurs 5% of the time and that the concentrate contains 2% U. However, as discussed in Section 3.2 above, we question whether 5% is the appropriate estimate of exposure time for handling slag. In the cost estimate for the proposed Hooker plant, Thomas (1944) assumed that one man would be required per day (48 hours/week) to load and unload barrels for an 80-ton per month operation. This would be somewhat reduced if the operating rate was 42 tons per month of slag. We also question whether the concentrate contained only 2% U.

Finding 3: The basis for assuming that internal exposure from slag dust occurred 5% of the time needs to be re-examined, as does the assumption that the concentrate contained 2% U. It appears that the exposure time is understated by about a factor of 5 and the amount of uranium in the concentrate is understated by at least a factor of 2.5.

NIOSH estimated that the inhalation exposure was 340 pCi/calendar-day ($43.1 \text{ dpm/m}^3 \times 1.2 \text{ m}^3/\text{hr} \times 8 \text{ hr/day} \times 300 \text{ work-days}/365 \text{ calendar-days}$). NIOSH also estimated that the ingestion exposure was 5.9 dpm/calendar-day using guidance in OCAS-TIB-009 (OCAS 2004). The TIB-009 guidance specifies that the daily ingestion intake is 0.2 times the airborne activity, or 8.62 dpm/work-day (0.2×43.1). Apparently, NIOSH adjusted this to a calendar-day basis assuming 250 work-days per year ($8.62 \times 250/365 = 5.9 \text{ dpm/calendar-day}$). For consistency with the calculation of inhalation intakes, we believe that the correct value should be 7.1 dpm/calendar-day ($8.62 \times 300/365$). While the difference is trivial in terms of dose received by an AWE worker, values in the TBD should be consistent and accurate.

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Finding 4: NIOSH should review the ingestion intake to ensure that it is calculated in a manner consistent with calculation of the inhalation intake.

3.4 REVIEW OF SECTION 5.1 “SLAG BARREL” AND SECTION 5.2 “CONCENTRATE BARREL”

NIOSH performed MCNPX calculations to estimate photon and beta doses at various distances from a barrel of slag (0.2 wt% U) and a barrel of concentrate (2 wt% U). Results of these calculations are presented in Tables 2 and 3 of the TBD and are summarized in Table 3-1 here. We note that photon exposure is expressed differently in Table 2 and Table 3. Both tables include the phrase “External Dose Rate” in the table title. However, the units of measure for photons in Table 2 are mR/hr, while in Table 3 the units of measure are mrem/hr. The text in Section 5.1 states that:

MCNPX was utilized to calculate the dose rate from direct photons and bremsstrahlung x-rays at a distance of one foot and one meter from the barrel. Dose conversion coefficients listed in ICRP 1996 Table A.1 were utilized for this calculation.

Based on this information, one can conclude that the units of measure in Column 2 of Table 2 should be mrem/hr not mR/hr. This distinction is important, because it can have a significant impact on selecting organ dose conversion factors from OCAS-IG-001 (OCAS 2007).

Finding 5: NIOSH should confirm that the correct units of measure are cited in Tables 2 and 3.

SC&A independently performed MCNPX calculations for a barrel of slag, which were summarized in Appendix A of SC&A 2011a. Based on our interpretation of the available documents, we assumed that the slag contained 1 wt% U. SC&A also included the shielding effects of the wooden barrel on photon exposures, which were calculated at the barrel mid-section. Beta doses were calculated above an uncovered barrel.

To facilitate comparisons, Table 3-1 also includes approximate doses/exposures for 0.2 wt% U slag obtained by adjusting the SC&A calculations to the lower uranium concentration. Perusal of Table 3-1 shows that the photon doses from slag barrels as calculated by NIOSH are in good agreement with the slag adjusted values calculated by SC&A. The same is true for contact beta doses. Beta doses at 1 foot are significantly higher as calculated by NIOSH, resulting in doses that are more claimant favorable. While the methodologies used by both SC&A and NIOSH are comparable, as discussed above, we believe that a slag content of 1% U and a concentrate content of at least 5% are supported by the new information.

Table 3-1. MCNPX Calculations of External Dose from Barrels of Slag and Concentrate

Source	Component	U content (wt%)	Photon Dose (mrem/hr)		Beta Dose (mrem/hr)	
			@ 1 ft	@ 1 m	contact	@ 1 ft
NIOSH	Slag	0.2	1.94E-03	5.78E-04	1.91E-01	4.62E-02
	Concentrate	2.0	1.65E-02	4.91E-03	1.93E+00	4.44E-01
SC&A	Slag	1.0	1.78E-02	3.59E-03	8.5E-01	7.0E-05
	Slag Adjusted*	0.2	3.56E-03	7.18E-04	1.7E-01	1.4E-05

* 20% of value for 1% U

3.5 REVIEW OF SECTION 5.3 “EXTERNAL DOSE FROM SURFACE CONTAMINATION”

NIOSH developed photon and beta dose conversion factors for exposure from contaminated surfaces using MCNPX and summarized the results in Table 4 of the TBD. We note that the text discussing Table 4 always refers to dose rates, while the photon dose conversion factor is expressed in terms of exposure rate (mR/hr).

Finding 6: NIOSH should review the units of measure for the photon dose conversion factors in Table 4 and determine if they are correct. If the units are correct, the text needs to be revised to discuss exposure rates rather than dose rates.

The photon dose conversion factor from Table 4 is 6.79E-10 mR/hr per dpm/m² (or mrem/hr based on the discussion above). The photon dose rates were calculated at a distance of 1 ft from a 100-m diameter circle using MCNPX. Surface contamination was assumed to be 1 dpm/m² alpha. Equilibrium with short-lived decay products was also assumed. The energy distribution was determined to be 80.2% <30 keV, 12.3% 30–250 keV, and 7.5% >250 keV. For comparison, we calculated the photon dose conversion factor for surface contamination using the version of Federal Guidance Report 13 available on CD, which used ICRP 60 (ICRP 1990) tissue weighting factors. The dose conversion factor based on equilibrium between U-238, Th-234, Pa-234m, and U-234 was 6.99E-10 mrem/hr per dpm/m², a value in good agreement with the value in the Hooker TBD.

To calculate the surface dose/exposure, NIOSH assumed that deposition occurred for 2,400 hours, based on an air concentration of 43.1 dpm/m³ and a terminal settling velocity of 0.00075 m/s for 5 µm AMAD spherical particles resulting in a surface concentration of 279,410 dpm/m². This general approach is reasonable, but the doses in Table 4 could be subject to adjustment based on resolution of several of the above findings.

4.0 RECONCILIATION OF PRIOR SC&A FINDINGS

SC&A's findings based on its review of Appendix AA and the Hooker Petition Evaluation Report were discussed in detail at the ABRWH Uranium Refining Atomic Weapons Employers Work Group meeting on May 16, 2011 (Transcript 2011). NIOSH provided responses to the SC&A findings either verbally or via a white paper (Allen 2011a). The findings matrices presented in Tables 4-1 and 4-2 summarize the issues related to Appendix AA and to the Hooker Petition Evaluation Report and the actions on each finding taken by the Work Group. The Work Group determined that all of the findings had been resolved. However, as discussed in Section 3.2 above, review of NIOSH 2011b suggests that sufficient slag was available from ElectroMet to process about 42 tons per month at Hooker, rather than 10 tons per month as assumed by NIOSH. Consequently, SC&A believes that Finding 1 regarding Appendix AA and Finding B regarding the Petition Evaluation Report should be reopened based on the current review of NIOSH 2011b. SC&A also believes that Finding A of the ER should be reopened based on new information indicating that the input slag contained about 1% U.

Table 4-1. Hooker Electrochemical Issues Matrix (TBD-6001 Appendix AA)

Finding or Observation	SC&A Review ^a	NIOSH Initial Response	Work Group Position Based on NIOSH Response
Observation 1	NIOSH should clarify whether or not photofluorography was used at AWE sites.	NIOSH added clarifying text to the TBD ^c stating that PA chest x-rays should be used (Transcript ^b p. 21, line 16).	The Work Group was satisfied with the NIOSH response. On a broader scale there was agreement that, unlike AEC sites, the default position for AWE sites should be x-rays rather than photofluorography, if there was no evidence to the contrary.
Finding 1	NIOSH should re-examine the assumption that dumping of barrels could be done in 1 day per month.	NIOSH included additional information in the TBD on the quantity of slag available within the AEC complex, supporting the assumption that processing of slag one day per month was reasonable.	The Work Group determined that the finding was closed (Transcript p. 45, line 5).
Finding 2	NIOSH should account for all activities causing inhalation exposure, not just those involved in dumping barrels of C-2 slag.	The TBD includes airborne exposures from dumping drums of slag and filtering digester output.	The Work Group determined that the finding was closed (Transcript p. 48, line 13).
Finding 3	While SC&A does not agree with some of the underlying assumptions in their approach, the NIOSH approach appears to be bounding for dose reconstruction. However, our independent analyses indicate that the values for intake rate are unrealistically high.	The methodology based on TBD-6001 was eliminated and was replaced in the TBD by slag handling data from Mallinckrodt, Fernald and Electromet. The inhalation exposure was based on the 95 th percentile of the slag handling data.	The Work Group determined that the finding was closed (Transcript p. 52, line 5).

Table 4-1. Hooker Electrochemical Issues Matrix (TBD-6001 Appendix AA)

Finding or Observation	SC&A Review^a	NIOSH Initial Response	Work Group Position Based on NIOSH Response
Observation 2	If conversion of external exposure to a calendar-day basis is based on 350 days per year, the basis for this assumption should be provided. In addition, NIOSH should provide example calculations to show how the values in Table 7.3 of TBD-6001 were derived.	There was a math error in Appendix AA, but this was eliminated with the new approach in the TBD.	The Work Group was satisfied that the observation was adequately addressed (Transcript p. 52, line 19).
Finding 4	NIOSH should correct the external exposure rates in Table AA.3.	There was a math error in calculating external exposure rates, but the finding is not relevant since the TBD uses a revised approach.	The Work Group determined that the finding was closed (Transcript p. 54, line 5).
Finding 5	Rather than applying the values in Table 7.3 as default/ bounding values, NIOSH should derive the correct external dose values using MicroShield or MCNP.	NIOSH used MCNPX to calculate external doses in the TBD. They noted that there was a calculational error in their MCNPX calculation that will require correction. On June 17, 2011, NIOSH issued Revision 1 to the TBD correcting the error.	The Work Group determined that the finding was closed (Transcript p. 55, line 20).
Observation 3	For consistency with the TBD-6001 source document, the units in Table AA.4 should be specified as mrad or mrem/ calendar-day rather than mR/ calendar-day.	Since TBD-6001 is no longer used, the observation is not relevant.	The Work Group concurred that the issue was no longer relevant (Transcript p. 56, line 12).
Finding 6	NIOSH should consider whether use of shallow dose estimates based on slag sampling is a more plausible approach than pro-rating exposures from a large uranium object. Alternatively, NIOSH could consider using a conservative estimate of the concentration of uranium in the barrel, and take into consideration self-shielding and the shielding from the barrel wall using MicroShield or MCNP.	In the TBD, NIOSH used MCNPX to calculate shallow doses. NIOSH noted that was a spreadsheet error in the MCNPX calculations that required correction. On June 17, 2011, NIOSH issued Revision 1 to the TBD correcting the error.	The Work Group considered whether or not it was appropriate to close out a finding if an error needed to be corrected at some future time. It was agreed that the finding had been addressed (in this case use of MCNP) even though the exact value of the MCNP calculation remained to be corrected. The finding was closed (Transcript p. 65, line 21).
Finding 7	NIOSH should provide an example calculation showing how they arrived at an inhalation intake of 1 pCi/calendar-day.	The approach was revised in the TBD using 95 th percentile values for measured airborne concentrations from surrogate facilities and 1 year of deposition.	The Work Group concluded that the finding was adequately addressed (Transcript p. 66, line 13).

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Table 4-1. Hooker Electrochemical Issues Matrix (TBD-6001 Appendix AA)

Finding or Observation	SC&A Review ^a	NIOSH Initial Response	Work Group Position Based on NIOSH Response
Finding 8	NIOSH should justify the use of a re-suspension factor of 1E-06/m.	Since most of the airborne exposure is out-of-doors in conditions where contamination would be washed away, use of a re-suspension factor of 1E-06/m is appropriate.	There was substantive discussion about whether use of 1E-06/m was appropriate for indoor exposures, but it was determined that indoor dust levels were more than an order of magnitude lower than those outdoors which would tend to offset a higher re-suspension factor. In addition, no decay in the quantity of re-suspended dust was assumed to occur over the residual period. The Work Group concluded that the finding was adequately addressed (Transcript p. 86, line 7). Broader questions regarding the general applicability of a re-suspension factor of 1E-06 and other issues related to ORAUT-OTIB-0070 (ORAUT 2008 ^d) are being considered by the Procedures Work Group.
Finding 9	NIOSH should justify that the approach taken to calculate inhalation exposures during the residual period is bounding, and take into consideration SC&A's review of ORAUT-OTIB-0070.	The approach used to calculate internal exposures was revised for the TBD and the airborne concentration was assumed to remain constant during residual period. Consequently, SC&A's critique of ORAUT-OTIB -0070 was not relevant to Hooker.	The Work Group concluded that the finding was adequately addressed (Transcript p. 86, line 16).
Finding 10	NIOSH needs to correct the calculation of external exposure during the residual period and revise the basis for converting this exposure to pCi/calendar-day.	The calculational procedure for external exposure during the residual period was revised in the TBD.	The Work Group concluded that the finding was adequately addressed (Transcript p. 86, line 22).

a – SC&A 2010. *Review of the NIOSH Site Profile for the Hooker Electrochemical Company. Battelle-TBD-6001. Appendix AA.* SCA-TR-SP2010-0034. September 2010.

b – Transcript: ABRWH Uranium Refining Atomic Weapons Employers Work Group, May 16, 2011.

c – TBD: *Technical Basis Document for the Hooker Electrochemical Company, Niagara Falls New York.* DCAS-TKBS-0009. Rev. 0. Effective Date: April 4, 2011 (NIOSH 2011a).

d – ORAUT 2008. *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities.* ORAUT-OTIB-0070, Revision 00. Oak Ridge Associated Universities Team, Cincinnati, Ohio. March 10, 2008.

**Table 4-2. Hooker Electrochemical Issues Matrix
(Petition Evaluation Report for SEC-00141)**

Finding or Observation	SC&A Review^a	NIOSH Initial Response	Work Group Position Based on NIOSH Response
Finding A	<i>NIOSH should re-examine its assumption that the slag contains 0.2% U; the assumption of 1% U is more favorable to claimants and, given the information presented here, it is bounding.</i>	This issue was re-examined during preparation of the TBD and the available information suggests that the incoming slag concentration is 0.2%.	The Work Group considered that this finding was adequately addressed (Transcript p. 94, line 4).
Finding B	<i>NIOSH should review its estimate of the monthly slag throughput at Hooker to insure that all relevant data have been considered.</i>	NIOSH included additional information in the TBD on the quantity of slag available within the AEC complex, supporting the assumption that processing of slag one day per month was reasonable.	The Work Group considered that this finding was adequately addressed (Transcript p. 94, line 22).
Finding C	<i>NIOSH should consider revising Appendix AA to base internal exposures on surrogate slag handling data, rather than on surrogate data from TBD-6001 scrap recovery operations.</i>	NIOSH revised the basis for internal exposures from using scrap handling data taken from TBD-6001 to using slag handling data at other AEC facilities.	Since the revised approach used in the TBD also relied on surrogate data, the issue was raised as to whether SC&A had reviewed the use of surrogate data against the Board's criteria. SC&A stated that they had not been tasked to conduct such a review. However, NIOSH was tasked with such a review at the previous Work Group meeting. Later in the meeting, NIOSH reviewed their analysis regarding the use of surrogate data. ^c At that time it was agreed that NIOSH should revise the surrogate data white paper to include details on airborne samples used in their analysis. SC&A would then review the white paper (Transcript pp. 166–170).
Finding D	<i>NIOSH should clarify whether 1.6 mrep/hr for gamma and 11.5 mrep/hr for beta or the values contained in Tables AA.3 and AA.4 of Appendix AA should be used for a bounding calculation.</i>	The approach to bounding external exposures was changed in the TBD to use MCNP calculations rather than surrogate data.	The Work Group considered that this finding was adequately addressed (Transcript p. 112, line 2).

**Table 4-2. Hooker Electrochemical Issues Matrix
(Petition Evaluation Report for SEC-00141)**

Finding or Observation	SC&A Review^a	NIOSH Initial Response	Work Group Position Based on NIOSH Response
Finding E	<i>While clearly bounding, the measured gamma dose from the St. Louis Airport Site slag pile may not be representative of C-2 slag.</i>	St. Louis Airport Site data on C-2 slag were not used in the TBD. They were replaced with MCNP calculations.	Both SC&A and NIOSH agreed that resolution of this finding was akin to that for Finding D. (Transcript p. 125, line 18.) Because of some confusion as to which finding was being discussed (E or F), the Work Group did not specifically take action on Finding E, but we recommend that the finding be closed. Although Finding E was not specifically addressed by the Work Group, it was later noted by the Chairman that all the issues had been closed out (Transcript p. 130, line 1).
Finding F	<i>The PER should recognize that slag was present during the residual period, at least through 1958, and ensure that this information is incorporated into the bounding external exposure calculation for the residual period.</i>	NIOSH presented evidence that the documentation referring to slag remaining at Hooker during the residual period was actually referring to slag at the LOOW which was operated by Hooker. ^d	The Work Group considered that this finding was adequately addressed (Transcript p. 124, line 12).
Finding G	<i>Depending on employment history, use of a resuspension factor of 1E-06/m for the residual period may not be bounding when calculating inhalation doses. If NIOSH believes that use of this resuspension factor is appropriate, they should provide justification describing, for example, clean-up procedures conducted after the cessation of operations.</i>	Since most of the airborne exposure is out-of-doors in conditions where contamination would be washed away, use of a resuspension factor of 1E-06/m is appropriate.	The Work Group considered that this finding was adequately addressed (Transcript p. 127, line 9).

**Table 4-2. Hooker Electrochemical Issues Matrix
(Petition Evaluation Report for SEC-00141)**

Finding or Observation	SC&A Review^a	NIOSH Initial Response	Work Group Position Based on NIOSH Response
Observation A	<i>NIOSH should explain why they accepted the petitioners' assumptions regarding the duration of the operating period, since we are not aware of any evidence to support the extended operating period.</i>	This issue was discussed in the 2011 white paper by Allen (DCAS) where it was pointed out that operational exposures are calculated only for the period July 11, 1944, through January 15, 1946, although the covered period extends to December 31, 1948.	The Work Group was satisfied with NIOSH's explanation as to the differences between the covered period and the operating period (Transcript p. 129, line 13).

- a – SC&A 2011a. *A Focused Review of The Hooker Electrochemical Company Petition Evaluation Report For SEC-0014*. Contract No. 20002009-28555. SCA-SEC-2011-0018, Rev. 0. January 2011.
- b – Transcript: ABRWH Uranium Refining Atomic Weapons Employers Work Group, May 16, 2011.
- c – TBD: *Technical Basis Document for the Hooker Electrochemical Company, Niagara Falls New York*. DCAS-TKBS-0009. Rev. 0. Effective Date: April 4, 2011.
- d – White paper by D. Allen (DCAS). *Observation A & Finding F, Hooker Electrochemical SEC Review, TBD-6001 Working Group*. April 2011. (Allen 2011a)
- e – White Paper by D. Allen (DCAS). *Surrogate Data Evaluation – Hooker Electrochemical Company*. April 2011. (Allen 2011b)

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5.0 USE OF SURROGATE DATA

Surrogate data was used in the Hooker TBD to estimate the airborne concentrations from handling C-2 slag. Contemporary data were collected from Fernald, MCW, and ElectroMet for these estimates. NIOSH reviewed this use of surrogate data in Allen 2011b and their conclusions are summarized below:

The usage of surrogate data at Hooker Electrochemical is consistent with the criteria described in the Board's document. Bounding, but plausible, estimates for internal exposure at Hooker Electrochemical can be prepared using the data collected from other facilities that performed a variety of similar uranium processing operations, and for which monitoring information is available.

At its May 11, 2012, meeting, SC&A was requested by the Uranium Refining Atomic Weapons Employers Work Group to review the NIOSH White Paper (Allen 2011b) on the use of surrogate data in the Hooker TBD. Results of this review were documented in SC&A 2011b. SC&A concluded that:

Based on our review, we believe that NIOSH has addressed the ABRWH surrogate data criteria in an appropriate manner, and that the use of surrogate data at Hooker is consistent with the Board criteria. Use of the selected surrogate data will result in plausible bounding estimates for internal exposures at Hooker.

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6.0 SUMMARY

Based on its review of the Hooker TBD (NIOSH 2011b), SC&A developed six findings as follows:

Finding 1: NIOSH should review the assumptions regarding the composition of the incoming slag and the outgoing concentrate.

Finding 2: NIOSH should re-examine its position that external exposures were based on slag input to the leaching process of 10 tons per month. It is possible that external exposures are understated by a factor of about 5.

Finding 3: The basis for assuming that internal exposure from slag dust occurred 5% of the time needs to be re-examined, as does the assumption that the concentrate contained only 2% U. It appears that this exposure time is understated by about a factor of 5 and the amount of uranium in the concentrate is understated by at least a factor of 2.5.

Finding 4: NIOSH should review the ingestion intake to ensure that it is calculated in a manner consistent with calculation of the inhalation intake.

Finding 5: NIOSH should confirm that the correct units of measure are cited in Tables 2 and 3.

Finding 6: NIOSH should review the units of measure for the photon dose conversion factors in Table 4 and determine if they are correct. If the units are correct, the text needs to be revised to discuss exposure rates rather than dose rates.

Findings 1, 2, and 3 are the result of new information uncovered during the course of this review.

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APPENDIX A: DUST SAMPLES USED BY SC&A TO CALCULATE INTERNAL EXPOSURES

Table A-1. Airborne Dust Concentrations From Handling C-2 Slag

Site	Sample	Description	Air Conc. (dpm/m ³)	Reference
Fernald	1639	BZ laborer using push broom to clean loose material from floor.	198	SRDB 42628, p. 13
Fernald	1640	Ditto	232	SRDB 42628, p. 13
Fernald	1641	Ditto	233	SRDB 42628, p. 13
Fernald	1642	Ditto	490	SRDB 42628, p. 13
Fernald	1643	Ditto	257	SRDB 42628, p. 13
Fernald	1644	Ditto	346	SRDB 42628, p. 13
Fernald	1645	Ditto	261	SRDB 42628, p. 13
Fernald	1646	Ditto	200	SRDB 42628, p. 13
Fernald	1647	Ditto	627	SRDB 42628, p. 13
Fernald	1648	Ditto	336	SRDB 42628, p. 13
Fernald	1649	Ditto	195	SRDB 42628, p. 13
Fernald	1650	Ditto	338	SRDB 42628, p. 13
Fernald	1105	BZ laborer inside gondola with hatchet and shovel. Man cuts and shovels material from side of gondola and pitches onto pile on pad.	15	SRDB 42628, p. 14
Fernald	1106	Ditto	15	Ditto
Fernald	1107	Ditto	30	Ditto
Fernald	1108	Ditto	37	Ditto
Fernald	1109	Ditto	97	Ditto
Fernald	1110	Ditto	162	Ditto
Fernald	1111	Ditto	n.d.	Ditto
Fernald	1112	Ditto	69	Ditto
Fernald	1113	Ditto	15	Ditto
Fernald	1114	Ditto	47	Ditto
Fernald	1115	Ditto	32	Ditto
Fernald	1116	Ditto	83	Ditto
Fernald	1117	Ditto	80	Ditto
Fernald	1118	Ditto	68	Ditto
Fernald	1119	Ditto	36	Ditto
Fernald	1120	Ditto	135	Ditto
Fernald	1121	Ditto	181	Ditto
Fernald	1122	Ditto	32	Ditto
Fernald	1123	Ditto	83	Ditto
Fernald	1124	Ditto	64	Ditto
Fernald	1125	Ditto	30	Ditto
Fernald	1126	Ditto	23	Ditto
Fernald	1127	Ditto	53	Ditto
Fernald	1128	Ditto	79	Ditto
Fernald	1129	Ditto	34	Ditto
Fernald	1130	Ditto	45	Ditto
Fernald	1131	BZ hand shoveling airport scrap into 30-gal containers. No visible dust.	106	SRDB 42628, p. 16
Fernald	1132	Ditto	91	Ditto
Fernald	1133	Ditto	75	Ditto
Fernald	1134	Ditto	38	Ditto

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Table A-1. Airborne Dust Concentrations From Handling C-2 Slag

Site	Sample	Description	Air Conc. (dpm/m ³)	Reference
Fernald	1135	Ditto	n..d.	Ditto
Fernald	1136	Ditto	19	Ditto
Fernald	1137	Ditto	95	Ditto
Fernald	1138	Ditto	75	Ditto
Fernald	1139	Ditto	49	Ditto
Fernald	1140	Ditto	45	Ditto
Fernald	1141	Ditto	30	Ditto
Fernald	1142	Ditto	19	Ditto
Fernald	3556	BZ operator dumping drum of slag liner into outside crusher dumping station.	110	SRDB 42628, p. 90
Fernald	3472	Ditto	108	Ditto
Fernald	3558	Ditto	61	Ditto
Fernald	3557	Ditto	32	Ditto
Fernald	4906	BZ operator dumping 55-gal drum of MgF ₂ into leach tank, taking drum off and relidding drum.	1125	SRDB 42628, p. 93
Fernald	4907	Ditto	1674	Ditto
Fernald	4908	Ditto	1533	Ditto
Fernald	6993	BZ operator dumping drum of C-liner from 2nd floor drum dumper	793	SRDB 42627, p. 61
Fernald	7509	Ditto	829	Ditto
Fernald	7302	Ditto	424	Ditto
Fernald	626	BZ dumping can of C-liner into dumping station.	247	SRDB 34544, p. 2
Fernald	623	Ditto	191	Ditto
Fernald	736	Ditto	255	Ditto
Fernald	T899	Ditto	206	Ditto
Electromet	III. 2 & 6	Bomb Room, barrel slag and weigh	456	SRDB 8917, p. 7
Electromet	N/A	Shovels slag into lean and rich drums	398	SRDB 8930, p. 19
MCW	Nov-53	Changing slag drums	107	SRDB 20675, pp. 19, 23
MCW	Nov-53	Ditto	7	Ditto
MCW	Apr-53	Ditto	81	Ditto
MCW	Oct-52	Ditto	27	Ditto
MCW	a	BZ removing C-special drum	237	SRDB 9343, p. 19
MCW	b	Ditto	60.8	Ditto

Appendix A References

Brealia [sic], A.J., 1949. *Electro Metallurgical Co. Occupational Exposure to Radioactive Dust August 17–19, 1949*. November 10, 1949. SRDB Ref ID: 8930. [A.J. Breslin, New York Operations Office, Atomic Energy Commission]

Caplan, K.J., 1951. From K.J. Caplan (MCW) to Thayer (AEC), Subject: *Results of Dust Study Six-E*. February 26, 1951. SRDB Ref ID: 9343.

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MCW no date: *MCW Plant 6E, Occupational Exposure to Airborne Contaminants*, MCW-18. References a study done November 18–20, 1953. Mallinckrodt Chemical Works, Industrial Hygiene Branch, Health and Safety. SRDB Ref ID: 20657.

NLO 1956. *Analytical Data Sheet Plant 8, BZ Results*. Fernald. National Lead of Ohio. SRDB Ref ID: 34544.

NLO 1958. *Plant 8 Analytical Data Sheet, Air Dust, 1957–1970*. Fernald. National Lead of Ohio. March 7 to October 13, 1958. SRDB Ref ID: 42627.

NLO 1959. *Plant 8 Analytical Data Sheet, Air Dust, 1957–1970*. Fernald. National Lead of Ohio. February 6 to December 24, 1959. SRDB Ref ID: 42628.

Various, 1947–1948, *Reports on Dust Hazards at Electrometallurgical Company*; various authors; dates from December 1947 through May 1948; SRDB Ref ID: 8917.

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APPENDIX B: REPRODUCTION OF SLAG PLANT OPERATING INSTRUCTIONS

HOOKER ELECTROCHEMICAL COMPANY
NIAGARA FALLS, N.Y.
FORM-672 4.42

September 12, 1944

OUTLINE FOR OPERATING C-2 SLAG PLANT

C-2 slag is a mixture of fine and coarse material. The operation is designed to concentrate the slag and reduce its bulk. There are two main parts in the operation:

1. **ACID TREATMENT** The fines are dissolved in acid to remove lime. The filter cake from this reaction is one form of this product.
2. **SCREENING** The rejects from screening the feed are barreled as a second form of product.

PROCEDURE

Charge two or three feet of water into an empty tank equipped with an agitator.

Add 50 barrels of lime as rapidly as possible. The coarse screen re-jects should be collected in wooden barrels.

Acid should be turned into the tank as soon as three barrels have been added. Slag should be added steadily and rapidly, so that the tank does not turn acid.

After the slag has been added, continue adding acid until the pH of the solution has dropped to 5. (It is necessary to take frequent tests toward the end of the reaction, since the pH of the solution will drop rapidly once the lime has been dissolved. If the pH drops lower than five, the metal agitator and pipe will chew out rapidly.)

When the pH has dropped to 5, discontinue the acid addition and allow the tank to digest for 6 hours, testing the pH hourly.

When the six hour digestion period is complete, it is necessary to adjust the pH. **THE SOLUTION MUST BE ALKALINE – pH 7 OR ABOVE, BEFORE FILTERING.** Drop in one bag of lime; then test the pH. Add more lime if necessary to make the necessary adjustment. One bag of lime should usually suffice.

Next filter the batch, recycling to the same tank until the filtrate runs clear; then run the filtrate to D tank.

After the filtration is complete, wash the press for at least 12 hours. The wash water may be run to the sewer.

IT IS MOST IMPORTANT THAT ALL THE DISPOSAL ACID BE USED FOR C-2 SLAG. Each hour that acid runs to the lime pit is wasted time for the slag plant. The work SHOULD be planned with this in mind.

The lumps should be rescreened if necessary to free them from fines. The barrels should be reheaded, weighed and stenciled with the net weight, name, (C-2 LUMPS) and lot number. The batch number should also be included.

The filer cake should be packed in metal drums, closed and stenciled with the name (C-2 CONC), net weight and lot number.

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Before dumping the filtrate in C tank, a quart sample should be taken and given to the control chemist for testing. If O K, the batch may be dumped into the sewer. If not, see AVT for further instructions.

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APPENDIX C: QUANTITY OF C-2 SLAG GENERATED PER TON OF URANIUM METAL PRODUCED

A key question regarding the Hooker process was “how much slag was available for processing?” If one knows the amount of uranium produced at ElectroMet and the ratio of the mass of bomb liner to mass of uranium product, the mass of liner (or C-2 slag) can be estimated. Thayer (1955) cites a value of 0.432 lbs of liner per lb of UF₄. Given the timeframe and the context of the discussion in that reference, the estimate refers to crushed MgF₂ liners rather than dolomite which were used at ElectroMet.

Spedding et al. (1945) provides the basis for estimating the quantity of fused dolomite used in the reduction bombs. A 10-in reduction bomb, described on p. 14 of that report, uses 168 lbs of UF₄ in the charge. The bomb is 40 in long and has a 10.125-in inner diameter. A mandrel tapering from 9 in to 8.75 in is used to establish the annulus to be filled with dolomite (average annulus width – 0.625 in). The annulus volume is 746 in³. Assuming that the density of fused dolomite is 0.104 lb/in³ (2.88 g/cc) (<http://books.google.com/books?id=0ugkNtlWKWEC&pg=PA218&lpg=PA218&dq=fused+dolomite&source=bl&ots=tJuJUEusZz&sig=xTNh9le-iCuZaiBdNupNzlTzWT0&hl=en&sa=X&ei=PMA4UdfBK9Co0AHEI4CgBA&ved=0CDAQ6AEwAA#v=onepage&q=fused%20dolomite&f=false>), the mass of the liner is 92 lb⁵ and the mass ratio of liner to UF₄ is 0.54. As a check on this value, Section 5.4.4 of Spedding et al. 1945 notes that the cost of liner is 8.65¢/lb U and the liner raw material cost is 13.5¢/lb of liner for electrically-fused dolomite or 0.64 lbs of liner/lb U. Since 1.319 lbs of UF₄ are required to produce 1 lb of U, the mass ratio of liner to UF₄ is 0.49 – a value in reasonable agreement with the estimate based on the annulus volume.

References

Spedding, F.H., H.A. Wilhelm, and W.A. Keller 1945. *The Production of Uranium by the Reduction of UF₄ by Mg*. CT-2712. Ames Laboratory, June 26, 1945. <http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA322484>

Thayer 1955. Letter from Harold E. Thayer, MCW, to F. H. Belcher, USAEC, *Capacity Slag Grinding Plant*. May 13, 1955. SRDB 4012.

⁵ This assumes about 7 lbs of dolomite is at the top and at the bottom of the bomb.