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ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

A REVIEW OF NIOSH'S PROGRAM EVALUATION REPORT DCAS-PER-065, "ANACONDA"

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AP	anterior-posterior
AWE	Atomic Weapons Employer
cm^2	square centimeter
d/yr	day per year
DCAS	Division of Compensation Analysis and Support
DCF	dose conversion factor
dpm, d/m	disintegrations per minute
dpm/day	disintegrations per minute per day
dpm/m^2	disintegrations per minute per square meter
dpm/m^3, $d/m/M^3$	disintegrations per minute per cubic meter
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
DR	dose reconstruction
Fi	fraction of activity on the hand that is ingested
FUSRAP	Formerly Utilized Sites Remedial Action Program
HASL	Health and Safety Laboratory
hr/d	hours per day
IMBA	Integrated Modules for Bioassay Analysis
m	meter
m^3/hr	cubic meter per hour
m/sec	meter per second
MAC	maximum allowable concentration
MDL	minimum detection limit
MED	Manhattan Engineer District
mg	milligram
mg/cm^2	milligram per square centimeter
mg/m^3	milligrams per cubic meter
mg/yr	milligram per year
mR/year	milliroentgen per year

mrad/hr	millirad per hour
mrem	millirem
mrep/hr	millirep per hour
m/s	meters per second
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH OCAS Claims Tracking System
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
PEP	Program Evaluation Plan
PER	Program Evaluation Report
R	Roentgen
sec/hr	seconds per hour
SRDB	Site Research Database
TBD	technical basis document
TIB	technical information bulletin
URL	Uniform Resource Locator

1.0 STATEMENT OF PURPOSE

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

The process for evaluating potential impacts of programmatic changes on previously completed DRs has been proceduralized in OCAS-PR-008, *Preparation of Program Evaluation Reports and Program Evaluation Plans*, Revision 02, (NIOSH 2006a), dated December 6, 2006. This procedure describes the format and methodology to be employed in preparing a Program Evaluation Report (PER) and a Program Evaluation Plan (PEP).

A PER provides a critical evaluation of the effect(s) that a given issue/programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact(s) on the probability of causation (POC) of previously completed DRs with POCs of <50%.

During the full Board meeting held January 25, 2017, SC&A was directed to perform a review of DCAS-PER-065, *Anaconda*, Revision 0 (NIOSH 2015, hereafter referred to as PER-065). Since the site profile (also known as the technical basis document – TBD) for the Anaconda site was never reviewed, SC&A was also directed to perform a full review of the site profile for Anaconda, as appears in Battelle-TBD-6000 Appendix G, *Site Profiles for Atomic Weapons Employers that Worked Uranium Metals*, *Appendix G - Anaconda*, Revision 01, dated August 19, 2014 (NIOSH 2014a, hereafter referred to as TBD-6000-AppG, Revision 01). Section 2 of this PER-065 review constitutes a full review of the site profile.

In conducting a PER review, SC&A is committed to perform the following five subtasks, each of which is discussed in this report:

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

Subtask 2: Assess NIOSH's specific methods for corrective action. In instances where the PER involves a technical issue that is supported by document(s) [e.g., white papers, technical information bulletins (TIBs), procedures] that have not yet been subjected to a formal SC&A review, Subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, Subtask 2 will simply provide a brief summary/conclusion of this review process. In this particular PER review, Subtask 2 will serve as a site profile review since the Board and SC&A have never reviewed the Anaconda site profile. The implications of this review are that, unlike other PER reviews,

which focus on changes in the scope and technical approach made by NIOSH from a previous site profile to the site profile of interest to the PER, this PER review includes a full site profile review.

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

Subtask 4: Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. It is assumed that the selection of the DRs and the total number of DR audits per PER will be made by the Advisory Board using case selection criteria recommended by SC&A based on the results of Subtask 2.

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

2.0 RELEVANT BACKGROUND INFORMATION

Section G.2 of the Anaconda site profile (TBD-6000-AppG, Revision 01) provides a description of the Atomic Weapons Employer (AWE) activities that took place at Anaconda and cites a number of references that describe the operations. The original site profile, Battelle-TBD-6000 Appendix G, *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals, Appendix G – Anaconda Co.*, Revision 0, dated April 30, 2007 (NIOSH 2007, hereafter referred to as TBD-6000-AppG, Revision 0), provides similar material describing the site and its activities.

SC&A reviewed these citations and confirmed the completeness and accuracy of the description of AWE and post-AWE activities that are described in Section G.2 of the site profile. In summary, the Anaconda site (formerly known as the American Brass Company) located in Westbury, Connecticut, was first employed by the Manhattan Engineer District (MED, the predecessor to the Atomic Energy Commission [AEC]) to help in the development of gaseous diffusion barriers for use in uranium enrichment. These activities did not involve radioactive materials. However, in 1956, Anaconda was involved in a pilot project where four copper-clad uranium billets were extruded to evaluate uranium extrusion procedures to manufacture uranium fuel that could be used in support of weapons development. It is reported that these extrusion activities were performed over a one-hour time period. These pilot studies were followed by additional extrusions involving what appeared to be limited to 10 billets, although the original plan was to extrude 500 billets. In October 1959, as many as an additional 50 billets were extruded at an estimated rate of four billets per hour, for a total of 12.5 hours.

It is apparent that these uranium metal-handling activities were not full production activities, as were performed at many other AWE facilities at that time (e.g., Bethlehem Steel) and involved relatively short run times and a limited number of workers. The site profile explains that the following assumptions are used as the basis for DR during AWE operations at Anaconda:

1. The 1956 pilot study took place on September 29, 1956, and required 1 full 8-hour shift to perform.
2. 50 billets were extruded in March 1957, and required two full 8-hour shifts.
3. Extrusion activities took place from October 19 to October 21, 1959, and required three full 8-hour shifts.

TBD-6000-AppG, Revision 01 also explains that it is assumed that any individual worked only 8 hours during a given shift.

3.0 SUBTASK 1: IDENTIFY THE CIRCUMSTANCES THAT NECESSITATED THE NEED FOR DCAS-PER-065

As explained in the "Record of Issues Resolution" section of the Anaconda site profile, TBD-6000-AppG, Revision 0 was issued on April 30, 2007, and TBD-6000-AppG, Revision 01 was issued August 19, 2014. In both cases, the site profile was based on guidance provided in the contemporaneous versions of Battelle-TBD-6000 (Battelle-TBD-6000, PNWD-3738, *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals*, Revision 0,

dated December 13, 2006 [NIOSH 2006c, hereafter referred to as TBD-6000, Revision 0] and Battelle-TBD-6000, *Site Profiles for Atomic Weapons Employers that Worked Metals*, Revision 01, dated June 17, 2011 [NIOSH 2011b, hereafter referred to as TBD-6000, Revision 01]). When TBD-6000 was revised, it was necessary to revise the Anaconda site profile, TBD-6000-AppG, which necessitated NIOSH issuing PER-065.

Like many uranium-handling AWEs, DRs for workers at Anaconda were based primarily on TBD-6000 (NIOSH 2006c, NIOSH 2011b), and took into consideration the types of uranium-handling activities at the facility, the worker job categories, the amount of uranium handled, the time period when the AWE activities took place, the potential and nature of exposures that took place during inactive AWE time periods when no AWE operations took place (i.e., time periods when the facility resumed its non-AWE operations, such as working with steel), and time periods following the termination of AWE operations (the residual period).

Inspection of the original and revised site profiles for Anaconda reveals that the major changes made in the revision reflect corresponding changes to TBD-6000. Therefore, to understand the major changes that were made to the site profile for Anaconda, it is necessary to understand the changes that were made to TBD-6000 from Revision 0 (December 13, 2006) to Revision 01 (June 17, 2011).

A description of the revision made in going from Revision 0 to Revision 01 of TBD-6000 is conveniently described in DCAS-PER-055, *TBD-6000 Revision*, Revision 0, September 12, 2014 (NIOSH 2014b, hereafter referred to as PER-055), as follows:

> *First, Table 3.10 contains conversion factors to determine the beta and gamma dose rates from uranium surface contamination. The photon value was recalculated in revision 1 causing a slight decrease. A beta dose rate value was added that did not exist in revision 0.*
>
> *The second change is that revision 0 estimated surface contamination from airborne activity by allowing it to settle. For internal dose, the calculation assumed the airborne settled for 365 days continuously. However, for external dose, some, but not all, the calculations assumed the airborne settled for only 7 days. During a review of TBD-6000, it was determined that a 30 day settling time was appropriate and revision 1 used this value.*
>
> *In Table 5.1 and the same value summarized in Table 5.3, the external dose from surface contamination was based on 365 days of settling. As a result, the photon values in these tables decreased in revision 1. Beta dose was not accounted for in revision 0 but is included in revision 1. Therefore, the new beta doses included in these tables will result in increased reconstructed doses over revision 0. .*
>
> *In Table 6.4, the photon dose from contamination is higher in revision 1 due to the dose in this table being based on 7 days of settling. The beta dose is also higher in this table because revision 0 did not account for beta dose from contamination.*

As a result of these changes, claims with external dose that was calculated from surface contamination could need to be re-evaluated.

Though not explicitly addressed in PER-055, ORAUT-OTIB-0070, *Dose Reconstruction during Residual Radioactivity Periods at Atomic Weapons Employer Facilities*, Revision 01, March 5, 2012 (NIOSH 2012, hereafter referred to as OTIB-0070), has applicability to the site profile for Anaconda with respect to exposure to residual radioactivity. OTIB-0070 applies to periods of time when AWE activities were not underway, and therefore, would apply at Anaconda following the termination of AWE activities. This is an important change to NIOSH guidance pertinent to AWE facilities that should also have necessitated a PER for Anaconda, even though it is not stated as such in PER-065.

Another important change in guidance that might have applicability to the Anaconda PER-065 is revisions to the methods by which doses associated occupational medical exposures are reconstructed (i.e., medical x-ray examinations in ORAUT-OTIB-0006 *Dose Reconstruction from Occupational Medical X-ray Procedures*, Revision 04, June 20, 2011 [NIOSH 2011a, hereafter referred to as OTIB-0006]). This potentially applicable DR guidance is not explicitly referred to in the "Record of Issues Resolution" section of the Anaconda site profile, but is addressed in this PER-065 review.

It is important to note that the latest revisions to TBD-6000, OTIB-0070, and OTIB-0006 were reviewed and approved by the Board. Hence, the primary objectives of this PER-065 review are to ensure that: (1) the assumptions used to define worker exposure scenarios that are specific to Anaconda are reflected in the PER and its supporting TBD, (2) any Anaconda-specific data pertinent to reconstructing external, internal, and medical exposure are reflected in the PER and its supporting TBD, and (3) any exposure scenarios that required the use of TBD-6000, OTIB-0070, and/or OTIB-0006 are reflected in TBD-6000-AppG as used in support of the PER.

4.0 SUBTASK 2: ASSESS NIOSH'S SPECIFIC METHODS FOR CORRECTIVE ACTION

SC&A reviews the site profile in this section, including comparing the original and revised versions, to:

1. Ensure that the revised TBD-6000-AppG completely and accurately describes the AWE and post-AWE activities that took place at Anaconda.
2. Ensure that the revision is complete in terms of reflecting all the site-specific information and data applicable to performing dose reconstructions.
3. Ensure that the revision is complete in terms of taking into consideration the most recent generic guidance that might be applicable to DRs at Anaconda (i.e., TBD-6000, OTIB-0070, and OTIB-0006).
4. Ensure that TBD-6000-AppG makes use of all applicable information, data, and guidance in a scientifically sound and claimant-favorable manner.

These lines of inquiry represent a site profile review.

4.1 SITE-SPECIFIC INFORMATION AND GUIDANCE

4.1.1 Characterization of Operation During and Following AWE Activities

Section 3.0 summarizes the AWE and post-AWE activities that took place at Anaconda as described in the site profile.

SC&A's Comments

The site profile description of AWE and post-AWE activities, as well as other important information for DR at Anaconda, rely on descriptive and quantitative information contained in cited sources that appear in the Reference section of the site profile. SC&A examined each of these data sources and found that the site profile accurately extracted and interpreted the information. In addition, SC&A examined all the data sources contained in the site research database (SRDB) returned by a search on "Anaconda" that were not cited in the site profile to determine if they contained any relevant additional information or contradicted any information relied upon in the site profile. In all cases, SC&A found that the information from these non-cited data sources corroborated the information from the cited data sources.[1]

Observation #1. SC&A identified one minor discrepancy in reviewing the references. The correct uniform resource locator (URL) for the cited "U.S. Department of Energy website" ("DOE website") is: https://ehss.energy.gov/search/facility/findfacility.aspx. SC&A recognizes that the DOE URL might have changed since NIOSH issued the site profile.

4.1.2 Occupational Medical Dose

With respect to occupational medical exposures, Section G.3 of the site profile (TBD-6000-AppG, Revision 01) explains the following:

> *No detailed information regarding occupational medical dose was found in any of the site research or telephone interviews. Information to be used in dose reconstructions, for which no specific information is available, is provided in ORAUT-OTIB-0006, the technical information bulletin covering diagnostic x-ray procedures. This estimate will assume each employee received one AP chest x-ray each year of the covered period which includes 1942 as well as 1956 through 1959.*

Based on SC&A's understanding of NIOSH's policy regarding medical x-ray exposure, workers at AWE facilities are not presumed to have been required, as a condition of employment, to receive annual x-ray examinations unless there is affirmative evidence that such exposures were actually part of the AWE's contract with the government and the examinations were performed at the facility. However, all 17 of the appendices of TBD-6000 have guidance similar to that for Anaconda, as referenced above. Table 2 in Section 5 of this report shows that annual occupational medical doses were assigned for all of the non-compensable overestimate and best estimate DR cases performed to date for Anaconda. All of the TBD-6000 appendices recommend that dose reconstructors assign occupational medical dose for individuals who worked during the

[1] Eighty-three documents appeared under "Anaconda" in the SRDB as of the date of this report.

covered periods at those AWE facilities using the guidance in OTIB-0006. This represents a consistent and claimant-favorable procedure. SC&A has no findings regarding the assignment of occupational medical dose.

4.1.3 Occupational Internal Dose

Section G.4 of TBD-6000-AppG, Revision 01 describes the data and methods used by NIOSH to reconstruct internal exposures to workers at Anaconda. This information is not repeated here. In summary, the TBD explains that the Health and Safety Laboratory (HASL) monitored airborne dust concentrations of uranium during AWE operations in 1956 and 1959. The data consisted of both general air samples and breathing zone concentrations at the location of sawing operations.

Internal Exposures During Extrusion Operations

Based on the reported data, NIOSH assumes that workers involved in extrusion operations were exposed to airborne uranium concentrations of 39 disintegrations per minute (dpm) per cubic meter (dpm/m^3) and makes standard assumptions regarding inhalation and ingestion rates and durations. For time periods between AWE operations, NIOSH assumes that workers are exposed to uranium deposited on surfaces and includes both external exposures and inhalation and ingestion internal exposures from resuspended uranium.

SC&A's Comments

SC&A briefly reviewed all 83 documents on the SRDB that are associated with the Anaconda facility. SRDB Ref. ID 9363 contains a letter dated December 2, 1959, from Harold Glauberman of the Field Services Branch to A.J. Breslin, Chief of the Field Services Branch. The letter, which is reproduced below, describes the types of surveys performed at Anaconda during the October 1959 operations and summarizes the results. It also makes reference to the survey performed following the October 1956 operation.

> *General air samples were obtained around the press area and associated operations. Breathing zone samples were taken of the sawing, drilling and deburring operations as well as a few operations in the press area. Measurements of alpha surface contamination and beta air dose rate were obtained in a number of locations.*
>
> *Air samples and radiation measurements are listed in the attached tables. As in our previous survey of October 2, 1956, all samples were below the MAC; the highest concentration was 39 d/m/M^3. In approximately 1/3 of the samples, no alpha activity was detected.*
>
> *Breathing zone concentrations at the sawing operations were nil, the average breathing zone concentrations at the drilling and deburring operation was 5 d/m/M^3. The average general air concentration was 3.3 d/m/M^3 in the vicinity of the press and adjacent areas and 0.3 d/m/M^3 in the saw, drill and testing areas.*
>
> *Direct radiation measurements of surfaces for alpha contamination ranged from background (<200 d/m/100 cm^2) to 600 d/m/100 cm^2, with the latter value found*

at the die cutting station and the table adjacent to the Lindberg furnace. Beta radiation intensities at the billet storage area were 19 mrep/hr at one foot. Similar intensities were found near the extruded tubes on the run-out table and in the testing area.

Summary

Exposures to airborne alpha emitting dust are well below the permissible concentration. Surface contamination is confined to a few locations and is insignificant. Significant beta radiation intensities are to be found in the vicinity of uranium billets and tubes as would be expected. Although employees apparently remain in these areas for only short periods of time, there is potential exposure to direct radiation. An estimate of exposure could be obtained by issuing film badges for a few weeks. The need for continuing the service could be decided on the basis of the film data.

Attachments: Tables I and II

This document (Glauberman 1959) specifically states that the highest airborne dust loading observed was 39 dpm/m^3 and a substantial fraction of the airborne dust concentration measurements were below the minimum detection limit (MDL). Although the letter does not specify whether this was a general air or breathing zone sample, the recommendation of the highest measured value is claimant favorable. This letter does indicate that all of the air sample and radiation measurements were attached in two tables. However, SC&A could not find these data tables in this or any other SRDB document. Even though the use of 39 dpm/m^3 appears sound and claimant favorable, a review of these air sampling data, if available, would reinforce the assumptions used in the TBD. Another document that was found during our research, *Data Analysis Results 1947 Through 1961*, SRDB Ref. ID 11452, is a compilation of all data analysis results at AWE facilities from 1947–1961. Pages 30 through 32 of that document are raw data air sampling results taken at Anaconda (referred to here as American Brass) but the data are not dated and most of the entries are illegible. They are included here as Appendix A.

Internal Inhalation Exposures from Resuspension between AWE Campaigns

The internal inhalation exposures from resuspension between AWE campaigns are derived using the following data and assumptions:

1. The measured general airborne concentration of the 39 dpm/m^3 during uranium extrusion operations.
2. A deposition velocity of 0.00075 meters per second (m/sec) for a 96-hour extrusion campaign, with no cleanup or natural attenuation.
3. On this basis, the surface contamination level is assumed to be 10,109 dpm per square meter (dpm/m^2) from 1956 through 1959.
4. A resuspension factor of 1.0E-5/m, resulting in a chronic airborne uranium concentration from resuspension of 0.1 dpm/m^3 during non-AWE operations.

SC&A's Comments

These assumptions are scientifically sound and claimant favorable in light of our review of the site-specific AWE operation and air sampling data and the basic approach used in OTIB-0070 for deriving residual surface contamination and resuspension of uranium following the termination of an AWE operation. The following presents the calculations that we believe were used by NIOSH to derive the airborne dust loadings during the time periods from 1956 through 1959, when no extrusion activities were performed.

$$39 \text{ dpm/m}^3 \times 0.00075 \text{ m/sec} \times 96 \text{ hr} \times 3{,}600 \text{ sec/hr} = 10{,}109 \text{ dpm/m}^2$$

$$10{,}109 \text{ dpm/m}^2 \times 1.0\text{E-}5/\text{m} = 0.1 \text{ dpm/m}^3$$

SC&A considers the last value claimant favorable because the highest dust loading of 39 dpm/m^3 was used, when a more central value could have been used. A campaign duration of 96 hours was assumed, which is equivalent to 4 consecutive days of AWE operations; i.e., a long period compared to the duration of any of the individual extrusion campaigns. In addition, no credit is taken for natural attenuation of deposited uranium, and a reasonably conservative resuspension factor of 1.0E-5/m was employed. Taken in combination, these assumptions are plausible and claimant favorable in terms of deriving inhalation exposures in the time period between extrusion operations.

Internal Ingestion Exposures between AWE Campaigns

Table G-1 of the site profile (TBD-6000-AppG, Revision 01) recommends an inadvertent ingestion rate of 5.34 dpm/day from inadvertent ingestion of deposited activity for each 8-hour shift.

SC&A's Comments

Ingestion exposures during operations are derived using OCAS-TIB-009, *Estimation of Ingestion Intakes*, Revision 0, April 13, 2004 (NIOSH 2004). This procedure has been reviewed and approved by the Board for deriving inadvertent ingestion exposures to uranium during uranium-handling operations. The basic approach is based on a model that assumes the following:

> *The amount of activity ingested on a daily basis can be approximated by assuming it to be 0.2 times the activity per cubic meter of air. The* [Fi] *value for the ingestion should be the same as that used for inhalation*

Therefore, the inadvertent ingestion rate should be derived as follows:

$$39 \text{ dpm/m}^3 \times 0.2 \times 250/365 = 5.3 \text{ dpm/day}$$

The adjustment factor of 250/365 accounts for the fact that the input for Integrated Modules for Bioassay Analysis (IMBA), used to derive annual doses, assumes exposures for 365 days per year, while the actual exposures would be limited to 250 days per work year (assuming full-time employment). This value closely matches the value in Table G-1 of the site profile (TBD-6000-AppG, Revision 01) of 5.34 dpm/day, and is claimant favorable, because it would apply to

inadvertent ingestion during AWE operations, when, in fact, the amount of deposited activity on surfaces would decline due to natural attenuation once uranium handling operations ceased.

4.1.4 External Exposures

Table G.2 of the site profile (TBD-6000-AppG, Revision 01) presents the annual external exposures for 1956 through 1959, taking into consideration the duration of uranium-handling operations in each year as described above. The following is quoted directly from Table G.2 of the site profile:

Table G.2 – External Dose **[NIOSH 2014a]**

Year	*Photon (mR/year)*	*Beta – whole body (mrem/year)*	*Beta – hands and forearms (mrem/year)*
1956	*8.3*	*84*	*921*
1957	*16.6*	*167*	*1841*
1958	*0.008*	*0.77*	*0.77*
1959	*25.0*	*250*	*2761*

SC&A's Comments

Section G.5 of TBD-6000-AppG, Revision 01 explains that beta radiation surveys performed by HASL in 1959 observed exposure rates of 19 millirep per hour (mrep/hr) at one foot from billets and 6 mrep/hr at 3 feet from the billets, where a mrep can be considered equivalent to a mrem (Glauberman 1959).[2] The Glauberman memo also reports on alpha radiation measurements (not mentioned in the site profile):

> *Direct radiation measurements of surfaces for alpha contamination ranged from background (<200 d/m/100 cm^2) to 600 d/m/100 cm^2, with the latter value found at the die cleaning station and the table adjacent to the Lindberg furnace.…Exposures to airborne alpha emitting dust are well below the permissible concentration. Surface contamination is confined to a few locations and is insignificant.*

The site profile (TBD-6000-AppG, Revision 01) also estimated the external exposure rates using the generic values adopted in TBD-6000, Revision 01, which has been thoroughly reviewed and approved by the Board. Given that TBD-6000 provides a more complete and thorough characterization of the radiation fields and exposure rates in the vicinity of uranium metal at uranium metal handling facilities and that these values are comparable to or more claimant favorable than the measured dose rate data reported by HASL for this facility, NIOSH elected to use the exposure and dose rate data provided in TBD-6000, Revision 01, as the basis for deriving external exposures at Anaconda.

[2] Glauberman 1959 also notes that "Similar intensities were found near the extruded tubes on the run-out table and in the testing area"; this is not mentioned in the site profile.

Using TBD-6000, Revision 01, values as their basis, the site profile makes the following basic assumptions for deriving external exposure rates to operators near uranium metal at Anaconda.

1. An external photon exposure rate of 2.08 millirem per hour (mrem/hr) and external beta exposure rate of 20.8 mrem/hr at 1 foot from uranium metal.
2. An external skin exposure rate from beta exposure in contact with the uranium metal of 230 mrem/hr.
3. Operators are exposed at 1 foot from the metal and their hands are in direct contact with the metal for 50% of a work day for each 8-hour work shift that a worker is involved with uranium handling (i.e., operators).
4. Operators are also exposed to residual surface contamination, as recommended in Table 3.10 of TBD-6000, Revision 01, every working day from 1956 through 1959. Note that Table 3.10 recommends a photon dose conversion factor (DCF) of 3.9E-10 milliroentgen per hour (mR/hr) per dpm/m^2 and a beta exposure rate DCF of 3.82E-8 millirad per hour (mrad/hr) per dpm/m^2 at 1 meter above a contaminated circle of with a 100-meter radius and with natural uranium aged 100 days (i.e., sufficient time for the short-lived progeny of uranium to grow in).

These assumptions are consistent with those recommended in TBD-6000, Revision 01. For example, Table 6.1 of TBD-6000, Revision 01, recommends an external whole-body penetrating dose rate of 2.08 mrem/hr at one foot from a rectangular ingot. Section 6.3 of TBD-6000, Revision 01, recommends the following: "The 7 mg/cm^2 dose from non-penetrating radiation when the skin is in contact with an unshielded slab of uranium metal is 230 mrem/hour."

Section 6.2 of TBD-6000, Revision 01, also recommends the following assumption regarding exposure duration for different categories of workers:

> *a worst-case assumption should be made, which is that all work was done with a uranium metal slab, and the following assumptions are made about a worker's exposure conditions:*
>
> - *Operator: 50% of the workday was spent at 1 foot from the surface of the metal*
> - *General Laborer: 50% of the workday was spent at 1 meter from the metal surface*
> - *Supervisor: exposure was equal to 50% of a general laborer's exposure*
> - *Clerical: exposure was equal to 10% of a supervisor's exposure.*

Section 6.3 also recommends the following:

> *Exposure assumptions for hands-on contact with uranium metal for the four job categories assumes:*

- *Operator: 50% of the workday was spent with hands in contact with the surface of the metal*
- *General Laborer: exposure would be 50% of the exposure of the operator*
- *Supervisor: exposure would be 10% of the exposure of the general laborer (assuming the supervisor seldom has a reason to touch metal)*
- *Clerical: 0 (assuming the clerical worker has no reason to touch metal)*

Hence, the site profile and its associated PER-065 for Anaconda use fundamental assumptions and DCFs that have been reviewed by the Board and found to be scientifically sound and claimant favorable.

Given these basic assumptions and DCFs, the site profile assigns the external annual exposures to Anaconda workers as shown in Table G.2 of the site profile (see above), which takes into consideration the number of shifts that operators performed AWE operations in 1956 through 1959. As discussed above, based on the actual records of extrusion operations at Anaconda, the site profile uses the following assumptions to derive annual exposures during extrusion operations:

1956: One 8-hour shift on September 29, 1956

1957: Two 8-hour shifts in March 1957

1958: No AWE operations in 1958

1959: Three 8-hour shifts between October 19th and October 21st in 1959

For example, for 1956, Table G-2 assigns a whole-body photon dose of 8.3 mR/year, a beta dose (at a distance of 1 meter) of 84 mrem/yr, and beta hands and forearm dose of 921 mrem/yr. The following is an attempt to match these values:

8 hours/yr × 2.08 mrem/hr × 0.5 = 8.3 mrem/yr for external whole-body dose from a billet during an 8-hour extrusion operation. This value closely matches the photon dose for 1956 in Table G.2 of the site profile. Our calculations show that the external photon dose from deposited residual radioactivity is negligible. Also note that the photon doses associated with extrusion operations are directly proportional to the number of shifts each year when extrusion operations were performed. Hence, SC&A concurs with the annual exposures derived by NIOSH to reconstruct photon exposures during extrusion operations from 1956 through 1959, as provided in Table G.2 of the site profile.

Section G.5 of the site profile indicates that the beta dose at 1 foot from an ingot is 20.8 mrem/hr, or about 10 times the photon dose, which is a reasonable value. Hence, a beta dose at 1 foot of 84 mrem/yr is appropriate for 1956. A contact beta skin dose of 921 mrem/yr for 1956 is considered plausible, since previous uranium metal investigations revealed the contact skin dose (primarily from beta emissions) of 230 mrem/hr. Hence, assuming exposure for 50% of the time during a 1-hour shift yields a contact beta dose of 230 mrem/hr × 4 hrs = 920 mrem, which is essentially identical to the value reported in Table G.2 of the site profile.

With respect to external exposures in 1956, due to residual radioactivity, Section G.4 of the site profile explains that a simple bounding approach was used, as described in Section G.4. This approach assumes that, for the entire four-year period of AWE operations, the level of residual surface contamination was assumed to be 10,109 dpm/m^2. Using this bounding assumption, we obtain the following penetrating and non-penetrating dose due to residual surface contamination:

Penetrating

> 10,109 dpm/m^2 × 3.94E-10 mrem/hr per dpm/m^2 × 8 hr/day × 250 days/yr = 7.9E-3 mrem

Non-Penetrating

> 10,109 dpm/m^2 × 3.82E-8 mrem/hr per dpm/m^2 × 8 hr/day × 250 days/work year = 0.77 mrem

These exposures to residual surface contamination are negligible as compared to the exposures associated with handling a billet and can be ignored.

For time periods where extrusion operations were not being performed, there was the potential for external exposures from residual radioactivity. However, as described in Section G.6 of the site profile (TBD-6000-AppG, Revision 01),

> *Residual contamination potentially existed between operations with uranium at Anaconda. However, surveys showed the potential was low and so no residual contamination period was designated after 1959. The periods between operations is*[sic] *accounted for in a favorable manner in sections G.4 and G.5. Also, since there was no radioactive material associated with the operations described for 1942, no residual contamination is assumed prior to 1956.*

Several sources corroborate this statement, including one reporting on elimination of the Anaconda site from the Formerly Utilized Sites Remedial Action Program (FUSRAP):

> *The Anaconda Company site was surveyed by the Health and Safety Laboratory (HASL) during 1956 and 1959. All radiation levels associated with the AEC operations were found to be within typical background levels for Connecticut. The Director of the Division of Remedial Action determined that the radiation levels are below the criteria for remedial action and the Anaconda Company site is to be terminated from the Formerly Utilized Sites Remedial Action Program for unrestricted use* (Coffman undated).

SC&A concurs with the methods used in the site profile for reconstructing external penetrating and non-penetrating exposures.

5.0 SUBTASK 3: EVALUATE THE PER'S STATED APPROACH FOR IDENTIFYING THE UNIVERSE OF POTENTIALLY AFFECTED DRs

Section 3.0 of PER-065 states that all DRs with POCs less than 50% will be revisited under this PER and that 10 claims were identified. SC&A concurs with this comprehensive approach to reevaluating cases associated with this PER.

SC&A reviewed all the Anaconda DRs and found a total of 14 cases in various stages of completion. Of these 14 cases, SC&A identified a total of 10 claims with a POC <50%, one claim which was compensated and 3 cases which were not completed. Table 1 below summarizes the 14 Anaconda claims.

Table 1. Anaconda Claims

Case ID	Date DR completed	Target organ(s)	Assigned dose (rem)	POC	PER-065 status	Assigned X-ray	Procedures Used
[redacted]	2004	colon	34.965	38.47%	no records	annual	no TBD-6000
[redacted]	2006	bile duct	1.42	40.26%	no records	annual	no TBD-6000; OTIB-6
[redacted]	2004	red bone marrow	75.7	46.94%	No records	annual	OTIB-4, OTIB-6
[redacted]	2004, 2007	pancreas, kidney	0.367, 0.367	1.49%	no records	annual	TBD-6000, OTIB-6, PROC-61
[redacted]	2007	lung	0.381	1.19%	no records	annual	TBD-6000, OTIB-6
[redacted]	2005	vocal cords	2246	94.64%	no records	no	OTIB-4
[redacted]	2004	prostate	33.215	24.45%	no records	annual	OTIB-4
[redacted]	2004	colon	28.52	28.20%	no records	annual	OTIB-4
[redacted]	2007	prostate	10.812	0.53%	no records	annual	TBD-6000, OTIB-4, OTIB-6, PROC-61
[redacted]	2008	lung	0.168	0.45%	no records	annual	TBD-6000, OTIB-6
[redacted]	2009	prostate	0.139	0.27%	pulled	annual	TBD-6000, OTIB-7
[redacted]	n/a	colon, SCC, BCC	n/a	n/a	pulled	n/a	claim submitted but DR not completed, no files on NOCTS
[redacted]	n/a	BCC, colon	n/a	n/a	pulled	n/a	claim submitted but DR not completed, no files on NOCTS
[redacted]	n/a	colon	0.179	<50%	n/a	n/a	Final DOL decision not on file

SC&A's Comments

The information on the NIOSH OCAS Claims Tracking System (NOCTS) site did not appear to include the PER status of the 14 cases. There are no findings pertaining to the selection criteria used to identify claims potentially affected by PER-065 and the need for re-evaluation of doses for these claims.

6.0 SUBTASK 4: CONDUCT AUDITS OF A SAMPLE SET OF DRs AFFECTED BY DCAS-PER-065

Based on information presented in Subtasks 1 through 3, SC&A recommends the selection of three (3) cases with significant employment periods as operators/laborers for the time period 1956 through 1959. In addition, the cases should be selected such that we can evaluate the degree to which the DR methodologies employed the most recent guidance provided in TBD-6000, Revision 01 (for the time periods involving uranium extrusion operations), OTIB-0070 (for the time periods between extrusion operations), and OTIB-0006 (to ensure that the assigned doses associated with occupational medical x-ray examinations followed the most recent revision to OTIB-0006).

7.0 REFERENCES

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NIOSH 2004. *Estimation of Ingestion Intakes*, OCAS-TIB-009, Revision 0, National Institute of Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. April 13, 2004.

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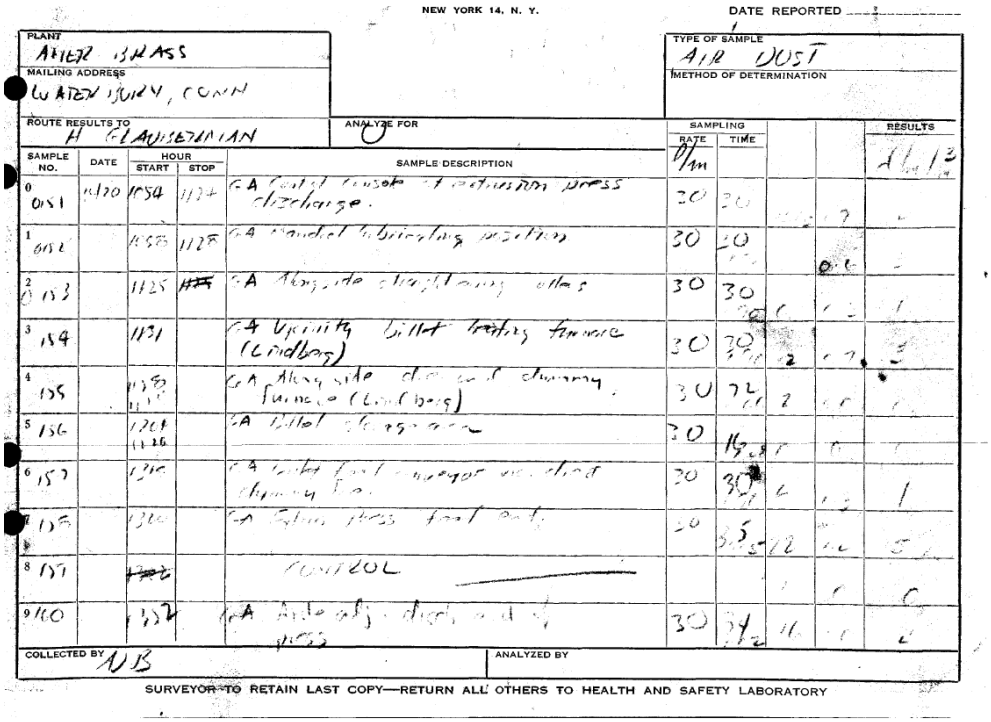
NIOSH 2014b. *TBD-6000 Revision*, DCAS-PER-055, Revision 0, National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio. September 12, 2014.

NIOSH 2015. *Anaconda*, DCAS-PER-065, Revision 0, National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio. November 30, 2015.

U.S. AEC (Atomic Energy Commission) Undated. *Data Analysis Results 1947 Through 1961*, U.S. Atomic Energy Commission, New York Operations Office Health and Safety Division, New York, New York. Undated. [SRDB Ref. ID: 11452]

APPENDIX A: AIR DUST LOADING DATA FOR AMERICAN BRASS (ANACONDA) (SRDB REF. ID 11452, PAGES 30–32)

Figure 1. Example 1 of Illegible Anaconda Air Dust Loading Data



NEW YORK 14, N. Y. DATE REPORTED

PLANT: AMER BRASS
MAILING ADDRESS: WATERBURY, CONN
TYPE OF SAMPLE: AIR DUST
METHOD OF DETERMINATION:
ROUTE RESULTS TO: H GLADIESZMIAN
ANALYZE FOR: U
SAMPLING RATE: 01/m
RESULTS: d/m/ft³

SAMPLE NO.	DATE	HOUR START	HOUR STOP	SAMPLE DESCRIPTION	SAMPLING TIME			RESULTS
0 0151	1/20	1054	1124	CA [illegible] discharge.	30	30		
1 0152		1155	1125	CA [illegible]	30	30		
2 0153		1125	1155	CA [illegible]	30	30		
3 154		1131		CA Upright billet heating furnace (Lindberg)	30	30		
4 155		1159 1131		CA Along side of [illegible] furnace (Lindberg)	30	30		
5 156		1201 1126		CA Billet [illegible]	30	15		
6 157		1210		CA [illegible]	30	30		
7 158		1210		CA [illegible]	30	30		
8 157		~~1210~~		CONTROL				
9 160		1132		CA [illegible]	30	30		

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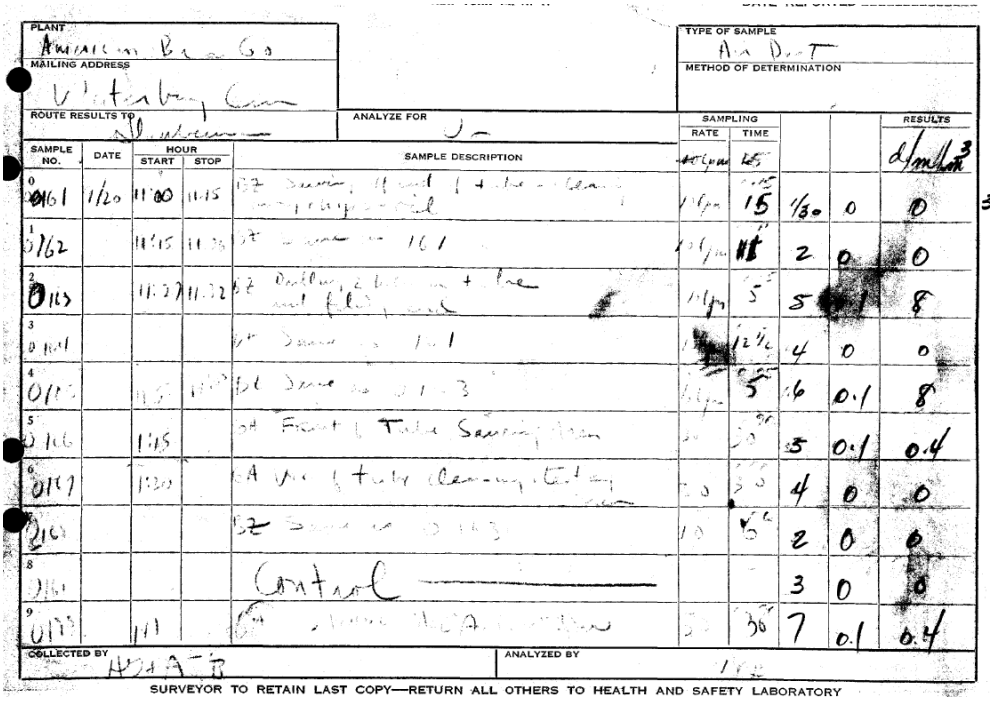
Figure 2. Example 2 of Illegible Anaconda Air Dust Loading Data



PLANT: American Brass Co
MAILING ADDRESS: Waterbury Conn
TYPE OF SAMPLE: Air Dust
METHOD OF DETERMINATION:
ROUTE RESULTS TO:
ANALYZE FOR:
SAMPLING RATE:
RESULTS: d/m/ft³

SAMPLE NO.	DATE	HOUR START	HOUR STOP	SAMPLE DESCRIPTION	SAMPLING TIME			RESULTS
0 0161	1/20	11:00	11:15	[illegible]	15	1/30	0	0
1 0162		11:15	[illegible]	[illegible]	[illegible]	2	0	0
2 0163		11:27	11:32	[illegible]	5	5	1	8
3 0164				[illegible]	12½	4	0	0
4 0165		[illegible]	[illegible]	[illegible]	5	6	0.1	8
5 0166		1115		[illegible]	[illegible]	5	0.1	0.4
6 0167		1120		[illegible]	[illegible]	4	0	0
7 0168				[illegible]	[illegible]	2	0	0
8 0169				Control		3	0	0
9 0170		1111		[illegible]	30	7	0.1	0.4

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Figure 3. Example 3 of Illegible Anaconda Air Dust Loading Data