Review of DCAS-PER-073: Birdsboro Steel Foundry and Machine Company

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Background of Facility

- **History**
  - **Industrial Operations**

    While it was open, Birdsboro Steel Foundry and Machine Company in Birdsboro, Berks County, Pennsylvania (later known as Birdsboro Corp.) was known as the oldest foundry in the United States, tracing its roots back to William Bird's New Pine Forge, founded in 1740. Birdsboro Steel provided products to the United States military for every major conflict through the Korean War. The company closed down in 1988 after a lengthy strike and the inability to compete with increasing foreign steel imports. (Historical Society of Pennsylvania, 2016)
  - **Name of Facility**

    1951 US Government memo: Trip to **Birdsboro Steel Foundry and Machine Company**

    1952 letter from R. J. Smith, Chief, Operations Division, New York Operations Office, Atomic Energy Commission, to L. King, **Birdsboro Steel Foundry & Machine Company**

    1987 handwritten memo: Elimination Recommendation

    Owner: **Birdsboro Steel Foundry & Machine Company**

    Site name: Birdsboro Steel & Foundry
  - DOE Facility List: Birdsboro Steel & Foundry
  - Birdsboro produced steel castings (hence "Birdsboro Steel Foundry") and produced steel-making machinery for sale to other facilities (hence "Machine Company")

Observation 1

In the interest of technical and historical accuracy, the site should be referred to as the "Birdsboro Steel Foundry and Machine Company."

- **Documented AWE Operations**
  - Shipment of eight assorted pieces of uranium billets, weighing 346 lb, received from Birdsboro for storage at Lake Ontario Ordinance Works (LOOW) in the week preceding November 15, 1951. No documentation of purpose nor duration of time at Birdsboro.
  - Birdsboro involved in design of rolling mill for Fernald—reasonable, since the company produced machinery for rolling steel. Not an AWE activity.
  - The eight pieces of billets, with an average weight of 43 lb, were likely the result of test rollings at Birdsboro. (A billet, in the shape of a cylinder or a rectangular prism, is an intermediate product between an ingot and, in this case, a uranium fuel rod.)
  - Five 1–2 inch wafers, presumably of uranium, shipped to Birdsboro from Model City, NY (near LOOW), according to letter of February 1, 1952. Weights: 1.9–2.5 lb, 11.5 lb total. “After completion of work . . . this office [New York Operations Office of the Atomic Energy Commission (AEC)] should be contacted before disposition of material.”
  - No documentation of the purpose of the wafers. NIOSH speculated that these were subject to microscopic analysis of grain structure. Such analyses were performed on uranium rods rolled at the Bethlehem Steel plant in Lackawanna, New York—subject of report of a trip on October 17, 1951. However, no references have been found of such studies having been performed at Birdsboro.

SUBTASK 1: ASSESS NIOSH'S EVALUATION AND CHARACTERIZATION OF THE ISSUES THAT NECESSITATED DCAS-PER-073 AND ITS POTENTIAL IMPACTS ON DR

- **Background**
  - **TBD-6000, Rev. 0**—Generic guidance for AWEs that worked uranium & thorium metals, December 13, 2006

    First guidance document to address such AWEs
    - **Appendix B, Rev. 0**, Birdsboro, November 21, 2007
  - **TBD-6000, Rev. 1**—Generic guidance for AWEs that worked uranium metals, June 17, 2011
    - **Appendix B, Rev. 1**, Birdsboro, June 2, 2015

      Nominally revised for conformity with TBD-6000, Rev. 1, actually a total rewrite

Comparison of Exposure Pathways in Appendix B, Rev. 0 and Rev. 1

Year	Inhaled intake (pCi/d)		Ingested intake (pCi/d)		External exposure (mrem/y)	
	Rev. 0	Rev. 1	Rev. 0	Rev. 1	Rev. 0	Rev. 1
1951	209	42.9	1.95	30.7	11.4	10.4
1952	64.9	45.7	0.605	154	2.28	1.28

The operational period at Birdsboro spanned two years: 1951 and 1952. In both years, the ingested intakes prescribed by Appendix B, Rev. 1, were significantly higher than those listed in Rev. 0. Consequently, it was not possible to exclude any cases by period of employment. Given that DRs had been performed for only four former Birdsboro employees, NIOSH made the expedient decision to perform new DRs for all four cases under the PER.

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

- **Reason for Revising Appendix B**

  The reason stated by NIOSH for revising Appendix B was to conform to the revision to TBD-6000. A comparison of the revised TBD to the original version shows that there were no significant changes in the exposure pathways for organs other than skin that would affect the Birdsboro site profile. However, NIOSH did perform a fundamental revision of the exposure scenarios, based on a reassessment of the handling and working of uranium metal at Birdsboro, resulting in major changes in the exposure scenarios. Another fundamental change was in the methodology used to assess the ingestion pathway.

- **Exposure Scenarios**

  In Appendix B, Rev. 1, NIOSH postulated that Birdsboro had received the uranium metal in order to perform microscopic analyses of the metal surfaces. NIOSH assumed that Birdsboro cut the pieces to prepare samples for the analyses, and that the work took 8.8 h, one-fifth of the 44-h workweek assumed for this time period in TBD-6000. NIOSH postulated that Birdsboro received the billets on April 17, 1951, the earliest date that billets were produced at Simonds Saw and Steel Co. in support of the design of the Fernald rolling mill. The machining of the billets at Birdsboro was assumed to take place on the same day. The machining of the five wafers was assumed to take place on February 1, 1952, the date of the AEC letter notifying Birdsboro of their shipment.

  Observation 2

  The statement that TBD-6000 assumed that the standard workday was 8.8 hours is based on a misinterpretation. In fact, TBD-6000 assumed a 44-h week, which was based on working 8 h/d Monday–Friday and working half a day (4 h) on Saturday, a common practice in the early 1950s.

- **Dates of Operations**

  Although it would have a trivial effect on the estimated doses, the assumed dates of operations are implausible. If the billets were rolled at Simonds Saw and Steel in Lockport, New York, on April 17, 1951, it is implausible that they could have been machined on the same day at Birdsboro, which is over 300 miles away, especially since the machining was assumed to take an entire workday. A more likely date would be April 19, 1951, allowing one day for shipment after the rolling.

  The wafers were shipped by Railway Express, a commercial carrier, from Model City, New York, also over 300 miles from Birdsboro. It is likely that the letter confirming the shipment, dated February 1, 1952, would have been written the day the metal was shipped. It is implausible that the wafers could have been machined at Birdsboro on the same day. Since this date fell on a Friday, the earliest likely date the wafers would have been machined would be February 4, the following Monday.

  Observation 3

  We recommend that NIOSH adopt April 19, 1951, as the date for processing the 346 lb of billets and February 4, 1952, for working on the five wafers.

- **Occupational Internal Dose**
    - **Inhaled Intakes**
        - **NIOSH Assessment**

          NIOSH assumed an air concentration with a geometric mean of 3,160 dpm/m^3, the daily weighted average (DWA) for a surface grinder, during operations in both 1951 and 1952. This airborne activity settled to the floor at a rate of 0.00075 m/s, resulting in a surface contamination of 75,082 dpm/m^2. This activity then became resuspended. Using a resuspension factor (RF) of 1×10^{-5} m^{-1}, NIOSH derived an airborne activity of 0.751 dpm/m^3, which it used to calculate intakes during the working hours following the first operation in 1951 until the second operation in 1952. The second surface grinding operation, assumed to have taken place on February 1, 1952, also generated airborne activity that settled to the floor, doubling the previous level of surface contamination, which in turn doubled the airborne activity due to resuspension during the remainder of the operational period (i.e., until the end of 1952).
        - **SC&A Assessment**

          We performed a revised analysis of the inhaled intakes, assuming an airborne concentration of 3,533 dpm/m^3, which is the DWA of a rolling operator, during an 8-h workday on April 19, 1951. We assumed that this activity settled out during an 8-h period, resulting in a surface contamination of 76,313 dpm/m^2, which resulted in a resuspended airborne concentration of 0.761 dpm/m^3. The rest of the intake calculations paralleled those performed by NIOSH, except that we assumed that the surface grinding of the wafers took place on February 4, 1952, and that the workdays were 8 h on weekdays and 4 h on Saturdays. We calculated the actual workweeks following the rolling or machining of the uranium, based on the calendar, for assessing intakes of resuspended activities. The net result of this revision is an increase in the total intake in 1951 but a decrease in 1952, for a decrease of ~3.4% in the total inhaled intakes for both years.

Observation 4

The methodology used by NIOSH had the net effect of slightly overestimating the inhaled intakes of uranium.

- **Ingested Intakes**

  According to NIOSH, OCAS-TIB-009 is not suitable for estimating ingested intakes because the uranium machining operations were of short duration, which did not allow the uranium airborne and surficial activities to achieve equilibrium. NIOSH estimated ingestion on the basis of the calculated surface contamination levels, assuming an ingestion rate of 1.1×10^{-4} m^2/h, citing NUREG/CR-5512, vol. 1 as a reference. Thus, given a surficial activity concentration of 75,082 dpm/m^2 in 1951, the ingestion rate was 8.26 dpm/h (75,082 dpm/m^2 x 1.1×10^{-4} m^2/h = 8.26 dpm/h).

  We compared this methodology to that in OCAS-TIB-009, which cited three pathways that contribute to the ingested intakes. The first (Mode 1)—the ingestion of material that is originally inhaled—is included in the inhalation pathway. The second (Mode 2) is the deposition of the airborne activity on a beverage cup, and the third (Mode 3) is the hand-to-mouth transfer from a contaminated surface. During a prolonged operational period, the latter two pathways make approximately equal contributions. During times when there are no uranium operations, the airborne uranium activity concentration is greatly reduced—0.751 vs. 3,160 dpm/m^3 in the present analysis—so that the contribution of Mode 2 can be neglected. However, the Mode 3 pathway can be applied in the present case.

  OCAS-TIB-009 developed a method for calculating the Mode 3 contribution that assumed that each workday a worker ingested 10% of the activity on his hand, which was assumed to have an area of 4 × 6 inches, or 0.0155 m^2. The surficial activity on the hand was equal to that on the surface contaminated by uranium aerosol deposition. Using the surface contamination level of 75,082 dpm/m^2, we obtained an ingestion rate of 14.5 dpm/h for an 8-h day during 1951, compared to 8.26 dpm/h calculated by NIOSH.

- **Reasons for Adopting Alternative Methodology:**
  - Consistent with the OCAS-TIB-009 model developed by NIOSH that was reviewed by the ABRWH and cited in numerous site profiles.
  - Consistent with assessments of ingestion rates during residual periods at other worksites (e.g., General Steel Industries [GSI], Carborundum, Hooker Electrochemical), where the ingestion rate during the operational period was assigned to the start of the residual period.
  - Claimant favorable—intake rate 76% higher than method employed by NIOSH.

Observation 5

NIOSH used an ingestion rate that is inconsistent with rates used in exposure assessments for other worksites that were based on OCAS-TIB-009 and is not claimant favorable. This is an overarching issue that applies to other sites and should be addressed in a wider context.

Observation 6

NIOSH erroneously cited the source of the ingestion rate of 1.1×10^{-4} m^2/h as NUREG/CR-5512, vol. 1 (1992), which listed an approximate value of 1×10^{-4} m^2/h, based on four published results varying by an order of magnitude. The value of 1.1×10^{-4} m^2/h used by NIOSH was based on NUREG/CR-5512, vol. 3 (1999), by different authors who performed a detailed study of ingestion rates and found this to be the average value of a derived probability density function.

- **Occupational External Dose from Penetrating Radiation**
  - **Exposure to Uranium Metal**
    - NIOSH assumed operator handled uranium metal for 1 week (44 h) in 1951 and again in 1952
    - Distance = 1 ft, 50% exposure duration
    - 1951 source: short billet
    - 1952 source: slug

Dose Rates at 1 Foot from Various Configurations of Natural Uranium Metal

Shape	Inner diameter or width (in)	Outer diameter or thickness (in)	Length (in)	Weight (lb)	Dose rate (mrem/h)	Annual dose (mrem)
Slug	0.82	1.66	4	4.48	0.0524	1.28[a]
Long Billet	—	5	28	376	0.703	15.5[b]
Short Billet	—	6	12	232	0.469	10.4[b]
Flat Plate	3.1	0.18	18	6.87	0.231	5.21[a]

Source: Anderson, J. L., and N. E. Hertel. 2005. "Bremsstrahlung doses from natural uranium ingots." *Radiat Protect Dosimetry, 115*(1–4), 298–301
[a] Includes 0.125 mrem from exposure to contaminated surfaces in 1952
[b] Includes 0.0462 mrem from exposure to contaminated surfaces in 1951

- Selected uranium shapes do not represent metal handled at Birdsboro.
  - Billets handled in 1951 were produced from 5-inch diameter ingots. Billets were between the thickness of a rod and a 5-inch ingot. Long billet: weight close to total weight of 8 uranium pieces (346 lb), annual dose more claimant favorable.
  - Slug a hollow cylinder, does not represent wafers: cylindrical slices, 1–2 inches thick, cut from rods. Better surrogate for 1952 is flat plate: weight closest to 11.5-lb weight of five wafers (operator might have been exposed to more than one wafer at the same time), annual dose more claimant favorable.

o **Exposure to Radiographic Sources**

- NIOSH overlooked other sources of external exposure that were present at Birdsboro at the time of the uranium work.
  - CATI interviews reported use of radium, ^{60}Co, x-ray machines, and betatron; included a verbal description of photograph showing use of sources consistent with “fishpole” technique for radium radiography.
- SC&A interviewed former worker employed shortly after the covered period. Worker reported that a betatron, a 500 mCi radium source, and a ^{60}Co source were used at Birdsboro.
- University of Illinois at Urbana–Champaign has list of Allis-Chalmers betatrons dated December 26, 1952, which includes “Birdsboro Foundry” that had a 22-MV betatron installed in 1952.
- Steel Founders’ Society of America (1961): Birdsboro had nondestructive test facilities comprising:
  - 24-MV betatron
  - 300-kVp x-ray machine
  - 200 mCi ^{60}Co
  - 500 mg radium (≈ 500 mCi)

- Available information is entirely consistent with information on radiographic operations at GSI.
  - Greatest source of external photon exposure at GSI was 500-mCi ^{226}Ra source employing fishpole technique.
  - External exposure scenarios developed for GSI can constitute surrogate data for Birdsboro.
    - Assign external exposures to operators in 1951–1952 as triangular distribution:
      - Minimum 6.279 R/y
      - Mode 11.345 R/y
      - Maximum 15 R/y
    - Limiting values: do not include external exposures from uranium metal (omitted at GSI).
  - Betatron exposures in 1952:
    - 5.112 rad/y air kerma from 30 keV photons in posteroanterior (PA) geometry
    - Neutron dose from steel radiography
      - 0.857 mrem ambient dose equivalent (H*[10]) per 8-h shift
      - 2,200-h work year
      - 117.8 mrem annual dose (0.857 mrem/shift × 2,200 h/y ÷ 8 h/shift = 117.8 mrem/y)
  - External photon exposure rates of administrative personnel (anyone normally working in an office environment not routinely entering the production areas) = 571.5 mR/y (1951–1952).

Finding 1: NIOSH neglected the external exposure to documented radiographic sources in assigning external doses to Birdsboro workers.

- **Beta Doses to Skin Other Than Hands and Forearms From Handling Uranium Metal**
  - SC&A-recommended beta dose in 1951
    - = 10X photon dose rate from long billet (SC&A-recommended shape) + beta dose from contaminated surfaces calculated by NIOSH
    - = 0.703 mrem/h × 10 x 44 h/y × 50% + 4.48 mrem = 159 mrem
  - Beta dose in 1952 assigned by NIOSH consistent with SC&A's MCNPX analysis of a uranium wafer, performed as part of the present review

Observation 7

The beta dose rate to skin other than that of the hands and forearms in 1951 should be based on the long billet, as described by TBD-6000. We make this an observation rather than a finding, since the change in the skin dose would be small compared to the much larger dose from radiographic sources cited in Finding 1.

SUBTASK 3: EVALUATE THE PER'S STATED APPROACH FOR IDENTIFYING THE NUMBER OF DOSE RECONSTRUCTIONS REQUIRING REEVALUATION OF DOSE

- NIOSH searched for all completed claims with verified employment at Birdsboro site during the covered period that had a probability of causation (POC) of less than 50%. This search identified four claims.
- SC&A observed that the Birdsboro web page of the U.S. Department of Labor cited five cases referred to NIOSH for DR—the POC was less than 50% in all five cases.
- Our search for Birdsboro cases in the NIOSH OCAS Claims Tracking System (NOCTS) identified five claimants, four of whom were employed during the covered period, all with POC < 50%:
  1. DR performed prior to the issuance of TBD-6000, Rev. 0, relied on generic guidance (i.e., OTIB-0004), which specified maximum plausible intakes of radioactive materials and external exposures.
     - Intakes and doses orders of magnitude greater than Appendix B, Rev. 1.
  2. DR report issued after TBD-6000, Rev. 0, but prior to Appendix B, Rev. 0. DR relied on TBD-6000 for external exposure, intakes were based on data from Simonds Saw and Steel, scaled to the ratio of the masses of uranium handled at Birdsboro and Simonds Saw.
  3. DR performed after Appendix B, Rev. 0, issued—but external based on OTIB-0004, internal based on Simonds Saw.
     - DR #2 & #3 had intakes orders of magnitude lower than either Appendix B, Rev. 0, or Rev. 1.
  4. Only DR based on the intakes and external exposures in Appendix B, Rev. 0.
  - DR #1 could have been excluded from PER due to the large overestimates of assigned doses and intakes. NIOSH chose to repeat the DR rather than justify excluding this one case from the PER.
- SC&A had no findings pertaining to the identification of claims that were impacted by DCAS-PER-073.

SUBTASK 4: CONDUCT AUDITS OF A SAMPLE SET OF DOSE RECONSTRUCTIONS AFFECTED BY DCAS-PER-073

- **Selection of Dose Reconstructio**ns

  To complete our evaluation of DCAS-PER-073, we need to audit cases that represent a range of parameters that adequately characterize the cases evaluated by NIOSH. Under Subtask 3, we have already performed a cursory examination of the DR reports to determine the extent to which they depended on earlier NIOSH guidance documents. Since the cancer site and period of employment are listed on the cover page of each DR report, it was simplest to use the actual cases to determine the selection criteria that would enable us to perform an adequate review.

  Privacy requirements preclude a discussion of the individual cases at this time—it is included in the report previously furnished to the Subcommittee for Procedure Reviews.