DOE Review 10/02/2015

Division of Compensation Analysis and Support Technical Basis Document for the Electro Metallurgical Company Niagara Falls, New York	Document Number: DCAS-TKBS-0007 Effective Date: 09/24/2015 Revision No.: 01 Page 1 of 37
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RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
02/14/2011	02/15/2011	00	Changes Battelle-TBD-6001 Appendix to a standalone document. Change is primarily format only. Does not incorporate review comments.
03/24/2015	Draft	01-Draft A	Revision to incorporate Special Exposure Cohort designation information throughout the document. Added and revised information throughout the document regarding a correction in the start date for MED work. Substantial update of the document with re-analysis of the external and internal dosimetry data. Constitutes a total rewrite of the document.
04/01/2015	Draft	01-Draft B	Revision to incorporate an additional figure.
06/01/2015	Draft	01-Draft C	Incorporated changes based on review comments.
06/30/2015	06/30/2015	01-Draft D	Additional comments incorporated.
9/1/2015	9/1/20145	01-Draft E	Incorporated comments from review.
9/22/2015	09/24/2015	Rev 01	Incorporated comments from review to incorporate a GSD of 3 uncertainty for external and internal dose.

1.0 Introduction

Technical basis documents and site profile documents are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular Department of Energy (DOE) or Atomic Weapons Employer (AWE) facilities or categories of DOE or AWE facilities. They will be revised in the event additional relevant information is obtained about the affected DOE or AWE facility(ies). These documents may be used to assist NIOSH staff in the evaluation of Special Exposure Cohort (SEC) petitions and the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used to refer to an area, building, or group of buildings that served a specific purpose at a DOE or AWE facility. It does not mean nor should it be equated to an "AWE facility" or a "DOE facility." The terms AWE and DOE facility are defined in sections 7348l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), respectively. An AWE facility means "a facility, owned by an atomic weapons employer, that is or was used to process or produce, for use by the United States, material that emitted radiation and was used in the production of an atomic weapon, excluding uranium mining or milling." 42 U.S.C. § 7384l(5). On the other hand, a DOE facility is defined as "any building, structure, or premise, including the grounds upon which such building, structure, or premise is located … in which operations are, or have been, conducted by, or on behalf of, the [DOE] (except for buildings, structures, premises, grounds, or operations … pertaining to the Naval Nuclear Propulsion Program)," and with regard to which DOE has or had a proprietary interest; or "entered into a contract with an entity to provide management and operation, management and integration, environmental remediation services, construction, or maintenance services." 42 U.S.C. § 7384l(12). The Department of Energy (DOE) determines whether a site meets the statutory definition of an AWE facility and the Department of Labor (DOL) determines if a site is a DOE facility and, if it is, designates it as such.

Accordingly, a Part B claim for benefits must be based on an energy employee's eligible employment and occupational radiation exposure at a DOE or AWE facility during the facility's designated time period and location (i.e., covered employee). After DOL determines that a claim meets the eligibility requirements under EEOICPA, DOL transmits the claim to NIOSH for a dose reconstruction. EEOICPA provides, among other things, guidance on eligible employment and the types of radiation exposure to be included in an individual dose reconstruction. Under EEOICPA, eligible employment at a DOE facility includes individuals who are or were employed by DOE and its predecessor agencies, as well as their contractors and subcontractors at the facility. Unlike the abovementioned statutory provisions on DOE facility definitions that contain specific descriptions or exclusions on facility designation, the statutory provision governing types of exposure to be included in dose reconstructions for DOE covered employees only requires that such exposures be incurred in the performance of duty. As such, NIOSH broadly construes radiation exposures incurred in the performance of duty to include all radiation exposures received as a condition of employment at covered DOE facilities in its dose reconstructions for covered employees. For covered employees at DOE facilities, individual dose reconstructions may also include radiation exposures related to the Naval Nuclear

Propulsion Program at DOE facilities, if applicable. No efforts are made to determine the eligibility of any fraction of total measured exposure for inclusion in dose reconstruction.

NIOSH does not consider the following types of exposure as those incurred in the performance of duty as a condition of employment at a DOE facility. Therefore these exposures are not included in dose reconstructions for covered employees (NIOSH 2010):

- Background radiation, including radiation from naturally occurring radon present in conventional structures
- Radiation from X-rays received in the diagnosis of injuries or illnesses or for therapeutic reasons

The following information from the Department of Energy's Office of Health, Safety and Security EEOICPA Find Facilities webpage defines the EEOICPA covered periods for the Electro Metallurgical Company (DOE 2013).

Site:	Electro Metallurgical Company
Location:	Niagara Falls, New York
Covered Period:	8/13/1942-12/31/1953

This document contains a summary of the description of the site as well as the Atomic Energy Commission activities performed there, and provides the technical basis to be used to evaluate the occupational radiation doses for EEOICPA claims.

The Secretary of Health and Human Services has designated a class of employees from the Electro Metallurgical site for inclusion in the Special Exposure Cohort (SEC). The approved class consists of all employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Electro Metallurgical site in Niagara Falls, New York, for the period from August 13, 1942 through December 31, 1947 for a number of work days aggregating at least 250 work days, occurring either solely under this employment, or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort (NIOSH 2012).

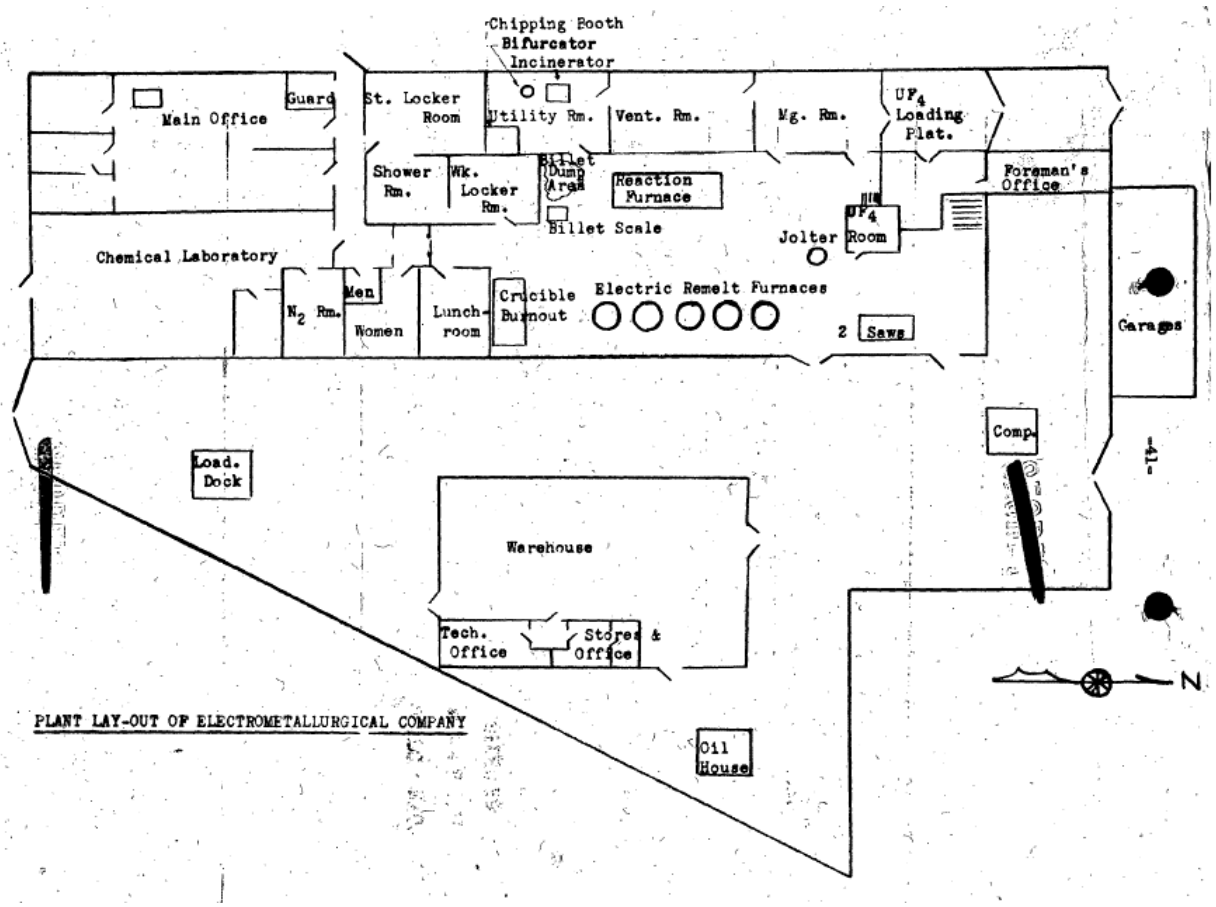
NIOSH has determined, and the Secretary, Health and Human Services has concurred that it is not feasible to estimate internal exposures with sufficient accuracy for all workers at the site for the period August 13, 1942 through December 31, 1947 at the Electro Metallurgical Company (NIOSH 2012, HHS 2012). Any available personal monitoring data should be used to reconstruct an individual's exposure at Electro Metallurgical during this time period. However, unmonitored internal exposures during this time period cannot be reconstructed.

2.0 Site Description and Operational History

The Electro Metallurgical Company (a subsidiary of Union Carbide and Carbon) entered into a contract with the Manhattan Engineer District (MED) (Contract No. W-7405-Eng.14) to design, engineer, construct, and operate a uranium plant/facilities that transformed metal salt into metal. Construction started on December 29, 1942 (MED 1943a). Electro Metallurgical was also

requested to begin casting of metal ingots immediately using existing equipment in order to increase metal production; Electro Metallurgical reported that in November 1942 that they had initiated the process using existing facilities (MED 1943b). The metal ingots cast at Electro Metallurgical were sent to the University of Chicago for analysis. It is not known exactly how much metal was cast in their existing facility but 175 pounds were cast in the last week of December 1942 (MED 1943b). The plant became operational in March of 1943. Figure 1 shows the layout of the facility which helps show the level of intermixing of process and non-process areas.

Figure 1: Layout of the Electro Metallurgical facility (AEC 1949 p51).



The Electro Metallurgical Company uranium operations were located south of Pine Avenue and east of its intersection with Packard Road, Niagara Falls, New York. Available information indicates that uranium operations (including the business office, lunchroom, and shipping areas) were conducted within a single building. The building was a one-story cinder block and wood structure, which measured approximately 50 feet by 219 feet located in an area now occupied by the current Building 166 of the Union Carbide Corporation building complex (DOE 1986). In addition to the area plant, there was also an addition known as the Magnesium Room, measuring 77 feet by 19 feet. Equipment installation was performed by Electro Metallurgical personnel, who made numerous minor changes after operations had started, but before the plant was

reported 100% complete. As a result, the actual completion date for the construction (June 15, 1943) was reported after operations had started in the new facility. Electro Metallurgical was also tasked to conduct ore processing research as part of its initial contract. This program was conducted for a short time beginning in April 1945 and concluding in August 1945 using small quantities of low-grade African ore (MED 1945). Very little specific information is available to NIOSH regarding operational exposure levels for the ore research during this early period nor of the clean-up of those operations. By employing a wet process involving chemical leaching, the exposure potential from these processes was likely low (MED 1945b; MED 1945c). This work occurred during the time period in which Electro Metallurgical has been designated as included in the Special Exposure Cohort.

The Electro Metallurgical Company, a subsidiary of Union Carbide and Carbon Corporation, was liquidated on November 30, 1948 and the company and all its assets were assigned as the Electro Metallurgical Division of Union Carbide and Carbon Corporation (UCC 1948).

Electro Metallurgical purchased the building and equipment from the AEC at the end of the final contract that concluded on June 30, 1953. This transfer terminates the facility from being a covered facility and there is no residual period because it was a DOE facility. Cleanup of the facility to contemporaneous release standards was a condition of the sale of the property by the AEC to Union Carbide. The plant and equipment were decontaminated through washing, vacuuming, and in some locations, removing concrete floors and wooden platforms. These decontamination activities occurred after the sale of the property. A survey in October 1952 provided baseline data as well as recommendations for the cleanup to approve the transfer (AEC 1953b). A condition of the transfer of the property was that Electro Metallurgical Company would complete the required cleanup to specified tolerance levels within 1 month of the transfer as indicated in the sale agreement (AEC 1953a). The AEC came to the site on August 11, 1953 (after the end of the covered period) to conduct the post cleanup surveys and found the company was in the process of completing the decontamination that included the removal of certain structures that were permanently contaminated. AEC personnel provided further instructions to Electro Met on how to complete the decontamination and how to burn and dispose of the uranium residues in wood structures. The AEC completed the survey on August 14, 1953 (AEC 1953c). The AEC used the results from this survey to conclude that Electro Met had met the conditions for the facility to be released to the company and issued a report September 28, 1953 (AEC 1953C, AEC 1953d).

Process descriptions from early 1943 (MED 1943d) describe that a series of bombs failed in the furnaces causing them to blow the mixture into the furnaces and shoot flames and sparks upwards (e.g. a blowout). The document describes that while no damage was done to the equipment, the effect on moral on the women operators forced a stop work until the cause could be determined. The cause was found to be an increase in the moisture content of the dolomite liner which had risen from 0.3 to 1% and changes to material specifications corrected the issue. Other tests are described during this early period which included variations in the bolting patterns of the reduction bombs which resulted in horizontal flames during the blowouts from these experiments. The report described the activity as “does not appear safe or desirable for a bomb of this size”. All of these activities occurred during the period designated as and SEC at Electro Metallurgical. The reporting of a large number of women operators during this time

period does not match with what HASL observed in 1948 (all men were noted to be working in the plant in November 1948 (AEC 1949G)) and further establishes the inability to properly match personnel with job titles at this facility.

The Area Plant building was demolished in 1957 (DOE 1985 p25).

Some information is available regarding construction contractors who worked in the Area Plant during early operational periods. A detailed description of the building in 1946 and contractors who built it is described in a report (MED 1943A). Construction activities were conducted during uranium production operations. Various reports further describe that the main Electro Met plant provided service personnel to assist with maintenance of the Area Plant from its main group of personnel (not dedicated to the Area Plant) and this status changed from time to time as various periods of standby and work during standby occurred.

3.0 Process Description for Operational Periods

The Area Plant received uranium tetrafluoride from Union Carbide's Linde Air Products Division plant at Tonawanda, New York (Linde Ceramics Plant), and converted it into uranium metal in a small contained facility located on the main company's property as described in the site description section of this document. The plant converted uranium tetrafluoride to uranium metal by heating the uranium salt with magnesium and casting into 110-135 kilogram ingots and then the ingots were recast into billets. The uranium metal products were shipped to numerous facilities which included Hanford Engineer Works, Argonne National Laboratory, DuPont's Chamber Works, Simonds Saw and Steel, Revere Copper and Brass, and Joslyn Manufacturing and Supply Co (DOE 1985, page 24-25). Process residues were shipped to other sites, including Lake Ontario Ordnance Works, Mallinckrodt Chemical Company, Vitro Manufacturing, DuPont Chambers Works, and Hooker Electrochemical, for uranium recovery, storage, or disposal. Electro Met also recast scrap metal from Simonds Saw and Steel, Chapman Valve Manufacturing Company, and American Rolling Mill Company. Electro Met's contract also contained a provision for conducting research and development (DOE, 1986).

Production of uranium on the premises began prior to completion of the building which was officially completed in June of 1943. Three shifts per day were run over the entire processing history based on reports reviewed by NIOSH. Uranium production operations were suspended from September 1, 1946 through September 30, 1947 (DOE 1986). Operations continued from October 1947 until production of uranium metal was stopped on September 28, 1949 and placed in standby on September 30, 1949 (DOE 1986). Average production rates are included in Table 2. The production area continued to be used by other operations during this time period and a documented cleanup of the facility did not occur until after the facility was transferred from the AEC to Electro Metallurgical. (DOE 1985, p 24).

Design capacity of the plant was approximately 50 tons of uranium metal (as billets) per month. During operations from April 1943 through August of 1946 (when the plant was placed in standby mode) the plant produced approximately 44 tons of metal billets per month. After restarting operations, Electro Met produced approximately 26 tons of metal billets per month during fiscal year 1948, and approximately 35 tons of metal billets per month during fiscal year 1949 (NYOO 1951, p. 38). Operational and standby periods are outlined in Table 2 below. Time periods in which no uranium work was occurring are defined as "standby," even though other non-radiological processes may have been occurring. The table includes operations conducted during the "Standby Period" of which NIOSH is aware. The "Standby" contracts required Electro Met to maintain the equipment and processes in a state of readiness and in other cases they used the contaminated equipment for other production in support of AEC operations.

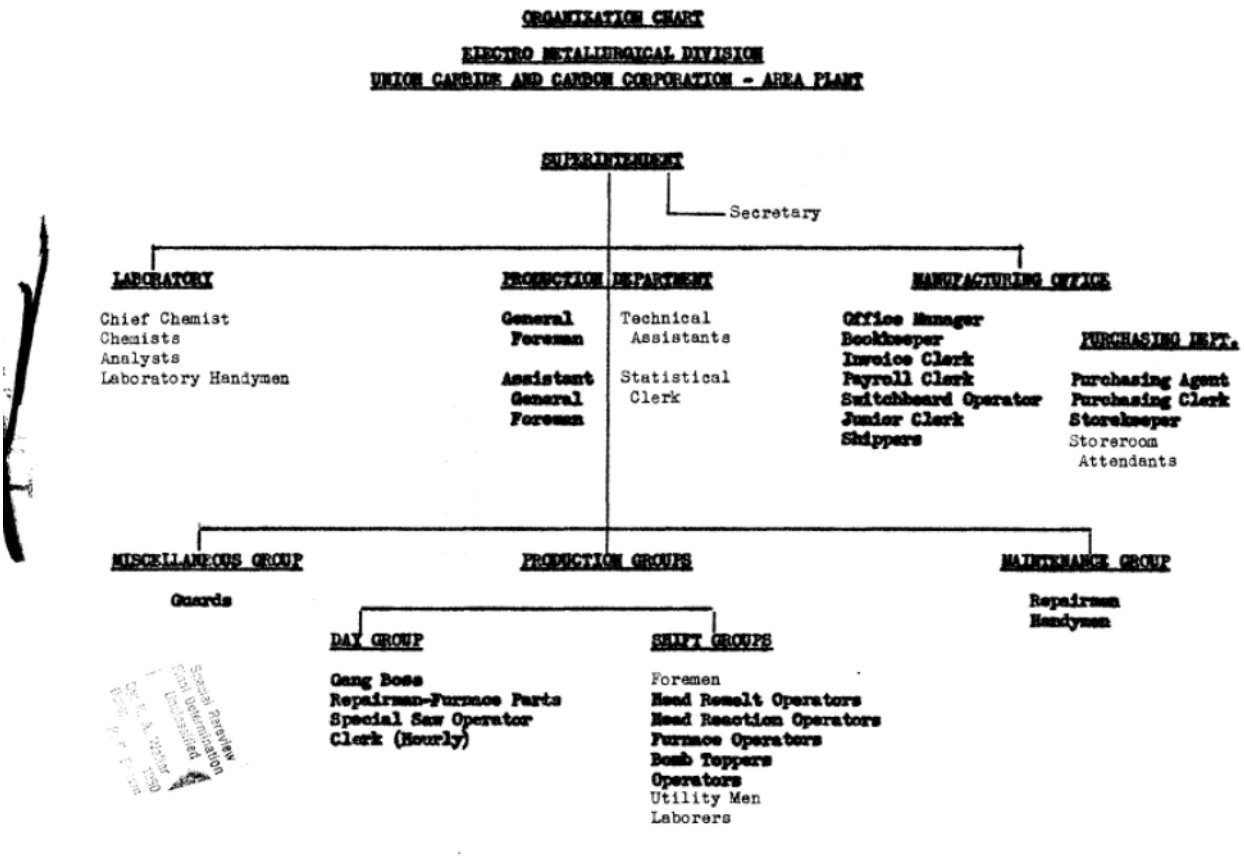
Table 1 provides a list of job titles, summary of duties they were reported to do, and typical areas that they occupied at the Area Plant. HASL reports on the Area Plant include job descriptions and areas where they worked in the plant (AEC 1949b and MED 1949b), and a more complete description is dated November 2, 1948 (AEC 1948a, pp 39-41).

Additional documentation shows the organizational chart of the Area Plant of Electro Met. Both the HASL reports and the organizational chart show that some work was shift work (3 shifts per day) and others work groups only operated one shift per day (Figure 2). A group of main plant employees reportedly to number around 30 provided support to the Area Plant in a part time capacity (electricians and pipe fitters) which ranged from a few days per year or a few days per month (AEC 1948a, p 32). NIOSH is unaware of any complete list of personnel for the Area Plant at Electro Met during its operational history. Construction workers companies other than Electro Metallurgical completed work in the Area Plant during active operations as previously described in this report (MED 1943A).

Table 1: Job titles and descriptions at Electro Met (AEC 1949b)

Job Type	Title	Description
Supervisory	General Foreman, Shift Foreman, Foreman	Plant area
	Guard	Two guard stations –guard office and general plant area. The plant guard had different duties (entered the green salt area) than the other guards (AEC 1949f).
	Storekeeper, Storeroom attendant	Storeroom
Operations workers	Laborer	Support of other operations workers
	Bomb Topper, Jolter	North central of area. Packs and seals top of reaction vessel (bomb). Wheels reaction vessel to vice, closes top, inserts gasket, seals and bolt, then wheels reaction vessel to next processing station
	Green room operator	Closed room, North of bomb topping area. Wheels dolly into green salt room. Places funnel on bomb. Preps mix of UF_4 and magnesium. Charges bomb with mixture and cleans out mixture. Cleans up work area.
	Head Reaction Operator	Center of area. Inspects and places reaction vessels into furnace by means of an electric hoist. Heats furnace to temperature, keeping data records on furnace operations.
	Head Remelt Operator, Furnace Operator	East end of area. Operates high-frequency electric vacuum furnace to melt and cast metal. Places ingot molds, charges, and seals furnaces. Removes ingot molds and preps furnace for next heat. Cleans furnace –scoops out sand and screens into a bucket; empties screened sand from bucket into bottom section of furnace and levels it off. Weighs and records weight of charge and finished ingots.
	Janitor	Cleaning plant area, office area, locker room, lunch room, receiving and shipping areas.
	Handyman, Repairman	Plant area, receiving and shipping area. Maintained graphite furnace parts. Used reamers, seaters, facers and other tools to shape graphite parts.
	Utility Men	Opens bomb lid. Shovels slag from floor and removes bomb to storage area.
	Bomb unloading and chipping, Utility Men	Utility room (West center of area). Opens bombs, jolts out doughnuts or derbies, chips doughnuts or derbies, chips doughnuts in chipping booth, shovels slag into the bifurcation, barrels and weighs slags.
	Repairman Furnace Parts, Graphite man	South east end of area. Maintains graphite furnace parts. Brushes and blows out the crucibles and molds.
	Special Saw Operator	North Eeast end of area. Sets up and operates power hack saws to cut metal bar stock to length. Stamped identification marks on samples.
Laboratory	Chemist	Chemistry Laboratory area. Sample prep room.
	Technical, Junior Technician	Duties not described in reports
	Laboratory Handyman	Chemistry Laboratory area. Prepares uranium metal samples in sample prep room. Cleaned laboratory table.

Figure 2: Organizational structure of Electro Met (UCC 1949 page 41)



The AEC involvement with the site ended when contract W-7405-Eng. 14 expired on June 30, 1953 (DOE 1986) which coincided with the sale of the building to Electro Met. No documentation was found indicating there were other sources of radiation beyond what has been described at Electro Metallurgical during the covered period between 1942 and 1953. Processes used in the Area Plant caused uranium progeny to be non-uniformly distributed and/or concentrated in the materials and equipment causing documented high beta doses to some workers. The Area Plant did not have a routine external dosimetry program during most of its operations and only had occasional health physics support in the later operational years on an ad hoc basis. Further details are discussed in the external dosimetry section.

The Area Plant was the subject of numerous internal and external exposure concerns through the entire operating history. Initial beta dose measurements in processes that concentrate uranium progeny and evaluation of the contamination of gloves and re-used protective gear led to recommended changes in work habits and more frequent changing of protective gear (e.g. weekly changes of leather gloves for some operations). Essentially no changes to ventilation or work practices for the reduction of internal exposures were reported to occur until the extremely high measurements obtained by HASL in December 1947 were reported to have resulted in improved plant housekeeping and operational procedures (AEC 1951, p 52). However, HASL

personnel stated that the reduction they measured in August of 1948 may have been influenced because the doors of the plant were open (due to the heat) when they made the measurements unlike measurements made during the cold winter months. The 1949 report (issued immediately prior placing the facility in standby in October 1949) indicated that the facility should receive a thorough vacuum cleaning and washing of the entire area (AEC 1951, page 52) however no confirmatory report in NIOSH's possession indicates such a cleaning occurred.

NIOSH has obtained only limited data regarding contaminated laundry from Electro Met (which was processed offsite at Linde in the Tonawanda facility). Laundered clothing limits were set at 500 dpm/100 cm^2. Available measurements start in 1948 and show that Electro Met exceeded those limits. One memo quotes that coveralls from Electro Met were determined to produce up to 15 mrep/hr fields at 1" when being laundered by the Linde laundry facility (AEC 1948a page 42). However, since NIOSH is relying on measured external dose, this contamination is already considered in the external dosimetry being evaluated. The historical records available to NIOSH include other measured contamination levels of laundry from Electro Met if warranted for a particular dose reconstruction (AEC 1947, MED 1943b).

Very limited bioassay data are available for the site. The urine data (see AEC 1950c) include results principally from December 1947 and late 1949 which effectively bounds the time frame of the second operational period at Electro Met.

NIOSH will include a third operational period for six months in 1951. Uranium handling from January –June 1951 likely occurred based on a contract that: "… directed Union Carbide to conduct research and development of methods of forming metal that would minimize unnecessary machining, finishing, and waste" under AEC contract AT-(40-1)-1090. Although the contract is not specific, the metal involved is presumed to be uranium based on DOE reports (DOE 1985, p 24). Additional information describing research work on "fissionable material" by the Area Plant during this time reinforces that it was uranium metal research (MED 1942 page 145). No exposure data are available for this period for the uranium metal forming contract. However NIOSH will use the data collected during the second production phase to determine dose to personnel (external and internal) as described in the appropriate sections.

Table 2: Electro Metallurgical Operating History

Description	Non-uranium related standby operations	Start date	Stop Date	Uranium metal production rates*
Operations 1	n/a	08/13/1942	08/31/1946	~44 tons/mo
Standby 1	Calcium metal production	09/01/1946	09/30/1947	n/a
Operation 2	n/a	10/301/1947	09/30/1949	~26 tons/mo (10/47-6/48) ~35 tons/mo (6/48-6/49)
Standby 2	n/a	10/01/1949	01/01/1951	n/a
	Zr Production during standby	April 1950	September 1950	n/a
Operations 3***	n/a	01/01/1951	06/30/1951	Not provided (research quantities)
Standby	n/a	06/30/1951	06/30/1953	n/a

*production average provided on page 38 of AEC 1951

3.2 Summary of standby operations

3.2.1 1st standby period

The Area Plant was in full operation for nearly four years. The MED ordered that production cease on August 1, 1946 and the plant was prepared to be placed in standby condition during the month of August. The first standby ran from September 1, 1946 through September 30, 1947. This first standby period occurred after nearly four years of production under war time standards. The MED requested Electro Metallurgical to check and maintain the equipment to insure it would be functional to allow a quick resumption (less than one month notice) of production activities during periods of uranium production suspension (MED 1942, p63). Electro Met also used the facility during this time period to produce calcium metal (MED 1942, pp 66-67). NIOSH has no information regarding cleanup of the facility to place it in standby condition. It is clear that at least some Electro Met personnel continued to occupy these areas. The contract at the time (MED 1942, p63) specifically mentions that the separate guards and maintenance personnel assigned to the Area Plant would not be required but that the personnel would be pulled from the main force of Electro Met and that this re-organization of personnel would occur no later than October 1, 1946. Because this and other activities may have continued to have created an exposure potential.

3.2.2 2nd and 3rd standby periods and transfer to Electro Met

The Area Plant was again placed in Standby Condition in September 1949 after two years of operations. Records indicate that the production activities at the Area Plant ceased on September 30 (1949) and that work to place the facility in a state of active stand-by was started immediately (AEC 1949d, page 9). One document states that in October 1949, the plant was placed on standby after a thorough vacuum cleaning and washing of the entire area (AEC 1951, p52) but this is the only document that NIOSH knows of that mentions this cleanup and the information regarding a cleanup is contrary to other information available.

A survey of the Area Plant was made in the areas where the three guards and maintenance men would be expected to occupy at the beginning of the 2nd Standby period. All areas were below the maximum of 6 mrep/hour (beta and gamma) according to the report (MED 1943B p8). The memo made recommendations to keep the occupants away from certain areas and that the individuals were expected to wear a film badge for the first two weeks (approximately November/December 1949) to validate the dose was below the limit and then the film badge service would only be done occasionally to serve as a check. NIOSH does not have any badge results from this period nor any reports to confirm these assumptions.

In April 1950, under AEC contract AT (30-1) -861, the Area Plant was reactivated for casting zirconium metal sponge into ingots for the Navy Critical Requirement program under contract to Titanium Alloy Manufacturing company (TAM). The zirconium metal operations did not pose a radiological hazard other than exposure to residual uranium remaining since cessation of uranium operations in 1949 according to the reports. Initial projections of the Zr sponge project

and details of the expected number of employees are available to NIOSH (SRDB 59219). They were reported to be conducted in the furnace area of the plant (one of the highest radiation zones during operations). The June 1950 Tonawanda monthly report (AEC 1950A) reported that for the month of June 1950 Electro Met produced 63 zirconium ingots. The plant was returned to standby in September 1950 upon completion of the Zr work. Additional uranium handling from January –June 1951 may have occurred based on a contract that: "… directed Union Carbide to conduct research and development of methods of forming metal that would minimize unnecessary machining, finishing, and waste" under AEC contract AT-(40-1)-1090. Although the contract is not specific, the metal involved is presumed to be uranium. (DOE 1985, p 24). No exposure data (internal or external) are available for this period for the uranium metal forming research contract. No cleanup information is available to NIOSH.

Monthly reports describe some conditions during this second standby period. The plant was inspected April 14, 1950 and described as being in very good condition and that three maintenance men were still on the payroll for standby (AEC 1950b, p16). Some activities continued to be reported such as the shipment of graphite molds to Hanford at the instruction of the NYOO in March of 1950.

The AEC construction of new production facilities in the early 1950's allowed for the permanent closure of the Area Plant. Electro Met and the AEC agreed to the transfer of the property to occur on June 30, 1953 with the stipulation that Electro Met clean the site up to the agreed upon levels. On Aug 11, 1953 members of the AEC traveled to Electromet and found that Electromet personnel were in the process of removing wooden structures from around the vacuum casting furnaces, piping and other structural equipment (AEC 1953C). Electro Met planned to continue to use the facility for commercial radiation work.

One DOE report from 1985 mentions that the area was used for the production of titanium just prior to the demolition of the plant (DOE 1985, page 25). However, NIOSH has no information regarding these activities. Demolition of the plant occurred in 1957, well after the June 30, 1953 sale of the plant to Electro Metallurgical company.

A survey of the facility was conducted December 10-12, 1952 and a report issued February 3, 1953 with recommendations on cleanup and release of the facility (AEC 1953c, page 1). These December 1952 surveys were described as being conducted using 1 1/8" Whatman filters for smears over a 150 cm^2 area. General air samples were also collected using Whatman #41 filter paper (1 1/8") at 20 L per minute in locations such as the graphite burnout, vacuum casting and the billet saw area. Direct measures of beta/gamma radiation was measured using survey meters. The gross contamination measurements were taken before and after wiping the equipment with a rag to determine degree of decontamination that may be expected with a simple 'rough' cleaning method (AEC 1952, p2).

Additional surveys of the facilities by the AEC were conducted August 11 and 14, 1953 (DOE 1985, page 25) and the facility certified for release from the AEC to Electromet September 28, 1953. Electromet had decontaminated the plant and equipment prior to the survey (DOE 1985, page 28). A DOE follow-up measurement was completed August 24, 1976 but the facility had

been demolished and the debris removed. The bill of sales of the property and conditions in that document clearly indicates the transfer occurred on June 30, 1953 (AEC 1953e).

4.0 Internal Dose

4.1 Operations and Standby Periods 1942-1947

NIOSH has concluded that it is not feasible to estimate internal exposures with sufficient accuracy for all workers at the site for the period August 13, 1942 through December 31, 1947 at the Electro Metallurgical Company (NIOSH 2012). Any available personal monitoring data should be used to reconstruct an individual's internal exposure at Electro Metallurgical during this time period. However, unmonitored internal exposures during this time period cannot be reconstructed.

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

4.2 Operations and Standby Periods 1948-1953

Air sample data was principally collected in two large efforts by HASL with additional samples collected by Union Carbide health physics personnel in what appears to be an ad hoc fashion. Air samples for the first of the two HASL reports were collected principally in November of 1948 (identified as Electro Met-1, AEC 1949B) and determined that the time weighted average exposure was 577 times the maximum permissible level for some members of the Area Plant. While there are some measurements conducted for various operations by Union Carbide health physics personnel from Linde (the Tonawanda, aka Linde Ceramics site), they appear to be ad hoc and without further write-up. These include a report provided in early 1948 which include relatively high air concentration results but not nearly as high as those obtained by HASL in its first report (AEC 1948C, page 3). These differences may be attributable to difference in methods between Union Carbide and HASL. The Union Carbide's method descriptions include the use of weighing the filter papers used to collect the airborne uranium instead of the well documented radiometric methods using filter paper collection used by HASL.

The second large air sample campaign was conducted in August of 1949 (identified by HASL as Electro Met-2; AEC 1949F) at the very end of the operational period. The time weighted average (TWA) values determined from these measurements was lower than reported from the November 1948 samples and this was attributed to some changes that occurred to the practices and ventilation as well as the fact that the facilities doors were open in August unlike during the November measurements. NIOSH has chosen to only use the data from the November air sampling campaign because the later data was collected following undisclosed changes that occurred some point in the process and it is unclear when they happened. NIOSH believes this is a claimant favorable approach because the data collected in August of 1949 determined a lower time weighted averages than the November 1948 data. Furthermore, HASL ascribed that at least some of the reduction in intake rates observed from the November 1948 to the August 1949 surveys included the open windows and doors in the Area Plant during the latter survey.

NIOSH has chosen to use the highest TWA determined by HASL during the November 1948 sampling (i.e. the green salt room operator) along with an uncertainty of geometric standard deviation (GSD) of 3 as the air concentration data for use during all operational periods at Electromet beginning January 1, 1948. These values were used to estimate ingestion intakes per the requirements of OCAS-TIB-0009 (NIOSH 2004) during both the operational and standby periods.

Uranium operations were suspended twice at the site during the period 1948 through 1953. As previously mentioned, the AEC requested the plant machinery be operated periodically to insure it could be brought online quickly. The uranium inventory was likely significantly reduced. Therefore, during those times, all personnel will be assigned intake rates based on the TWA for the highest non-operational job title rate determined at Electromet during this November 1948 exposure assessment. This is intended to account for internal dose that would be received from uranium contamination that may have remained in and around the process equipment. TWA determined by HASL for these non-operator job categories ranged from 2 to 3 times the maximum permissible level for job titles including guards, janitors and repair men. A claimant favorable value of 210 dpm/m^3 (3 times the maximum permissible level) with a GSD of 3 will be used to uranium air concentration data during standby periods, however the ingestion intakes .

Dose from uranium will be evaluated in a claimant favorable fashion using either type M or type S solubility. The dose estimate should be based on the one that produces the highest dose. The time weighted averages indicated a normal work day of 515 minutes, 8 hours of work plus 20 minutes for lunch and 15 minutes in the locker room to change clothes. The dose estimate is based on this 515 minutes per day, 5 days per week and 50 weeks per year.

The ingestion for each period was determined using the methods and assumptions from TIB-009 based on air concentration data. Substantial floor contamination was clearly present as sweeping up of residues generated air borne concentrations up to 97,000 dpm/m^3.

TIB-009 default rates were adjusted for the 515 min/work day schedule for Electro Met (for mode 2 ingestion rates, mode 3 is unaffected) for a value of 0.2057 times the air concentration and scaled to a calendar day intake rate by multiplying by 250 days of work per 365 day year. NIOSH will assume that the ingestion rate does not change during the standby period as no cleanup of the facility is assumed to have occurred. Table 4 summarizes the internal dose for personnel at the Area Plant during the covered period.

No internal dose prior to 1/1/1948 will be assigned at Electro Met as previously described based on inclusion in the SEC. Internal dose can be determined in the SEC period for individuals with uranium bioassay data using standard assumptions.

Figure 3 shows the values and dates of samples for the limited uranium bioassay campaigns that were conducted at the Area Plant. The very high uranium concentration data determined in the urine provides further support for the high intake rates determined by HASL and used for dose reconstruction by NIOSH beginning January 1, 1948.

Table 3: Time weighted average (TWA) exposures by job title as determined by HASL in Electromet-1 Report (AEC 1949B)

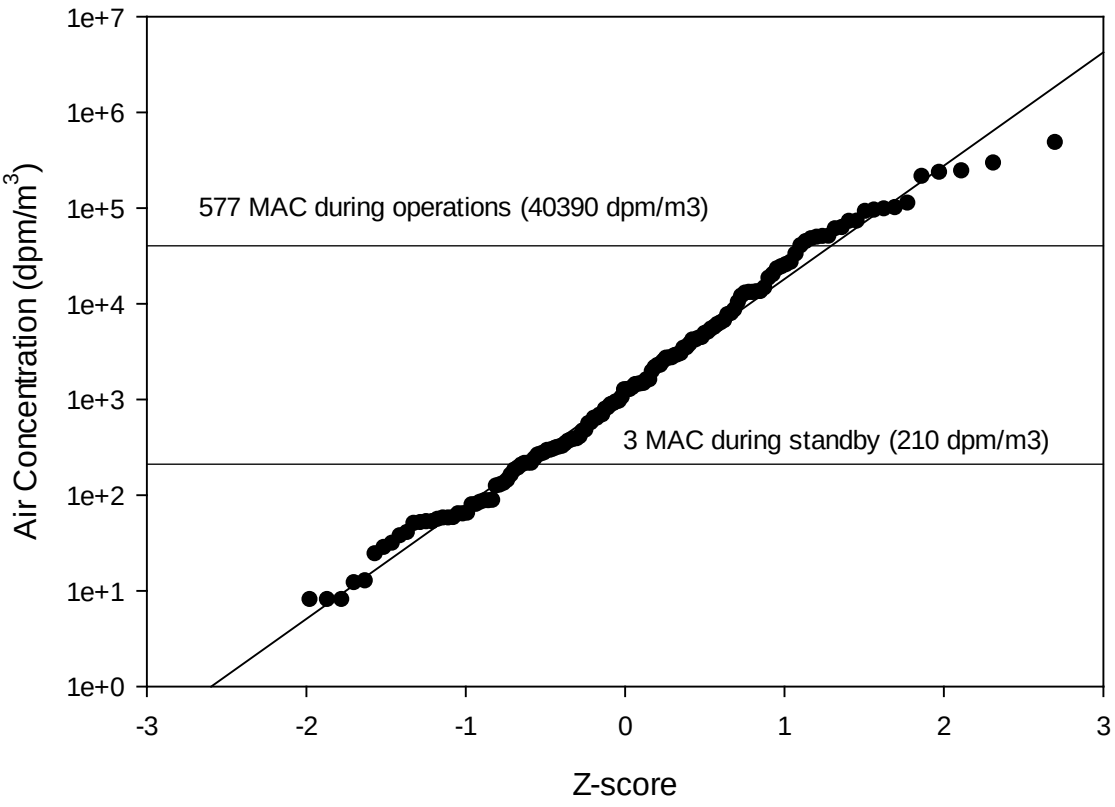
Job Title	TWA Multiples of the Preferred Level (70 dpm/m^3)
General Foreman*	3.1
Foreman*	3.3
Shift foreman*	3.5
Head remelt operator	12.6
Furnace operator	12.6
Head reaction operator	5.5
Green salt room operator	**577.0**
Bomb topper	5.1
Bomb unloader	17.0
Saw operator	4.0
Repair man (furnace parts)	32.0
Repair man*	**3.0**
Handy man*	2.0
Store room attendant*	0.9
Storekeeper*	0.5
Janitor*	2.7
Guards*	2.6
Office personnel*	0.4
Technician	1.0
Laboratory handy man	26.6
Chemist*	0.8

*Air samples used in evaluating exposures for marked job titles were general air samples of the areas frequented by personnel (as determined by HASL)

Table 4: Summary of Internal Dose at Electro Metallurgical Plant

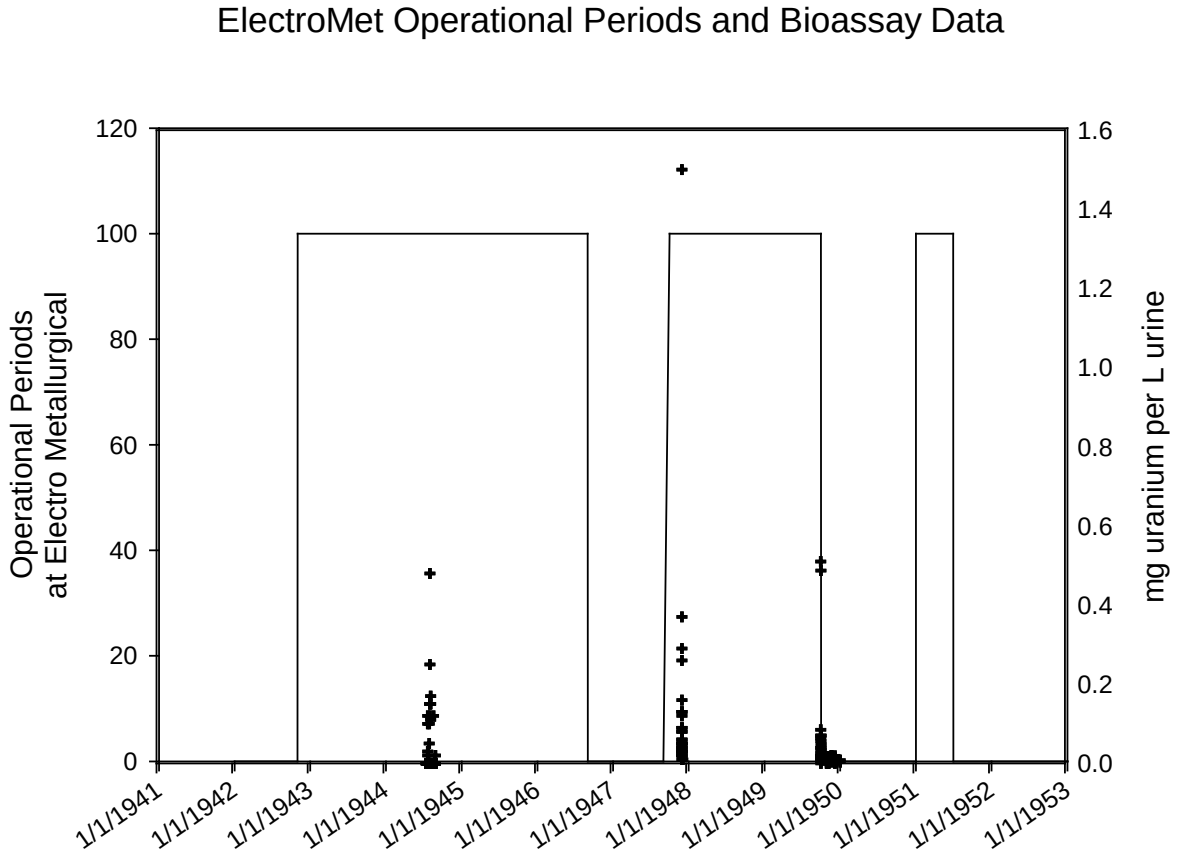
Description	Start	Stop	Air Concentration (dpm/m3)	Calendar Day Intake Rate (dpm/ calendar day)	Ingestion (dpm/calendar day)	Distribution
Operation 1	08/13/1942	08/31/1946	SEC Period based on internal dose of uranium – no internal dose calculation using air sample data. Dose calculations using bioassay data collected for an individual feasible may be feasible (only for those with bioassay data).			
Standby 1	09/01/1946	09/30/1947				
Operations 2	10/01/1947	09/30/1949	Second operational period is partially in the SEC period			
	10/01/1947	12/31/1947	SEC Period			
	1/1/1948	9/30/14949	40,390	416,017	5691	GSD=3
Standby2	10/01/1949	01/01/1951	210	2163	5691	GSD=3
Operations 3	01/01/1951	06/30/1951	40,390	416,017	5691	GSD=3
Standby 3	06/30/1951	06/30/1953	210	2163	5691	GSD=3

Figure 3: Plot of the log normal distribution of air sampling data at the Area Plant from HASL Electromet-1 with reference lines for the intake rates to be used during operations and standby periods (SRDB 8931)



Bioassay data

Figure 4: Uranium bioassay conducted at the Area Plant and operational periods.



5.0 External Dose

The Area Plant at Electro Met was an important uranium metal production facility for the Manhattan Project and continued to play an important role for the AEC during the 1947-1949 time period. Electro Met ran three shifts of workers to meet delivery needs when it was operational as noted in various reports. During standby periods the plant was sometimes used for non-uranium production activities during which time NIOSH has no indication that a cleanup occurred as noted in Table 2.

Area Plant Work Force

Contemporaneous reports provide that some 50-70 persons operated the Area Plant, others also mention that others from the plant provided support as needed with an estimated 30 additional persons who are not recorded including electricians and pipe fitters. Comparison of records available to NIOSH indicate that there are individuals with internal dosimetry monitoring (urinalysis) that were not badged. NIOSH does not have available to it a list that it considers complete with all the names and exposure potentials during all the operational or standby periods and the HASL reports are snap shots in time which record only the current job titles and persons

and did not describe that they were comprehensive regarding personnel who may have conducted those operations.

Additional documentation shows the organizational chart of the Area Plant as previously discussed. Both the HASL reports and the organizational chart show that some work was shift work (3 shifts per day) and others work groups only operated one shift per day (Figure 2). Other sources site that another group of employees of approximately 30 supported the Area Plant part time (electricians and pipe fitters) which ranged from a few days per year or a few days per m8onth (AEC 1948a, p 32). NIOSH is unaware of any complete list of personnel for the Area Plant at Electro Met during its operational history. As previously mentioned, construction workers from other companies completed work in the Area Plant during active operations (MED 1943A).

Operations that affect external dose

The Area Plant conducted operations that converted 'green salt' to uranium metal. These operations involved a number of jobs that exposed workers to enhanced beta fields because of operations which concentrated uranium progeny on the surfaces of the metal and also surfaces and residues of the production process (e.g. molds and slag). The Area Plant employed various operations that concentrated progeny of uranium and from the early operations onward it was realized that high beta dose was related to several operations. One such report in April of 1949 (AEC 1948a, p34) describes furnace operators being exposed as measured with a film badge at "approximately 500 to 700 mr per week" well above the recommended levels and values up to 1900 mrad/week non-penetrating dose were measured in 1949.

Other factors that may affect the determination of dose include including the wearing of excessively contaminated gloves (values up to 2 R per 8 hour day were measured in 1944 (MED 1944, p5)) which continued to be mentioned as a problem even in 1949 well after recommendations were made to correct the issue to maintain doses within tolerance levels (AEC 1948a, p 34).

In 1948 it became apparent that the laundry from the Area Plant, which was actually laundered at Linde Ceramics, was contaminated. Levels up to 15 mrad/hr beta were measured on coveralls from the Area Plant by direct reading instruments. However, since doses are being based on measured photon doses, the issue of the contaminated laundry will not affect the assignment of dose at Electro Met.

Available Data

Limited external dosimetry data was collected over the operating history of the Area Plant. Very little personal external dosimetry is available during the first production phase at Electro Met. Many of this small group of measurements conducted in this first period were determined to be fogged. NIOSH has not found substantial changes that occurred for the first period with the exception of recommendations for changing out protective clothing (e.g. leather gloves) that was noted in 1944 (MED 1944). Whether any change was made to the actual practices during this time period is not known but seems unlikely given the continued poor reports that occurred even through the second operational phase.

A more substantive measurement of external dose was conducted during the second operational period. NIOSH has personal external dosimetry results for 58 employees representing 21 job titles at the Area Plant during June 1948 through September 1949 time period. Some of these names match up with those who obtained internal monitoring but others do not. Analysis of this data set provides for a claimant favorable dose reconstruction method (all workers at the 95th percentile) as compared to operator category of TBD-6000.

Additional recommendations were made following the HASL facility review in November of 1948 and were summarized as proposed changes in a May 1949 report to reduce both internal and external exposures (MED 1943b, p 16). The products and production methods for uranium metal used at the Area Plant create enhanced beta dose fields and Electro Met reported that a number of individuals exceeded weekly tolerance limits during the time periods when they badged the employees. Enhanced beta fields were related to specific processes and job categories. No TWA external dose estimates are available from HASL for Electro Metallurgical.

NIOSH will (i) use data collected during the second operational period to estimate external dose during the first operation period, (ii) the first standby period, (iii) the second operational period, (iv) the second standby period, (v) the third operational period, and (vi) the third standby period. Specifically, during the operation phases NIOSH will use the 95% of the lognormal distribution of the external dose data collected during the second operational period for all workers at Electro Met and use the geometric mean (GM) for all workers in the standby periods. The analysis and summary of the dose by period is provided below and additional information provided below. Each of these values will be assigned as the geometric mean for the period with a GSD of 3.

Film badge results taken between June 1948 and September 1949 were found for 58 employees at Electro Metallurgical (AEC 1948b, AEC 1949a, AEC 1949c, AEC 1949e). Figure 5 shows the positive photon data for the results available to NIOSH for the second operational period. The data included a broad spectrum of titles and provided both beta and gamma dosimetry data as well some ring badge dosimetry. The data was reviewed and duplicates eliminated and only external dosimetry records which included name and title was used for this analysis. Other data was duplicative, represented partial exposures during the week, or the badge was not worn. All badges identified as being “scapular” were also deleted (76 measurements). Scapular badges represented an experimental program whose intent was to compare the badge readings from underneath the clothing to readings outside the clothing and also to determine if any contamination affected the readings (AEC 1948a p28). However, results from the scapular program showed impossible readings from the Area Plant as mentioned in a 1948 memo to Electro Met. The values indicated that the current badge program was likely measuring dose under the clothing as the scapular values were below values being reported (that the scapular badges were being above the clothing and the normal badge in underneath the clothing) inverted (higher than the base line measurements). A small number of scapular data are included in the NIOSH dataset and indeed these values include data which appears to be reversed badging. The scapular data indicates that the external dose values for the Area Plant, and in particular the beta measurements, may have been under reported since it is likely they were obtained from under the employees clothing. It is unknown the degree of proper badge placement versus those who may have not properly wore their badges. Determination of beta dose would be impacted

substantially more that the gamma dose and therefore a claimant favorable multiplication of the gamma dose by 10 will be used rather than the actual measured data set based on TBD-6000.

Figure 5: External dosimetry data from the second operational period at the Area Plant (only positive data shown).

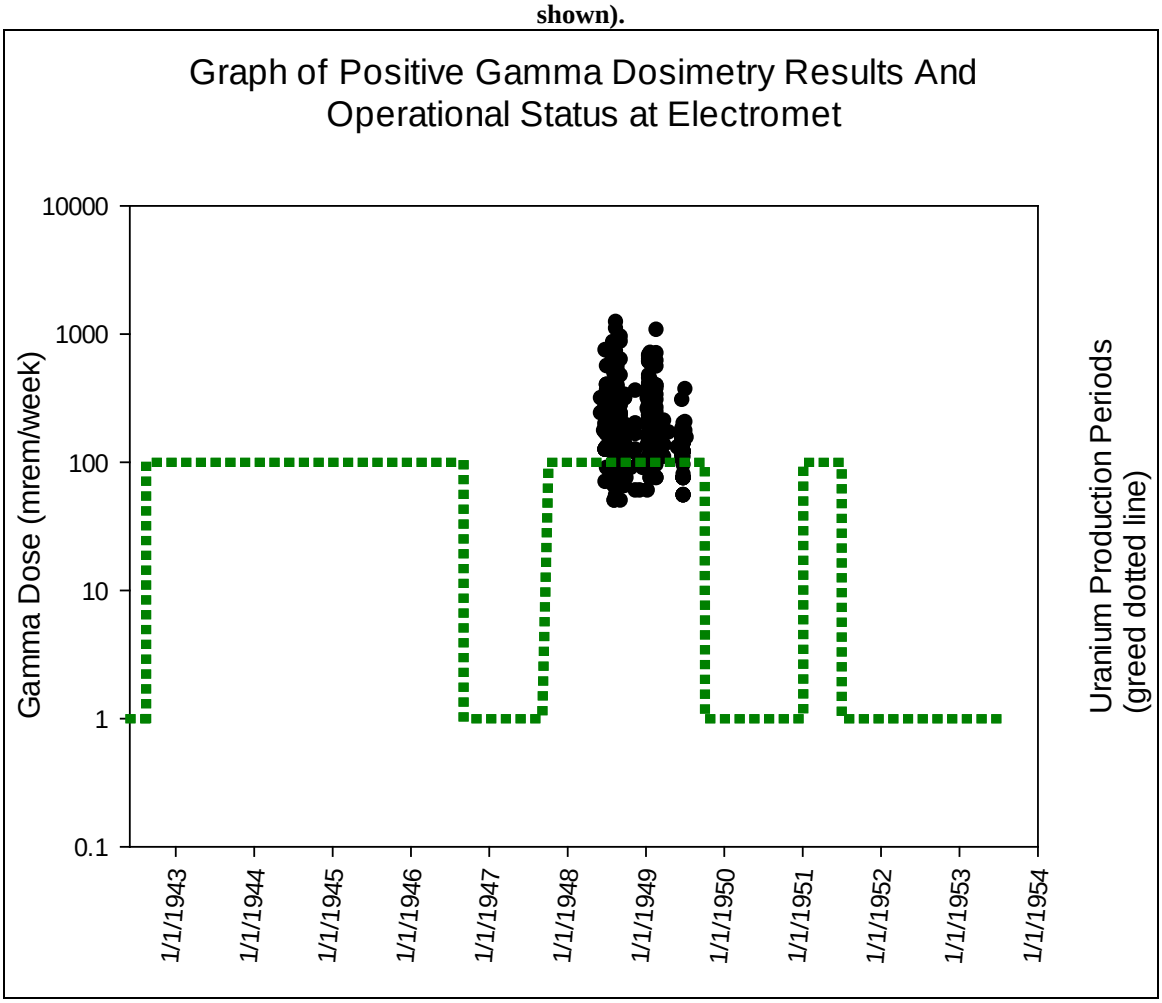


Table 5 provides a summary of the data available by job title and summarizes whether what fraction of the data was above the detection limit of the time (50 mrem/week gamma and 50 mrad/week beta). Photon data was analyzed using a rank order analysis of the lognormally distributed data for both the beta and gamma weekly doses. It is obvious that analyses and graphs of positive gamma dose will be biased high since a substantial portion of the data is less than the detection limit. These graphs serve as a check of the distribution by job title using box and whisker plots and they were reviewed to verify that no stratification of the data was required. Review of the data by job title and comparison to the 95% level for both beta and gamma dose does not produce any job that required consideration for stratification analysis as will be described below. The rank ordered distribution of photon dose and corresponding 95% values are shown in Figure 6 and the beta distribution in Figure 7 and the statistical analysis of the

badge results summarized in Table 6. NIOSH will used the 95% photon dose for all workers during the operational phases and the geometric mean of the distribution of the photon dose during standby periods and apply them geometric mean for the period with a GSD of 3. The analysis of the positive photon doses are shown in a box and whisker plot which verifies that there is no need for additional stratification based on photon dose measurements (Figure 8).

Table 5: External Dosimetry Monitoring by Job Title at Electro Met

title	Measurements Available	# Gamma <MDA	# Beta <MDA	% Gamma >MDA	% Beta >MDA
Bomb Topper	101	80	42	20.8%	58.4%
Foreman	32	28	25	12.5%	21.9%
Furnace Operator	134	107	6	20.1%	95.5%
General Foreman	34	28	29	17.6%	14.7%
Guard	33	31	25	6.1%	24.2%
Handyman	78	70	35	10.3%	55.1%
Head Reaction Operator	109	93	61	14.7%	44.0%
Head Remelt Operator	152	122	16	19.7%	89.5%
Janitor	77	64	48	16.9%	37.7%
Jr. Chemist	3	1	0	66.7%	100.0%
Laboratory Handyman	71	61	54	14.1%	23.9%
Laborer	258	219	66	15.1%	74.4%
Operator	228	174	43	23.7%	81.1%
Repairman	94	79	36	16.0%	61.7%
Repairman Furnace Pts.	54	44	11	18.5%	79.6%
Shift Foreman	97	81	72	16.5%	25.8%
Sp. Saw Operator	46	38	12	17.4%	73.9%
Storekeeper	27	22	16	18.5%	40.7%
Storeroom Attend	73	64	42	12.3%	42.5%
Tech. Assistant Jr.	74	62	49	16.2%	33.8%
Utility Man	203	162	74	20.2%	63.5%
total	1978	1641	766	17.0%	61.3%

Beta Dose

Non-penetrating beta dose is primarily associated with the hands and forearms, and then other skin surfaces, of a worker who handles uranium metal in close proximity. Battelle-TBD-6000, Section 6.3, details a method to estimate skin doses for the hands and forearms of a worker who handles uranium metal as well as the other skin surfaces. NIOSH will use 10 times the photon

dose used for dose reconstruction to determine "other skin" dose during all periods value rather than rely on the measured beta doses because of bias regarding the badge location as previously discussed (that the badges may have been worn under the clothing).

Comparison of the measured beta/gamma dose ratio was determined by job title only for positive beta and gamma measured values (Figure 10). The values for the enhancement of beta dose for 3operations that concentrate uranium decay products as described in TBD-6000 section 3.3.1 which says the whole body beta dose may approach 10 times the whole body photon dose.

Evaluation of the beta/gamma ratio for various job titles for badges where both the photon and beta dose were positive indicates a geometry mean value of approximately 5 for some jobs where both results on a badge are positive (Figure 9). This is substantially less than the routine assumption of 10 times the gamma dose and the results are questionable because of the noted that improper badge usage was noted and was found to cause substantial problems evaluating the scapular badge results. Review of the limited badge data identified as scapular which was correctly paired with a second badge typically indicated that the beta dose above the clothing was approximately two to four times the level under the clothing. This data set is only for four workers, with 8 paired measurements and for a very short time period. Therefore, the beta dose for "other skin" shall be based on 10 times the gamma dose for the period in question. Also, while NIOSH has several hundred ring dosimeter values, they were without worker titles and offer little information about how they were worn (with or without protective gear). Furthermore the ring badges were worn by only a fraction of the employees and only for a limited time. Therefore NIOSH will rely on the calculated dose rates for the operator category from TBD-6000 to determine the beta dose to the hands and forearms of workers during operational times as a claimant favorable determination. NIOSH will used the geometric mean of the lognormal distribution of whole body photon dose times 10 during standby periods to determine all skin dose (hands, forearms, and other skin).

Figure 6: Rank ordered probability plot of Electro Metallurgical Weekly Photon Dose Data above the detection limit for all monitored workers at Electro Metallurgical 1948-1949

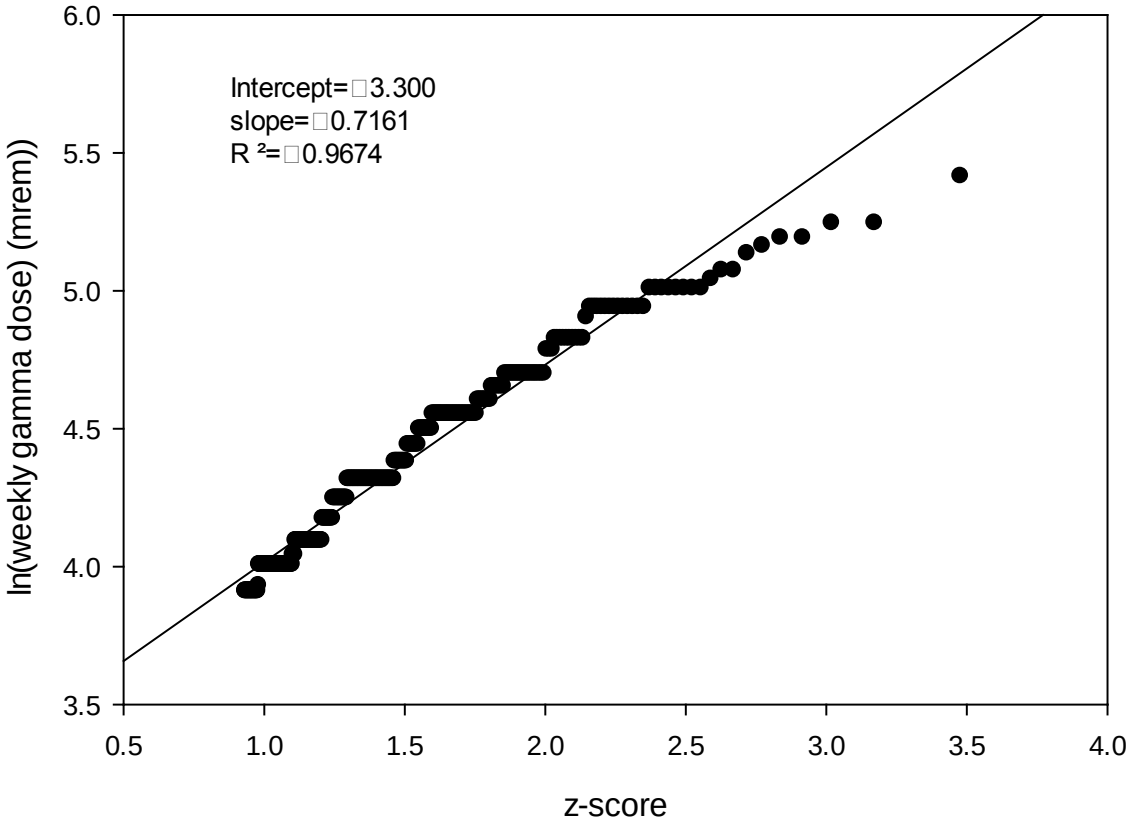


Figure 7: Rank ordered probability plot of Electro Metallurgical Weekly Beta Dose Data above the detection limit for all monitored workers at Electro Metallurgical 1948-1949

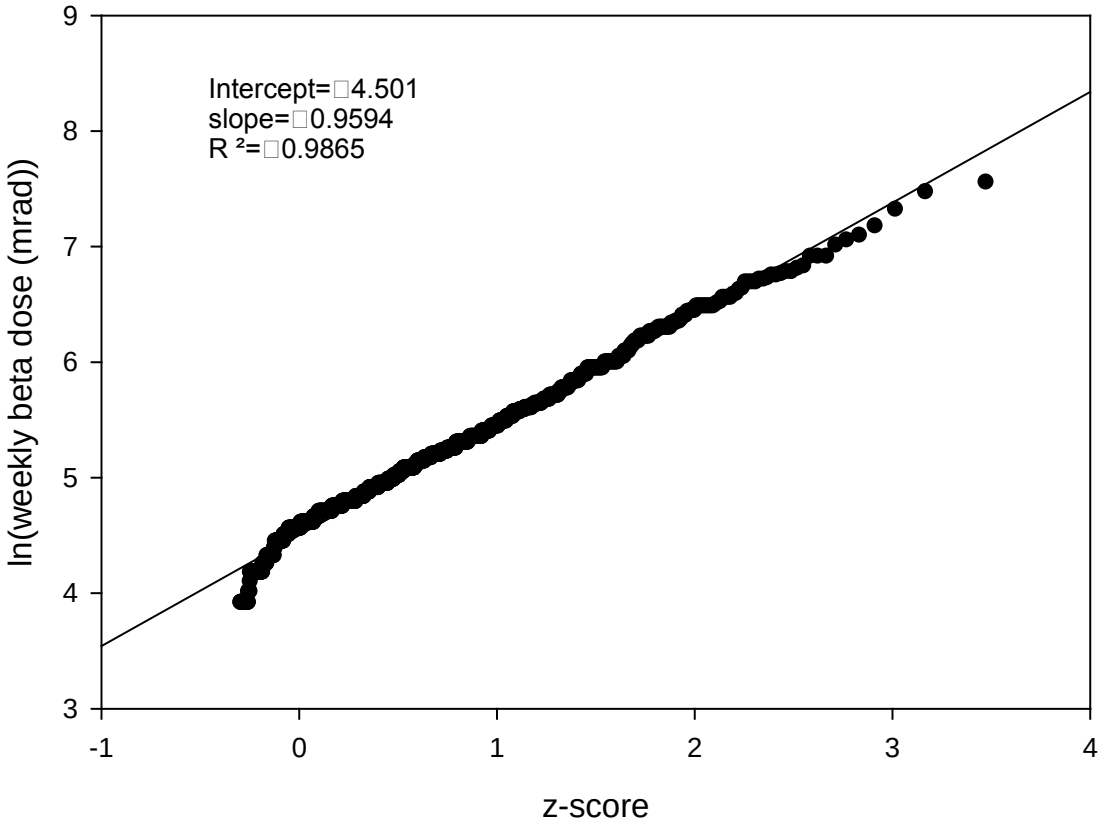


Table 6: Weekly dose values determined from the badges of monitored workers at Electro Met during the period 1948-1949.

		Weekly Beta Dose (mrad)	Weekly Gamma Dose (mrem)
Graphical Analysis of natural log transformed data	Slope	0.9594	0.7161
	Intercept	4.501	3.300
	R^2	0.9865	0.9674
Calculated values for weekly dose	GM	90.11	27.11
	GSD	2.61	2.05
	95^{th} % (mR)	436.7	88.06

The external dosimetry summary at Electro Met includes:
1-The external dose from Table 7 shall be used to determine dose for all Electro Met employees.
2-Photon and Beta dose during operations was determined using the 95^{th} percentile of all badged worker data (for comparison, the operator category from TBD-6000 whole body dose is 2500 mrem/year and the beta dose is 25000 mrad/year))
3- Photon dose during standby was determined using the geometric mean of all badged worker data
4- Non-penetrating dose to other skin is assigned based on the recommended 10 times the photon dose to account for incorrectly worn badges. The values based on the badge results (95^{th} and geometric mean) are provided for comparison to the assigned value.
5- The non-penetrating dose to the hands and forearms is based on the data from section 6.3 of TBD-6000 and is used during the operational period only. Beta doses to the hands and forearms during standby periods are determined using whole body skin dose values (10 times the GM of photon dose).
6-The annual dose values shall be assigned as the geometric mean for that period with an uncertainty equal to a GSD of 3.
7-Values in Table 7 represent the dose for a calendar work year and should be scaled to the appropriate employment by scaling the weekly value to a normalized 50 work weeks per calendar year. Hence the 95 percentile penetrating photon dose of 88.06 mrem/week was scaled by multiplying by 50 weeks per work year. For a worker determined to work 12 weeks in the operational phase for 1947, that worker would be assigned a photon dose of (4403 mrem/yr)x(12 weeks/52 weeks/yr)=1016 mrem (constant distribution).

Table 7: External dose summary for Electro Met based (annual value base on a 50 week work year)

Description	Start	Stop	Photon whole body[1,3] (mrem/year)	Non-penetrating dose to other skin to assign[2,3,4,5] (mrad/yr)	Non-penetrating dose to hands and forearms[2,6] (mrad/year)
Operation 1	08/13/1942	08/31/1946	4403	44030	276000
Standby 1	09/01/1946	09/30/1947	1356	13560	13560
Operations 2	10/01/1947	09/30/1949	4403	44030	276000
Standby 2	10/01/1949	01/01/1951	1356	13560	13560
Operations 3	01/01/1951	06/30/1951	4403	44030	276000
Standby 3	06/30/1951	06/30/1953	1356	13560	13560

1-assigned as photons with an energy of 30-250 keV and converted to organ doses using the appropriate dose conversion factors
2-assigned as electrons with an energy >15 keV
3-Dose during operations determined based on the 95th percentile, standby based on the geometric mean of the measured dose for badged employees during operations. Both applied as the period specific geometric mean with a GSD of 3.
4-Dose to the other skin non-penetrating based on badge results which were noted to be improperly worn. Provided for comparison to assigned doses only.
5- Skin non-penetrating dose determined based on 10 times the photon dose to be assigned
6- Metal worker operator dose to be assigned for the hands and forearms non-penetrating dose during operations (TBD-6000) and the same as other skin during standby periods.

Figure 8: Comparison of the 95th percentile weekly gamma dose (z-score derived) to the positive gamma dose by worker title for the period 1948-1949. The geometry mean of the positive data from one group group exceeded the 95th but additional review verified the 95th percentile was claimant favorable for all groups.

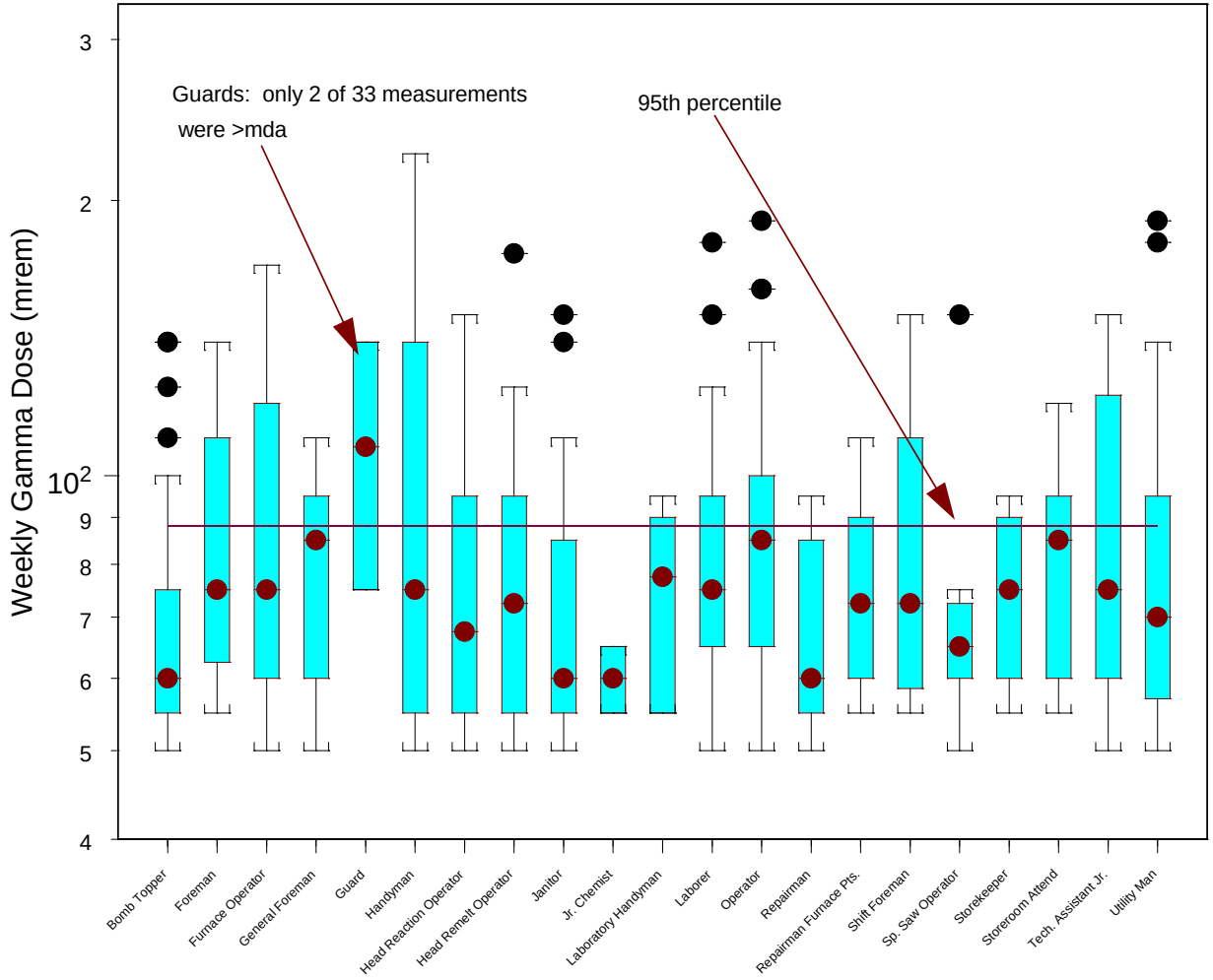


Figure 9: Comparison of the 95th percentile weekly beta dose (z-score derived) to the positive beta dose for all worker job titles. The GM for any job title was not found to exceed the 95th percentile dose for all the data. Dose was natural log transformed prior to analysis (95% value=437 mrad/week).

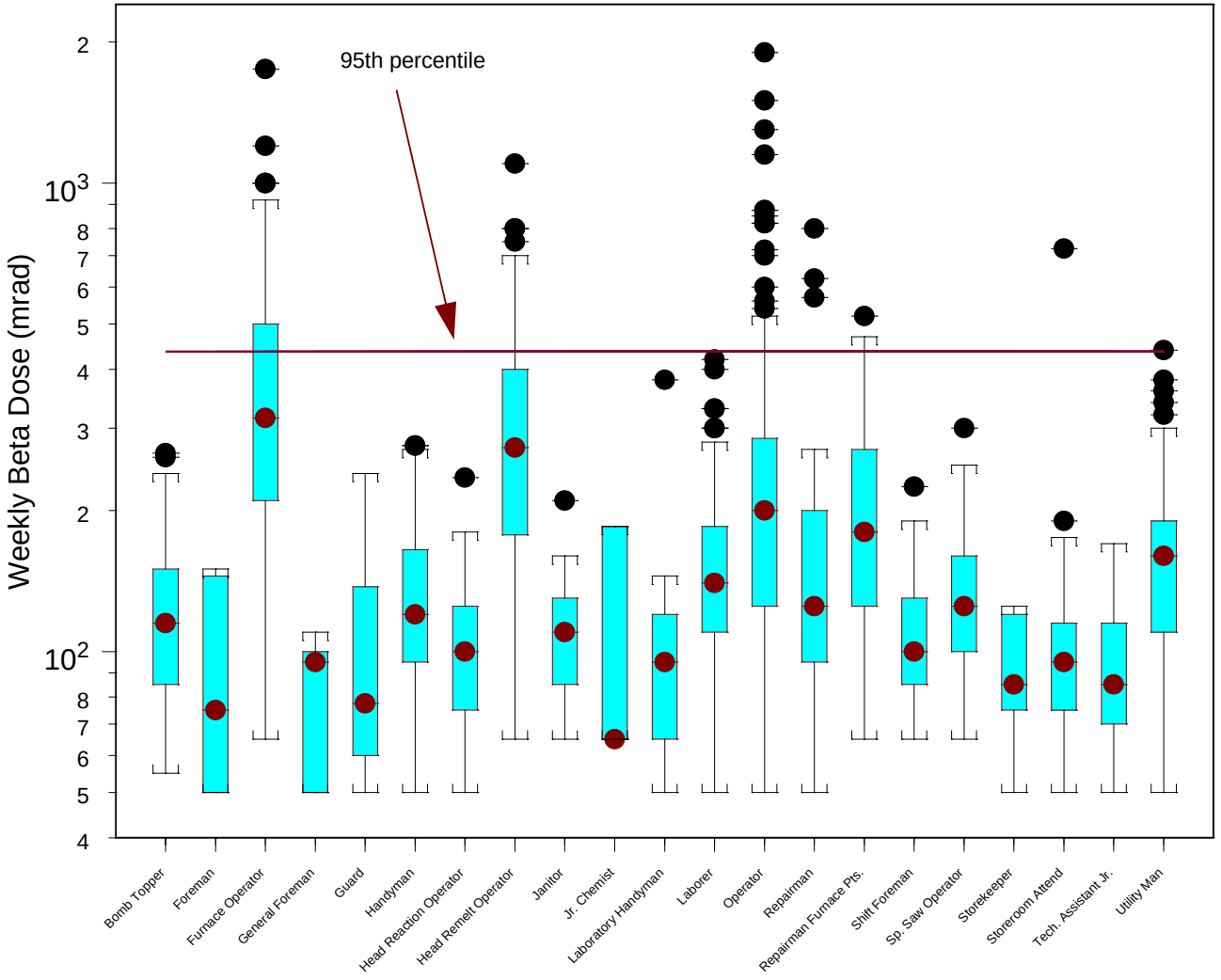
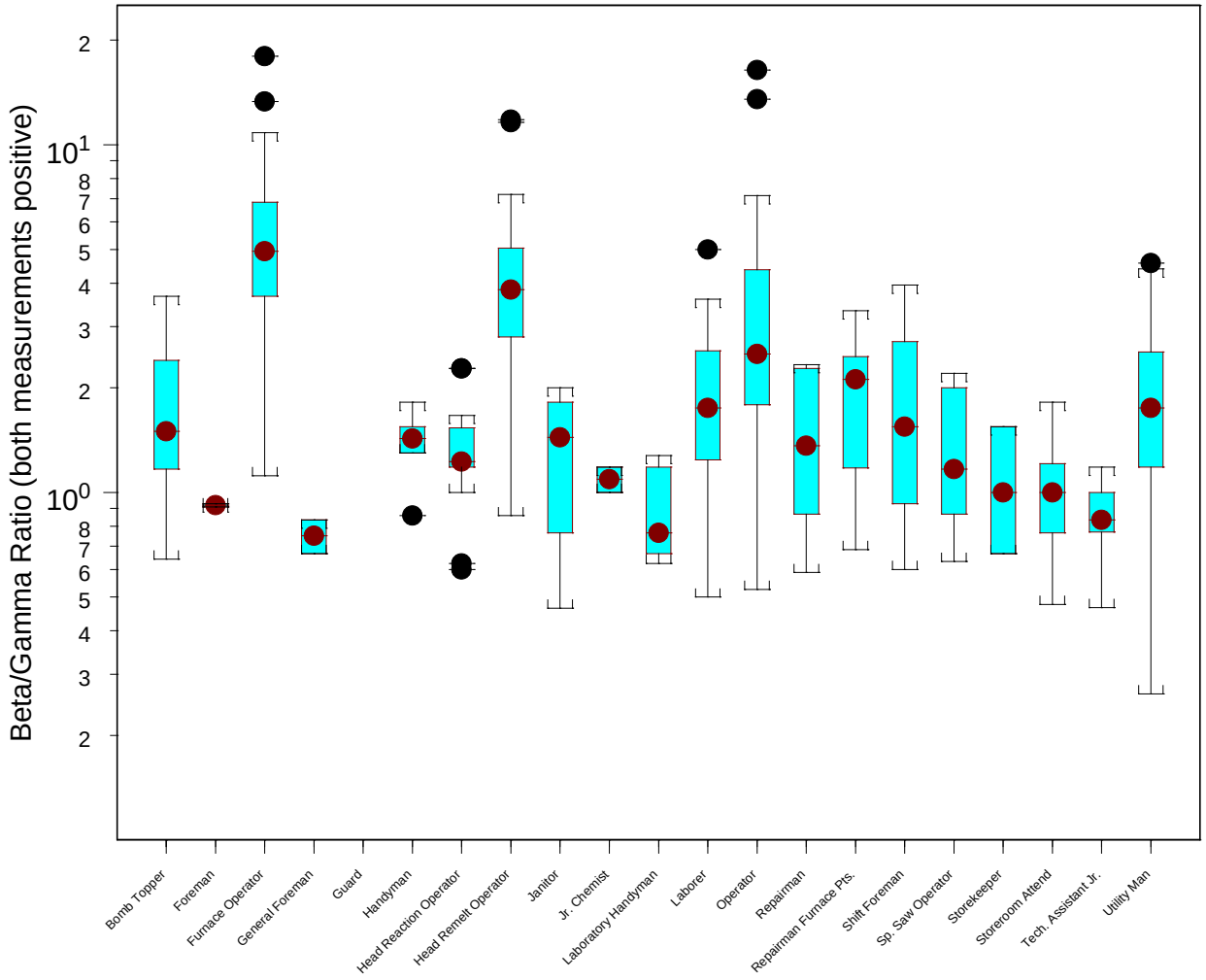


Figure 10: Beta/gamma ratio of positive weekly dose values by job title where both measurements were greater than the minimum detectable amount.



6.0 Occupational Medical Dose

A memo reviewing the medical program at Electro Metallurgical was written by the MED in 1945 (MED 1945a). The memo recommended pre-employment, annual and termination X-rays. No information regarding occupational medical dose was found in any of the site research or Computer Assisted Telephone Interview materials. A memo in 1949 from the AEC to Electro Met however, confirmed that they were using x-ray equipment installed at the plant to conduct examinations (AEC 1948a p 33). Information to be used in dose reconstructions, for which no specific information is available, is provided in ORAUT-OTIB-0006, Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures (ORAUT 2011). The assumed frequency in this document is PA chest X-ray for pre-employment, annual, and termination examinations between the years 1942 and 1953 (the covered period). Annual organ doses are entered into the NIOSH-IREP program as the annual dose due to an acute exposure to photons (E=30-250 keV). The distribution is assumed to be normal with a standard deviation of 30%.

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Bioassay data are included in SRDB Ref ID's 8887, 8944, 11452, 35738.

External data are included in SRDB Ref ID's 11547 and 11548.

While other files may contain data, they are duplicates of the information contained in the references above.