Response to Metals and Controls Corp. Working Group Comments

Response Paper

National Institute for Occupational Safety and Health

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INTRODUCTION

On August 24, 2017, the National Institute for Occupational Safety and Health (NIOSH) presented the SEC-00236 Metals and Controls Corp. (M&C) Evaluation Report (ER) to the Advisory Board on Radiation and Worker Health (Board). After that presentation, a petitioner raised a concern about the ER's adequacy regarding maintenance work. The petitioner stated that he:

> *…took great care to define the class of workers under evaluation in this petition as precisely and as narrowly as possible to coincide with workers for whom there is a high degree of confidence that they received elevated exposures to residual radioactive contamination* [Elliott 2017, PDF p. 6].

In response to this concern, on September 5, 2017, NIOSH initiated strategies for determining if dose reconstruction methods proposed in the SEC-00236 ER provided a plausible upper bound to maintenance- worker exposures and for continuing research to further develop the ER. These strategies included plans for reviewing monitoring records in the Site Research Database (SRDB) and for searching for former M&C workers for the purpose of interviewing them.

On October 24-26, 2017, personnel from NIOSH, the Oak Ridge Associated Universities (ORAU) Team, and Sanford Cohen & Associates (SC&A) interviewed 12 former M&C workers and individuals knowledgeable about maintenance work. Interviewers asked questions about the frequency and duration of this type of work, including heating, ventilation, air conditioning (HVAC), utility lines, drain lines, and new equipment installations.

On April 13, 2020, during an M&C Working Group (WG) meeting, SC&A presented the Issues Resolution Roadmap for Metals and Controls Corporation SEC Petition-00236 [SC&A 2020] and provided updates to the Working Group and petitioners. After the presentation, the WG and petitioners discussed the issues, expressed some concerns, and made comments. This response paper addresses those comments.

WORKING GROUP COMMENTS AND NIOSH RESPONSES

NOTE: The following text provides summaries and excerpts from the WG meeting followed by NIOSH responses. Verbatim text is italicized.

WG COMMENT 1: A general concern was expressed similar to what the petitioner previously stated that the maintenance work performed at M&C is unique [HHS 2020a, PDF p. 61], and therefore, standard modeling procedures do not apply.

> *Despite these limitations, NIOSH has been trying to force-fit the unique conditions of the M&C Maintenance Workers into a standard set of assumptions for Residual Period AWE Facilities* [Elliott 2020].

The WG requested that NIOSH provide a summary of bounding methods used for sites that had their residual radiation periods added to the SEC in order to compare the types of exposures that NIOSH determined were infeasible to bound in the past, and how M&C compares to them.

NIOSH Response: The following is a summary of AWE sites with residual radiation periods (as they are currently defined) that NIOSH evaluated for inclusion to the SEC.

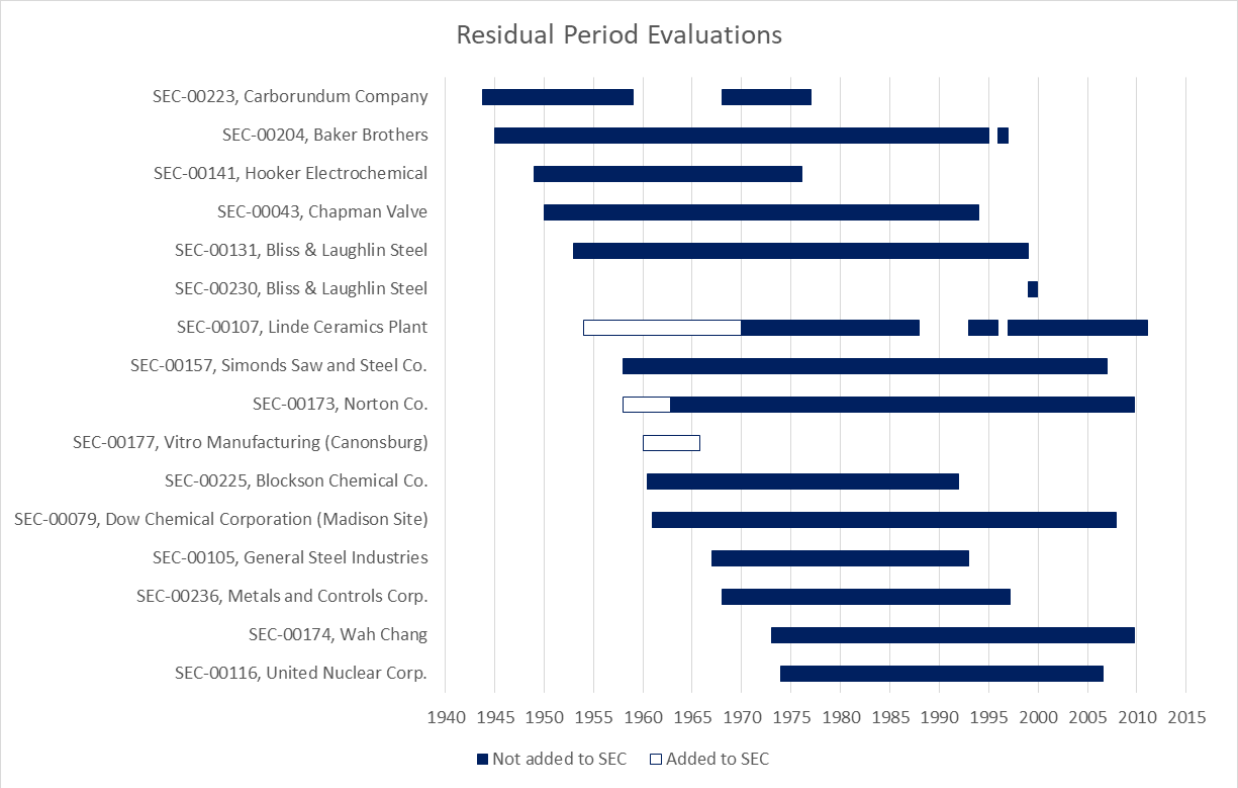
ERs provide NIOSH's conclusion about whether doses can be bounded for workers who are members of the class evaluated in the report, which is based on (but may be a modified version of) the class requested by a petitioner. Although some petitions requested the evaluation of a class that included specific job descriptions [NIOSH 2006a, PDF p. 4; NIOSH 2015a, PDF p. 4], NIOSH expanded the class under evaluation. In all ERs that included residual periods, NIOSH evaluated radiological exposures for all site workers, regardless of job title, and for all locations within those sites. The class requested by the petitioner and the subsequent class evaluated by NIOSH are listed below for each ER.

During residual radiation periods, the principal source of AWE-related internal and external radiation doses is the resuspension of contamination created during previous uranium and thorium operations. Uranium, thorium, and many of their progeny are alpha emitters. In general, internal exposures are the limiting factor for these exposures when determining whether doses may be bounded.

The doses are bounded based on measurements of airborne or surface contamination and applying the methodology described in Battelle-TBD-6000, *Site Profiles for Atomic Weapons Employers That Worked Uranium and Thorium Metals* [NIOSH 2006b]; ORAUT-OTIB-0070, *Dose Reconstruction During Residual Radioactivity Periods at Atomic Weapons Employer Facilities* [ORAUT 2012]; and OCAS-TIB-009, *Estimation of Ingestion Intakes* [NIOSH 2004].

So far, 16 petitions for 15 sites were evaluated in which part, or the entire evaluated class, falls within each site's residual period, including the SEC-00236 M&C class. Uranium was present at all of these sites and thorium is documented to have been at the following seven sites: Simonds Saw and Steel Co.; Norton Co.; Blockson Chemical Co.; Dow Chemical Corporation (Madison Site); Metals and Controls Corp.; Wah Chang; and United Nuclear Corp.

Figure 1 provides a plot of the periods evaluated in these 16 petitions. Three evaluations resulted in additions to the SEC. For two of these (SEC-00107, Linde Ceramics Plant and SEC-00173, Norton Co.), some of the evaluated period was added to the SEC; for the third (SEC-00177, Vitro Manufacturing [Canonsburg]), the entire evaluated period was added.



Source: [SRDB Ref ID: 106641; 172457; 180810; 180812; 32744; 156493; 180813; 120949, 135195; 94436; 94854; 180811; 39873; 124233; 176720; 100983; 101606]

Figure 1. Residual periods within 16 evaluated class periods.

As shown in Figure 1, three of the evaluated sites had split residual periods:

- SEC-00204, Baker Brothers: January 1, 1945 through December 31, 1994; and January 1 through December 31, 1996 [NIOSH 2012, PDF pp. 19-22].

- SEC-00223, Carborundum Company: October 1, 1943 through December 31, 1958; and January 1, 1968 through December 31, 1992 [NIOSH 2015b, PDF pp. 22-26].

- SEC-00107, Linde Ceramics Plant: January 1, 1954 through December 31, 1987; January 1, 1993 through December 31, 1995; and January 1, 1997 through March 1, 2011 (see the Linde discussion below for details).

Details of the production, remediation, and residual periods can be found in their respective ERs; however, each had an initial operational period followed by a first residual period, then further operations and a subsequent residual period(s). Residual periods were terminated upon final site remediation and confirmation surveys.

AWE Sites with Residual Radiation Period Classes Added to the SEC

Some or all of the residual periods at three sites were added to the SEC: Linde Ceramics Plant, Norton Co., and Vitro Manufacturing (Canonsburg). Each site's residual period is provided in parentheses.

- SEC-00107, Linde Ceramics Plant (January 1, 1954 through July 31, 2006)

  The class requested by the petitioner was the class evaluated by NIOSH in the SEC-00107 ER. The class included all Department of Energy and Atomic Weapons Employer employees who worked at the Linde Ceramics Plant in Tonawanda, New York, during the period from January 1, 1954 through July 31, 2006 [NIOSH 2008a, PDF p. 4].

  Between 1942 and 1948, ores were processed at the site for the separation of uranium. In 1962, during the residual period, renovations began in the primary process building. Although the building was remediated, these renovations may have accessed and released contamination missed during the remediation. The highest concentrations were from jackhammering in 1969. After 1970, the building was used as a shipping and receiving warehouse [ORAUT 2015, PDF pp. 15, 18].

  The ER stated that NIOSH found that it can estimate radiation doses for members of the class for the entire evaluated period with sufficient accuracy [NIOSH 2008a, PDF p. 4]. After review of the report and discussion of the methods proposed to estimate worker exposures, the Advisory Board split the evaluated period into two periods: the renovation period from January 1, 1954 through December 31, 1969; and the balance of the residual period from January 1, 1970 through July 31, 2006. The Board reviewed monitoring data and process and source-term information for production activities for the period January 1, 1954 through December 31, 1969. NIOSH proposed that the use of Linde decontamination and decommissioning (D&D) data from the previous decontamination effort (in the early 1950s) was sufficient to bound workers during the renovation period. Specifically, the maximum air-monitoring concentration measured during jackhammering, which was 2.3 times the Maximum Allowable Concentration (MAC) [NIOSH 2008a, PDF p. 24]. Assuming 2500 work hours per year, and using the largest ICRP 60 dose conversion factor for uranium-234, this concentration would amount to an inhalation committed effective dose of 5,479 mrem/yr.

  However, given the uncertainty associated with work assignments at the site, combined with proposed doses that were too high or "overestimating" for the non-D&D workers, Board members felt that the application of decontamination intake rates was bounding, but not plausible for site-wide application over a 16-year period [HHS 2011a, PDF pp. 122–131, 245–278]. Therefore, the Board recommended that the following class be added to the SEC:

  > *All Atomic Weapons Employees who worked at the Linde Ceramics Plant in Tonawanda, New York, from January 1, 1954 through December 31, 1969, 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 in the Special Exposure Cohort [HHS 2011b].

For the period January 1, 1970 through July 31, 2006, the Advisory Board agreed with NIOSH that it can estimate doses. Air concentration data collected during the remediation, and from a 1976 survey, were used to estimate air concentrations for the years between 1970 and 1976 (assuming an exponential decrease). Air concentrations for the years after 1976 were assumed to be the same as 1976 [ORAUT 2015, PDF pp. 69-70].

- SEC-00173, Norton Co. (January 1, 1958 through October 31, 2009)

The petitioner requested an evaluation of a class that included all employees of the Norton Company who worked in any building or area at the Norton Company location on New Bond Street in Worcester, Massachusetts from January 1, 1960 through December 31, 1972. Based on its research, NIOSH expanded the class under evaluation to include all atomic weapons employees who worked in any building or area at the facility owned by the Norton Co. in Worcester, Massachusetts during the residual radiation period from January 1, 1958 through October 31, 2009 [NIOSH 2011a, PDF p. 4].

Between 1945 and 1956, Norton Co. manufactured hexagons containing uranium and thorium oxides. During the period from January 1, 1958 through October 7, 1962, Norton Co. employees performed teardown operations in Building 112. Workers removed refractory materials, equipment, and wastes from the AWE radioactive processes, and performed contamination clean-up. These actions significantly altered the materials present and placed employees close to the disturbed materials. Bioassay and air sampling data were identified for the periods both before and after this time, but no data were identified during teardown and clean-up operations. There was also a lack of data during the operational period, which resulted in an SEC for that period as well because of the inability to characterize the pre-teardown and clean-up conditions. The Norton ER concludes:

NIOSH does not have adequate internal monitoring or workplace monitoring data to bound doses that were potentially received during the dismantling, clean-up, packaging, and burial of AWE materials and contamination [NIOSH 2011a, PDF p. 28].

The ER further states that doses could not be reconstructed during teardown operations from January 1, 1958 through October 10, 1962, and proposed that a class be added to the SEC. The Board concurred with the following recommendation:

All atomic weapons employees who worked in any building or area at the facility owned by the Norton Co. (or a subsequent owner) in Worcester, Massachusetts, during the period from January 1, 1958 through October 10, 1962, 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 [HHS 2011c, PDF p. 3].

For the period from October 11, 1962 through October 31, 2009, NIOSH determined that available data were sufficient to calculate worker exposures. NIOSH obtained gross alpha air monitoring results collected at Norton Co. near the end of the AWE operations period as well as during the residual radiation period that were sufficient to reconstruct worker exposures during the remainder of the residual period [NIOSH 2011a, PDF p. 28].

- SEC-00177, Vitro Manufacturing (Canonsburg) (January 1, 1960 through September 30, 1965)

  The class requested by the petitioner included all employees who worked in any area at the Vitro Manufacturing facility in Canonsburg, Pennsylvania during the time period from January 1, 1958 through April 30, 1960. NIOSH divided the petitioner-requested class into two periods to be separately evaluated: January 1, 1958 through December 31, 1959 was evaluated in the SEC-00177 ER; January 1, 1960 through September 30, 1965 was subsequently evaluated in an addendum to that ER [NIOSH 2011b, PDF p. 4].

  From 1930 to 1942, the site extracted radium and uranium salts from carnotite ore and processed residues for commercial purposes. Beginning in 1942, Vitro Manufacturing began processing African uranium ores and uranium concentrates, and in 1948, began processing scrap materials from other AWE sites. In 1955, uranium oxide wastes from Canada were shipped to the site for further processing NIOSH [2011b, PDF pp. 17-18].

  The addendum to the SEC-00177 ER examined the residual period [NIOSH 2011d]. During the previous operational period, the site processed uranium ores and generated waste piles containing uranium and progeny no longer in equilibrium due to processing. Between 1960 and 1965, the site performed remediation, transfer, and burial of the residue waste piles. The ER Addendum pointed out:

  > *NIOSH does not have access to personnel monitoring, workplace monitoring, or source term data to estimate unmonitored internal and external exposures for Vitro Manufacturing (Canonsburg) workers during the period of residue storage and site decommissioning and burial operations from January 1, 1960 through September 30, 1965* [NIOSH 2011d, PDF p. 6].

  Given this lack of data and inability to estimate the source term in the waste piles, the ER Addendum recommended to the Board that the entire residual period be added as a class to the SEC:

  > *All Atomic Weapons Employees who worked at Vitro Manufacturing in Canonsburg, Pennsylvania, from January 1, 1960 through September 30, 1965, 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 in the Special Exposure Cohort* [HHS 2013a, PDF p. 22].

NIOSH Conclusion: It is clear these three residual periods added to the SEC were for sites with unusual work activities that had high dose potential for which NIOSH was unable to evaluate the source term; this is not the case at M&C. The distinction between the potential for a high dose and the potential for a lower dose is important because according to a former Board Chair:

> *In circumstances where the absolute value of the exposure may be much higher, we're much more concerned with how accurate these dose estimates may be* [HHS 2013b, PDF p. 18].

AWE Sites That Do Not Have Residual Radiation Period Classes Added to the SEC

In the remaining 12 ERs, covering 11 different sites, NIOSH concluded that it had sufficient information to calculate worker doses for the residual periods associated with the classes under evaluation. Although the WG did not request this summary, NIOSH believes this information provides additional context regarding the issue at hand.

- SEC-00223, Carborundum Company (October 1, 1943 through December 31, 1958; January 1, 1968 through December 31, 1992)

  The class requested by the petitioner was the class that NIOSH evaluated; it included all employees who may have worked in any area of the Carborundum Company site between January 1, 1943 and December 31, 1976 [NIOSH 2015b, PDF p. 4].

  During the first operational period between 1945 and 1958, the site performed experimental grinding of uranium. During the second operational period between 1959 and 1967, the site had several contracts to synthesize and study uranium and plutonium compounds.

  In each operational period, doses were calculated based on dust-sample data collected during those times. Doses for each residual period were based on the dose calculations for the preceding operational period, as adjusted using the guidance in ORAUT-OTIB-0070 [ORAUT 2012]. For each of the residual periods, doses were calculated for work in production areas and work in non-production areas [NIOSH 2015b, PDF p 55].

- SEC-00204, Baker Brothers (January 1, 1945 through December 31, 1994; January 1, 1996 through December 31, 1996)

  The class that was requested by the petitioner was the class NIOSH evaluated; it included all employees who may have worked in any area of the Baker Brothers site from June 1, 1943 through December 31, 1996 [NIOSH 2012, PDF p. 4].

  In 1943 and 1944, the site machined uranium metal. In 1995, the site was remediated. Surface contamination levels at the start of the first residual period were estimated using Battelle-TBD-6000 [NIOSH 2006b] and ORAUT-OTIB-0070 [ORAUT 2012]. Air concentrations from resuspension of dust combined with air monitoring data from 1989 allowed NIOSH to calculate worker doses during the first residual period [NIOSH 2012, PDF

p. 37]. For the second residual period in 1996, air data during remediation activities in 1995 were used as an upper bound estimate of air concentrations [NIOSH 2012, PDF p. 39].

- SEC-00141, Hooker Electrochemical (January 1, 1949 through December 31, 1976)

  The class requested by the petitioner was later modified by the petitioner to include all employees who worked in any location at the Hooker Electrochemical site during the operational period from January 1, 1943 through December 31, 1948, and the residual period from January 1, 1949 through December 31, 1976. This is the class NIOSH evaluated [NIOSH 2010a, PDF p. 4].

  From 1943 through 1948, the site used hydrochloric acid to concentrate uranium from slag materials sent from other sites [NIOSH 2010a, PDF p. 14]. Using air dust levels measured during Hooker operations and air radioactivity results from a similar site, NIOSH was able to estimate air concentrations during production and calculate the deposition that would result from one year of operations. Doses for the residual period were calculated based on the resuspension of this contamination [NIOSH 2010a, PDF p. 26].

- SEC-00043, Chapman Valve (January 1, 1950 through December 31, 1993)

  The class requested by the petitioner included:

  > *Guards, captain of guards, chief inspectors, inspectors, engineers, master mechanics, heat treater foremen, steamfitters, machine repairers, assistant to director of research, steam fitting and plumbing maintenance foremen, machine shops and maintenance general superintendents, electricians, chief electricians, milling machine operators, centerless grinder operators, portable grinder machinists, chipper machinists, assemblers, tool crib machinists, turret lathe operators, janitors, janitor helpers, decontamination workers, firefighters, and general foremen who worked at Chapman Valve Manufacturing Company in Indian Orchard, Massachusetts, from 1948 through 1949 and from 1991 through 1995* [NIOSH 2006a, PDF p. 4]

  NIOSH modified the petitioner-requested class to one that included all employees who were monitored or should have been monitored, for radiological exposures while performing Atomic Energy Commission work at the Chapman Valve site from January 1, 1948 through December 31, 1949, and from January 1, 1991 through December 31, 1993. The 1994–1995 portion of the residual period was not evaluated in the ER [NIOSH 2006a, PDF p. 4].

  The site machined uranium metal in 1948. A radiological survey of the site by Oak Ridge National Laboratory in August 1992 included analyses of dust, debris, and soil samples. Based on the results of that survey, NIOSH was able to estimate the re-suspended dust during the residual period and calculate worker doses [NIOSH 2006a, PDF p. 30]. This is an example of sample data being back-projected in a similar manner to M&C.

- SEC-00131, Bliss & Laughlin Steel (January 1, 1953 through December 31, 1998)

  The class requested by the petitioner included all employees of Bliss & Laughlin Steel between June 1, 1948 and December 31, 1998. The start of the covered period was determined by the Department of Labor to be January 1, 1951. NIOSH evaluated a class of all workers at the Bliss & Laughlin Steel site during the period from January 1, 1951 through December 31, 1952 and/or during the residual period from January 1, 1953 through December 31, 1998 [NIOSH 2009a, PDF p. 10].

  In 1951 and 1952, the site machined uranium metal. Using air concentrations based on machining uranium, along with breathing zone and general area air results from Bliss & Laughlin during its operational period, NIOSH was able to estimate the amount of surface contamination that would result after one year of operations. Worker doses during the residual period were calculated based on the resuspension of this contamination [NIOSH 2009a PDF p. 25].

- SEC-00230, Bliss & Laughlin Steel (January 1, 1999 through December 31, 1999)

  After the evaluation for SEC-00131, the end date of the covered period was extended through December 31, 1999. The class requested by SEC-00230 petitioner included all employees of Bliss & Laughlin Steel for the period from January 1, 1951 through January 31, 1999. NIOSH determined that the petition and supporting documents did not provide substantially new information, and therefore, did not meet the criteria required to re-examine the period previously evaluated in SEC-00131. The only portion of the requested class that met the criteria for re-examination was from January 1–31, 1999. NIOSH extended the class under evaluation to include the full year of 1999. Thus, the NIOSH-evaluated class included all atomic weapons employees who worked in any area at the Bliss & Laughlin Steel site in Buffalo, New York, during the period from January 1, 1999 through December 31, 1999 [NIOSH 2009b, PDF p. 4].

  NIOSH determined that the internal and external dose reconstruction approaches for employees through December 31, 1998 were also applicable and bounding for employees between January 1, 1999 and December 31, 1999 [NIOSH 2009b, PDF p. 5].

- SEC-00157, Simonds Saw and Steel Co. (January 1, 1958 through December 31, 2006)

  The class requested by the petitioner was the class evaluated by NIOSH; it included all employees who worked in any area at the Simonds Saw and Steel site during the applicable covered operational and residual periods from January 1, 1948 through December 31, 2006 [NIOSH 2010b, PDF p. 4].

  Between 1948 and 1957, the site forged and rolled uranium and thorium metal. Air data from the operational period (1949–1953) and in the residual period in 1982, along with ORAUT-OTIB-0070 depletion methods [ORAUT 2012], were used to estimate air concentrations

during the residual period until 1982. Estimates for the years between 1982 and 2006 were set at 1982 levels [NIOSH 2010b, PDF p. 56].

- SEC-00225, Blockson Chemical Co. (July 1, 1960 through December 31, 1991)

  The class requested by the petitioner included all maintenance and operations personnel who worked in any area at Blockson Chemical Co. in Joliet, Illinois, from July 1, 1960 through December 31, 1991. NIOSH modified the class under evaluation to include all employees who worked in any area of the Blockson Chemical Co. site from July 1, 1960 through December 31, 1991 [NIOSH 2015a, PDF p. 4].

  Between 1951 and 1960, under an AEC contract, the site separated uranium from ores. Using bioassay results from the operational period, NIOSH calculated the initial air concentration at the beginning of the residual period. A 1978 radiation survey of the site provided surface contamination levels within the process building. Using these data, NIOSH was able to calculate the rate of depletion for the intervening years. These calculations, along with radon measurements taken during the residual period, allowed the calculation of worker doses during the residual period [NIOSH 2015a, PDF p. 28].

- SEC-00079, Dow Chemical Corporation (Madison Site) (January 1, 1961 through November 30, 2007)

  The SEC-00079 ER was presented to the Board on May 3, 2007. It evaluated uranium and thorium exposures between January 1, 1957 and December 31, 1960 and uranium exposures between January 1, 1961 and December 31, 1998. In January 2009, the Department of Energy notified the Department of Labor and NIOSH that thorium contamination during the residual period between January 1, 1961 and December 31, 1998 was covered [NIOSH 2008c, PDF p. 4].

  In Addendum 2 to the SEC-00079 ER, NIOSH evaluated the period from January 1, 1961 through December 31, 1998 for thorium. NIOSH determined that exposure to residual thorium was possible in all areas of the site and that job description could not be used to limit the class [NIOSH 2008c, PDF p. 8]. This is equivalent to the evaluation of a class of all workers in any area at the Dow Chemical Corporation Madison Site from January 1, 1961 through December 31, 1998.

  Between 1957 and 1960, the site extruded uranium metal, straightened uranium rods sent from another site, and manufactured thorium alloys. Using breathing zone and area air concentration data collected during the operational period, and air concentrations from 2006, NIOSH was able to estimate air concentrations from thorium residues during the residual period [NIOSH 2008c, PDF p. 9].

- SEC-00105, General Steel Industries (January 1, 1967 through December 31, 1992)

  The petitioner requested a class that included all individuals who worked in any location at the General Steel Industries site from January 1, 1953 through December 31, 1966, and/or during the residual period from January 1, 1967 through December 31, 1992. NIOSH determined that radiological operations ended on June 30, 1966 [NIOSH 2008b, PDF p. 20], and for purposes of the ER, NIOSH modified the class under evaluation to include the periods from January 1, 1953 through June 30, 1966, and/or the residual period from July 1, 1966 through December 31, 1992 [NIOSH 2008b, PDF p. 4]. The residual period is currently defined as from January 1, 1967 through December 31, 1992 [HHS 2020b, PDF p. 47].

  The site performed quality control on uranium ingots manufactured at another site. Using air concentration data from facilities that conducted similar operations, NIOSH was able to estimate surface contamination during operations. Worker doses during the residual period were calculated based on resuspension of that contamination [NIOSH 2008b, PDF p. 25].

- SEC-00174, Wah Chang (January 1, 1973 through July 31, 2006)

  The petitioner requested a class that included all employees who worked in all buildings at the Wah Chang site from January 1, 1971 through January 11, 1979. NIOSH modified the class under evaluation to include all employees who worked in any building at the Wah Chang site for the operational period from January 1, 1971 through December 31, 1972, and the residual radioactivity period from January 1, 1973 through October 31, 2009 [NIOSH 2010c, PDF p. 4].

  In 1971 and 1972, the site melted uranium into ingots using furnaces insulated with thorium oxide. Using air concentrations during 1971 operations to calculate contamination deposition at the beginning of the residual period, and then estimating the resuspension of the material, NIOSH was able to calculate worker doses during the residual period [NIOSH 2010c, PDF pp. 31-32].

- SEC-00116, United Nuclear Corp. (January 1, 1974 through December 31, 2006)

  The petitioner requested a class that included all site employees that worked in any area of the site from January 1, 1958 through December 31, 1969 and January 1, 1970 through June 30, 2011 due to residual contamination. At the time the ER was issued (January 28, 2011), the end of the covered operational period was December 31, 1973, and the end of the residual covered period was defined by DOE as July 31, 2006. NIOSH modified the class under evaluation to include all site employees that worked in any area of the site from January 1, 1958 through December 31, 1973 and the residual radiation period January 1, 1974 through July 31, 2006 [NIOSH 2010d, PDF p. 4]. The covered periods for the site are currently defined by DOE as an operational period from January 1, 1958 through December 31, 1973 and a residual period from January 1, 1974 through March 1, 2011 [HHS 2020b, PDF p. 116].

> Between 1956 and 1972, the site manufactured uranium and uranium compounds. In 1964, the site manufactured uranium-thorium fuel pellets. Using operational period air concentrations to calculate contamination deposition at the beginning of the residual period, and air results from the residual period, NIOSH was able to calculate worker doses during the residual period [NIOSH 2010c, PDF p. 42].

NIOSH Conclusion: M&C operations were similar to operations at these other sites. Uranium was machined at most of these sites; thorium is documented to have been at over half of them. Residual-period tasks performed by workers at these other sites, including contaminated soil excavation and welding and torch-cutting in contaminated areas, have been evaluated. The pathways leading to internal exposures from alpha-emitting radionuclides such as uranium and thorium are identical for workers at all of these sites: the inhalation and ingestion of resuspended, contaminated dust.

The methods proposed for M&C by NIOSH and SC&A are similar and consistent with those previously approved by the Board to bound worker exposures during residual periods, including developing ratios between materials with known concentration data and materials with historically unmeasured concentrations.

The types of radioactivity, the crafts personnel who worked with it, and the tasks performed are found across all of the AWE sites. The worker radiation exposures and the applicability of the bounding methods during the M&C residual period do not stand out as unusual amongst AWE sites.

Although the procedures used by NIOSH [ORAUT 2012] appear to be designed for routine exposures, NIOSH and the Board have adapted and relied upon them to bound non-routine exposures, such as those that occurred during M&C maintenance, or at other AWEs with foundries and steel mills.

WG COMMENT 2: A general concern was expressed that although NIOSH used the same procedures to bound doses at M&C as were used at other AWE sites the WG was not convinced the supporting data was sufficiently accurate, or adequate [HHS 2020a, PDF p. 84]. For example, the WG believes that dust-loading values are not accurate, and some occupancy times are too short [HHS 2020a, PDF pp. 34, 53].

NIOSH Response: When considering the concept of sufficient accuracy, NIOSH adheres to the regulations as they have been interpreted in past SECs. According to the 42 CFR Part 83 regulation:

> *Radiation doses can be estimated with sufficient accuracy if NIOSH has established that it has access to sufficient information to estimate the maximum radiation dose, for every type of cancer for which radiation doses are reconstructed, that could have been incurred in plausible circumstances by any member of the class* [42 CFR 83.13, 2018, PDF p. 10].

To accomplish this, NIOSH must have access to reliable information regarding the identity and maximum quantity of each radionuclide to which members of the evaluated class were potentially exposed, along with information describing the processes and physical environments in which the exposures may have occurred. However, per 42 CFR Part 83, access to personal dosimetry data and area monitoring data is not necessary to estimate the maximum radiation doses that could have been incurred by any member of the evaluated class [42 CFR 83.13, 2018, PDF pp. 10–11].

NIOSH procedures require bounding estimates to be developed with scientifically plausible data. Specifically, data that apply to, and are appropriate for use in, the exposure model [HHS 2013b, PDF p. 33]. NIOSH verifies the pedigree of these data to ensure they are reliable.

During periods of residual contamination, NIOSH would typically have access to sparse workplace monitoring data, and often, no worker monitoring data. To determine the internal and external exposures to covered workers at AWE facilities during periods of residual contamination, NIOSH developed standard procedures specifically written to deal with the reconstruction of doses during periods where monitoring data are sparse or nonexistent. When there is little or no monitoring data, these procedures rely on surrogate data and models to estimate internal and external exposure. With support from SC&A, the Board has reviewed and concurred with each of these procedures for scientific validity [NIOSH 2019a, PDF p. 8]. Furthermore, the Board has reviewed and concurred with dose reconstructions completed using these procedures.

The Board's position and the guidance NIOSH has been following is that concern for the plausibility of circumstances used for bounding (e.g., one person doing all the maintenance work) is NOT an issue in the realm of very low doses, and specifically, during AWE residual periods such as at M&C [HHS 2013b, PDF p. 17]. In the words of the former Board Chair:

> *…if you look back at all of our decisions for a period of time -- and I think it also goes to our evaluation of dose reconstruction. If the absolute value of the exposure is relatively low, then we're willing to accept more variability in the dose if it's being calculated for an individual. And if the exposure's absolute values are higher, then we're looking for a more accurate dose reconstruction method* [HHS 2013b, PDF p. 20].
>
> *I would say one element of this where to draw the line and how we approach this, I think it is sort of, how much of a dose are we dealing with or potential dose? And with the residual period, we are going to have lots of situations -- we have already had them -- where we don't have very much information on the activities and the ability, usually very little sampling data. We are going to be using OTIB-70 a lot in these situations without knowing much about what individuals did on the site* [HHS 2011a, PDF p. 145].

There are uranium dose estimates available for every exposure scenario in either NIOSH or SC&A papers, as compiled in Table 1.

Table 1. Summary of annual uranium dose estimates.

SRDB Ref ID	Model	Internal Dose (mrem)	External Dose[a] (mrem)	Duration of Occupancy
179901, PDF p. 14	Subsurface	31	8	2 months
179901, PDF p. 19	HVAC	1.77	N/A	1-hour
179901, PDF p. 20	Roof and Ceiling	3.65	4	1-month
175938, PDF p. 11	Welding	5.88	N/A	48 hours
172715, PDF p. 17	Remaining	2[b]	36	~9 month
Total	N/A	44.3	48	12 months

[a] Source: [SC&A 2020, PDF p. 25]

[b] In subsequent discussions, NIOSH agreed to use a resuspension factor of 10^{-5}/m.

NIOSH believes it has estimated the maximum radiation dose that could have been incurred under plausible circumstances. Even under these maximizing conditions (e.g., the use of the 95th percentile, 10^{-3} resuspension, 200 mg/m^3 dust load, the same person doing all the work, and most claimant-favorable solubility type), the estimated doses to workers during the residual contamination period are quite small.

WG COMMENT 3: Although the doses are small, the WG questioned the adequacy of survey data from the 90s to bound doses incurred in the 70s and 80s. According to one member:

> *I still do not agree with using the data from the '80s and '90s, particularly the '90s. The work that they were doing was to characterize in order to dig up and remove contamination, not to assess dose to workers. So, I'm not in agreement there* [HHS 2020a, PDF p. 45].

NIOSH Response: As described above in the response to Comment 1, NIOSH developed bounding scenarios from contamination survey data that were intended by the site to characterize an area for 15 of the 16 AWE sites evaluated. The ER that did not use such data was SEC-00107, Linde, where NIOSH interpolated air concentration measurements from before and during the residual period. In fact, surface- and mass-based contamination surveys are almost never performed by radiological facilities for assessing doses. However, they are routinely used retrospectively and prospectively to assess exposure potential. Numerous current regulatory documents provide guidance for using contamination survey data to estimate a bounding worker exposure and using it retrospectively to estimate a worker's dose, or prospectively to determine monitoring needs. The application of resuspension factors and dust-load estimates to surface- and mass-based contamination surveys is a very common and accepted approach used today to meet the requirements in 10 CFR 20 and 10 CFR 835. The Board has routinely approved the use of such data to bound doses when the data selected creates a clamant-favorable and plausible dose estimate.

NIOSH reviewed the data used to bound doses to maintenance workers and found that it was compiled from datasets from as early as 1983, and from areas that were not remediated. The following is a summary of some of the data used to bound exposures.

During summer 1983, the NRC mobilized ORAU's Radiological Site Assessment Program to conduct an independent radiological assessment of the site. ORAU surveyed the Burial Site location and around the perimeter of Building 10. The report documented the presence of isolated areas of soil contamination above the NRC's unrestricted release criteria [CPS 1992, PDF pp. 11–12]. Additional Burial Area surveys took place in June 1992 [CPS 1992, PDF pp. 27–40].

In late 1993, M&C conducted preliminary surveys and identified the existence of elevated radiation levels on the southwest side of Building 5. Subsequent surveys, including subsurface soil measurements taken in March 1994 indicated the need to perform remediation activities at this location [Texas Instruments 1994, PDF p. 989].

A drainage system investigation was performed in September 1995, immediately after the Pilot-Scale Interiors Remediation Project and before the Full-Scale Interiors Remediation Project. An aggressive investigation schedule was implemented to assess the potential for inadvertent exposures to non-radiological workers performing routine, drainage system maintenance [Texas Instruments 1996, PDF p. 7].

The petitioner stated that this drainage system survey performed in 1995 represents conditions before D&D activities; therefore, it offers "good insight into conditions to which employees were exposed" [Affidavit 2016, PDF p. 4].

In an attempt to corroborate the drain line data, NIOSH examined similar data obtained at other AWE sites. Six sites were identified that documented drain-line sediment sample results. These data were used to determine the likelihood that the 95th percentile specific activity for Metals and Controls could be considered bounding. The six sites reviewed were Vitro Rare Metals Plant, Bridgeport Brass (Adrian Site), Horizons Metal Handling Facility, Peek Street, Mallinckrodt, and De Soto. Table 2 below summarizes these data.

Table 2. Drain line data from various AWE sites.

SRDB Ref ID	Site	Report Year	Highest Results for Drain Sediment	Summary of Results
3737, PDF p. 10	Vitro Rare Metals Plant	1978	270 pCi U238/g	10 total samples. All other results range from 2.5 to 51 pCi U238/g.
14422, PDF p. 30	Bridgeport Brass, Adrian Site	1982	11,000 pCi U238/g	Three sample results reported. Other results were 20 and 480 pCi U238/g.
16269, PDF p. 63	Horizons Metal Handling Facility	1977	No Uranium 2,530 pCi Th232/g	34 sample results reported. All others were negative except for three samples. Other positive samples were 10, 13, and 318 pCi Th232/g.
33259, PDF pp. 50–53	Peek Street	1994	430 pCi U238/g	43 sample results reported. All but one ranged from 0.72 to 57 pCi U238/g. The exception was 200 pCi U238/g.
74779, PDF p. 133	Mallinckrodt	1978	56,000 pCi U238/g	Seven sample results reported. Five were in the range from 25 to 110 pCi U238/g. The other two were 1,780 and 11,700 pCi U238/g.
171603, PDF pp. 10–11	De Soto	1988	4210 pCi alpha/g	39 gross alpha samples results. 22 results were less than 100 pCi alpha/g. 15 results were between 100 and 500-pCi alpha/g. One result was between 500-1000. Only the maximum value was greater than 1000 pCi alpha/g.

In each of the above cases, the maximum specific activity was at least an order of magnitude larger than the majority of the other samples. This indicates that although there could be sporadic hot spots (i.e., at the 95th percentile), one is unlikely to encounter systemic exposures to drain-line sediment at the 95th percentile. Therefore, NIOSH believes that even if a sporadic hot spot was occasionally encountered at a level greater than the 95th percentile, given the rarity of this occurrence, the assumption that all routine exposures occurred at the 95th percentile would still be bounding. This is because, in reality, the sampling data indicate that the majority of drain-line sediment is more likely to be encountered at a level closer to the 50th percentile specific activity, which tends to be at least an order of magnitude lower. The M&C drain-line data are consistent with this conclusion: of the 20 sediment results, 16 samples are at least an order of magnitude less than the 95th percentile.

Contamination Surveys during the Residual Period

Although comprehensive sample data used to characterize earlier periods did not become available until 1983–1995, NIOSH is aware of the safety program that was in place during the residual period. M&C was known for its development of sensitive monitoring equipment and had requirements to perform routine contamination surveys of the facility [Metals and Controls 1968, PDF p. 10].

M&C engineers were considered pioneers in low-level alpha counting and quantitative gamma spectrometry. Beginning in the 1950s, M&C's Instrument Engineering Section developed

nondestructive testing methods for quality control, including radiography and radiation monitoring [Metals and Controls 1956, PDF p. 24]. M&C's intensive cleaning program during the AWE facility operational period required daily surface surveys to check for nuclear materials [Metals and Controls 1956, PDF p. 27].

Although the WG expressed skepticism that the 95th percentile bounds contamination levels that existed before the 1983–1995 surveys, M&C's area monitoring provides assurance that this value is conservative. During the first 14 years of the residual period (1968-1981), M&C performed routine alpha contamination surveys in Building 10. If widespread removable alpha contamination existed at levels higher than the 95th percentile in the areas where maintenance was performed, then the routine surveys would have eventually identified tracking throughout the plant during this 14-year period.

WG COMMENT 4: A WG member took exception to NIOSH's use of surrogate data obtained during an outdoor excavation to bound indoor exposures even though SC&A's independent method came to a similar result [HHS 2020a, PDF p. 33].

NIOSH Response: First, a correction may be helpful because a WG member might have misunderstood some information presented by NIOSH in the subsurface model. The member stated:

> *…you're looking at the maximum bad case, if you will, inside in the Building 10 subsurface and you're using data -- good data from 1995, right -- or 1994-'95 -- '95. With the '95 data with measurements -- good quality measurements for those workers that were working in that excavation, the inside value for the uranium was 1.5 × 10^{-12} µCi/ml. And the outside was a factor of 50 below it, 2.5 × 10^{-14}. So, it is exactly with good data for a limited number of people, not necessarily the workers in the plant, but the people who were contracted and doing this work, the outside uranium, you know, concentration was much, much less than the inside. And that's the concern that I have that you're using the outside loading data from Mound to extend to inside whereas, in fact, that is a very low value compared to the value that people have inside. And there's one measurement right there that contradicts what you were saying that the inside -- or the outside measurement might be larger than the inside* [HHS 2020a, PDF pp. 37-38].

The air concentrations the WG member refers to are not from measurements taken during actual excavation work, but rather, were calculated by NIOSH based on the 95th-percentile dust-loading value from the Mound Plant study, and the 95th-percentile contamination levels of the outdoor and inside areas from Metals and Controls. The reason that the air concentration that NIOSH proposes for inside work is 50 times higher than the outside concentration is not due to the dust-loading value (the same value is applied to both locations), but rather, is due to the much higher contamination levels found inside [NIOSH 2018, PDF p. 12]. This made sense to NIOSH because the drain lines inside Building 10 contained M&C's worst-case subsurface contamination, as evidenced by the data and according to the petitioner:

> *…in the exterior soils, [contamination] was not insignificant. Although, I will tell you that clearly the "mother lode," to use a colloquial term, was in drains in Building 10* [ORAUT 2017a, PDF p. 10].

However, to assign doses, NIOSH proposed that when the subsurface-work-area (e.g., inside or outside) cannot be determined, the most claimant-favorable location will be assigned [NIOSH 2018, PDF p. 16].

In addition, in NIOSH's *Metals and Controls Corp. Maintenance Worker Exposure Model* [NIOSH 2018, PDF p. 10], NIOSH pointed out that the Mound Plant study was a good surrogate for M&C's outside scenario *and different from* M&C's inside scenario, but nevertheless bounds it. NIOSH understands that outdoor work provides many more air-changes and a greater volume of air for dilution. However, at Mound, the high-volume air samplers were positioned close to the excavation to perform a dust-loading study, which reduces the impact of the larger outside air volume. With the use of the 95th percentile case from that study, the smaller air volume available for work inside of a large industrial facility is offset by the limited airborne- generating capacity of snakes and shovels (1-4 pounds per shovel dropped 1-3 feet) on wet soil inside as compared to the backhoes used outside (hundreds to a couple of thousand pounds of material dug, pushed, and dropped from 6-14 feet).

There is this further insight into the Mound study from Dr. Taulbee, who was present at Mound at the time:

> *I have one additional comment for you to consider in this when you're comparing the indoors and outdoors comparison. In general, I would agree with what you're saying when you consider the disproportionate factors of being indoors and outdoors for an equal volume of soil being moved. But in this particular case for the Mound data, in particular, large volumes of soil were being moved and the high-volume air sampler was positioned to try and capture the bulk of that -- of the dust cloud as the dirt was being dumped into the dump trucks and running there along the side of the road. So, for equal volumes of dirt being moved, I would agree with you 100 percent that indoor could be higher, but we do have to consider the water table that Pat was mentioning there earlier as a factor. But also, please consider the volume of soil that would be moved via an excavator versus somebody with a shovel trying to dig out to clear out a pipe or to get to the pipe* [HHS 2020a, PDF p. 43].

WG COMMENT 5: A WG member commented that explosions and fires are not considered in bounding methods especially the HVAC model. The member remarked:

> *…we haven't really addressed the explosions or the fires that took place in Building 10* [HHS 2020a, PDF p. 49].

NIOSH Response: NIOSH reviewed the interview transcript that described the aluminum-powder explosion in the southeast corner (high bay) of Building 10. Note: For context, Building 10 is approximately 625 feet long, and this explosion occurred at the end of the building farthest away from the unclad fuel-manufacturing area.

Worker #10: It was from a manufacturing process. As it turned out, they weren't doing proper cleaning on the manufacturing side so there was an explosion that set off the aluminum dust explosion. The explosion lifted the roof off the steel. One guy got third-degree burns on his arm. …created dust everywhere. It lifted the whole roof of the building.

Mr. McCloskey: What was the response to the dust everywhere? Did they have a building-wide clean up afterward?

Worker #10: We were locked out of the area. The State came in and took over. They wouldn't let us back in until they secured it. My guys built the new building outside. It was right here and came over this way. It was like a bunker. Because of the process, the R&M people had to rebuild the machinery. We spent six weeks right through Christmas building that to get it going, and it was all hands on deck [ORAUT 2017b, PDF pp. 14-15].

NIOSH is aware that the Attleboro Fire Dept. conducted routine inspections of the M&C facility [Texas Instruments 1976, PDF p. 146]; however, an SRDB search for records of events, including the one described above, failed to find any references to fires or explosions at M&C post-1967.

In addition, NIOSH inquired with the Director of the State of Massachusetts Department of Public Health, Radiation Control Program, and the state's Director of the Department of Fire Services to find records of events or incident inspection reports; they have not identified any records of fires or explosions.

In conclusion, NIOSH agrees with SC&A's assertion that additional dust created by a fire or explosion would dilute the specific activity concentrated in the HVAC system, thus making NIOSH's HVAC model more claimant favorable during these rare events [HHS 2020a, PDF p. 52].

WG COMMENT 6: A former worker has a concern regarding exposures to Ra-226 glass beads [HHS 2020a, PDF p. 88; HHS 2018, PDF p. 130], and other exposures during maintenance work, including excavation, roof, ceiling area, and HVAC work [HHS 2018, PDF pp. 123-131].

NIOSH Response: From 1965 to 1967, Texas Instruments performed commercial work that produced 5,000 electrical breakers containing radium-bearing luminescent markers for the U.S. Navy. This work involved placing a luminous glass bead with Ra-226 coating onto each toggle switch so that the switch would glow in the dark. The activity was estimated at 0.12 μCi for each bead.

This Ra-226 commercial work was limited to a single process in Building 1 and was kept separate from M&C's AWE Facility weapons-related work. M&C's Ra-226 work is not considered an EEOICPA-covered exposure during the subsequent residual radiation period addressed by the SEC-00236 ER [NIOSH 2017, PDF p. 22].

The other exposure scenarios described by this former worker are addressed by the models NIOSH and SC&A developed for maintenance work.

CONCLUSION

NIOSH researched maintenance work at M&C and worked with all stakeholders, including the petitioners and the M&C Working Group, to create and develop bounding exposure models. NIOSH believes that all of the exposure models adequately bound maintenance exposures experienced by M&C workers during the residual radiation period.

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