Metals and Controls Corp. Maintenance Worker Exposure Model

White Paper

National Institute for Occupational Safety and Health

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Pat McCloskey
Mutty Sharfi
Oak Ridge Associated Universities Team

Reviewed By:
Christine Corwin
Peter A. Darnell, CHP, RRPT
James W. Neton, Ph.D. CHP
Division of Compensation Analysis and Support

INTRODUCTION

NIOSH presented the Evaluation Report (ER) for SEC-00236, Metals and Controls Corp. (M&C) to the Advisory Board on Radiation and Worker Health (Board) on August 24, 2017. At the conclusion of that presentation, a petitioner raised a concern about the adequacy of the ER in addressing maintenance type work. In response to this concern, on September 5, 2017, the National Institute for Occupational Safety and Health (NIOSH) initiated strategies to continue M&C research and to further develop SEC-00236. NIOSH's strategies included plans to review monitoring records in the Site Research Database (SRDB) and plans to search for former M&C workers so that NIOSH could conduct interviews with them.

From October 24 through October 26, 2017, NIOSH, Oak Ridge Associated Universities (ORAU), and Sanford Cohen & Associates (SC&A) personnel interviewed 12 former M&C workers and individuals knowledgeable about maintenance work. Interviewers asked questions regarding the frequency and duration of work, including HVAC, utility and drain line maintenance, and new equipment installations. During the interviews it became apparent that Building 10 experienced recurring issues with water drainage (ORAUT 2017-b, PDF p. 6; 2017-e, PDF p. 5; 2017-g, PDF p. 8; 2017-i, PDF p.7; 2017-j, PDF, p. 5) and underwent multiple equipment change-outs that necessitated subsurface and overhead work. Although this work was sporadic and sometimes emergent in nature, it exposed workers in a manner that did not agree with the method described in the SEC-00236 ER (i.e., surface contamination resuspension). Interview responses also showed that covered workers performed significant subsurface work in areas outside of Building 10 (ORAUT 2017-h, PDF p. 11; 2017-j, PDF pp. 4, 9) and because the site was non-union, the work could be assigned to several different groups (ORAUT 2017-b, PDF p. 6; 2017-c, PDF p. 12; 2017-g, PDF pp. 4, 8, 11), which is also corroborated by Nuclear Regulatory Commission (NRC) inspections (NRC 1981–1982, PDF p. 13). By March 13, 2018, information obtained from the interviews was upload into the SRDB (ORAUT 2017-a,-b, -c, -d, -e, -f, -g, -h, -i, -j, -k, -l).

In addition to the interviews, other notable actions included the following:

- November 8, 2017 - The Metals and Controls Working Group, SC&A, DCAS, and ORAU team members held a teleconference to discuss technical issues associated with developing exposure models regarding maintenance work.
- February 6, 2018 - NIOSH obtained additional monitoring data regarding remediation work performed by Creative Pollutions Solutions in 1992 and 1994 (CPS 1992-b; CPS 1994).
- February 13, 2018 - NIOSH received SC&A's report titled *Review of SEC Petition ER SEC-00236*.
- April 23, 2018 - NIOSH issued the *Metals and Controls Corp. Subsurface Exposure Model* White Paper and made it available to SC&A and the Working Group.
- May 3, 2018 - During a Working Group meeting, SC&A presented their findings and observations associated with the SEC-00236 ER. The petitioners also made a statement and provided a letter with their concerns. After the meeting, an issues matrix was created.

- August 22, 2018 - During a full Board meeting, the Working Group presented their findings and observations associated with the SEC-00236 ER and NIOSH provided an update. The petitioners also made a statement and provided a letter with their concerns at the meeting.

This White Paper provides an exposure model based on data obtained from the time when the SEC-00236 ER was presented and includes information about exposures that occurred during maintenance work activities not previously discussed in the SEC-00236 ER or the Subsurface Exposure Model White Paper.

BUILDING 10 HVAC MAINTENANCE

M&C workers were required to maintain Building 10's HVAC system. This system would have handled air that potentially contained resuspended contaminants generated during AWE operations. In SC&A's report *Review of SEC Petition Evaluation Report SEC-00236 Metals and Controls Corporation* (Mauro 2018), they provided the following assessment of this HVAC maintenance:

> (PDF p. 21) *M&C workers were also involved in maintaining the heating, ventilation, and air conditioning (HVAC) systems, which required periodic cleaning of the HVAC ducts and replacing large dust filters. From the interviews, we have some information on how this work was done, how often it was done, who did the work, and the number of work hours each activity required.*
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> (PDF p. 23) *Worker interviews revealed that, during the residual period, M&C maintenance workers routinely entered HVAC ductwork in the various buildings, including Building 10, to clean out the interior surfaces of the ductwork, maintain the air movers, and replace large dust filters. There was some uncertainty about how often this type of maintenance work was performed on the HVAC systems in each building. However, workers explained that quarterly maintenance on these systems was desirable, but these activities usually were performed less frequently. In theory, these maintenance activities could have resulted in periodic exposures to uranium dust because uranium dust was (1) chronically airborne within Building 10 due to chronic resuspension from surfaces and (2) episodically airborne due to various maintenance activities, such as cutting through concrete floors and maintenance work performed in the rafters of the building, where relatively large amounts of dust accumulated. In addition, workers stated that there were occasional off-normal incidents, such as fires and perhaps two explosions that could have resulted in short-term elevated levels of dust and smoke that could also have contained some uranium particulates.*
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> *Such dust would have been largely ventilated through the HVAC systems, where the particulate material may have deposited on the interior surfaces of the HVAC ductwork and also onto the filters used to remove dust before the ventilated air was recycled back into the buildings. It is likely that HVAC workers involved in cleaning and maintaining the HVAC ducts and the air movers and in removing and replacing the filters were exposed to elevated levels of dust. One worker explained that the filters often crumbled*

and needed to be removed in the form of crumbled sections followed by vacuuming. It was explained by one worker, who performed these activities, that the airborne level of dust was high during filter replacement. These workers wore dust masks on occasion and likely inhaled considerable quantities of dust. In addition, it is likely that the workers' clothing and skin were contaminated with dust. Though these activities were periodic and perhaps not of a protracted duration, they appear to represent a potential source of internal and external exposure to uranium-contaminated dust.

(PDF pp. 28-29) *The strategy that we used to place a plausible upper bound on the inhalation doses to workers involved in filter change-out is described as follows.*

It can be assumed that the gross alpha activity on HVAC filters can become at least partially airborne during filter replacement. It is reasonable to assume that this activity would be associated with airborne dust in Building 10, that the chronic concentration of the dust in the building could have been on the order of 100 µg/m³ (see Appendix D.1), and that the chronic airborne concentration of gross alpha activity in Building 10 was 0.0123 dpm/m³, as discussed in Section 2.1.1 (12.3 ÷ 100 cm² × 1E4 cm²/m² × 1E-5/m = 0.0123 dpm/m³). Hence, the estimated specific activity of the airborne dust could have been 0.0123 dpm/m³ ÷ 100 µg/m³ = 1.23E-4 dpm/µg.

As discussed in Appendix D.2, a nuisance dust loading above 100 mg/m³ would be barely breathable. For the purposes of this assessment, let us assume that the worker changing the filter was exposed to this dust loading for 1 hour during each change-out. Under these conditions, the upper-end concentration of gross alpha would be as follows:

$$1.23E\text{-}4\ dpm/\mu g \times 100\ mg/m^3 \times 1{,}000\ \mu g/mg = 12.3\ dpm/m^3$$

The 1-hour dose commitment to the extra-thoracic airways of such a worker would be as follows:

$$12.3\ dpm/m^3 \times 1.2\ m^3/h \times 7.2E\text{-}5\ Sv/Bq \times 1/60\ Bq/dpm \times 1E5\ mrem/Sv = 1.77\ mrem/h$$

Inherent in this calculation is the assumption that (1) the chronic airborne concentration of gross alpha activity was 0.0123 dpm/m³ and (2) the chronic dust loading in Building 10 was 100 µg/m³. Based on this calculation, it appears that the internal exposure resulting from this scenario can be considered of little concern.

In this analysis, it is assumed that buildup of particulates on the filter continues for 1 year before filter replacement, and, therefore, the worker is exposed to elevated dust concentrations for only 1 hour per year. If we assume that filter replacement is 2, 4, or 12 times per year, the amount of time a worker is exposed per year increases, but the quantity of uranium on the filter is corresponding lower. Hence, filter replacement frequency does not affect the annual internal doses associated with this exposure scenario.

NIOSH agrees with SC&A's assessment and conclusion regarding exposures associated with M&C's HVAC system maintenance work in Building 10.

SUBSURFACE INSIDE BUILDING 10

The subsurface environment inside the walls of Building 10 that workers were exposed to is well characterized. The residues inside the worst case (i.e., Priority-1) drain lines are characterized in Exhibit 1, *Texas Instruments Incorporated Attleboro Facility Building Interiors Remediation Drainage System Characterization* (Weston 1996-a) as provided by the petitioner. In the introduction of Weston 1996-a, it states, "The drainage system investigation was performed immediately after the Pilot-Scale Interiors Remediation Project and prior to the Full-Scale Interiors Remediation Project. An aggressive investigation schedule was implemented in support of Nuclear Regulatory Commission (NRC) license termination and to assess the potential for inadvertent exposures to non-radiological workers performing routine drainage system maintenance" (PDF, p. 7). The [Name Redacted], who started working in the Environmental Safety and Health department in 1983 and was the [Job Title Redacted], stated that Exhibit 1 represents conditions prior to Decontamination and Decommissioning (D&D) activities; therefore, it offers "good insight into conditions to which employees were exposed" (Affidavit 2016, PDF, p. 4). In Exhibit 1, characterization methods are described and sample locations and analytical results are provided (in pCi/g) for pipe residues. Radiation surveys were also performed with NaI(Tl) gamma scintillation detectors (Weston 1996-a, PDF p. 14). The locations selected for sampling were based upon:

- Review of "as-built" diagrams;
- Historical information and/or suspected transfer of contaminated material in drain lines; and
- Radiological survey data from previous investigations and removal actions (Weston 1996-a, PDF p. 7).

The facility map depicted in Weston (1996-c) shows the relative locations of the drain lines (PDF pp. 172-173); they are categorized according to their sediment content and total uranium concentrations in pCi/g as follows:

- Priority-1: 1,000 to 53,000 (max);
- Priority-2: 500 to 1,000; and
- Priority-3: Less than 500.

An October 1996 report from remediation contractor Weston describes the work controls and exposures associated with the removal of the worst-case drain lines. The report includes volumetric (pCi/g) sample data, breathing-zone air-monitoring data (Highest monthly average reported as <2.4E-12µCi/ml), and assigned doses for the work (20 mrem/quarter CEDE) (Weston 1996-c, PDF p. 22). Photos of this work depicting personal protective clothing and work controls are available in a slide presentation regarding the decommissioning efforts (Elliott, 1996, PDF p. 15).

The Priority-1 drain lines, worked on by M&C employees and removed by Weston, contained the highest subsurface radioactive material concentrations to which workers were exposed. According to someone familiar with the D&D work, "…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 2017-c, PDF p. 10).

SUBSURFACE AREAS OUTSIDE BUILDING 10

Some workers performed maintenance and new installations that required them to dig in soils in outside areas contaminated with radioactive material from Atomic Weapons Employer (AWE) operations (ORAUT 2017-j, PDF pp. 4, 9; ORAUT 2017-h, PDF p. 11). These subsurface areas are well characterized.

At the request of the NRC, ORAU conducted a radiological survey of the former **Waste Burial Area** located to the southwest of Building 12 and the outdoor **Area Surrounding Building 10** during April and May of 1984. The survey included a ground-penetrating radar survey to locate buried materials. Areas were gridded and surveyed with NaI(Tl) gamma scintillation detectors to identify locations for volumetric sampling. Surface samples were collected and boreholes were drilled 2-3.5 meters deep to collect additional samples. Soil samples analyzed by gamma spectrometry included radionuclides of U-238, U-235, Th-232, and Ra-226 (Sowell 1985, PDF p. 13–21). Analytical results are found in Tables 4 and 5A of the survey (Sowell 1985, PDF pp. 60-73) for surface samples from the Burial Area, and in Table 6 (Sowell 1985, PDF pp. 75–79) for the borehole samples. Tables 11 and 12A contain the analytical results for the surface samples taken of the outdoor area surrounding Building 10 (Sowell 1985, PDF pp. 90-94), and Table 13A provides the borehole sample data (Sowell 1985, PDF pp. 96–97). Additional subsurface samples of the Building 10 perimeter are available in *Radiological Surveys of Open Land Areas Texas Instruments Incorporated Attleboro, Massachusetts* (CPS 1995, PDF pp. 1165-1166). In their summary, ORAU concluded that the results indicated the presence of isolated areas of surface and subsurface contamination that were located mainly within the boundaries of the suspected burial site; however, there were small areas of surface contamination outside the burial site and in a few locations around Building 10 (Sowell 1985, PDF p. 27).

Creative Pollutions Solutions (CPS) summarized the results from the 1984 ORAU subsurface characterization of the Burial Area in a 1992 report which included updated sampling and analysis that supported the 1984 ORAU results and conclusions (CPS 1992-a, PDF p. 5). The 1992 CPS report also documents a pilot study where CPS excavated contaminated portions of the Burial Area while performing air monitoring. Four out of five breathing zone results were less than Minimum Detectable Activity (MDA), and the fifth resulted in 4.1E-2 MPC-h (CPS 1992-a, PDF p. 25). Photos of the outdoor remediation work depicting personal protective clothing and work controls are available in a slide presentation regarding the decommissioning (Elliott 1996, PDF pp. 10-13).

The **Metals Recovery Area** near Building 5 was the location where some open burning occurred during AWE operations. Subsurface volumetric soil sample data are available (CPS undated, PDF pp. 11−24; Texas Instruments 1994, PDF p. 9).

The soils in the **Stockade Area**, located between Buildings 10 and 11, were contaminated because wastewater and pickling acid solutions were staged in drums on the ground within an area enclosed with a stockade fence (CPS 1995, PDF p. 1066–1074; Texas Instruments 1994, PDF p. 33).

The **Railroad Spur Area** is located between the Metals Recovery and Stockade areas. M&C did not handle radioactive material in this area; however, it is believed that soils became contaminated due to transference from the two neighboring areas (CPS 1995, PDF p. 1066–1074; Texas Instruments 1994, PDF p. 33).

The **Building 12 West and South Lawn Areas** were contaminated during the 1968 Building 12 construction project when contaminated soils from the Burial Area were transferred during final grading (Weston 1996-b, PDF pp. 108-110; Texas Instruments 1994, PDF p. 35).

BOUNDING SUBSURFACE EXPOSURE MODEL

ORAUT-OTIB-0070 (2012) provides guidance on mass-based assignments used here to calculate air concentrations, given volumetric sample data and appropriate dust loading factors. In addition, former workers provided information regarding frequency, duration, and safety controls associated with the subsurface work that allows NIOSH to determine occupancy rates. Based on information gained from interviews, workers could have had as much as 1 month per year exposure to subsurface work (ORAUT 2017-i, PDF p.7; ORAUT 2017-j, PDF p. 5; ORAUT 2017-e, PDF p. 5; ORAUT 2017-b, PDF p. 6; ORAUT 2017-g, PDF p. 8). M&C workers in the Facilities Construction and Maintenance Services Organization (Facilities) or Production Machine Operators/Helpers and Production Repair & Maintenance (R&M) organizations having access to, and worked within Buildings 4, 5, and 10, or that performed subsurface work in the area surrounding Building 10, in the former Burial Area, the Metals Recovery Area, the Building 11 Stockade Area, the Building 11 Railroad Spur Area, and in the Building 12 West and South Lawn Areas, are considered to be “maintenance” workers. The remaining atomic weapons employees having access to, and work within Buildings 4, 5, and 10, are considered non-production or administrative employees and will be assigned doses accordingly with methods in the revised ER.

Inside Building 10 Volumetric Sample Data

The subsurface work environment inside Building 10 was characterized with 20 sediment samples collected from the drainage system in 1995, prior to remediation. Those samples were analyzed for uranium with isotopic identification and were compiled in a spreadsheet where the geometric mean (GM, 185.52 pCi/g) and geometric standard deviation (GSD, 9) were calculated. The drainage system under Building 10 required frequent maintenance during the residual period, including the years prior to the characterization. Since this maintenance could have potentially removed sediments with the highest uranium concentration and made the GM value under-conservative, NIOSH calculated the 95th percentile concentration (6,887.84 pCi/g) and will use it to bound exposures.

Outside Areas Volumetric Sample Data

The following outside areas including the area surrounding Building 10, in the former Burial Area, the Metals Recovery Area, the Building 11 Stockade Area, the Building 11 Railroad Spur Area, and in the Building 12 West and South Lawn Areas were characterized with 2,391 soil samples collected prior to remediation. 1,629 of these samples were analyzed for gross alpha, and the remaining 762 were analyzed for uranium and thorium using isotopic identification.

The gross alpha and uranium samples were compiled in a spreadsheet where the GM (9.54 pCi/g) and GSD (4.61) were calculated. The outside subsurface areas required frequent maintenance during the residual period, including the years prior to characterization. Since this maintenance could have potentially removed sediments with the highest uranium concentration and made the GM value under-conservative, NIOSH calculated the 95th percentile concentration (117.86 pCi/g) and will use it to bound exposures.

The gross alpha and thorium samples were compiled in a spreadsheet where the GM (4.57 pCi/g) and GSD (6.02) were calculated. Since subsurface maintenance could have potentially removed sediments with the highest thorium concentration and made the GM value under-conservative, NIOSH calculated the 95th percentile concentration (87.55 pCi/g) and will use it to bound exposures.

Dust Loading

Worker affidavits and interviews described the subsurface work as very intrusive and included accessing contaminated materials that had accumulated for decades without work controls to mitigate the hazard. The default dust-loading value of 100 µg/m^3 value suggested in ORAUT-OTIB-0070 (2012) and NUREG/CR-5512 (1992), meant for use in screening analysis as a long-term average, is not appropriate for M&C subsurface work where workers actively disturbed the contaminated material during episodic responses throughout a given year. ORAUT-OTIB-0070 (2012) provides a justification for increasing resuspension factors, as operations become more vigorous (PDF p. 8).

In addition, this justification is corroborated by research performed to determine dust-loading factors during contaminated-soil excavation activities for the Mound Plant Canal Clean-up Project (Taulbee 2018). During the Mound Project, air-sample collection media were weighed before and after taking each sample to determine their dust loading in grams. The volume flow rate was recorded before and after taking each sample, then the average flow rate was determined and multiplied with the sampling duration to determine the total volume of air in cubic meters.

In total, data from 294 hi-volume air samples were recorded to get a distribution of the dust-loading factor (Figure 1). From the Figure 1 plot, the geometric mean is identified as 7.18 x 10^{-5} g/m^3 and the 95th percentile as 2.2 x 10^{-4} g/m^3.

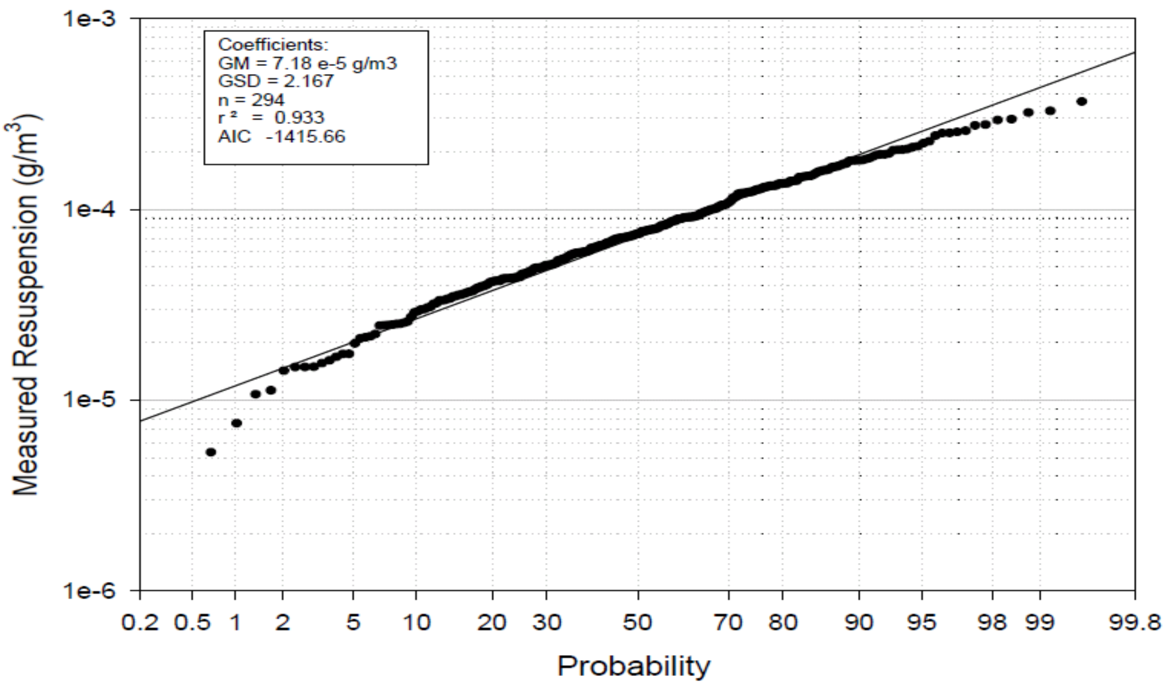

Figure 1. Measured Dust-loading Factor from High Volume Air Sample Data taken spring 1997 during Mound Canal Project.

NIOSH analyzed operations at Mound and M&C to determine if the Mound dust-loading data could be used as a surrogate for dust loading at M&C in accordance with OCAS-IG-004 (2008). The following five criteria are listed in Section 3 of OCAS-IG-004 and describe how the criteria are applicable to dust loading at M&C.

- **Source Term -** NIOSH has knowledge of the types and general quantities of material processed at M&C. NIOSH has access to extensive sample data and process information about uranium and thorium-generating activities at M&C as referenced above.
- **Facility and Process Similarities -** Excavation activities for the Mound Plant Canal Clean-up Project occurred over several months during the spring of 1997. The Mound Plant is located near Miamisburg in western Ohio. Excavation activities at Mound involved using a backhoe to remove soils. Using water as a dust suppressant was sporadic and not consistently applied. In addition, windbreaks, tents, or ventilation were not used.

  Both outside and inside subsurface work at M&C occurred from 1968 through 1996. As with Mound's excavation activities, outside subsurface work involved using a backhoe to remove soils. Inside subsurface work at M&C involved shoveling and snaking soils and drain residues. Also like Mound, there was sporadic and inconsistent application of water used as a dust suppressant during outside and inside subsurface work. Windbreaks, tents, or ventilation were also not used.

  Therefore, the Mound excavation activities and the outside subsurface work at M&C are substantially similar. There could be differences that make the Mound excavation activities more likely to generate airborne dust than the *inside* subsurface work at M&C; however, the Mound data provide a plausible upper bound for M&C dust loading.

- **Temporal Considerations -** The era of excavations at Mound (1996) and at M&C (1968-1996) are similar enough when considering the equipment, methods, and work performed at both sites. For example, the hi-volume air samplers used for the Mound study are still an appropriate method for quantifying dust loading to this day. Furthermore, the passage of time has not significantly altered backhoe operations, or their ability to generate airborne dust.
- **Data Evaluation -** The quality of the mound surrogate data, depicted in Figure 1 above, can be described as having a high degree of precision and consistency throughout the 294 samples, with a geometric standard deviation of 2.167.
- **Review of Bounding Subsurface Exposure Models -** The geometric mean (7.18×10^{-5} g/m^3) and 95th percentile dust-loading factor (2.2×10^{-4} g/m^3) calculated from the Mound study are realistic to use for M&C subsurface exposure modeling. The dust-loading factor is more than double the ORAUT-OTIB-0070 (2012) default value (described above to be unrealistically low for modeling M&C operations).

In addition to the OCAS-IG-004 criteria, another method to assess if the 95th percentile dust-loading factor is appropriate for modeling M&C subsurface work is to compare the urinalysis results for remediation workers to the postulated model. CPS conducted remediation of the Burial Area in 1993 (CPS 1993), which involved the use of a backhoe, hand shoveling, and screen separation of soils. CPS's use of water as a dust suppressant was sporadic and not consistently applied largely because the water table was encountered at a depth of approximately 6 feet (ORAUT 2017-j, PDF p.6; ORAUT 2017-h, PDF p. 11; ORAUT 2017-d, PDF p. 5, 6; ORAUT 2017-e, PDF p. 5; ORAUT 2017-g, PDF p. 14, 15). In addition, CPS did not use windbreaks, tents, or ventilation. During this work, *in vitro* bioassay was performed for all site personnel requiring access to the Burial Area Exclusion Zone during excavation. The bioassay process involved fluorometric analysis of uranium within urine. At no time did the bioassay results exceed action levels (45 pCi/L) specified within the Health and Safety Plan (CPS 1992-b, PDF p. 30), and all reported values were less than 4 μg/L total uranium (CPS 1992-b, PDF p. 49).

In 1994, CPS conducted remediation of the Metals Recovery Area using the same methods as before; however, they performed bioassay for only the primary excavation personnel. The scope of urinalysis was limited this time based on air sampling results. The bioassay process again involved fluorometric analysis of uranium within urine, and all reported bioassay results were less than 1 μg/L total uranium (CPS 1994, PDF p. 31).

NIOSH projected the amount of uranium that could be collected from a reference man breathing air at a concentration of the proposed 95th percentile dust-loading factor (2.2×10^{-4} g/m^3) for 30 days. The calculation determined that M&C subsurface workers, for the three uranium solubility classes, should have an expected excretion rate of Type F 268 μg/L, Type M 40 μg/L, and Type S 1.2 μg/L at the end of a 30-day exposure. Comparing these calculated results with the measured results for the CPS workers (4 and 1 μg/L) demonstrates that the selected dust-loading factor is bounding and claimant favorable.

For comparison and perspective, it may be useful to consider the full-scale remediation of M&C's worst-case subsurface contamination. A report from remediation contractor Weston, from July 1995 through September 1996, describes the work controls and exposures associated with extensive remediation of the Building 10 subsurface. During this work, Weston removed and disposed of all the Priority-1 drain lines and surrounding soils, including 520 linear feet (LF) of 4-inch vitreous clay drainpipe, 400 LF of 4-inch cast iron drainpipe, and 360 LF of 4-inch polyvinyl chloride drainpipe. An additional 620 LF of Priority 2 drainpipes were decontaminated in place during this work. Standard removal techniques included using concrete saws, breakers, and heavy equipment such as Bobcats and backhoes. No respiratory protection was required, and safety measures such as dust suppressants, containment tents, or ventilation were used sparingly. Photos of this work depicting personal protective clothing and work controls are available in a slide presentation regarding the decommissioning efforts (Elliott 1996 PDF p. 15). Comprehensive personal monitoring was performed; all Weston workers performing this remediation of the "motherlode of M&C contamination" were assigned doses of 20 mrem/quarter TEDE (Weston 1996-c, PDF p. 21).

Therefore, the default ORAUT-OTIB-0070 (2012) dust-loading value will be increased to the 95th percentile value of 2.2 x 10^{-4} g/m^3 (220 μg/m^3) from the Mound Project study, and when multiplied with the 95th percentile value-specific-activity of the applicable volumetric sample data, results in air concentrations of:

- Inside uranium: 1.52 E-12 μCi/ml;
- Outside uranium: 2.59 E-14 μCi/ml; and
- Outside thorium: 1.93 E-14 μCi/ml.

BUILDING 10 ROOF AND OVERHEAD AREA

During the AWE operational period (1952-1968) major portions of Building10 were engaged in the manufacture of nuclear reactor fuel for the U.S. Navy and commercial power and AEC research reactors, along with various components of natural and depleted uranium. With the exception of the High Flux Isotope Reactor (HFIR) project, these operations were concluded by 1968. The building areas used for the concluded operations were then decontaminated, surveyed for radioactivity, and released for general use between 1966 and 1968. Since that time, the AWE areas were used for manufacturing with non-radioactive materials (Texas Instruments 1982, PDF p. 12).

M&C AWE operations involved numerous metal finishing operations including melting, forging, extrusion, rolling, chemical milling, machining, welding, and assembly. Several of these operations would have generated fumes and aerosol particulate emissions captured by the local exhaust ventilation and deposited on the roof or on roof-mounted equipment (Elliott 2018, PDF p. 5; ORAUT 2017-j, PDF pp. 6, 13). In addition, some contaminants generated during AWE operations that may not have been captured by ventilation were resuspended and accumulated in the overhead area.

Building 10 underwent numerous upgrades and modifications after HFIR operations ceased in 1981 (Weston 1996-c, PDF p. 7). However, prior to 1981 the Fuel Manufacturing Area (FMA) was separated into two areas by floor-to-ceiling partitions: (1) the Unclad Fuel Manufacturing Area (UFMA), which was dedicated to fabricating bare uranium materials and was considered a contaminated area, and (2) the Clad Fuel Manufacturing Area (CFMA), which handled only clad material and was maintained as a clean area. Figure 2 shows a diagram of the Unclad and Clad fuel-manufacturing areas that was separate from the HFIR area. The UFMA, approximately 1,200 ft^2 in size, was surrounded by the CFMA, approximately 14,000 ft^2 in size, and was maintained at a negative pressure relative to the surrounding CFMA. No exposed or unclad special nuclear material (SNM) was processed in the CFMA (NRC & Texas Instruments 1982-1983, PDF pp. 15, 53; Ketzlach 1978). All unclad SNM processing in the UFMA was performed in dry boxes or hoods with ventilation conforming to NRC requirements (NRC & Texas Instruments 1982-1983, PDF pp. 15, 52). Two exhaust fans ventilated and removed air from the UFMA. One ventilation stack equipped with a high-efficiency filter exhausted air from the press room in the UFMA at a rate of 616 ft^3 per minute (cfm), and another stack exhausted air from the furnace area at a rate of 500 cfm (Texas Instruments 1979, PDF p. 17).

During the HFIR D&D verification inspection conducted by the NRC from August 31 through September 2, 1982, the NRC surveyed the roof of Building 10 near the exhaust from the high-efficiency filter system and the exhaust from the fuel manufacturing area and the ceiling, walls, and columns of the general manufacturing area (outside the fuel manufacturing area) (NRC & Texas Instruments 1982-1983, PDF p. 16). Four hundred ten (410) individual direct alpha, beta-gamma measurements were taken during this NRC inspection. Direct alpha measurements did not exceed 600 dpm (95% < 50 dpm) except for two ceiling grids that were 1200 dpm and a third ceiling grid that was 1300 dpm. A total of one hundred fifty-four (154) wipes for removable alpha and beta contamination were taken during this NRC inspection. All wipes for removable contamination were less than 200 dpm alpha, and 50 dpm beta (the majority being less than 10 dpm alpha, 30 dpm beta) with the exception of one wipe on a ceiling pipe being 543 dpm alpha and 357 dpm beta. The NRC concluded that fixed and removable contamination levels measured during the inspection were comparable to those in M&C's closeout survey (NRC & Texas Instruments 1982-1983, PDF p. 17).

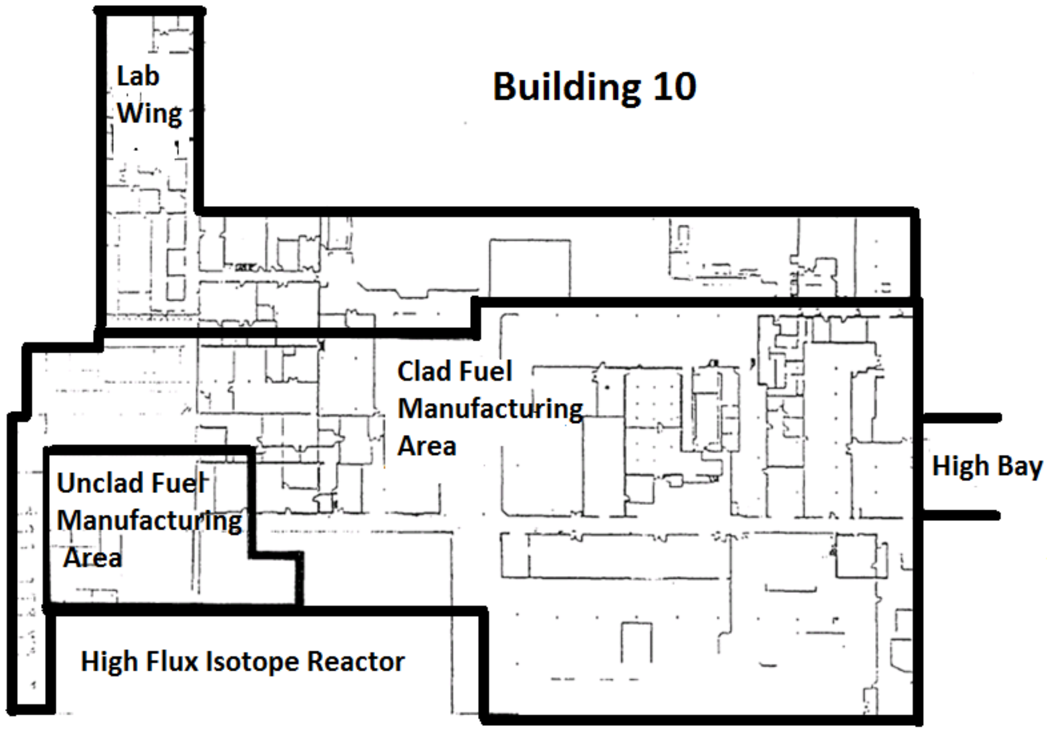

Figure 2 (From SEC 236 ER p. 16). Diagram of Clad and Unclad Fuel-Manufacturing Areas

Although the HFIR project area was released for unrestricted use following the closeout survey (NRC & Texas Instruments 1982-1983, PDF p. 12), at that time M&C could not locate documentation verifying that the areas used for AWE operations had been successfully decontaminated between 1966 and 1968. To remedy this, M&C performed verification surveys of the AWE areas and submitted a report to the NRC by letter dated November 2, 1982, to show that the AWE areas were successfully decontaminated prior to 1968 and remain so. This report included surveys of the walls and ceiling vault of the UFMA (outside the HFIR project area) (Texas Instruments 1982, PDF pp. 13, 16).

On January 31-February 2, 1983, the NRC performed a closeout inspection of facilities formerly engaged in AWE operations, including a review of the licensee's survey report and independent measurements in Building 10. The inspection involved 43 direct inspection hours by two NRC region-based inspectors and included verification surveys of the former fuel vault ceiling and walls. Nine hundred thirty-eight individual, direct alpha, beta-gamma, and gamma radiation measurements were taken in the AWE areas. Direct alpha measurements did not exceed 175 dpm/100cm^2 (92.6% < 50 dpm). The NRC concluded that fixed and removable contamination levels inside the AWE areas, measured during their inspection, were comparable to those in the M&C closeout survey (NRC & Texas Instruments 1982-1983, PDF pp. 6-9).

Building 10's roof is built-up with tar and gravel. Insulation and a vapor seal are placed between the tar and the steel-sheet channels that form the building's ceiling. Steel beams and trusses in the high bay (24 ft) areas and I-beams in the low bay (15-17 ft) areas (ASTRA 1962, PDF p. 24) support the roof.

During the residual period, while performing maintenance work in the Building 10 overhead area and on the roof, M&C workers were potentially exposed to contamination remaining from AWE operations. This work included installing pipe racks; replacing lights; welding supports to the trusses to fortify the roof; cutting and drilling up through the roof to make penetrations for running services to rooftop equipment such as air-conditioning systems, recirc water, chilled water supply and return, steam and condensate return; and installing equipment on the roof (ORAUT 2017-a, PDF p. 4; ORAUT 2017-g, PDF p. 7).

NIOSH is aware that contractors and M&C maintenance workers vacuumed and cleaned the overhead area. However, for the most part, reports indicate that the overhead area contained a large amount of accumulated dust (ORAUT 2017-h, PDF p. 12; ORAUT 2017-e, PDF p. 10).

BUILDING 10 ROOF AND OVERHEAD AREA BOUNDING EXPOSURE MODEL

Texas Instruments divided the areas to be surveyed into one-meter square grids. NIOSH used the 285 grid average alpha-contamination survey results taken in 1982 (prior to the 1996 D&D) to characterize the roof and overhead work environment. The survey results were from direct probe measurements of total surface contamination; therefore, NIOSH will assume that 10% of the measured activity was associated with removable activity per guidance in ORAUT-OTIB-0070. Ten of these survey results are from the walls and ceiling of the Unclad Fuel Manufacturing Area outside of HFIR (Texas Instruments 1982, PDF p. 27) and 275 from the General Manufacturing Area (outside the Fuel Manufacturing Area) on the ceiling, pipes, bus ducts, wall and columns (1.5 meters high to ceiling), and the roof near the ventilation exhaust ducts. These surveys were performed by M&C and verified by NRC inspectors (NRC & Texas Instruments 1982-1983, PDF pp. 70-72, 75-83, 140-141).

NIOSH used the survey results and determined the GM removable contamination level (1.09 dpm/100 cm^2) and the GSD (3.61).

The Building 10 overhead and roof areas required frequent maintenance during the residual period, including the years prior to the surveys used to characterize this area. Since this maintenance could have potentially removed accumulated dust with the highest uranium concentration and made the GM value under-conservative, NIOSH calculated the 95^{th} percentile contamination level (8.99 dpm/100 cm^2) and will use it to bound exposures.

Maintenance workers often performed aggressive operations (e.g., cutting and drilling) that would disturb the heavy accumulated dust in the overhead; therefore, NIOSH will apply a resuspension factor of 10^{-4} for this work. NIOSH used the 95^{th} percentile contamination level, the GSD, and resuspension factor to determine the air concentration that roof and overhead maintenance workers were exposed to (4.05 E-14 μCi/ml).

INGESTION RATES

Ingestion rates were determined using NUREG/CR-5512 (1992) Volume 1. Section 6.3.2 methods (50 mg/workday) will be used for subsurface work, and a factor of 10^{-4} m^2/hour will be applied to the surface contamination levels for roof and overhead work.

EXTERNAL RATES

Film badges at the end of AWE operations (i.e., 1967) were processed quarterly by Landauer (Landauer 1967). NIOSH will use all of the 1967 results and determine the quarterly, GM dose, and the GSD. Since the maintenance work lasted no more than two months per year, external exposures will be assigned at the rate of two thirds the quarterly dose rate determined for the beginning of the residual period using the quarterly GM dose and GSD. No source-term depletion will be applied because of the potential for the maintenance area environments (e.g., inside clogged drains, rafters) to be less impacted by environmental reduction factors and routine cleaning.

OCCUPANCY RATE

Based on affidavits and interview responses, NIOSH will assume an occupancy rate of 1 month per year (i.e., 173 hours or 22 workdays) for subsurface work. If the subsurface work area (e.g. inside or outside) cannot be determined, the most claimant favorable work location will be assigned. In addition, NIOSH will assume an occupancy rate of 1 month per year (i.e., 173 hours or 22 workdays) for the roof and overhead work; for a total of 2 months per year for the typical maintenance worker. Maintenance workers will also receive assigned residual exposures for the remaining 10 months of each year at the same rate as the other workers that did not perform maintenance work.

CONCLUSION

NIOSH has considered all of the information presented in this paper and has used it to develop a maintenance worker exposure model for Metals and Controls Corp. that accounts for the descriptions of work by former employees, pre-remediation sample data, and a realistic dust-loading model. NIOSH believes that this model adequately bounds maintenance exposures experienced by M&C workers during the residual radiation period.

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