Response to Comments from the Metals and Controls Corp. Work Group Meeting held on September 2, 2020

Response Paper

National Institute for Occupational Safety and Health

January 21, 2021

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INTRODUCTION

On September 2, 2020, during an M&C Working Group (WG) meeting, SC&A and NIOSH presented updates to the Working Group and petitioners. After the presentations, 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 transcript followed by NIOSH responses. Verbatim text is italicized.

WG Comment 1: A Working Group member expressed a concern that there were additional fires or explosions beyond the aluminum dust explosion addressed by NIOSH in a previous response paper, *Response to Metals and Controls Corp. Working Group Comments* [NIOSH 2020a, PDF pp. 24-25].

> *Chair Beach: One of them was explosions in the manholes. And they knew that because they had to go in and clean up in the manholes from those fires and explosions. And then, another reference, there was explosions in Building 10 all the time. So, I know your comment leads us to believe that as soon as there was the fire and explosion, everybody moved out. But I think there was more fires, maybe, in different parts of the building, based on the other interviews. And it wasn't always the case, they moved everybody out. So that's just my comment on that* [NIOSH 2020b, PDF pp. 44–45].

NIOSH Response to WG Comment 1: NIOSH reviewed the interview transcripts, including those mentioned by the WG member at the September 2, 2020 meeting. The following is a summary of those transcripts.

Fires:

Regarding fires at M&C, one interviewee stated that uranium would sometimes catch on fire. This individual also remembered a metal fire on the roof of Building 10 in the late 1980s. The individual speculated that the roof fire started after magnesium debris from the production area was deposited there by an exhaust fan [ORAUT 2017a, PDF pp. 9–10].

Positive temperature coefficient (PTC) powder explosion:

Another interviewee described a PTC powder explosion in the late 1980s or early 1990s that shook Building 10 and caused dust to fall from the ceiling area. The individual believes that the explosion occurred because PTC accumulated in the ceiling area and was then detonated by an ignition source in the fire blast room. In response to the explosion, M&C hired a subcontractor to clean the area, including wiping down the overhead and everything below [ORAUT 2017a, PDF pp. 9–10].

Other explosions:

A third interviewee described dust explosions in Building 10's Flame Spray Area. These were associated with the propane and hydrogen furnaces employed to anneal metal. In response, M&C converted their furnaces from gas-fired to electrical units, and eventually got out of the metal-annealing business. This individual also mentioned explosions in the electrical-buss ducts in Building 4, as well as a couple of explosions in electrical manholes between Buildings 10 and 4 [ORAUT 2017b, PDF pp. 16–17].

NIOSH examined the events referenced by the WG member and has not identified a significant radiological component to any of them. For example, NIOSH is not aware of radioactive material storage in manholes at M&C. In addition, NIOSH reviewed SRDB reports for additional information regarding these or any fires and explosions and has not found any reports that indicate a potential for radiation exposures beyond those that are already bounded by existing contamination-resuspension exposure models, or that indicate its proposed path forward is not bounding.

From its research, NIOSH has not found indications that "… there was explosions in Building 10 all the time," as related by a WG member (see WG Comment 1). Furthermore, NIOSH did not intend to imply that "… as soon as there was the fire and explosion, everybody moved out." NIOSH was, however, trying to convey the site's response to a specific fire as indicated by available reports.

WG Comment 2: The WG asked if the drain lines in Building 10 were used during the residual period, and if using the drain lines would reduce the concentration over time due to the addition of non-radioactive material. Also, a WG member asked about sample data from one pipe in the west end of Building 10 that was one million dpm/100 cm^2 [NIOSH 2020b, PDF pp. 51–59].

> *Chair Beach: Well, if you go back to Linde, Linde was two populations. One was a low dose and one was a higher dose and you really didn't know what the exposure potential was and I guess that's my argument here is there was one pipe in that west end that was up to a million that they found. So with the cleanup that was involved, you don't really know how much of the source term was taken out of there in that 30, or 15 to 30-year period* [NIOSH 2020b, PDF pp. 16–17].

> *Chair Beach: …There's nothing really here that gives us an actual concentration activity distribution for maintenance and cleaning that was performed. How do we know what was cleaned out of the pipes? And how does that -- would it degrade over time? Bob Barton brought up an interesting topic, looking at the scale and how it degrades over time. Is that something that we can explore for M&C?*

> *Dr. Mauro: …your concern is that, as I understand it, is that drainage has residue in it that would deposit in the pipelines of interest to us, diluting the concentrations of the uranium. So that what we're looking at in 1996 by way of distributions of uranium in pipelines may be lower than what was actually there in the 1970s because of this*

accumulating residue. …were those drainage lines in operation during the AWE period? And I'm not quite sure whether that's the case. If they were not, then this issue goes away. If they were, then it becomes a question, okay, to what degree could there have been some dilution.

Mr. Barton: … when we're dealing with something like pipe scale, you know, that contamination is placed, you know, 1968 or whenever AWE operations ended. And then, several decades pass. And if you are still using that drain line, then basically what you, or at least to me, would logically end up with is a combination of the contaminated scale and non-contaminated scale that just builds up over time. So I guess the simple question is, when we look at the 95^th^ percentile in the 90s, is that really reflective of what the 95^th^ percentile would be in the 80s and the 70s? [NIOSH 2020b, PDF pp. 51–54].

NIOSH Response to WG Comment 2: Although there are reports of drain-line work from interviewed workers, NIOSH has not found any records indicating that major sections of drain lines were isolated or bypassed. The suggestion that only non-radioactive material was added to the drain lines after the cessation of AWE operations in 1967 is not accurate for Building 10. Non-covered HFIR operations continued until 1981. In fact, from 1967 until 1981, the only nuclear work performed at M&C was the manufacture of fuel elements for HFIR [Texas Instruments 1996a, PDF p. 13]. Therefore, it is likely that radioactive sediment contributions to the drain lines continued until 1981 from HFIR, and afterward from D&D activities until the drain lines themselves were removed in 1996. If anything, this makes the NIOSH model more conservative because of the contribution of HFIR radioactive material (not EEOICPA-covered) to the subsurface source term.

Furthermore, regarding the AWE source term at M&C, it must be noted that at least 80% of the work performed with radioactive materials was for the naval reactors program (not EEOICPA-covered). The remainder was for the Air Force's Aircraft Nuclear Propulsion Program (also not covered), the AEC's national laboratories, and government-funded research reactors [Texas Instruments 1996a, PDF p. 9].

So again, NIOSH's bounding method is conservative because the doses assigned during the residual period do not subtract more than 80% of the non-covered source term. When this fact is combined with the other elements of NIOSH's bounding model (e.g., the same person doing all the work, the use of the 95^{th}-percentile contamination level, a 212 $\mu g/m^3$ dust load for wet sediment, assuming all airborne sediment is respirable, and using the most claimant-favorable solubility type), NIOSH believes it has estimated the maximum radiation dose that could have been incurred by workers during the residual period. NIOSH also agrees with the following point raised by SC&A:

In order for those levels of exposure to occur, we're assuming that the soil beneath Building 10, which is one of the dominant pathways, is at about 1 percent of the concentration of natural uranium. And now, if you think about the volume of soil underneath Building 10, we're talking about tons of uranium that were lost in the AWE handling. So in effect, it's a circumstance that I believe is a substantial overestimate

> *because no NRC operation is going to proceed and allow the loss of thousands and thousands of pounds of uranium in the process.*
>
> *This is almost prima facie evidence that the fundamental strategy we're using is extremely conservative. Because if that much uranium was lost, it would have been, now we're talking during the AWE operations which is responsible for the subsurface uranium in the AWE period.*
>
> *So this is something we've never mentioned before. And it gives another level of argument of why the scenarios we picked are extremely conservative. I hope you understand the point I'm making… That we've truly bounded what might have been in the subsurface environment because at that level at that one percent of the uranium, that would be quite a loss of processed uranium that would have occurred and would have been noticed by the NRC* [NIOSH 2020b, PDF pp. 24-25].

In an attempt to understand the non-uniform subsurface activity and determine if something abnormal was involved with the scaling of M&C drain lines, NIOSH examined similar conditions at other AWE sites. Six sites were identified that documented drain-line sediment sample results. These data were used to determine if the M&C results were significantly different from the other sites. The six sites reviewed were Vitro Rare Metals Plant, Bridgeport Brass (Adrian Site), Horizons Metal Handling Facility, Peek Street, Mallinckrodt, and De Soto. Table 1 below summarizes these data.

Table 1. Comparison of Sporadic Drain-Line Hot Spots for Six AWE Sites.

SRDB Ref ID	Site	Report Year	Highest Results for Drain Sediment	Summary of Results
3737, PDF pp. 63, 138, 144, 186, 192, 199	Vitro Rare Metals Plant	1978	270 pCi U-238/g	Ten total samples. All other results range from 2.5 to 51 pCi U-238/g.
14422, PDF p. 30	Bridgeport Brass, Adrian	1982	11,000 pCi U-238/g	Three sample results reported. Other results were 20 and 480 pCi U-238/g.
16269, PDF p. 63	Horizons Metal Handling Facility	1977	No uranium. 2,530 pCi Th-232/g	34 sample results reported. All others were negative except for three samples. Other positive samples were 10, 13, and 318 pCi Th-232/g.
33259, PDF pp. 50–53	Peek Street	1994	430 pCi U-238/g	43 sample results reported. All but one ranged from 0.72 to 57 pCi U-238/g. The exception was 200 pCi U-238/g.
74779, PDF p. 133	Mallinckrodt	1978	56,000 pCi U-238/g	Seven sample results reported. Five were in the range from 25 to 110 pCi U-238/g. The other two were 1,780 and 11,700 pCi U-238/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 cases above, the maximum specific activity was at least an order of magnitude larger than the majority of the other samples, which indicates the presence of sporadic hot spots (similar to M&C). Therefore, NIOSH believes there was not a significant difference in the mechanism of deposition and accumulation of sediment and pipe scale at M&C when compared to other sites.

In summary, the sample data that NIOSH used was collected by M&C to assess the potential for inadvertent exposures to non-radiological workers performing routine drainage-system maintenance [Texas Instruments 1996b, PDF p. 7]. The petitioner stated that this 1995 drainage-system survey represents conditions before D&D activities; therefore, it offers "good insight into conditions to which employees were exposed" [redacted 2016].

Regarding the sample data from one pipe that was one million dpm/100 cm^2, NIOSH found the following information:

> *During contaminated concrete removal at the north side of the Screen Print Room (Area 7), the initiation point of a 4-inch vitreous clay (VC) mainline was encountered. This line exhibited surface contamination levels (on the pipe interior) as high as 1,000,000 dpm/100 cm^2, although did not contain a visible accumulation of residue. Approximately 15 feet of line was removed until surface contamination levels within the pipe were reduced to background levels. Minor soil contamination was noted near the initiation point of the line and excavated. Soil concentrations were 71.6 and 9.8 pCi/g in soils near the initiation point and line-removal termination point, respectively. In contrast to the Caged Area, the Screen Print Room uranium enrichment indicated previous use of depleted uranium* [Texas Instruments 1996b, PDF pp. 10–11].

When NIOSH models exposures to workers during excavation-type operations, it believes it is appropriate to use mass-based sample data (e.g., pCi/g) to characterize the exposure environment. Typical soil-sampling plans are designed to provide characterizations that enable NIOSH to develop models more representative of the subsurface work than do swipes of surface contamination. Although there is potential for isolated hot spots, there is no indication (nor would one expect there to be an indication) of systemic conditions at these hot spot levels. Therefore, NIOSH considers the use of the 95th percentile to be bounding.

WG Comment 3: A Petitioner and a Working Group member expressed concern regarding the routine alpha contamination surveys performed in Building 10 as described by NIOSH in the response paper, *Response to Metals and Controls Corp. Working Group Comments* [NIOSH 2020a, PDF pp. 22–23].

> *Petitioner: NIOSH asserts that M&C performed routine alpha contamination surveys in Building 10 during the first 14 years of the residual period, from 1968 to 1981. I personally -- mind you, I didn't start until 1983, working at M&C -- but I personally have never before heard mention of such routine alpha contamination surveys. And I've never seen any data of these surveys in Building 10. Presumably, if they did, in fact, take place, they likely would have been limited to the small area where M&C continued to conduct fuel manufacturing until 1979 to support the high-flux isotope reactor program, or HFIR, not the entire building* [NIOSH 2020b, PDF p. 112].
>
> *Chair Beach: …the first 14 years of the residual period. The '68 '81 timeframe. For you have samples. There's no SRDB noted with that paragraph so I wasn't able to go back and find where you're getting those doses and that seems to be new information to me. Can you go back and tell us where those air samples are, what document?* [NIOSH 2020b, PDF p. 31]

NIOSH Response to WG Comment 3: In *Response to Metals and Controls Corp. Working Group Comments* [NIOSH 2020a, PDF pp. 22-23], NIOSH attempted to make the case that M&C's area monitoring assures that the 95th percentile soil-contamination value is conservative based on routine surveys of Building 10 during the first 14 years of the residual period (1968-

1981). In its response, NIOSH did not address doses or air samples, as mentioned in the WG member's quote above.

To make its case, NIOSH referenced the Metals and Controls Health and Safety Manual that was in place at the start of the residual radiation period. NIOSH believes this manual adequately describes M&C's established concern for contamination control, as follows:

> *…Therefore procedures have been established for the control of surface contamination to reduce the possibility of spreading significant amounts into uncontrolled areas whereby both individuals and product may be exposed to excessive levels of radioactivity. It is the policy of M&C to maintain levels of surface contamination as low as may be practical…* [Metals and Controls 1968, PDF p. 9].

The M&C manual instituted requirements for routine work-area contamination surveys. Surveys were required of personal shoes and clothing, any item leaving the work area, and all production materials before entering the work area. The manual also required the constant review of these surveys by supervisors, and investigations if control levels were exceeded [Metals and Controls 1968, PDF. pp. 9–10].

In addition to the information previously provided, NIOSH is aware that the NRC enforced these contamination surveys so that whenever M&C wanted to change administrative requirements (e.g., frequency of surveys), they sent a request to the NRC [Texas Instruments 1976, PDF pp. 8–45].

NRC inspections during the residual period provide NIOSH with independent assurance that radiological controls were monitored or maintained [AEC 1963–1971, PDF pp. 9–16; NRC 1981–1982]. NRC inspectors stated:

> *Each of the four operators interviewed demonstrated good knowledge of the nuclear safety requirements for the operation… They also demonstrated knowledge of the precautions they should take for their personal radiation protection. There was only one difference between the operations described by the operators and the operation described in the Standard Operation.* [NRC 1981–1982, PDF p. 15].
>
> *The alpha survey instrument used at the exit from the Fuel Manufacturing Area (FMA) was operating properly. The inspector observed that the operating personnel surveyed themselves upon leaving the FMA* [NRC 1981–1982, PDF p. 15].
>
> *The licensee also had a record of the training of an individual in health physics. This individual assumed some of the health physics duties after this training* [NRC 1981–1982, PDF p. 16].

The areas where AWE facility weapons-related operations occurred were cleaned as those operations ended [NRC 1982, PDF p. 15]. There are contamination surveys available for the first two years of the residual period (1968–69). Table 2 below shows the survey locations within Building 10.

Table 2. M&C Contamination Survey Locations in Building 10.

SRDB Ref ID	Location
69269	Locker Room
69271	Lunch Room
69276	Machine Shop
69293	X-ray and Inspection Area
69167	Furnace Area
69181	Acid Room

Additional survey data can be found in the summary table of historical alpha contamination compiled as part of the HFIR environmental monitoring program. That historical summary has been recreated below as Table 3.

Table 3. Typical Contamination Survey Results for the M&C HFIR Project.

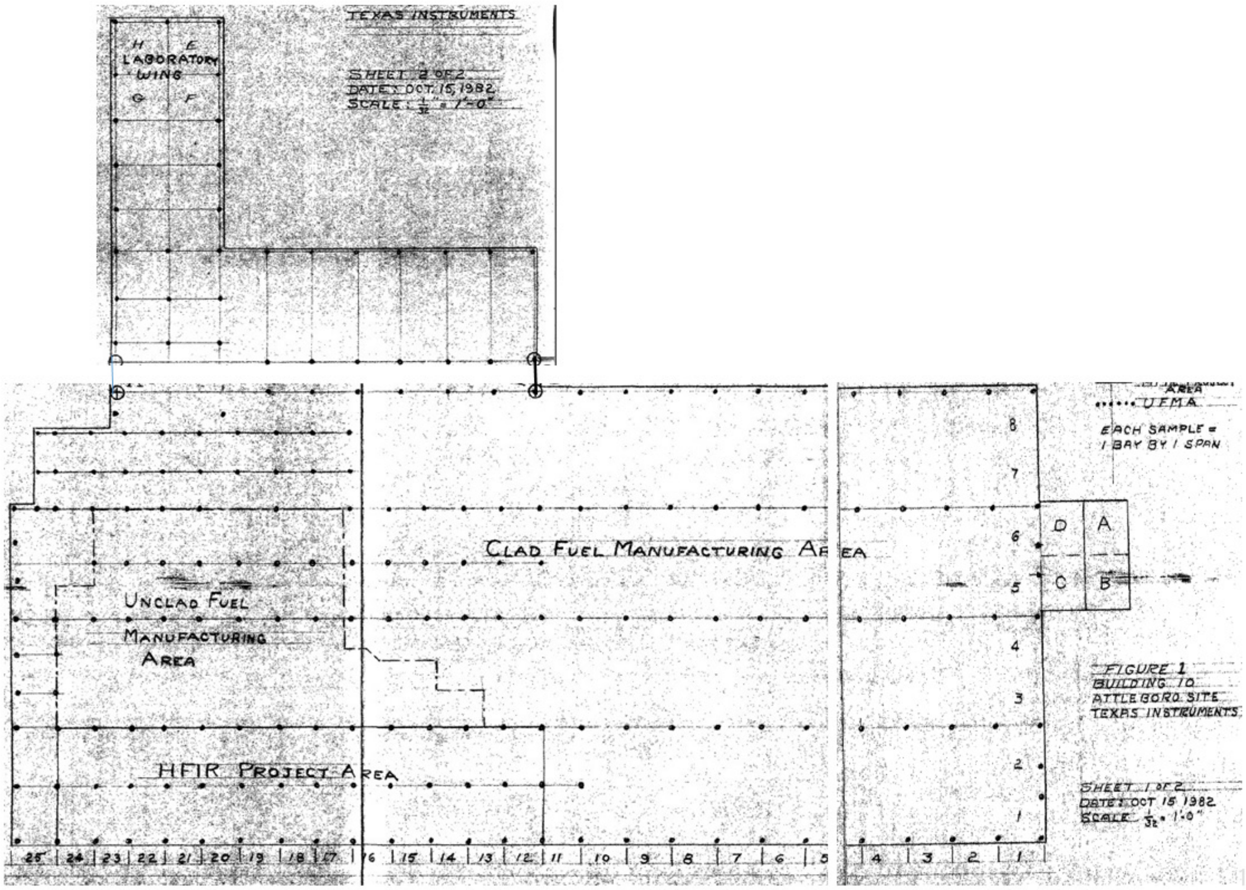
Area Surveyed	Removable (dpm/100 cm^2)	Fixed (cpm/100 cm^2)
FMA walls	24	320
FMA floors	284	2800
FMA equipment	800	10600
Personnel Pass-through Room (PPR) walls	<10	<80
PPR floors	<10	<40
PPR equipment	<10	<40
Outer clothing for exiting FMA	<50	<400
Protective clothing within FMA	<500	<50000
GMA walls	~1	<5
GMA floors	~1	<5
GMA equipment	~1	<5
Exposed skin of personnel entering GMA from FMA	~1	<50
Items and equipment entering GMA from FMA	~1	<5

Source: Texas Instruments [1979], PDF p. 45

Note: Contamination surveys of the Personnel Pass-through Room were performed weekly; GMA surveys were performed monthly [Texas Instruments 1979, PDF p. 17].

Note: The majority of Building 10 was designated as the general manufacturing area (GMA) [aka the Clad Fuel Manufacturing Area]. This was the area where clad special nuclear material (SNM) was permitted to be handled. The fuel manufacturing area (FMA) [aka the Unclad Fuel Manufacturing Area] was a smaller area surrounded by the GMA where unclad SNM was handled.

Figure 1 below presents the Building 10 floorplan layout, which illustrates the relative sizes of the various work areas, especially the Clad Fuel Manufacturing Area (surveyed monthly) [Texas Instruments 1979, PDF p. 13].



Source: NRC [1982], PDF p. 18

Figure 1. Building 10 Floorplan Layout (1982)

In 1979, M&C stated that they had been able to maintain control of contamination because of:

> *…the administrative attention given to maintaining the confinement of radioactive material and controlling the spread of area surface contamination. Also, the powder is dense material and does not aerosol. The most significant cause is the well-defined, simplified, and production required process steps of handling the material. Neither methods of handling (e.g., process flows) nor material characteristics (e.g., coarse particulate) are permitted to be altered without consideration for the impact on health physics. The results of these administrative practices form the basis for the adequacy of the HFIR Project Environmental/Bioassay Monitoring Program* [Texas Instruments 1979, PDF p. 43].

WG Comment 4: A WG member requested that NIOSH provide a consolidated list of the exposure models that will be used to bound exposures for SEC-00236.

> *Chair Beach: I just think we need to get our hands around exactly what NIOSH is planning on doing, and then SC&A. Because we keep coming up with all these different models and I don't know about anybody else, but it is, it's a lot to throw in, for my mind. And you just get back to the basics of what samples do you have? Do you have samples of thorium in the pipes? No. So you're using models from outside that are, in my mind, not a good representation of what happened at M&C* [NIOSH 2020b, PDF p. 92].
>
> *Chair Beach: … I need to ask NIOSH to fine-tune what they're going to use. You have several of your own models. You have SC&A's models. Where are we at? What is NIOSH going to use to reconstruct those for the workers at Metals & Controls?* [NIOSH 2020b, PDF p. 106]

NIOSH Response to WG Comment 4: Since the SEC-00236 ER was presented to the Board in August 2017, NIOSH and SC&A have had numerous exchanges while developing these exposure models. The resulting models that NIOSH intends to use to bound exposures reflect those extensive efforts. They are provided below.

Subsurface Inside

The subsurface work environment inside Building 10 was characterized by 20 sediment samples that were collected and analyzed for isotopic uranium before remediation. The drainage system required frequent maintenance during the residual period, including the years before the characterization. Since this maintenance could have removed the sediments with the highest concentration, NIOSH calculated the 95^{th} percentile concentration (6,888 pCi/g) and will use it to bound uranium exposures [NIOSH 2018a, PDF p. 8].

Although M&C analyzed Building 10 subsurface samples for uranium, NIOSH can bound thorium exposures by assuming the subsurface sediments contained equivalent amounts by weight of natural uranium and thorium-232. Since the specific activity of natural uranium is 6.83E5 pCi/g [NIOSH 2006], the 95^{th} percentile concentration (6,888 pCi/g) corresponds to approximately 1% natural uranium by weight in the sediment. Therefore, NIOSH can assume the Building 10 subsurface sediments were contaminated with 1% of the specific activity of thorium-232 (1.1 E5 pCi/g) per gram of sediment. Using this approach, NIOSH calculated a concentration of 1,109 pCi/g and will use it to bound thorium exposures [NIOSH 2019, PDF p. 8].

Subsurface Outside

The 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 before remediation. Of these samples, 1,629 were analyzed for gross alpha, and the remaining 762 were analyzed for isotopic uranium and thorium.

The outside subsurface areas required frequent maintenance during the residual period, including the years before characterization. Since this maintenance could have removed sediments with the highest concentration, NIOSH calculated the 95th percentile uranium concentration (117.86 pCi/g) using the gross alpha and uranium samples, and the 95th percentile thorium concentration (87.55 pCi/g) using the gross alpha and thorium samples and can use these values to bound exposures [NIOSH 2018a, PDF p. 9].

Dust Load Factor for Inside and Outside Subsurface Work

NIOSH examined an excavation at the Mound site and determined it to be a useful general model for dust loading during excavations of soils and plans to include it in the next ORAUT-OTIB-0070 revision [ORAUT 2012]. This model is directly applicable to M&C's Outside Area excavations and conservatively bounds M&C's Inside Building 10 work.

In the initial subsurface exposure models for M&C, NIOSH used the 95th percentile dust-load value calculated by Mound employees for use at their site. However, additional Mound data became available and NIOSH evaluated it. There were three areas monitored at Mound: the excavation itself, the staging area, and the support area. The excavation area had the highest concentrations at 213 µg/m^3, followed by the staging area (where a front-end loader dumped soils into railroad cars) at 212 µg/m^3, and the support area, which had the lowest concentrations at 137 µg/m^3. NIOSH did not use the data from the support area because it was described as a non-working, background type of area. Using this more complete data set, NIOSH calculated an empirical 95th percentile value of 212 µg/m^3 and can use this value in conjunction with the 95th percentile uranium and thorium concentrations to bound exposures during subsurface work [ORAUT 2020].

Roof and Overhead Area

M&C divided the areas to be surveyed into one-meter square grids. NIOSH used the 285 grid average alpha-contamination survey results taken in 1982 (before the 1996 D&D) to characterize the Building 10 roof and overhead work environment. The results were from direct probe measurements; therefore, NIOSH can assume that 10% of the measured activity was associated with removable activity per the guidance in ORAUT-OTIB-0070 [ORAUT 2012].

Ten of these survey results are from the walls and ceiling of the Unclad Fuel Manufacturing Area [NRC 1982, PDF p. 27] and 275 are from the Clad Fuel Manufacturing Area on the ceiling, pipes, buss 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 1983, PDF pp. 70–72, 75–83, 140–141].

The roof and overhead areas required frequent maintenance during the residual period, including the years before the surveys used to characterize these areas. Since this maintenance could have potentially removed accumulated dust with the highest concentration, NIOSH calculated the 95th percentile removable contamination level (8.99 dpm/100 cm^2) and can 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 and use the 95^{th} percentile removable contamination level to determine the air concentration that roof and overhead maintenance workers were exposed to (0.09 dpm/m^3).

Welding Operations

NIOSH characterized the Building 10 Roof and Overhead Area using the total surface activity and assumed 10% of that activity was removable and available to generate airborne activity. NIOSH can continue to assign doses using this method for other work in the overhead area (e.g., light bulb replacements); however, for welding, NIOSH will assume 100% of the activity is resuspended.

In addition, NIOSH modeled exposures for the entire overhead area uniformly using a 10^{-4} resuspension factor. NIOSH is aware that good work practice requires clean bare metal before welding, which can include wire brushing and grinding. NIOSH believes this weld-preparation work to be the portion of the welding task capable of generating the highest airborne concentration. Also, NUREG-1400 [NRC 1993] Section 1.2.3 indicates that a dispersibility factor of 10 should be used to model intakes involving grinding operations. Therefore, NIOSH will increase the resuspension factor and apply a value of 10^{-3} to the 95^{th}-percentile total contamination level.

In summary, NIOSH will use the 95^{th}-percentile total gross-alpha contamination level (89.94 dpm/100 cm^2) and a 10^{-3} resuspension factor to determine the air concentration (8.99 dpm/m^3) during the 48 hours of welding each year.

HVAC Maintenance

NOTE: Significant portions of this model were originally developed by SC&A [SC&A 2018, PDF pp. 27–29].

The geometric mean (GM, 12.3 dpm/100cm^2) was calculated from 7,765 gross-alpha swipe data collected at the end of AWE operations in 1966 and 1968 [Texas Instruments 1964–1969; 1965–1966; 1965–1969; 1966abcd; 1966–1967abcdefg; 1966–1968; 1966–1969abcd]. Using this GM surface contamination value and a 10^{-5} resuspension factor, the gross alpha airborne concentration in Building 10 was determined to be 0.0123 dpm/m^3.

Typical dust loading during normal, non-maintenance-type operations in Building 10 was assumed to be 100 μg/m^3, based on guidance in ORAUT-OTIB-0070 [ORAUT 2012]. Therefore, the estimated specific activity of the airborne dust was 0.0123 dpm/m^3 ÷ 100 μg/m^3 = 1.23E-4 dpm/μg.

Within the HVAC system, since a nuisance dust loading above 100 mg/m^3 would be barely breathable, NIOSH will assume that the worker changing the filter was exposed to this dust loading for one hour during each change-out. Under these conditions, the gross alpha air concentration would be as follows: 1.23E-4 dpm/μg × 100 mg/m^3 × 1,000 μg/mg = 12.3 dpm/m^3.

Remaining Exposures

NOTE: This model was modified after the ER was presented as a result of subsequent WG discussions regarding the use of the GM contamination level instead of the 95^{th} percentile, and the use of an increased resuspension factor.

For exposures incurred by workers for the balance of the year, NIOSH will use the GM (12.3 dpm/100cm^2) of 7,765 gross-alpha swipe data collected at the end of AWE operations in 1966 and 1968 [Texas Instruments 1964–1969; 1965–1966; 1965–1969; 1966abcd; 1966–1967abcdefg; 1966–1968; 1966–1969abcd]. Using this GM surface contamination value and a 10^{-5} resuspension factor, the gross alpha airborne concentration in Building 10 was calculated to be 0.0123 dpm/m^3. Source-term depletion adjustments (per the guidance in ORAUT-OTIB-0070) will be considered to determine the non-maintenance exposure rates throughout the residual period [ORAUT 2012].

Occupancy Rate

Based on affidavits and interview responses, NIOSH will assume an occupancy rate of two months per year for subsurface work (2000 hours per year x 2/12 {fraction of year} = 333.33 hours per year). If the subsurface work area (e.g., inside or outside) cannot be determined, the most claimant-favorable work location will be assigned.

NIOSH will assume an occupancy rate of 1 month per year for roof and overhead work (2000 hours per year x 1/12 {fraction of year} = 166.67 hours per year) [NIOSH 2018a, PDF p. 16].

Interviews conducted by NIOSH indicated that welding was one of the activities frequently performed while in the overhead area and that the amount of time spent was approximately four hours per month or 48 hours per year on average [ORAUT 2017a, PDF p. 15]. NIOSH will assume that welding tasks occupied this amount of time per year.

In the HVAC exposure model, NIOSH assumed the buildup of particulates on filters continued for one year before filter replacement, and that the worker was exposed to elevated dust concentrations inside the HVAC system for one hour per year. If it is assumed that filter replacement was performed more often, then the amount of time a worker was exposed increases; however, the quantity of uranium on the filter is correspondingly lower. Therefore, the filter-replacement frequency does not affect the annual internal doses associated with this exposure scenario.

For the remaining exposures, NIOSH will subtract the maintenance work from a 2000-hour work year and assume 1451 hours of exposure.

Ingestion

At the September 2, 2020 WG meeting, a WG member stated the following:

> *Dr. Kotelchuck: Your calculation of ingestion of radioactive material comes from resuspension and breathing in material and some of it gets into the mouth and digestive*

> *system. What about people who were working without gloves, without taking minimum precautions? But ultimately, …we who are concerned about what was going on in terms of radiation safety in that plant in that period have to be able to make a reasonable argument, or make some reasonable estimation, about the harm that's caused by ingesting unusual amounts of radioactive material because of lack of proper radiological precautions* [NIOSH 2020b, PDF p. 99].

NIOSH Response: The method NIOSH used is similar to OCAS-TIB-009 in that it accounts for any inadvertent hand-to-mouth exposures [NIOSH 2004] so that any employees in the plant (e.g., administrative) are included. Ingestion rates were determined using NUREG/CR-5512 [NRC 1992]; 50 mg/workday will be used for subsurface work, and a factor of 10^{-4} m^2/hour will be used for the other scenarios that are based on surface contamination levels [NIOSH 2018a, PDF p. 16].

Nuclide Selection

NIOSH will choose the most claimant-favorable mixture of thorium or uranium when estimating worker doses from gross alpha estimates. For thorium, both natural and triple-separated mixtures will be considered. For uranium, the alpha activity will be assessed as 100% uranium-234 and the contaminants associated with recycled uranium in Battelle-TBD-6000 will be considered [NIOSH 2006].

External Rates

Film badges at the end of AWE operations (i.e., 1967) were processed quarterly by Landauer [Landauer 1965–1974, PDF pp. 18–20, 97–133]. NIOSH used all the “X” or “Gamma” exposure results from 1967 to determine the quarterly geometric mean (GM) dose rate and geometric standard deviation (GSD). The quarterly GM gamma dose rate was determined to be 12 mrem/quarter (or 4 mrem/month) with a GSD of 2.61. Since the GSD is less than the Battelle-TBD-6000 default value of 5 [NIOSH 2006], the GSD will be increased to 5 and assessed assuming a claimant-favorable gamma energy of 100% 30–250 keV.

NIOSH used all the Type 2 or “Skin” exposure results from 1967 to determine the quarterly geometric mean (GM) dose rate and geometric standard deviation (GSD). The quarterly GM skin dose rate was determined to be 36 mrem/quarter (or 12 mrem/month) with a GSD of 1.98. Since the GSD is less than the Battelle-TBD-6000 default value of 5 [NIOSH 2006], the GSD will be increased to 5 and assessed assuming an electron energy of 100% >15 keV.

These dose rates will be applied to the maintenance work exposures with no adjustments for source-term depletion 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. For all non-maintenance work exposures, source-term depletion adjustments will be considered (per the guidance in ORAUT-OTIB-0070) to determine the non-maintenance exposure rates throughout the residual period [ORAUT 2012].

Worker Categories

At the January 9, 2020 WG meeting, NIOSH stated that all M&C workers would be assigned the doses applied to maintenance workers because it is unclear which workers were involved in various maintenance activities. Table 4 below presents a summary of annual dose estimates.

Table 4. Maximum Annual Dose Estimates.

Model	Uranium Internal Dose (mrem)[a]	Thorium Internal Dose (mrem)[a]	External Dose (mrem)	Duration of Occupancy (hr/yr)
Subsurface[b] inside	17	29	8[b]	333.33[c]
Subsurface[b] outside	<1	2	8[b]	333.33[c]
Roof and Overhead	<1	<1	4	166.67
Welding	6	17	1	48
HVAC	8	23	<1	1
Remaining[d]	<1	1	35	1451
TOTAL	33	71	49	2000

[a] Internal doses are committed effective doses provided for comparison. Under the EEOICPA, annual organ doses are calculated for assignment.

[b] The more favorable of the inside or outside will be assigned based on a specific claim's cancer details.

[c] Only one subsurface location (i.e., inside or outside) will be assigned.

[d] Exposure rates during the remaining period will decrease over time due to source-term depletion. Therefore, the exposure rate in this table represents the dose rates for the maximum intake year (i.e., first year of the residual period).

CONCLUSION

NIOSH researched residual period exposures 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 the models presented herein adequately bound exposures experienced by M&C workers during the residual radiation period.

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