*Draft*

Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

# Issues Resolution Roadmap for Metals and Controls Corporation SEC Petition-00236

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*SC&A, Inc. Technical Support for the Advisory Board on Radiation and Worker Health's Review of NIOSH Dose Reconstruction Program*

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# Abbreviations and Acronyms

| | |
|---|---|
| ABRWH, Board | Advisory Board on Radiation and Worker Health |
| AWE | Atomic Weapons Employer |
| Bq/yr | becquerel per year |
| D&D | decontamination and decommissioning |
| DCAS | Division of Compensation Analysis and Support |
| dpm/100 $cm^2$ | disintegrations per minute per 100 square centimeters |
| dpm/µg | disintegrations per minute per microgram |
| EPA | U.S. Environmental Protection Agency |
| ER | evaluation report |
| GSD | geometric standard deviation |
| HFIR | High Flux Isotope Reactor |
| hr | hour |
| HVAC | heating, ventilation, and air conditioning |
| kg | kilogram |
| m | meter |
| $m^3$/hr | cubic meters per hour |
| M&C | Metals and Controls Corporation |
| mrem | millirem |
| mrem/hr | millirem per hour |
| mrem/yr | millirem per year |
| µg | microgram |
| µg/$m^3$ | microgram per cubic meter |
| NIOSH | National Institute for Occupational Safety and Health |
| NMMSS | Nuclear Materials Management and Safeguards System |
| NRC | U.S. Nuclear Regulatory Commission |
| ORAU | Oak Ridge Associated Universities |
| ORAUT | Oak Ridge Associated Universities Team |
| OTIB | ORAUT technical information bulletin |
| Pb | lead |
| pCi | picocurie |
| pCi/g | picocuries per gram |

| | |
|---|---|
| $pCi/m^3$ | picocuries per cubic meter |
| pCi/yr | picocuries per year |
| Ra | radium |
| RF | resuspension factor |
| SEC | Special Exposure Cohort |
| SRDB | Site Research Database |
| TBD | technical basis document |
| Th | thorium |
| U | uranium |
| WG | work group |
| yr | year |

# 1 Overview

This document presents a summary and description of the issues identified during the review and subsequent discussions of Special Exposure Cohort (SEC) Petition-00236 for Metals and Controls Corporation (M&C). The petition has been discussed during a series of meeting outlined in table 1.

*Table 1. Summary of meetings discussing SEC-00236*

| Date | Groups meeting |
|---|---|
| 8/24/2017 | Advisory Board on Radiation and Worker Health |
| 10/26–28/2017 | NIOSH and SC&A site interviews with employees and petitioners |
| 11/8/2017 | WG, SC&A, DCAS, and ORAU teleconference |
| 5/3/2018 | Work Group on Metals and Controls Corp. |
| 8/22/2018 | Advisory Board on Radiation and Worker Health |
| 11/20/2018 | Work Group on Metals and Controls Corp. |
| 12/13/2018 | Advisory Board on Radiation and Worker Health |
| 1/9/2020 | Work Group on Metals and Controls Corp. |

Out of these meetings, 14 documents have been produced as outlined in table 2.

*Table 2. Summary of documents produced supporting the review of SEC Petition Evaluation Report 00236*

| Date | Issuing group | Title |
|---|---|---|
| 2/12/2018 | SC&A | Review of SEC Petition Evaluation Report SEC-00236 Metals and Control Corporation (SC&A, 2018a) |
| 2/22/2018 | NIOSH/DCAS | SC&A Review of the SEC00236 M&C Petition Evaluation Report (NIOSH, 2018a) |
| 2/28/2018 | NIOSH/ORAU | Issues Matrix for SEC00236 M&C (NIOSH, 2018f) |
| 4/23/2018 | NIOSH/ORAU | Metals and Controls Corp. Subsurface Exposure Model (NIOSH, 2018b) |
| 9/12/2018 | NIOSH/ORAU | Metals and Controls Special Exposure Cohort (SEC 236) Issues Matrix (NIOSH, 2018c) |
| 9/17/2018 | SC&A | Response to NIOSH White Paper on M&C Dated April 23, 2018 (SC&A, 2018b) |
| 10/18/2018 | NIOSH/DCAS | NIOSH Response to the SC&A Review of the NIOSH White Paper Dated April 23, 2018 (NIOSH, 2018d) |
| 10/24/2018 | NIOSH/ORAU | Metals and Controls Corp Maintenance Exposure Model (NIOSH, 2018e) |
| 11/29/2018 | SC&A | SC&A Draft Review of NIOSH's White Paper Dated October 24, 2018 (SC&A, 2018c) |
| 4/8/2019 | NIOSH/ORAU | Metals and Controls Corp Thorium and Welding Exposure Model (NIOSH, 2019a) |
| 6/18/2019 | NIOSH/ORAU | Metals and Controls Corp. SEC-00236 Petitioner Concerns (NIOSH, 2019b) |
| 7/26/2019 | SC&A | Review of NIOSH's "Metals and Controls Corp. Thorium and Welding Exposure Model" (SC&A, 2019a) |
| 11/27/2019 | NIOSH/ORAU | SC&A Review of Metals and Controls Corp. Thorium and Welding Exposure Model (NIOSH, 2019c) |

| Date | Issuing group | Title |
|---|---|---|
| 12/30/2019 | SC&A | Review of NIOSH's "Metals and Controls SEC-00236 Petitioner Concerns" (SC&A, 2019b) |

The petitioners were heavily involved in meetings of the Metals and Controls Corp. Work Group (WG), helping the WG better understand the variety of activities that took place at the site that require dose reconstruction. With the help of the petitioners, the National Institute for Occupational Safety and Health (NIOSH) and SC&A acquired considerable information characterizing the types of maintenance and refurbishing activities that took place during the residual period. In addition, a large body of data was compiled characterizing the types and concentrations of radionuclides present indoors and outdoors at the site and in the subsurface environment, including inside drainage lines.

These documents and petitioner comments led to the identification of a number of formal issues, as listed in table 3. The list of issues began with SC&A's April 2018 review of the NIOSH (2017) SEC petition evaluation report (ER) (April 2018) which was prepared after a series of interviews on October 26–28, 2017, in Mansfield, MA between M&C workers and petitioners and NIOSH and SC&A personnel. Following SC&A's review of the ER, a series of reports, white papers, and WG meetings addressed the SC&A findings and the new information acquired as a result of the interviews.

*Table 3. Summary of findings*

| Original date | Issue number |
|---|---|
| 2/12/2018 | SEC ER Finding 1 |
| 2/12/2018 | SEC ER Finding 2 |
| 2/12/2018 | SEC ER Finding 3 |
| 2/12/2018 | SEC ER Observation 1 |
| 2/12/2018 | SEC ER Observation 2 |
| 2/12/2018 | SEC ER Observation 3 |
| 2/12/2018 | SEC ER Observation 4 |
| 2/12/2018 | SEC ER Observation 5 |
| 5/3/2018 | Petitioner SEC Issue 1 |
| 5/3/2018 | Petitioner SEC Issue 2 |
| 5/3/2018 | Petitioner SEC Issue 3 |
| 5/3/2018 | Petitioner SEC Issue 4 |
| 5/3/2018 | Petitioner SEC Issue 5 |
| 5/3/2018 | Petitioner SEC Issue 6 |
| 5/3/2018 | Petitioner SEC Issue 7 |
| 5/3/2018 | Petitioner SEC Issue 8 |
| 5/3/2018 | Petitioner SEC Issue 9 |
| 5/3/2018 | Petitioner SEC Issue 10 |
| 9/17/2018 | Subsurface Recommendation 1 |
| 9/17/2018 | Subsurface Recommendation 2 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 2 |

| Original date | Issue number |
|---|---|
| 12/13/2018 | 12/13/2018 Petitioner Concern 3 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 4 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 5 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 6 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 7 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 8 |
| 12/13/2018 | 12/13/2018 Petitioner Concern 9a |
| 12/13/2018 | 12/13/2018 Petitioner Concern 9b |
| 7/26/2019 | Welding/Thorium Finding 1 |
| 7/26/2019 | Welding/Thorium Finding 2 |
| 7/26/2019 | Welding/Thorium Observation 1 |
| 7/26/2019 | Welding/Thorium Observation 2 |
| 7/26/2019 | Welding/Thorium Observation 3 |

Through the formal issue resolution process, these issues organically evolved and expanded into several broader exposure models. For this reason, the formal issues raised in review have not formally had their status changed and are all either open or in progress. Discussions of some of these issues warrant closure. The appendices to this document attempt to summarize the status of each issue and make a recommendation to update the status when appropriate.

In addition, many of the issues evolved and expanded during the course of the issue resolution process. This document is an attempt to identify and summarize each main exposure scenario and the findings, observations, and issues associated with each main exposure scenario or overarching issue. To the extent the information is available, the methods and assumptions used by NIOSH and SC&A to reconstruct the doses associated with each exposure scenario are presented and issues are identified. A recommendation is then provided regarding whether the issue should be closed or remain in progress. Each exposure scenario and its associated issues consider radioisotopes of concern, internal exposures associated with inhalation and inadvertent ingestion, and external exposure to penetrating and nonpenetrating radiation.

It is suggested that NIOSH review the values and summaries provided in this report. Given the evolution of all the assumptions and associated derived exposures, the project would benefit from a revised ER or the issuance of a site profile that captures the collective revisions and additional analysis provided in the white papers and reports.

As directed by the Designated Federal Official in an email dated January 31, 2020, this report recommends closing any issue where there are small differences between the assumptions used by SC&A and NIOSH, the doses are small, and both sets of assumptions are considered scientifically sound and claimant favorable. This is a slight deviation from the criteria used for previous assignments, where “In Abeyance” was assigned to issues were there was agreement on all aspects of the issue, but the site profile or SEC petition evaluation report had not yet been revised and published. In addition, previously, if some differences still existed between the assumptions used by SC&A and NIOSH for a given issue, the issue was designated as “In Progress.” Only for those issues where there are a substantive and significant differences in

assumption, models, and strategies for addressing a given exposure scenario is the issue identified as "In Progress."

SC&A believes that the only issues that remain in progress deal with thorium exposures and welding exposures. Issues related to thorium and welding exposures are in progress because SC&A is currently performing a review of documents issued by NIOSH on these topics.

Since this roadmap is to be used as a tool to facilitate issues resolution, the appendices present each SC&A finding and observation, as provided in its reports to the Advisory Board on Radiation and Worker Health (Board), followed by a description of the status of each issue.

# 2 Building 10 Exposure Scenarios

## 2.1 Subsurface Building 10

Based on statements from the petitioners and worker interviews, it was identified that it was not uncommon for pipes within Building 10 to back up or have drainage issues. To address this issue, workers had to snake the pipes and sometimes replace segments of the pipes. It was discovered that the pipes were not remediated at the end of Atomic Weapons Employer (AWE) operations and that some pipes were substantially contaminated. This may have caused an exposure risk to the person involved in the maintenance activities.

### *2.1.1 Related formal issues*

Table 4 outlines the formal issues related to this issue that have been raised. Each issue is addressed in detail in the appendices. They are identified here as a means of outlining the issues that impact the exposure scenario.

*Table 4. Summary of formal issues related to Building 10 subsurface model*

| Date issue identified | Issue number | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 2/12/2018 | SEC ER Finding 1 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 4 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 5 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 7 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 10 | Closed | Closed |
| 9/17/2018 | Subsurface Recommendation 1 | Closed | Closed |
| 9/17/2018 | Subsurface Recommendation 2 | In Progress | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 2 | In Progress | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 3 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 6 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 7 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 9a | Closed | Closed |

### *2.1.2 Discussion*

One of the issues that was discussed extensively at the meetings identified in table 1was the ability to reconstruct the doses to M&C workers involved in subsurface maintenance and repurposing activities in Building 10. All participants agreed that a considerable amount of subsurface work took place in Building 10 during the residual period, and that this work involved replacement and repair of subsurface drainage lines and conduits, including snaking clogged drainage lines and the removal of subsurface soil. These activities took place periodically throughout the residual period, and, at the time, none of the workers and other personnel at M&C were aware that there was residual radioactive material in the drainage lines and subsurface soil beneath Building 10. Not until well into the 1990s did it became apparent that many workers involved in maintenance and repurposing activities during the residual period may have come into close proximity to relatively elevated levels of uranium and thorium contamination of

subsurface soil, sludge in conduits, and sludge removed from subsurface drains by snaking operations. SC&A found that the sludge inside these pipes and the surrounding soils had the highest uranium concentrations among the various indoor and outdoor locations at the facility. Close contact with this material by M&C workers might have inadvertently resulted in the inhalation of airborne radioactive particles, ingestion of radioactively contaminated soil and sludge, and external exposure to beta and gamma emitters contained in the subsurface soil, sludge, and other material snaked from the clogged drainage systems.

Table 5, excerpted from table 1 of SC&A's November 29, 2018, report (SC&A, 2018c), with modifications to reflect current discussions, provides a convenient comparison of the key assumptions used by NIOSH and SC&A to derive subsurface internal exposures in Building 10 during the residual period.

*Table 5. Comparison of key modeling assumptions used by SC&A and by NIOSH for reconstructing internal doses to subsurface workers in Building 10*

| Parameter | SC&A (2018a) | NIOSH (2018e) |
|---|---|---|
| Contamination level | 95th percentile (ordered data calculated 5,878.1 pCi/g) | 95th percentile (lognormal calculated 6,887.84 pCi/g) |
| Dust loading | 200 µg/m$^3$ | 220 µg/m$^3$ |
| Breathing rate | 2.5 m$^3$/hr | 1.2 m$^3$/hr |
| Exposure duration | 2 months | 2 months |
| U inhalation rate | 40 Bq/yr | Not provided |
| Dose | 31 mrem/yr effective dose commitment | Not provided |

Note that although there are differences in many of the assumptions used by NIOSH and SC&A for reconstructing the subsurface doses to M&C workers in Building 10, we believe that both sets of assumptions are scientifically sound and claimant favorable, and SC&A is prepared to accept NIOSH's assumptions.

#### 2.1.2.1 Data representativeness and uranium concentrations

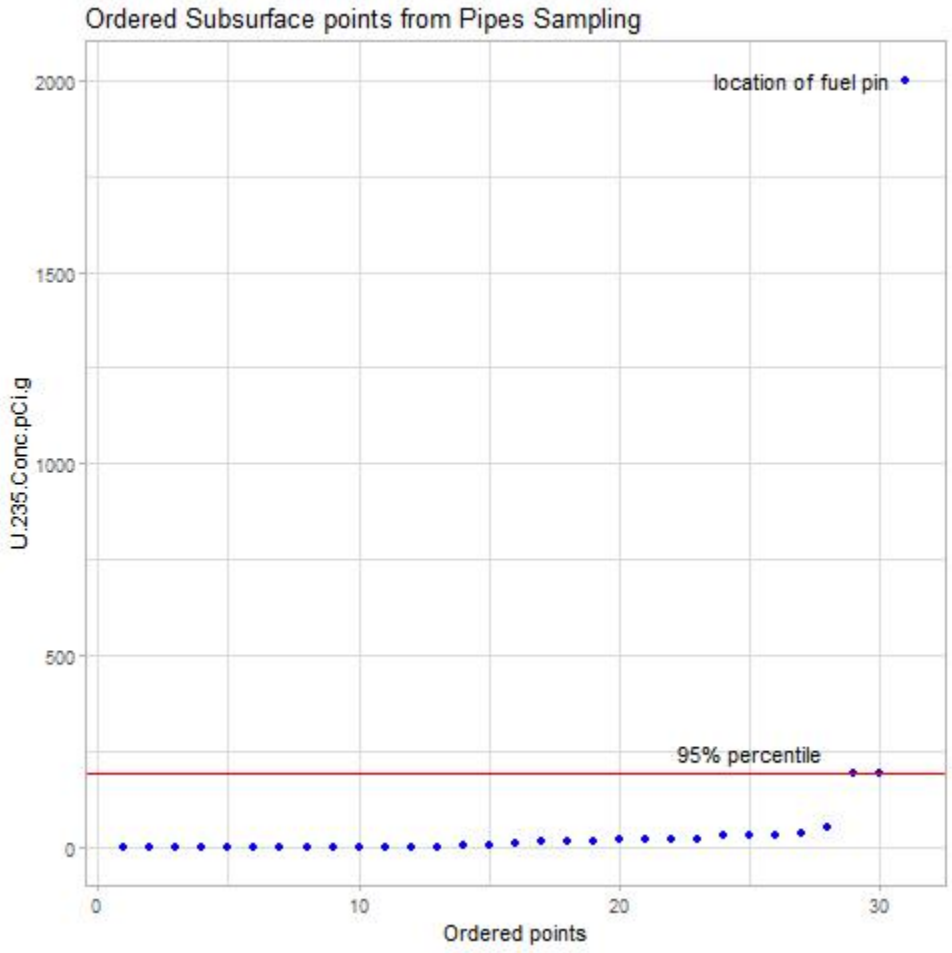
It could be argued that the radiological data set collected in the 1980s and 1990s is likely representative of the contamination levels that existed at the site during the earlier years of the residual period. Therefore, it can be used to model and assign plausible upper bound exposures M&C workers might have experienced during the entire residual period, including the early years, such as the 1970s and 1980s, a time period when radiological data characterizing the subsurface environment, including drainage lines, were nonexistent. However, the petitioners argue that the data collected during the 1990s are not representative of the extent and levels of contamination in the subsurface environment in Building 10, including drainage lines, because, during the residual period, drainage lines were snaked and/or removed, and subsurface soil was removed as part of ongoing maintenance and repurposing activities. As such, a considerable amount of radioactive material was likely inadvertently removed during the activities that took place in the residual period, beginning in January 1968. On this basis, the petitioners conclude that the data collected primarily in the 1990s cannot be used to reconstruct the doses experienced by M&C workers during the residual period. The petitioners are effectively arguing that the maintenance and repurposing activities inadvertently removed the soil and drainage line sludge that contained the highest concentrations of radionuclides and inadvertently left behind only the

soil and sludge that contained the lower concentrations of radionuclides. SC&A contends that such a scenario is not plausible.

SC&A argues that these data can, in fact, be used to assign plausible upper bound doses to M&C workers during the residual period, including the early years of the residual period. SC&A is not arguing that a considerable amount of radioactive material was not inadvertently removed during maintenance and refurbishing. SC&A contends that the M&C workers did not specifically focus on the removal of radioactive material. SC&A contends that, though the total quantity of radioactive material in the subsurface environment of Building 10 might have been reduced as a result of maintenance and refurbishing activities, it is unlikely that the upper end of the distribution changed substantially. The 1995 pipe characterization found uranium concentrations in the pipes in Building 10 ranged from 9.75 picocuries per gram (pCi/g) to 53,224.7 pCi/g. The highest readings were obtained from the location a fuel pin was found within the pipes and downstream of that spot.

SC&A acknowledges that, in the process of snaking and repairing the drainage lines and removing subsurface soil as part of repurposing activities, the material that was removed might have been the material that contained elevated levels of contamination, thereby resulting in a radionuclide concentration distribution in the soil and sludge that was characterized in the 1990s being lower than the radionuclide concentration distribution that existed during the residual period. To account for this possibility, SC&A and NIOSH agree that, to model exposures, we assume all of the soil and sludge in the subsurface environment during the entire residual period should be assumed to be present at the upper 95th percentile concentration of the radionuclides measured in the pipelines during the 1995 survey. Figure 1 shows the rank order concentration of uranium-235 (U-235) in sludge in the subsurface pipelines. These establish the basis for the 95th percentile uranium concentrations.

*Figure 1. Ordered data*




To reconstruct the external and internal exposures to M&C subsurface workers during the residual period, SC&A compiled the data characterizing the radionuclide concentrations in the pipes in Building 10 that were collected in the 1990s. SC&A found the upper 95th percentile of total uranium in the pipes calculated by ordered data to be 5,878.1 pCi/g. As a point of comparison, the specific activity of natural uranium is 0.683 pCi per microgram. This corresponds to 6.8E5 pCi/g of pure natural uranium; i.e., this would be the concentration of uranium in the sludge if the sludge were pure natural uranium. Therefore, we assumed that all the soil and sludge in the subsurface environment in Building 10 during the residual period was about 1 percent of the concentration of pure natural uranium.

One might argue that virtually all of the elevated contaminated sludge, which contained the highest concentrations of uranium (and presumably also thorium), was removed during snaking operations and the replacement of subsurface pipelines. Under these circumstances, the petitioners' arguments would be compelling. However, the location where the highest readings were taken was found to be 90 percent clogged and contained a fuel pin. SC&A believes that the high end concentrations of uranium that were used as the basis of our calculations remained in place throughout the residual period.

Evidence that high end concentrations of uranium remained in the pipelines into the 1990s is provided in Roy F. Weston, Inc. (1996), "Texas Instruments Incorporated Attleboro Facility Building Interior Remediation Drainage System Characterization.". That report describes the drainage systems, including the results of radiological surveys of these systems, revealing elevated levels of uranium present inside the pipelines, which were clearly present throughout the residual period. The surveys found a portion of a uranium rod 5 inches long and 2 inches in diameter in one pipeline. Other residue in pipe sludges was found to contain uranium at concentrations of 53,000 pCi/g at one location and 1,517 pCi/g at another location (Weston, 1996, p. 5). The 53,000 pCi/g concentration is approximately 10 percent of the concentration of pure natural uranium. The soil in the vicinity of the pipelines also contained elevated levels of enriched uranium, in one case on the order of 2,000 pCi/g.

To further ensure that the doses to every M&C worker are bounded, SC&A assumes that all M&C workers were in intimate contact with the upper 95th percentile concentration of radionuclides observed in the 1995 remediation study, as if the same worker performed all the maintenance and refurbishing work year after year. In reality, we know that different workers at different times "went into the hole" to perform these activities. Nevertheless, we assume that the same person is always doing this work, and we are assigning those doses to every M&C worker at the site. In effect, we are assuming that every worker spent 2 months per year every year in the hole in intimate contact with the upper 95t$^{h}$ percentile concentrations of the radionuclides measured in the subsurface soil, sludge, and pipelines. Hence, assuming that all the subsurface soil and sludge in the subsurface environment in Building 10 is at the upper 95th percentile level of the uranium concentrations observed in the sludge inside the pipelines in Building 10 as part of the 1996 site characterization program is, in fact, a highly conservative assumption that bounds the uranium concentrations that M&C workers might have been exposed to throughout the residual period.

#### 2.1.2.2 Dust loading

Finally, for the purpose of reconstructing the inhalation exposures to the workers in the hole, we are assuming that the airborne dust concentration (also referred to as the dust loading), which contains the upper 95th percentile concentration of uranium observed in the pipelines in the 1990s, is always at 200 micrograms per cubic meter (μg/m$^3$). This value is in the range of values recommended in NUREG/CR-5512, volume 1 (NRC, 1992), for reconstructing inhalation doses to workers involved in remediation activities. NIOSH instead used a value of 220 μg/m$^3$, which is the upper 95th percentile of the dust loadings seen in a Mound study. Both are within the range of the values recommended in section 6.3 of NUREG-CR/5512, volume 1, for these types of scenarios and are acceptable.

This does not acknowledge that the soil was often moist because of the high water table on site. It is likely that the actual dust concentrations experienced by the workers in the hole were well below that concentration because it is known that moist soil does not readily resuspend.

#### 2.1.2.3 Exposure duration

As indicated on page 25 of SC&A's February 2018 review of the SEC ER, SC&A estimated a uranium inhalation rate of 20 becquerels per year (Bq/yr) from subsurface activities in Building 10 using the above assumptions and an annual exposure duration of 1 month (184 hours) per

year. This resulted in an effective dose of 15.6 millirem per year (mrem/yr). During subsequent WG meetings, petitioners indicated that they believed that 1 month per year for these types of activities is too low. As a result, SC&A and NIOSH agreed to increase the exposure duration to 2 months per year, resulting in an effective dose from the inhalation of uranium of 31.2 mrem/yr for this activity.

SC&A and NIOSH independently selected the input assumptions from the available data and the results of the interviews. The resulting doses are quite small. In light of this discussion, SC&A believes that either set of assumptions or a combination of the two sets are reasonable.

### *2.1.3 Recommendations*

SC&A believes that no matter which set of assumptions are used, the doses are modest, and both SC&A's and NIOSH's approach to reconstructing these doses are reasonable, scientifically valid, and claimant favorable. SC&A recommends that this set of SEC issues can be **Closed**.

## 2.2 Building 10 HVAC maintenance exposures

One issue identified during the interviews is maintenance work on the heating, ventilation, and air conditioning (HVAC) systems in Building 10. Interviewees described a dusty environment that workers had to enter to change filters and clean and maintain the air handling systems inside Building 10.

### *2.2.1 Related formal issues*

A number of formal issues related to this issue have been raised, outlined in table 6. Each issue is addressed in detail in the appendices. They are identified here as a means of identifying all issues that impact the exposure scenario.

*Table 6. Summary of formal issues related to Building 10 subsurface model*

| Date issue identified | Issue number | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 5/3/2018 | Petitioner SEC Issue 5 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 8 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 10 | Closed | Closed |
| 9/17/2018 | Subsurface Recommendation 1 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 | Closed | Closed |

### *2.2.2 Discussion*

Building 10 HVAC maintenance was modeled in SC&A's (2018a) initial ER review and discussed with the WG during the May 3, 2018, meeting (M&C WG, 2018a, p. 76 ff.). SC&A's and NIOSH's approach to this scenario is that the uranium dust loading on filters and inside ductwork can be derived based on knowledge of the average uranium contamination levels observed on floors and surfaces at the end of AWE operations (e.g., picocuries per square meter), and using a resuspension factor of 1E-5 per meter (m), to obtain the average airborne concentration of uranium dust in Building 10 in units of picocuries per cubic meter ($pCi/m^3$). Then, it is assumed that the mass loading of airborne dust is 200 $\mu g/m^3$, which is multiplied by the derived airborne concentration of uranium ($pCi/m^3$) to obtain the average specific activity of

uranium on airborne dust in Building 10 in units of pCi/µg. This is the estimated specific activity of the dust on the HVAC filters and inside ductwork. It is then assumed that, when the filters were changed, workers were exposed to dust in the HVAC ducts and on the filters, assuming an airborne dust loading of 100 milligrams per cubic meter ($mg/m^3$) to maximize the dust loading ($pCi/m^3$) experienced by these workers. The 100 $mg/m^3$ airborne dust concentration is the concentration that is considered to be barely breathable for any extended period of time. The internal dose associated with this scenario is the product of the dust loading, the breathing rate, the appropriate inhalation dose coefficient, and the duration of exposure. The result of this calculation is 1.77 millirem per hour (mrem/hr) of exposure associated with HVAC maintenance. This dose rate does not include the contribution of thorium.

If it is assumed that the chronic airborne dust loading in Building 10 is lower, such as 100 $\mu g/m^3$, the derived dose rate doubles. The annual dose associated with this activity depends directly on the duration of exposure associated with each HVAC maintenance operation and the number of hours of each maintenance operation requires. There is certainly room for discussion about many of the values of the parameters, but this is a matter of judgement. However, the analysis shows that we are talking about relatively low dose rates.

In the NIOSH white paper dated October 24, 2018, NIOSH fully accepted SC&A's assessment and conclusions regarding the internal exposures HVAC exposure scenario (NIOSH, 2018e).

#### *2.2.3 Recommendation*

SC&A recommends that this issue be **Closed**.

## 2.3 Building 10 roof and overhead area

The petitioners raised a concern that roof penetrations and work in the overhead areas were areas where maintenance workers may have unknowingly been exposed to residual radioactivity.

#### *2.3.1 Related formal issues*

A number of formal issues related to this issue have been raised, outlined in table 7. Each issue is addressed in detail in the appendices.

*Table 7. Summary of formal issues related to Building 10 roof and overhead model*

| Date issue identified | Issue | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 5/3/2018 | Petitioner SEC Issue 2 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 5 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 9 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 10 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 | Closed | Closed |

This issue was discussed at the November 20, 2018, WG meeting, documented in the meeting transcript beginning on page 28 (M&C WG, 2018b). NIOSH explained that the roof and overhead areas of Building 10 were contaminated during AWE operations, and that data were collected in this area by the U.S. Nuclear Regulatory Commission (NRC) in 1982. The area surfaces of the roof and overhead area were very dusty, the types of measurements made by the

NRC were with hand-held survey meters and swipe samples, and the results are expressed in units of disintegrations per minute per 100 square centimeters (dpm/100 $cm^2$). NIOSH characterized the contamination of the building roof and overhead areas using 154 wipes for removable alpha and beta contamination and used the 95th percentile contamination levels of 8.99 dpm/100 $cm^2$. For the purpose of deriving the airborne concentration of gross alpha activity, NIOSH assumed 10 percent of this activity was removable and a resuspension factor of 1E-4/m and derived an airborne dust loading of 4.05 E-14 microcuries per cubic centimeter and an exposure duration of 173 hours per year (hr/yr), resulting in an effective dose equivalent rate to the lung of 0.01 mrem/hr due to type S uranium. Assuming the same person always performs this activity, the annual dose equivalent to the lung is 3.65 mrem/yr.

During the discussions, Board member Dr. Kotelchuck expressed concern that some of the outdoor areas may have been exposed to the elements and, therefore, the measurements made in 1982 may not be representative of the contamination levels during the earlier years of the residual period. NIOSH explained that this is one of the reasons that the upper 95th percentile contamination levels were used in the analysis, and it applies to the fixed contamination. The upper 95th percentile of the data was 8.99 dpm/100 $cm^2$ gross alpha, which was available for resuspension and used one of the highest resuspension factors used on this project, i.e., 1E-4/m, to derive the airborne dust loading that M&C workers involved in this type of maintenance activity might experience. Notwithstanding the various concerns, NIOSH obtained dose rates on the order of 0.01 mrem/hr.

The most important issue is that SC&A also looked at the swipe data and came away with contamination levels 20 percent higher than the values estimated by NIOSH due to differences in how zeros were treated in the data. Although there was a lot of discussion on the differences in the methods used by SC&A and NIOSH, SC&A considers this very good agreement, given that two independent sets of researchers reviewed the data as shown in table 8.

*Table 8. Internal exposures from HVAC maintenance in Building 10*

| Parameter | SC&A | NIOSH |
|---|---|---|
| Specific activity(gross alpha) | 1.23E-4 dpm/µg | 1.23E-4 dpm/µg |
| Dust loading | 100 mg/$m^3$ | 100 mg/$m^3$ |
| Breathing rate | 1.2 $m^3/m^3$ | 1.2 $m^3/m^3$ |
| Dose rate | 1.77 mrem/hr | 1.7 mrem/hr |

### *2.3.2 Recommendation*

SC&A recommends **closing** this issue, with the exception of the overarching thorium exposure issue.

## 2.4 Exposures associated with welding

The petitioners raised additional concerns at the November 20, 2018, meeting regarding welding activities that they believed were not sufficiently addressed by previous NIOSH and SC&A reviews. In response to these concerns NIOSH issued a white paper, “Metals and Controls Corp. Thorium and Welding Exposure Model” (NIOSH, 2019a), on April 8, 2019. SC&A reviewed this white paper in a memorandum, “Review of NIOSH’s ‘Metals and Controls Corp. Thorium and Welding Exposure Model’” (SC&A, 2019b), on July 26, 2019. NIOSH subsequently

responded in a paper dated November 27, 2019 (NIOSH, 2019c). These documents were discussed at the January 9, 2020, WG meeting, and SC&A is in the process of generating responses to the formal issues discussed in these documents.

### *2.4.1 Related formal issues*

A number of formal issues related to welding have been raised, outlined in table 9. Each issue is addressed in detail in the appendix.

*Table 9. Summary of formal welding-related issues*

| Date issue identified | Issue | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 11/29/2018 | Petitioner SEC Issue Welding | In Progress | Closed |
| July 26, 2019 | Welding/Thorium Finding 2 | In Progress | Closed |
| July 26, 2019 | Welding/Thorium Observation 2 | Closed | Closed |
| July 26, 2019 | Welding/Thorium Observation 3 | Closed | Closed |

NIOSH's (2019c) response paper discusses SC&A's concerns that a resuspension factor of 1E-2/m should be used, as opposed to 1E-3/m, when deriving the inhalation dose to workers involved in cleaning metal surfaces prior to welding operations. NIOSH disagrees with SC&A's position on this issue, and SC&A is currently preparing a white paper addressing it. Hence, we suggest that this issue remain **In Progress**.

SC&A also suggested that NIOSH should assign doses using the most claimant-favorable isotope of thorium or uranium, selected from isotopes known to have been used at M&C. NIOSH agreed with this comment.

### *2.4.2 Recommendation*

SC&A recommends that these issues remain **In Progress**.

# 3 Non-Building 10 Exposure Scenarios

## 3.1 Outdoor exposures including those in the vicinity of the waste burial pit

Several interviewees also indicated that a substantial amount of subsurface work occurred outside of buildings and sometimes included digging around and in the radioactive waste burial grounds. It is also known that during construction, the burial site was disturbed and material from the site may have been distributed over the construction site. Workers who were involved in disturbing this site and workers who were in the general area may have been inadvertently exposed to residual radioactivity.

### *3.1.1 Related formal issues*

A number of formal issues related to welding have been raised, outlined in table 10. Each issue is addressed in detail in the appendix.

*Table 10. Summary of formal outdoor-related issues*

| Date issue identified | Issue | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 5/3/2018 | Petitioner SEC Issue 3 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 4 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 5 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 7 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 10 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 3 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 4 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 5 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 6 | Closed | Closed |

### *3.1.2 Discussion*

#### 3.1.2.1 Internal exposures above ground and below ground outside

Considerable surface and subsurface data were collected in many outdoor areas in 1984 by the NRC and again in the early 1990s in support of license termination. Page 8 of NIOSH's October 24, 2018, white paper states that 2,391 soil samples were collected prior to remediation, 1,629 samples were analyzed for gross alpha, and 762 samples were collected for uranium and thorium and analyzed using isotopic identification (NIOSH, 2018e). Using the upper 95th percentile value, NIOSH used 117.86 pCi/g for the dose calculations for uranium and 87.5 pCi/g for thorium. The airborne dust concentrations that contain these radionuclides are assumed to be 220 $\mu g/m^3$, based on Mound data. Note that SC&A used 200 $\mu g/m^3$, both of which fall within the range of values recommended in section 6.3 of NUREG/CR-5512, volume 1 (NRC, 1992), for remediation projects.

For aboveground internal exposures, SC&A suggests assuming average soil contamination, 2,000 hr/yr exposure duration, and a chronic dust loading of about 200 $\mu g/m^3$. For subsurface exposures, SC&A derived the upper 95th percentile of the radionuclide concentrations observed

in subsurface samples, along with an exposure duration of perhaps 200 hr/yr and a dust loading of about 200 μg/$m^3$ as the basis for estimating internal doses associated with outdoor subsurface work.

Page 25 of SC&A's (2018a) review of the ER provides an estimate of the internal exposures experienced by workers involved in subsurface work in the vicinity of the outdoor burial pit. SC&A found that, even assuming 2,000 hr/yr of exposure, the inhalation dose from this exposure pathway from all radionuclides considered was found to be extremely small. Though not presented in the report, table 11 is the estimated annual radionuclide intake and associated effective annual doses associated with this pathway.

*Table 11. Summary of dose estimates*

| Radionuclide | Annual intake (pCi/yr) | Annual inhalation dose commitment (mrem/yr) |
|---|---|---|
| U-235 | 0.15 | 4.7E-3 |
| U-238 | 1.26 | 3.7E-2 |
| Th-232 | 0.51 | 4.7E-2 |
| Ra-226 | 0.29 | 3.7E-3 |
| Pb-210 | 0.29 | 6.0E-3 |
| Total | — | 9.8E-2 |

In theory, we can assume that a worker might be involved in subsurface work in Building 10 2 months per year and spend 10 months per year exposed outdoors to resuspended contaminated dose. Given this scenario, the additional dose from this pathway of less than a mrem per year can be ignored. Alternatively, we can assign the subsurface internal exposures to uranium in Building 10 to the subsurface exposures to outdoor workers. The data indicate that such an approach would be extremely claimant favorable but would still result in relatively small doses.

#### 3.1.2.2 Recommendation

SC&A recommends that this issue be **Closed**, with the possible exception of thorium issues.

### *3.1.3 External exposures associated with aboveground outdoor activities*

It is known that the soils surrounding Building 10, burial grounds, and other outdoor areas were contaminated during the residual period. Workers had the potential to be exposed to this contamination unknown by walking over contaminated soil or doing work nearby.

#### 3.1.3.1 Discussion

SC&A obtained all the outdoor surface and subsurface data collected in the 1980s and 1990s. For aboveground external exposures, SC&A used 473 sets of surface and subsurface soil samples that were collected and analyzed for isotopes of uranium, thorium-232 (Th-232), and radium-226 (Ra-226). SC&A calculated an annual effective dose of 5.32 mrem to a worker exposed to the soil having the average concentrations of these radionuclides and their radioactive progenies, based on the external dose coefficients from Federal Guidance Report No. 13 (EPA, 1999) for infinite depth. Average concentrations were used because it is not reasonable to assume that, above ground, M&C workers would always be in the areas with the highest radionuclide concentrations.

This average annual dose is less than the monthly dose modeled by NIOSH using dosimetry and thus is bounded by the NIOSH modeling.

#### 3.1.3.2 Recommendation

SC&A recommends that this issue be **Closed.**

### *3.1.4 External exposures below ground outside*

It is known that the soils surrounding Building 10, burial grounds, and other outdoor areas were contaminated during the residual period. It is also known that on at least two occasions, workers excavated the soil in these areas.

#### 3.1.4.1 Discussion

SC&A determined the external dose rates to a worker in an excavation at the burial ground. We first calculated the weighted average concentrations of radionuclides reported by Sowell (1985) for core samples collected at 28 locations for which core sample data were reported at two or more depths. We then calculated the dose rates that would be experienced by a worker exposed to an infinite layer of soil contaminated at the concentrations equal to those of the core samples, using the Federal Guidance Report No. 12 (EPA, 1993) external dose coefficients. We then selected the 95th percentile of these 28 results. Assuming a worker was exposed for 200 hr/yr, their annual effective dose from this pathway would have been 2.08 mrem. If we assume that they spent 90 percent of working hours on the surface and the remaining 10 percent in an excavation, the total annual external effective dose would have been 6.87 mrem.

This average annual dose is less than the monthly dose modeled by NIOSH using dosimetry and thus is bounded by the NIOSH modeling.

#### 3.1.4.2 Recommendation

SC&A recommends that this issue be **Closed**.

## 3.2 Wastewater treatment

SC&A's (2018a) review of the ER addresses other exposure scenarios identified during the October 2017 interviews. These include exposures associated with wastewater management and exposures outdoors, where M&C workers were close to remediation activities that were taking place in the 1990s and may have been exposed to concentrated radioactive materials associated with these activities. These doses were found to be negligible and do not require further explicit consideration.

### *3.2.1 Related formal issues*

There were no formal issues identified that related to this issue. SC&A identified it as a potential concern in its ER review; however, it was found to not be an issue.

### *3.2.2 Recommendation*

SC&A recommends that this issue be **Closed.**

# 4 Broader Overarching Issues

## 4.1 External exposures

A number of issues have been raised relating to how external exposures can be modeled because workers were not monitored during the residual period.

### *4.1.1 Related formal issues*

A number of formal issues related to external dose have been raised, outlined in table 12. Each issue is addressed in detail in the appendices.

*Table 12. Summary of formal issues related to external dose*

| Date issue identified | Issue | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 2/12/2018 | SEC ER Finding 2 | Closed | Closed |
| 2/12/2018 | SEC ER Finding 3 | Closed | Closed |
| 2/12/2018 | SEC ER Observation 4 | Closed | Closed |
| 2/12/2018 | SEC ER Observation 5 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 1 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 5 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 10 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 3 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 7 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 9a | Closed | Closed |

### *4.1.2 Discussion*

In the SEC ER, NIOSH (2017) proposed using dosimetry data from the end of operations to apply to bound doses to workers. This analysis resulted in NIOSH calculating the 95th percentile of measured doses to be 150 mrem/yr (12.5 mrem/month). SC&A's (2018a) review of the ER identified a number of issues related to the use of data in this way. NIOSH retooled their approach in the September 12, 2018, M&C SEC issues matrix (NIOSH, 2018c) and derived a beta skin dose of 12 mrem/ month and a penetrating dose of 4 mrem/ month. Because the geometric standard deviation (GSD) calculated in this approach was less than the TBD-6000 (DCAS, 2011) default value, NIOSH proposes using a GSD of 5 in order to be claimant favorable.

SC&A reviewed the NIOSH modeling and agreed with the penetrating dose modeled. SC&A modeled beta doses and had a modestly different interpretation of beta results. SC&A calculated a comparable but lower dose of 9.7 mrem/month. The difference is modest, so SC&A believes this concern is not worth pursuing further.

SC&A also had a concern that the dosimetry from the end of the AWE period in 1967 might not be applicable to workers during the residual period due to different work activities that are believed to have been performed in the two periods. In its ER review, SC&A ((2018a) modeled doses from standing on an infinite slab of the 95th percentile concentration from the pipes and

calculated a dose of 12.75 mrem/month. Additionally, SC&A modeled dose from standing on an infinite slab contaminated with the 95th percentile of the 1982 Texas Instruments sampling results (234.44 dpm/100 $cm^2$) and calculated an annual exposure of 0.0185 milliroentgen per year. The HVAC maintenance scenario also resulted in a dose of less than 1 mrem per year. Although SC&A has remaining concerns about the applicability of the 1967 data to the residual period, based on these calculated doses, SC&A finds the NIOSH calculation to be bounding for the work scenarios in Building 10.

#### *4.1.3 Recommendation*

SC&A recommends that this issue be **Closed** because the NIOSH model bounds all scenarios modeled by SC&A.

### 4.2 Substitute data issue

There are no known bioassay or dosimetry data that apply to workers during the residual period. As such, NIOSH makes use of data from remediation and decontamination and decommissioning (D&D) activities late in the residual years. The petitioners have expressed concerns that the data collected during the remediation and D&D surveys in the 1970s, 1980s, and 1990s are not representative of the earlier time periods. They have argued that material in the earlier years may have been inadvertently removed, thus reducing the amount of radioactive material available to be measured in the later years.

#### *4.2.1 Related formal issues*

A number of formal issues related to substitute data have been raised, outlined in table 13. Each issue is addressed in detail in the appendices.

*Table 13. Summary of formal issues related to substitute data uses*

| Date issue identified | Issue | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 5/3/2018 | Petitioner SEC Issue 1 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 2 | Closed | Closed |
| 5/3/2018 | Petitioner SEC Issue 3 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 3 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 7 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 9a | Closed | Closed |

#### *4.2.2 Discussion*

NIOSH's (2018e) white paper on the maintenance worker exposure model summarizes the application for license termination as follows (p. 13):

> 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).

No significant differences were observed between the data collected at the termination of AWE operations and the data collected in the NRC 1983 surveys, giving evidence that contamination levels (at least at the measured locations) did not change substantially from the end of AWE operations up to the time of the 1983 survey. A similar statement is made that the 1983 data compare well with the data collected in the 1990s.

This section does not contain any recommendations, but it is important in that it helps to support the position of SC&A and NIOSH that data collected in the 1980s and 1990s can be used to reconstruct doses to M&C maintenance workers during the residual period.

## 4.3 Exposures to thorium

It is known that a small amount of thorium work was done on the same equipment on which uranium work was done. The petitioners have raised a number of issues related to thorium work done on site and the challenges of reconstructing doses when there are limited thorium sampling results.

### *4.3.1 Related formal issues*

A number of formal issues related to thorium have been raised, outlined in table 14. Each issue is addressed in detail in the appendices.

*Table 14. Summary of formal thorium-related issues*

| Date issue identified | Issue | TBD issue status recommendation | SEC issue status recommendation |
|---|---|---|---|
| 5/3/2018 | Petitioner SEC Issue 5 | In Progress | Closed |
| 5/3/2018 | Petitioner SEC Issue 10 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 1 | Closed | Closed |
| 12/13/2018 | 12/13/2018 Petitioner Concern 2 | In Progress | Closed |
| 7/26/2019 | Welding/Thorium Finding 1 | Closed | Closed |
| 7/28/2019 | Welding/Thorium Observation 1 | Closed | Closed |

### *4.3.2 Discussion*

In April 2019, NIOSH issued a white paper proposing to assume the subsurface environment contained equivalent amounts of natural uranium and Th-232 as a means of quantifying thorium contamination when no thorium measurements are available (NIOSH, 2019a). NIOSH indicates that this is sufficiently conservative because it is believed that the site processed 29 times as much uranium as Th-232 (activity ratio of 188 times more uranium). When gross alpha contamination surveys are available, NIOSH will continue to assume 100 percent of the material is the most claimant favorable isotope of uranium or thorium.

SC&A reviewed this paper in a follow-up memorandum dated July 26, 2019 (SC&A, 2019a). SC&A expressed concerns that NIOSH assumed that, except where actual uranium and thorium concentrations in soil samples are provided, equal mass concentrations of uranium and thorium in the sludge are contained in pipes in Building 10.

On November 27, 2019, NIOSH issued "SC&A Review of Metals and Controls Corp. Thorium and Welding Exposure Model" (NIOSH, 2019c), summarizing NIOSH's response to SC&A's (2019a) comments. NIOSH provides arguments supporting their position. NIOSH also does not agree with SC&A's concerns regarding the methods used to derive ingestion doses. Both of these issues are under review.

#### *4.3.3 Recommendation*

SC&A recommends that these issues remain **In Progress**.

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# Appendix A: Issues identified in SC&A's February 12, 2018, Review of the NIOSH Evaluation Report

This appendix includes each of SC&A's (2018a) findings and observations in our February 12, 2018, review of the evaluation report (ER), along with the National Institute for Occupational Safety and Health's (NIOSH's) responses and the Metals and Controls Corporation Work Group's (M&C WG's) suggested followup investigations.

## A.1 SC&A Finding 1

Internal exposures associated with subsurface maintenance and repurposing activities in Building 10 during the residual period should be explicitly included in the ER. NIOSH should not assume that there is sufficient conservatism inherent in the internal dose reconstruction methods employed in the ER to account for these exposures.

### *A.1.1 Status*

In NIOSH's white paper, "Metals and Controls Corp. Subsurface Exposure Model," dated April 23, 2018, NIOSH concurs with SC&A on this issue (NIOSH, 2018b). Hence, we consider this issue resolved.

### *A.1.2 Recommendation*

SC&A recommends that this issue be **Closed**.

## A.2 SC&A Finding 2

NIOSH incorrectly transcribed some of the Landauer film badge dosimetry reports and incorrectly calculated annual 95th percentile external penetrating doses to workers in the residual period.

### *A.2.1 Status*

On page 2 of the February 22, 2018, memorandum from NIOSH to the M&C WG (NIOSH, 2018a), NIOSH stated that this error will be corrected in the next revision of the ER. This issue is also addressed in the September 12, 2018, issues matrix (NIOSH, 2018c), along with the method that will be used to correct this error. SC&A reviewed this issue and concurs with NIOSH's strategy for addressing this issue.

### *A.2.2 Recommendation*

The September 2018 issues matrix (NIOSH, 2018c) recommends that this issue be **Closed**.

## A.3 SC&A Finding 3

NIOSH incorrectly calculated annual 95th percentile beta skin doses to workers in the residual period.

### *A.3.1 Status*

In the issues matrix dated February 28, 2018, NIOSH stated that "NIOSH will correct this in the revised ER" (NIOSH 2018f, p. 3). In the September 12, 2018, issues matrix, NIOSH (2018c)

provided a description of the revised approach they plan to use to reconstruct beta doses to skin. SC&A reviewed NIOSH's approach to reconstructing external beta doses to skin and is critical of the approach, suggesting an alternative interpretation of results. NIOSH model a dose of 12 millirem (mrem)/month, while SC&A calculated a dose of 9.7 mrem/month. These differences are modest. NIOSH has recommended increasing the geometric standard deviation to 5 (consistent with TBD-6000 default assumptions (DCAS, 2011)).

#### *A.3.2 Recommendation*

SC&A recommends that this issue be **Closed**.

### A.4 SC&A Observation 1

SC&A suggests that a more appropriate approach to deriving the chronic airborne concentration of uranium from resuspension during the residual period would be to use the average value for the swipe data (i.e., 12.3 disintegrations per minute per 100 square centimeters) and a resuspension factor of 1E-5 per meter. This would result in chronic uranium inhalation rates that are about 2 times higher, but well within a reasonable range for these types of exposures, given the available data.

#### *A.4.1 Status*

On page 2 of its February 22, 2018, memorandum NIOSH (2018a) stated that it is reviewing this suggestion and will provide an updated approach for accounting for resuspension. In the September 2018, issues matrix, NIOSH (2018c) agrees with SC&A's concerns and SC&A's suggested approach to resolving this specific issue.

#### *A.4.2 Recommendation*

With respect to Observation 1, we recommend that this issue be **Closed**.

### A.5 SC&A Observation 2

The distinction between production and non-production workers should be better defined in the ER. After discussions with NIOSH, it was determined that the production worker group is intended to refer to workers who may have entered production areas. This includes construction trade workers, including but not limited to those listed in the ER. Additional text adding clarity to this point would ensure this distinction is consistently applied to workers.

#### *A.5.1 Status*

In the September 2018 issues matrix, NIOSH (2018c) agreed to revise the ER to clarify the language describing the worker categories addressed in the ER and provides an example of how the language will be revised. During further discussion on this matter at the January 9, 2020, WG meeting, NIOSH acknowledged that all M&C workers will be assigned the doses applied to maintenance and repurposing workers, since it is unclear which workers were involved in various maintenance and repurposing activities.

#### *A.5.2 Recommendation*

SC&A recommends that this observation be **Closed**.

## A.6 Observation 3

NIOSH should consider adopting the approach used in the ER for Carborundum and the ER and technical basis document (TBD) for General Steel Industries for deriving ingestion doses during the residual period.

### *A.6.1 Status*

On page 3 of its February 22, 2018, memorandum, NIOSH (2018a) states the following:

> When estimates of air concentration values are available, the OTIB-009 approach is the preferred approach. When air concentration data is not available, but surface contamination values are, NIOSH uses NUREG/CR-5512.

The September 12, 2018, issues matrix makes the following additional statement:

> The contamination data used for estimating ingestion rates are taken from the end of AWE operations and decayed over time consistent with the source-term depletion rate calculated with OTIB-70 methods. [NIOSH, 2018c, p. 11]

SC&A agrees that the NUREG/CR-5512 approach is appropriate for use in deriving ingestion doses associated with contamination of surfaces during the residual period.

### *A.6.2 Recommendation*

SC&A recommends that this issue be **Closed**.

## A.7 SC&A Observation 4

Exposures experienced by High Flux Isotope Reactor (HFIR) workers cannot be used "as supporting evidence to validate the bounding method used in Section 7 of this report" as stated on page 24 of the ER.

### *A.7.1 Status*

In the September 12, 2018, issues matrix, NIOSH (2018c, p. 13) states the following:

> NIOSH agrees that exposures to personnel working within the HFIR Fuel Manufacturing Area were likely much larger than exposures to covered personnel. NIOSH will delete or edit our comparison to the reference cited by SC&A (SRDB 24654 p. 34) to clarify the assessment.

SC&A accepted the NIOSH response at the May 3, 2018, WG meeting.

### *A.7.2 Recommendation*

SC&A recommends that this issue be **Closed**.

## A.8 SC&A Observation 5

SC&A is concerned that it may be inappropriate to use external dosimetry data collected during the last year of Atomic Weapons Employer (AWE) operations as the basis for bounding the external doses during the residual period.

### *A.8.1 Status*

At the May 3, 2018, WG meeting, SC&A stated that reliance on film badge data may be inappropriate because fuel was on site during the film badge readings and, to a much less extent, present in the residual period. NIOSH stated that the new method uses the geometric mean of the data as opposed to the 95th percentile, and that 45 percent of the film badge results were reported at the minimum detectable activity. NIOSH believes these data are conservative. NIOSH also pointed out that the Nuclear Materials Management and Safeguards System (NMMSS) inventory data should the 694 kilograms (kg) of uranium present in 1966 and 172 kg present in 1967. This indicates that the 1967 data were obtained during a period when the AWE source term was significantly reduced.

SC&A independently modeled external dose from heating, ventilation, and air conditioning maintenance work, standing in Building 10 and doing subsurface pipe work. Each of these scenarios resulted in a lower dose than that modeled by NIOSH. Although SC&A has remaining concerns about the applicability of dosimetry data, SC&A finds that the NIOSH-modeled dose bounds the exposure scenarios modeled by SC&A. Additionally, SC&A believes the doses modeled by NIOSH represent plausible external dose to maintenance workers.

### *A.8.2 Recommendation*

Because the NIOSH-modeled doses bound the scenarios modeled by SC&A, SC&A recommends this issue be **Closed**.

# Appendix B: Issues Raised by Petitioners during the May 3, 2018, Work Group Meeting

## B.1 Petitioner SEC Issue 1 (P1)

The petitioners argue that the position taken by the National Institute for Occupational Safety and Health (NIOSH), that the doses and the experience of the remediation contractors involved in characterization and cleanup work in the 1990s can be used as a surrogate for doses to Metals and Controls Corporation (M&C) workers during the residual period, cannot be supported. The petitions explain that, since the cleanup contractors were under the direct control of a comprehensive health physics program and the M&C workers during the residual period were not, there is really no equivalence between the two sets of activities and radiation exposures.

### *B.1.1 Discussion*

SC&A acknowledges the petitioner's concern and has adopted its own approach to reconstructing doses that does not depend on the observed exposures experienced by contractor remediation workers. In a similar manner, NIOSH has developed a method for reconstructing doses to M&C workers that does not depend on the observed doses experienced by cleanup contractors.

### *B.1.2 Recommendation*

SC&A recommends that this issue be **Closed** because neither NIOSH nor SC&A adopt the doses experienced by remediation workers as a surrogate for the doses that might have been experienced by M&C workers.

## B.2 Petitioner SEC Issue 2 (P2)

The 1982 decommissioning surveys, on which the U.S. Nuclear Regulatory Commission based its decisions to release the building interiors for unrestricted use, were substantially flawed. More importantly, they were limited in scope. They only covered accessible former Atomic Weapons Employer (AWE) manufacturing areas (note: most of the former AWE manufacturing areas had already been repurposed by this time and were under heavy use 24 hours per day, so access was extremely limited). There were no intrusive surveys of subsurface areas, or inside the drains and utility trenches that served the former AWE areas, or any of the overhead areas, or any of the exterior areas where waste had been managed. Also, as evidenced by the comprehensive characterization surveys conducted in 1994 and 1995, the 1982 surveys missed considerable amounts of residual activity even in the limited areas they did cover.

### *B.2.1 Discussion*

NIOSH responded to the petitioners' concerns on page 17 of the September 2018 issues matrix (NIOSH, 2018c). NIOSH indicates that, "NIOSH considers accessible contamination levels to be more appropriate for use in modeling exposures to the typical worker, as opposed to the contamination in inaccessible areas that was removed during D&D after 1994." Both SC&A and NIOSH make use of these data in a limited manner to address specific maintenance scenarios.

### *B.2.2 Recommendation*

SC&A recommends that this issue be **Closed**.

## B.3 Petitioner SEC Issue 3 (P3)

The petitioners express concern that, since the 1992 data characterize contamination at the burial ground, it is questionable whether those data can be used to reconstruct doses to workers exposed to residual contamination in other outdoor areas.

### *B.3.1 Discussion*

Both SC&A and NIOSH did not limit reconstruction of outdoor exposures to data from the burial grounds but made use of all of the available data. However, there are issues related to differences in the data and methods used by NIOSH and SC&A related to reconstructing doses to M&C workers outdoors.

### *B.3.2 Recommendation*

SC&A recommends **closing** this specific issue because the differences in the exposures between NIOSH and SC&A are understandable, and the doses are very small.

## B.4 Petitioner SEC Issue 4 (P4)

The petitioners express concern that both SC&A and NIOSH assumed that the duration of intrusive activities, such as subsurface maintenance and repurposing activities, was 1 month per year during the residual period.

### *B.4.1 Discussion*

Initially, SC&A and NIOSH employed 1 month per year duration based on our interpretation of the information gathered during the October 2017 interviews. Workers indicated that they thought the floor was torn up for these activities a total of 1 month per year. Both organizations agree that that there is a lot of uncertainty in that assumption, and, given the uncertainty, both organizations plan to increase the exposure duration to 2 month per year. It is important to point out that both organizations assumed that the same person is always involved in these activities, which we know, based on the interviews, is not the case; i.e., many different workers were assigned to intrusive activities.

### *B.4.2 Recommendation*

SC&A recommends that this issue be **Closed**.

## B.5 Petitioner SEC Issue 5 (P5)

The petitioners express concern that there are no data on thorium from the pipe surveys., and therefore there is “no way of knowing how much thorium source term was present in the residual radioactivity to which the M&C maintenance workers were exposed” (NIOSH, 2018c, p. 20).

### *B.5.1 Discussion*

Both SC&A and NIOSH have made assumptions regarding the concentration of thorium in soil and sludge. SC&A and NIOSH differ in how we approached this issue, which is still under active deliberation.

#### *B.5.2 Recommendation*

SC&A recommends designating this issue **In Progress** until these issues are resolved.

### B.6 Petitioner SEC Issue 6 (P6)

The petitioners argue that, while NIOSH may be able to conservatively assume the worst case for the gross alpha measurements and reconstruct the dose to the organ of concern that would result in the highest dose, whether that be for thorium or uranium, the same cannot be said of the subsurface drains, where we only have isotopic uranium analysis and some direct measurements of beta/gamma radiation. Therefore, we can never know for sure what the exposures were to M&C maintenance workers who were exposed to source materials in the drains.

#### *B.6.1 Discussion*

Both SC&A and NIOSH have made assumptions regarding the concentration of thorium in soil and sludge. SC&A and NIOSH differ in how we approached this issue, which is still under active deliberation.

#### *B.6.2 Recommendation*

SC&A recommends placing this issue **In Progress** due to the ongoing discussion relating to thorium exposures

### B.7 Petitioner SEC Issue 7 (P7)

The petitioners express concern that the Sowell (1985) data are limited as the basis for reconstructing doses to M&C workers outdoors, especially subsurface workers.

#### *B.7.1 Discussion*

SC&A discusses this issue in section 2.3.2 of the Special Exposure Cohort (SEC) evaluation report review (SC&A, 2018a), which indicates that the doses are minimal. Alternatively, if there are limitations in the data, as stated by the petitioners, SC&A and NIOSH can assign all M&C workers involved in subsurface outdoor activities the doses derived for subsurface activities in Building 10.

#### *B.7.2 Recommendation*

SC&A recommends **closing** this issue as an SEC issue but designating this issue as **In Progress** as a site profile issue until a decision is made on the most appropriate strategy for addressing this issue.

### B.8 Petitioner SEC Issue 8 (P8)

The petitioners express concern that the methods used by SC&A to estimate the buildup of dust inside the heating, ventilation, and air conditioning ductwork and filters are underestimated because our analysis is limited to the buildup from resuspended uranium on surfaces during the residual period and does not include grime that may be present in the ductwork and filters residual from the AWE period.

#### *B.8.1 Discussion*

SC&A is basing our analysis on the assumption that the filters are periodically changed, and that any activity on the filters during the residual period is due to accumulation of activity deposited on the filters during the residual period. This matter was discussed at length at the November 20, 2018, M&C work group meeting (M&C WG, 2018b, beginning on page 10 of the transcript). It is important to point out that the activity on the dust is based on the resuspension of gross alpha surface activity measured at the end of AWE operations. Hence, the contribution of AWE operations to the activity of dust on the filters is accounted for in this manner. In addition, since the filters are assumed to have been periodically exchanged, other airborne activity associated with AWE operations likely did not contribute to activity on dust on filters during the residual period.

#### *B.8.2 Recommendation*

SC&A recommends that this issue be designated as **Closed** as both an SEC and site profile issue, with the exception of issues related to thorium.

### B.9 Petitioner SEC Issue 9 (P9)

The petitioners express concern that exposure to M&C workers involved in roof maintenance may have been underestimated because there should be no source term depletion. They express that each penetration is a new location and, thus, the source term should not be depleted for each roof penetration.

#### *B.9.1 Discussion*

SC&A believes the petitioner is misinterpreting the term "source term depletion." The term is not a reference to the source term being reduced in subsequent roof penetrations because the area was disturbed. Instead, it refers to a reduction in source term from environmental reduction factors and routine cleaning. NIOSH (2018e) indicates that no source term depletion is applied in their modeling of maintenance worker exposure.

#### *B.9.2 Recommendation*

SC&A recommends that this issue be **Closed**.

### B.10 Petitioner SEC Issue 10 (P10)

The petitioners express concern that the data acquired during the 1982 surveys cannot be used to reconstruct the doses to M&C workers in subsurface areas.

#### *B.10.1 Discussion*

NIOSH created a new method to model subsurface exposures that does not rely on the 1982 decommissioning surveys.

#### *B.10.2 Recommendation*

SC&A recommends this issue be **Closed**.

# Appendix C: Recommendations from SC&A's "Response to NIOSH White Paper on M&C Dated April 23, 2018" (September 17, 2018)

This memorandum presented SC&A's (2018b) review of the National Institute for Occupational Safety and Health (NIOSH) white paper, "Metals and Controls Corp. Subsurface Exposure Model," dated April 23, 2018 (NIOSH, 2018b). It represents a continuation of the process that began with SC&A's February 12, 2018, review (SC&A, 2018a) of the NIOSH evaluation report (ER) (NIOSH, 2017).

The following sections summarize the recommendations made in SC&A's memorandum, discuss them, and make recommendations on changes in status.

## C.1 Recommendation 1

NIOSH should consider a more bounding concentration of uranium in soil for the purpose of reconstructing internal exposures to Metals and Controls Corp. (M&C) workers involved in subsurface activities beneath Building 10.

### *C.1.1 Discussion*

NIOSH has adopted this approach; refer to the discussion beginning on page 21 of the transcript of the November 20, 2018, M&C work group (WG) meeting (M&C WG, 2018b).

### *C.1.2 Recommended status*

SC&A recommends that this issue be **Closed**.

## C.2 Recommendation 2

NIOSH should consider adopting an inhalation rate commensurate with elevated breathing rates induced by physical exertion while individuals are involved with subsurface work.

### *C.2.1 Discussion*

NIOSH has not addressed this concern, nor do they specify a breathing rate in the ER or subsequent subsurface dose modeling discussions. SC&A assumes they intend to use the standard breathing rate of 1.2 cubic meters per hour ($m^3$/hr) used in most dose reconstructions. SC&A contends this is too low. SC&A assumes a breathing rate of 2.5 $m^3$/hr, which is the recommended breathing rate for adult males engaging in moderate activities, including "heavy indoor cleanup [and] performance of major indoor repairs and alterations" in the U.S. Environmental Protection Agency (EPA) "Exposure Factors Handbook" (EPA, 1997). Although it is unlikely that any individual respired at this rate during the entirety of their subsurface work, this rate bounds potential intakes.

### *C.2.2 Recommended status*

SC&A recommends that this issue be designated as **In Progress**.

# Appendix D: Petitioner Concerns Raised at the December 13, 2018, Advisory Board Meeting

During the December 13, 2018, meeting of the Advisory Board on Radiation and Worker Health (ABRWH, 2018), the petitioner made a statement and provided a letter that raised a number of issues concerning the approach and methodologies used by the National Institute for Occupational Safety and Health (NIOSH) and SC&A. After the meeting, NIOSH addressed the concerns raised by the petitioner in a response paper dated June 18, 2019 (NIOSH, 2019b). SC&A reviewed that response and responded in a December 30, 2019, memorandum (SC&A, 2019b).

## D.1 12/13/2018 Petitioner Concern 1

The petitioner questioned if NIOSH can reconstruct doses to Metals and Controls Corp. (M&C) maintenance workers with sufficient accuracy because (1) the source term characterization is incomplete, (2) there is incomplete knowledge of worker exposures to the source term, (3) the worker exposures were not monitored, and (4) there is no worker population that can be used as a surrogate to evaluate exposures to the M&C workers.

### *D.1.1 Discussion*

This issue pertains directly to SC&A Special Exposure Cohort (SEC) Finding 1. NIOSH claimed that doses can be reconstructed in a scientifically sound and claimant-favorable manner. SC&A concurred with this conclusion. The only exceptions to this agreement are the remaining concerns about specific assumptions related to welding and thorium exposures.

### *D.1.2 Recommendation*

SC&A recommends this issue be **Closed**.

## D.2 12/13/2018 Petitioner Concern 2

The petitioners express concern that we cannot reconstruct doses to personnel exposed to thorium in the drain lines because they were only characterized for isotopic uranium.

### *D.2.1 Recommendation*

Discussion of thorium exposures is still ongoing. SC&A recommends that this issue remain **In Progress** as a site profile issue.

## D.3 12/13/2018 Petitioner Concern 3

The petitioners express concern that we cannot reconstruct doses to personnel exposed to the drain lines because they were disturbed an unknown number of times. They argue that there is no guarantee that the levels measured represent the maximum level present.

### *D.3.1 Discussion*

SC&A agrees that it is not possible to conclusively say that the measured values represent the maximum levels found in the subsurface pipes below Building 10. However, that is not the intent

of the modeling. The intent of the modeling is to identify a value that on average bounds the potential exposure experienced by workers. The highest reading in the subsurface area came from the location where a fuel pin was found in the pipe and downstream of that location. The remainder of the sampling results show significantly lower concentrations. Since this maintenance work involving the pipes and subsurface environment could have potentially removed sediments with the highest uranium concentration, the arithmetic mean, or geometric mean of the survey data cannot be used to represent a bounding exposure. NIOSH and SC&A calculated the 95th-percentile concentration from the soil samples and will assume every subsurface Building 10 exposure occurred at that level.

#### *D.3.2 Recommendation*

SC&A recommends that this issue be **Closed**.

### D.4 12/13/2018 Petitioner Concern 4

The petitioners express concern that there is a bias in the alpha screening methodology.

#### *D.4.1 Discussion*

In the response paper dated June 18, 2019, NIOSH (2019b, p. 6) indicated:

> The M&C gross alpha screening method was developed during the pilot study excavation of the former burial area where M&C split samples, analyzed half of the samples with their field method, and sent the other half to Lockheed Analytical Laboratories for independent verification. M&C determined that their screening method results correlated very well with the isotopic uranium analyses by Lockheed Analytical Laboratories (CPS [1992], PDF pp. 12, 37).

NIOSH also stated that it "reviewed M&C's sampling practices and gross alpha screening method and has not identified a bias that would affect the conservativeness of our exposure model" (NIOSH, 2019b, p. 7). SC&A performed an independent analysis and came to the same conclusion.

#### *D.4.2 Recommendation*

SC&A recommends this issue be **Closed**.

### D.5 12/13/2018 Petitioner Concern 5

Petitioners express concern that M&C workers in the vicinity of the area where large volumes of contaminated soil and debris were removed during the cleanup period in the 1990s may have experienced some exposures.

#### *D.5.1 Discussion*

There is agreement that large volumes of material were removed from the facility. Much of this material was located in areas not readily accessible. Exposure scenarios where workers may have come in contact with these materials have been modeled by SC&A and NIOSH.

#### *D.5.2 Recommendation*

SC&A recommends that this concern be **Closed**.

### D.6 12/13/2018 Petitioner Concern 6

Petitioners express concern that the use of a 1-month duration per year for the various intrusive activities in the subsurface environment and overhead might be too low.

#### *D.6.1 Discussion*

The 1-month duration was based on information given during worker interviews. In response to this concern, NIOSH increased the duration of the exposures to 2 months per year for maintenance activities within Building 10. SC&A finds this assumption reasonable given the uncertainties in time associated with this work. SC&A notes that there were many buildings on site. Taking into account the worker statements about the high-water table on site, SC&A believes it is likely that other buildings at the facility experience similar water problems. Only those subsurface exposures in Building 10 and, to a lesser extent, Building 4 are intended to be covered by this model.

#### *D.6.2 Recommendation*

SC&A recommends that this concern be **Closed**.

### D.7 12/13/2018 Petitioner Concern 7

Petitioners express concern that exposures as measured for site remediation workers in the 1990s and air dust loadings from Mound work cannot be used as a surrogate for exposures to M&C workers during the residual period.

#### *D.7.1 Discussion*

The first part of this issue is identical to Petitioner SEC Issue 1 (P1), discussed in section B.1 of appendix B.

With respect to the Mound dust loading data, NIOSH's assumptions regarding dust loading using Mound data are slightly higher than the dust loading of 100 micrograms per $m^3$ used by SC&A in its analysis. Given the similar magnitude of the dust loadings reached by approaching the problem in different defensible ways, SC&A believes that the NIOSH dust loading assumption of 220 micrograms per $m^3$ is reasonable.

#### *D.7.2 Recommendation*

SC&A suggests that this concern be **Closed**.

### D.8 12/13/2018 Petitioner Concern 8

The petitioners refer to a letter by Congressman Kennedy asking that NIOSH acknowledge the uncertainty in the dose reconstruction methods used by NIOSH and that data from the 1960s, 1980s, and 1990s are not suitable for reconstructing doses to M&C workers during the 1990s.

#### *D.8.1 Discussion*

For reasons discussed in this report, we believe that M&C internal exposures can be reconstructed using the methods described by both SC&A and NIOSH, with consideration given to small differences in the assumptions used by SC&A and NIOSH.

#### *D.8.2 Recommendation*

SC&A recommends that this concern be **Closed** as an SEC issue.

### D.9 12/13/2018 Petitioner Concern 9a

Petitioners repeated the concern about using observed exposures measured for remediation workers as a surrogate for exposures to M&C workers during the residual period. This issue is discussed in section D.7 under 12/13/2018 Petitioner Concern 7.

#### *D.9.1 Discussion*

In response to this concern, NIOSH explained in its June 18, 2019, response paper that NIOSH only used the decontamination and decommissioning (D&D) exposure data for its comparative value and not for dose reconstruction modeling (NIOSH, 2019b). NIOSH used monitoring data from measurements obtained before D&D along with maximizing assumptions to accommodate any extreme conditions encountered by M&C maintenance personnel to create bounding exposure models.

#### *D.9.2 Recommendation*

SC&A recommends that this concern be **Closed**.

### D.10 12/13/2018 Petitioner Concern 9b

The petitioners echo concerns that it is “impossible to identify every conceivable exposure scenario.” They believe that “ it is impossible to reconstruct the bounding dose received by any member of this vulnerable population in anything that can be considered a scientifically sound and claimant favorable manner.”

#### *D.10.1 Discussion*

NIOSH explained in its June 18, 2019, response paper that “NIOSH researched M&C maintenance work and interviewed workers to model exposures associated with their worst-case tasks. Whenever new exposure scenarios were identified, NIOSH evaluated them and created additional exposure models as necessary” (NIOSH, 2019b, p. 12). As long as bounding exposures can be assigned for the limiting exposure scenarios and these exposures are assigned to all workers, it is not necessary to identify and reconstruct every possible exposure scenario. Unless the petitioners believe that there are exposure scenarios that are more limiting than those addressed by NIOSH and SC&A, there is no need to address additional scenarios.

#### *D.10.2 Recommendation*

SC&A recommends that this concern be **Closed**.

# Appendix E: Issues Identified in SC&A's Review of NIOSH's M&C Thorium and Welding Exposure Model

The petitioners raised additional concerns about thorium on site and welding activities that they believed were not sufficiently addressed by previous National Institute for Occupational Safety and Health (NIOSH) and SC&A reviews. In response to these concerns, NIOSH issued a white paper, "Metals and Controls Corp. Thorium and Welding Exposure Model (NIOSH, 2019a), on April 8, 2019. SC&A reviewed this white paper in a July 26, 2019, memorandum (SC&A, 2019a). NIOSH subsequently responded in a November 27, 2019, paper (NIOSH, 2019c). These documents were discussed at the January 2020 work group meeting, and SC&A is in the process of generating responses to the formal issues discussed in these documents.

The following sections summarize the formal issues discussed in these papers, discuss the issues, and make recommendations on the status of these issues.

## E.1 Observation 1

The uranium inventory cited by NIOSH is inconsistent with that in the source document.

According to the NIOSH (2019a) thorium white paper, the cited inventory (ASTRA, 1992) comprised 244 kilograms (kg) of thorium and 7,097 kg of uranium. However, table 2 of ASTRA (1992) appears to indicate a larger amount of uranium, 7,854 kg, as calculated in table 1 of SC&A's review of the white paper (SC&A, 2019a). Furthermore, according to the totals listed in SC&A's table 1, the mass of the total uranium inventory is 32 times that of thorium, not 29 times as stated in the NIOSH white paper. These discrepancies should be resolved.

### *E.1.1 Discussion*

In response to this concern, NIOSH acknowledges this was a data entry error. The inventory is not used in the proposed dose methodology.

### *E.1.2 Recommendation*

SC&A recommends that this concern be **Closed**.

## E.2 Finding 1

NIOSH underestimated the thorium-232 (Th-232) concentration in the sediments and residues in the pipes under Building 10, leading to an underestimate of Th-232 intakes by workers performing subsurface activities.

SC&A calculated the ratios of the Th-232 concentrations to the corresponding uranium-235 (U-235) concentrations in the 88 samples described by Sowell (1985, table 6A) and derived a geometric mean of 4.062 from these 88 ratios. Applying this ratio to the 95th percentile U-235 concentration of 1,529 picocuries per gram (pCi/g) in the pipe sediments, we obtained a Th-232 concentration of 6,211 pCi/g in the pipe residues. Applying the 95th percentile dust loading of $2.2\times10^{-4}$ grams per cubic meter cited by the NIOSH (2018e) maintenance worker white paper, we obtained an air concentration 1.366 picocurie per cubic meter. Assuming that workers were exposed to this activity concentration for 1 month each year, we estimated an inhaled intake of 275 pCi (10.2 becquerels) per year, which led to an effective dose of 53.7 millirem per year

(mrem/yr) from this pathway. According to OCAS-TIB-009 (NIOSH, 2004, p. 4), the daily ingestion rate "can be approximated by assuming it to be 0.2 times the activity per cubic meter of air." Applying this guidance, we obtain an effective dose from ingestion of Th-232 of 0.02 mrem/yr. Our total effective dose from both pathways is more than 3-fold higher than the dose of 14.78 mrem/yr cited by NIOSH (2018e).

#### *E.2.1 Discussion*

In response to this concern, NIOSH (2019c) stated that they disagreed with the paired-sample method used by SC&A to determine a U-235/Th-232 ratio. NIOSH (2019c, p. 5) goes on to state, "because M&C's work with uranium greatly exceeded their thorium work, the assumption that there is an equivalent mass of thorium and uranium in the Building 10 subsurface is conservative and technically defensible."

SC&A is currently drafting a response to this issue.

#### *E.2.2 Recommendation*

SC&A recommends that this concern remain **In Progress** while active discussions on the topic continue.

### E.3 Observation 2

NIOSH should clarify the source of the 4-hour per month time estimate.

SC&A reviewed the reference cited for this estimate (ORAUT, 2017) and could not find any discussion that documented that assumption.

#### *E.3.1 Discussion*

In its November 27, 2019, response paper, NIOSH provided a corrected reference to a worker interview (ORAUT, 2017, PDF p. 15).

#### *E.3.2 Recommendation*

SC&A recommends that this concern be **Closed**.

### E.4 Finding 2

NIOSH understated the resuspension factor (RF) related to activities accompanying welding.

SC&A believes that the highly dispersive nature of the activities accompanying welding—grinding and wire brushing to achieve a clean surface—should be modeled using the highest reported RF in an indoor environment. According to ORAUT-OTIB-0070, table 3-1, "vigorous sweeping by two workmen" resulted in RFs of $1.02\times10^{-2}$ to $4.2\times10^{-2}$. We recommend a rounded value of $10^{-2}$, at the lower end of the range, since it is unlikely that the grinding and brushing occupied the entire time the worker was involved in the welding activities. This would lead to a 10-fold increase in the inhaled intakes estimated by the NIOSH white paper.

### *E.4.1 Discussion*

In its November 27, 2019, response to this concern, NIOSH (NIOSH, 2019c, p. 6) stated:

> The decision to use a resuspension factor of $10^{-2}$ as opposed to $10^{-3}$ is considered a TBD issue. However, NIOSH believes the assumption of a resuspension factor of $10^{-3}$ is representative and bounding of the work activities and conditions at M&C. Work activities are a distribution of activities, of which the majority of resuspension factors in Table 3-1 of OTIB-0070 are sizably smaller (in most cases orders of magnitude smaller) than the proposed resuspension factor of $10^{-3}$. Therefore, NIOSH believes that the use of a $10^{-3}$ resuspension factor is claimant favorable and bounding.

### *E.4.2 Recommendation*

SC&A recommends that this concern remain **In Progress** as a site profile issue.

## E.5 Observation 3

In estimating doses from the welding scenario, NIOSH should assign doses using the most claimant-favorable isotope of thorium or uranium, selected from isotopes known to have been used at M&C.

SC&A does not understand the basis for the additional dose from the inhalation of Th-232: If all the alpha activity were due to U-234, there would have been no thorium. Since there does not appear to be any straightforward means of apportioning the surficial activity among the uranium and thorium isotopes, the activity should be assigned to whichever radionuclide results in the highest dose in a given case. This would be consistent with NIOSH's statement (NIOSH, 2019a, p. 5): "For those areas where gross alpha contamination surveys are available, NIOSH will continue to estimate worker doses using the most claimant-favorable isotope of thorium or uranium." Since the intakes in the welding scenario are based on the 95th percentile value derived from gross alpha contamination surveys, this procedure should be applied.

### *E.5.1 Discussion*

In its November 27, 2019, response to this concern, NIOSH (2019c) agreed with the observation and will choose the most claimant-favorable isotope of uranium or thorium when estimating worker doses.

### *E.5.2 Recommendation*

SC&A recommends that this concern be **Closed**.