NIOSH Response to SC&A's Review of Internal Exposures to Thorium and its Progeny at the KCP during Mg-Th Machining

Response Paper
Rev. 0

National Institute for Occupational Safety and Health

July 7, 2015

Pat McCloskey
Oak Ridge Associated Universities Team
-

Reviewed by Peter Darnell and Jim Neton
Division of Compensation Analysis and Support

PURPOSE

In January 2015, NIOSH provided a response paper titled, *Internal Exposures to Thorium and its Progeny at the Kansas City Plant during Mg-Th Machining*, addressing SC&A's issues contained within their August 2014 paper titled, *Review of Internal Exposures to Thorium and Its Progeny at the Kansas City Plant during Mg-Th Machining Operations*. SC&A reviewed NIOSH's response paper and provided another response on May 12, 2015, titled *Review of NIOSH's White Paper: Internal Exposures to Thorium and its Progeny at the Kansas City Plant during Mg-Th Machining*.

In their latest May 12th response, SC&A agreed with NIOSH that Mg-Th machining operations began at KCP in August 1961 and those exposures from operations can be bounded with the Evaluation Reports (ER) methodology through March 31, 1963.

For the remaining period, 1963–1979, SC&A agrees the ER's bounding method (3E-11 µCi/ml) is claimant favorable. However, SC&A requests monitoring data and validation showing that controls and working conditions did not worsen during those years with incomplete monitoring data. The issue centers on the need for a better understanding of operational parameters such as (1) machining workload (i.e., Was Mg-Th even being machined?), (2) location (Was it co-located with DU operations?), and (3) dates of operations. The following sections discuss NIOSH's understanding of the processing and control of Mg-Th alloy at KCP from 1963 through 1979.

Clarifications regarding April 1963–August 28, 1970

Prior to the January 2015 Work Group meeting, while reviewing NIOSH's January 2015 paper, SC&A noticed what appeared to be "contradictory information about the period April 1963–August 1970" and asked for some clarification to enable a clearer exchange at the subsequent meeting.

In response to SC&A's request, NIOSH provided the following clarification to SC&A and the Work Group:

> The wording here could have been better. First off, we have not reviewed information regarding Mg-Th machining during the period April 1963–August 1970. It remains obvious that these Mg-Th operations were small-scale and my point was that while the "more important" DU operations were in full swing, it makes sense that KCP's focus would have shifted to DU, and Mg-Th documentation would dwindle.

> We have kept April 1963–August 1970 as a Mg-Th operational period for our bounding method (3E-11 µCi/ml) since we do not have records of D&D work at the start of this period, and believe this work would have continued in Department 20 until it was moved into the Model Shop in 1970.

Since January, NIOSH has continued to obtain and review documents (e.g., medical records, inventory) and perform interviews. Based on a review of the information available from the 1963–1970 period, NIOSH has determined that Mg-Th operations were suspended beginning April 1, 1963, and did not begin again until after receiving approval from Health Services on August 28, 1970 (SRDB 128433, PDF p. 2). This suspension of activities during this time period is corroborated by inventory information that does not support a start date any earlier for the second campaign. One data source with inventory information beginning in 1969, documents the presence of Mg-Th inventory starting in 1971 (SRDB 135987). Another source, the Nuclear Materials Management and Safeguards System (NMMS), corroborates the inventory information and also documents the presence of Mg-Th beginning in 1971 (SRDB 137786).

The Weekly Activities reports also corroborate the suspension of Mg-Th operations. They document a very small staff (consisting of five personnel) working one shift, and D&D in Department 22 (the area where this work would have been done) beginning in May 1964, and by August 1964, half of the machines were removed from the area, and the staff were reduced to two, part-time personnel (SRDB 137860).

Second Campaign, August 1970–December 1977

NIOSH has reviewed a memorandum that helps to better define the dates of operations for the second operational campaign starting in 1970 and ending in 1977 (SRDB 128420). In this memorandum, a 1970 start date was identified by Model Shop management, which corroborates the operational information discussed above. The 1977 ending date agrees with the Source and Special Nuclear Material inventory information, which shows the last receipt in March 1977 (SRDB 135987), and NMMS information does not indicate a later date of operations other than waste management (SRDB 137786).

SC&A has requested air-monitoring results applicable to work during this period. NIOSH has not located additional data other than results from three weeks of air-monitoring previously discussed in NIOSH's ER, a January 2015 Response Paper, and SC&A's August 2014 and May 2015 Response Papers where KCP industrial hygienists followed development and production through its various machining operations, and reported that the "air-borne concentrations of thorium and its daughter-decay products were within the limits specified by the AEC's Standards for Protection Against Radiation" (SRDB 108264, PDF p. 16). Although NIOSH has not located additional air monitoring data, there are other factors considered in establishing the basis for the ER's bounding method.

Pyrophoricity

One factor considered by NIOSH is the pyrophoric nature of Mg-Th and the controls KCP implemented to prevent fires. From the beginning of these operations in 1961, KCP was sensitive to this hazard and required onsite fire department involvement prior to any Mg-Th work (SRDB 108264, PDF p. 44). KCP was more explicit about this hazard in 1963, "This alloy (Mg-Th) is a potential problem primarily as a result of the pyrophoricity of the magnesium" (97% of the alloy) (SRDB 128181, PDF p. 5). Health and Safety (H&S) guidelines followed throughout the second campaign in the 1970s continued to address pyrophoricity, and included the statement "the Fire Protection Department shall be contacted before initiation of project and regarding any alterations in processing" (SRDB 128433, PDF p. 4).

Interviews in March 2015 corroborate this respect for the hazard, and adherence on the floor was confirmed with statements such as the following: "We were told Mg-Th was extremely flammable."

Mg-Th's pyrophoric nature was the driver for many of the other industrial hygiene (IH) controls implemented including: "Good Housekeeping" to prevent waste and dust accumulation; a very important fire suppression technique for pyrophoric materials; and "wetting controls" which provided collateral health physics' benefits by reducing airborne dust generation.

Wetting Controls

Another factor NIOSH considers relevant in our determination of the ER's bounding method is that all reports indicate Mg-Th work was a wet process. Some machining operations such as those utilizing the Tape Lathe at Post #F-25.5 were performed completely submerged in coolant (SRDB 108264, PDF p. 18).

KCP implemented IH Best Practices with H&S guidelines and management procedures. These practices included employing all of the controls considered state-of-the-art for the 1970s, and most (e.g., medical surveillance and respiratory protection) continue unchanged to this day. Section D.1 of the H&S Guide issued at the beginning of this campaign in 1970 (SRDB 128433, PDF p. 4) states, "In all machining operations, the material shall be machined "wet," using the mineral oil base coolant, Cadet Z." A year later in 1971, this Guide was revised to reflect a change in the issuing department from H&S to Industrial Hygiene and Health Physics (SRDB 128155). However, all of the IH best practices remained in tact, including the Section D.1 requirement to perform machining operations "wet" (SRDB 128155). The 1975 revision of this guide changed Section D.1 to add requirements for establishing a restricted area within the Model Shop where this work was to be performed, and the wetting controls requirement was moved to Section D.2 (SRDB 108264, PDF p. 4). KCP's implementation and adherence to these wetting controls was also corroborated by interviewees conducted during the March 2015 site visit with statements such as "Chips were kept wet."

Given that the material was wet, it is not plausible that KCP machinists would generate a significant amount of dust. After 1970, the Mg-Th was 2% Th by weight, and it would not seem plausible to reach concentrations as great as 3E-11 on a consistent basis. NIOSH estimates that breathing 3E-11 air, one would inhale ~33 grams of alloy in a year—a high number for a wet process.

NIOSH also considered data found in SC&A's 2007 report, *A Focused Review of Operations and Thorium Exposures at the Dow Chemical Company Madison Plant* (SRDB 53614), which describes dosimetric implications of working with the same Mg-Th Dow supplied to KCP. One worker's affidavit stated that on mill #1, there was "no airborne dust." He opined, "Any generated dust would have been smothered by the mill coolant" (PDF p. 22).

SC&A's report provides data from air samples collected in the breathing zone of workers that were performing aggressive activities with Mg-Th that would have likely exceeded the airborne generating capacity of KCP's machining work. These activities included open-wheel surface grinding, air-operated vibration sanding, buffing, and "drumming" Mg-Th powder. For comparison, the highest observed air concentration in the workers' breathing zone while performing these airborne generating activities at Dow was 3.9 E-12 µCi/ml. Using information SC&A provided in Section 3.5 (PDF p. 32), this concentration would yield a dose of less than 4 mrem/hr or 8 rem/year (CEDE).

SC&A offered the following description of the available data at Dow: "With respect to radiological data pertinent to reconstructing internal exposures, it is clear that the data are limited to a few air samples; however, these data are informative" (PDF p. 29). NIOSH believes that these operations at Dow represent a worst-case exposure scenario, and it is not likely that KCP machinists were exposed to a higher concentration on a 2000-hour time-weighted-average (TWA) basis.

One additional observation from the SC&A report regarding Dow that NIOSH finds informative is the following: "In spite of the fact that only limited processing of uranium was done in Building 6, while Mg-Th alloys had been processed there for more than 30 years, the uranium contamination was far greater. This observation is consistent with other evidence presented in this report indicating that thorium mobility is low" (PDF p. 25).

Source Term

SC&A has requested corroborating data, and in the absence of such data recommends source-term-based exposure modeling. The following is taken from the conclusion of the SC&A May 2015 white paper:

> *SC&A recommends that in the absence of measurement data, NIOSH should validate its proposed 3E-11 μCi/ml air concentration limit through source term-based exposure modeling, followed by suitable sample dose reconstructions to demonstrate the feasibility of applying this limit for the various operational time periods in question (i.e., 1963-1966, 1966-1970, 1970-1979).*

Following SC&A's recommendation, NIOSH has reviewed the available source-term information. NIOSH has not located extensive source term information and recognizes that inventory information is limited. However, this apparent lack of information could be explained by the small-scale nature of these operations, and/or that there simply was not much inventory after KCP started tracking it in 1969. For example, the Source and Special Nuclear Material inventory information has no data from October 1973 until December 1975, which is explained by the Waste Management plan that indicates a break in these Operations by virtue of no waste generated in 1974 (SRDB 134675, PDF p. 315).

NIOSH was able to locate the largest inventory for 1973 (SRDB 135987). Quantities were identified as being received during eight separate months during the year and totaled 42 kg of thorium. If we apply Equation 1.2 from NUREG 1400 to this largest (worst-case) annual amount, we can calculate an intake amount (I).

$$\mathbf{I = Q \times 10^{-6} \times R \times C \times D}$$

Where:

- Q = The total quantity of unencapsulated thorium processed for the year, or 42,000 g is used.

- R = The release fraction of thorium likely to be released into the workplace, taken from Table 1.1. Although the dominant material forms were solids, exposure potential increased as material was machined; therefore, "nonvolatile powders" or 0.01 is used.

- C = The Confinement fraction. Although all machining operations used worksite local ventilation (400 CFM with absolute filters) and material was maintained wet, we take no credit for it and use a factor of 1.

- D = The Dispersibillity factor. Although KCP's machining operations were likely less-energetic than the examples given in the NUREG, NIOSH will conservatively use their suggested factor of 10.

Yields: I = 4.2E-3 g/year

Using the specific activity of Th-232 (1.1E-7 Ci/g), we can convert this to 4.62E-10 Ci/year or 17.1 Bq/year. We can compare the amount 17.1 Bq/year to the intake amount based on the ER's bounding concentration (3E-11 µCi/ml) calculated by SC&A (Finding 7, PDF p.13) as 2664 Bq/year. Therefore, this source-term calculation shows an intake rate much smaller (156 times) than that based on the ER's method.

Although a sufficient amount of conservatism has been used in this calculation, NIOSH suggests the assumption of 1973 as a worst-case and the throughput for that year (42 kg) could be validated by reviewing the classified NMMS data in Germantown.

NIOSH provides this NUREG 1400 source-term calculation to satisfy SC&A's request. It is only meant to provide an additional layer of assurance, and add to a preponderance of evidence justifying that the ER's method is bounding.

Conclusion

NIOSH, along with SC&A and the Advisory Board Work Group, has been reviewing KCP documents and interviewing personnel since 2004 regarding radiological work at KCP. For the last several years, NIOSH has specifically been searching for Mg-Th information. NIOSH continues to seek and review additional information.

Based on a review of the information available at this time, NIOSH believes the weight of evidence supports the ER's bounding method, as modified with the Advisory Board's and SC&A's assistance, as plausible and claimant favorable.

REFERENCES

SRDB 53614, *A Focused Review of Operations and Thorium Exposures at the Dow Chemical Company Madison Plant* (Draft)

SRDB 108264, PDF p. 4, *Revised Health and Safety Guide for Handling Magnesium-Thorium in Department 851* (August 28, 1970; Revised July 16, 1975); Document spans PDF pp. 3-6

SRDB 108264, PDF p. 16, *Correspondence and Results-Summary of Air Samples of Magnesium-Thorium Project in D/851*; Document spans PDF pp. 16-20

SRDB 108264, PDF p. 18, *Correspondence and Results-Summary of Air Samples of Magnesium-Thorium Project in D/851*; Document spans PDF pp. 16-20

SRDB 108264, PDF p. 44, *Recommendations for Handling Magnesium-Thorium Alloy*

SRDB 128155, *Handling Magnesium-Thorium in Dept. 851* (select pages from "Industrial Hygiene and Health Physics Guide")

SRDB 128181, PDF p. 5, *Magnesium-Thorium (3.5% MAX.) Alloy Suggested Care and Handling Methods*; Document spans PDF pp. 5-7

SRDB 128420, *D/823 Radioactive Materials Usage*

SRDB 128433, PDF p. 2, *Development Support Project Using Magnesium-Thorium Alloy*

SRDB 128433, PDF p. 4, *Revised Health and Safety Guide for Handling Magnesium-Thorium in Department 851* (August 28, 1970); Document spans PDF pp. 3-5

SRDB 134675, PDF p. 315, *Radioactive Waste Management Site Plan* (1974 Submission); Document spans PDF pp. 313-322

SRDB 135987, *Statements of Measurement Methods/Balance Report/Inventory*

SRDB 137786, *Handwritten Inventory Notes*

SRDB 137860, *Weekly Activities Reports*