



MEMORANDUM

TO: Advisory Board on Radiation and Worker Health, Work Group on Carborundum Company
FROM: Robert Anigstein and John Mauro, SC&A
DATE: November 10, 2016
SUBJECT: Review of NIOSH Use of Surrogate Data in the SEC Evaluation Report for Carborundum

On October 27, 2016, Thomas Tomes (NIOSH/DCAS) issued a memorandum titled “Use of Surrogate Data at the Carborundum Company” (Tomes 2016). In an email message on the same day, Ted Katz, Designated Federal Official to the Advisory Board on Radiation and Worker Health (ABRWH), asked SC&A to review this report (Katz 2016).

Tomes (2016) reviewed the use of surrogate data from TBD-6000 (Allen 2011) in the SEC Evaluation Report for Carborundum (ER) (Jessen and Scalsky 2015) in order to determine if the use of these data satisfied the criteria specified in OCAS-IG-004 (OCAS 2008). Since SC&A is the technical support contractor to the Advisory Board, we deemed it appropriate to determine if the use of surrogate data conformed to the board’s own criteria (ABRWH 2010).

Advisory Board Criteria for the Use of Surrogate Data

We first list the five criteria for use of surrogate data, as stated by the Advisory Board (ABRWH 2010).

Criterion 1: Hierarchy of Data

It should be assumed that the usual hierarchy of data would apply to dose reconstructions for that site (individual worker monitoring data followed by co-worker data followed by workplace monitoring data such as area sampling followed by process and source term data). This hierarchy should be considered when evaluating the potential use of surrogate data. Surrogate data should only be used to replace data if the surrogate data have some distinct advantages over the available data and then only after the appropriate adjustments have been made to reflect the uncertainty inherent in this substitution.

Criterion 2: Exclusivity Constraints¹

[In situations where] there are no or very little monitoring data available . . . the use of the surrogate data as the basis for individual dose reconstruction would need to be stringently justified. This judgment needs to take into account not only the amount of

¹ Only the relevant text from Criterion 2 is quoted here.

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surrogate data being relied on relative to data from the site but also the quality and completeness of that surrogate data.

Criterion 3: Site or Process Similarities

One of the key criteria for judging the appropriateness of the use of surrogate data would be the similarities between the site (or sites) where the data were generated and the site where the surrogate data are being utilized. The application of any surrogate data to an individual dose reconstruction at a site should include a careful review of the rationale for utilizing that source of data. Factors that could be considered include, but are not limited to, similarity of the production processes, presence or absence of conditions that might affect exposure, and monitoring methods employed at the site(s). The potential availability of other sources of surrogate data needs to be considered and the selection of the surrogate data used for dose reconstruction justified. Some of the questions to be considered where appropriate are:

- Are there other sources of surrogate data that were not used?
- Do these other potential sources contradict or undermine the application of the data from the selected site?
- Are there adequate data characterizing the site being used that would help support its application to other sites?
- Do the surrogate data reflect the type of operations and work practices in use at the facilities in question?

Surrogate data should not be used if the equivalence of working conditions, source terms, and processes of the surrogate facility to the one for which dose reconstructions are being done cannot be established with reasonable scientific or technical certainty as outlined here.

Criterion 4: Temporal Considerations

Consideration also needs to be given to the period in question, since working conditions and processes varied in different periods. Surrogate data should belong in the same general period as the period for which doses are sought to be reconstructed unless it can be demonstrated that the working conditions, procedures, monitoring methods, and (perhaps) legal requirements were comparable to the period in question.

Criterion 5: Plausibility

The manner in which the surrogate data are to be used must be “plausible” with regard to the reasonableness of the assumptions made. The plausibility determination should address issues of:

- **Scientific plausibility.** Are the assumed models (e.g., bioassay, concentration gradients) scientifically appropriate? Have the models been validated (where feasible) using actual monitoring data collected in a similar situation?

- Workplace plausibility. Are the assumed processes and procedures (including monitoring) plausible for the facility in question? Have all of the factors that could significantly impact exposure been taken into account? Is adequate information available about the facility in order to be able to make a fair assessment?

Use of Surrogate Data in the SEC Evaluation Report for Carborundum

External Exposure to Penetrating Radiation from Uranium Metal during the First Operational Period

Tomes (2016) cited three instances in which surrogate data from TBD-6000 were used in the ER. We first discuss the estimate of doses from external exposure to penetrating radiation from uranium metal during the first operational period (June 1, 1943, to September 27, 1943). Neither Tomes nor the ER cite the actual external doses used to estimate doses during this period. Tomes states:

As provided in the ER section 5.1.1, the source term for the 1943 work at Carborundum is well known. The work was limited to natural uranium metal slugs, which are included in the various shapes of metal evaluated [in] TBD-6000. The source terms are similar.

However, this is not the source term specified in the ER, which states:

In the absence of personnel-specific external dosimetry records during the first operational period, external dose from uranium will be estimated using the data found in the TBD, *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals*. . . . Specifically, the section of Tables 7.8 and 7.9 pertaining to pre-1951 dose rate for “Machining” should be used.

Tables 7.8 and 7.9 list intakes of uranium dust by inhalation and ingestion, respectively, not external doses. External doses to workers in various job categories are listed in the Excel file “Carborundum Methodology 2015-07-23 FINAL.xlsx” (henceforth referred to as “Methodology.xlsx”), which is one of three documents that present the proposed prescriptions of the National Institute for Occupational Safety and Health (NIOSH) for dose reconstructions (DRs) for Carborundum workers and are available on the Division of Compensation Analysis and Support (DCAS) restricted website. These doses correspond to those listed in Table 6.4 of TBD-6000 for machining operations prior to 1951. The major component of these doses is exposure to uranium metal. The default source—the basis for the values in Table 6.4—is a rectangular uranium ingot with dimensions of 24 H 16 H 4 inches thick (60.96 H 40.64 H 10.16 cm) (Anderson and Hertel 2005). Such an ingot has a mass of 477 kg (1,052 lb), as listed in Table 1 of the present memo.

Table 1. Dose Rates at 1 Foot from Various Shapes of Natural Uranium Metal

Shape	Mass (kg)	Dose rate at 1 ft (mrem h ⁻¹)	Specific dose rate at 1 ft (mrem h ⁻¹ kg ⁻¹)
Ingot	477.0	2.08	0.00436
Slug	2.032	0.0524	0.0258
Plate	3.118	0.231	0.0741

Source: Anderson and Hertel 2005

Reviewing the use of these data against the five criteria presented above, we draw the following conclusions:

- The external dose rates satisfy the hierarchy-of-data criterion, since there are no site-specific radiation measurements for the uranium machining operations at Carborundum.
- The external dose rates satisfy the exclusivity constraints for the same reason given above.
- The external dose rates do not satisfy the site-or-process-similarities criterion. Although the dose rates modeled for TBD-6000 result from exposures to natural uranium metal, which is presumed to have been the radiation source at Carborundum in 1943, the size and shape of the metal is quite different. According to the ER, the uranium was assumed to be in the form of Clinton slugs, which were described as cylinders, 1.1 inches (2.79 cm) in diameter by 4 inches (10.16cm) long. Since uranium has a density of 18.95 g/cm^2 , the slugs would have had a mass of 1.18 kg (~2.6 lb), far less than the rectangular ingot.
- The temporal-considerations criterion is not applicable, since the calculations that are the basis of the TBD-6000 model would not change with time.
- The external dose rates do not satisfy the plausibility criterion. Since the total mass of uranium shipped to Carborundum was ~30 lb, assuming that the radiation levels were the same as those from a 1,052-lb ingot is implausible.

According to TBD-6000: “For an individual site, there may be information on which shape applied to a site’s operations However, for the generic case, a worst-case assumption should be made, which is that all work was done with a uranium metal slab.” Since site-specific information is available, there is no need to use a worst-case assumption. NIOSH should use such information and reasonable assumptions regarding the quantity and form of the uranium metal handled and processed at Carborundum. For instance, NIOSH could consider basing the dose rates on the uranium slug, one of the shapes listed in TBD-6000, Table 6.1. This slug was modeled as a hollow cylinder, with an inner radius of 1.041 cm, an outer radius of 2.108 cm, and a length of 10.16 cm (Anderson and Hertel 2005). Such a slug has a mass of 2.03 kg (~4.5 lb) and resembles the Clinton slug far more than does the rectangular ingot. The dose rate at a distance of 1 ft from the surface of the slug is listed in Table 6.1 as 0.0524 mrem/h, vs. 2.08 mrem/h for the ingot. A bounding case would be an array of seven slugs, with a total mass of ~31 lb. An upper bound of the dose rate at 1 foot could be estimated as 7 times the dose rate from one slug, or 0.367 mrem/h, which is 18% of the rate from the rectangular ingot. Such a dose rate could be substituted for the values of the “Metal whole body dose” listed in TBD-6000, Table 6.4, to calculate the doses entered in “Methodology.xlsx.” Dose rates from penetrating radiation at 1 m from the metal could be calculated in a similar manner.

External Exposure to Penetrating Radiation from Uranium during the Second Operational Period

A second instance of the use of surrogate data is the estimate of doses from external exposure to penetrating radiation from uranium during the second operational period. “Methodology.xlsx” used the TBD-6000 external dose rates based on the rectangular uranium ingot. However, the mass of this ingot far exceeds the actual amount of uranium handled at Carborundum during this period. Table 5-2 of the ER summarized the uranium operations during this period, including quantities of uranium in various

batches of uranium products. The maximum quantity cited in this table was in a request for 10 lb (4.5 kg) of uranium shot. Another entry refers to batches ranging from about 30 g to 6 lb (2.7 kg). All other batches listed in this table fall into this range.

Applying the five criteria to the use of surrogate data from TBD-6000 to represent external doses during this period, we again conclude that the external dose rates do not satisfy the site-or-process-similarities criterion, nor the plausibility criterion, for the reasons discussed previously. The other three criteria are either satisfied or inapplicable, as discussed earlier.

Although no single shape or quantity can be used to describe the uranium processed or handled during this period, NIOSH could elect to use the dose rates from a uranium plate, shown in Table 1 of this memo, to bound the external exposures to uranium. The mass of the plate, ~3.1 kg (6.9 lb) is consistent with the largest single batch of uranium cited in the ER and only slightly less than the 10 lb of uranium shot requested by Carborundum. This shape also has the highest specific dose rate (dose rate per unit mass of uranium metal) of the shapes listed in Table 1, as well as of all other shapes modeled by Anderson and Hertel (2005). Consequently, use of this shape to represent the external dose rates from the largest batch of uranium processed at Carborundum would yield a plausible yet claimant-favorable upper bound, given the limited amount of uranium handled at this site.

Intakes of Uranium Aerosols during the First Operational Period

According to the ER: “Internal doses from uranium intakes during the first operational period are estimated using the data from the pre-1951 ‘Machining’ operation in Tables 7.8 and 7.9 of the Technical Basis Document: *Site Profiles for Atomic Weapons Employers That Worked Uranium Metals*.” We note that the operator is assigned an intake of 43,632 dpm per calendar day as the median of a lognormal distribution with a GSD of 5. The arithmetic mean of this distribution is 159,323 dpm per calendar day, which corresponds to an average breathing zone concentration of 20,192 dpm/m³.

Reviewing the use of these data against the five criteria presented above, we draw the following conclusions:

- The internal doses satisfy the hierarchy-of-data criterion, since there are no site-specific airborne dust measurements for the uranium machining operations at Carborundum.
- The internal doses satisfy the exclusivity constraints for the same reason.
- The internal doses satisfy the site-and-process-similarities criterion: Uranium machining operations at Carborundum involved centerless grinding. Harris and Kingsley (1959), in reporting airborne uranium concentrations generated by this process, stated that, “without ventilation, breathing zone concentrations as high as 13,000 [dpm/m³] have been recorded.”
- The temporal-considerations criterion is satisfied. TBD-6000 states, “These results are typical of the state of technology in the late 1950s, as surveyed by Harris and Kingsley,” which was about 15 years earlier. However, since the cited breathing zone concentration was not ameliorated by ventilation, it is unlikely that the working conditions at facility surveyed by these authors would have been any more favorable to the worker’s health and safety than those at Carborundum in 1943. NIOSH assigned the operator an intake of 43,632 dpm per calendar day as the median of a

lognormal distribution with a GSD of 5. The arithmetic mean of this distribution is 159,323 dpm per calendar day, which corresponds to an average breathing zone concentration of 20,192 dpm/m³. We find that, given the limited quantity of uranium metal in the present case, the values listed in TBD-6000 are sufficiently bounding.

- The internal dose rates satisfy the plausibility criterion. The average breathing zone concentration of 20,192 dpm/m³ is consistent with the concentration of 13,000 dpm/m³ cited by Harris and Kingsley, if we allow for uncertainty and variability.

Conclusions

External Dose Rates from Uranium Metal during First and Second Operational Periods

We note that neither Tomes (2016) nor the ER explicitly cite the dose rates from external exposure to penetrating radiation from uranium metal during first and second operational periods, nor do they identify the specific model(s) to be used to determine such dose rates. On the basis of “Methodology.xlsx,” we found that these dose rates correspond to the rates listed in Table 6.4 of TBD-6000. Those rates, in turn, are based on MCNP calculations of dose rates from a rectangular uranium ingot which is much more massive, and results in much higher dose rates, than the quantities of uranium metal present at Carborundum during either period. Consequently, we find that the use of these dose rates is inconsistent with the Advisory Board’s surrogate data criteria, and with TBD-6000 itself, which refers to these dose rates as a worst-case assumption.

However, this conclusion does not invalidate the conclusion in the ER that NIOSH can reconstruct doses from external exposure to uranium metal during the two operational periods. This is a site profile issue but not an SEC issue.

We have suggested acceptable methodologies that NIOSH could employ for this purpose. NIOSH should consider the use of such methods when preparing final instructions to dose reconstructors to use in estimating doses to former Carborundum employees.

Intakes of Uranium Aerosols during the First Operational Period

We conclude that use of TBD-6000, Tables 7.8 and 7.9, to estimate intakes of uranium aerosols during the first operational period is consistent with the five Advisory Board criteria for the use of surrogate data.

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