



Carborundum Company Work Group Background and SC&A Review of Site Profile for the Carborundum Company

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Work Group background

- ◆ There have been 5 work group meetings for the Carborundum Company
 - August 18, 2016; November 17, 2016; March 13, 2017; December 4, 2018; and June 13, 2019
- ◆ Discussions included the National Institute for Occupational Safety and Health's (NIOSH's) Special Exposure Cohort (SEC) evaluation report for the Carborundum Company, and SC&A's review of the evaluation report
- ◆ SC&A's review identified 7 findings

SC&A evaluation report review – Finding 1

- ◆ No methodology to support doses to the skin of the hands and forearms from x-ray diffraction (XRD)
- ◆ August 18, 2016
 - NIOSH responded with a methodology using glovebox worker doses assuming 50% exposure
 - SC&A felt that this was bounding
 - Work group closed the finding
- ◆ March 13, 2017
 - Due to a reduction in the uranium source term, XRD dose was evaluated again
 - SC&A interviewed a worker and recommended an exposure time of 5 minutes instead of 2 minutes per sample
 - Differences in the assumed geometry used by SC&A and NIOSH
 - Work group agreed it was a site profile issue; closed from SEC perspective

Finding 1 – additional discussions

December 4, 2018

- ◆ NIOSH concurred with SC&A's suggestion to assume an exposure duration of 5 minutes per sample
- ◆ NIOSH also to apply correction factor of 2.48 to adjust the dose rate for low energy photons
- ◆ NIOSH to use more appropriate organ dose conversion factors for 10 kiloelectron volt (keV) photons
- ◆ Work group closed the finding

SC&A evaluation report review – Finding 2

- ◆ NIOSH did not address thorium as a possible radiation source
- ◆ August 18, 2016
 - SC&A discussed an interview with a worker that indicated thorium was used to make pellets at the site
 - NIOSH stated that there are no records of thorium other than this interview
 - If thorium was present, contamination would have been picked up with uranium contamination data; however, dose from inhalation of thorium would be higher than if it was assumed to be uranium-234
 - Work group moved this to a site profile issue, not an SEC issue
- ◆ March 13, 2017
 - NIOSH responded that dose from any thorium residue would have been insignificant compared to the dose from uranium
 - SC&A agreed; work group closed the finding

SC&A evaluation report review – Finding 3

- ◆ Thickness gauges containing strontium-90 not discussed by NIOSH
- ◆ August 18, 2016
 - NIOSH found that the division handling the gauges was in a facility in a different city (not a covered site)
 - Work group closed the finding

SC&A evaluation report review – Finding 4

- ◆ No occupational medical dose assigned for the first operational period
- ◆ August 18, 2016
 - NIOSH agreed that these doses should be assigned
 - Work group closed the finding
- ◆ March 13, 2017
 - SC&A identified discrepancies in the example dose reconstruction (DR) regarding the surrogate organ used for the dose estimate and the associated uncertainty
 - NIOSH would make corrections

SC&A evaluation report review – Finding 5

- ◆ No occupational medical dose assigned for the second operational period in the example DR
- ◆ August 18, 2016
 - NIOSH agreed that these doses should be assigned
 - Work group closed the finding

SC&A evaluation report review – Finding 6

- ◆ NIOSH used Federal Guidance Report 12 to calculate doses from submersion in a cloud of radioactive dust rather than using values from Battelle-TBD-6000 (“TBD-6000”)
 - TBD-6000 used in other dose estimates in the evaluation report
- ◆ August 18, 2016
 - NIOSH agreed that TBD-6000 should be used to estimate submersion dose
 - Work group closed the finding

SC&A evaluation report review – Finding 7

- ◆ SC&A was unable to reproduce some doses from the example DR
- ◆ August 18, 2016
 - NIOSH acknowledged that Class F uranium was used in error
 - Some aspects of the DR have used efficiency methods
 - SC&A agreed that NIOSH could reconstruct doses, but noted the importance of having all the assumptions properly documented
 - Work group closed from an SEC perspective
- ◆ March 13, 2017
 - SC&A identified additional minor errors in the example DR
 - Work group still believed DR could be done with sufficient accuracy, details to be worked out

Use of surrogate data at the Carborundum Company

- ◆ On October 27, 2016, NIOSH issued a memo discussing the appropriateness of using surrogate data from TBD-6000 for dose estimates at the Carborundum Company, which SC&A reviewed and responded to
- ◆ Criteria for surrogate data:
 - Hierarchy of data
 - Exclusivity constraints
 - Site or process similarities
 - Temporal considerations
 - Plausibility
- ◆ Discussed during November 17, 2016, work group meeting

Surrogate data

- ◆ External dose estimated using TBD-6000 values for a uranium ingot for first and second operational periods
 - Site and process similarities criterion not fulfilled
 - An ingot (477 kilograms (kg)) is much larger than the amount of material at the site
 - 13.6 kg for first operational period; 4.5 kg for second period
 - Plausibility criterion not fulfilled
 - Difference in source term size
- ◆ SC&A suggested to estimate the dose from 7 slugs for first operational period
- ◆ SC&A suggested to estimate the dose from uranium plate for second operational period

Surrogate data – response (November 17, 2016)

NIOSH reviewed SC&A's November 10, 2016, memo and agreed to reevaluate which dose rates should be used

Surrogate data – response (March 13, 2017)

- ◆ NIOSH agreed to use uranium slug dose rates for the first operational period
 - Work group closed the issue
- ◆ NIOSH agreed to use uranium plate for the second operational period
 - Discussion about how the beta doses should be estimated
 - SC&A believed that the doses could be reconstructed, but settling the details would be a site profile issue instead of an SEC issue
 - Work group closed the issue from an SEC perspective
 - At the December 4, 2018, meeting NIOSH agreed to use the dose rates from the uranium plate and the beta dose rates calculated by SC&A
 - Work group closed the issue

SC&A review of NIOSH response and example dose reconstructions

- ◆ Memo issued by SC&A on June 30, 2017
- ◆ Identified additional findings and observations
 - Topics similar in nature to those previously identified

SC&A 2017 finding: exposure duration

- ◆ Inconsistent annual exposure durations assumed in the example DR
 - 2,500 hours per year vs. 2,400 hours per year
 - Discussed during December 4, 2018, work group meeting
 - NIOSH updated the calculations to use the work hours prescribed in TBD-6000
 - Work group closed the finding

SC&A 2017 finding: probability distribution

- ◆ Incorrect probability distribution used for external exposure to uranium metal
 - Discussed during December 4, 2018, work group meeting
 - NIOSH acknowledged it was an error in the spreadsheet and would be corrected
 - Work group closed the finding

SC&A 2017 finding: Monte Carlo N-Particle glovebox model

- ◆ Incorrect source term and glovebox model used in Monte Carlo N-Particle (MCNP) analysis
- ◆ Discussed during the December 4, 2018, work group meeting
 - Differences in the glovebox and dosimeter geometry used by NIOSH and SC&A
 - Both assumed enough plutonium pellets to reach 100-gram limit
 - Differences in the dose conversion factors used from International Commission on Radiological Protection (ICRP) Publication 74 (“ICRP 74”)
 - SC&A used values from a newer table; NIOSH used older values from previous guidance
 - Minimal difference in resulting dose

MCNP glovebox model additional discussion – June 13, 2019

- ◆ ICRP 74 values
 - NIOSH intended to keep using the older ICRP 74 values for consistency with other sites
 - NIOSH does not believe the data are outdated, as a draft ICRP report has similar values to what NIOSH is using
 - SC&A believes the newer values should be used as they are slightly more claimant favorable
 - Work group decided to wait on this issue until the pending ICRP report is issued
- ◆ MCNP glovebox modeling
 - NIOSH used an updated version of MCNP which fixed some errors
 - NIOSH adopted SC&A's suggestion for the glovebox and dosimeter geometry
 - Work group closed these issues

SC&A 2017 finding: uranium and plutonium exposure for glovebox workers

- ◆ SC&A recommended assigning intakes of both uranium and plutonium for the uranium-plutonium pellet fabrication
 - Discussed during December 4, 2018, work group meeting
 - Uranium and plutonium were sampled separately in different locations
 - NIOSH agreed to assign the higher dose when considering the reading as either uranium or plutonium
 - Work group closed the finding

SC&A 2017 observation: energy distribution for contaminated surfaces

- ◆ An incorrect probability distribution type was used for external dose in the example DR
 - Discussed during December 4, 2018, work group meeting
 - NIOSH acknowledged that this was due to a spreadsheet error and would be fixed
 - Work group closed the finding

SC&A 2017 observation: ingestion rates

- ◆ SC&A found a small rounding error in the way NIOSH converted air concentrations to ingestion rates leading to a slight underestimation of dose
 - Discussed at December 4, 2018, work group meeting
 - NIOSH updated the spreadsheet to resolve the issue
 - Work group closed the observation



SC&A 2020 Carborundum Company site profile review

Occupational medical dose

- ◆ First operational period only 4 months long
 - NIOSH assumes workers receive a single x-ray
 - ORAUT-OTIB-0006 prescribes pre-employment, annual, and termination x-rays
- ◆ Second operational period
 - NIOSH follows ORAUT-OTIB-0006 guidance and assigns preemployment, annual, and termination x-rays



Observation 1

Workers employed prior to the first operational period whose employment terminated during this period should be assigned two medical x-rays if it is plausible that they could have undergone both an annual and a termination x-ray during this period.

Occupational internal dose – first operational period

- ◆ NIOSH assigns inhalation and ingestion intakes of uranium based on TBD-6000 intakes for machining
- ◆ Three categories of workers
 - Operators
 - Laborers
 - Supervisors

Occupational internal dose – first residual period inhalation

- ◆ NIOSH followed guidance from TBD-6000
- ◆ Calculated a surface concentration based on 30 days of airborne activity settling
- ◆ Applied resuspension factor of 10^{-5} per meter
- ◆ Assumed a 48-hour work week
- ◆ NIOSH used ORAUT-OTIB-0070, rev. 01, to adjust the intakes to account for source depletion
- ◆ Intakes for 1951 through 1955 were reduced to account for a 44-hour work week, and in 1956 intakes reduced to account for a 40-hour work week

Occupational internal dose – first residual period ingestion

- ◆ First year set equal to ingestion during the first operational period
- ◆ Intakes for remainder of the residual period adjusted using ORAUT-OTIB-0070, rev. 01, and to account for work week lengths

Occupational internal dose – second operational period

- ◆ NIOSH used airborne activity measurements to estimate inhalation intakes for workers in different labor categories
- ◆ Workers associated with the Global Plant (not Atomic Weapons Employer-related work) assigned doses from the first residual period
- ◆ All other workers assigned uranium intakes for 1959 through 1960
 - Intakes of either plutonium or uranium for 1961 through 1967, whichever is more claimant favorable
 - Plutonium assumed to be 5-year-old weapons-grade
 - Isotopic ratios consistent with previous SC&A review

Occupational internal dose – second residual period

- ◆ SC&A confirmed that workers in areas of the site that had residual contamination from the first operational period would have higher uranium intakes during the second residual period than workers exposed to residual contamination from the second operational period
 - Uranium laboratory was built after the end of the first operational period
- ◆ Workers should be assigned uranium intakes based on the first residual period for the appropriate years, or intakes of residual plutonium for this period, whichever is more claimant favorable

Occupational external dose – first operational period

- ◆ NIOSH estimated dose rates assuming the source term was 10 uranium slugs
- ◆ NIOSH used TBD-6000 to estimate beta skin dose of 0.524 millirad per hour (mrad/h) from a single slug
 - SC&A MCNP modeling resulted in 0.54 mrad/h
- ◆ NIOSH assigned external dose from submersion and from floor contamination using TBD-6000 methodologies
 - Floor contamination assumed the airborne activity was allowed to settle for 30 days
 - SC&A verified NIOSH's doses

Observation 2

Need to specify doses to the skin of the hands and forearms from direct contact with uranium metal slugs.

- ◆ TBD-6000 beta dose estimates are for skin not in direct contact with uranium metal
- ◆ The site profile does not specify a beta dose to the skin of the hands and forearms in direct contact with the uranium metal

Occupational external dose – first residual period

- ◆ NIOSH set the initial external exposure rates from floor contamination equal to those during the first operational period
 - Dose rates were then adjusted using ORAUT-OTIB-0070, rev. 01
 - Dose rates also adjusted for later years for different work week lengths
- ◆ SC&A confirmed these values

Occupational external dose – second operational period

- ◆ Three sources of external exposure:
 - Uranium metal
 - Fuel pellets with mixed uranium and plutonium carbide
 - X-ray diffraction
- ◆ Sources located in different areas of the plant, a worker could have been exposed to only one of the first two from 1959–1960, and one of the three from 1961–1967
 - Plutonium not on site until 1961
- ◆ NIOSH states that the most claimant-favorable source is to be used for the appropriate time period

Occupational external dose – uranium metal

- ◆ NIOSH assumed the source was a metal plate from TBD-6000
 - Highest ratio of external dose to mass of shapes in TBD-6000
 - Beta doses based on MCNP modeling
 - SC&A verified dose rates given by NIOSH
- ◆ NIOSH also calculated dose from submersion in airborne contamination
 - Based on general air samples
 - NIOSH derived inhalation intake of a laborer and doubled this value for operators



Observation 3

Need to specify doses to the skin of the hands and forearms from direct contact with flat uranium plate.

- ◆ The site profile does not specify a beta dose to the skin of the hands and forearms in direct contact with the uranium metal

Observation 4

NIOSH doubled the airborne activity concentration from air sampling data to derive the dose rates.

- ◆ NIOSH used a airborne activity concentration of 14.77 disintegrations per minute per cubic meter (dpm/m³), which is twice the 95th percentile concentration of 7.38 dpm/m³ derived from uranium air samples collected in 1959 and 1961

Occupational external dose – fuel pellets

- ◆ NIOSH modeled external exposure to a single fuel pellet using MCNP
 - Composition of the fuel pellet was specified by the empirical formula $(U_{0.8}Pu_{0.2})C$ with a small admixture (0.003%) of americium
 - Where U is uranium; Pu is plutonium; C is carbon
- ◆ Previous reviews of the MCNP modeling for the fuel pellet and glovebox scenario had 3 issues since addressed by NIOSH
 - NIOSH had issued a report with new data to support their method of calculating dose conversion coefficients for photons
 - NIOSH used a newer version of MCNP (6.2) which corrected a source biasing error
 - NIOSH agreed to position both the pellet and dosimeters at an elevation of 24 centimeters (cm) above the floor of the glovebox

Observation 5

NIOSH should use the correct empirical formula $(U_{0.8}Pu_{0.2})C_{0.95}$ cited by the Carborundum Company fuel development progress reports.

- ◆ The empirical formula used by NIOSH was a deviation from what was in the 1962 project progress report (Site Research Database Reference ID 61995) previously cited by SC&A in its January 27, 2016, SEC evaluation report

Finding 1

The two dosimeters in MCNP input files are centered at 20 cm above the floor of the glovebox, which does not agree with the description in the site profile, and places them 4.57 cm below the center of the source. The geometry in the neutron dose analysis is different than what was used in the photon analysis, even though they are the same scenario.

- ◆ The site profile states the pellet is 24 cm above the glovebox floor, but the input files demonstrate the pellet is 24.57 cm above the glovebox floor
- ◆ Two dosimeters are centered at a height of 20 cm above the floor
- ◆ In the neutron input files the source is 20.57 cm above the glovebox floor

Observation 6

NIOSH should use the most current value of the natural isotopic abundance of carbon-13 in the calculation of neutron flux of the fuel pellet.

- ◆ The input files prepared by SC&A used an isotopic abundance of carbon-13 of 0.0106
- ◆ After accounting for the difference in the carbon constituent due to the different empirical formula (Observation 5), the carbon-13 concentration in NIOSH's analysis was less than expected

Observation 7

NIOSH should use the same isotopic composition of the fuel sources in both the Source 4C and MCNP analyses.

- ◆ The mass fractions of plutonium and uranium isotopes between the two input files differ
 - Assumption of fresh fuel produced by Hanford Atomic Products Operations vs. fuel that has been aged for 5 years
 - Source 4C files assumed 24% enriched uranium; MCNP files had 0.37% uranium-235

Finding 2

The site profile erroneously instructs dose reconstructors to apply ICRP Publication 60 (“ICRP 60”) neutron dose correction factors to doses calculated using MCNP.

- ◆ The site profile says to apply ICRP 60 correction factors from ORAUT-OTIB-0055 to neutron doses
- ◆ The MCNP simulations for neutron doses incorporate the neutron fluence to dose correction factors
- ◆ Calculations of neutron doses to specific organs would use correction factors from ORAUT-OTIB-0055, which are derived from ICRP 74

Occupational external dose – XRD

- ◆ NIOSH assigns an annual exposure of 1.033 roentgen from <30 keV photons to the XRD apparatus operators
 - Follows the agreements between the work group, NIOSH, and SC&A

Occupational external dose – second residual period

- ◆ Residual uranium contamination from the first operational period is higher than that from the second operational period
- ◆ Operations took place in different locations; workers could not be in both places at once
- ◆ Workers assumed to be exposed to the first residual period contamination, to be claimant favorable



Questions?