TO: Advisory Board on Radiation and Worker Health Work Group on TBD-6000
FROM: Robert Anigstein and John Mauro, SC&A
SUBJECT: Updated Review of Occupational Internal Dose at GSI
DATE: May 30, 2012

Update of "Review of 'Site Profiles for Atomic Weapons Employers That Worked Uranium and Thorium Metals - Appendix BB: General Steel Industries,' Battelle-TBD-6000, Appendix BB," Occupational Internal Dose

Background

On May 21, 2012, Ted Katz asked SC&A to report on our reviews of the residual period at GSI. However, the evaluation of exposures to residual contamination at GSI, as presented in Appendix BB, section BB.6: "Residual Contamination" (Allen and Glover 2007), is based on the evaluation of occupational internal dose described in section BB.5. We therefore needed to review Allen and Glover's internal exposure assessment during the period of AEC operations, as well as during the residual period.

Intakes During Uranium Handling Operations—DCAS Assessment

Allen and Glover (2007) based the intake rate of airborne uranium during uranium handling operations on that of a uranium slug production operator listed in the parent document, TBD-6000 (Allen 2011, Table 7.8).[1] The listed intake, 651 pCi per calendar day, was assumed to reflect an annual exposure of 2,000 h. The annual exposure to uranium handling at GSI was based on the purchase orders from the Mallinckrodt Chemical Works, which specified a monthly cost as well as an hourly charge. These purchase orders provide a means of estimating the time spent handling uranium during various periods. Allen and Glover calculated the average exposure per calendar day by dividing the intake listed in TBD-6000 by 2,000 h, the nominal work-year, and then multiplying it by the duration of uranium handling operations during each year, derived from the purchase orders. They then increased this amount by 1% to account for the increased specific activity of uranium resulting from activation during betatron irradiation.

Intakes During Uranium Handling Operations—SC&A Observations

Allen and Glover (2007) listed the intakes derived by the above model in units of dpm/calendar day. However, these intakes were based on the value 651 pCi per calendar day in TBD-6000. The authors did not convert the units; consequently, these intakes were understated by a factor of 2.22 (1 pCi = 2.22 dpm). Subsequent dose reconstructions that were audited by SC&A utilize these values as dpm, and are consequently in error. Whereas this pathway makes a small and usually insignificant contribution to doses to organs outside the respiratory tract, it has a significant impact on the reconstruction of doses to the lungs.

[1] The original reference was to the 2006 version of this document. The relevant parameter values are unchanged in the revised version.

An observation with a lesser impact concerns the monthly hours for the period January 1, 1953–June 30, 1958. Although NIOSH assumes that the uranium operations started on January 1, 1953, the first available purchase order covers the period March 1, 1958–June 30, 1958. It stipulates an estimated cost of $500/mo, at an hourly rate of $16. This implies an expenditure of 31.25 h/mo, or 375 h/y. Since this is the first extant purchase order, it is reasonable and claimant favorable to assume this annual rate for the period January 1, 1953–June 30, 1958. Allen and Glover (2007), citing later purchase orders that stipulate a cost of $450/mo, assume an exposure duration of 337.5 h/y during this entire period, effectively ignoring the first purchase order.

Intakes Between Uranium Handling Operations—DCAS Assessment

To estimate the intakes of uranium between periods of uranium handling operations, Allen and Glover (2007) derived a surficial contamination based on the deposition of uranium aerosols during uranium handling operations. They assumed this surficial activity would become resuspended following the uranium handling operations, resulting in a constant airborne concentration following the uranium handling operations.

Allen and Glover (2007) modeled the areal uranium concentrations by citing the DWA (daily weighted average) air concentration for the operator involved in uranium slug production and canning of 198 dpm/m^3 (Allen 2011, Table 7.6). They assumed that this concentration prevailed only during the time that the GSI workers were actually handling the uranium metal. Since, according to the authors' scenario, the workers spent one-half of the time setting up and taking down the shot, and one-half performing the actual exposure from the betatron control room, they were in the room with the uranium metal for only one-half of the total time devoted to uranium handling operations. The authors did not reduce the duration of the intake of uranium aerosols by that fraction, but they did reduce the time the uranium was suspended in the air and was settling to the floor. They multiplied the airborne dust loading of 198 dpm/m^3 by the assumed terminal velocity of uranium aerosols of 7.5×10^{-4} m/s to obtain an accumulation rate of 0.1485 dpm m^{-2} s^{-1}. They integrated this rate over the reduced hours of uranium handling during one year to obtain an areal concentration. They then applied a resuspension factor (RF) of 1×10^{-6} m^{-1} to obtain an airborne uranium concentration and consequent intake rate for the periods between uranium handling operations.

Intakes Between Uranium Handling Operations—SC&A Observations

In our review of TBD-6000, we observed that an RF of 1×10^{-6} m^{-1} might be low by about an order of magnitude (SC&A 2007). This value is cited by Abu-Eid et al. (2002) for screening analyses of the building occupancy scenario by the Nuclear Regulatory Commission (NRC). However, this scenario is for the release of buildings following decontamination and decommissioning (D&D). As stated in the issues resolution matrix, "There are two key assumptions that underlie the use of such a value. First, the surface contamination occurred sometime in the past, and no new contaminants are being introduced. Second,

> "It is assumed that surfaces will be cleaned or washed during decommissioning. This will remove most of the loosely bound and some of the more tightly bound particles. Following the above discussion, surfaces that have been cleaned would

> be expected to have a smaller RF than surfaces that have not been cleaned, given the same levels of surface contamination. [Abu-Eid et al. 2002, p 4]

Clearly, neither of these assumptions apply to an operating facility that performs work on uranium . . . ." (SC&A 2009)

The current revision of this document (Allen 2011) retains this original value. If the RF were increased by a factor of 10, the airborne dust loading and the consequent intakes would increase in the same proportion.

We observe an inconsistency in the modeled intakes of uranium during the uranium handling operations and in the accumulation of uranium deposited on floors and other surfaces. In modeling the intake during uranium operations, Allen and Glover (2007) assumed that the uranium remained airborne during the entire time of uranium operations, so that betatron operators and other workers continued to be exposed to the uranium aerosols even while the betatron was operating and no workers were in the shooting room. If that were the case, the uranium would also have continued depositing on the floor during this time, whereas the authors assumed that the deposition only occurred while the workers were in the shooting area, and apparently stopped once they were in the control room. Furthermore, there are different accounts of the uranium radiography procedures from former betatron operators, including accounts of brief "corner shots," presumably to determine the amount of defective metal in the casting that needed to be sawed off, as well as shots of "betatron slices." Evidence was also found for the radiography of relatively thin ingots produced at Weldon Spring, which would have required shorter radiographic exposures and would thus have led to a higher fraction of time spent by operators in the shooting room, in the proximity of the uranium. A consistent, reasonable, and claimant-favorable approach would be to assume continuous deposition during the entire period of uranium handling operations, thus doubling the areal concentration accumulated during one year.

The highest duration of uranium handling operations, 437.5 h/y, was during the period July 1, 1961–June 30, 1962. Allen and Glover (2007) used this duration to calculate the upper bound of the areal uranium concentration: 1,170 dpm/100 cm^2. They assumed that this concentration prevailed from July 1, 1961, until the end of the residual period, December 31, 1993. The uranium intakes during the residual period were calculated by multiplying the areal concentration by the RF, then multiplying by the inhalation rate and by the average work hours. If, as discussed above, the areal concentration were doubled and the RF increased by a factor of 10, the daily uranium intakes would increase by a factor of 20. A further increase would result from increasing the exposure duration from 2,400 to 3,250 hours per year, the value currently accepted by NIOSH for external exposure assessments at GSI. The net result would be to increase the intake from 0.932 to 24.97 dpm per calendar day.

External Exposure During Residual Period

Allen and Glover (2007) assigned the highest external exposure rate measured during the 1989 GSI FUSRAP survey (Cottrell and Carrier 1990), 90 µR/h at the surface of a vacuum cleaner, to workers employed at GSI during the residual period. We concur that this is a claimant-favorable

assumption; however, we observe that, for consistency with other time periods, the exposure duration should be increased from 2,400 hours to 3,250 hours per year.

Summary of SC&A Observations

In summary, we present the following issues and observations regarding the assessment of occupational internal doses, as presented by Allen and Glover (2007). We list them in order of significance, starting with the issue that has the greatest potential impact on internal doses.

- Intakes of uranium during uranium handling operations are understated by a factor of 2.22, due to a failure to convert the units (pCi to dpm) of the intake by a slug production operator listed in TBD-6000.

- A resuspension factor of 1×10^{-6} m^{-1} is inapplicable to an operating facility. An RF of 1×10^{-5} m^{-1} represents a more reasonable value.

- The model of the buildup of uranium on contaminated surfaces, which assumes deposition took place only when the workers were in the shooting room with the uranium metal, is inconsistent with the calculation of intakes of uranium aerosols during uranium operations, which were assumed to occur during the entire time of uranium operations. We recommend modeling the deposition as persisting during the entire period of uranium operations.

- Intakes during January 1, 1953–June 30, 1958 were based on 337.5 h/y. We believe that uranium handling operations during this period should be based on the first extant purchase order, dated March 6, 1958, which implies an expenditure of 375 h/y.

- External exposures during residual period should be based on an exposure duration of 3,250 hours per year to be consistent with other assessments

Further SC&A Observation on Exposure Assessments for the Residual Period

Allen and Glover (2007) assumed a constant level of surficial contamination during the residual period, based on the maximum calculated contamination level during the operational period. We agree that this is certainly a claimant-favorable assumption. However, since the maximum surficial contamination reported by Cottrell and Carrier (1990) was 540 dpm/100 cm^2, NIOSH could avail itself of the methodology recommended in OTIB-0070 (Sharfi 2012), in the following manner.

Allen and Glover (2007) assumed that the highest contamination level resulted from operations during the period July 1, 1961–June 30, 1962. If this level were increased to 2,340 dpm/100 cm^2, as we recommended, one could derive an exponential rate of decline from the midpoint of this period, January 1, 1962, to March 16, 1989, [2] as follows:

[2] Cottrell and Carrier (1990) reported that the survey was performed in March 1989. We use the middle of the month in this calculation.

$$A(t) = A_0 e^{-\lambda t}$$

$$\lambda = -\frac{\ln\left(\frac{A(t)}{A_0}\right)}{t}$$

λ = rate of change of surficial contamination
= 0.0539 dpm/100 cm^2 per year

$A(t)$ = areal activity concentration at time t
= 540 dpm/100 cm^2
t = 27.2 y

A_0 = 2,340 dpm/100 cm^2

The first of the above equations could be used to calculate the contamination level and hence the intake rate during each year of the residual period.

References

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