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ISSUE RESOLUTION MATRIX FOR SC&A FINDINGS ON APPENDIX BB, REV. 1, TO TBD-6000

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Original Date: September 25, 2015

Updated: November 13, 2015

INTRODUCTION

The present document presents an updated summary of the issues arising from the SC&A review of "Site Profiles for Atomic Weapons Employers that Worked Uranium Metals Appendix BB – General Steel Industries," Revision 1 (Allen 2014). It is current as of the last meeting of the Work Group on TBD-6000 on November 3, 2015. It supplements but does not replace the "Issue Resolution Matrix for SC&A Findings on Appendix BB to TBD-6000," last updated January 15, 2014. The extensive changes in the description of site activities and dose reconstruction methodologies in the revised appendix made the previous matrix obsolete. However, the previous matrix provides a valuable historical account of the development of the exposure scenarios and dose assessments at GSI.

Time Line of Appendix BB, Rev. 1, Issues Matrix

- June 23, 2014: Allen (2014) issued Battelle-TBD-6000, Appendix BB, Rev. 1.
- December 10, 2014: Anigstein and Mauro (2014) issued a review of Appendix BB, Rev. 1, that included nine findings.
- January 8, 2015: Allen (2015a) issued a general response to the SC&A review. Allen agreed in principle with six of our nine findings: In the case of three of these six findings, he accepted the changes recommended by SC&A, while in the case of another three findings, he proposed minor increases to our recommended doses/intakes. Allen disagreed with the remaining three findings: He proposed a new skin dose assessment methodology that would substantially lower the doses from two of the exposure scenarios presented in Appendix BB, Rev. 1.
- January 8, 2015: Allen (2015b) issued a detailed methodology for assessing ß doses to the skin of the layout man that accounted for the intermittent irradiation of the steel castings and the range of radiographic exposures of the castings handled by this individual.
- January 26, 2015: Anigstein and Mauro (2015a) issued a review of the first NIOSH response paper (Allen 2015a). In the process of preparing our replies, we found another issue, which became Finding 10.
- January 30, 2015: Anigstein and Mauro (2015b) issued a review of the second NIOSH response paper (Allen 2015b). We verified the mathematical model developed by NIOSH to calculate the dose rates from castings that had been intermittently irradiated, but questioned some of the parameters used in the proposed dose assessments
- February 5, 2015: The Work Group on TBD-6000 met by teleconference. James Neton (NIOSH/DCAS) stated that editorial comments in the SC&A review of Appendix BB, Rev. 1, would be addressed in Revision 2. During the discussion of Finding 5, which stated that a radiographer during the Radium Era (1952–1962) could have performed all the radium radiography and still spent time in the betatron building, three of the four work group members agreed with or leaned towards the SC&A position. Based on NIOSH responses to the SC&A findings, the work group members

unanimously concurred that NIOSH had agreed to resolve the issues reflected in Findings 1, 3, 4, 7, 8, and 9, and that these issues can therefore be closed. Differences remain between NIOSH and SC&A on Findings 2, 5, and 6.

- July 10, 2015: Allen (2015c) issued a Response Paper that addressed the four SC&A findings on Appendix BB, Rev. 1, that remained unresolved.
- September 11, 2015: Anigstein and Mauro (2015c) issued a review of the NIOSH response paper (Allen 2015c).
- September 25, 2015: SC&A issued a new issues matrix on Appendix BB, Rev. 1.
- November 3, 2015: The Work Group on TBD-6000 met by teleconference, with three of the four members participating.[1] The four remaining findings were discussed in the order in which they were presented by Allen (2015c). The discussion was facilitated by a presentation by Anigstein and Mauro (2015d) that was viewable by participants, other than members of the public, and was subsequently posted on the NIOSH/DCAS website. NIOSH and SC&A agreed on the resolution of Findings 2 and 6, which were concerned with beta skin doses to the betatron operator and the layout man, respectively. The Work Group unanimously concurred and recommended that both findings be closed. NIOSH and SC&A initially disagreed on part of Finding 10: the fraction of time the hands and forearms of the betatron operator were exposed to the residual radiation from the betatron. The Work Group agreed with the SC&A recommendation of 100% exposure–NIOSH concurred and the Work Group recommended the finding be closed. NIOSH and SC&A initially disagreed on Finding 5: the amount of time a radiographer using radium spent in the betatron building, and the amount of uranium radiography he performed during that time. The Work Group recommended a compromise value of 50% of his shift spent in the betatron and that he likewise be assumed to have performed 50% of the uranium radiography in any given year. NIOSH and SC&A concurred with these recommendations and the Work Group recommended the finding be closed.
- November 13, 2015. SC&A revised the issues matrix.

Status Summary

- The Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve all 10 findings, which can therefore be *closed.*

[1] A transcript of the meeting is not available at this time. The summaries and accounts of this meeting presented in the current report are therefore based on notes and recollections of the participants.

Issue Resolution Matrix for SC&A Findings on Appendix BB, Revision 1

Issue 1: Neutron Dose Rates

SC&A Finding: Allen (2014) cited values of neutron dose rates without specifying which dosimetric quantities were calculated. Based on the similarity of his numerical values to neutron effective doses calculated by SC&A for the same scenarios, we conclude that these are effective dose rates, which are incompatible with the dose conversion factors listed in OCAS-IG-001 (OCAS 2007). All the neutron doses need to be recalculated—we suggest that DCAS uses neutron ambient dose equivalent, H*(10), rates.

NIOSH Response (1/08/15) (Allen 2015a): "DCAS will revise the calculations to use either ambient dose equivalent or deep dose equivalent conversions."

Board Action (2/05/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 1 and that this finding can therefore be closed.

Issue 2: Beta Dose to Skin of Betatron Operator

SC&A Finding: Allen (2014, Table 5) listed annual ß doses to the skin of the betatron operator, other than the skin on his hands and forearms, that are 12%–33% lower than the SC&A values. The ß doses to the skin on his hands and forearms are 3%–14% lower than the SC&A values for the years 1963–1966. These differences need to be resolved.

NIOSH Response (1/08/15) (Allen 2015a):

> DCAS and SC&A exchanged files and reconciled differences late in 2013 prior to the drafting of the revision to Appendix BB. Appendix BB contains those values. Even though not included in the text of the summary for this finding, SC&A acknowledges in the body of this memo that they originally neglected to account for the one meter beta dose so it was calculated and added to the total dose as part of their review. This explains the difference between the Appendix BB and SC&A's recalculated values.
>
> DCAS intends to correct this in the next revision to Appendix BB. However, the original calculations assumed the steel was irradiated for 30 continuous hours. DCAS intends to adjust the initial dose rate to account for the intermittent irradiation as described in a white paper that recalculates the layout man's beta dose. DCAS also intends to assume the steel was irradiated long enough to reach an equilibrium activity.

NIOSH Response (7/10/15) (Allen 2015c):

> In 2013, NIOSH and SC&A exchanged files to reconcile differences in the betatron operator beta dose calculations. In drafting revision 1 to Appendix BB, NIOSH realized an inconsistency existed in the calculations. The uranium dose calculation assumed work for 7.5 hours per 8 hour shift, which apparently accounted for a lunch break. The irradiated steel dose numbers, however, assumed 8 hours of work. NIOSH changed the uranium dose calculation to 8 hours to be consistent.
>
> [Anigstein and Mauro (2014)] pointed out that both SC&A and NIOSH had previously failed to include the 1 meter beta dose. NIOSH agreed that this dose should be included and [Allen (2015a)] indicated that this dose would be added in the next revision. NIOSH further indicated their intention to adjust the beta dose to account for intermittent irradiation of castings. SC&A stated during the 2/5/2015 meeting that there were other differences and presented a table showing SC&A values versus NIOSH values. The SC&A values included the 1 meter dose while the NIOSH values did not. NIOSH responded during the meeting that the other difference was the 8 hours NIOSH used for

the uranium doses. The information below shows the timeline and values using 1953 as an example. It should be noted that revision 1 of Appendix BB did not list the steel and uranium values separately, only the total was provided.

Uranium Hand and Forearm Beta Dose

- [Anigstein and Mauro (2013)] = 31.96 rem
- Appendix BB rev.1 = 33.98 (31.86 rem if 7.5 hours per shift is used)
- SC&A 12/10/2014 memo [Anigstein and Mauro (2014)] = 31.96 rem

Steel Hand and Forearm Beta Dose

- [Anigstein and Mauro (2013)] = 2.76 rem
- Appendix BB rev.1 = 2.76
- SC&A 12/10/2014 memo [Anigstein and Mauro (2014)] = 3.33 rem

The beta dose from irradiated steel in [Anigstein and Mauro (2014)] includes 1 meter doses that were left out of the 12/5/2013 SC&A memo [Anigstein and Mauro (2013)] and revision 1 of the Appendix. NIOSH recalculation of that dose now is 3.38 rem based on assumptions used in revision 1 (compared to 3.33 from SC&A). Adjusting this value to account for intermittent irradiation rather than 30 continuous hours produces a new value of 1.54 rem.

Uranium Whole Body Beta Dose

- [Anigstein and Mauro (2013)] = 2.03 rem
- NIOSH rev 1 = 2.16 rem (2.03 rem if 7.5 hours per shift is used)
- SC&A 12/10/2014 [Anigstein and Mauro (2014)] = 2.03 rem

Steel Whole Body Beta Dose

- [Anigstein and Mauro (2013)] = 1.7 rem
- NIOSH rev 1 = 1.71 rem
- SC&A 12/10/2014 memo [Anigstein and Mauro (2014)] = 2.29 rem

The beta dose from irradiated steel in [Anigstein and Mauro (2014)] includes 1 meter doses that were left out of [Anigstein and Mauro (2013)] and revision 1 of the Appendix. NIOSH recalculation of that dose now is 2.33 rem based on assumptions used in revision 1 (compared to 2.29 from SC&A). Adjusting this value to account for intermittent irradiation rather than 30 continuous hours produces a new value of 1.05 rem.

SC&A Reply (9/11/15) (Anigstein and Mauro 2015c): We recently performed a realistic simulation of photoactivation of a uranium disk and the subsequent doses to the skin of the betatron operator from the photoactivation products as well as the short-lived progeny of natural uranium, obtaining more accurate doses that were somewhat lower. Although the doses used by DCAS are claimant favorable, DCAS may wish to revise their uranium values in light of the more recent SC&A results.

We reviewed the DCAS calculation of the photoactivation of irradiated steel and the subsequent doses to the skin of the betatron operator. We had previously found that the model was mathematically correct (Anigstein and Mauro 2015b). We conclude that the skin doses calculated by DCAS are bounding and claimant favorable.

NIOSH Response (11/03/15): During a meeting by teleconference, NIOSH agreed to adopt the beta skin doses based on the realistic model proposed by SC&A.

Board Action (11/03/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 2 and that this finding can therefore be closed.

Issue 3: No Dedicated Radiographic Facility in No. 6 Building Prior to 1955

SC&A Finding: The copetitioner has presented persuasive evidence that the dedicated radiographic facility in No. 6 Building was constructed in 1955. The mode of the triangular distribution of photon exposure rates during 1952–1962 is based on the use of that facility. Assuming that the radiographer remained at the 2 mR/h boundary of the controlled area during the radiographic exposures rather than in the not-yet-constructed radiographer's office increases the mode from 9.69 to 11.28 R/y during 1952–1955.

NIOSH Response (1/08/15) (Allen 2015a):

> DCAS agrees with SC&A however, a slight correction is necessary. The calculations used by SC&A in their review report assumed the 15 seconds to place or retrieve the source was part of the exposure time. In the previous calculation, the time placing and retrieving the source was in [addition] to the exposure time. In keeping with that interpretation, the new calculated dose would be 11.34 R/y rather than 11.28 R/y. DCAS intends to use the 11.34 value.

SC&A Reply (1/26/15) (Anigstein and Mauro 2015a):

> The exposure duration assumed by DCAS in deriving exposures at the 2-mR/h boundary during the 1952–1955 period is consistent with the previously adopted exposure duration in the radiographer's office during the 1956–1962 period, as well as being slightly more claimant favorable. We therefore do not object to the DCAS decision to assign the value of 11.34 R/y to the mode of the triangular distribution for 1952–1955.

Board Action (2/05/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 3 and that this finding can therefore be closed.

Issue 4: Maximum of Triangular Distribution of Photon Exposures for 1961 Should Be 12 R/y

SC&A Finding: Because AEC lowered the exposure limit to a maximum of 3 R per quarter, or 12 R/y, effective January 1, 1961, the maximum of the triangular distribution of photon exposures for 1961 should be 12 instead of 15 R/y.

NIOSH Response (1/08/15) Allen (2015a): "DCAS agrees. The error will be corrected in the next revision to Appendix BB."

Board Action (2/05/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 4 and that this finding can therefore be closed.

Issue 5: Combined Exposures to ^{226}Ra and Betatron Operations during 1952–1962

SC&A Finding: Since radiography using ^{226}Ra sources occurred during only 30% of a given shift, it is plausible that the same radiographer would have worked in the betatron building, performing radiography on uranium and steel, during the remainder of his shift. It is plausible and claimant-favorable to assume that the radiographer participated in all the uranium work during a given year and spent the balance of his time on the betatron radiography of steel. He should thus be assigned a ß dose to the skin as well as a neutron dose in addition to a triangular distribution of photon exposures during 1952–1962.

NIOSH Response (1/08/15) (Allen 2015a):

> The 30% value that SC&A cites is actually the amount of time the radium source is exposed. The process of performing radiography requires a number of other steps, including marking the casting, moving the source to and from the location, placing the film, removing the film, developing the film, determining the duration of the shot, etc.
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> In the betatron building, it was assumed it took 15 minutes between shots on the same casting. It was further assumed the castings were often marked up prior to entering the betatron building. That was the job of the layout man for large castings but there is no indication a separate person was used for the smaller castings that would be radiographed using radium or cobalt sources. Therefore, it would not be unreasonable to double the time between shots to 30 minutes. Ten shots per shift times 30 minutes per shot equals 5 hours of work per shift. Adding the 2.4 hours of shooting time to that accounts for the majority of the shift.

SC&A Reply (1/26/15) (Anigstein and Mauro 2015a):

> The betatron was used to radiograph large, thick castings. The initial shots were set up by the betatron operator and a helper. Since the betatron beam was directional and strongly focused, it was necessary to precisely align the position and direction of the head of the betatron apparatus with the film that was placed behind the casting. In contrast, the radium sources were used for relatively thin castings. Since the radiation is isotropic, there was no directional orientation and the position of the source was less critical.

According to the recollections of [redacted], [redacted] GSI radiographer [redacted], a radiographer working with radium could also work with the betatron. "During his weekend shifts as a radiographer, he did both radium and betatron radiography—perhaps 50–60% of the time using the betatron, the remainder using radium."

> Finally, we note that . . . "A *maximum* of 30% of each shift is used for actual exposure [NRC 2009a, p. 12, italics added]." Thus, the radium exposures may have taken less than 30% of the time on some shifts, allowing the radiographers more time to work on the betatron.
>
> We therefore believe that, for the purpose of assigning limiting neutron doses and ß skin doses, radiographers working with radium should be assumed to have also worked in the betatron building. Given the limited number of hours devoted to uranium radiography, it is plausible and claimant favorable that the same radiographer could have participated in all of the uranium radiography, as well as some of the betatron radiography of steel, during the Radium Era. (Anigstein and Mauro 2015a)

Board Action (2/05/15): During a meeting by teleconference of the Work Group on TBD-6000, three of the four work group members agreed with or leaned towards the SC&A position.

NIOSH Response (7/10/15) (Allen 2015c):

> In the fast paced work in the betatron building, operators indicated 15 minutes between shots was a reasonable value. Therefore, we will consider that a reasonable value for the radium radiography as well. The radium radiography exposure estimate is based on 10 shots per 8 hour shift with the shots themselves taking 30% of the shift. That is 144 minutes per shift for the shots plus 150 minutes between totaling 294 minutes. If the employee is assumed to be exposed as a betatron operator the remaining 186 minutes per shift it would equal 38.75% of the shift.

In light of this, NIOSH proposes adding 38.75% of the values in Table 1 to the radium radiography dose. This differs from the SC&A recommendation in three ways. First, SC&A recommended 70% rather than 38.75%. Second, SC&A recommended adding only beta and neutron dose but not gamma dose. NIOSH can find no basis for adding these without the gamma dose so NIOSH is recommending adding gamma dose also. Third, SC&A recommended adding 100% of the uranium dose plus enough steel dose to account for the remainder of the time.

NIOSH sees no basis for biasing the doses towards the uranium work. In the past, there has never been any relationship alleged between radium work and uranium work so this biasing doesn't appear to be appropriate.

SC&A Reply (9/11/15) (Anigstein and Mauro 2015c):

There are no relevant data that would support the assumption of 15 min between shots. Mr. [redacted] reported taking 12–15 s to transport the radium source from the lead pig, which was kept inside the radiography room, and position it for the exposure. It would not have taken much longer to position and remove the films, which would have been also stored nearby. It was not necessary to develop each film prior to exposing the next one. According to the Atomic Energy Commission's (AEC) "Compliance Inspection Report" (NRC 2009b), [redacted], [redacted] [redacted], reported that the exposures ranged from 1 to 70 min. Assuming 2.4 h of exposure and 10 shots per shift, the average shot took 0.24 h ([8 × 0.3] ÷ 10 = 0.24) or ~14 min. The longer shots provided ample time to develop the previously exposed films, which could be processed in batches. Since a typical casting was larger than one x-ray film, it took several exposures to radiograph one casting. There was no need to transport the casting between shots—repeat shots could have been taken in quick succession: position the film, position the radium source, wait for the exposure to finish. This procedure bears no relationship to betatron radiography, which involved using electrical controls to move and aim the betatron apparatus and retiring to the control room to set the controls for the next shot. GSI workers have reported that the castings radiographed with the betatron tended to be large and complex, requiring a significant setup time. The very reason that the betatron was installed at GSI was to radiograph hulls of Army tanks and other castings that were too large for the isotope sources (^{226}Ra and later ^{60}Co).

Allen (2015c) disagreed with our assumption that the radiographer working with radium should be assumed to have participated in all the betatron radiography of uranium during a given year. Our reason is the same as the reason for assuming that a single worker was involved in all the uranium radiography in the first place. Since GSI workers worked in shifts, one could argue that the same worker did not necessarily participate in all the uranium work. Nevertheless, since one worker could have been involved in all this work, it has been agreed that the GSI dose assessments would assume that one worker did, in fact, participate in all the uranium radiography. This assumption is equally valid if such a worker were absent from the betatron building working with radium for perhaps 40% of the time. This assumption is thus plausible, claimant favorable, and consistent with the rest of the agreed-upon dose assessment methodology.

The triangular distributions of external photon doses during the Radium Era that have been adopted by the Work Group on TBD-6000, NIOSH, and SC&A are derived from the calculated exposures to ^{226}Ra sources and the AEC exposure limits. Since these did not incorporate the exposures to the hypothetical residual radiation from the betatron, we agree with Allen's (2015c) recommendation that photon doses to the skin from such radiation, discussed in Finding 10, should be added to the radium radiographer's skin dose in proportion to the time he spent in the betatron building.

Board Action (11/03/15): During a meeting by teleconference, the Work Group on TBD-6000 recommended that the radiographer using radium be assumed to have spent 50% of his shift in the betatron building, and that he likewise be assumed to have performed 50% of the uranium radiography in any given year. NIOSH and SC&A concurred with these recommendations and the Work Group unanimously recommended that the finding be closed.

Issue 6: Beta Skin Dose to Layout Man

SC&A Finding: The ß doses to the skin of the hands and forearms of the layout man as well as to the skin on the rest of his body listed by Allen (2014, Table 6) are significantly lower than those calculated by SC&A.

NIOSH Response (1/08/15): Allen (2015b) created a complex ß skin dose scenario based on our very early description of the layout man's exposure to delayed γ radiation from irradiated steel (SC&A 2008). Allen's source term comprised four types of castings:

1. a thick casting that had been subjected to an infinite number of long shots (60 min each, with 15-min pauses, at a distance of 6 ft) but at 24-h intervals—24 h of intermittent exposures, 24 h of decay, etc.—on which the layout man worked for an entire 8-h shift;
2. a thin casting subjected to an infinite number of short shots (3 min each, with 15-min pauses, at a distance of 9 ft), again at 24-h intervals, on which the layout man also worked for an entire 8-h shift;
3. a thick casting subjected to an infinite number of long shots (see item 1, above), but at 2.5-h intervals, on which the layout man worked for 75 min;
4. a thin casting subjected to an infinite number of long shots (see item 2, above), but at 30-min intervals, on which the layout man worked for 15 min.

Allen assumed that 90% of the layout man's shift was devoted to the two types of thin castings, and 10% to the thick castings. Within this breakdown, he assumed 90% of the time devoted to thick castings was devoted to type 1 castings (described in item 1, above), and 10% to type 2. The same 90:10 ratio was assumed for types 3 and 4.

SC&A Reply (9/11/15) (Anigstein and Mauro 2015c): The scenarios described by Allen do not realistically represent the operations at GSI: A single casting would not be shuttling between the betatron and the layout man indefinitely. However, it is physically possible and appears to be conceptually bounding. We disagree with the assumption that it would take the same amount of time to mark the defects on a thin casting as on a thick one. Based on the recollections of a former GSI radiographer [redacted], teleconference of the Work Group on TBD-6000, the thicker, more complex castings had more defects. This was confirmed by Thurber (2015), and by AFS (n/d), which refers to a cavity caused by axial shrinkage and states: The defect is partly a function of the section thickness designed into the casting. We believe that the ratio of times needed to mark up thick:thin castings could range from 1:1, as assumed by Allen, to 5:1, the ratio of exposure cycles. We propose a ratio of 3:1, the midpoint of these two values, which results in 25% of the layout man's time being spent on long shots. Using such a ratio, the model proposed by Allen yields a ß dose to the skin of the hands and forearms that is ~54% higher than those calculated by Allen, while the dose to the skin on the rest of the body is ~52% higher. We believe that these doses are plausible and claimant favorable.

NIOSH Response (11/03/15): During a meeting by teleconference, NIOSH agreed to adopt the assumption that the layout man spent 25% of his time on long shots.

Board Action (11/03/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 6 and that this finding can therefore be closed.

SC&A Finding: Due to an apparent calculational error, the inhalation of uranium dust during the handling of the metal during the first 6 months of 1966 is understated by a factor of 2.

NIOSH Response (1/08/15) (Allen 2015a): "DCAS agrees. The intake was inadvertently averaged over the full year instead of 6 months. The error will be corrected in the next revision to Appendix BB."

Board Action (2/05/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 7 and that this finding can therefore be closed.

Issue 8: Ingestion Intakes Not Consistent with OCAS-TIB-009

SC&A Finding: The intakes of uranium particulates via ingestion listed by Allen (2014, Table 10) are significantly higher than the rates derived by applying OCAS-TIB-009 (OCAS 2004) to the airborne uranium dust concentrations, averaged over the work year. Although Allen's rates are claimant favorable, they should be corrected for the sake of consistency with other site profiles, or an explanation given why these rates are valid.

NIOSH Response (1/08/15) (Allen 2015a):

> DCAS agrees. OCAS-TIB-009 is intended to apply to continuous operations and no adjustment was made for intermittent uranium work at GSI. DCAS agrees this would [sic] it would be more appropriate to use the average airborne activity for the year. However, DCAS suggests using the average annual airborne activity for the highest year, rather than changing the ingestion rate based on the amount of uranium work for a particular year. The ingestion rate is related to the surface contamination present and that value does not start at zero each year. Thus, contamination from a previous year can affect the ingestion rate in a following year. Since the highest year ingestion rate would be the first years, DCAS intends to revise the appendix to use that ingestion rate (calculated in the SC&A memo and verified by DCAS) for all years. This would also be the ingestion rate for the first year of the residual period.

Board Action (2/05/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 8 and that this finding can therefore be closed.

Issue 9: Ingestion Intakes during Residual Period

SC&A Finding: The intakes of uranium particulates via ingestion during the residual period listed by Allen (2014, Table 11) are inconsistent with OCAS-TIB-009 (OCAS 2004), as discussed in Finding 8. Furthermore, they are inconsistent with Allen's methodology for the operational period, since the rate for the first year is equal to the inhalation, rather than ingestion, rate during the last year of AEC operations.

NIOSH Response (1/08/15) (Allen 2015a):

> DCAS agrees. The inhalation rate for the last operational year was inadvertently used as the ingestion rate for the first year of the residual period. Thus, the value should have been 15.44 dpm/day rather than the 15.88 dpm/day used in the Appendix. As stated in our response to Finding 8, DCAS intends to use the ingestion rate for the highest operational year for the beginning of the residual period in the next revision to Appendix BB.

Board Action (2/05/15): During a meeting by teleconference, the Work Group on TBD-6000 unanimously concurred that NIOSH had agreed to resolve the issue reflected in Finding 9 and that this finding can therefore be closed.

Issue 10: External Exposure of Betatron Operator

SC&A Finding: Allen (2014, Table 9) lists dose estimates for the skin of the hands and forearms of the betatron operator during 1952–1963 as 1,300 mrem/y. This value is based on the hypothetical 30-keV residual photon radiation from the betatron apparatus after shutdown and was calculated in terms of effective dose rates, which are incompatible with the dose conversion factors listed in OCAS-IG-001 (OCAS 2007).

We suggest an alternative estimate of the residual photon radiation from the betatron apparatus, employing assumptions and methods similar to those used to derive the estimate of 26 mrem/week effective dose presented by Anigstein and Olsher (2012). That estimate utilized the ratio of absorbed dose to the female breast from 30-keV photons in the posteroanterior (PA) orientation to air kerma listed by ICRP (1997, Table A.5). Again using this value—0.0489 Gy/Gy—we derive a value of 204.5 mrad/week air kerma that corresponds to the MDA of the film badge dosimeter of 10 mrem (10 mrem/week ÷ 0.0489 = 204.5 mrem/week). Since OCAS-IG-001 does list air-kerma-to-organ-dose conversion factors, this quantity can be used for dose reconstructions. Since the radiation is assumed to have an energy of 30 keV, we suggest that NIOSH uses the maximum dose conversion factor listed in OCAS-IG-001 for <30 keV photons in the PA orientation.

NIOSH Response (7/10/15): (Allen 2015c) accepted our proposed limiting value of 204.5 mrad/week air kerma in the PA orientation (Anigstein and Mauro 2015a). Allen proposed to use this air kerma rate, together with the maximum air-kerma-to-skin-dose conversion factor for photons, E_γ <30 keV (0.654 rem/rad [OCAS 2007]), to calculate the dose to the skin on the back and sides. However, he assigned only one-half of this dose to the skin on the hands and forearms, since he assumed that the worker's hands were at the side of the body only one-half of the time and in front of the body the rest of the time. He assigned an additional dose of one-half the MDL of the film badge—5 mrem/week or 0.25 rem/y—to account for the time the hands were in front of the body. The skin on the anterior portion of the body, other than the skin of the hands and forearms, was assigned a dose of 0.5 rem/y.

SC&A Reply (9/11/15) (Anigstein and Mauro 2015c): Although we agree that the worker would not always have his hands at his sides, we do not agree that his hands and forearms would have been completely shielded by his torso during one-half of the time he was working. That would only happen if his hands and forearms were held close together, which cannot be assumed to occur during one-half of his activities. Although some shielding of the hands and forearms by the torso may have occurred during some unknown portion of the setup period, in the absence of more specific information, we recommend that NIOSH assigns bounding doses to the skin of the hands and forearms of 6.687 rem/y (10.225 rad × 0.654 rem/rad = 6.687 rem). We agree with the assignment of 0.5 rem/y to the skin on the anterior portion of the body, other than the hands and forearms, since the dose to that skin would be approximately the same as the dose recorded by the film badge dosimeters.

Board Action (11/03/15): During a meeting by teleconference, the Work Group on TBD-6000 recommended that the hands and forearms of the betatron operator should be assumed to have been exposed to the residual radiation from the betatron 100% of the time he is in front of the betatron. NIOSH concurred and the Work Group unanimously recommended that the finding be closed.

References

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