SC&A, inc.

MEMORANDUM

TO:	Advisory Board on Radiation and Worker Health, Work Group on TBD-6000
FROM:	Robert Anigstein and John Mauro, SC&A
DATE:	December 9, 2016
SUBJECT:	Reply to NIOSH Response Paper Regarding Appendix BB, Revision 2

On November 8, 2016, David Allen (NIOSH/DCAS) issued a paper (Allen 2016b) in response to the SC&A review (Anigstein and Mauro 2016) of Appendix BB, Revision 2 (Allen 2016a). In an email message on December 6, 2016, Ted Katz, Designated Federal Officer to the Advisory Board on Radiation and Worker Health (ABRWH), agreed that SC&A should review this report (Katz 2016).

The SC&A review (Anigstein and Mauro 2014) of Appendix BB, Revision 1 (Allen 2014), produced nine findings. In a subsequent memo, Anigstein and Mauro (2015) identified a tenth finding. In our most recent memo, Anigstein and Mauro (2016) agreed that Allen (2016a) resolved Findings 2–8.

Finding 1: Neutron Dose Rates

The original Finding 1 in the SC&A review of Appendix BB, Revision 1, addressed the use of neutron dose rates based on effective doses, for which no dose conversion factors (DCFs) are provided in OCAS-IG-001 (OCAS 2007). In Revision 2, Allen (2016a) substituted neutron dose rates based on ambient dose equivalents (H*[10]), for which DCFs are provided. However, as we stated in our previous memo, Allen's method of calculating organ dose equivalents by applying DCFs for the 0.1–2 MeV energy range to these neutron dose rates was not claimant favorable. Using the single example of doses to the lung, we calculated the organ doses by taking the sum of the products of the neutron H*(10) dose rates in each energy range listed by OCAS, multiplied by the DCF for that energy range. The results demonstrated that Allen's method understated the doses to the lungs by 20%–45% for the three neutron exposure scenarios: betatron operators radiographing and handling uranium, betatron operators radiographing steel, and the layout man exposed to stray radiation from the betatron.

In his response paper, Allen (2016b) proposed substituting DCFs for the 2–20 MeV energy range and showed that, in the case of doses to the lungs, the results were claimant favorable for the three neutron exposure scenarios described above. However, this conclusion is not valid for some of the 13 organs or tissues for which neutron DCFs are listed by OCAS (2007). Table 1 lists the dose rates to each of these organs or tissues, calculated by taking the sum of the products of the neutron H*(10) dose rates in each energy range listed by OCAS multiplied by the DCF for the given organ for that energy range. The resulting dose rates are compared to the dose rates calculated by multiplying the total neutron H*(10) dose rates by the 2–20 MeV DCFs for the respective organs. As shown in the table, the latter methods results in organ dose equivalents that are 4%–19% lower for 4 of the 13 organs.

Table 1. Neutron Dose Rates to Various Organs, Using DCFs for Various Energy Ranges (mrem/shift)

Organ or tissue	Betatron operator										Layout man				
	Uranium radiography					Steel radiography					Steel radiography				
	All E[a]	0–10 keV[b]	Δ_1[c]	2–20 MeV[d]	Δ_2[e]	All E	0–10 keV	Δ_1	2–20 MeV	Δ_2	All E	0–10 keV	Δ_1	2–20 MeV	Δ_2
Bladder	3.044	6.106	101%	2.713	-11%	1.040	2.256	117%	1.002	-4%	1.824	4.838	165%	2.150	18%
Red bone marrow	1.395	2.706	94%	1.765	27%	0.484	1.000	106%	0.652	35%	0.887	2.144	142%	1.398	58%
Bone surface	1.550	2.873	85%	1.656	7%	0.539	1.062	97%	0.612	14%	0.992	2.276	129%	1.312	32%
Female breast	2.977	3.738	26%	2.748	-8%	1.077	1.381	28%	1.015	-6%	2.210	2.962	34%	2.177	-1%
Colon	2.138	4.666	118%	2.243	5%	0.724	1.724	138%	0.829	14%	1.233	3.697	200%	1.777	44%
Esophagus	1.740	3.653	110%	2.131	23%	0.596	1.349	126%	0.787	32%	1.052	2.894	175%	1.689	61%
Lungs	1.942	3.532	82%	2.328	20%	0.679	1.305	92%	0.860	27%	1.278	2.798	119%	1.845	44%
Ovaries	1.978	4.430	124%	2.215	12%	0.668	1.636	145%	0.818	23%	1.127	3.509	211%	1.755	56%
Testes	3.699	5.360	45%	2.999	-19%	1.315	1.980	51%	1.108	-16%	2.579	4.246	65%	2.376	-8%
Liver	2.408	4.726	96%	2.428	1%	0.828	1.746	111%	0.897	8%	1.484	3.745	152%	1.924	30%
Remainder	1.891	3.534	87%	2.185	16%	0.658	1.306	99%	0.807	23%	1.215	2.800	130%	1.731	42%
Skin	2.184	2.530	16%	2.277	4%	0.799	0.935	17%	0.841	5%	1.671	2.005	20%	1.804	8%
Thyroid	3.054	5.953	95%	2.690	-12%	1.047	2.199	110%	0.994	-5%	1.861	4.716	153%	2.131	15%

[a] Sum of products of neutron doses spanning all neutron energy ranges listed by OCAS (2007), multiplied by effective DCFs for H*(10) from neutrons incident in AP orientation

[b] Sum of neutron doses spanning all neutron energy ranges, multiplied by the effective DCF for H*(10) from 0–10 keV neutrons incident in AP orientation

[c] Δ_1 = 0–10 keV ÷ All E − 1

[d] Sum of neutron doses spanning all neutron energy ranges, multiplied by the effective DCF for H*(10) from 2–20 MeV neutrons incident in AP orientation

[e] Δ_2 = 2–20 MeV ÷ All E − 1

We still recommend that NIOSH use the DCFs specific to each energy range in calculating neutron doses to the various organs and tissues. However, should that be too cumbersome, we recommend using DCFs for the 0–10 keV energy range. As shown in Table 1, these factors result in neutron dose equivalents to each organ that are 16%–211% higher than the doses calculated by applying the energy-specific DCFs. As Allen (2016b) observed, neutron doses make relatively small contributions to the total dose in the scenarios described by Allen (2016a). Consequently, using these claimant-favorable DCFs would be acceptable for estimating neutron doses to GSI workers.

Finding 10: External Exposure of Betatron Operator

The original Finding 10, identified by Anigstein and Mauro (2015), addressed the use of dose rates from the hypothetical residual radiation from the betatron after shutdown based on effective doses, for which no DCFs are provided by OCAS (2007). In Revision 2, Allen (2016a) substituted air kerma rates, for which DCFs are provided, and listed the units as rad/y. However, he did not identify the dosimetric quantity as air kerma, leading to possible ambiguity as to which DCFs should be applied for calculating organ dose equivalents. Furthermore, as we stated in our most recent memo, since the residual radiation is hypothesized to have an energy of 30 keV, the maximum rather than the average DCF that corresponds to E < 30 keV should be used for dose reconstructions.

In his response paper, Allen (2016b) agreed to textual changes to be incorporated in the next revision to Appendix BB that fully address our concerns. Consequently, we recommend that Issue 10 be closed.

References

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Katz, T. 2016. "RE: TBD-6000 WG," December 6, 2016, personal email to Robert Anigstein, SC&A, Inc., and Paul Ziemer, ABRWH. Copies to other members of the ABRWH Work Group on TBD-6000; James Neton and David Allen, NIOSH/DCAS; and John Mauro and John Stiver, SC&A.

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