Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

DRAFT REVIEW OF ORAUT-OTIB-0055: TECHNICAL BASIS FOR CONVERSION FROM NCRP REPORT 38 NEUTRON QUALITY FACTORS TO ICRP PUBLICATION 60 RADIATION WEIGHTING FACTORS FOR RESPECTIVE IREP INPUT NEUTRON ENERGY RANGES

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DRAFT REVIEW OF ORAUT-OTIB-0055: TECHNICAL BASIS FOR CONVERSION FROM NCRP REPORT 38 NEUTRON QUALITY FACTORS TO ICRP PUBLICATION 60 RADIATION WEIGHTING FACTORS FOR RESPECTIVE IREP INPUT NEUTRON ENERGY RANGES	Page 2 of 19
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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
CFR	*Code of Federal Regulations*
ICRP	International Commission on Radiological Protection
IREP	Interactive Radio Epidemiological Program
keV	kilo electron volt
MeV	million electron volt
MMES	Martin Marietta Energy Systems
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NRC	U.S. Nuclear Regulatory Commission
OCAS	Office of Compensation Analysis and Support, currently referred to as the Division of Compensation Analysis and Support
OR	Oak Ridge
ORAUT	Oak Ridge Associated Universities Team
PIC	pocket ionization chamber
TIB	Technical Information Bulletin
RBE	Relative Biological Effectiveness
SC&A	S. Cohen and Associates (SC&A, Inc.)
TIB	Technical Information Bulletin
TLD	thermoluminescent dosimeter
w_R	weighting factor

EXECUTIVE SUMMARY

During its July 31, 2012, meeting, SC&A was tasked by the Advisory Board on Radiation and Worker Health (Advisory Board) Subcommittee on Procedures Review to conduct a review of ORAUT-OTIB-0055, *Technical Basis for Conversion From NCRP Report 38 Neutron Quality Factors to ICRP Publication 60 Radiation Weighting Factors for Respective IREP Input Neutron Energy Ranges* (ORAUT 2006). ORAUT-OTIB-0055 outlines a wider technical basis for conversion from recorded neutron dose to dose equivalent using the International Commission on Radiological Protection (ICRP) Publication 60 radiation weighting factors. ORAUT-OTIB-0055 offers a method that dose reconstructors can utilize to remove the site-specific quality factors (Q_s) from personal monitoring or radiation survey data at the facility being assessed.

SC&A's review of ORAUT-OTIB-0055 is divided into two main parts. The first part reviews and summarizes the development of neutron-relative biological effectiveness factors, quality factors and radiation weighting factors, and outlines the progression of recommendations provided. The second part of the review assesses whether this technical information bulletin (TIB) meets objectives to support and provide adequate guidance for dose reconstruction.

SC&A's review of ORAUT-OTIB-0055 resulted in the following findings:

(1) The neutron radiation weighting factors basis for ORAUT-OTIB-0055 (i.e., ICRP Publication 60) is outdated; updated scientific recommendations by ICRP have been made since ICRP Publication 60. Updated recommendations were published in 2003 with ICRP Publication 92 (ICRP 2003) and in 2007 with ICRP Publication 103 (ICRP 2007).

(2) The recommendation provided in ORAUT-OTIB-0055 for selecting the appropriate neutron energy is not consistent with the recommendation given in OCAS-IG-001 (OCAS 2007).

(3) NCRP Report 38 was published in 1971 and ORAUT-OTIB-0055 does not present the rationale for using NCRP Report 38 as the basis for adjusting pre-1973 neutron measurement, rather than NCRP Report 20 (published in 1957), NCRP Report 17 (published in 1954) or the minutes of the First Tripartite Conference (Taylor 1984).

(4) Table 3-1 in ORAUT-OTIB-0055 presents a neutron quality factor of 3 as the historical dosimetry guideline for thermal neutrons. This is inconsistent with the minutes documented for the 1949 Tripartite Conference at Chalk River, which presents the Relative Biological Effectiveness (RBE) for thermal neutrons as 5, instead of 3. Likewise, the preface to NCRP Report 17 (page v) states that an RBE of 5 for thermal neutrons is recommended, but no discussion of thermal neutrons was found in the body of Report 17.

1.0 INTRODUCTION

This review of ORAUT-OTIB-0055, *Technical Basis for Conversion from NCRP Report 38 Neutron Quality Factors to ICRP Publication 60 Radiation Weighting Factors for Respective IREP Input Neutron Energy Ranges* (ORAUT 2006), was prepared by SC&A's Stephen Marschke. As with other technical information bulletins (TIBs), ORAUT-OTIB-0055 is a working document that provides historical background and guidance information that is used to support the development of dose reconstruction at certain sites. TIBs are amended when additional pertinent information is obtained and can be used to assist NIOSH staff in dose reconstruction.

1.1 PURPOSE OF TECHNICAL INFORMATION BULLETIN ORAUT-OTIB-0055

The purpose of ORAUT-OTIB-0055 is to provide "…a broader technical basis to convert from recorded neutron dose to dose equivalent using the ICRP Publication 60 radiation weighting factors (ICRP 1991)." ORAUT-OTIB-0055 provides a discussion on the need to adjust for the neutron dose for each worker to account for the change in neutron quality factors between historical and current guidance and recommendations.

2.0 ORAUT-OTIB-0055 REVIEW

2.1 BRIEF HISTORY OF NEUTRON WEIGHTING FACTORS

Described below is a brief history of the major documents used in the development of neutron-relative biological effective (RBE) factors, quality factors, and radiation weighting factors. Figure 2.1-1 compares the recommended RBE, quality, or radiation weighting factors from the documents discussed. ORAUT-OTIB-0055, OCAS-IG-001, and ICRP Publication 92 each provide more information on the development of these factors.

- On September 29 and 30, 1949, the Tripartite Conference was held at Chalk River, Canada (Taylor 1984). During the conference, the RBE factors of 5 and 10 for thermal (<0.025 keV) and fast (<20 MeV) neutrons, respectively, were agreed to by the Committee.

- On November 22, 1955, the National Committee on Radiation Protection and Measurements (NCRP) published Report No. 20 (NCRP 1957). In Report 20, Table 2 (page 15), the NCRP provides 11 discrete RBE factors for neutrons in the energy range from thermal to 10 MeV. For thermal neutrons, an RBE of 3 is recommended; the RBE then decreases to 2 at 0.1 keV, before increasing to a maximum of 10.5 at 1 MeV; and finally the RBE falls to 6.5 for neutrons of 10 MeV. In Figure 2.1-1 the NCRP Report 20-recommended neutron RBEs are shown as the solid green line with solid green triangles.

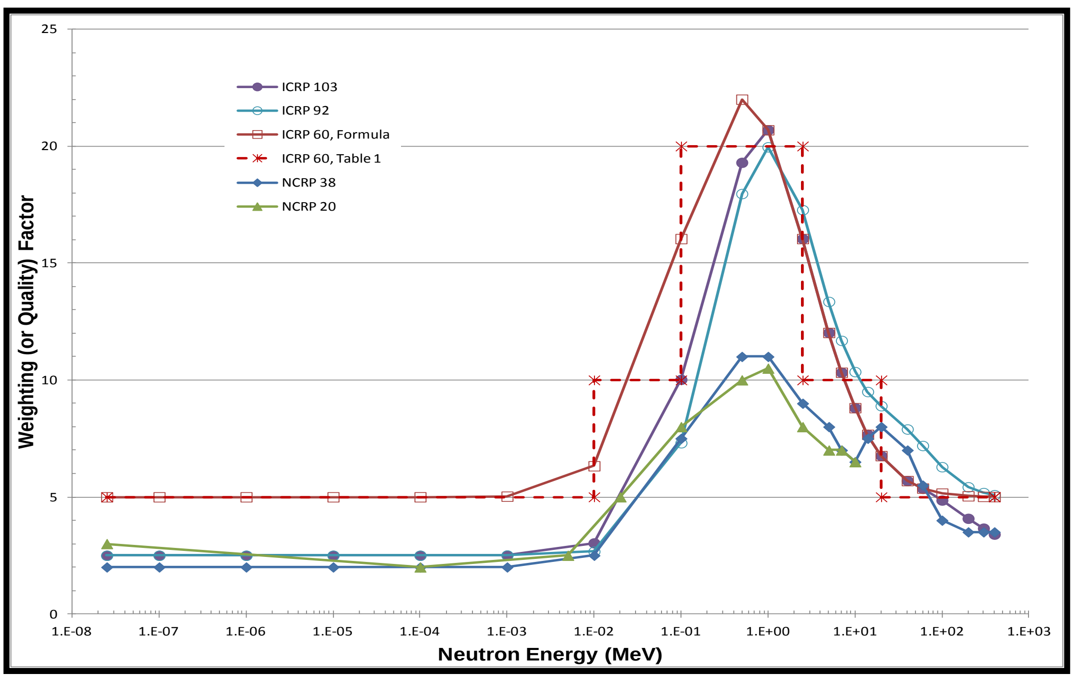

Figure 2.1-1: Comparison of Neutron Weighting (or Quality) Factors

- On January 4, 1971, the NCRP published Report No. 38 (NCRP 1971). In Report 38, Table 2 (page 16), the NCRP provides 22 discrete mean quality factors for neutrons in the energy range from thermal (2.5×10^{-8} MeV) to 400 MeV. At 1 keV and below, the NCRP 38-recommended neutron quality factor is 2; the quality factor peaks at 11 for 0.5 to 1 MeV neutrons before it falls to 3.5 for neutrons at 200 MeV and above. In Figure 2.1-1, the NCRP Report No. 38-recommended neutron quality factors are shown as the solid blue line with solid blue diamonds.

  In 10 CFR §20.1004, Table 1004(b)-2, the Nuclear Regulatory Commission (NRC) still requires using the NCRP 38-recommended neutron quality factors. However, when the neutron energy is unknown, the NRC requires that a quality factor of 10 be used [Table 1004(b)-1].

- In 1991, the International Commission on Radiological Protection (ICRP) issued Publication 60 (ICRP 1991). In Publication 60, the ICRP recommends that the neutron weighting factors provided in Table 1 of the publication (and reproduced below in Table 2.1-1) be used.

Table 2.1-1: ICRP Publication 60 Neutron Weighting Factor

Neutron Energy	ICRP Publication 60 Neutron Weighting Factor
<10 keV	5
10 keV to 100 keV	10
>100 keV to 2 MeV	20
>2 MeV to 20 MeV	10
>20 MeV	5

ICRP Publication 60 specifically recommends use of the stepwise factors of Table 2.1-1. However, to assist in providing consistency in calculations, Publication 60, paragraph A12 (page 82), provides the following mathematical relationship between the weighting factor (w_R) and neutron energy:

$$w_R = 5 + 17exp(-ln(2E_n)^2/6)$$

Where: w_R = The neutron weighting factor
E_n = Neutron energy

The ICRP cautions that there "is no intention to imply any biological meaning to this relationship. It is simply a calculation tool" (ICRP 1991, page 82). In Figure 2.1-1, the mathematical relationship is shown by the solid red line with the empty boxes, while the stepwise factors are shown by the dashed red line with red stars.

- In 2003, the ICRP issued Publication 92 (ICRP 2003). In Publication 92, the ICRP proposed that the neutron radiation weighting factor (w_R) be modified from the factors recommended in Publication 60. The proposed modification preserved the weighting factor value at 1 MeV, but by being substantially smaller at lower neutron energies, it accounted for the large dose contribution from secondary photons at low neutron energies. Also, at energies between 1 and 100 MeV, the Publication 92-proposed weighting factors somewhat exceed the Publication 60 values. The Publication 92-proposed weighting factors are in line with the dependence of the effective quality factor on neutron energy (ICRP 2003, page 78).

The proposed Publication 92 neutron weighting factors are shown in Figure 2.1-1 as a solid light blue line with empty circles, and were based on the following equation taken from Publication 92, footnote 9 (page 78).

$$w_R \quad = \quad 2.5[2 - exp(-4E_n) + 6exp(-ln(E_n)^2/4) + exp(-ln(E_n/30)^2/2)]$$

All parameters have been previously defined.

- In 2007, the ICRP issued Publication 103 (ICRP 2007). In Publication 103, the ICRP recommendations shifted from the previous process-based protection approach using practices and interventions to an approach based on the exposure situation. The most significant changes compared with the data in ICRP Publication 60 (ICRP 1991) are the decrease of w_R in both the low-energy range and at neutron kinetic energies above 100 MeV. See Annex B of ICRP Publication 103 for further explanation.

  The Publication 103 neutron weighting factors are shown in Figure 2.1-1 as a solid purple line with filled circles, and were based on the following equation taken from Publication 103, equation 4.3 (page 66).

$$w_R \quad = \quad \begin{cases} 2.5 + 18.2e^{-[ln(E_n)]^2/6} & E_n < 1\ MeV \\ 5.0 + 17.0e^{-[ln(2E_n)]^2/6} & 1\ MeV \ \leq\ E_n \ \leq 50\ MeV \\ 2.5 + 3.25e^{-[ln(0.04E_n)]^2/6} & E_n \ > 50\ MeV \end{cases}$$

- In 2010, the ICRP published Publication 116 (ICRP 2010). In Publication 116, the ICRP presents reference conversion coefficients for effective dose and organ-absorbed doses for various types of external exposures that were calculated following ICRP Publication 103.

Table 2.1-2: Neutron Quality Factor, Q, or weighting factor, wR.

Neutron energy (MeV)	Historical dosimetry guidelines[a]	NCRP Report 38 group averaged quality factor[b]	ICRP Publication 60 neutron weighting factor	Ratio[c]
Thermal	3	2.35	5	2.13
0.5 eV–10 keV	10			
10 keV–100 keV		5.38	10	1.86
100 keV–2 MeV		10.49	20	1.91
2 MeV–20 MeV		7.56	10	1.32
20 MeV–60 MeV		6.96[d]	5	1.00[e]

a. First Tripartite Conference at Chalk River in 1949 (Taylor 1984) and NCRP Report 17 (NCRP 1954).

b. See ORATU-OTIB-0055, Figure 3-1.

c. Ratio of the ICRP 60 weighting factor to the group averaged NCRP 38 quality factor for each neutron energy group.

d. "Not applicable" is usually inserted here rather than the NCRP group averaged value of 6.96, which is larger than the ICRP 60 weighting factor of 5 for 20-to-60-MeV neutrons and results in a non-claimant-favorable reduction in the corrected dose for this neutron energy group.

e. Ratio for adjusting neutron dose from NCRP 38 quality factor to ICRP 60 weighting factor is arbitrarily set equal to unity to avoid a non-claimant-favorable reduction in the corrected dose for this neutron energy group.

Finding: Table 2.1-2 provides a neutron quality factor of 3 as the historical dosimetry guideline for thermal neutrons. The minutes from the 1949 Tripartite Conference at Chalk River state the RBE for thermal neutrons as 5, not 3. Likewise, the preface to NCRP Report 17 (page v) states that an RBE of 5 for thermal neutrons is recommended, but no discussion of thermal neutrons was found in the body of Report 17.

Finding: NCRP Report 38 was published in 1971. The rationale for using NCRP Report 38 as the basis for adjusting pre-1973 neutron measurements, rather than NCRP Report 20 (published in 1957), NCRP Report 17 (published in 1954) or the First Tripartite Conference minutes (published in 1949) is not presented.

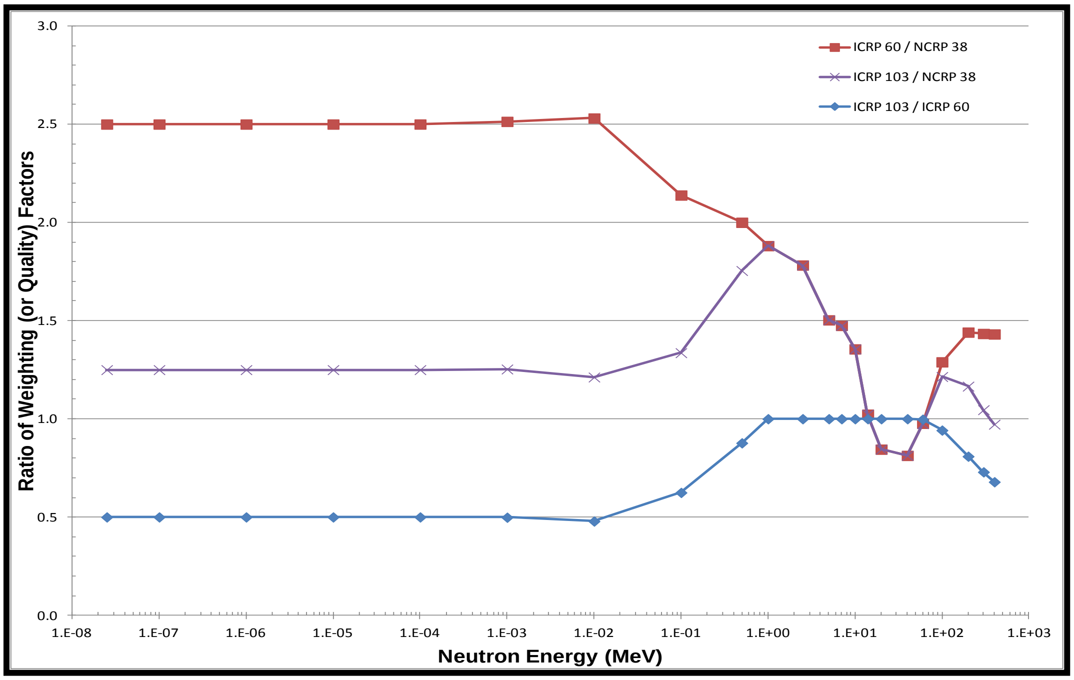

Figure 2.1-2: Ratio of Neutron Weighting (or Quality) Factors

2.2 APPLIED EXAMPLE

Table 2.2-1 is an example of the difference in the radiation weighting factors between ICRP 60 and ICRP 103. The dose values calculated using ICRP 60 are higher and therefore claimant favorable compared to the dose values calculated using ICRP 103 guidelines.

Table 2.2-1: Y-12 Neutron Weighting (or Quality) Factor

Energy (MeV)	Quality Factor		Weighting Factor		
	Bldg 9212	Bldg 9983	ICRP 60, Table 1	ICRP 60, Formula	ICRP 103
2.57E-07	2.3	2.3	5	5	3
5.48E-07	2.1	2.1	5	5	3
1.06E-06	2.1	2.1	5	5	3
2.25E-06	2.1	2.1	5	5	3
4.77E-06	2.1	2.1	5	5	3
1.01E-05	2.2	2.2	5	5	3
2.14E-05	2.1	2.1	5	5	3
4.52E-05	2.1	2.1	5	5	3
9.58E-05	2.0	2.0	5	5	3
2.03E-04	2.0	2.0	5	5	3
4.34E-04	2.0	2.0	5	5	3
9.13E-04	2.0	2.0	5	5	3
1.92E-03	2.0	2.0	5	5	3
4.07E-03	2.0	2.0	5	5	3
8.62E-03	2.0	2.0	5	6	3
1.82E-02	2.8	2.8	10	8	4
3.86E-02	4.3	4.3	10	11	6

Table 2.2-1: Y-12 Neutron Weighting (or Quality) Factor

Energy (MeV)	Quality Factor		Weighting Factor		
	Bldg 9212	Bldg 9983	ICRP 60, Table 1	ICRP 60, Formula	ICRP 103
8.18E-02	6.6	6.6	10	15	9
1.67E-01	8.5	8.5	20	19	13
3.37E-01	10.1	10.0	20	22	17
6.79E-01	10.9	10.9	20	22	20
1.39E+00	9.8	9.9	20	19	19
2.78E+00	8.1	8.2	10	15	15
5.54E+00	7.0	7.0	10	11	11
1.12E+01	6.9	6.9	10	8	8
2.04E+01	6.9	6.9	5	7	7
Total					
Bldg 9212	9.9	–	18.9	19.7	18.6
Bldg 9983	–	7.9	14.2	15.5	14.4

Based on data from NIOSH OR 03-033, "MMES Neutron Field Measurement Data, Y-12 Building 9212" and NIOSH OR 03-034, "MMES Neutron Field Measurement Data,Y-12 Building 9983" (Wiley 2003)

2.3 REVIEW COMMENTS

2.3.1 ICRP Publication 103

When 42 CFR 82 was published on May 2, 2002, the ICRP recommended the radiation weighting factors that are presented in Publication 60 (ICRP 1991), Table 1, as indicated from the following excerpt:

> *The equivalent dose(s) will be calculated using the current, standard radiation weighting factors from the International Commission on Radiological Protection.*[1]
>
> [1] *The current weighting factors of the International Commission on Radiological Protection are provided in ICRP 60: '1990 Recommendations of the International Commission on Radiological Protection.' Ann. ICRP 21 (1–3):6.* [42 CFR §82.10(j)]

Since 2002, the ICRP has revised its recommendations regarding radiation weighting factors at least twice; in 2003 with Publication 92 (ICRP 2003), and in 2007 with Publication 103 (ICRP 2007). Figure 2.1-1 compares the neutron weighting factors from the three ICRP publications. As shown, the most significant differences between the two publications are the decrease of the Publication 103 weighting factors in both the low-energy range and at energies above 100 MeV compared to the Publication 60 factors.

Finding: The basis for ORAUT-OTIB-0055 (i.e., ICRP Publication 60) is outdated. Since ICRP Publication 60 was published, the ICRP has revised its recommendations regarding neutron radiation weighting factors, with the latest recommendations being provided in ICRP

Publication 103. While SC&A recognizes that ORAUT-OTIB-0055 (effective date June 5, 2006) predates ICRP Publication 103, notwithstanding issues regarding claimant favorability, we believe that NIOSH should consider updating OTIB-0055 to reflect the most recent ICRP guidance.

2.3.2 Consistency with OCAS-IG-001

In ORAUT-OTIB-0055, Section 3 "Neutron Dose Equivalent Adjustments" (page 9), the following guidance is given on how dose reconstructors should adjust the historical neutron dose record to account for the revised neutron weighting factor:

> *…, dose reconstructors should use the following claimant-favorable recommendations in the absence of detailed information on the neutron energies involved in a worker's exposure: (1) assume the corrected neutron dose equivalent to be twice the measured dose, missed dose, or dose based on a neutron-to-photon ratio, and (2) assume the neutron energies to be in the energy range from 0.1 to 2 MeV.* [ORAUT 2006, page 9]

The above guidance is repeated in ORAUT-OTIB-0055, Section 4 "Discussion" (page 11). This guidance appears to be in contrast with guidance given in OCAS-IG-001, Section 2.2 (OCAS 2007), which states:

> *When no energy information can be found, the exposure scenarios discussed in* [**Table**] *can be used to estimate the predominant* [neutron] *energy.*

Finding: The recommendation given in ORAUT-OTIB-0055 for selecting the appropriate neutron energy when detailed information on the neutron energies involved in a worker's exposures is not available differs from the recommendation given in OCAS-IG-001 for the same scenario.

Table 2.3-1: Neutron Energy Intervals and Associated ICRP 60 Weighting Factor and Some Examples of Exposures or Facilities Where the Specific Neutron Energy Might be Encountered

Neutron Energy (MeV)	ICRP 60 Weighting Factor, w_R	Typical Exposure Scenario
< 0.01	5	Low-energy neutron exposures include thermal neutrons commonly found around nuclear reactors or moderated neutron sources. More prevalent around heavy water reactors.
0.01–0.10	10	Intermediate energy neutron exposures can also result from operation around nuclear reactors, as high-energy neutrons are moderated to thermal energies.
0.10–2.00	20	Commonly called fission spectrum neutrons, this is the most typical energy range from operation of light-water or graphite-moderated reactors.
2.0–20.0	10	Reactions between alpha particles from materials such as plutonium or polonium and light materials such as beryllium can result in the production of neutrons. These reactions are commonly called (α,n) reactions. This neutron energy interval also includes 14 MeV neutrons from fusion reactions.
> 20.0	5	Exposures to neutrons greater than 20 MeV can result from work around accelerators.

Source: OCAS-IG-001, Table 2.2

3.0 REVIEW CHECKLIST

3.1 ORAUT-OTIB-0055 REVIEW CHECKLIST

Table 3.13.1-1: ORAUT-OTIB-0055 Review Checklist

Document No.: ORAUT-OTIB-0055	**Effective Date:** 06/05/2006
Document Title: Technical Basis for Conversion from NCRP Report 38 Neutron Quality Factors to ICRP Publication 60 Radiation Weighting Factors for Respective IREP Input Neutron Energy Ranges	
Auditor: Stephen Marschke	

No.	Description of Objective	Rating 0–5*	Comments
1.0	**Determine the degree to which procedures support a process that is expeditious and timely for dose reconstruction.**		
1.1	Is the procedure written in a style that is clear and unambiguous?	5	
1.2	Is the procedure written in a manner that presents the data in a logical sequence?	5	
1.3	Is the procedure complete in terms of required data (i.e., does not reference other sources that are needed for additional data)?	4	Inconsistent dose adjustment, see Section 2.3.2.
1.4	Is the procedure consistent with all other procedures that are part of the hierarchy of procedures employed by NIOSH for dose reconstruction?	5	
1.5	Is the procedure sufficiently prescriptive in order to minimize the need for subjective decisions and data interpretation?	5	
2.0	**Determine whether the procedure provides adequate guidance to be efficient in instances where a more detailed approach to dose reconstruction would not affect the outcome.**		
2.1	Does the procedure provide adequate guidance for identifying a potentially high probability of causation as part of an initial dose evaluation of a claim?	N/A	
2.2	Conversely, for claims with suspected cumulative low doses, does the procedure provide clear guidance in defining worst-case assumptions?	N/A	
3.0	**Assess the extent to which procedures account for all potential exposures and ensure that resultant doses are complete and based on adequate data.**		
3.1	Assess quality of data collected via <u>interviews</u>:	-----	
3.1.1	Is scope of information sufficiently comprehensive?	N/A	
3.1.2	Is the interview process sufficiently flexible to permit unforeseen lines of inquiry?	N/A	
3.1.3	Does the interview process demonstrate objectivity, and is it free of bias?	N/A	
3.1.4	Is the interview process sensitive to the claimant?	N/A	
3.1.5	Does the interview process protect information as required under the Privacy Act?	N/A	
3.2	Adequacy and use of <u>site-specific data</u> pertaining to:	-----	
3.2.1	Personal dosimeters (e.g., film, TLD, PICs)	N/A	
3.2.2	In vivo/In vitro bioassays	N/A	
3.2.3	Missing dosimetry data	N/A	
3.2.4	Unmonitored periods of exposure	N/A	

Table 3.13.1-1: ORAUT-OTIB-0055 Review Checklist

Document No.: ORAUT-OTIB-0055	**Effective Date:** 06/05/2006
Document Title: Technical Basis for Conversion from NCRP Report 38 Neutron Quality Factors to ICRP Publication 60 Radiation Weighting Factors for Respective IREP Input Neutron Energy Ranges	
Auditor: Stephen Marschke	

No.	Description of Objective	Rating 0–5*	Comments
4.0	**Assess procedure for providing a consistent approach to dose reconstruction regardless of claimants' exposures by time and employment locations**		
4.1	Does the procedure support a prescriptive approach to dose reconstruction?	5	
4.2	Does the procedure adhere to the hierarchical process as defined in 42 CFR 82.2?	5	
5.0	**Evaluate procedure with regard to fairness and giving the benefit of the doubt to the claimant**		
5.1	Is the procedure claimant favorable in instances of missing data?	5	
5.2	Is the procedure claimant favorable in instances of unknown parameters affecting dose estimates?	5	
5.3	Is the procedure claimant favorable in instances where claimant was not monitored?	N/A	
6.0	**Evaluate procedure for its ability to adequately account for the uncertainty of dose estimates.**		
6.1	Does the procedure provide adequate guidance for selecting the types of probability distributions (i.e., normal, lognormal)?	N/A	
6.2	Does the procedure give appropriate guidance in the use of random sampling in developing a final distribution?	N/A	
7.0	**Assess procedures for striking a balance between technical precision and process efficiency.**		
7.1	Does the procedure require levels of detail that can reasonably be accounted for by the dose reconstructor?	5	
7.2	Does the procedure avoid levels of detail that have only limited significance to the final dose estimate and its POC?	5	
7.3	Does the procedure employ scientifically valid protocols for reconstructing doses?	3	See Section 2.3.1

* Rating system of 1 through 5 corresponds to the following: 1=No (Never), 2=Infrequently, 3=Sometimes, 4=Frequently, 5=Yes (Always). N/A indicates not applicable.

4.0 CONCLUSION

ORAUT-OTIB-0055 presents a discussion on the need to modify the neutron quality factors presented in NCRP Report 38 to ICRP Publication 60 radiation weighting factors. The TIB presented a corrected neutron dose equivalent methodology that is recommended for use in dose reconstruction for measured dose, missed dose, and dose determined based on neutron-to-photon ratios. This TIB also recommended the use of claimant-favorable values when there is insufficient detailed information on neutron energies, mainly for neutron doses measured prior to 1957 and the publication of NCRP Report 20 (NCRP 1957).

SC&A's review of ORAUT-OTIB-0055 resulted in four findings. The first finding identified inconsistencies in the historical dosimetry guideline for thermal neutrons. The RBE for thermal neutrons is presented as a value of 5, instead of 3, as is in the Tripartite Conference at Chalk River minutes. A discussion supporting the recommended RBE of 5 for thermal neutrons is not provided in NCRP Report 17. Secondly, no rationale is provided for the use of NCRP Report 38 as the basis for adjusting pre-1973 neutron measurements. SC&A found that ICRP Publication 60, which forms the neutron radiation weighting factors basis for ORAUT-OTIB-0555, is outdated by more recent recommendations presented in ICRP Publications 92 (2003) and 103 (2007). Lastly, SC&A found the recommendation given in ORAUT-OTIB-0055 for selecting the appropriate neutron energy when detailed information on the neutron energies involved in a worker's exposures is not available differs from the recommendation given in OCAS-IG-001 for the same scenario.

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