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ACRONYMS AND ABBREVIATIONS

DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
GM	geometric mean
GSD	geometric standard deviation
NDRP	Neutron Dose Reconstruction Project
NIOSH	National Institute for Occupational Safety and Health
N-P	neutron-to-photon
PDF	Portable Document Format
RFP	Rocky Flats Plant
TIB	technical information bulletin
U.S.C.	United States Code
σ	standard deviation
§	Section

1.0 PURPOSE

Technical information bulletins (TIBs) are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained. TIBs may be used to assist the National Institute for Occupational Safety and Health (NIOSH) in the completion of individual dose reconstructions.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy [DOE] facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [EEOICPA; 42 U.S.C. § 7384l(5) and (12)].

The purpose of this document is to provide guidance on the application of neutron dose from the Rocky Flats Neutron Dose Reconstruction Project (NDRP) to NIOSH dose reconstructions. In addition to neutron dose guidance, this TIB includes information about NDRP reconstructed gamma dose and methods to determine missed gamma dose utilizing the NDRP reconstructed gamma dose.

2.0 APPLICATION AND LIMITATIONS

Except for the application of N-P ratios as described in Section 4.1.6, the methods described in this TIB apply only to workers at Rocky Flats Plant (RFP) plutonium facilities during the period from 1952 to 1970. There are three important caveats or limitations:

- The final NDRP neutron dose for 1970 may not be accurate. Recorded dosimeter data was not always complete.
- The gamma dose information for 1970 may not be present.
- The information on gamma dose was collected only when applicable to NDRP effort.
- Neutron dose for energy employees not included in the NDRP should continue to be calculated in accordance with the Rocky Flats external dose technical basis document (ORAUT 2004).

3.0 BACKGROUND

The NDRP data are in three main types of Portable Document Format (PDF) files. The NDRP protocol document contains detailed descriptions of the content of these files (ORISE 2005).

- Neutron Dose Summary – Yearly summary of the neutron dose components, the errors associated with the values, and reconstructed gamma dose
- Neutron Dose Detail – Details by exchange period in a given year of the neutron dose components
- Individual Timeline – Further details by exchange period in a given year about the original neutron dose, calculation of NDRP dose, the building location, and penetrating gamma dose

The total neutron dose needed for dose reconstruction consists of three quantities listed in the summary and detail presentations. These quantities are:

- Non-affected original neutron dose – The original neutron dose equivalent that was not affected by an NDRP dose based on a reread film or glass plate. A blank in this field indicates either that the original neutron dose was affected or that there was no original neutron dose on the dosimetry worksheet for a given monitoring period.

- NDRP neutron dose – The neutron dose estimate from the NDRP evaluation (from reread films or glass plates). A blank in this field indicates either that the original neutron dose was verified to be correct or that the original film or plates were unreadable.

- Notional neutron dose – The neutron dose equivalent estimated by the NDRP evaluation for each gap. Notional dose is a weighted combination of two dose determination methods. Method 1 is based on the worker's average neutron dose per day obtained from films reevaluated by the NDRP for a given calendar year and building. Method 2 is based on applying an average neutron-to-gamma ratio to reported penetrating gamma doses for a given building and calendar year. ORISE (2005, Section 11.3) contains a comprehensive description of the notional dose calculation. A blank in this field indicates that either the original dose report was correct or that the reread film or plate (dose under the "NDRP Neutron Dose" heading) was adequate to replace the original film, or that there was no indication of neutron exposure based on the buildings the employee was in and that there was no gamma dose that could be used to estimate the exposure.

The Neutron Dose Summary file provides error values for the annual doses in the form of standard deviations (1σ) for the NDRP and notional doses. The NDRP and notional doses have normal distributions with 1-σ error values. The non-affected dose also has a normal distribution, but dose reconstructors must calculate the error associated with this component in accordance with *External Dose Reconstruction Implementation Guideline* (NIOSH 2002) and *Supplementary External Dose Information for Rocky Flats Plant* (ORAUT 2005).

4.0 GENERAL APPROACH

4.1 Use Of Neutron Dose Reconstruction Project Data In Dose Reconstructions

This section provides guidance for the use of the NDRP neutron dose components in different types of reconstructions.

4.1.1 Minimized Dose

In situations where only a minimum value of NDRP dose is necessary to complete a NDRP reconstruction, the dose reconstructor should apply the final neutron dose in the Neutron Dose Summary file as a constant. This quantity consists of the non-affected original neutron dose, the NDRP neutron dose, and the notional neutron dose without modification by uncertainty values.

4.1.2 Maximized Dose

In situations where a maximized NDRP dose can be applied to a reconstruction, the uncertainty values associated with each dose component can be added to the respective doses to estimate a 95% upper confidence interval dose. The summed 95% upper confidence level dose may be applied as a constant. The Neutron Dose Summary file provides annual 1-σ values for NDRP neutron dose and notional neutron dose and these may be multiplied by

1.645 to estimate a 95% uncertainty. For non-affected original neutron dose, dose reconstructors should use the 95% uncertainty factors in ORAUT (2005). In addition, for data from 1951 to 1963, dose reconstructors must multiply the non-affected original neutron dose by 2.50 to account for unmonitored neutron dose below 800 keV. This is the most claimant favorable value from the Rocky Flats external dose technical basis document (ORAUT 2004).

4.1.3 Best-Estimate Dose

For dose reconstructions that require a best estimate of NDRP dose, dose reconstructors should combine the three components and their associated uncertainties as specified in Section 2.1.1.3.4 of NIOSH (2002) using the annual 1-σ values for NDRP neutron dose and notional neutron dose in the Neutron Dose Summary file. For non-affected original neutron dose, dose reconstructors should use the 95% uncertainties provided in ORAUT (2005) to calculate a 1-σ value. In order to account for unmonitored neutron dose below 800 keV for data from 1951 to 1963, dose reconstructors should multiply only the non-affected original neutron dose by the appropriate location/job specific value from Table 6-18 of the external dose TBD depending on the specific work location of the claimant, if known. If the work location is not known then the maximum value applicable from Table 6-18 of the RFP TBD should be used .

4.1.4 1970 Neutron Dose

The 1970 NDRP data do not conform to the standards applied to previous years as explained in ORISE (2005). For reconstructions where maximized dose can be used, the difference between original neutron dose and the NDRP neutron dose can be added to the overall penetrating dose reported by DOE in site dosimetry files, which is a combination of photon and neutron dose. When a minimized or best-estimate value is needed, a neutron-to-photon (N-P) ratio (see section 4.1.6 in this document) can be used to evaluate the reported penetrating dose (total neutron plus photon dose in the DOE site dosimetry files) and determine the neutron and gamma components.

4.1.5 Missed Neutron Dose

In some instances, there is no NDRP dose or notional dose reconstructed for a listed dosimeter cycle. If there is no entry for the NDRP or notional dose, it should not be assumed to be a zero. However, if there is a zero in the unchanged original reported neutron dose or the NDRP evaluation dose, or notional dose, and the final dose is zero, then missed dose is appropriate. This situation is evident upon examination of the neutron section of the Individual Timeline files. When a missed dose occurs, dose reconstructors should calculate the missed neutron dose using the one-half limit of detection (LOD/2) method in NIOSH (2002) for that reported final zero. Estimated missed neutron dose should not be applied if the original reported zero value has been changed to a final positive result by the NDRP reevaluation of dosimeter results or application of the notional dose.

4.1.6 Neutron-to-Photon Ratio, 1970 to 1976

The NDRP report provides N-P ratios for the period from 1952 to 1969. Because the dose data from DOE contain a penetrating quantity that is a combination of neutron and gamma dose through 1976, application of N-P ratios to reported dose for the period from 1970 to 1976 must occur in order to determine the specific neutron and gamma components of the penetrating dose. Due to significant changes in operations at RFP after 1969, NDRP project staff indicated that data for the period from 1977 to the present should be used to determine an N-P ratio for the period from 1970 to 1976. All NIOSH worker data from 1977 to the present were analyzed, and a N-P ratio was determined for those claims that exhibited a positive neutron dose. The N-P ratio data for this period fit a lognormal distribution with a geometric mean (GM) of 0.42 and a geometric standard deviation (GSD) of 3. Dose reconstructors should use those values to determine the portion of the DOE-recorded penetrating dose attributable to neutron exposure for reconstructions that involve employment between 1970 and 1976. Table 4-1 provides a summary of the analyzed N-P ratio data.

Table 4-1. Annual N-P ratio for 1977 to 2000.

Year	GM	GSD
1977	0.33	3.31
1978	0.57	2.53
1979	0.37	3.31
1980	0.43	2.57
1981	0.51	2.41
1982	0.4	2.4
1983	0.42	3.01

Year	GM	GSD
1984	0.41	3.07
1985	0.42	3.37
1986	0.49	2.93
1987	0.36	3.56
1988	0.6	2.83
1989	0.36	3.5
1990	0.35	3.77

Year	GM	GSD
1991	0.29	2.41
1992	0.4	2.03
1993	0.61	1.93
1994	0.41	2.35
1995	0.35	2.28
1996	0.26	4.1
1997	0.44	2.18

Year	GM	GSD
1998	0.39	3.03
1999	0.45	2.79
2000	0.6	1.8
Overall	0.42	3

In order to determine the portions of penetrating dose attributable to gamma and neutron exposure the following relationships can be used:

- Gamma Dose = Penetrating Dose/1.42
- Neutron Dose = (Penetrating Dose) – (Gamma Dose)

The results for gamma and neutron dose should be applied as a lognormal distribution with a geometric standard deviation of 3. This approach can be used for all cases whether compensable or non-compensable.

4.2 Gamma Dosimetry

This section provides guidance for the use of the NDRP gamma dose components.

4.2.1 NDRP Reported Gamma Dose

As noted earlier, the NDRP reported gamma dose only includes those gamma doses that were in some way used to estimate neutron dose and thus are usually less than the DOE dosimetry reports from the site. In some cases the gamma dose in the NDRP evaluation files is greater than the penetrating gamma dose reported in the DOE site dosimetry files. In that event, the greater

dose should be used for maximizing and best-estimate cases. The smaller dose may be used for minimizing cases.

4.2.2 Reconstructed Gamma Dose

For workers who had wrist dosimetry but no whole-body dosimetry, the NDRP project calculated a reconstructed gamma dose based on a ratio of wrist to whole-body dose. Both the Summary file and the gamma section of the Individual Timeline file list this dose denoted by an asterisk (*). Because this gamma dose does not appear in the original DOE data, dose reconstructors should add it to the reconstruction.

4.2.3 Missed Gamma Dose

The Individual Timeline files provide gamma data for each readout cycle that was needed to estimate neutron dose. As discussed above, the gamma data is not necessarily complete for any year (including 1970), as that was not the purpose of the NDRP evaluation, and so cannot be used to directly estimate the number of recorded zeros. However, the reported positive results can be subtracted from the maximum number of likely zeros based on the RFP external TBD; this would represent the maximum number of zeros possible. The minimum number of zeros can be estimated by directly counting reported zeros in the Individual Timeline file. A best estimate of zeros should apply the approach discussed in OCAS-IG-001 (NIOSH 2002). This data will allow more accurate estimation of the number of recorded zero doses for purposes of calculating the missed gamma dose using the LOD/2 method.

REFERENCES

NIOSH (National Institute for Occupational Safety and Health), 2002, *External Dose Reconstruction Implementation Guideline*, OCAS-IG-001, Rev. 1, Office of Compensation Analysis and Support, Cincinnati, Ohio.

ORAUT (Oak Ridge Associated Universities Team), 2004, *Technical Basis Document for Rocky Flats Plan t- Occupational External Dosimetry*, ORAUT-TKBS-0011-6, Rev. 00, Oak Ridge, Tennessee.

ORAUT (Oak Ridge Associated Universities Team), 2005, *Supplementary External Dose Information for Rocky Flats Plant*, ORAUT-OTIB-0027, Rev. 0, Oak Ridge, Tennessee.

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