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A Standard Complex-Wide Conversion/Correction Factor for Overestimating External Doses Measured with Thermoluminescent Dosimeters

Foreword

The Manhattan Engineering District, and, later, the Atomic Energy Commission (AEC) had early responsibility for processing nuclear weapons material. The AEC was superceded in this function (briefly) by the Energy Research and Development Agency (ERDA), then the Department of Energy (DOE). This document presents assumptions for the latter period, when the AEC and DOE were the responsible agencies. For the purposes of this document the term ‘DOE’ is used as a term of convenience to mean the Department of Energy and its predecessor agencies.

Essentially all DOE sites followed a similar evolution in external dosimetry technology. Early two-element film dosimeters, followed by multi-element film dosimeter designs, gave way in the 1970’s and 1980’s to the use of thermoluminescent dosimeters (TLDs) for personnel dose monitoring. Personnel dosimetry programs under the DOE have been accredited under the DOE Laboratory Accreditation Program (DOELAP) since the latter 1980s (DOE 1986). DOELAP-accredited dosimetry programs are considered accurate for purposes of dose reconstruction under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA).

The present document is intended to provide assumptions to apply to a limited set of cases for specific sites only during delimited periods of applicability. Specifically, this technical information bulletin (TIB) presents external radiation dose assumptions that may be applied to dose reconstructions involving cases for which dose estimates may be prepared based solely on recorded deep and/or shallow dose that incorporate dose monitoring information only from years when monitoring was performed with TLDs.

It is possible to formulate reasonable, overestimating complex-wide assumptions for interpreting recorded photon dose due to the high degree of standardization of the DOE’s TLD-based dosimetry programs; the methodology described below will generate a reasonable overestimate of external radiation dose for cases that are likely non-compensable. In accordance with the process efficiencies discussed in 42 CFR 82, use of an overestimated dose allows the expeditious processing of likely non-compensable cases.

1.0 Introduction

The objectives of this document are: 1) to discuss the degree of standardization of DOE thermoluminescent dosimeter (TLD) measurements and 2) to develop a standard correction factor that will overestimate dose. Information in this document examines the performance of TLD dosimeters, application of the standard correction factor to overestimate doses, and to address uncertainties from the following sources.

- Variation in workplace photon radiation fields
- Variation in exposure geometries
- Variation in organ of concern, and the range of values for organ dose conversion factors presented in the National Institute of Occupational Safety and Health's (NIOSH) OCAS-IG-001, 'External Dose Reconstruction Implementation Guideline' (NIOSH 2002).

While accounting for these uncertainties, the method proposed here will take into account similarities among sites complex wide in the following attributes.

- Similar dose response performance by photon energies among the TLDs used
- Similar minimum detection levels (MDL)
- A standard exchange frequency

A single conversion/correction factor that takes a large number of programs and features into account must admit a great deal of error into any estimate that it modifies. This error is permissible under this program, so long as the error is in the claimant's favor. Specifically, any error must overestimate rather than reduce the claimant's probability of causation.

For this reason, the conversion/correction factor proposed here overestimates any given claimant's dose. As the intent is to overestimate the dose to take advantage of an efficiency progress, this methodology proposed here is useful only for likely non-compensable claims.

The assumptions here will be inappropriate for certain organs outside the considered range of organ dose conversion factors. For this reason cancers of skin and eye, and cases requiring dose reconstruction to the bone surface are not to be prepared using the claimant-favorable overestimates resulting from this document. These assumptions also exclude assignment of shallow doses, which precludes dose reconstruction for cancers to the skin, testes (unless used as a surrogate for another organ), or breast.

2.0 Dosimetry Development and Basis of Comparison

2.1 Dosimetry Development

Radiation response characteristics of the dosimetry technology for respective DOE sites are highly similar. The majority of Manhattan Engineering District (MED) sites followed a similar evolution in dosimetry technology from the two-element film dosimeter design developed in 1944 (Pardue et al), the use of multi-element film dosimeter designs and later, all sites implemented thermoluminescent dosimetry methods because of the ease of automation and nearly tissue-equivalent radiation response to photon radiation. The judgment in this TIB is that equivalent thermoluminescent dosimetry technology was used for several of the DOE sites evaluated in this analysis as shown in Table 2-1.

Table 2-1. MED/AEC/DOE Sites with Equivalent Beta/Photon Dosimetry Capabilities

Site	Thermoluminescent Dosimeter Year of First Use	
	Site-Specific	Commercial
Fernald	n.a.	1985
Hanford	1972	1995
Idaho National Environmental and Engineering Laboratory (INEEL)	1966	1986
Los Alamos National Laboratory (LANL)	1978	1999
Mound	n.a.	1978
Oak Ridge National Laboratory (ORNL)	1976	1988
Pantex	1973	1980
Rocky Flats Plant (RFP)	1969	1983
Savannah River Site (SRS)	1970	1982
Y-12	1980	1988

Classification of equivalency for other sites not listed in Table 2-1 was either not evaluated or could not be done without additional information regarding specific dosimeter design features, etc., as noted in Attachment A.

Later TLD technologies that comply with the DOELAP accreditation are considered to be equivalent to $H_p(10)$. Some doses under earlier TLD programs may require adjustments to ensure that dose is not underestimated. Any correction factor applied will need to be of sufficient magnitude to compensate for or overestimate the uncertainty contribution from the variation of site-specific administrative practices to assign and exchange dosimeters, conduct quality control, calculate and record dose for individual workers, etc., and to account for the variation of radiation fields from site to site.

A survey of dosimetry technology at selected DOE sites was done to evaluate the respective site dosimetry systems used historically to measure dose from beta and photon radiation. The results of this survey are presented in Attachment A.

2.2 Basis of Comparison

Historically, since the initiation of the MED in the early 1940s, various radiation dose concepts and quantities have been used to measure and record occupational dose. A basis of comparison for reconstruction of dose is the *Personal Dose Equivalent*, $H_p(d)$, where d identifies the depth (in mm) and represents the point of reference for dose in tissue. For weakly penetrating radiation of significance to skin dose, d = 0.07 mm and is noted as $H_p(0.07)$. For penetrating radiation of significance to "whole body" dose, d = 10 mm and is noted as $H_p(10)$. Both $H_p(0.07)$ and $H_p(10)$ are the radiation quantities recommended for use as the operational quantity to be recorded for radiological protection purposes by the International Commission on Radiological Units and Measurements (ICRU 1993). In addition, $H_p(0.07)$ and Hp(10) are the radiation quantities used in the DOE Laboratory Accreditation Program (DOELAP) used to accredit DOE personnel dosimetry systems since the 1980s (DOE 1986). The International Agency for Research on Cancer (IARC) Three Country Combined Study (Fix et al 1997a) and IARC Collaborative Study (Thierry-Chef et al 2002) selected $H_p(10)$ as the quantity to assess error in historical recorded “whole body” dose for workers in the IARC nuclear worker epidemiologic studies.

3.0 Dose Reconstruction Parameters

Examinations of the beta and photon (x-ray, gamma ray) radiation type, energy and geometry of exposure in the workplace, and the characteristics of the respective dosimeter response, respectively, are relevant to the assessment of bias and uncertainty of the original recorded dose in relation to the radiation quantity $H_p(10)$. The bias and uncertainty for the current DOE dosimetry systems is well documented for $H_p(0.07)$ and $H_p(10)$ under the DOELAP. The performance of current dosimeters can be compared with performance characteristics of historical dosimetry systems in the same, or highly similar, facilities or workplaces.

Overall, accuracy and precision of the original recorded individual worker doses and their comparability to be considered in using NIOSH (2002) guidelines depend on (Fix et al 1997b):

- **Dosimetry technology** includes the physical capabilities of the dosimetry system, such as the response to different types and energies of radiation, in particular in mixed radiation fields.

- **Calibration** of the respective monitoring systems and similarity of the methods of calibration to sources of exposure in the workplace.

- **Workplace radiation fields** at each site/facility that may include mixed types of radiation, variations in exposure geometries, environmental conditions.

- **Administrative practices** adopted by each site to calculate and record personnel dose based on technical, administrative, and statutory compliance considerations.

Each of these dependent factors must be evaluated. For cases requiring a detailed dose estimate, these evaluations must be based upon an analysis of site-specific information which is then applied to formulate the best possible dose estimate. For likely non-compensable cases, when a less-detailed, overestimating dose estimate is appropriate, a correction factor that modifies recorded deep dose to incorporate variance across these attributes may be used. Such a generic, overestimating correction/conversion factor is the goal of the present document.

3.1 Dosimetry Technology

The history of implementation of TLD-based external dosimetry programs is shown in Table 3-1 for Hanford, INEEL, ORNL and SRS.

The adequacy of the TLD dosimetry methods in the later days to accurately measure radiation dose is determined from response characteristics of the dosimetry technology according to the radiation type, energy, exposure geometry, etc., as described in later sections. The dosimeter exchange frequency at the respective sites was gradually lengthened, generally corresponding to the time period of the regulatory dose controls (GE 1954).

Table 3-1. Chronology of DOE Site Implementation of TLD-Based Personnel Dosimetry Systems

Facility	Period start	Period end	Type	DOELAP Accredited [2]
Fernald	85	92	Commercial Panasonic TLD System	1990
Hanford	72	94	Hanford TLD System	1988
	95	-	Commercial Harshaw TLD System	
Los Alamos National Laboratory (LANL)	78	98	LANL TLD System	1987
	99		Commercial Harshaw TLD System	
Mound	78-		Commercial Harshaw TLD System	
Nevada Test Site (NTS)	79	86	NTS TLD System	
	87	-	Commercial Panasonic TLD System	
Oak Ridge National Laboratory (ORNL)	75	80	ORNL TLD System	1989
	81	88	UCCND TLD System	
	89	-	Commercial Harshaw TLD System	
Pantex			Commercial Panasonic TLD System	
Rocky Flats Plant (RFP)	69	82	RFP TLD System	1991
	83		Commercial Panasonic TLD System	
Savannah River Site (SRS)	70	81	SRS TLD System	1987
	81	-	Commercial Panasonic TLD System	
Y-12	80	88	UCCND TLD System	1989
	89		Commercial Harshaw TLD System	

3.1.1 Potential Missed Dose. A consideration in the analysis of this TIB concerns the estimation of missed dose based on OCAS-IG-001 guidance (NIOSH 2002). Table 3-2 summarizes information concerning the estimated maximum potential missed dose for the respective personnel beta/photon dosimeter type, exchange frequency and Minimum Detection Level (MDL) based on selected information from Attachment A. The respective MDLs for current TLD systems are identified in the respective site external dosimetry documentation using the DOELAP laboratory testing protocol (DOE 1986).

[2] Year of first successful DOELAP performance testing listed.

Table 3-2. Maximum Annual Potential Missed Dose.

Dosimeter Type	Exchange Frequency	Laboratory MDL (rem)[3]	Max. Annual Missed Dose (rem)[4]
Site-specific TLDs	Monthly (n=12)	0.02	0.24
	Quarterly (n=4)	0.02	0.08
Commercial TLDs	Monthly (n=12)	0.01	0.12
	Quarterly (n=4)	0.01	0.04

3.1.2. Site Specific Thermoluminescent Dosimeter. The respective DOE sites proceeded to implement thermoluminescent dosimeter (TLD) capabilities. TLD systems replaced the multi-element film dosimeters at essentially all of the respective sites as noted in Attachment A. The TLD systems used at DOE sites had nearly tissue-equivalent response characteristics. This is particularly evident in comparison with earlier film dosimeter response characteristics. Figure 3-1 illustrates the energy dependence of the lithium fluoride (i.e., Harshaw) and lithium borate (i.e., Panasonic) based thermoluminescent dosimeters in comparison with $H_p(10)$. This is representative of the response characteristics for the TLD systems presented in Attachment A.

3.1.3 Commercial TLD. As noted in Attachment A, the respective DOE sites proceeded to implement commercial dosimetry systems that were generally highly comparable in performance with the site-specific TLD systems and with each other. The respective DOE site-specific and commercial TLD systems became accredited under DOELAP beginning in the latter 1980s. These systems have been routinely reaccredited during subsequent, typically two-year, accreditation cycles.

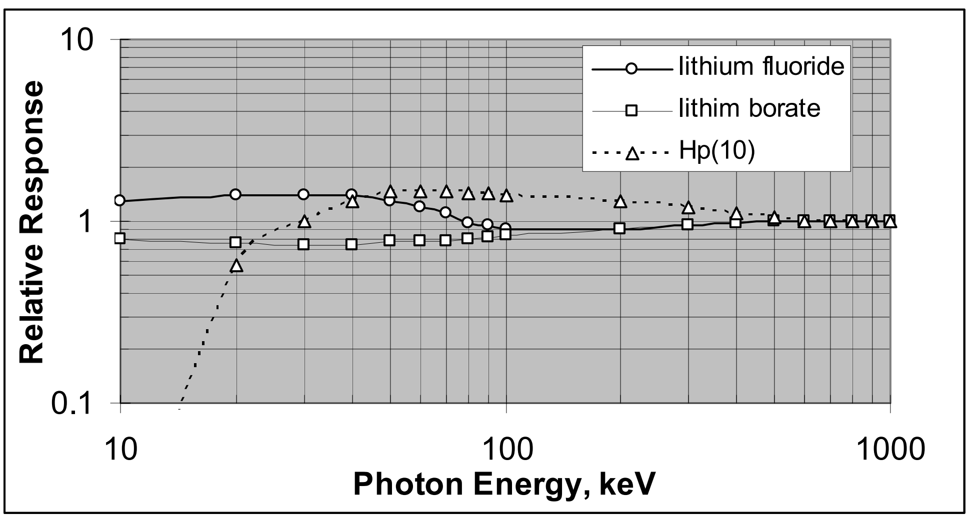

Figure 3-1. Photon Energy Dependence in comparison with $H_p(10)$ (adopted from Becker 1973).

[3] Estimated MDLs based on site practice. Dose values are often recorded at levels less-than the MDL.
[4] Maximum annual missed dose (OCAS-IG-001)

3.2 Calibration

The international adoption of the Roentgen as a measure of the radiation quantity *Exposure* in 1928 provided a means to compare national standards laboratory capabilities to measure *Exposure* from photon radiation and a means to standardize a dosimeter response to beta radiation (i.e., in reference to the response from radium or x-rays). Agreement between the standard chambers of several national laboratories to selected photon beams within ±1% was established in 1931 (Hine and Brownell 1956). MED site calibration capabilities were based on the national standards laboratories and these site capabilities were used to calibrate dosimetry systems, in the beginning, with ^{226}Ra gamma radiation. As such, the basic calibration of the respective DOE dosimetry systems to the higher energy photons represented by ^{226}Ra is likely quite good. Parker (1945) demonstrated the basic capability for the Metallurgical Laboratory, ORNL and Hanford sites to calibrate their dosimetry systems to ^{226}Ra and this is indicative of the basic capability for sites to calibrate their dosimetry systems to higher energy photon radiation.

The potential error in recorded dose is dependent not only on the higher energy photon response of the dosimetry technology but also on response characteristics to each radiation type, energy, and geometry that is represented in the workplace. The similarity between the radiation fields used for calibration and that present in the workplace is a significant issue. The potential error is much greater for dosimeters with significant variations in response such as for the film dosimeter response to low energy photon radiation. DOE sites required significant effort to assure adequate capabilities. An example of a calibration protocol is presented for Hanford as follows:

> Hanford dosimeters were originally calibrated using ^{226}Ra gamma, Uranium beta, and 80 keV x-rays (HEW 1946). The uranium calibration data was used to routinely evaluate the nonpenetrating dose from the open window response of Hanford dosimeters beginning in 1950 (Wilson 1987). Routine irradiation in-air (i.e., no phantom) of calibration film was done for each batch of film. This included ten exposure levels from 100 to 30,000 mR to ^{226}Ra gamma radiation, seven exposure levels from 100 to 5,000 mrads to Uranium beta radiation and 100 to 1,000 mR from 80 keV x-ray radiation (HEW 1946). Calibration films were processed with all personnel dosimeters. In the early 1950s, Hanford k-fluorescent x-ray capabilities were used to develop dosimeter response characteristics for the lower energy photon fields in plutonium facilities (Wilson 1987; Fix et al 1994, 1982, 1981; Wilson et al 1990) describe technical characteristics of Hanford recorded dose to the Hp(10) dose based on studies made for Hanford's participate in the DOELAP performance testing formally required in the latter 1980s (DOE 1986). Fix et al (1982) concluded that a ten percent decrease would result in routine Hanford dose results with the on-phantom calibrations for ^{137}Cs photon radiation. This effect is partially compensated by the 3% increase in the calculated dose resulting from use of the ^{137}Cs dose to exposure conversion factor (Fix et al 1982: Study 2).

3.3 Dosimeter Performance Studies

Historically, intercomparison studies of dosimeter capabilities using laboratory and workplace irradiations were often done. Several of the earlier intercomparison studies involving the Hanford dosimeters in laboratory and workplace exposures are summarized in Wilson et al (1990, Table 3-4 summarizes the results for Hanford TLDs). In addition, many sites use extensive internal control (i.e., blank or background and irradiated), calibration and audit dosimeters that were processed with the personnel dosimeters. The results of these dosimeters were routinely used to assess the acceptability of overall performance. In addition, several sites routinely evaluated PIC and dosimeter estimated dose, and where there were inconsistencies to conduct a written evaluation.

In recent years, further studies of early dosimeter performance compared to Hp(10) have been made because of its use in worker health effect studies. The International Agency for Research on Cancer (IARC) conducted a dosimeter intercomparison study to higher-energy (i.e., >100 keV) photons of ten commonly used historical dosimetry systems used throughout the world (Thierry-chef et al 2002). The IARC Study considered that exposure to dosimeters worn by workers could be characterized as anterior-posterior, rotational and isotropic irradiation geometries, or as a combination thereof. Dosimeter response to selected photon energies was measured using two phantoms. These phantoms were used to simulate the effect of the worker's body on the measured dosimeter response. The first phantom was the ISO (International Standards Organization) water-filled slab phantom, which is used for dosimeter calibration and performance testing. The second phantom was an anthropomorphic Alderson Rando Phantom. This phantom is constructed from a natural human skeleton cast inside material that has a tissue equivalent response. Table 3-3 shows results for the DOE Savannah River Site (SRS) commercial thermoluminescent dosimeter and this is expected to be representative of other DOE TLD systems. Table 3-4 summarizes results for the Hanford TLD system during 1972-83 and 1984-1994 based on information in Fix et al (1994).

Table 3-3. IARC Testing Results for US beta/photon Dosimeters.[5]

Geometry	**Phantom**	**118 keV**		**208 keV**		**662 keV**	
		Mean	SD/ Mean	Mean	SD/ Mean	Mean	SD/ Mean
US-22 (SRS Multi-Element Thermoluminescent Dosimeter)							
A-P	Slab	0.9	4.4	0.9	3.9	0.9	3.5
A-P	Anthropomorphic	0.8	3.1	0.9	2.1	0.9	3.9
Rotational	Anthropomorphic	1.1	3.1	1.2	1.5	1.0	4.1
Isotropic	Anthropomorphic	0.9	0.3	1.0	2.5	0.9	1.6

Table 3-4. Testing Results for TLD Dosimeters for Energy and Angular Response. [4,6]

Beam Energy (keV)	**1972-83**		**1984-94**	
	AP	**Rotational**	**AP**	**Rotational**
70 (M150 X-ray)	1.05 (1.3)	1.17 (1.5)	0.95 (1.3)	1.06 (1.5)
120 (H150 X-ray)	0.96 (1.2)	1.14 (1.3)	0.87 (1.2)	1.03 (1.3)
662 (^{137}Cs)	1.1 (1.2)	1.22 (1.3)	1.0 (1.2)	1.11 (1.3)

4.0 Site-Specific Information

Site-specific information is necessary to develop detailed dose estimates. This is done to evaluate the performance of the dosimetry technology in the actual workplace radiation fields and the site-specific administrative practices regarding use of the dosimeters and practices.

[5] Ratio of recorded dose to $H_p(10)$

[6] Fix et al, 1994, TLD data only presented. Bias factor shown with estimated 95% uncertainty factor in parenthesis. Summary data for M150 calculated in the same manner as presented in Fix et al for H150 and ^{137}Cs with an increased 95% uncertainty factor as shown in the Table..

This establishes a basis to calculate and record occupational dose for individual workers. For likely non-compensable cases, however, a standard correction factor may be applied that overestimates dose to account for site-specific variations. Such a complex-wide correction factor is developed in section 5.0, below.

4.1 Workplace Radiation Fields

Common beta/photon personnel dosimeter parameters important to $H_p(10)$ performance in the workplace are summarized in Table 4-1. Based on the energy response characteristics, DOE thermoluminescent dosimeters are expected to reasonably measure the $H_p(10)$ dose under workplace radiation fields for long-term workers with many dosimeter results since this tends to average the dosimeter response for extremes in workplace exposure geometries and radiation fields. Adjustments to dose measured by TLDs is not recommended with the exception that the biases presented in Table 4-1 are of sufficient concern to utilize a standard correction/conversion factor, for claimant favorable dose assignment, discussed in Section 5.

Table 4-1.
Common Workplace Photon Dosimeter $H_p(10)$ Performance[7]

Parameter	Description	Workplace Bias[8]
Exposure Geometry	Dosimeter systems commonly calibrated using anterior-posterior (A-P) laboratory irradiations.	Recorded dose of record likely **too low** since dosimeter response is often lower at angles other than A-P in comparison with Hp(10) for an A-P exposure geometry for the common practice to use A-P dosimeter calibrations. Effect is highly dependent upon radiation type and energy.
Missed Dose	Doses less than Minimum Detection Level recorded as zero dose.	Recorded dose of record likely **too low.**
Environmental Effects	Workplace heat, humidity, etc., fades dosimeter signal.	Recorded dose of record likely **too low.**

5.0 Complex-Wide Standard Overestimating Correction/Conversion Factor

5.1 Correction/Conversion Factor

A standard conversion factor is promulgated here that, with a single value, increases the assigned dose to claimants with the objective to over-estimate the actual Hp(10) dose. The use of this factor is intended to assure claimant favorable assigned dose for potential site-specific exposure conditions and calibration practices that, without correction, may have resulted in an underestimated dose. A uniform procedure for applying missed dose is proposed that is realistic and efficient for examining pertinent claims.

Site-specific attributes correction factor: The simplest possible way to approach these cases involves a single standard correction/conversion factor that overestimates the variance among sites to provide a for doses measured with TLDs. This factor will take into account, and overestimate, corrections that may be required to convert the dose as measured from site to site to a standard value of Hp(10). Some values of factors that would correct for variations in calibration and site-specific workplace conditions are listed in the table below, developed from the foregoing.

[7] Judgment based on common dosimeter response characteristics and workplace radiation fields.
[8] Recorded dose compared to Hp(10).

Table 5-1. Consolidated Results for Geometry and Calibration Method (from Tables 3-3 and 3-4)

Irradiation	Geometry/Phantom	Ratio of Reported Dose to Given Hp(10) by Photon Energy in keV[9]			
		70	118,[10] 120[11]	208	662
A-P	Slab		1.1	1.1	1.1
A-P, 72-83	Anthropomorphic	1.05	0.96		1.1
A-P, 84-94	Anthropomorphic	0.95	0.87		1.0
Rotational	Anthropomorphic		1.1	1.2	1.0
Rot, 72-83	Anthropomorphic	1.17	1.14		1.22
Rot, 84-94	Anthropomorphic	1.06	1.03		1.11
Isotropic	Anthropomorphic		0.9	1.0	0.9
Average		1.06	1.01	1.1	1.06

As can be seen, correction of each of these values would require application of factors with a value over the range of 0.87 to 1.22. The highest 95% uncertainty factors presented in Fix et al (1994) were 1.3, or for the range in reported dose for the beams greater than 100 keV examined compared to Hp(10) of 0.7 (0.87/1.3) to 1.6 (1.22 * 1.3). There is interest in lower photon energies and Fix et al show measurements for a 70 keV filtered x-ray beam. This information was used with an increased 95% uncertainty factor of 1.5 as shown in Table 3-1. This increases the range, in comparison to Hp(10) from 0.58 (0.87/1.5) to 1.83 (1.22 * 1.5).

Standard overestimating organ dose conversion factor: The second source of variation in the organ dose assigned based on the recorded deep dose value for TLDs is the individual organ dose conversion factor. The values of the maximum photon $H_p(10)$-to-organ dose conversion factor (DCF_{max}), listed in the External Dose Reconstruction Implementation Guide (NIOSH 2002)), were evaluated across the three energy ranges for all organs excluding the eye, skin, testes, breast, and bone surface. The value of the maximum DCF varies from a low of 0.154 to a maximum of 1.066 (for photons of energies > 250 keV to the thyroid). A value of 1.100, rounded for simplicity, captures the few values greater than unity while overestimating the organ dose relative to the majority of the listed DCFs.

Standard Overestimating Correction/Conversion Factor: multiplying the two proposed factors above results in a standard combined correction and conversion factor of 2.01 for the 95% uncertainty, or to account for greater than 95% uncertainty and simplicity, a factor of 2.00. This single value can be applied to all deep doses reported by DOE sites to arrive at a claimant-favorable estimate of the dose to any organ excluding the eye, skin and bone surface. Additional doses from reported shallow dose would need to be evaluated separately, as applicable, depending on the organ of interest.

[9] Values have been modified from response ratios (in parentheses) to multiplicative correction factors.
[10] IARC, (Thierry-Chef, 2002)
[11] Wilson, et al., 1990

Standard value for missed dose: The consistency of inter-site comparison of levels of detection suggests a standard value for missed dose of 0.020 rem per dosimeter reading (see Section 3.1.1) It should be noted that this factor is based on laboratory testing, and it is not known how this may be reflected in MDLs for dosimeters in use in the field. To ensure a claimant-favorable approach, the assumed value for missed dose is increased to 0.030 rem in the absence of site-specific information. This value is twice the value for missed dose for the site-specific TLDs in use at the Savannah River Site, and six times the missed dose for the DOELAP-approved TLDs; the value is 50% greater than the missed dose for Hanford site-specific TLDs, and three times the value for missed dose with Hanford DOELAP-approved TLDs. The claimant-favorability in this overestimate is intended to offset the uncertainty in missed dose for early TLDs, as discussed in section 3.1.1, above, when the DOELAP testing protocol was not in place. It should be noted that personnel dosimeter performance testing was conducted for many years prior to DOELAP (Roberson et al 1983, Unruh et al 1967 and Gorson et al 1965) and was the subject of an AEC notice in 1963 (AEC 1963). Additional claimant-favorability may be applied at the discretion of the dose reconstructor by: 1) applying the missed dose to all badge cycles in addition to the recorded value, and 2) not applying the 'LOD/2' approach to missed dose described in the OCAS-IG-001 (NIOSH 2002).

Standard assumption for dosimeter exchange frequency: The transition of the badge exchange frequency to a monthly exchange frequency of most sites is known (see Attachment A). As can be seen, most sites transitioned to a standard monthly exchange frequency during the period of using TLDs. Thus, for the period of applicability of the assumptions in this TIB, badge exchange frequencies are assumed to be monthly although the actual exchange period should be considered in Attachment A, the site profile or the site-specific Technical Basis Document. For dose estimates prepared using these assumptions, claimant-favorability is gained by neglecting quarterly exchange frequencies.

5.2 Application of the Standard Assumptions proposed in the TIB.

Standard values for the correction factors proposed above are summarized in table 5-2 below. These values are applied based upon the period of applicability for the site in question from the date of first use of TLDs through the DOELAP-accredited periods, when Hp(10) equivalency is expected. The dates reproduced in Table 5-3 reflect the dates after which the assumptions in this TIB may be applied. The entries for INEEL and Rocky Flats are post the date of TLD first use. This is due to the potential unreliability of correction factors prior to 1970. As indicated in Attachment A, most sites implemented TLD in the 1970s. The response characteristics of early TLDs (prior to 1970) requires further evaluation and is therefore excluded.

Table 5-2. Standard Overestimating Correction/Conversion (C/C) Factor And Standard Missed Dose for TLDs.

Period of Applicability (by site)	Missed Dose Per Cycle (rem)	Assumed Exchange Frequency	Standard Overestimating C/C Factor
From Table 5-3	0.03	Monthly	2

Table 5-3. Periods of Applicability for These Assumptions, by Site

Site	Apply Assumptions From Listed Year (Year of First Use of TLDs)
Fernald	1985
Hanford	1972
INEEL	1970
LANL	1978
Mound	1978
Nevada Test Site	1979
ORNL	1975
Pantex	1973
RFP	1971
SRS	1970
Y-12	1980

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Attachment A

MED/AEC/DOE Site Beta/Photon Dosimeter Characteristics

Years	Dosimeter	Filters	MDL (mSv)	Routine Exchange
Fernald				
52-	Two-Element Film Dosimeter	OW, Ag 1mm	0.4	Weekly
Late 53 or early 54	ORNL Two Element Film Dosimeter			Biweekly
59-85				Monthly
85 - 92	Commercial Panasonic TLD			Monthly
				Quarterly
Hanford				
44	Pocket ionization chamber		0.05	Daily
44 - 54	Two Element Film Badge	OW,Ag 1mm	0.4	Weekly
55 - 56	Two-Element Film Badge	"	0.4	Biweekly
57 - 62	Multi-Film Badge	OW,Al, Ag	0.4	Biweekly
62 - 63	Multi-Element Film Badge	OW,Fe, Ta	0.4	Monthly
63 - 72	Multi-Element Film Badge	"	0.2	Monthly
72 - 77	Hanford 5-chip TLD	Al. Cd, Sn, plastic	0.2	Monthly
78 - 83	Hanford 4-chip TLD	Al. Cd, Sn, plastic	0.2	Monthly
84 - 94	Hanford 5-chip TLD (1989 - DOELAP Accredited)	Al. Cd, Sn, plastic	0.2	Monthly
95 - ongoing	Commercial Harshaw TLD	Teflon Hemispherical Button, Cu, Plastic, OW	0.1	Quarterly
Idaho National Environmental and Engineering Laboratory (INEEL)				
51 - 58	Film Badge	OW,Cd 1 mm	0.5	
59 - 68	Film Badge	OW,multiple filters	0.3	
69 -	INEEL TLD	Multiple filters	0.15	
66-85	Two Chips	OW,Al (203 mg/cm^2), Cd (950 mg/cm^2)		
86	Panasonic 814/808	Al/plastic		
Los Alamos National Laboratory (LANL)				
43 - 44	Pocket ionization chambers			Daily
44 - 48	Brass film Badge	No windows or filters		Monthly
49 - 50	Brass “clip” Badge	Only partial shielding of film		Monthly
50 - 51	Multiple Element film badge	Brass and lead filters, open		Monthly
51 - 62	Multiple Element film badge	Brass and Cd filters, open (unfiltered acetate for a period)		Monthly
62 - 78	“Cycolac” plastic film badge	Multi-element filtered		Monthly
78 - 98	LANL TLD badge (1987 DOELAP Accredited)	Two versions, with and without Cd filters	0.1	Monthly

Years	Dosimeter	Filters	MDL (mSv)	Routine Exchange
99-ongoing	Commercial Harshaw TLD	Teflon Hemispherical Button, Cu, Plastic, OW		
Mound				
47-?	Two Element Film Badge	OW,1 mm metalic filter	0.5	
?-80	Multiple Element Film Badge	multiple filters	0.3	
1978-	Harshaw 8810 TLD	multiple filters	0.1	
Nevada Test Site (NTS)				
51-3/57	Varied film			
4/57	Current film		0.3	Monthly
61 - 66	DuPont 301-4	28 mil Pb		
66 - 71	DuPont 556 film NTA for neutrons			
3/71	Kodak Type III for gamma			
79 - 86	TLD Albedo			
1/87-ongoing	Commercial Panasonic TLD			
Oak Ridge National Laboratory (ORNL)				
43-44	Pocket ionization chamber		0.02	Daily
7/44 - 1/51	Two Element Film Badge	OW, 1 mm Cd	0.3	Weekly
1/51 - 1/53				weekly if >10% of RPG; all others annual
1/53 - 56	Multi-Element Film	Cu, Cd, Pl, OW		weekly if >10% of RPG; all others annual
1/56-1/61				quarterly if >10% of RPG; all others annually
1/61-1/75			0.2	
1/75-1/80	ORNL 2 Chip TLD	Al, Pl,OW, Cd	0.1	
1/81-1/88	UCCND 2 chip TLD			
1/89 - ongoing	Commercial Harshaw TLD	Teflon Hemispherical Button, Cu, Plastic, OW		
Pantex				
1/52-10/63	Tracerlab film badges			
11/63-2/76	Landauer film badges			
1973	Pantex TLD			
1980	Commercial Panasonic TLD			
Rocky Flats Plant (RFP)				
51 - 62	Stainless Steel OR design Film	OW, Cd (~0, 1 mm), brass (10 mills)	40 mR	Weekly, semimonthly, monthly
63 - 68	Multielement Film	OW, Cd (~0, 1 mm, Cu)	40 mR	Semimonthly, monthly, quarterly
69 - 70	TLD 700	OW, brass (~0, 10 mills)	20 mR	Semimonthly, monthly, quarterly
71 - 82	TLD 700	OW, brass(~0, 10 mills)	20 mR	Semimonthly,

Years	Dosimeter	Filters	MDL (mSv)	Routine Exchange
				monthly, quarterly
83 - 90	Panasonic 802	OW, (36 mg/cm^2), plastic (390-490 mg/cm^2), Pb (1160 mg/cm^2)	20 mrem	Semimonthly, monthly, quarterly
91 - ongoing	Panasonic 802		10 mrem	Semimonthly, monthly, quarterly
Savannah River Site (SRS)				
51 -	ORNL Two Element Film Badge	OW,Cd 1mm	0.4	
- 59	SRS Two Element Film Badge	OW,Cd 1mm	0.4	
59 - 70	Multiple Element Film Badge	OW,Al, Ag	0.3	
70 - 81	SRS TLD	multiple filters	0.05	
81 - ongoing	Commercial Panasonic TLD			
Y-12				
48 - 49	PIC		~0.05	Weekly
48 - 57	ORNL Stainless Steel Two – Element Film Badge	OW, 1 mm Cd	0.3-0.5	Weekly
57 - 61				Monthly
61 - 80	UCC-ND Four Element Film Dosimeter	Cd, Al, Plastic, OW		Quarterly
80 - 88	UCC-ND Two-Chip TLD	Al, OW	0.1	Quarterly, annual
88 - ongoing	Commercial Harshaw Four -Chip TLD	Teflon hemispherical button, Cu, plastic, OW	0.1	Quarterly, annual

Attachment B.,

Summary of Overestimation Implicit in the Standard Overestimating Assumptions

Site-specific correction factor: The discussion above demonstrates the near tissue-equivalency of TLD dosimeters. For most workplace conditions, a value of a modification factor at or near unity would be appropriate. By correcting to the most limiting case (a ROT geometry at a low energy of 70 keV), $H_p(10)$ is overestimated by as much as approximately 80%.

Standard organ dose conversion factor: For the organs considered under this set of assumptions, dose conversion factors from the IG are somewhat less than one, with two exceptions, the testes and the thyroid. Using the assumed organ dose conversion factor of 1.100 overestimates dose received by the organ by a very small amount for these two organs, but by a larger factor for most organs.

Standard level of Missed Dose: For all cases processed in accordance with this TIB, the value for missed dose is assumed to be 0.030 rem. This value is high for all DOELAP-accredited dosimetry programs. The level of detection value for ORNL, for instance is 0.010 rem, for years 1981 to the present. Application of the standard value here results in overprediction of 200%, or an annual value of 0.360 rem in a year when *no* dose is recorded for ORNL cases.

Standard Badge exchange frequency. As early as the late 1950's, DOE sites began using less frequent dosimeter exchanges, lowering missed doses. Personnel who typically received little dose would normally be assigned quarterly or annual TLD exchange frequencies. Applying a monthly cycle overpredicts missed dose for these individuals by giving them, in the example for ORNL above, 360 mrem in missed dose, when a more accurate missed dose value based upon actual exchange frequencies is 120 or 30 mrem, respectively, for the assumed MDL.