Office of Compensation Analysis and Support **Technical Information Bulletin**	**Document Number:** **OCAS-TIB-0010** **Effective Date: 05/18/2005** **Revision No. 1**
Special External Dose Reconstruction Considerations for Glovebox Workers	
Signature on File **Approval:____________________________ Date: 5/18/05** **J.W. Neton, Health Science Administrator**	**Supersedes:** **Revision 0**

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
5/18/2005	5/18/2005	1	Updated document to provide methodology and guidance on applying correction factors to glove box workers for over and under estimation of dose.

1.0 Purpose

The purpose of this technical information bulletin (TIB) is to provide guidance on dose reconstructions for glove box workers. It can be used in overestimating or underestimating dose in accordance with the dose reconstruction flow process detailed in OCAS-PR-003, “Performing and Reporting Dose Reconstructions”. Specifically, if the initial overestimate dose results in an excess of 50% of the POC this TIB will then be used for an underestimate in the secondary dose evaluation using low end values for dose correction factors. Guidance on “best estimate” dose reconstruction will be published in a separate document. This TIB discusses the special exposure characteristics that may be encountered by energy employees who work with gloveboxes and provides special dose correction factors or modifiers that should be applied to affected energy employee’s dose. It should be noted that throughout this technical information bulletin, the term glove box is used, however, in the early years of the Atomic Energy Commission (AEC) facilities; these types of units were commonly called dry boxes as their original intent was to isolate radioactive materials. Throughout this report these terms should be considered equivalent.

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2.0 Special Exposure Considerations

There are two special considerations when conducting dose reconstructions for glovebox workers. The first is the exposure geometry and the second is photon energy considerations. The combination of these factors could result in an underestimation of the reconstructed dosimeter and missed dose to organs located in the lower torso region of the body (stomach, liver, bladder, prostate, ovaries, testes, etc…) The degree of underestimation is dependent on many factors, which include the distance between the radiological source (exposure geometry), the materials used to construct the glove box (attenuation or shielding), and the relative duration (time) that an energy employee conducted work in the glovebox. In general, very little is known about the duration of the exposure which is typically dependent upon the specific duties of the energy employee.

2.1 Exposure Geometry

Exposure geometry is a special consideration in dose reconstruction of energy employees who primarily worked in glove boxes. An underestimation of the dose could occur if the energy employee wore his/her dosimeter on the lapel and not the center area of the chest or on the waist. This underestimation could result due to the difference in relative distance between the external radiation source, the organ of interest, and the dosimeter. Only organs in the lower torso are affected, since due to glove box design these could be closer to the radiological source than the dosimeter. The dose to lung is considered to have been reasonably approximated by the dosimeter at least to within the dosimeter uncertainty and the dose to the face and head would have been slightly lower than the dose measured by the dosimeter worn on the lapel.

2.2 Photon Energy

Another special consideration is the photon energy spectrum measured by the dosimeter. Low energy photons have a relatively low penetration power and are easily attenuated by thin metal shielding. As a result, the design of the glovebox is an important consideration in accurately estimating the low energy photon dose. A review of the literature indicates that the design of gloveboxes varied widely.[1, 2] In some instances almost fully metal glove boxes were used with only a small area for viewing (Figure 1), other glove boxes had relatively large viewing areas (Figure 2-4), and others had a combination of multiple viewing areas with some opening center mass of the lower torso (Figure 5).

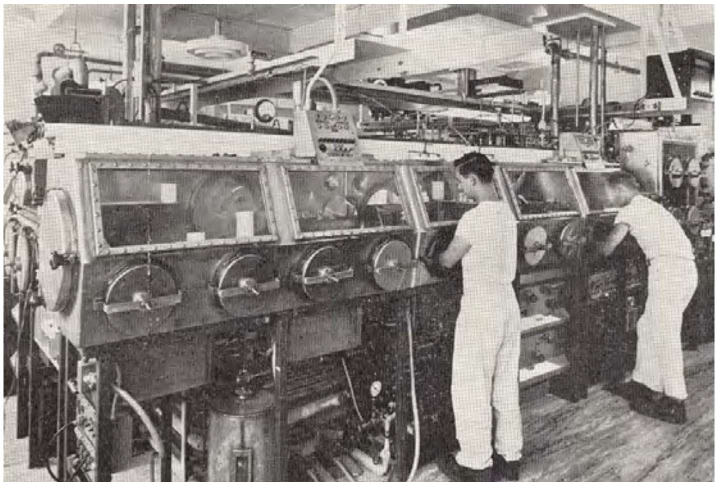

Figure 1 Plutonium gloveboxes at LANL [1]

Figure 2 Plutonium gloveboxes at Chalk River [1]

Figure 3 Plutonium gloveboxes at Hanford [2]

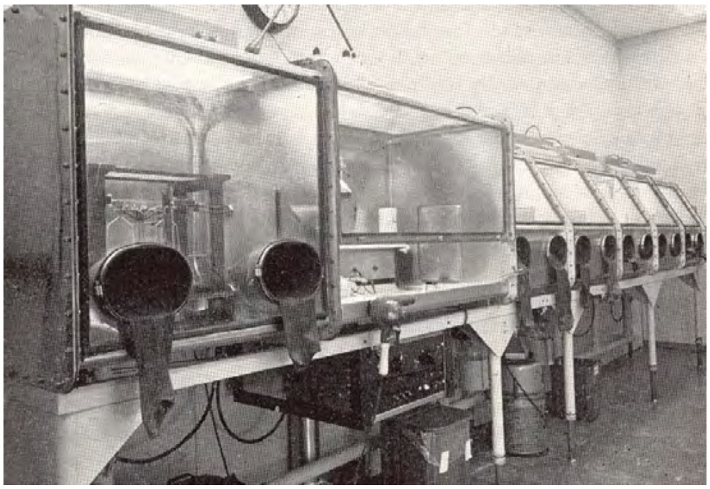

Figure 4 Plutonium gloveboxes at LANL's CMR facility [(1)]

Figure 5 Other plutonium gloveboxes at Hanford. Note the viewing area in direct line with the lower torso in the center between the gloves. [(2)]

Since the actual glovebox design is not known for each dose reconstruction scenario, a claimant favorable approach is used by assuming the glovebox had a large viewing face with relatively little difference in photon attenuation between the external source and the organ of interest and between the external source and the dosimeter. This is considered a reasonable but necessary claimant favorable assumption, since identifying the actual glovebox design at each facility (DOE site, building, room, etc.) would be time consuming. In addition, during the course of an energy employee's employment, it is likely that they conducted work in many different types of gloveboxes, thus a time dependent work location correction factor for each glovebox design would be necessary to account for such differences. The tendency of this assumption is toward an overestimate of the dose rather than an underestimate.

While the face (viewing area) of a glovebox was typically constructed using a clear polymer type material such as Lucite[3], the sides and bases of gloveboxes are almost always constructed of sturdy materials such as wood, aluminum, and most commonly steel. These materials generally shield an individual worker from side exposure to low energy photons. As a result the low energy photon dose is virtually 100% from the anterior- posterior exposure geometry duets the radiological materials in the specific glovebox where the energy employee conducted his/her work. On the other hand, the intermediate and high energy photon dose would be a combination of the direct work in the glovebox as well as surrounding gloveboxes and process lines. Due to these differences, two different exposure correction distributions were developed; one for low energy photons (< 30 keV), and one for intermediate (30-250 keV) and high (> 250 keV) energy photons.

3.0 Methodology

3.1 Low energy photons from a single glovebox

An evaluation of the degree of dose underestimation by the dosimeter was conducted using several different exposure geometry scenarios. In each scenario the radiation source was assumed to be directly in line with the specific organ of interest in the lower portion of the torso. To accurately estimate the dose underestimation, the actual height of the glovebox with relation to the energy employee's organ of interest and the distance to their lapel would be necessary (Figure 6). Using 24 inches is a reasonable but necessary claimant favorable assumption for simplicity of calculation. In general, the correction factors for smaller stature workers would be less than those indicated in this technical information bulletin as the 24 inches is based on a moderately tall worker. In some instances especially in the case of small stature workers, some of the organs could be below the bottom of the glovebox, thus low energy photons are virtually completely shielded (attenuated) and intermediate energy photons more attenuated than those measured on the dosimeter (Note the relative difference in worker stature in Figure 3).

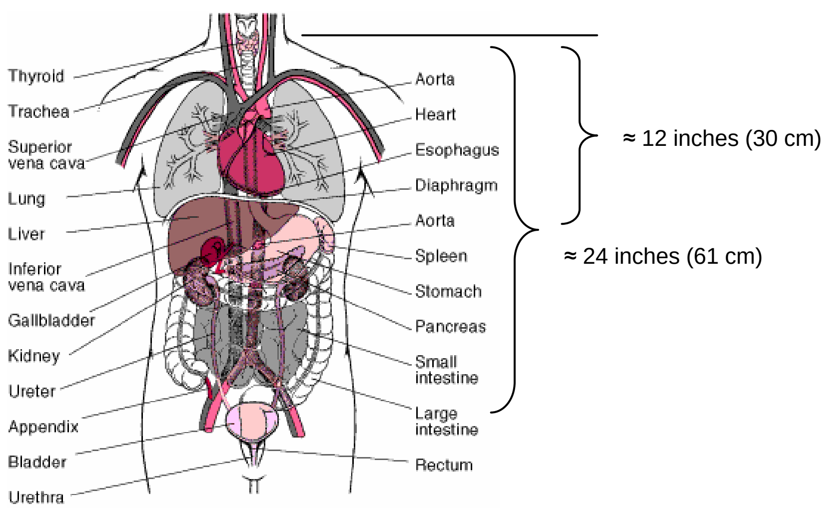

Figure 6 Diagram of Human Torso [4]

An average distance of 24 inches (61 cm) was assumed to be the distance between the lower torso and the lapel. The distance between the radiation source and the lower torso was varied from 6 inches to 18 inches. These distances were selected as the general range from which a worker could conduct most of their work in the glovebox. A source closer than 6 inches while technically possible in some glovebox designs is not very likely given the body geometry and with respect to the glovebox. In some instance (Figure 2) a nearly straight down movement would be needed position a source 6 inches from the lower torso. On the converse, 18 inches was selected as a reasonable upper distance. While some workers with longer arms might have been able to reach the back of the glovebox, in general a comfortable working distance for most workers would be between 10-14 inches between the source and the lower torso with a central tendency estimated at approximately 12 inches.

Using the inverse-square distance variation discussed above, the underestimation of the dose as measured by the dosimeter would range from a factor of 17.0 at 6 inches to 2.8 at 18 inches. Since this correction factor distribution is somewhat subjective and based on reasonable assumptions, a triangular distribution is assumed to reasonably approximate the uncertainty distribution (Figure 7). The minimum parameter of this triangular distribution is 2.8, the mode is 5.0, and the maximum is 17.0.

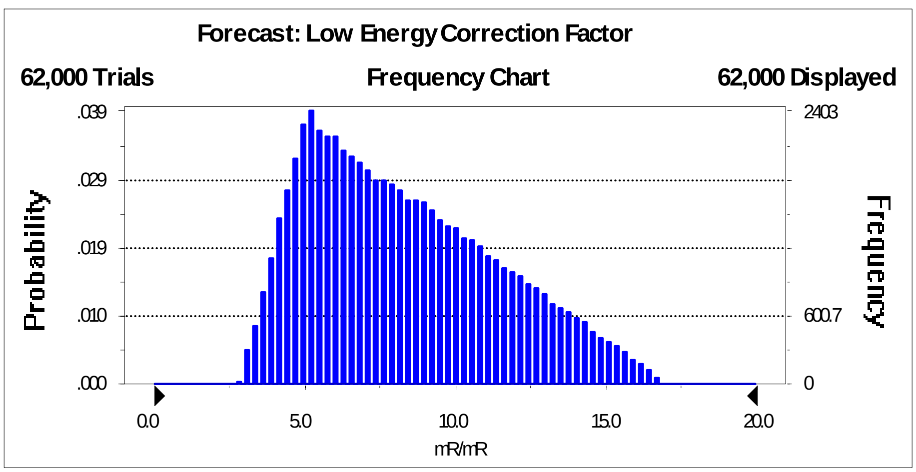

Figure 7 Triangular distribution assumptions for the low energy photon correction factor

3.2 Intermediate and high energy photons from multiple gloveboxes

The correction factor provided in Figure 7 is a reasonable estimate for low energy photons in a single glove box; however, to use this factor for intermediate and/or high energy photons could significantly overestimate the true organ dose. This overestimation would result since radiation sources at distance greater than 30 inches were not considered although clearly they would have been measured by a dosimeter located on the lapel.

At source distances greater than 48 inches, the relative difference between the dose to the lower torso and the lapel is less than 25% (factor 1.25) which is typically within the uncertainty of the dosimeter measurement. Thus the intermediate and high energy photon dose to the lower torso is approximately equal to the dose measured by the dosimeter on the lapel.

To estimate the contribution from multiple gloveboxes, a long line source at the three distances discussed in section 3.1 (6, 12, and 18 inches) was used. Microshield®[5] calculations were performed using these scenarios assuming 5 - 48 inch gloveboxes in a row. Using this methodology, the dose contribution from uniform sources lined in a glovebox varied from 57% to 76%. The central estimate assuming the 12 inch distance was 64%. This is considered a reasonable and possibly an upper bound of the dose contribution from intermediate and high energy photons, especially since this contribution neglects doses that could be received from dual glovebox lines as shown in Figure 1.

However, giving some credit to the possibility that 100% of the intermediate and high energy photon dose could be from the single glovebox, where no dose fraction modification would be appropriate, a new relative fraction distribution can be developed assuming a triangular distribution with a lower bound of 0.357, a mode of 0.64 and an upper bound of 1.0. This distribution was combined with the correction factor distribution through Monte Carlo sampling using Crystal Ball®[5] to estimate the correction factor that should be applied to the intermediate and/or high energy measured photon dose (Figure 8).

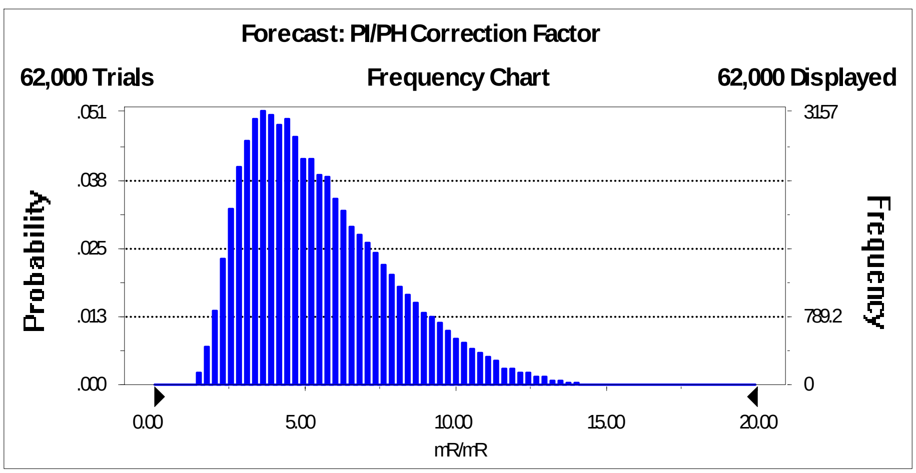

Figure 8 Intermediate and high energy photon correction factor distribution

This joint distribution is best approximated as a log normal distribution with a geometric mean of 5.0 with a geometric standard deviation of 1.55. The upper 95th% of the distribution is 10.3.

3.3 Reasonable Claimant Favorable Assumptions

Listed below are several claimant favorable assumptions used in the development of this methodology that could result in an overestimate of the actual dose.

- Claimant favorable glovebox design
- Direct line of sight to organ of interest
- Distance from lower torso to lapel based on tall workers

Obtaining data to precisely evaluate each of these parameters requires extensive time and research on an individual basis and in some instances it is known that the information cannot be obtained (i.e. facility has undergone D&D or other significant modification over time).

4.0 Applicability to Neutron Doses

The high energy photon correction factors described above may also be appropriate to measured neutron dose and potentially to some applications using neutron to photon (n-p) ratios. An evaluation of the applicability to neutron dose requires a site specific evaluation.

When a neutron to photon ratio method is used to estimate the neutron dose, it is important to know the general location of the photon and the neutron dosimeter. In the case of the Savannah River neutron to photon (n-p) ratios, the ratio was developed from joint measurement data of the TLD typically worn on the lapel and the neutron dosimeter (belly button dosimeter) worn around the waist. In this instance, the correction factor should not be applied since the measured neutron dose is a good representation of the dose to the lower torso. In later years, however, when the dosimeter combined photon and neutron TLD elements, a correction factor would need to be applied.

However at other facilities, if the NTA film dosimeter was worn on the lapel and a ratio was determined based on a photon dosimeter also worn on the lapel. Then the correction factor should be applied. The most efficient method for doing so would be to apply the correction factor to the photon dose before applying the neutron to photon ratio.

5.0 Special Dose Conversion Factor for Plutonium

In NIOSH's External Dose Reconstruction Implementation Guideline[7], organ dose conversion factors are tabulated by averaging the energy specific values from ICRP 74 (1996)[8] over the IREP photon energy range. The lowest photon energy interval in Interactive RadioEpidemiological Program (IREP) is categorized as less than 30 keV. Plutonium emits several x-rays in this energy range; however, a simple average as used in the Implementation Guideline may not result in the most accurate dose conversion factor. For Plutonium work, the average x-ray energy is approximately 17 keV. As a result, using 20 keV as a claimant favorable single point estimate is most appropriate. Since the low energy photon dose from glove box work is predominately in the anterior-posterior (AP) geometry, single point estimate values were calculated for 16 organs listed in ICRP 74[8]. When estimating the low energy photon organ dose from glovebox work, the values in Table 1 should be used.

Table 1 Special Dose Conversion Factors (DCF's) for Plutonium glovebox work. DCF's These were calculated assuming AP geometry and 20 keV mono-energetic photons.

Organ	Personal Dose Equivalent ($H_p(10)$) – Organ Dose (H_T)	Ambient Dose Equivalent ($H^*(10)$) – Organ Dose (H_T)	Exposure (R) – Organ Dose (H_T)
Bladder	0.146	0.147	0.088
Bone (Red Marrow)	0.024	0.024	0.014
Bone (Surfaces)	0.165	0.166	0.099
Breast (Female)	0.761	0.762	0.457
Colon	0.024	0.024	0.015
Esophagus	*	*	*
Eye	1.493	1.495	0.897
Ovaries	*	*	*
Testes	0.823	0.825	0.495
Liver	0.068	0.069	0.041
Lung	0.050	0.050	0.030
Remainder	0.053	0.053	0.032
Stomach	0.144	0.144	0.087
Thymus	0.264	0.264	0.158
Thyroid	0.586	0.587	0.352
Uterus	0.002	0.002	0.001

* 20 keV values not listed in ICRP 74[8] – Use < 30 keV DCF's from OCAS-IG-001[7] or an appropriate surrogate organ

6.0 Summary

This Technical Information Bulletin provides guidance for dose reconstruction to organs located in the lower torso. The correction factors for over and underestimation of dose provided in Tables 2.a and 2.b respectively are for photons emanating from gloveboxes and measured using a dosimeter worn on the lapel. The < 30 keV factors should be applied to the 17 keV dose typically measured with the open window of the dosimeter. The dose correction factors from Table 1 are then applied for plutonium exposures. The 30-250 keV factors should be applied to all intermediate and high energy photon doses recorded either as the shielded element of the dosimeter or as the deep dose.

Table 2.a Lower torso **overestimate** dose and/or exposure rate correction factors for glovebox work

Photon Energy	**Distribution**	Minimum	Mode	Maximum

< 30 keV	Triangular	2.8	5.0	17.0
		Geometric Mean	Geometric Standard Deviation (GSD)	Upper 95th%
30-250 keV > 250 keV	Lognormal	5.0	1.55	10.3

Table 2.b Lower torso **underestimate** dose and/or exposure rate correction factors for glovebox work

Photon Energy	Distribution	Minimum		
< 30 keV	Triangular	2.8		
		Minimum		
30-250 keV > 250 keV	Lognormal	2.0		

7.0 References

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3. Watson, E. C. (1959) A Film Technique for Measuring the Exposure Dose from Plutonium, *Health Physics*, Vol. 2 pp. 207.

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7. 42 CFR 82, *Methods for Radiation Dose Reconstruction Under the Energy Employee Occupational Illness Compensation Program Act of 2000*; Final Rule, Federal Register/Vol.67, No. 85/Thursday, May 2, 2002, p 22314.

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