ORAU Team **Dose Reconstruction Project for NIOSH** Technical Information Bulletin – Interpretation of Dosimetry Data For Assignment of Shallow Dose	Document Number: ORAUT-OTIB-0017 Effective Date: 01/19/2005 Revision No.: 00 Controlled Copy No.: ______ Page 1 of 14
Subject Expert: Steven E. Merwin Document Owner Approval: Signature on File Date: 01/11/2005 Edward F. Maher, Task 5 Manager Concurrence: Signature on File Date: 01/11/2005 Richard E. Toohey, Project Director Approval: Signature on File Date: 01/19/2005 James W. Neton, Associate Director for Science	Supersedes: None

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1.0 PURPOSE

The purpose of this Technical Information Bulletin (TIB) is to provide information to allow ORAU Team dose reconstructors to assign shallow doses for skin cancer cases, and for cases involving other organs affected by non-penetrating radiation including the breast and testes (to be included in a subsequent revision). Both general and site-specific information are provided.

2.0 BACKGROUND

Almost since the inception of operations at DOE sites, it has been known that non-penetrating (shallow) doses, notably from exposure to beta particles emitted by isotopes of uranium and their daughter products, needed to be evaluated. Consequently, dosimetry systems typically included more than one dose measurement including an uncovered, or open-window reading, allowing for the measurement of non-penetrating radiation doses. These open-window (OW) measurements form the basis for the assignment of skin doses under the EEOICPA Subtitle B program; they are also important for assessing doses to other organs such as the breast and testes, which are impacted by non-penetrating radiation.

There are a number of confounding factors that complicate the assignment of skin dose based solely on open-window dosimeter measurements. Examples include:

- Insufficient information is obtained by an open-window measurement to allow partitioning of dose by radiation type and energy as required by the IREP program. Even under today's standards, dosimetry systems and radiation dose limits are designed to ensure protection against adverse health effects, not the calculation of cancer risk. This is especially true for skin dose measurements. Thus, the dosimetry systems are designed such that the doses are measured accurately in order to demonstrate compliance with established dose limits. In order to partition the measured shallow dose into radiation types and energies relevant to the IREP program, additional information must be evaluated by the dose reconstructor, such as shielded (S) dosimeter readings corresponding to penetrating doses, and source term information contained in the TBDs.

- Site reporting schemes. At some sites and during certain time periods, doses were not reported as penetrating or non-penetrating. Thus, knowledge of the reporting scheme and interpretation of the data are required.

- Over-response to low-energy photons. Although early film dosimeters were relatively accurate for measuring beta doses, they are known to have over-responded significantly to low-energy photons (such as those emitted from plutonium isotopes and daughter products). Although attempts were made at some sites to correct for the over-response through calibration techniques or after-the-fact corrections, it is not always straightforward to reproduce the procedures adopted at the sites.

- Limit of detection issues. Limits of detection (LODs) for open window measurements vary significantly based on type of radiation and energy. This complicates the assignment of missed dose.

- Security credentials. At some sites security credentials were placed over the dosimeter badge, including the open window portion. This resulted in an attenuation of beta particles, especially those of lower energies. Even though the badges may have been calibrated to correct for this attenuation, low-energy beta emitters could not be detected if the credential was thick enough to filter out all or most of the particles prior to their reaching the dosimeter.

Recognizing the confounding factors described above, the approach to calculating shallow dose described in this document is intended to facilitate the completion of the great majority of compensable and non-compensable skin cancer cases without performing extensive research on individual cases, erring on the side of claimant favorability 1) when necessary due to the lack of information, or 2) intentionally in order to address multiple confounding factors in a manner that facilitates the completion of dose reconstructions in a timely manner. Cases that involve special circumstances such as unique exposure geometries, exposure to low-energy beta particles, the presence of shielding materials, etc., will require special consideration to complete the dose reconstruction in a defensible manner.

3.0 GENERAL APPROACH

Dose to the skin can be associated with penetrating radiation (i.e., radiation that impacts tissue at a depth of 1 cm or more), non-penetrating radiation, or both. Penetrating radiation includes medium and high-energy photons and neutrons of all energies, and non-penetrating radiation consists of low-energy photons (such as X-rays emitted by plutonium isotopes) and beta particles (Note: low-energy photons and high-energy beta particles are more correctly considered weakly penetrating, since a small fraction of the energy may be deposited at depths in tissue greater than 1 cm).

As mentioned in Section 2.0, evaluation of skin doses is complicated by the fact that sites sometimes did not report doses as penetrating or non-penetrating. For example, the open-window reading from a dosimeter may have been reported directly as “OW,” but this value would include the contribution from both penetrating and non-penetrating radiation. In other cases, the sites may have reported a result as “Skin Dose,” but the value reported may have included only the non-penetrating component or both the penetrating and non-penetrating components. To further complicate matters, the values reported may or may not include contributions from neutrons, which in most cases were monitored separately but were reported under different schemes. If the TBD does not provide clear information, the reporting schemes can typically be identified by evaluating the data. For example, if the reported OW values are always equal to or higher than the S values, this is an indication that the OW reading includes both penetrating and non-penetrating radiation.

General Approach Summary
The general approach to determining skin dose involves only a few basic steps. These steps may be supplemented or modified for certain sites and timeframes, e.g., when additional dosimeter elements were present that provided more information. The basic steps include:

1. Translate the reported doses into non-penetrating and penetrating doses, separating out reported neutron doses, if applicable.

2. Assign the penetrating dose as photons, with the energy partitioned as 30-250 keV and/or 250 keV according to the TBD.

3. Assign the non-penetrating dose as electrons >15 keV (corrected to account for attenuation, if applicable), or photons <30 keV if the employee worked in a plutonium facility.

4. Add missed electron and/or photon dose.

5. Include measured and/or missed neutron dose, if applicable.

6. All dose conversion factors for the skin should be assumed to be 1.

In general, non-penetrating radiation doses should be assigned as <30 keV photons if the employee worked with or around Pu, otherwise, > 15 keV electrons should be assigned. If unknown, consider the following guidance:

a. For a non-compensable case, it is acceptable to assume the non-penetrating dose is associated with <30 keV photons, as this maximizes POC.

b. For a compensable case, it is acceptable to assume the non-penetrating dose is associated with >15 keV electrons, as this minimizes POC.

c. If the compensability decision hinges on this issue, and if the partitioning of the non-penetrating dose cannot be decided based on the available information, additional research may be required.

Electron Attenuation
All measured and missed non-penetrating doses that are considered electrons should be corrected to account for attenuation by clothing or personal protection equipment (PPE), if applicable. No attenuation should be assumed if the skin cancer was diagnosed in an area not normally covered by clothing, such as the face. Information on beta attenuation factors can be found in the DOE Standard "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities," DOE-STD-1136-2000 (which is based on the DOE *Health Physics Manual of Good Practices for Uranium Facilities*, EGG-2530).

Exposure Geometry
The nature of beta particles suggests that some recorded doses may significantly overestimate or underestimate the actual dose to the skin at the cancer diagnosis location. For example, for a 100% AP exposure geometry the actual beta dose to the back would be zero, yet a dosimeter worn on the chest would record the incident dose, and thus the shallow dose reported by the site would significantly overestimate the skin dose of concern. On the other hand, if the exposure geometry were primarily PA, the dosimeter would significantly underestimate the beta dose to the back. It is recommended that if there is an indication that the recorded dose significantly underestimates the actual dose at the cancer location due to exposure geometry, attenuation, or other issues, the reported results should be adjusted upward accordingly. However, if there is an indication but no definitive evidence that the recorded dose significantly overestimates the actual dose, no correction should be made, even for a "best estimate" dose reconstruction. The exception to this rule is the over-response of film to low-energy photons (discussed below); site-specific instructions regarding this issue are provided in the attachments.

Over-response of Film to Low-Energy Photons
Film dosimetry can over-respond to 16 keV and 59 keV X rays by factors of 8.5-12 and 14-19 respectively (Wilson, 1990). Because of this over-response to low-energy photons, a nominal multiplication factor of 0.6 is prescribed in this document for non-penetrating doses assumed to be from <30 keV photons measured with film, unless information is available indicating that the dosimeters were calibrated for low-energy photon exposure or the doses reported by the site include a correction for the over-response (see additional discussion below). The factor of 0.6 is claimant-favorable in view of the available data, and is high enough to ensure that if the open-window readings were actually attributable 100% to beta particles and not low-energy photons, the calculated probability of causation (POC) would be greater under the low-energy-photon assumption. Missed doses assigned as <30 keV photons should also include this correction factor, because missed doses

are based on nominal limits of detection (LODs), which for film significantly overestimates the potential missed low-energy photon dose.

Typically, film dosimetry systems that incorporated both open-window and shielded measurements did not correct for low-energy photon over-response. However, unless it can be established that the site did not already apply a correction to the reported doses to account for film over-response (e.g., the site TBD may provide this information, or the records may provide evidence), in order to ensure claimant favorability the factor of 0.6 should not be applied by the dose reconstructor.

Uncertainty

In this document, approaches have been presented that represent claimant-favorable assumptions in recognition of the fact that all available information necessary to develop a true best estimate of the shallow dose partitioned in a manner consistent with the IREP input parameters is not reasonably possible. Thus, a dose reconstruction based on the guidance in this document is likely to be inherently claimant favorable. Consistent with this approach, even though there may be considerable uncertainties in the measured doses and in the appropriate partitioning by radiation type and energy, it is recommended that all measured doses be treated as a constant. An additional consideration is that treating acute doses as a distribution is not likely to have a significant impact on the calculated probability of causation (POC); for example, for some cancer types an acute 30-250 keV photon dose treated as a constant actually results in a slightly higher POC than if the same dose were treated as a normal distribution with a standard deviation of 30%. Missed doses should be divided by 2 and treated as a lognormal distribution consistent with OCAS-IG-001.

4.0 APPLICATIONS AND LIMITATIONS

1. This document provides information for calculating "best estimate" doses to the skin.[1] Subsequent revisions will address the breast, testes, and other organs affected by non-penetrating dose. However, doses to the skin calculated according to this TIB can be considered overestimates for the purpose of assigning claimant-favorable doses to other organs potentially impacted by non-penetrating radiation.

2. This document provides site-specific information only for the Savannah River Site (SRS), Hanford, and the Gaseous Diffusion Plants (GDPs). Subsequent revisions will provide site-specific information for other major DOE sites. However, this information may be used for other sites with similar dosimetry systems and reporting protocols, provided that adequate documentation exists to ensure that doses are not being underestimated for a non-compensable case or overestimated for a compensable case.

[1] Although claimant-favorable assumptions are embedded in the methodology out of necessity, the calculations can be considered best estimates because they cannot be further refined based on the available information in a reasonable timeframe.

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ATTACHMENT A
Skin Dose Assignment for Savannah River Site Cases

General Information

In the film badge era, the OW reading likely included a significant over-response to low-energy photons; therefore, prior to 1971, measured doses assigned as <30 keV photons should be multiplied by 0.6 if there is no indication in the records that the dosimeter was calibrated for low-energy photons.[2]

A. The penetrating component of skin dose (and the non-penetrating component of skin dose for Pu workers) must be multiplied by the appropriate era-specific correction factor (e.g., 1.119) per the TBD and OCAS-TIB-006.

B. Missed doses should be calculated based on the following LODs:

- 1951 – 1970: 50 mrem for OW, 40 mrem for S
- 1971 – 1983: 25 mrem for OW, 15 mrem for S
- 1984 – present: 20 mrem for OW, 5 mrem for S

C. For 1982 and later, these instructions supersede the information in Section 3.0 (Shallow Dose Interpretation) of OCAS-TIB-006.

Procedure

Measured Dose

1. Subtract the reported S reading from the reported OW reading. This is the calculated non-penetrating dose.

1. Assign the calculated non-penetrating dose as either electrons E>15 keV, or photons E<30 keV. In the former case, a correction factor should be provided for clothing, if applicable, depending on likely clothing thickness and beta energy; in the latter case, if applicable (see General Information above) a correction factor of 0.6 should be applied prior to 1971 to account for film over-response, and the era-specific correction factor should be applied.

2. Multiply the reported S reading (separating out the neutron dose, as applicable) by the appropriate era-specific correction factor. This is the corrected penetrating photon dose.

3. Assign the corrected penetrating photon dose as photons, partitioned by energy according to the SRS TBD or OCAS-TIB-006.

4. Assign the reported neutron dose (if applicable) partitioned by energy and correct for neutron quality according to the TBD (using an organ DCF of 1).

Missed Dose

5. For any badge cycle with a zero result in either the OW or S reading, or both, assign a single missed dose as explained in Items 6-8 below.

6. If only the OW reading was reported as zero, the missed dose assigned should be the appropriate OW LOD for that era (divided by 2, treated as lognormal) and considered electrons (corrected for

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[2] As discussed in OCAS-OTIB-0006, a 17-keV calibration curve in the DOE records is evidence of calibration for low-energy photons based on the employee's work with Pu.

attenuation, if applicable) or low-energy photons (multiplied by 0.6 in the film badge era, if applicable) consistent with the approach taken in Step 2.

7. If only the S reading was reported as zero, the missed dose assigned should be the appropriate S LOD for that era (divided by 2, treated as lognormal) and considered 30-250 keV photons.

8. If both the OW and S readings were reported as zero, the missed dose assigned should be the appropriate OW LOD for that era (divided by 2, treated as lognormal) and considered 30-250 keV photons.

9. During the film-badge era, if there was a potential exposure to neutrons, assign unmonitored neutron dose based on neutron-gamma ratios per the TBD (using an organ DCF of 1).

10. During the TLD era, for a person potentially exposed to neutrons, if a zero neutron result were recorded, assign missed dose per the TBD (using an organ DCF of 1).

Examples of skin dose assignments for SRS badge readings in 1970 (assuming no clothing correction and no calibration curve in record for low-energy photons) (mrem).

OW reading	S reading	Measured dose assigned	Missed dose assigned
50	0	50 (electrons) or 50 X 0.6 X 1.119 = 33.57 (low-energy photons)	40/2 = 20 (30-250 keV photons)
0	0	None	50/2 = 25 (30-250 keV photons)
100	60	40 (electrons) or 40 X 0.6 X 1.119 = 26.856 (low-energy photons) AND 60 X 1.119 = 67.14 (photon energy per TBD or OCAS-TIB-006)	None
100	100	100 X 1.119 = 119.00 (photon energy per TBD or OCAS-TIB-006)	None
0	40	40 X 1.119 = 44.76 (photon energy per TBD or OCAS-TIB-006)	50/2 = 25 (electrons) or 50/2 X 0.6 = 15 (low-energy photons)

ATTACHMENT B
Skin Dose Assignment for Hanford Cases

General Information

A. In the film badge era, the OW reading likely included a significant over-response to low-energy photons; however, starting in April 1957, an additional dosimeter element was included in the badge design to facilitate an accurate measurement of X-ray dose. Therefore, prior to April 1957, measured doses assigned as <30 keV photons should be multiplied by 0.6 (only if, as described in Section 3.0, evidence exists indicating that the recorded doses were not adjusted downward by the site to account for the over-response).

B. Missed doses should be calculated based on the following LODs:

- 1944 – 1971: 50 mrem for non-penetrating (OW), 40 mrem for penetrating (S)
- 1972 – 1994: 30 mrem for non-penetrating, 20 mrem for penetrating
- 1995 – present: 50 mrem for non-penetrating, 10 mrem for penetrating

C. Hanford used a variety of dosimetry types and reporting schemes during its history. The dose reconstructor must ensure that the non-penetrating and penetrating doses have been adequately interpreted from the data reported. For example, when beta and gamma doses are reported by the site, these typically represent the non-penetrating and penetrating doses, respectively, and collectively represent the total skin dose. However, when the data are reported as open-window and shielded, the open-window measurement represents the total skin dose and the shielded measurement represents only the penetrating component.

D. Hanford used a variety of measurement techniques and reporting schemes for neutron dose. These doses may or may not have been included in the reported skin (or shallow) or whole-body (or deep) doses. As is the case for reconstructing doses for organs not impacted by non-penetrating radiation, the calculation of dose to the skin requires that any neutron doses have been separated from the reported dose quantities and treated separately in IREP.

E. As described in the Hanford Occupational Environmental Dose TBD, workers from the mid 1940s to the mid 1950s may have been exposed to radioactive particles emitted from facility stacks.

Procedure

Measured Dose

1944-March 1957

1. Determine the non-penetrating dose by subtracting the reported S reading from the reported OW reading.

2. Assign the non-penetrating dose as either electrons >15 keV (corrected for attenuation, if applicable), or photons <30 keV if the employee worked primarily with or near plutonium, such as in PFP. In the latter case, a correction factor of 0.6 should be applied to account for film over-response, if a correction by the site is not evident in the records as described above and in Section 3.0.

3. Assign the penetrating photon dose as photons, partitioned by energy according to the Hanford TBD.

4. Assign the reported neutron dose (if applicable) partitioned by energy and corrected for neutron quality according to the TBD (using an organ DCF of 1).

April 1957-1971

5. Assign the non-penetrating dose as the reported beta dose (assigned as >15 keV electrons, which should be corrected for attenuation, if applicable) and 65% of the reported X-ray dose (assigned as <30 keV photons).

6. Assign the penetrating dose as the reported gamma dose (assigned as photons, partitioned by energy according to the Hanford TBD) and 35% of the reported X-ray dose (assigned as 30-250 keV photons).

7. Assign the reported neutron dose (if applicable) partitioned by energy and corrected for neutron quality according to the TBD (using an organ DCF of 1).

1972-1994

8. Determine the non-penetrating dose by subtracting the reported penetrating reading (typically reported as deep or whole body) from the reported non-penetrating reading (typically reported as shallow or skin).

9. Assign the non-penetrating dose as either electrons >15 keV (corrected for attenuation, if applicable), or photons <30 keV if the employee worked primarily with or near plutonium, such as in PFP.

10. Assign the penetrating photon dose as photons, partitioned by energy according to the Hanford TBD.

11. Assign the reported neutron dose (if applicable) partitioned by energy and corrected for neutron quality according to the TBD (using an organ DCF of 1).

1995-Present

12. Determine the non-penetrating dose by subtracting the reported deep photon reading from the reported shallow reading.

13. Assign the non-penetrating dose as either electrons >15 keV (corrected for attenuation, if applicable), or photons <30 keV if the employee worked primarily with or near plutonium, such as in PFP.

14. Assign the penetrating photon dose as photons, partitioned by energy according to the Hanford TBD.

15. Assign the reported neutron dose (if applicable) partitioned by energy and corrected for neutron quality according to the TBD (using an organ DCF of 1).

Missed Dose

16. For any badge cycle with a zero result in any of the element readings, assign a single missed dose.

17. If only the OW (or beta, or non-penetrating) reading was reported as zero, the missed dose assigned should be the appropriate non-penetrating LOD for that era (divided by 2, treated as lognormal) and considered electrons (corrected for attenuation, if applicable) or low-energy photons (multiplied by 0.6 prior to 1957). For the period 1957-1971, when X-ray doses were reported separately, a non-zero value reported for X-rays indicates that the missed dose should

be considered electrons, and a zero value reported for X-rays indicates that the missed dose should be considered 30-250 keV photons.

18. If only the S (or gamma, or penetrating) reading was reported as zero, the missed dose assigned should be the appropriate penetrating LOD for that era (divided by 2, treated as lognormal) and considered 30-250 keV photons.

19. If both the OW and S readings were reported as zero, the missed dose assigned should be the appropriate non-penetrating LOD for that era (divided by 2, treated as lognormal) and considered 30-250 keV photons.

20. During the film-badge era, for a person potentially exposed to neutrons, assign unmonitored neutron dose based on neutron-gamma ratios per the TBD (using an organ DCF of 1).

21. During the TLD era, for a person potentially exposed to neutrons, if a zero neutron result was recorded, assign missed dose per the TBD (using an organ DCF of 1).

Examples of skin dose assignments for Hanford badge readings in 1980 (assuming no clothing correction) (mrem).

Shallow reading	Deep reading	Measured dose assigned	Missed dose assigned
50	0	50 (electrons or low-energy photons)	20/2 = 10 (30-250 keV photons)
0	0	None	30/2 =15 (30-250 keV photons)
100	60	40 (electrons or low-energy photons) AND 60 (photon energy per TBD)	None
100	100	100 (photon energy per TBD)	None
0	40	40 (photon energy per TBD)	30/2 = 15 (electrons or low-energy photons)

Examples of skin dose assignments for Hanford badge readings in 1970 (assuming no clothing correction) (mrem).

Beta reading	X-ray reading	Gamma reading	Measured dose assigned	Missed dose assigned
50	0	0	50 (electrons)	40/2 = 20 (30-250 keV photons)
0	0	0	None	50/2 =25 (30-250 keV photons)
100	20	60	100 (electrons) AND 20 X 0.65 = 13 (<30 keV photons) AND 20 X 0.35 = 7 (30-250 keV photons AND 60 (photon energy per TBD)	None
100	0	100	100 (electrons) AND 100 (photon energy per TBD)	50/2 = 25 (30-250 keV photons)

ATTACHMENT C
Skin Dose Assignment for Gaseous Diffusion Plant Cases

General Information

A. In general, the contribution to skin dose at DOE gaseous diffusion plants (GDPs) from low-energy photons is extremely small compared to the contribution from beta particles.

B. Missed doses should be calculated based on the following LODs:

Paducah

- 1953 – 1980: 50 mrem for OW, 40 mrem for S
- 1981 – 1988: 30 mrem for OW, 20 mrem for S
- 1989 – present: 20 mrem for OW, 20 mrem for S

Note: The Paducah TBD states an OW LOD of 120 mrem for 1953-1980. However, this value appears to be speculative when compared against the LOD values for similar dosimetry systems at other sites at that time (see attachments A and B and the information for Portsmouth and K-25 below). As stated in the TBD, "In 1953, PDGP began using dosimeter and processing technical support from Oak Ridge National Laboratory…practices were similar to those used at ORNL and other major sites…ORNL has provided PGDP with dosimeters from early in the operations period through the present." Based on the information provided, it appears that the LOD value reported in the TBD is based on considerations involving low-energy beta emitters; however, this would significantly overestimate the LOD (and missed dose) when the principal source of exposure is uranium, since the dosimeters were calibrated using uranium slabs. Therefore, the value has been reduced in this TIB to 10 mrem above the reported photon LOD. The dose reconstructor should consult the TBD to address potential exposures to Tc-99.

Portsmouth

- 1954 – 1980: 30 mrem for OW, 30 mrem for S
- 1981 – 1982: Not Applicable for OW, 15 mrem for S
- 1983 – 1998: 40 mrem for OW, 10 mrem for S
- 1999 – present: 30 mrem for OW, 10 mrem for S

Note: For 1981 and 1982 there was no open window dosimeter measurement, so non-penetrating doses were not measured directly. Therefore, for this period the dose reconstructor must use judgment based on 1) extrapolation from prior and later years (if the employee's job and exposure conditions was consistent throughout the period), 2) application of shallow to deep dose ratios, or 3) co-worker studies. Additional research may be required to determine an appropriate method for the case.

K-25

- 1945 – 1987: 30 mrem for OW, 30 mrem for S
- 1988 – present: 5 mrem for OW, 5 mrem for S

Note: K-25 does not distinguish between open-window and shielded dosimeter measurements when reporting MDLs. It is implied that the MDLs should be considered the same.

C. To account for a potential exposure to Tc-99, which would not have been measured accurately by the dosimeters used at the sites, missed Tc-99 dose should be added as prescribed in the site TBD for some workers.

Procedure

Measured Dose

1. Subtract the reported S reading from the reported OW reading. This is the calculated non-penetrating dose.

2. Assign the calculated non-penetrating dose as electrons >15 keV. A correction factor should be provided for clothing, if applicable, depending on likely clothing thickness and beta energy.

3. Assign the reported S dose as photons, partitioned by energy according to the site-specific TBD.

4. Assign the reported neutron dose (if applicable) partitioned by energy and correct for neutron quality according to the TBD (using an organ DCF of 1).

Missed Dose

5. For any badge cycle with a zero result in either the OW or S reading, or both, assign a single missed dose.

6. If only the OW reading was reported as zero, the missed dose assigned should be the appropriate OW LOD for that era (divided by 2, treated as lognormal) and considered electrons (corrected for attenuation, if applicable).

7. If only the S reading was reported as zero, the missed dose assigned should be the appropriate S LOD for that era (divided by 2, treated as lognormal) and considered 30-250 keV photons.

8. If both the OW and S readings were reported as zero, the missed dose assigned should be the appropriate OW LOD for that era (divided by 2, treated as lognormal) and considered 30-250 keV photons.

9. Assign missed or unmonitored neutron dose per the TBD.

10. If applicable, assign unmonitored Tc-99 dose (as >15 keV electrons) per the TBD.

Examples of skin dose assignments for GDP badge readings in 1970 (assuming Paducah LODs, no clothing correction and no Tc-99 exposure) (mrem).

OW reading	S reading	Measured dose assigned	Missed dose assigned
50	0	50 (electrons)	40/2 = 20 (30-250 keV photons)
0	0	None	50/2 =25 (30-250 keV photons)
100	60	40 (electrons) AND 60 (photon energy per TBD)	None
100	100	100 (photon energy per TBD)	None
0	40	40 photon energy per TBD)	50/2 = 25 (electrons)