



**ORAU TEAM
Dose Reconstruction
Project for NIOSH**

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PUBLICATION RECORD

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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 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 facility” as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 (42 U.S.C. § 7384l(5) and (12)).

The purpose of this Technical Information Bulletin (TIB) is to provide information to allow ORAU Team dose reconstructors to assign doses to Paducah Gaseous Diffusion Plant (PGDP) workers who have no or limited monitoring data, based on site coworker data. The data in this TIB are to be used in conjunction with ORAUT-OTIB-0020, “Use of Coworker Dosimetry Data for External Dose Assignment.”¹

2.0 BACKGROUND

The ORAU Team is conducting a series of coworker data studies to permit dose reconstructors to complete certain cases for which external and/or internal monitoring data are unavailable or incomplete. Cases not having complete monitoring data may fall into one of several categories, including:

- The worker was unmonitored and, even by today’s standards, did not need to be monitored (e.g., a non-radiological worker).
- The worker was unmonitored, but by today’s standards would have been monitored.
- The worker may have been monitored but the data are not available to the dose reconstructor.
- Partial information is available but it is insufficient to facilitate a dose reconstruction.

As described in ORAUT-OTIB-0020,¹ some cases not having complete monitoring data can be processed based on assumptions and methodologies that do not involve coworker data. For example, many cases falling in the first category above can be processed by assigning ambient external and internal doses based on information in the relevant site Technical Basis Documents (TBDs).

As described in the PGDP External Dosimetry TBD,² operations at the site began in 1952, and in 1953 the site began using dosimeter and processing technical support provided by the Oak Ridge National Laboratory (ORNL). Until July 1960, dosimeters were issued to a limited number of individuals, i.e., those with the highest potential for exposure, and the badges were exchanged weekly. After that time, dosimeters were assigned to all workers who entered a controlled area, and the badges were exchanged and processed on a monthly or quarterly schedule. There does not appear to be any significant administrative practice that would jeopardize the integrity of the recorded dose of record.

3.0 GENERAL APPROACH

As described in ORAUT-OTIB-0020,¹ the general approach to developing coworker data for cases without external monitoring data involves two phases. The first (Phase I) permits cases to be processed when a “best and final” estimate of dose is not required for claim determination. The second (Phase II) facilitates the assignment of “best and final estimates” of dose, when necessary. This initial revision of this TIB provides coworker external dosimetry summary statistics applicable to Phase I dose reconstructions; coworker dose distributions applicable to Phase II dose reconstructions will be made available in a subsequent revision.

4.0 APPLICATIONS AND LIMITATIONS

1. Some PGDP workers may have worked at one or more other major sites within the DOE complex during their employment history. Thus, the data presented herein must be used with caution to ensure that for clearly non-compensable cases, unmonitored external doses from multiple site employment have been overestimated. This will typically require the availability of External Coworker Dosimetry Data TIBs for all relevant sites.
2. Summary statistics based on PGDP dosimetry data presented in this TIB do not extend beyond 1995 because at the time this TIB was drafted, data beyond 1997 were not available, and the data for 1996 and 1997 included too few data points to be considered reliable. However, the absence of these data (and the subsequent development of dose distributions) should not interfere with the processing of most PGDP cases having a lack of external dosimetry data since well before 1995 the monitoring and reporting practices at the site ensured that essentially all workers with a potential for external radiation exposure were monitored and the results are readily accessible. Should the need arise and sufficient data become available, coworker dosimetry data beyond the year 1995 will be presented in a subsequent revision to this TIB.
3. The data presented in this TIB address penetrating radiation from gamma radiation and non-penetrating radiation from beta radiation. Neutron data are not presented. However, the potential for neutron exposures at the PGDP is limited to certain site areas and facilities, and the associated doses were low.² Therefore, the TBD should be used as the basis for assigning neutron doses, when relevant, in addition to the photon and/or beta doses assigned in accordance with this TIB.
4. External on-site ambient doses should not be included in addition to the coworker doses assigned in accordance with this TIB, because any such doses would have been included in the dosimetry results reported by the site which were used as the basis for the coworker dose distributions presented below.^{2,4}

5.0 REFERENCES

1. ORAU Team, ORAUT-OTIB-0020, Use of Coworker Dosimetry Data for External Dose Assignment, Rev 00, December 29, 2004.
2. ORAU Team, ORAUT-TKBS-0019-6, Paducah Gaseous Diffusion Plant – Occupational External Dose, Rev 01, March 29, 2005.
3. NIOSH (National Institute for Occupational Safety and Health), External Dose Reconstruction Implementation Guideline, Rev. 0, OCAS-IG-001, Office of Compensation Analysis and Support, Cincinnati, Ohio, 2002.

4. ORAU Team, ORAUT-PROC-0060, External On-Site Ambient Dose Reconstruction for DOE Sites, Rev 00, March 7, 2005.
5. ORAU Team, ORAUT-OTIB-0017, Interpretation of Dosimetry Data for Assignment of Shallow Dose, Rev 00, January 19, 2005.

6.0 PGDP COWORKER DATA DEVELOPMENT

Dosimetry data for monitored PGDP workers from various sources were evaluated (see Attachment A). The data selected for development of coworker doses were 1) a "history tape" containing annual data between 1953 and 1975 and quarterly data between 1976 and 1988, and 2) a database titled "OHIS_External" containing mostly quarterly data between 1989 and 1997 (although the data for 1996 and 1997 were excluded from consideration, as discussed previously). In all cases, the reported data corresponded to deep doses (i.e., penetrating gamma radiation) and shallow doses (i.e., penetrating plus non-penetrating radiation).

The annual data reported between 1953 and 1975 were prorated to account for partial years of employment based on an analysis of the length of monitored employment associated with the data (see Section 7.0 for further discussion). The reported quarterly data between 1976 and 1988 were also prorated, but using a different approach (also described further in Section 7.0). The data between 1989 and 1995 included specific monitoring start and end dates, so the data were prorated based on 365 days/year. The data were prorated so that coworker doses representing a full year of monitored employment could be derived; this permits the dose reconstructor to assign appropriate doses based on specific employment dates and job descriptions.

The validity of the data selected for coworker dose development was confirmed by selecting a sampling of claimant dosimetry data submitted by the site as part of the EEOICPA Subtitle B program and comparing it to the data selected as described above. A review of annual data for ten claimants covering over 150 worker-years of monitored employment at PGDP indicated excellent agreement between the two data sets. Specifically, a perfect match was found for more than 95% of the reported values. It is concluded that the data cited above are acceptable for the development of coworker doses for the PGDP.

Adjustment for Missed Dose

According to the External Dose Reconstruction Implementation Guideline,³ missed doses are to be assigned for null dosimeter readings to account for the possibility that doses were received but not recorded by the dosimeter or reported by the site. Annual missed doses are calculated by multiplying the number of null badge readings by the reported dosimeter limit of detection (LOD) and summing the results. These values are used as the 95th percentile of a lognormal distribution for the purpose of calculating probability of causation which is determined by the Department of Labor (DOL); thus, in IREP the calculated missed doses are multiplied by 0.5 and entered in Parameter 1, and a value of 1.52 is entered in Parameter 2, to represent the geometric mean and geometric standard deviation, respectively.

The assignment of missed doses for monitored workers is particularly significant for PGDP claimants prior to August 1960 when workers were monitored weekly. Table 1 lists the maximum annual missed dose by era and type of radiation (penetrating gamma and non-penetrating) based on information presented in the site TBD² and ORAUT-OTIB-0017.⁵

Table 1. Missed external doses based on PGDP Occupational External Dosimetry TBD² and ORAUT-OTIB-0017.⁵

Period	Penetrating LOD (rem)	Non-penetrating LOD (rem) ^a	Exchange frequency	Maximum annual missed dose (rem)	
				Penetrating	Non-penetrating
1953–1959	0.04	0.05	Weekly	2.080	2.600
1960	0.04	0.05	Varied ^b	1.280	1.600
1961–1980	0.04	0.05	Varied ^c	0.160	0.200
1981–1988	0.02	0.03	Varied ^d	0.080	0.120
1989–Present	0.02	0.02	Quarterly	0.080	0.080

- ORAUT-OTIB-0017, Attachment C provides an explanation for the non-penetrating LODs for the PGDP.
- The exchange frequency was weekly through July 1960, then became less frequent (see note “c”).
- The TBD indicates that either monthly, quarterly, or annual exchange frequencies were used during this period, depending on work locations and the potential for exposure. A review of the data indicates that quarterly exchanges were predominant; thus, quarterly exchanges have been assumed here to calculate the maximum annual missed dose.
- The TBD indicates that either quarterly or annual exchange frequencies were used during this period, depending on the potential for exposure. A review of the data indicates that quarterly exchanges were predominant; thus, quarterly exchanges have been assumed here to calculate the maximum annual missed dose.

Special Considerations

Certain aspects of the external dosimetry practices at the PGDP documented in the TBD² were considered in the analysis of the site data. These include:

- In some cases, values less than the dosimeter LODs (listed in Table 1 above) were reported by the site. For example, values as low as a few millirem (mrem) were reported even though the penetrating LOD was considered to be 20 or 40 mrem (depending on the era).
- As discussed previously, prior to 1976, the data available to analyze coworker doses represent annual dose summaries for individual workers. Because these data include partial work years, the average annual doses reported tend to underestimate the average annual doses received by employees who worked an entire year.

As described in Section 7.0 below, a claimant-favorable approach was adopted in the development of coworker dose summaries, and this approach is intended to account for any underestimate of doses to radiological workers at the PGDP based on the considerations described above.

7.0 PGDP COWORKER ANNUAL DOSE SUMMARIES

Based on the information and approaches described above, PGDP coworker annual external dosimetry summaries were developed for use in the evaluation of external dose for certain claimants potentially exposed to workplace radiation, but with no or limited monitoring data provided by DOE. These summaries were developed using the following steps:

- As described in Section 6.0 above, for data between 1953 and 1975, the reported deep and shallow doses, which represented annual summary data, were modified to account for partial years of employment. This adjustment was made by analyzing the NOCTS employment data for PGDP workers and adjusting the reported doses upward by an appropriate multiplier corresponding to the average fraction of a year an employee worked at the site. For example, if in a particular calendar year the average employment period for all PGDP employees in NOCTS was 11 months, the reported annual doses were multiplied by 12/11, or 1.09. This permits the dose reconstructor to assign an appropriate prorated dose to account for partial years of employment or potential exposure.

2. For data between 1976 and 1988, the reported deep and shallow doses, which represented quarterly summary data, were modified to account for partial years of employment. Consistent with the guidelines in ORAUT-OTIB-0020,¹ doses for individuals with less than four quarters of data for a particular year were converted to annual doses by extrapolation (i.e., one quarterly result was multiplied by 4; two quarterly results were multiplied by 2; and three quarterly results were multiplied by 1.333).
3. For data between 1989 and 1995, the reported deep and shallow doses, which represented primarily quarterly data, were modified to account for partial years of employment by multiplying the data by $365/X$, where X corresponds to the number of days the employee was issued a dosimeter. This information was available for this period because the monitoring start and end dates were included with the data.
4. One-half of the maximum annual missed doses listed in Table 1 were added to the annual doses from Steps 1 through 3 (except for reported positive doses, in which case the maximum missed dose was reduced by the dose corresponding to one badge exchange because it is not possible that all individual badge results were zero if a positive annual dose was reported).
5. The 50th and 95th percentile annual penetrating and shallow doses were derived from the doses calculated in Step 4 by ranking the data into cumulative probability curves and extracting the 50th and 95th percentile doses for each year.
6. Because the reported shallow doses include both penetrating and non-penetrating radiation, the percentile doses pertaining to penetrating radiation identified in Step 5 were subtracted from the percentile doses pertaining to the reported shallow doses to derive percentile doses pertaining to non-penetrating radiation.
7. The results are presented in Table 2 below. These percentile doses should be used for selected PGDP workers with no or limited monitoring data using the methodologies outlined in Section 7.0 of ORAUT-OTIB-0020.¹ In general, the 50th percentile dose may be used as a best estimate of a worker's dose when professional judgment indicates the worker was likely exposed to intermittent low levels of external radiation. The 50th percentile dose should not be used for workers who were routinely exposed. For routinely exposed workers (i.e., workers who were expected to have been monitored), the 95th percentile dose should be applied. For workers who are unlikely to have been exposed, external on-site ambient dose should be used rather than co-worker doses.

Doses to organs impacted only by penetrating radiation (e.g., organs other than the skin, breast and testes) are calculated based only on the "Gamma" columns in Table 2 combined with the appropriate organ dose conversion factors (DCFs).³ Doses to the skin, breast and testes (and any other cancer location potentially impacted by non-penetrating radiation) are determined based on both the "Gamma" and "Non-penetrating" columns; gamma doses are assigned as photons with an energy range consistent with information in the external dosimetry TBD for the PGDP,² and non-penetrating doses are assigned as electrons >15 keV with corrections applied to account for clothing attenuation or other applicable considerations.⁵

With the methodology described above, null values for non-penetrating dose can occur because of the subtraction of the reported penetrating doses from the reported shallow doses and the claimant-favorable method described above to establish coworker doses based on the addition of potential missed doses. However, a "zero" value in Table 2 for non-penetrating dose will not result in a dose of zero being assigned to an organ such as the skin. For example, the 50th percentile dose to the skin in 1989 would be assigned entirely as 0.040 rem of photons. This approach does not result in an

underestimation of probability of causation (which is determined by DOL) because assigning beta dose as gamma dose in IREP has no negative effect, since the radiation effectiveness factors are the same for >15 keV electrons and >250 keV photons, and are higher for 30–250 keV photons.

8.0 PGDP COWORKER ANNUAL DOSE DISTRIBUTIONS

Reserved

Table 2. Annual PGDP external coworker doses modified to account for missed dose (rem).

Year	Gamma 95th%	Gamma 50th%	Non-pen 95th%	Non-pen 50th%
1953	1.656	1.128	1.729	0.701
1954	2.218	1.183	4.386	0.970
1955	2.344	1.067	5.574	1.048
1956	2.712	1.073	4.829	1.048
1957	2.224	1.072	4.511	0.580
1958	2.019	1.040	4.021	0.466
1959	1.900	1.083	5.148	0.694
1960	1.544	0.672	3.140	0.452
1961	1.048	0.134	1.647	0.036
1962	1.024	0.080	1.422	0.059
1963	0.868	0.080	0.818	0.037
1964	0.519	0.080	0.514	0.020
1965	0.243	0.080	0.194	0.020
1966	0.225	0.080	0.242	0.020
1967	0.236	0.091	0.343	0.025
1968	0.411	0.080	0.532	0.020
1969	0.541	0.080	0.989	0.020
1970	0.349	0.080	0.763	0.020
1971	0.558	0.080	1.039	0.020
1972	0.451	0.080	1.133	0.020
1973	0.407	0.080	1.254	0.020
1974	0.217	0.080	0.854	0.020
1975	0.247	0.090	0.604	0.055
1976	0.233	0.062	0.553	0.050
1977	0.189	0.062	0.398	0.055
1978	0.193	0.089	0.150	0.031
1979	0.109	0.080	0.265	0.054
1980	0.200	0.080	0.135	0.020
1981	0.090	0.040	0.324	0.020
1982	0.053	0.040	0.712	0.020
1983	0.070	0.040	0.535	0.020
1984	0.156	0.040	0.489	0.020
1985	0.070	0.040	0.615	0.020
1986	0.130	0.040	0.755	0.020
1987	0.070	0.040	0.415	0.020
1988	0.055	0.040	0.590	0.020
1989	0.053	0.040	0.067	0.000
1990	0.040	0.040	0.052	0.000
1991	0.040	0.040	0.033	0.000
1992	0.040	0.040	0.046	0.000
1993	0.043	0.040	0.042	0.000
1994	0.040	0.040	0.037	0.000
1995	0.040	0.040	0.055	0.000

ATTACHMENT A
PGDP EXTERNAL DOSIMETRY DATA REVIEW

PGDP Dosimetry Data database

There are many tables included in this database; they contain both internal and external dosimetry data. The external data listings are provided below, with their descriptions (from the document provided by PGDP).

- DRS_89_THRU_96 – External dosimetry records from 1989 to 1996.
- DRS_97_THRU_98 – External dosimetry records from 1997 to 1998.
- OHIS_EXTERNAL_DOSE – External dosimetry records from 1981 to 1997.
- OHIS_EXTREMITY_DOSE – Extremity dosimetry records from 1990 to 1995.
- OHIS_HP_SCHEDULE – Dosimetry scheduling information from 1987 to 1998.
- OHIS_JOB_HISTORY – Personnel job history information from 1986 to 1998.
- HISTORY_TAPE – External dosimetry records from 1953 to 1988.
- HIS20_EDD_CALCULATED_EXPOSURE – Calculated external dosimetry exposure records from 1980 to 1998.
- HIS20_EDD_INACTIVE_IRD_EXPOSURE – External dosimetry records from 1953 to 1998.