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Area Monitoring Dosimeter Program for the Pacific Northwest National Laboratory: Results for CY 2002

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Summary

In January 1993, Pacific Northwest National Laboratory (PNNL) established an area monitoring dosimeter program in accordance with Article 514 of the U.S. Department of Energy (DOE) Radiological Control Manual (RCM). The purpose of this program was to minimize the number of areas requiring issuance of personnel dosimeters and to demonstrate that doses outside Radiological Buffer Areas are negligible. In accordance with 10 CFR Part 835.402 (a) (1)-(4) and Article 511.1 of the PNNL Radiological Control Program Description, personnel dosimetry shall be provided to 1) radiological workers who are likely to receive at least 100 mrem annually and 2) declared pregnant workers, minors, and members of the public who are likely to receive at least 50 mrem annually. Program results for calendar years 1993-2001 confirmed that personnel dosimetry was not needed for individuals located in areas monitored by the program.

Area thermoluminescent dosimeters (TDLs) were placed at 117 locations in PNNL facilities during calendar year 2002. The TLDs were exchanged and analyzed quarterly. All routine area monitoring TLD results were less than 50 mrem annually after correcting for worker occupancy. The results support the conclusion that personnel dosimeters are not necessary for staff, declared pregnant workers, minors, or members of the public in these monitored areas.

Contents

Tables

Figures

1.0 Introduction

The U.S. Department of Energy Standard on Radiological Control (DOE Standard) (DOE 1999), first issued as the DOE Radiological Control Manual (RCM) in 1992, provides guidelines to assist line managers in meeting their responsibilities for implementing occupational radiological control programs. Article 514 of the DOE Standard, included in the PNNL Radiological Control Program Description, discusses the establishment and maintenance of a comprehensive area monitoring dosimeter program to minimize the number of areas requiring issuance of personnel dosimeters and to demonstrate that doses outside of radiological areas are negligible. This program complies with 10 CFR Part 835.401(a)(3), 401(a)(6), 402(a)(3), 401(a)(4), and 1003(b). As discussed in Article 514 of the PNNL Radiological Control Program Description, area monitoring dosimeters should do the following:

- record and document radiation levels in routinely occupied areas adjacent to areas where radiation or operations with radiation exist (not applicable when the radiation arises solely from low-energy beta sources such as ^{14}C or ^{3}H)
- support dosimetry investigations where personnel express concern about their work environment and exposure to ionizing radiation
- supplement existing monitoring programs in Radiologically Controlled Areas and provide data in the event of an emergency.

In January 1993, Pacific Northwest National Laboratory (PNNL)[(1)] established an area monitoring thermoluminescent dosimeter (TLD) program in accordance with Article 514 of the RCM. The program was conducted as outlined by Bivins[(2)] during calendar years (CY) 1993 and 1994. The program is now implemented according to RCP-5.1.04, "Area Monitoring TLD Program," issued in PNL-MA-266, *PNL Radiological Control Implementing Procedures*. Program results for previous years are found in Bivins and Stoetzel (1996a, 1996b, 1997, 1998, 1999, 2000, 2001, and 2002). Data from the program was also used to support the PNNL As Low As Reasonably Achievable (ALARA) program.

A description of the materials and methods used in collecting area monitoring TLD data and program results for CY 2002 are presented in this report. Neutron dose readings from the area TLDs are included in Section 3.0. Reporting of neutron dose data was initiated in the CY 1998 report (Bivins and Stoetzel 1999).

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(1) The Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle under Contract DE-AC06-76RL01830. Battelle also owns and operates private facilities near the Hanford Site.

(2) Bivins, S. R. February 24, 1993. Letter Report to D.P. Higby entitled "Area Monitoring Dosimeter." Pacific Northwest National Laboratory, Richland, Washington.

2.0 Materials and Methods

This section provides information on the type of TLDs used in the program, how they were located in the field, and frequency of exchange. Derivation of the investigation level, which triggers an evaluation into the potential cause of a reading, is also provided.

2.1 Description of Area TLDs

The Hanford Standard Dosimeter and the Hanford Combination Neutron Dosimeter were used in this program during CY 2002. The Hanford Standard Dosimeter was used at all locations; in addition, the Hanford Combination Neutron Dosimeter was positioned at three locations to better quantify neutron doses.

A brief description of each type of dosimeter is presented below. Appendix A provides a description of TLD processing, calibration, and the dose algorithm used in determining doses.

2.1.1 Hanford Standard Dosimeter

The Hanford Standard Dosimeter is accredited by the DOE Laboratory Accreditation Program (DOELAP) and is known commercially as a Harshaw 8825 dosimeter. The dosimeter contains TLD-700 chips in positions one, two, and three and a TLD-600 chip in position four. The TLD-600 chip is neutron-sensitive. The chips have thicknesses of 0.38 mm (100 mg/cm^2) in positions one, two, and four, and 0.15 mm (40 mg/cm^2) in position three. The TLD holder is constructed of black plastics with the following filtration:

1. position one - 242 mg/cm^2 acrylonitrilebutadienestyrene (ABS) plastic and 91 mg/cm^2 copper
2. position two - 1000 mg/cm^2 ABS plastic and Teflon®
3. position three - 8 mg/cm^2 Teflon® and 9 mg/cm^2 mylar
4. position four - 240 mg/cm^2 ABS plastic and 463 mg/cm^2 tin.

These dosimeters were read for shallow dose, deep dose, neutron dose, and eye dose. Only deep dose and neutron dose readings are discussed in this report.

® Teflon is a registered trademark of E. I. Du Pont de Nemours Co., Inc., Wilmington, Delaware.

2.1.2 Hanford Combination Neutron Dosimeter

The Hanford Combination Neutron Dosimeter consists of three components: 1) a beta-photon TLD, 2) an albedo neutron TLD, and 3) two CR-39 track-etch dosimeter foils. Instead of CR-39 track-etch dosimeter foils, the albedo neutron TLD is currently used to assess neutron dose. The beta-photon TLD is a Harshaw 8825 dosimeter. The albedo neutron TLD is a Harshaw 8816 dosimeter, which contains three TLD-600 phosphors and one TLD-700 phosphor. This albedo TLD has the following filter configurations:

- TLD-700 #1 (tin filters on the front and back)
- TLD-600 #2 (cadmium filter on front and tin filter on back)
- TLD-600 #3 (tin filter on front and cadmium filter on back)
- TLD-600 #4 (tin filters on front and back).

These dosimeters were read for shallow dose, deep dose, neutron dose, and eye dose. Only deep dose and neutron dose readings are discussed in this report.

2.2 Placement of Area TLDs

Area TLDs were placed in the following PNNL facilities (DOE-owned, DOE-leased, and Battelle private):

- all 300 Area PNNL facilities where staff worked at least eight hours per month
- all PNNL facilities where staff conducted radiological work (i.e., had a current Radiological Work Permit)
- all PNNL facilities located within 15 m (~50 ft) of another facility (including those of other Hanford Site contractors) containing a radiological area (indoors or outdoors).

TLDs positioned as such are referred to as “routine” area TLDs in this report. Area TLDs were also positioned in facilities as approved by the Radiological Control organization for special situations such as ALARA evaluations. In this report, these are referred to as “special” area TLDs.

A list of routine area TLD locations is included as Appendix B. There were no special area TLD locations during CY 2002. The number of area TLDs in each facility was determined according to the following criteria:

- at least one area TLD per facility
- one additional area TLD for every 25 staff members in facilities requiring area TLDs but not containing a Radiologically Controlled Area or a radiological area
- one additional area TLD for every 15 staff members in facilities requiring area TLDs and containing a Radiologically Controlled Area or a radiological area.

Hanford Combination Neutron Dosimeters were positioned as area TLDs at the following three locations to better quantify neutron doses:

- 325 Building, east equipment room on the second floor
- 325 Building, first floor hallway between Rooms 115 and 116
- 326 Building, Room 28B on the second floor.

Additional area TLDs were positioned as determined by the Radiological Control organization.

Each Hanford Standard Dosimeter used as an area TLD was oriented per guidance in PNL-MA-842, *Hanford External Dosimetry Technical Basis Manual*. If the potential source of exposure was from within the facility, the area TLD was placed on the wall opposite the potential source. If the potential source of exposure was located outside the facility, the area TLD was placed on the inside surface of the exterior wall with the Mylar window facing away from the wall. The TLDs were placed 1 to 2 m (3 to 6 ft) from the floor, depending on whether staff in the area would be standing or seated.

Each Hanford Combination Neutron Dosimeter used as an area TLD was placed on the front-face of a 5-gallon carboy filled with water. The neutron portion of the dosimeter was at least 7.5 cm (3 in) from any edge of the carboy. The physical size and weight of the 5-gallon carboy limited the locations where these dosimeters could be positioned.

Each area TLD was identified with an attached bar code label containing a facility ID (e.g., 337, LOC. 5) and a TLD identification number beginning with the letter "A" to denote an area TLD followed by a four-digit number (e.g., A3014).

2.3 Frequency of Area TLD Exchange

All area TLDs were scheduled to be exchanged and analyzed quarterly. The area monitoring TLD procedure allows facility managers to request a special exchange for any TLD in their facilities. The Safety & Health Manager may also request a special exchange for area TLDs in any facility. Any area TLD changed out was immediately replaced with another area TLD unless the area TLD location was being discontinued.

2.4 Data Review

Any area TLD results greater than or equal to 40 mrem in a quarter were investigated. This action level was established to ensure that an individual would not likely receive more than 50 mrem annually (the trigger level for requiring personnel dosimetry for declared pregnant workers, minors, and members of the public). The investigation level of 40 mrem per quarter was derived by dividing the 50 mrem annual limit by four and adjusting for worker occupancy.

The area TLDs were exposed for approximately 8760 h annually; individual occupancy was assumed to be 2000 h (8 h/d, 5 d/wk, and 50 wk/yr). Therefore, the occupancy-corrected quarterly limit is as follows:

Quarterly limit = (50 mrem/4)(8760 h/2000 h) = 55 mrem

The calculated 55-mrem quarterly limit was reduced to 40 mrem to allow for such factors as processing time, processing errors, the potential for individuals to be present more than 2000 h annually, and the potential for maximum exposure rates occurring during occupancy hours.

2.5 Quality Assurance and Quality Control

The Hanford External Dosimetry Project (HEDP) performed the measurements of the area TLDs. The HEDP laboratory is DOELAP accredited. Quality assurance and quality control programs are conducted in accordance with PNL-MA-859, *Hanford External Dosimetry Project Quality Manual*.

3.0 Results and Discussion

A summary of the deep dose area monitoring TLD results for CY 2002 is provided in Table 3.1. Quarterly area monitoring TLD results are grouped into one of three dose ranges (i.e., ≤10 mrem; >10 mrem but <40 mrem; ≥40 mrem). In six locations, deep dose results exceeded the quarterly investigation level of 40 mrem; however, none of these locations had potential personnel exposures of 50 mrem after considering worker occupancy. The results support the conclusion that personnel dosimeters are not necessary for staff in the areas monitored by the area TLDs. A detailed discussion of these six area monitoring TLD locations is found in Section 3.1.

Table 3.1 - Summary of Area Monitoring TLD Results, CY 2002[a]

Parameter	Quantity
Number of area TLD locations	117
Total number of area TLDs analyzed in CY 2002	457[b]
Quarterly area TLD results by deep dose range:	
• ≤10 mrem	412
• >10 mrem but <40 mrem	20
• ≥40 mrem	25

a. This table provides data for routine area TLDs. No special area TLDs were located in the field during 2002.
b. The total number of area TLDs analyzed does not equal 468 (i.e., four times the number of area TLD locations) because locations were started and terminated at various times throughout the year and several area TLDs were lost.

The neutron dose readings from the Hanford Standard Dosimeters typically over-estimate neutron dose since they are calibrated to an unmoderated neutron source, and neutron fields in PNNL facilities are moderated by intervening shielding and building materials. To better quantify neutron doses, Hanford Combination Neutron Dosimeters were positioned at three locations starting in CY 2001 and continuing into CY 2002. Comparison of neutron results between the Hanford Standard Dosimeter and Hanford Combination Neutron Dosimeter are presented in Section 3.2, along with a discussion of six locations where the combined deep and neutron dose results for CY 2002 exceeded the quarterly investigation level of 40 mrem.

Individual area monitoring TLD results for each quarter, as well as annual totals, are presented in Appendix C. The results in Appendix C are not corrected for worker occupancy. Assuming workers to be present 2000 h/yr, results should be multiplied by 0.23 to correct for worker occupancy.

3.1 Area TLD Results (Deep Dose)

Quarterly "deep dose" area monitoring TLD results for facilities located outside the 300 Area (622R, 747A, 747A Trl, 2400 Stevens, EMSL, ESB, LSL-II, PSL, RTL, and Sigma V) were $\leq$10 mrem. The six locations with quarterly deep dose results $\geq$ 40 mrem "investigation level" were located in the 300 Area. Four of the locations were in the 325 Building with one each in the 326 Building and the 3720 Building. Figure 3.1 shows the trend of annual deep dose results at the six locations since the PNNL program was initiated in 1993. Table 3.2 provides estimated annual doses to an individual at the locations for CY 2002 considering occupancy. Estimated doses were below the 50 mrem annual dose, which requires personnel dosimetry for a declared pregnant worker, a minor, or a member of the public. Detailed reviews of each location are summarized below.

- TLD ID# A3062 (325, Loc. 2) was located in Room 5 of the mezzanine of the 325 Building on the north wall about chest height. This location was initiated in 1993. The increase in dose since 1997 (see Figure 3.1) was due to increased waste handling and storage activities in the basement of the 325 Building. Waste is frequently stored along the south wall of the basement just below Room 5. Routine surveys taken in the mezzanine annually showed that dose rates are less than the 50 μrem/h level requiring posting as a Radiological Buffer Area. Accounting for occupancy, an individual could have received approximately 44 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3175 (325, Loc. 5) and A3225 (325, Loc. 12) were located in the lunchroom of the east equipment room on the second floor of the 325 Building. This location was initiated in the second quarter of CY 1997. The annual deep dose result for CY 2002 had increased by approximately a factor of four over the doses in CY 1998 and CY 1999 (see Figure 3.1). The increase in deep dose results over the past three years was attributed to storage of additional radioactive material in Room 528 located below this area. To evaluate the significance of neutron dose readings reported from the Hanford Standard Dosimeter (A3175), a Hanford combination neutron dosimeter (A3225) was added to this location for a one-year period (third quarter 2001 through second quarter 2002). Table 3.3 compares the quarterly neutron dose readings from the Hanford Standard Dosimeter and the Hanford Combination Neutron Dosimeter. For this location, the Hanford Standard Dosimeter overestimated the neutron dose by a factor of approximately 7. The Hanford combination neutron dose (A3225) was discontinued the third quarter of CY2002 as enough information had been gathered on ratios of neutron dose from the standard dosimeter and the combination dosimeter. Accounting for occupancy, an individual could have received approximately 24 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3176 (325, Loc. 6) was located in the copy room in the second floor office area of the 325 Building. This location was initiated in 1998. The annual deep dose result for CY 2002 increased by a factor of four over the results from the previous several years (see Figure 3.1). This increase was attributed to sample preparation work on high-activity filters located in room 700. Much of the increased dose was from waste generated during this activity and stored in the room. The waste was removed during the fourth quarter of CY 2002 resulting in a significantly lower fourth quarter result. Accounting for occupancy, an individual could have received approximately 38 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3196 (325, Loc. 7) and A3226 (325, Loc. 11) were located on the wall between Room 115 and 116 on the first floor of the 325 Building. This location was started in the second quarter of CY 1999. The total deep dose for CY 2002 was 435 mrem about the same as previous years (see Figure 3.1). To evaluate the significance of neutron dose readings reported from the Hanford Standard Dosimeter (A3196) over the past several years, a Hanford Combination Neutron Dosimeter (A3226) was added to this location for a one-year period (third quarter 2001 through second quarter 2002). Table 3.3 compares the quarterly neutron dose readings from the Hanford Standard Dosimeter and the Hanford Combination Neutron Dosimeter. The Hanford Combination Neutron Dosimeter showed minimal neutron dose at this location. The Hanford combination neutron dose (A3225) was discontinued the third quarter of CY2002 as enough information had been gathered on ratios of neutron dose from the standard dosimeter and the combination dosimeter. Accounting for occupancy, an individual could have received approximately 25 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3178 (326, Loc. 7) was located on the east wall of Room 37B in the 326 Building. This location was started during CY 1997. This was the first year with a quarterly result greater than the screening level. The fourth quarter result was 69 mrem. This dose was attributed to researchers sorting and disposing high-activity samples in Room 15/17A located directly below Room 37B. All staff in affected areas on the "B" floor were issued personal TLDs during the exposure period. Accounting for occupancy, an individual could have received approximately 36 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3048 (3720, Loc. 2) was located on the bulletin board in the lunchroom of the 3720 Building. This location was initiated in 1993. Total measured deep dose for CY 2002 was 172 mrem, which is similar to doses for the past four years (see Figure 3.1). As documented in past annual reports, the cause of the elevated readings in CY 1997 and CY 1998 was radioactive material stored in a shielded glovebox in a laboratory across the hall from the lunchroom (see Bivins and Stoetzel 1999). During April/May 1999, radioactive material stored in the shielded glovebox was moved to the 331 Building. Major contributors to dose at this location now are SX tank soil samples stored in Room 603 and 612 and the shielded sample storage area in Room 506. As documented in past annual reports, TLD #A3048 is conservatively located on the wall next to the radioactive material. Accounting for occupancy, an individual could have received approximately 10 mrem during CY 2002 (see Table 3.2).

3.2 Routine Area TLD Results (Deep + Neutron Dose)

Neutron dose results for the Hanford Standard Dosimeter are based on a calibration on a phantom to unmoderated neutrons from bare ^{252}Cf. The neutrons typically reaching an area TLD location will be moderated by intervening shielding and building material; therefore, the dosimeter would be more appropriately calibrated in air to a ^{252}Cf source moderated by a 30-cm-diameter sphere of D_2O. This calibration showed that the neutron doses reported in Appendix C should be divided by a factor of 2.66 to obtain more accurate results. Field measurements made with a BF_3 detector showed that the correction factor of 2.66 could also be conservatively used to correct neutron readings for a location in the 331 Building. To better define neutron doses from the Hanford Standard Dosimeter, Hanford Combination Neutron Dosimeters were placed at selected locations, which had elevated neutron readings in the past on the Hanford Standard Dosimeters. These locations were 1) 325, Loc. 5 (east equipment on the second floor), 2) 325, Loc. 7 (first floor hallway between Rooms 115 and 116), and 3) 326, Loc. 9 (Rm 28B). Comparisons of neutron dose readings are found in Table 3.3. The results showed the Hanford Standard Dosimeter to over-respond by a factor of 1.1 – 9.2. The Hanford Standard Dosimeters in the 325 Building over-responded by an average of 7.0 compared to an average of only 1.5 in the 326 Building. The likely reason for this difference is that the source of the neutron exposure in the 326 Building is located closer to the area dosimeters with less intervening shielding compared to the neutron exposures in the 325 Building. Therefore, the 326 Building exposure configuration more closely aligns to the neutron calibration method for the Hanford Standard Dosimeter (i.e., calibration on a phantom to unmoderated neutron from bare ^{252} Cf).

Four area TLD locations had quarterly readings exceeding the 40 mrem "investigation level" when totaling the deep dose and neutron dose reading. A discussion of the four area TLD locations is presented below:

- TLD ID# A3063 (325, Loc. 3) was located on the second floor of the 325 Building outside Room 944. This location was initiated in CY 1998. Quarterly deep dose readings ranged from 17 to 28 mrem (84 mrem total) for CY 2002 which is similar to past years. Quarterly neutron doses ranged from 9 to 14 mrem (36 mrem total) which is similar to past years. Using the 2.66 correction factor, the annual neutron dose for CY 2002 is estimated to be 14 mrem. Accounting for occupancy, an individual could have received approximately 23 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3197 (325, Loc. 8) was located on the first floor of the 325 Building between Room 101 and 102. This location was initiated during the second quarter of CY 1999. Quarterly deep dose results for CY 2002 ranged from 20 to 28 mrem (93 mrem total for the year) which is similar to the quarterly results for previous years. Quarterly neutron doses ranged from 41 to 60 mrem (205 mrem total) for CY 2002, which is similar to the readings since the third quarter of CY 2000. Using the 2.66 correction factor, the annual neutron dose for CY 2002 is estimated to be 77 mrem. Doses are likely due to radioactive materials found in Room 22 of the basement below this hallway. Accounting for occupancy, an individual could have received approximately 10 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3218 (326, Loc. 9) and A3222 (326, Loc. 10) were located on the second floor of the 326 Building in Room 28B under the window on the south wall. TLD A3218 (Hanford Standard Dosimeter) was initiated during the fourth quarter of CY 1999 and TLD A3222 (Hanford Combination Neutron Dosimeter) was initiated during the first quarter of CY 2002. The deep dose readings were insignificant <10 mrem/quarter which is similar to past years. Neutron results for this location are found in Table 3.3. Quarterly neutron dose results from Hanford Standard Dosimeter were from 1.1 to 1.3 greater than dose results from the Hanford Combination Neutron Dosimeter at this location. Neutron doses for all the quarters exceed the 40 mrem screening limit. The source of the neutron activity was neutron source storage in room 9A. When these sources are removed from their storage locations during projects, personnel are evacuated from the areas immediately above Room 9A. Accounting for occupancy, an individual could have received approximately 11 mrem during CY 2002 (see Table 3.2).

- TLD ID# A3095 (EMSL, Loc. 3) was located inside the caged area on the south wall of room 1648 (accelerator room). Personnel typically do not enter the caged area during accelerator operations but are not restricted from doing so. This location was initiated in CY 1997. Quarterly deep dose readings for CY 2002 ranged from 6-8 mrem, which is similar to past years. Quarterly neutron dose readings for CY 2001 ranged from 0-84 mrem (102 mrem total), which is somewhat higher than past years. The increased reading may be due to accelerator operations within the area when working at higher voltages. The Radiological Control organization has implemented several special studies to better understand the elevated neutron readings at this location to include the following: 1) placement of neutron TLDs and track etch dosimeters at EMSL, Loc. 3 and EMSL, Loc. 4, and 2) measurements with a low-level neutron counter during accelerator operations suspected of causing the elevated neutron readings. Results of the special studies were not yet available. Assuming no neutron correction factor, the annual neutron dose for CY 2002 is estimated to be 102 mrem. Accounting for occupancy, an individual could have received approximately 7 mrem during CY 2002 (see Table 3.2).

Table 3.2 - Estimated Annual Dose to an Individual at Selected Locations, CY 2002

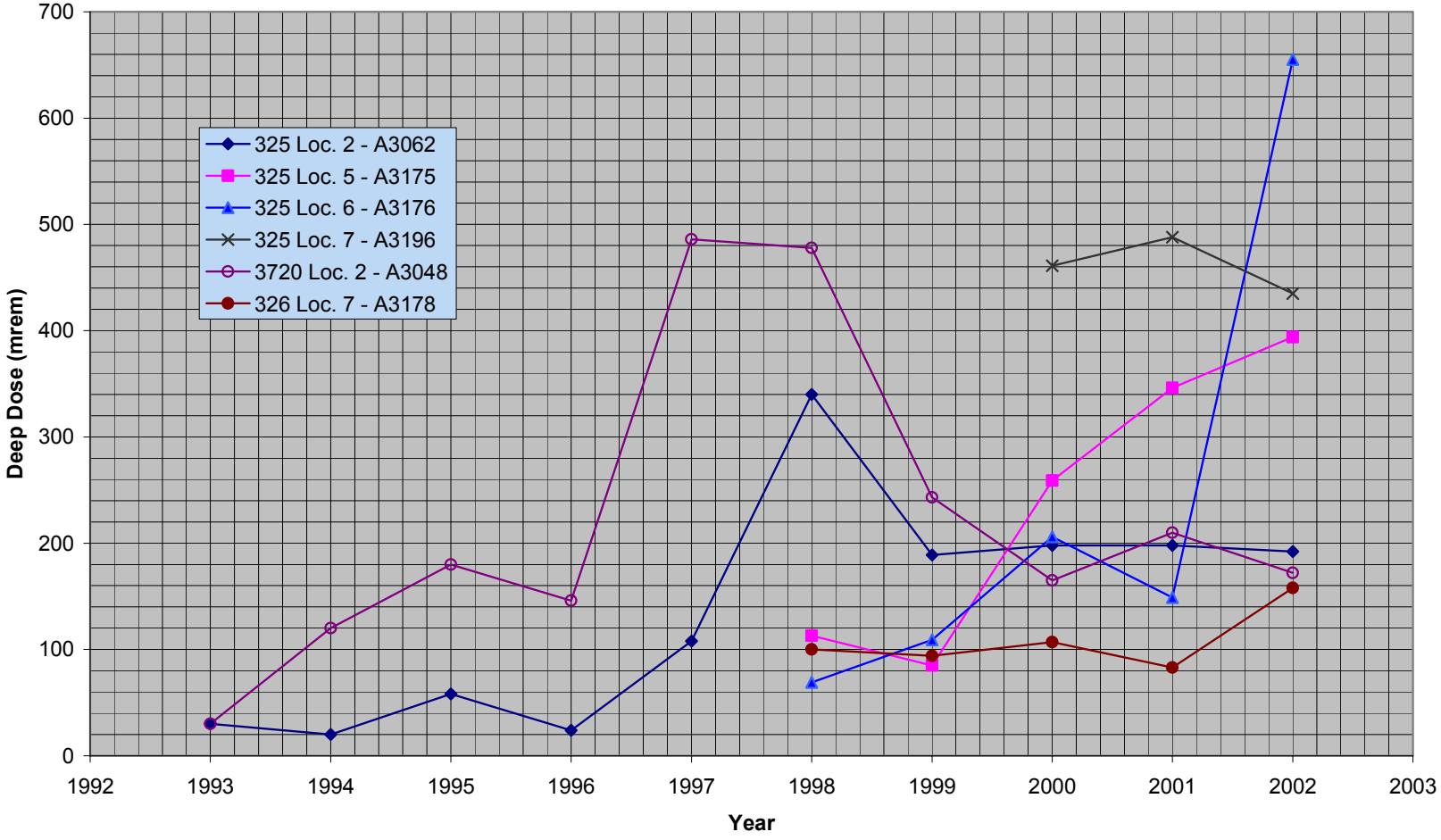
Location	Dosimeter Number	Annual Area TLD Reading (mrem)	Estimated Dose to Individual Assuming Full-Time Occupancy (mrem) [a]	Occupancy Factor	Estimated Annual Dose to Individual After Occupancy Corrections (mrem)
325, Loc. 2 (Rm 5)	A3062	192	44	1	44
325, Loc. 3 (Rm 944)	A3063	98[b]	23	1	23
325, Loc. 5 (east equip rm)	A3175, A3225	422[c]	97	¼	24
325, Loc. 6 (2nd floor, copy room)	A3176	655	151	¼	38
325, Loc. 7 (Rm 115/116)	A3196, A3226	441[d]	101	¼	25
325, Loc. 8 (Rm 101/102)	A3197	170[e]	39	¼	10
326. Loc. 7 (Rm 37B)	A3178	158	36	1	36
326, Loc. 9 (Rm 28B)	A3218, A3222	195[f]	45	¼	11
3720, Loc. 2 (lunch room)	A3068	172	40	¼	10
EMSL, Loc. 3 (Accel Rm)	A3095	129[g]	30	¼	7

a. Full-time occupancy assumes 2000 hours/y; therefore, need to multiply value in previous column by 0.23.
b. Dose was the sum of the deep dose reading for CY 2002 (84 mrem) and the neutron dose divided by 2.66 (36 mrem/2.66 = 14 mrem)
c. This dose represents the sum of the annual deep dose (394 mrem) and neutron dose (~28 mrem). The neutron dose reading was taken from the Hanford Combination Neutron Dosimeter (A3225). The neutron dose for the first and second quarter was 14 mrem; therefore, the annual neutron dose was projected to be ~28 mrem.
d. This dose represents the sum of the annual deep dose (435 mrem) and neutron dose (~6 mrem). The neutron dose reading was taken from the Hanford Combination Neutron Dosimeter (A3226). The neutron dose for the first and second quarter was 3 mrem; therefore, the annual neutron dose was projected to be ~6 mrem.
e. Dose was the sum of the deep dose reading for CY 2002 (93 mrem) and the neutron dose divided by 2.66 (205 mrem/2.66 = 77 mrem).
f. This dose represents the sum of the annual deep dose (14 mrem) and neutron dose (181 mrem). The neutron dose reading was taken from the Hanford Combination Neutron Dosimeter (A3222).
g. Dose was the sum of the deep dose reading for CY 2002 (27 mrem) and the neutron dose (102 mrem).

Table 3.3-Comparison of Neutron Doses between Hanford Standard Dosimeter and Hanford Combination Neutron Dosimeter, CY 2001 -2002

Quarter	Neutron Dose (mrem)								
	325, Loc. 5 (East Equipment Rm)			325, Loc. 7 (Rm 115/116)			326, Loc. 9 (Rm 28B)		
	Std (A3175)	Combo (A3225)	Ratio (Std/Combo)	Std (A3196)	Combo (A3226)	Ratio (Std/combo)	Std (A3218)	Combo (A3222)	Ratio (Std/combo)
2001-1	-	-	-	-	-	-	82	23	3.6
2001-2	-	-	-	-	-	-	34	9	3.8
2001-3	80	14	5.7	24	0	-	68	44	1.6
2001-4	75	11	6.8	0	0	-	61	51	1.2
2002-1	64	8	8.0	20	3	6.7	56	50	1.1
2002-2	55	6	9.2	20	0	-	49	40	1.2
2002-3	-	-	-	-	-	-	56	42	1.3
2002-4	-	-	-	-	-	-	53	49	1.1
Total	274	39	7.0	64	3	21	459	308	1.5

Figure 3.1 CY 2002 Deep Dose Trend Data



4.0 Conclusions

The area monitoring TLD program for CY 2002 was a useful tool in determining exposure trends in work areas located outside radiological areas. All routine area monitoring TLD results were less than 50 mrem annually after correcting for worker occupancy. The results support the conclusion that personnel dosimeters are not required for staff in these monitored areas.

5.0 References

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Appendix A

Area TLD - Processing, Calibration, and Dose Assessment

A.1 Processing

Harshaw 8800 series automated reader systems were used to process the area thermoluminescent dosimeters (TLDs) (i.e., Hanford Standard Dosimeter and Hanford Combination Neutron Dosimeter). Automated processing steps included the following:

- **Pre-issue reader annealings**: each dosimeter card is processed through the automated reader systems to remove any remaining residual signal from past occupational exposure or environmental background radiation. Each dosimeter card is annealed at 80ºC for 16 h before being issued.

- **Reader processing**: the reader heats all chips simultaneously at a rate of 25ºC/s until a maximum temperature of 300ºC is obtained.

- **Glow-curve recording**: the glow curve of all dosimeters is recorded and stored for a period of approximately 2 years.

A.2 Calibration

Area TLDs were calibrated using sources traceable to the National Institute of Standards and Technology (NIST). The primary calibration was the deep dose from an on-phantom ^{137}Cs exposure.

A.3 Dose Assessment

The contribution to the area TLD from naturally occurring environmental radiation was determined using the following equation:

$$E_i = G_i (FD - BD)$$

where E_i = estimated environmental background for chip i (^{60}Co mR-equivalent)
G_i = background growth rate (mR/d)
FD = field cycle days (days between previous and current processing date)
BD = blank days (mean days between previous and current processing for blank cards).

The adjusted chip readings are calculated using the following equation:

$$D_i = \frac{X_i B_i E_i}{(RRF_i * F_i)}$$

where D_i = adjusted chip reading for chip i (^{137}C rem-equivalent)
X_i = calibrated chip reading for chip i (^{60}Co mR-equivalent)
Bi = mean calibrated chip i reading from blank cards (^{60}Co mR-equivalent)
E_i = estimated environmental background for chip i (^{60}Co mR-equivalent)
RRF_i = ^{137}Cs relative response factor (RRF) for chip i (mR/rem)
F_i = fade factor for chip i.

Area TLD readings were provided for shallow dose, deep dose, neutron dose, and eye dose. Only deep dose and neutron results are included for discussion in this report.

A.4 Dose Algorithm

Dose algorithms for the Hanford Standard Dosimeter and Hanford Combination Neutron Dosimeter are found in Section 8 of PNL-MA-568.

A.5 Quality Control Program

Quality assurance and quality control programs are conducted in accordance with Section 5 of PNL-MA-859, *Hanford External Dosimetry Project Quality Manual*.

Appendix B

Locations of Area Monitoring TLDs

BLDG	TLD ID #	Location ID #	Description of Location
		Routine TLDs	
305-B	A3001	LOC. 1	South wall of Room 2 near vending machine
306-W	A3034	LOC. 1	Main entrance on first bulletin board
306-W	A3035	LOC. 2	Second floor lunchroom
306-W	A3036	LOC. 3	First floor - Room 131
318	A3040	LOC. 2	Main corridor of second floor across from Room 202
318	A3192	LOC. 4	First floor - main corridor outside Room 121
318	A3193	LOC. 5	Bulletin board across from Room 1128 (facing north)
318	A3194	LOC. 6	Room 169 (copy room) - north wall
318	A3022	TRL. 4	Bulletin board on the north wall (main entrance)
320	A3042	LOC. 1	Lobby
320	A3043	LOC. 2	Basement on bulletin board outside of Room 5 on east wall
323	A3195	LOC. 1	Lunchroom on south wall facing hot cell area
325	A3061	LOC. 1	Main lobby near north door
325	A3062	LOC. 2	Mezzanine, Room 5, north wall (chest height)
325	A3063	LOC. 3	Second floor - outside of Room 944
325	A3174	LOC. 4	Lunchroom (second floor)
325	A3175	LOC. 5	East equipment room (second floor, lunch area)
325	A3176	LOC. 6	Copy Room (second floor)
325	A3196	LOC. 7	First floor hallway between Rooms 115 and 116
325	A3197	LOC. 8	First floor hallway between Rooms 101 and 102
325	A3198	LOC. 9	Mezzanine, Room 76
325	A3199	LOC. 10	Mezzanine, Room 17
325	A3226	LOC. 11	First floor hallway between Rooms 115 and 116) – Hanford Combination Neutron Dosimeter
325	A3225	LOC. 12	East equipment room (second floor, lunch area) – Hanford Combination Neutron Dosimeter
326	A3064	LOC. 1	First floor - bulletin board in copy area (Room 15)
326	A3065	LOC. 2	First floor - in front of exit door to basement
326	A3066	LOC. 3	First floor - in corridor across from Room 48-B
326	A3067	LOC. 4	Second floor - lunchroom bulletin board
326	A3068	LOC. 5	Second floor - corridor near Room 40-C

BLDG	TLD ID #	Location ID #	Description of Location
326	A3157	LOC. 6	Basement - Room 14A bulletin board
326	A3178	LOC. 7	Room 37B (second floor, east wall)
326	A3200	LOC. 8	Second floor on bulletin board opposite Room 30-C
326	A3218	LOC. 9	Second floor, Room 28B, under window on south wall
326	A3222	LOC. 10	Second floor, Room 28B, under window on south wall (Hanford Combination Neutron Dosimeter)
329	A3071	LOC. 1	Lunchroom
329	A3072	LOC. 2	Room 115 - east wall
329	A3074	LOC. 4	North-south hallway (Room 2)
329	A3075	LOC. 5	North-south hallway (Room 6-C)
329	A3173	LOC. 8	Room 129 (above sink)
331	A3044	LOC. 1	First floor - mail room
331	A3045	LOC. 2	Second floor hallway on bulletin board outside of Room 22
331	A3046	LOC. 3	Third floor - Room 45
331	A3201	LOC. 4	First floor on bulletin board (east wall of Room 166B)
331	A3202	LOC. 5	First floor on bulletin board (east wall of Room 113A)
331	A3203	LOC. 6	First floor on bulletin board (northeast wall of Room 164)
331	A3204	LOC. 7	First floor, Room 164 on northeast wall
331	A3205	LOC. 8	First floor - outside of Room 110
331	A3206	LOC. 9	Second floor in corridor opposite of Room 30
331C	A3207	LOC. 1	North wall by entrance door
331D	A3208	LOC. 1	North wall by entrance door
331H	A3209	LOC. 1	Bulletin board by airlock area
336-1	A3073	LOC. 1	Bulletin board in Room 5 on east wall at entrance to Room 6
337	A3080	LOC. 1	First floor south - west wall of Room 1114
337	A3081	LOC. 2	First floor north - east wall of Room 1225
337	A3082	LOC. 3	Second floor south - west wall of Room 2112
337	A3083	LOC. 4	Second floor north - north wall of Room 2213
337	A3084	LOC. 5	Third floor south - Room 3124
337	A3085	LOC. 6	Third floor north - Mt. Rainier Room
338	A3177	LOC. 1	Conference Room/lunchroom (Room 24) - west wall
350	A3004	LOC. 1	Bulletin board in Room 137
350	A3005	LOC. 2	Bulletin board between Rooms 158 and 175
622-R	A3086	LOC. 1	Room 110 by red phone
622-R	A3087	LOC. 2	Exit sign in front of men's room
747-A	A3088	LOC. 1	Bulletin board on west wall by scale
747-A	A3089	TRL.1, LOC. 1	Bulletin board by south door
2400	A3113	LOC. 1	Secretary's desk located in main entrance
2400	A3114	LOC. 2	Bulletin board in entry way to Room 1414

BLDG	TLD ID #	Location ID #	Description of Location
2400	A3115	LOC. 3	High-bay bulletin board in entry to Lab 1445
2400	A3116	LOC. 4	Second floor on bulletin board outside of Room 2428
3718-A	A3006	LOC. 1	Bulletin board outside of main office
3720	A3047	LOC. 1	North and south corridor across from Room 221
3720	A3048	LOC. 2	Bulletin board in lunchroom (Room 401), north wall
3730	A3049	LOC. 1	Desk area near computers
3760	A3009	LOC. 1	Lobby
3760	A3010	LOC. 2	Second floor Room 215 (SE cubicle)
APEL	A3217	LOC. 1	Room 102 on north wall by radiation generating device
APEL	A3228	LOC. 2	Room 80
BRSW	A3227	LOC. 1	Room 1 (receiving area above desk on fence)
EMSL	A3093	LOC. 1	Accelerator Room (north wall)
EMSL	A3094	LOC. 2	Accelerator Room (east wall)
EMSL	A3095	LOC. 3	Accelerator Room (south wall enclosure)
EMSL	A3096	LOC. 4	Accelerator Room (south wall)
EMSL	A3097	LOC. 5	Accelerator Room (west wall)
EMSL	A3098	LOC. 6	Accelerator Room (control console)
EMSL	A3211	LOC. 7	Room 1422 on south wall by phone
EMSL	A3212	LOC. 8	Room 1330 on south wall
EMSL	A3213	LOC. 9	Room 1330 on east wall under cabinet
EMSL	A3214	LOC. 10	Room 1330 on southwest wall
EMSL	A3219	LOC. 11	Room 1330, x-ray machine
EMSL	A3220	LOC. 12	Room 1422, x-ray machine
EMSL	A3223	LOC. 13	Room 1330 on north wall
EMSL	A3224	LOC. 14	Room 1330 on northeast wall
ESB	A3092	LOC. 2	Entry way to Room 31
LSL-II	A3167	LOC. 1	Lunchroom
LSL-II	A3168	LOC. 2	Corridor outside of Lab 1404
LSL-II	A3169	LOC. 3	Lab 1508
LSL-II	A3170	LOC. 4	Lab 1419
LSL-II	A3171	LOC. 5	Office 1224
LSL-II	A3172	LOC. 6	Lab 1336
PSL	A3099	LOC. 1	Lab 1611
PSL	A3100	LOC. 2	Bulletin board in Lab 1504
PSL	A3101	LOC. 3	East entrance on secretary's desk
PSL	A3102	LOC. 4	Bulletin board in Lab 1304
PSL	A3103	LOC. 5	Corridor outside of Lab 315
PSL	A3210	LOC. 6	Room 1308 on west wall under cabinet
RTL	A3105	LOC. 1	Lab 428

BLDG	TLD ID #	Location ID #	Description of Location
RTL	A3106	LOC. 2	Lab 328
RTL	A3107	LOC. 3	Lab 218
RTL	A3108	LOC. 4	Outside Room 127 Secretary office
RTL	A3109	LOC. 5	Canteen above fire extinguisher
RTL	A3110	LOC. 6	Bulletin board in Room 21-A
Sigma V	A3186	LOC. 1	Room 1519 - west wall
Sigma V	A3187	LOC. 2	Room 1519 - south wall
Sigma V	A3188	LOC. 3	Room 1519 - north wall
Sigma V	A3189	LOC. 4	Room 1227 - north wall
Sigma V	A3190	LOC. 5	Room 1523 - west wall
Sigma V	A3191	LOC. 6	Room 1519 - ceiling

Appendix C

Area Monitoring TLD Results for CY 2002[(a)]

TLD Location	TLD ID#	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Annual
305B LOC. 1	A3001	0	1	1	1	3
306W LOC. 1	A3034	2	2	3	1	8
306W LOC. 2	A3035	3	3	3	2	11
306W LOC. 3	A3036	4	7	8	8	27
318 LOC. 2	A3040	3	3	2	2	10
318 LOC. 4	A3192	0	0	0	1	1
318 LOC. 5	A3193	0	0	1	0	1
318 LOC. 6	A3194	2	1	1	1	5
318 TRL. 4	A3022	0	0	0	0	0
320 LOC. 1	A3042	0	1	0	2	3
320 LOC. 2	A3043	5	5	4	5	19
323 LOC. 1	A3195	3	2	4	3	12
325 LOC. 1	A3061	0	0	1	0	1
325 LOC. 2	A3062	42	49	48	53	192
325 LOC. 3	A3063	28 (13)[e]	20 (14)[e]	17 (9)[e]	19	84 (36)[e]
325 LOC. 4	A3174	1	2	3	2	8
325 LOC. 5	A3175	76 (64)[e]	115 (55)[e]	75 (25)[e]	128	394 (144)[e]
325 LOC. 6	A3176	68	180	251	156	655
325 LOC. 7	A3196	102 (20)[e]	108 (20)[e]	110 (25)[e]	115	435 (65)[e]
325 LOC. 8	A3197	22 (57)[e]	20 (60)[e]	28 (41)[e]	23 (47)[e]	93 (205)[e]

Area Monitoring TLD Results for CY 2002[(a)] (continued)

TLD Location	TLD ID#	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)
		1st Quarter	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
325 LOC. 9	A3198	17	16	17	11	61
325 LOC. 10	A3199	9	11	8	11	39
325 LOC. 11	A3226 (Combo)	165 (3)[f]	132 (0)[f]	(d)	(d)	297 (3)[f]
325 LOC. 12	A3225 (Combo)	72 (8)[f]	105 (6)[f]	(d)	(d)	177 (14)[f]
326 LOC. 1	A3064	1	0	0	1	2
326 LOC. 2	A3065	0 (23)[e]	1 (18)[e]	0 (19)[e]	1 (20)[e]	2 (80)[e]
326 LOC. 3	A3066	0	0	1	0	2
326 LOC. 4	A3067	0	0	0	0	0
326 LOC. 5	A3068	1	1	1	1	4
326 LOC. 6	A3157	1	1	6	(b)	8
326 LOC. 7	A3178	24	26	39	69	158
326 LOC. 8	A3200	1	0	0	0	1
326 LOC. 9	A3218	3 (56)[e]	5 (49)[e]	3 (56)[e]	3 (53)[e]	14 (214)[e]
326 LOC. 10	A3222 (Combo)	9 (50)[f]	7 (40)[f]	8 (42)[f]	9 (49)[f]	33 (181)[f]
329 LOC. 1	A3071	0	0	0	0	0
329 LOC. 2	A3072	0	0	0	0	0
329 LOC. 4	A3074	0	1	0	1	2
329 LOC. 5	A3075	0 (11)[e]	0 (15)[e]	0 (8)[e]	1 (13)[e]	1 (47)[e]
329 LOC. 8	A3173	11	3	17	12	43
331 LOC. 1	A3044	1	1	1	1	4
331 LOC. 2	A3045	1	1	1	2	5
331 LOC. 3	A3046	3	2	3	(b)	8
331 LOC. 4	A3201	1	0	1	1	3
331 LOC. 5	A3202	2 (15)[e]	1 (14)[e]	2	2	7 (29)[e]
331 LOC. 6	A3203	0 (17)[e]	1 (19)[e]	1	1	3 (36)[e]
331 LOC. 7	A3204	8	9	8	7	32

Area Monitoring TLD Results for CY 2002[(a)] (continued)

TLD Location	TLD ID#	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)
		1st Quarter	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
331 LOC. 8	A3205	1 (26)[e]	2 (30)[e]	1	1	5 (56)[e]
331 LOC. 9	A3206	1	2	2	1	6
331C, LOC. 1	A3207	1	0	0	1	2
331D, LOC. 1	A3208	0	0	0	1	1
331H, LOC. 1	A3209	2	3	2	4	11
336-1, LOC. 1	A3073	3	3	3	3	12
337 LOC. 1	A3080	1	1	1	2	5
337 LOC. 2	A3081	2	2	3	4	11
337 LOC. 3	A3082	4	6	6	5	21
337 LOC. 4	A3083	1	3	4	4	12
337 LOC. 5	A3084	3	3	3	3	12
337 LOC. 6	A3085	4	4	4	3	15
338 LOC. 1	A3177	0	0	0	0	0
350 LOC. 1	A3004	0	0	0	1	1
350 LOC. 2	A3005	0	0	0	0	0
622R, LOC. 1	A3086	4	4	4	4	16
622R, LOC. 2	A3087	3	2	2	2	9
747A, LOC. 1	A3088	0	1	0	0	1
747A, Trl LOC. 1	A3089	0	0	0	0	0
2400 LOC. 1	A3113	0	0	0	0	0
2400 LOC. 2	A3114	0	0	0	0	0
2400 LOC. 3	A3115	0	0	0	0	0
2400 LOC. 4	A3116	0	0	0	0	0
3718A, LOC. 1	A3006	0	0	(d)	(d)	0

Area Monitoring TLD Results for CY 2002[(a)] (continued)

TLD Location	TLD ID#	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)
		1st Quarter	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
3720 LOC. 1	A3047	3	4	3	3	13
3720 LOC. 2	A3048	45	43	44	40	172
3730 LOC. 1	A3049	2	3	7	2	14
3760 LOC. 1	A3009	2	2	2	2	8
3760 LOC. 2	A3010	0	0	0	0	0
APEL LOC. 1	A3217	3	0	0	0	3
APEL LOC. 2	A3228	(c)	(c)	1	1	2
BRSW LOC. 1	A3227	(c)	1	3	1	5
EMSL LOC. 1	A3093	5	7	4 (18)[e]	6	22 (18)[e]
EMSL LOC. 2	A3094	8	7	6 (27)[e]	9	30 (27)[e]
EMSL LOC. 3	A3095	7	6	6 (84)[e]	8 (18)[e]	27 (102)[e]
EMSL LOC. 4	A3096	6	6	4	5	21
EMSL LOC. 5	A3097	4	5	4	5	18
EMSL LOC. 6	A3098	2	3	2 (21)[e]	3	10 (21)[e]
EMSL LOC. 7	A3211	0	0	0	1	1
EMSL LOC. 8	A3212	0	0	0	3	3
EMSL LOC. 9	A3213	0	0	0	0	0
EMSL LOC. 10	A3214	0	0	0	0	0
EMSL LOC. 11	A3219	0	0	0	0	0
EMSL LOC. 12	A3220	0	0	0	0	0
EMSL LOC. 13	A3223	0	0	0	0	0
EMSL LOC. 14	A3224	0	0	0	0	0
ESB LOC. 2	A3092	0	0	0	0	0
LSL-II LOC. 1	A3167	4	4	4	5	19
LSL-II LOC. 2	A3168	1	1	2	1	5
LSL-II LOC. 3	A3169	4	3	2	3	12

Area Monitoring TLD Results for CY 2001[(a)] (continued)

TLD Location	TLD ID#	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)	Deep Dose (mrem)
		1st Quarter	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
LSL-II LOC. 4	A3170	2	3	1	3	9
LSL-II LOC. 5	A3171	4	5	4	5	18
LSL-II LOC. 6	A3172	3	3	3	5	14
PSL LOC. 1	A3099	1	1	0	1	3
PSL LOC. 2	A3100	0	1	1	1	3
PSL LOC. 3	A3101	2	3	2	4	11
PSL LOC. 4	A3102	1	2	1	1	5
PSL LOC. 5	A3103	1	1	1	1	4
PSL LOC. 6	A3210	0	0	0	2	2
RTL LOC. 1	A3105	4	6	4	3	17
RTL LOC. 2	A3106	4	7	4	5	20
RTL LOC. 3	A3107	2	5	5	5	17
RTL LOC. 4	A3108	2	3	2	1	8
RTL LOC. 5	A3109	2	4	3	1	10
RTL LOC. 6	A3110	2	3	1	1	7
Sigma V, LOC. 1	A3186	0	0	0	1	1
Sigma V, LOC. 2	A3187	0	1	0	2	3
Sigma V, LOC. 3	A3188	0	1	0	1	2
Sigma V, LOC. 4	A3189	1	0	0	1	2
Sigma V, LOC. 5	A3190	0	0	0	4	4
Sigma V, LOC. 6	A3191	0	0	1	2	3

(a) - Multiply area TLD result by 0.23 to obtain dose estimates corrected for worker occupancy
(b) - Area TLD lost
(c) - Sample location not initiated yet
(d) - Sample location discontinued
(e) - Neutron dose from Hanford Standard Dosimeter
(f) – Neutron dose from Hanford Combination Neutron Dosimeter

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