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Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Area Monitoring Dosimeter Program for the Pacific Northwest National Laboratory: Results for CY 2004

S.R. Bivins
G.A. Stoetzel

June 2005

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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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 1993-2003 confirmed that personnel dosimetry was not needed for individuals located in areas monitored by the program.

Area thermoluminescent dosimeters (TDLs) were placed at 122 locations in PNNL facilities during calendar year 2004. 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

Summary iii

1.0 Introduction 1.1

2.0 Materials and Methods 2.1

2.1 Description of Area TLDs 2.1
2.1.1 Hanford Standard Dosimeter 2.1
2.1.2 Hanford Combination Neutron Dosimeter 2.2

2.2 Placement of Area TLDs 2.2

2.3 Frequency of Area TLD Exchange 2.3

2.4 Data Review 2.3

2.5 Quality Assurance and Quality Control 2.4

3.0 Results and Discussion 3.1

3.1 Area TLD Results (Deep Dose) 3.2

3.2 Area TLD Results (Deep + Neutron Dose) 3.3

4.0 Conclusions 4.1

5.0 References 5.1

Appendix A - Area TLD - Processing, Calibration, and Dose Assessment A.1

Appendix B - Locations of Area Monitoring TLDs B.1

Appendix C - Area Monitoring TLD Results for CY 2004 ..... C.1

Tables

3.1 Summary of Area Monitoring TLD Results, CY 2004 ..... 3.1

3.2 Estimated Annual Dose to an Individual at Selected Locations, CY 2004 ……. 3.5

3.3 Comparison of Neutron Doses between Hanford Standard Dosimeters and Hanford Combination Neutron Dosimeter, CY 2001 - 2004……. 3.6

Figures

3.1 Deep Dose Trend Data, CY 2004 ……..... 3.7

1.0 Introduction

The U.S. Department of Energy Standard on Radiological Control (DOE Standard) (DOE 2004), 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)(4), 401(a)(6), 402(a)(3), 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, 2002, 2003, and 2004). 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 2004 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 2004. The Hanford Standard Dosimeter was used at all locations; in addition, the Hanford Combination Neutron Dosimeter was positioned at two 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.

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

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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 2004. 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.
- near boundaries of RBAs established for dose purposes if dose rates are >20 µrem/h as determined by routine surveys

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

- 325 Building, Room 101
- 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.

The Hanford Combination Neutron Dosimeter in 326 Building, Room 28B used as an area TLD was placed on the front-face of the 5-gallon carboy filled with water. The Hanford Combination Neutron Dosimeter in 325 Building, Room 101 was placed on the bottom surface of the 5-gallon carboy since the neutron source was located below Room 101. 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.

Starting in CY 2005, area TLDs at the following locations will be changed to an annual exchange frequency: 622R, 747A, 747A Trl, 2400 Stevens, APEL, ESB, LSL-II, RTL, and Sigma V. PNNL (2004) provides the technical basis for extending the exchange frequency from quarterly to annually at these locations.

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 2004 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 five 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 four area monitoring TLD locations is found in Section 3.1.

Table 3.1 Summary of Area Monitoring TLD Results, CY 2004[a]

Parameter	Quantity
Number of area TLD locations	122
Total number of area TLDs analyzed in CY 2003	458[b]
Quarterly area TLD results by deep dose range:	
• ≤10 mrem	413
• >10 mrem but <40 mrem	26
• ≥40 mrem	19

a. This table provides data for routine area TLDs. No special area TLDs were located in the field during CY 2004.
b. The total number of area TLDs analyzed does not equal 488 (i.e., four times the number of area TLD locations) because locations were started and terminated at various times throughout the year.

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 two locations in CY 2004. 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 four locations where the combined deep and neutron dose results for CY 2004 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, APEL, BRSW, EMSL, ESB, LSL-II, PSL, RTL, and Sigma V) were ≤10 mrem except for EMSL Location 16. Four of the five locations with quarterly deep dose results ≥ 40 mrem "investigation level" were located in the 325 Building and the other in EMSL (i.e., Location 16). Figure 3.1 shows the trend of annual deep dose results at these locations since the PNNL program was initiated in 1993. Table 3.2 provides estimated annual doses to an individual at the locations for CY 2004 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 annual deep dose over the past 6 years has been relatively constant at approximately 200 mrem (see Figure 3.1). This dose is attributed to the building ventilation duct located near this area. 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 45 mrem during CY 2004 (see Table 3.2).

- TLD ID# A3175 (325, Loc. 5) was 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 at this location has increased since 1999 (see Figure 3.1). The increase in deep dose results over the past five years was attributed to storage of additional radioactive material in Room 528 located below this area. Accounting for occupancy, an individual could have received approximately 31 mrem during CY 2004 (see Table 3.2).

- TLD ID# A3196 (325, Loc. 7) was 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 2004 was 353 mrem and is trending downward from a peak reading of 488 mrem in CY2001 (see Figure 3.1). Dose is attributed to the building ventilation duct system located below the area. A monthly routine is performed in this area to verify postings and provide trend data. Accounting for occupancy, an individual could have received approximately 22 mrem during CY 2004 (see Table 3.2).

- TLD ID#A3240 (325, Loc. 13) was located outside of Room 600 at the entrance to the 600 Annex. This location was initiated during the second quarter of CY 2004; therefore, no annual trending data was available for Figure 3.1. The quarterly deep dose reading increased steadily for CY 2004. The projected annual deep dose for CY 2004 is ~420 mrem. Dose is attributed to the building ventilation duct system located below the area. A monthly routine is performed in this area to verify postings and provide trend data. Accounting for occupancy, an individual could have received approximately 25 mrem during CY 2004 (see Table 3.2).

- TLD ID#A3236 (EMSL, Loc. 16) was located in the northwest corner of Room 1544 of EMSL. This location is within a radiological buffer area (RBA), and was initiated during the fourth quarter of CY 2003. The quarterly deep dose readings for the third and fourth quarters increased nearly three times compared to the first and second quarterly doses. Co-57 sealed sources in Mossbauer spectrometers were used in this room. This increase is due to the addition of two more ^{57}Co sources. Accounting for occupancy, an individual could have received approximately 28 mrem during CY 2004. Since this area is posted as an RBA, workers in this area can receive greater than 100 mrem as they will have appropriate dosimetry.

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, over the past several years Hanford Combination Neutron Dosimeters have been placed at selected locations, which had elevated neutron readings on the Hanford Standard Dosimeters. During CY 2004, Hanford Combination Neutron Dosimeters were located at 1) 326, Loc. 9 (Rm 28B), and 2) 325, Loc. 12 (Room 101). 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 up to 9.7. The Hanford Standard Dosimeters in the 325 Building over-responded by a factor of 7.2 to 9.7 compared to those in 326 Building which over-responded by a factor of 1.0 to 3.6. 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 325 Building outside of Room 944. This location was initiated during 1993. Quarterly deep dose results for CY 2004 ranged from 15 to 24 mrem (84 mrem total for the year) which is similar to the quarterly results for previous years. Quarterly neutron doses ranged from 8 to 28 mrem (55 mrem total) for CY 2004, which is also similar to the quarterly readings for previous years. Using the 2.66 correction factor, the annual neutron dose for CY 2004 is estimated to be 21 mrem. Doses are likely due to radioactive materials found in laboratories directly below Room 944. Accounting for occupancy, an individual could have received approximately 6 mrem during CY 2004 (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 2004 ranged from 14 to 21 mrem (70 mrem total for the year) which is similar to the quarterly results for previous years. Quarterly neutron doses ranged from 22 to 45 mrem (140 mrem total) for CY 2004, which is similar to the readings for previous years. Using the 2.66 correction factor, the annual neutron dose for CY 2004 is estimated to be 53 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 7 mrem during CY 2004 (see Table 3.2).

- TLD ID #A3230 (325, Loc. 11) and A3231 (325, Loc. 12) were located in Room 101 of the 325 Building. These dosimeters were added during the third quarter of CY 2003 to better define neutron doses in the area. TLD #A3230 was a Hanford Standard Dosimeter and TLD #A3231 was a Hanford Combination Neutron Dosimeter. The annual deep dose result for CY 2004 was 71 mrem. Neutron results for this location are found in Table 3.3. Quarterly neutron dose results from the Hanford Standard Dosimeter were an average of approximately 8.5 times greater than the neutron dose results from the Hanford Combination Neutron Dosimeter at this location. The combined neutron dose result from the Hanford Combination Neutron Dosimeter was 33 mrem. Accounting for occupancy, an individual could have received ~24 mrem at this location during CY 2004 (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. For CY 2004, quarterly neutron dose results from Hanford Standard Dosimeter were up to 2 greater than dose results from the Hanford Combination Neutron Dosimeter at this location. Neutron doses for two of the four quarters exceeded 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 9 mrem during CY 2004 (see Table 3.2).

Table 3.2 Estimated Annual Dose to an Individual at Selected Locations, CY 2004

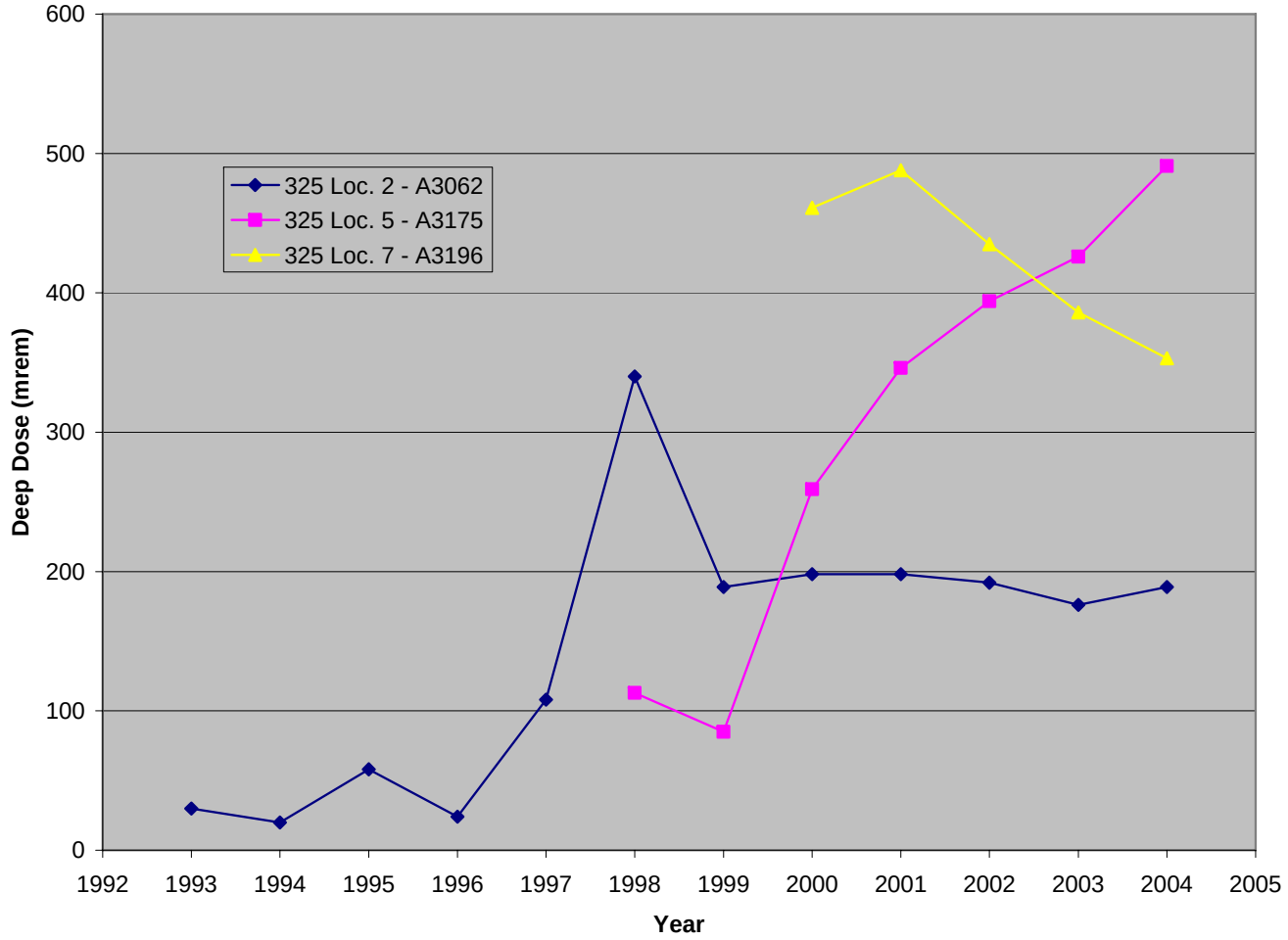
Location	Dosimeter Number	Annual Area TLD Reading (mrem)	Estimated Dose to Individual Assuming Full-Time Occupancy (mrem) [a]	Occupancy Factor	Estimated Annual Dose to Individual After Occupancy Corrections (mrem)
325, Loc. 2 (Rm 5)	A3062	194[b]	45	1	45
325, Loc. 3 (Rm 944)	A3063	105[c]	24	¼	6
325, Loc. 5 (east equip rm)	A3175	533[d]	123	¼	31
325, Loc. 7 (Rm 115/116)	A3196	376[e]	87	¼	22
325, Loc. 8 (hallway outside of Rm 101/102)	A3197	123[f]	28	¼	7
325, Loc. 11 and Loc. 12 (Rm 101)	A3230, A3231	104[g]	24	1	24
325, Loc. 13 (Rm 600)	A3240	430[h]	99	¼	25
326, Loc. 9 and Loc. 10 (Rm 28B)	A3218, A3222	165[i]	38	¼	9
EMSL, Loc. 16 (Rm 1544)	A3236	477	110	¼	28

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 2004 (189 mrem) and the neutron dose divided by 2.66 (12 mrem/2.66 = 5 mrem).
c. This dose represents the sum of the annual deep dose (84 mrem) and the annual neutron dose divided by 2.66 (55/2.66 = 21 mrem).
d. This dose represents the sum of the annual deep dose (491 mrem) and the neutron dose divided by 2.66 (112 mrem/2.66 = 42 mrem).
e. This dose represents the sum of the annual deep dose (353 mrem) and the neutron dose divided by 2.66 (62 mrem/2.66 = 23 mrem).
f. Dose was sum of deep dose reading (70 mrem) and neutron dose divided by 2.66 (140/2.66=53 mrem).
g. Dose was the sum of the deep dose reading (71 mrem) and the annual neutron dose (33 mrem). The neutron dose reading was taken the Hanford Combination Neutron Dosimeter (A3231).
h. This dose represents the sum of the projected annual deep dose (315 + 315/3 = 420 mrem) and the projected neutron dose divided by 2.66 (20/2.66 + 20/3/2.66 = 10 mrem).
i. This dose represents the sum of the annual deep dose (27 mrem) and annual neutron dose (138 mrem). The neutron dose reading was taken from the Hanford Combination Neutron Dosimeter (A3222).

Table 3.3 Comparison of Neutron Doses between Hanford Standard Dosimeter and Hanford Combination Neutron Dosimeter, CY 2001 -2003

Quarter	Neutron Dose (mrem)					
	325, Loc. 12 (Rm 101)			326, Loc. 9 (Rm 28B)		
	Std (A3230)	Combo (A3231)	Ratio (Std/combo)	Std (A3218)	Combo (A3222)	Ratio (Std/combo)
2001-1	-	-	-	82	23	3.6
2001-2	-	-	-	34	9	3.8
2001-3	-	-	-	68	44	1.6
2001-4	-	-	-	61	51	1.2
2002-1	-	-	-	56	50	1.1
2002-2	-	-	-	49	40	1.2
2002-3	-	-	-	56	42	1.3
2002-4	-	-	-	53	49	1.1
2003-1	-	-	-	46	38	1.2
2003-2	-	-	-	63	47	1.3
2003-3	121	13	9.3	68	55	1.2
2003-4	101	15	7.3	51	51	1.0
2004-1	89	12	7.4	61	56	1.1
2004-2	106	0	-	62	(missing)	-
2004-3	126	13	9.7	53	26	2.0
2004-4	69	8	8.6	67	56	1.2

Figure 3.1 CY 2004 Deep Dose Trend Data



4.0 Conclusions

The area monitoring TLD program for CY 2004 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.

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Appendix A

Area TLD - Processing, Calibration, and Dose Assessment

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

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	Room 916
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	A3230	LOC. 11	Room 101 (location in room)
325	A3231	LOC. 12	Room 101 (location in room) (Hanford Combination Neutron Dosimeter)
325	A3240	LOC. 13	Outside Room 600
325	A3241	LOC. 14	Second floor – in hallway between Room 955 and Room 956
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

BLDG	TLD ID #	Location ID #	Description of Location
326	A3068	LOC. 5	Second floor - corridor near Room 40-C
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)
326	A3229	LOC. 11	Room 17B/19B
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	A3205	LOC. 8	First floor - outside of Room 110
331	A3206	LOC. 9	Second floor in corridor opposite of Room 30
331	A3232	LOC. 10	Room 149
331	A3237	LOC. 11	Room 148 by RGD control panel
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

BLDG	TLD ID #	Location ID #	Description of Location
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
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
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
EMSL	A3235	LOC. 15	Room 1544 on north wall
EMSL	A3236	LOC. 16	Room 1544 northwest corner of room
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

BLDG	TLD ID #	Location ID #	Description of Location
PSL	A3103	LOC. 5	Corridor outside of Lab 315
PSL	A3238	LOC. 8	Rm 429, southwest wall by RGD
PSL	A3234	LOC 9	Rm 415
RTL	A3105	LOC. 1	Lab 428
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 2004

Appendix C

Area Monitoring TLD Results for CY 2004[(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	1	1	1	1	4
306W LOC. 1	A3034	3	3	(d)	(d)	6
306W LOC. 2	A3035	5	9	(d)	(d)	14
306W LOC. 3	A3036	1	1	(d)	(d)	2
318 LOC. 2	A3040	3	5	4	4	16
318 LOC. 4	A3192	2	2	0	0	4
318 LOC. 5	A3193	0	0	0	0	0
318 LOC. 6	A3194	0	2	4	2	8
318 TRL. 4	A3022	0	0	0	0	0
320 LOC. 1	A3042	0	0	0	0	0
320 LOC. 2	A3043	3	4	3	6	16
323 LOC. 1	A3195	1	4	4	3	12
325 LOC. 1	A3061	0	0	0	0	0
325 LOC. 2	A3062	42	50	46	51 (12)[e]	189 (12)[e]
325 LOC. 3	A3063	23	22 (8)[e]	24 (19)[e]	15 (28)[e]	84 (55)[e]
325 LOC. 4	A3174	0	0	2	0	2
325 LOC. 5	A3175	97	130 (21)[e]	114 (38)[e]	150 (53)[e]	491 (112)[e]
325 LOC. 6	A3176	17	15	18	29	79
325 LOC. 7	A3196	89	102 (22)[e]	71 (24)[e]	91 (16)[e]	353 (62)[e]
325 LOC. 8	A3197	17 (22)[e]	18 (45)[e]	14 (43)[e]	21 (30)[e]	70 (140)[e]

Area Monitoring TLD Results for CY 2004[(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	6	10	8	11	35
325 LOC. 10	A3199	11	11	12	11	45
325 LOC. 11	A3230	11 (89)[e]	20 (106)[e]	18 (126)[e]	22 (69)[e]	71 (390)[e]
325 LOC. 12	A3231 (Combo)	11 (12)[f]	18 (0)[f]	25 (13)[f]	17 (8)[f]	71 (33)[f]
325 LOC. 13	A3240	(c)	71	107 (20)[e]	137	315 (20)[e]
325 LOC. 14	A3241	(c)	7 (9)[e]	10 (22)[e]	11 (26)[e]	28 (57)[e]
326 LOC. 1	A3064	0	1	0	0	1
326 LOC. 2	A3065	2 (18)[e]	1 (22)[e]	1 (31)[e]	1 (31)[e]	5 (102)[e]
326 LOC. 3	A3066	0	1	0	1	2
326 LOC. 4	A3067	0	0	0	0	0
326 LOC. 5	A3068	0	0	0	0	0
326 LOC. 6	A3157	9	6	8	9	32
326 LOC. 7	A3178	1	3	1	2	7
326 LOC. 8	A3200	0	0	0	1	1
326 LOC. 9	A3218	3 (61)[e]	6 (62)[e]	3 (53)[e]	3 (67)[e]	15 (243)[e]
326 LOC. 10	A3222 (Combo)	8 (56)[f]	8 (0)[f]	2 (26)[f]	9 (56)[f]	27 (138)[f]
326 LOC. 11	A3229	0	8	11	23	42
329 LOC. 1	A3071	0	0	0	0	0
329 LOC. 2	A3072	0	0	4	0	4
329 LOC. 4	A3074	1	1	0	0	2
329 LOC. 5	A3075	0	0	0	0	0
329 LOC. 8	A3173	5	0	0	0	5
331 LOC. 1	A3044	1	1	0	0	2
331 LOC. 2	A3045	1	2	1	2	6
331 LOC. 3	A3046	2	2	2	3	9
331 LOC. 4	A3201	2	1	0	1	4

Area Monitoring TLD Results for CY 2004[(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. 5	A3202	7	7	7	6	27
331 LOC. 6	A3203	2	3	1	2	8
331 LOC. 8	A3205	8	5	1	7	21
331 LOC. 9	A3206	1	1	1	2	5
331, LOC. 10	A3232	3	5	5	6	19
331, LOC. 11	A3237	0	2	0	0	2
331C, LOC. 1	A3207	0	1	0	1	2
331D, LOC. 1	A3208	0	0	0	0	0
331H, LOC. 1	A3209	2	3	2	3	10
336-1, LOC. 1	A3073	1	2	2	2	7
337 LOC. 1	A3080	0	(d)	(d)	(d)	0
337 LOC. 2	A3081	4	(d)	(d)	(d)	4
337 LOC. 3	A3082	0	(d)	(d)	(d)	0
337 LOC. 4	A3083	0	(d)	(d)	(d)	0
337 LOC. 5	A3084	0	(d)	(d)	(d)	0
337 LOC. 6	A3085	0	(d)	(d)	(d)	0
338 LOC. 1	A3177	0	0	0	0	0
350 LOC. 1	A3004	0	0	0	0	0
350 LOC. 2	A3005	0	0	0	0	0
622R, LOC. 1	A3086	3	4	5	5	17
622R, LOC. 2	A3087	2	3	3	4	12
747A, LOC. 1	A3088	0	0	0	0	0
747A, Trl LOC. 1	A3089	0	0	1	0	1
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

Area Monitoring TLD Results for CY 2004[(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**
2400 LOC. 4	A3116	0	0	0	0	0
3720 LOC. 1	A3047	0	(d)	(d)	(d)	0
3720 LOC. 2	A3048	0	(d)	(d)	(d)	0
3730 LOC. 1	A3049	1	2	1	2	6
3760 LOC. 1	A3009	1	2	1	2	6
3760 LOC. 2	A3010	0	0	0	1	1
APEL LOC. 1	A3217	0	0	0	0	0
APEL LOC. 2	A3228	1	1	0	1	3
BRSW LOC. 1	A3227	2	3	1	1	7
EMSL LOC. 1	A3093	6	5	3	5	19
EMSL LOC. 2	A3094	7	9	6	6	28
EMSL LOC. 3	A3095	9	7	5	6	27
EMSL LOC. 4	A3096	9	5	3	4	21
EMSL LOC. 5	A3097	3	5	2	6	16
EMSL LOC. 6	A3098	5	2	1	3	11
EMSL LOC. 7	A3211	0	0	0	0	0
EMSL LOC. 8	A3212	0	0	0	0	0
EMSL LOC. 9	A3213	0	0	0	0	0
EMSL LOC. 10	A3214	1	0	0	1	2
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
EMSL LOC. 15	A3235	12	9	3	3	27
EMSL LOC. 16	A3236	76	51	188	162	477
ESB LOC. 2	A3092	0	0	0	0	0

Area Monitoring TLD Results for CY 2004[(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. 1	A3167	3	6	3	4	16
LSL-II LOC. 2	A3168	1	1	1	1	4
LSL-II LOC. 3	A3169	2	4	2	2	10
LSL-II LOC. 4	A3170	2	2	1	2	7
LSL-II LOC. 5	A3171	3	6	6	4	19
LSL-II LOC. 6	A3172	2	5	3	4	14
PSL LOC. 1	A3099	0	1	0	1	2
PSL LOC. 2	A3100	1	1	0	1	3
PSL LOC. 3	A3101	3	4	3	3	13
PSL LOC. 5	A3103	1	1	0	1	3
PSL LOC. 8	A3238	0	0	0	0	0
PSL LOC. 9	A3234	2	1	0	0	3
RTL LOC. 1	A3105	4	5	4	4	17
RTL LOC. 2	A3106	5	6	5	6	22
RTL LOC. 3	A3107	5	5	4	4	18
RTL LOC. 4	A3108	2	3	2	1	8
RTL LOC. 5	A3109	1	2	2	2	7
RTL LOC. 6	A3110	2	2	1	1	6
Sigma V, LOC. 1	A3186	2	0	0	1	3
Sigma V, LOC. 2	A3187	5	2	0	1	8
Sigma V, LOC. 3	A3188	1	1	0	1	3
Sigma V, LOC. 4	A3189	4	2	0	1	7
Sigma V, LOC. 5	A3190	1	1	0	1	3
Sigma V, LOC. 6	A3191	1	0	0	1	2

(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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