PNNL-13322

Pacific Northwest
National Laboratory
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Area Monitoring Dosimeter Program for the Pacific Northwest National Laboratory: Results for CY 1999

S. R. Bivins
G. A. Stoetzel

September 2000

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

In January 1993, Pacific Northwest National Laboratory (PNNL) established an area monitoring dosimeter program in accordance with Article 514 of the Department of Energy (DOE) Radiological Control Manual (RCM). 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 DOE Standard Radiological Control, 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 1993-1998 confirmed that personnel dosimetry was not needed for individuals located in areas monitored by the program.

A total of 123 area thermoluminescent dosimeters (TLDs) were placed in PNNL facilities during calendar year 1999. 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.

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1.0 Introduction

The Department of Energy Standard on Radiological Control (DOE Standard) (DOE 1999), first issued as the DOE Radiological Control Manual (RCM) in 1992, establishes practices for radiological control activities at DOE facilities. Article 514 of the DOE Standard 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 DOE Standard, area monitoring dosimeters

- 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[1] 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 CY 1993/1994, CY 1995, CY 1996, CY 1997, and CY 1998 are found in Bivins and Stoetzel (1996a), Bivins and Stoetzel (1996b), Bivins and Stoetzel (1997), Bivins and Stoetzel (1998), and Bivins and Stoetzel (1999), respectively. Data from the program was also used to support the PNNL As Low As Reasonably Achievable (ALARA) program.

The materials and methods used in collecting area monitoring TLD data and program results for CY 1999 are presented in this report. Neutron dose readings from the area TLDs were included in Section 3.0 of this report. 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 1999. The Hanford Standard Dosimeter was positioned at all but one location (3745 vault). The 3745 vault was used for storage of neutron sources; therefore, a Hanford Combination Neutron Dosimeter was positioned near the vault. The combination neutron dosimeter was discontinued at this location in the second quarter of CY 1999 when personnel vacated the building.

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. A more detailed description of each dosimeter and processing system is found in PNL-MA-568, *Hanford External Dosimetry Project Manual* (October 1996 issue).

2.1.1 Hanford Standard Dosimeter

This 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 plastic 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

This 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 the 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 and special area TLD locations is included as Appendix B. 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.

A review of area TLD locations in the 300 Area was performed during CY 1999 to verify compliance with the above placement criteria. Additional dosimeters were added to several facilities including 325, 326, and 331 to better comply with the placement criteria requiring one additional area TLD for every 15 staff members in facilities containing a radiological area. In addition, several area TLDs were placed around Lab 152 in the 331 Building to evaluate the impact of the addition of radioactive material from the 3720 Building.

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

Each Hanford Standard Dosimeter used as an area TLD was positioned facing the potential source of exposure. 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 facing the potential source. 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 for positioning this dosimeter.

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 for 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 Section 5 of PNL-MA-568 and Section 3 of PNL-MA-842, *Hanford External Dosimetry Project Technical Basis Manual* (September 1998 issue).

3.0 Results and Discussion

Table 3.1 summarizes area-monitoring TLD results for CY 1999. Quarterly area monitoring TLD results are grouped into dose ranges (i.e., ≤10 mrem; >10 mrem but <40 mrem; ≥40 mrem). In six locations, quarterly area monitoring TLD results (i.e., deep dose component) for routine locations 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.

Table 3.1. Summary of Area Monitoring TLD Results, CY 1999

Routine Area TLDs	**Quantity**
• Number of Area TLD Locations	123
• Total Number of Area TLDs Analyzed[(a)]	407
• Area TLD Results by Dose Range	
≤10 mrem	367
>10 mrem but <40 mrem	28
≥40 mrem[(b)]	12
Special Area TLDs	
• Number of Area TLD Locations	0
• Total Number of Area TLDs Analyzed	0
• Area TLD Results by Dose Range	
10 mrem	0
>10 mrem but <40 mrem	0
≥40 mrem[(b)]	0

(a) The total does not equal 492 (four times the number of TLD locations) because locations were started and terminated at various times throughout the year, and several samples were lost.
(b) The quarterly investigation level was 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 Routine Area TLD Results

Quarterly "deep dose" area monitoring TLD results for facilities located outside the 300 Area (622R, 747A, 747A Trl, 2400 Stevens, EMSL, ESB, HS-1, LSL-II, PSL, RTL, and Sigma V) were generally ≤10 mrem. One exception was a location in RTL that had a quarterly deep dose reading of 11 mrem. The

six locations with quarterly deep dose results greater than or equal to the 40 mrem "investigation level" were located in the 300 Area. Reviews were conducted on these locations and results are summarized below.

- TLD ID# A3062 (325 Loc. 2) was located in Room 5 of the mezzanine of 325 Building on the north wall about chest height. The total measured deep dose for CY 1993-CY 1996 ranged from 20-58 mrem. Total measured deep dose has increased in recent years to 108 mrem for CY 1997, 340 mrem for CY 1998, and 189 mrem for CY 1999. The upward trend in dose for the past three years is due to increased waste handling and storage activities in the basement of 325. Waste is frequently stored along the south wall of the basement just below Room 5. Routine surveys are taken in the mezzanine annually. The last survey conducted during October 1999 showed μrem readings ranging from 7 to 30 μrem/h, which were below the 50 μrem/h level, which requires posting as a Radiological Buffer Area. Based on the area TLD results for CY 1999, an individual conservatively assumed to spend 2000 hours/y in Room 5 near the north wall could have received 43 mrem. This dose is below the 50 mrem annual dose, which requires personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- TLD ID# A3176 (325 Loc. 6) was located in the copy room in the second floor office area of the 325 Building. The fourth quarter deep dose reading was equal to the 40 mrem "investigation level." Deep dose readings for the remainder quarters were less than 40 mrem. Readings for CY 1997 and 1998 were less than 20 mrem per quarter. Readings have doubled during CY 1999. The reason for the increased reading is likely an accumulation of waste in Lab 700 located directly under this area TLD. When corrected for worker occupancy, annual dose is projected at 25 mrem, well below the 50 mrem annual dose requiring personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- 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 new area TLD location started in the second quarter of CY 1999. The total deep dose readings for the final three quarters of CY 1999 was 306 mrem. Projected annual dose is ~400 mrem (or ~92 mrem assuming a worker is present 2000 hours per year). However, the occupancy factor for a hallway is ¼ per NCRP 1976; therefore, the adjusted projected annual deep dose is ~23 mrem. This is well below the 50 mrem annual dose requiring personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- TLD ID# A3178 (326, Loc. 7) was located on the second floor of 326 Building in Room 37B on the east wall. The deep dose reading for the first quarter was 41 mrem. Readings for all remaining quarters were less than the 40 mrem "investigation level" (13, 17, and 23 mrem respectively). This location was initiated in the fourth quarter of CY 1997. No other quarters had readings exceeding the "investigation level." When corrected for worker occupancy, annual dose for CY 1999 is projected at 22 mrem, well below the 50 mrem annual dose requiring personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- TLD ID# A3048 (3720 Loc. 2) was located on the bulletin board in the lunchroom of the 3720 Building. The total measured deep dose was 30 mrem for CY 1993, 120 mrem for CY 1994,

180 mrem for CY 1995, 146 mrem for CY 1996, 486 mrem for CY 1997, and 478 for CY 1998. Total measured deep dose for CY 1999 was 243 mrem, a significant decrease from the previous two years. As documented in past annual reports, the cause of the elevated readings 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 331 Building. This resulted in dramatic decrease in quarter readings from 133 mrem during the first quarter to 46 mrem, 31 mrem, and 33 mrem for the remaining quarters of CY 1999. As documented in past annual reports, TLD #A3048 is conservatively located on the wall next to the radioactive material. Therefore, doses to a member of the public, minor, or pregnant worker would be less than 50 mrem annually.

- TLD ID# A3185 (3745 Loc. 2) was located at the entrance to the radioactive material storage vault in the 3745 Building. This area TLD was a Hanford Combination Neutron Dosimeter and was placed in the field starting the third quarter of CY 1998. The TLD was located on the floor in front of the vault. This area dosimeter was removed after the first quarter of CY 1999 as 3745 Building was no longer an occupied facility and as such did not require an area dosimeter. Results for the first quarter of CY 1999 showed a deep dose of 24 mrem and a neutron does of 124 mrem. This was similar to results from previous quarters in CY 1998. A Hanford Standard Dosimeter, area TLD (TLD ID# A3158), located about 10 feet from A3185 showed zero dose for the first quarter of CY 1999. TLD ID# A3050 was located in the Counting Laboratory (north end of 3745 Building). This was the only routinely occupied area in 3745 Building and has had 0 mrem area TLD readings since it was initiated in CY 1993. Therefore, doses to a member of the public, minor, or pregnant worker would be less than 50 mrem annually.

Six area TLD locations had quarterly readings exceeding the 40 mrem "investigation level" when totaling the deep dose and neutron dose reading. Investigation of the results found that neutron dose results for area dosimeters are based on a calibration on phantom to unmoderated neutrons from bare ^{252}Cf. The neutrons reaching this area TLD location are moderated by intervening shielding and building material; therefore, the dosimeter was 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 can also be conservatively used to correct neutron readings for a location in 331 Building.

A discussion of the six locations where the neutron dose component prior to correction caused the 40 mrem "investigation level" to be exceeded is present below:

- TLD ID# A3175 (325 Loc. 5) was located in the lunchroom area of the east equipment room located on the second floor of the 325 Building. This location was initiated in the second quarter of CY 1997. The quarterly deep dose results and quarterly neutron dose results were similar to those reported in CY 1997 and CY 1998 (i.e., deep dose results ranged from 19-23 mrem and neutron dose results ranged from 23-36 mrem). The likely source of the neutron dose was Room 503, located beneath the east equipment room. Room 503 contains a fissile materials storage area. With the application of the

2.66 neutron correction factor discussed above, sums of the deep dose and neutron dose for each quarter were 30, 28, 32, and 37 mrem, less than the 40 mrem "investigation level."

- TLD ID# A3197 (325 Loc. 8) was located on the first floor of the 325 Building between Room 101 and 102. This new location was initiated during the second quarter of CY 1999. Deep dose quarterly results were 13, 38, and 38 mrem while the neutron quarterly results were 21, 17, and 33 mrem. After applying the neutron correction factor of 2.66, only the third and fourth quarters were above the 40 mrem "investigation level" when summing deep and neutron doses. The projected annual dose would be 147 mrem, reduced to 34 mrem after accounting for occupancy. This dose is below the 50 mrem annual dose, which requires personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- TLD ID# A3218 (326 Loc. 9) is located on the second floor of 326 Building in Room 28B under the window on the south wall. This new location was initiated during the fourth quarter of CY 1999. Deep dose quarterly result for the fourth quarter was 21 mrem. The neutron quarterly result was 35 mrem. Likely source of the neutron activity was source storage in room 9A. After applying the neutron correction factor of 2.66, the fourth quarter dose after summing deep dose and neutron dose was 34 mrem, which is below the 40 mrem "investigation level." The projected annual dose is 136 mrem, reduced to 31 mrem after accounting for occupancy. This dose is below the 50 mrem annual dose, which requires personnel dosimetry for declared pregnant workers, minors, or members of the public.

- TLD ID# A3202 (331 Loc. 5) is located on the first floor of 331 Building on a bulletin board on the east wall of Room 113A. This location was initiated during the second quarter of CY 1999. Deep dose quarterly readings were insignificant at ≤5 mrem. Neutron quarterly readings were 28, 38, and 44 mrem. The source of the neutron dose was $^{238}Pu/^{241}Am$ solution samples located in a shielded drum in Lab 152. This material was transferred from 3720 Building in April 1999. After applying the neutron correction factor of 2.66, none of quarterly dose readings were above the 40 mrem "investigation level" after summing deep and neutron doses. The projected annual dose was 65 mrem, but reduced to 15 mrem after accounting for occupancy. This dose is below the 50 mrem annual dose, which requires personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- TLD ID# A3203 (331 Loc. 6) is located on the first floor of 331 Building on the northeast wall of Room 164. This new location was initiated during the second quarter of CY 1999. Deep dose quarterly readings were insignificant at ≤8 mrem. Neutron quarterly readings were 45, 64, and 79 mrem. The source of the neutron dose was $^{238}Pu/^{241}Am$ solution samples located in a shielded drum in Lab 152. This material was transferred from 3720 Building in April 1999. After applying the neutron correction factor of 2.66, none of the quarterly dose readings were above the 40 mrem "investigation level" when summing deep dose and neutron dose. The projected annual dose was 112 mrem, only 26 mrem after accounting for occupancy. This dose is below the 50 mrem annual dose, which requires personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

- TLD ID# A3205 (331 Loc. 8) is located on the first floor of 331 Building outside of Room 110. This new location was initiated during the second quarter of CY 1999. Deep dose quarterly readings were insignificant at ≤2 mrem. Neutron quarterly readings were 35, 37, and 47 mrem. The source of the neutron dose was $^{238}Pu/^{241}Am$ solution samples located in a shielded drum in Lab 152. This material was transferred from 3720 Building in April 1999. After applying the neutron correction factor of 2.66, none of quarterly dose readings were above the 40 mrem "investigation level" when summing deep dose and neutron dose. The projected annual dose was 65 mrem, only 15 mrem after accounting for occupancy. This dose is below the 50 mrem annual dose, which requires personnel dosimetry for a declared pregnant worker, a minor, or a member of the public.

3.2 Special Area TLD Results

No special area TLDs were positioned in the field during CY 1999.

4.0 Conclusions

The area monitoring TLD program for CY 1999 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

Appendix A

Area TLD - Processing, Calibration, and Dose Assessment

A.1 Processing

Harshaw 8800 series automated reader systems were used to process the area 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 80°C for 16 h before being issued.

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

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

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-568 and Section 3 of PNL-MA-842.

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	A3039	LOC. 1	Front lobby
318	A3040	LOC. 2	Main corridor of second floor across from Room 202
318	A3041	LOC. 3	Main corridor outside instrument receiving
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 between Rooms 115 and 116
325	A3197	LOC. 8	First floor between Rooms 101 and 102
325	A3198	LOC. 9	Mezzanine, Room 76
325	A3199	LOC. 10	Mezzanine, Room 17
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
326	A3157	LOC. 6	Basement - Room 14A bulletin board
326	A3178	LOC. 7	Room 37B (second floor, east wall)

BLDG	TLD ID #	Location ID #	Description of Location
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
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
337	A3155	LOC. 7	Duplicating Room - north wall
338	A3177	LOC. 1	Conference Room/lunchroom (Room 24) – west wall
338	A3215	LOC. 2	Located by X-ray machine
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
2400	A3115	LOC. 3	High-bay bulletin board in entry to Lab 1445

BLDG	TLD ID #	Location ID #	Description of Location
2400	A3116	LOC. 4	Second floor on bulletin board outside of Room 2428
3718-A	A3006	LOC. 1	Bulletin board outside of main office
3718-B	A3007	LOC. 1	Above phone on north wall
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
3745	A3050	LOC. 1	Counting Laboratory - south wall
3745	A3158	LOC. 2	On wall about 10 ft from vault
3745	A3185	LOC. 2	In front of vault at floor level
3760	A3009	LOC. 1	Lobby
3760	A3010	LOC. 2	Second floor Room 215 (SE cubicle)
3760	A3011	LOC. 3	Second floor - copy room
APEL	A3217	LOC. 1	Room 102 on north wall by radiation generating device
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
ESB	A3091	LOC. 1	Inside of Room 14
ESB	A3092	LOC. 2	Entry way to Room 31
HS-1	A3179	LOC. 1	Room 88 – west wall
HS-1	A3180	LOC. 2	Room 88 – west wall near floor
HS-1	A3181	LOC. 3	Room 88 – north wall
HS-1	A3182	LOC. 4	Room 94 - east wall
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	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
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
Sigma V	A3216	LOC. 7	

Appendix C

Area Monitoring TLD Results for CY 1999

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	7	0	1	0	8
306W LOC.1	A3034	0	0	2	3	5
306W LOC.2	A3035	8	0	6	7	21
306W LOC.3	A3036	8	5	6	4	23
318 LOC.1	A3039	0	(d)	(d)	(d)	0
318 LOC.2	A3040	0	0	3	3	6
318 LOC.3	A3041	0	(d)	(d)	(d)	0
318 LOC.4	A3192	(c)	0	0	0	0
318 LOC.5	A3193	(c)	0	0	0	0
318 LOC.6	A3194	(c)	0	1	1	2
318 TRL.4	A3022	0	0	0	0	0
320 LOC.1	A3042	0	0	0	1	1
320 LOC.2	A3043	0	0	3	5	8
323, LOC.1	A3195	(c)	0	3	4	7
325 LOC.1	A3061	0	0	0	0	0
325 LOC.2	A3062	51	43	43	52	189
325 LOC.3	A3063	31	25 (13)[e]	22	23 (9)[e]	101 (22)[e]
325, LOC.4	A3174	0	0	1	0	1
325, LOC.5	A3175	20 (26)[e]	19 (23)[e]	23 (25)[e]	23 (36)[e]	85 (110)[e]
325, LOC.6	A3176	23	17	29	40	109
325, LOC.7	A3196	(c)	100 (20)[e]	97	109	306 (20)[e]
325, LOC.8	A3197	(c)	13 (21)[e]	38 (17)[e]	38 (33)[e]	89 (71)[e]
325, LOC.9	A3198	(c)	13	12	15	40
325, LOC.10	A3199	(c)	8	11	15	34
326 LOC.1	A3064	0	0	0	0	0
326 LOC.2	A3065	0	0	0 (14)[e]	1 (16)[e]	1 (30)[e]
326 LOC.3	A3066	0	0	1	0	1
326 LOC.4	A3067	0	0	0	0	0

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
326 LOC.5	A3068	0	0	0	1	1
326, LOC. 6	A3157	0	0	2	5	7
326, LOC.7	A3178	41	13	17	23	94
326, LOC.8	A3200	(c)	0	0	0	0
326,LOC.9	A3218	(c)	(c)	(c)	21 (35)[e]	21 (35)[e]
329 LOC.1	A3071	0	0	0	0	0
329 LOC.2	A3072	0	0	0	0	0
329 LOC.4	A3074	0	0	0	0	0
329 LOC.5	A3075	0	0 (20)[e]	0 (9)[e]	2 (13)[e]	2 (42)[e]
329, LOC. 8	A3173	0	6	5	7	18
331 LOC.1	A3044	0	0	1	2	3
331 LOC.2	A3045	0	0	2	2	4
331 LOC.3	A3046	0	0	2	3	5
331 LOC.4	A3201	(c)	0	0	1 (9)[e]	1 (9)[e]
331 LOC.5	A3202	(c)	0 (28)[e]	3 (38)[e]	5 (44)[e]	8 (110)[e]
331 LOC.6	A3203	(c)	0 (45)[e]	8 (64)[e]	5 (79)[e]	13 (188)[e]
331 LOC.7	A3204	(c)	10	15	4	29
331 LOC.8	A3205	(c)	0 (35)[e]	2 (37)[e]	2 (47)[e]	4 (119)[e]
331 LOC.9	A3206	(c)	0	1	2	3
331C, LOC.1	A3207	(c)	0	1	2	3
331D,LOC.1	A3208	(c)	0	2	1	3
331H, LOC.1	A3209	(c)	0	0	5	5
336-1, LOC.1	A3073	0	0	2	4	6
337 LOC.1	A3080	0	0	1	3	4
337 LOC.2	A3081	5	(b)	2	3	10
337 LOC.3	A3082	5	0	4	5	14
337 LOC.4	A3083	0	0	2	3	5
337 LOC.5	A3084	0	0	2	3	5

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
337 LOC.6	A3085	6	0	4	5	15
337, LOC. 7	A3155	8	0	6	8	22
338, LOC.1	A3177	0	0	0	0	0
338, LOC.2	A3215	(c)	(c)	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	7	0	5	7	19
622R LOC.2	A3087	0	0	3	4	7
747A LOC.1	A3088	0	0	0	0	0
747A Trl LOC.1	A3089	0	0	0	0	0
2400 LOC.1	A3113	0	0	0	0	0
2400 LOC.2	A3114	5	0	4	6	15
2400 LOC.3	A3115	0	0	0	0	0
2400 LOC.4	A3116	0	0	0	0	0
3718A LOC.1	A3006	0	0	2	1	3
3718B LOC.1	A3007	7	(d)	(d)	(d)	7
3720 LOC. 1	A3047	0	0	1	1	2
3720 LOC. 2	A3048	133	46	31	33	243
3730 LOC. 1	A3049	0	0	3	4	7
3745 LOC. 1	A3050	0	(d)	(d)	(d)	0
3745 LOC. 2	A3158	5	(d)	(d)	(d)	5
3745 LOC. 2	A3185	24	(d)	(d)	(d)	24
3745 LOC. 2	A3185	124 (f)	(d)	(d)	(d)	124 (f)
3760 LOC. 1	A3009	0	0	0	2	2
3760 LOC.2	A3010	0	0	0	0	0
3760 LOC.3	A3011	0	(d)	(d)	(d)	0
APEL, LOC.1	A3217	(c)	(c)	0	0	0
EMSL LOC.1	A3093	0	0	5	8	13
EMSL LOC.2	A3094	10	6 (13)[e]	7	10	33 (13)[e]

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
EMSL LOC.3	A3095	8	0 (25)[e]	6	9	23 (29)[e]
EMSL LOC.4	A3096	5	0	5	7	17
EMSL LOC.5	A3097	6	0	4	8	18
EMSL LOC.6	A3098	0	0 (12)[e]	1	3 (9)[e]	4 (21)[e]
EMSL LOC.7	A3211	(c)	(c)	0	0	0
EMSL LOC.8	A3212	(c)	(c)	0	0	0
EMSL LOC.9	A3213	(c)	(c)	0	0	0
EMSL LOC.10	A3214	(c)	(c)	0	0	0
ESB LOC.1	A3091	0	(d)	(d)	(d)	0
ESB LOC.2	A3092	0	0	0	1	1
HS-1, LOC.1	A3179	0	(d)	(d)	(d)	0
HS-1, LOC.2	A3180	0	(d)	(d)	(d)	0
HS-1, LOC.3	A3181	0	(d)	(d)	(d)	0
HS-1, LOC.4	A3182	0	(d)	(d)	(d)	0
LSL-II LOC.1	A3167	5	0	4	7	16
LSL-II LOC.2	A3168	0	0	1	4	5
LSL-II LOC.3	A3169	0	0	3	8	11
LSL-II LOC.4	A3170	0	0	3	5	8
LSL-II LOC.5	A3171	7	0	4	6	17
LSL-II LOC.6	A3172	0	0	4	6	10
PSL LOC.1	A3099	0	0	1	2	3
PSL LOC.2	A3100	0	0	0	2	2
PSL LOC.3	A3101	0	0	3	4	7
PSL LOC.4	A3102	0	0	1	3	4
PSL LOC.5	A3103	0	0	1	2	3
PSL LOC.6	A310	(c)	(c)	0	1	1
RTL LOC.1	A3105	6	0	4	6	16
RTL LOC.2	A3106	5	0	11	7	23
RTL LOC.3	A3107	5	0	5	7	17

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
RTL LOC.4	A3108	0	0	3	5	8
RTL LOC.5	A3109	0	0	2	3	5
RTL LOC.6	A3110	0	0	1	3	4
Sigma V, LOC.1	A3186	0	0	1	2	3
Sigma V, LOC.2	A3187	0	0	0	2	2
Sigma V, LOC.3	A3188	0	0	0	1	1
Sigma V, LOC.4	A3189	0	0	0	0	0
Sigma V, LOC.5	A3190	0	0	0	1	1
Sigma V, LOC.6	A3191	0	0	0	2	2
Sigma V, LOC.7	A3216	(c)	(c)	0	1	1

(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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