2

ORNL/TM-12365

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

Evaluation of Discrepancies Between Thermoluminescent Dosimeter and Direct-Reading Dosimeter Results

K. R. Shaw

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/TM-12365

Office of Radiation Protection

EVALUATION OF DISCREPANCIES BETWEEN THERMOLUMINESCENT DOSIMETER AND DIRECT-READING DOSIMETER RESULTS

K. R. Shaw

Date Published—July 1993

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I wish to thank Diane Embleton, Jo Ellen Francis, and Kim Sanders for helping throughout this project. They provided essential support in various parts of the project. Thanks should also go to Vince Bishop and Lynn Sowder for providing me with data collected from previous TLD and DRD comparisons, and to Kim McMahan and Randy Gorman for reviewing and providing comments on the report. I would also like to thank all those that attended the presentation of the preliminary results for this project and gave suggestions for further work.

EVALUATION OF DISCREPANCIES BETWEEN THERMOLUMINESCENT DOSIMETER AND DIRECT-READING DOSIMETER RESULTS

K. R. Shaw

ABSTRACT

Currently at Oak Ridge National Laboratory (ORNL), the responses of thermoluminescent dosimeters (TLDs) and direct-reading dosimeters (DRDs) are not officially compared or the discrepancies investigated. However, both may soon be required due to the new *U.S. Department of Energy (DOE) Radiological Control Manual*. In the past, unofficial comparisons of the two dosimeters have led to discrepancies of up to 200%. This work was conducted to determine the reasons behind such discrepancies. For tests conducted with the TLDs, the reported dose was most often lower than the delivered dose, while DRDs most often responded higher than the delivered dose. Trends were identified in personnel DRD readings, and it was concluded that more training and more control of the DRDs could improve their response. TLD responses have already begun to be improved; a new background subtraction method was implemented in April 1993, and a new dose algorithm is being considered. It was concluded that the *DOE Radiological Control Manual* requirements are reasonable for identifying discrepancies between dosimeter types, and more stringent administrative limits might even be considered.

---

1. INTRODUCTION

Currently at ORNL, each employee is assigned a TLD to determine occupational radiation exposure. Some employees (most often radiation workers) also receive a DRD, which allows self-monitoring of dose between TLD processing periods. TLDs are exchanged and processed on a quarterly schedule, while DRDs are read before and after work involving radiation exposure. The TLD results are considered the occupational dose of record. ORNL Health Physics Procedure RP-3.3 requires that "all employees and visitors issued a DRD shall record the dose they received during the entry, even if zero, on a Pocket Meter Data Sheet..."[1] This recording is usually done at the beginning and end of each day for those that regularly work in radiation areas. The results from the Pocket Meter Data Sheets are summed over the quarter and compared to the TLD results.

Comparative data collected at ORNL for the past several calendar quarters indicate the reported TLD results and the quarterly summed DRD response vary up to 200%. Some informal tests conducted by others placing TLDs and DRDs in radiation areas have also indicated similar discrepancies. At the present time, no investigations are done when the TLDs and DRDs differ. However, a commitment was made in response to a recent audit finding to investigate the cause of such discrepancies. Also, the new *DOE Radiological Control Manual*, when implemented, will require an investigation when the result from the DRD differs by more than 50% from the TLD result and the TLD result is greater than 100 mrem (ref. 2).

This study was undertaken to identify and document the magnitude of, and possible causes for, discrepancies between the TLD and DRD results. This study will also fulfill a commitment made in response to the audit findings and serve as a baseline document that can be used for future routine investigations.

2. PROCEDURE

2.1 SELECTION AND CALIBRATION

Twenty DRDs were collected from various users (usually from different complexes) and from assorted shipments. This was to ensure that DRDs used in this study represented the overall DRD population at ORNL. DRD chargers varied at different complexes; therefore, differences in the DRD responses due to the chargers were determined. Five of the DRDs were zeroed on two different primary types of chargers and the amount of drift was noted for each. The DRDs were then calibrated in air (as they are routinely done) to attain good data on their individual response. This was done to determine if any of the DRDs responded out-of-range or were off from the average. TLD cards were chosen at random from the available inventory.

2.2 CONTROLLED EXPOSURES

The first part of the experiment used controlled ^{137}Cs irradiations at the ORNL Radiation Standards and Calibration Laboratory (RaSCaL). Twenty DRDs and 24 TLDs were divided into four groups of six TLDs and five DRDs. Each DRD was paired with a TLD and the extra TLD of each group served as the transit dosimeter. The dosimeters in each group were irradiated together with the exception of the transit TLD. Groups 1 and 2 were irradiated to 40 mrem, and

Groups 3 and 4 were irradiated to 130 mrem. Some of the same dosimeters were used again in Groups 5 and 6, which were irradiated to 80 mrem. The exposures were done on a standard 30 x 30 x 15 cm polymethylmethacrylate (PMMA) phantom and the geometry was held constant for all irradiations. Figure 1 shows a diagram of how the dosimeters were placed on the phantom. The TLDs were annealed 7 d prior to irradiation to remove residual signal and to reduce the variability due to the loss of sensitivity (pre-fading). The TLDs were allowed to fade for 7 d after irradiation before reading. The DRDs were read immediately after irradiation and then again 7 d later. No difference was noted with the two readings.

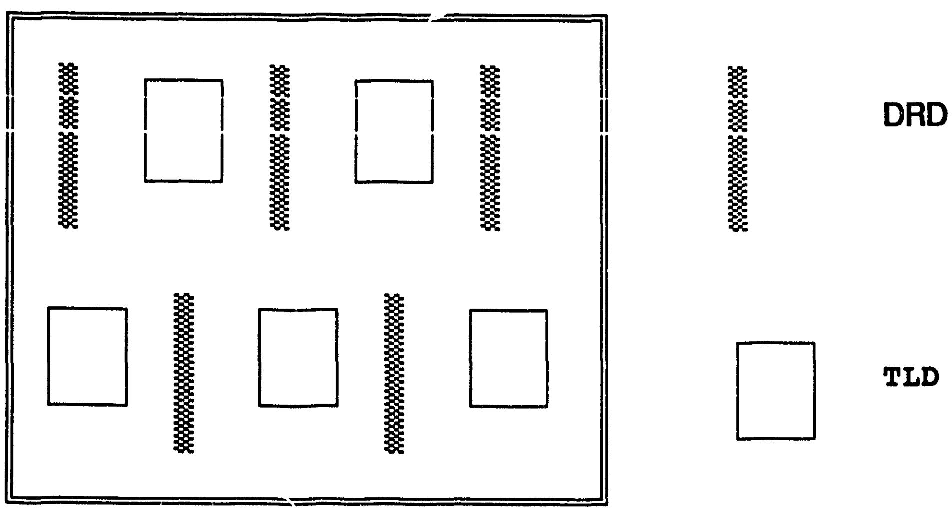

Fig. 1. Irradiation geometry on standard PMMA phantom for TLDs and DRDs at RaSCaL.

2.3 UNCONTROLLED EXPOSURES

The second part of the experiment took place at the High Flux Isotope Reactor (HFIR). These were general work area exposures for which many parameters (radiation type, delivered dose equivalent, angle of incidence, etc.) were not known. Four groups of five TLDs and five DRDs were placed in high-background areas around HFIR. These dosimeters were some of those used in the earlier tests, and they were placed in the same location in relation to one another as before. The dosimeters were placed in areas in which the general dose rate was unknown or varied depending upon the day or time. Two of the five DRDs out of each group were read on a weekly basis to determine the approximate dose the dosimeters were receiving. After 25 d of exposure, the four groups of dosimeters were returned to the lab to be read. Both the TLDs and the DRDs were read 1 d after they were retrieved from the field. As expected, each group of dosimeters reported a different exposure that was dependent on the location where they were placed. One of the four groups was placed in a lower background area; this resulted in values less than the TLDs' lower limit of detection and, therefore, this group is not included in the results of this paper.

2.4 HUMAN FACTORS

The last experimental part of this project looked at the possibility of human error involved in reading the DRD. Six people were asked to read a set of six DRDs that were charged to different levels ranging from 3 to 180 mR. Each person's interpretation was then recorded and compared. One person also tilted each of the dosimeters approximately +45° and -45° from the horizontal scale in order to determine the change in response due to position.

An evaluation of data from a HFIR informal test was also conducted. In this case, a comparison was done between TLD and DRD responses for actual people in the field. Each comparison was done over a quarter with two consecutive quarters completed. All discrepancies of the TLDs and DRDs were noted. The data was evaluated to determine any common link in the discrepancies, such as differences in TLD and DRD due to working division or dose level, and also to determine if people consistently read the DRD the same way.

3. RESULTS

3.1 CONTROLLED EXPOSURES

For irradiations performed at RaSCaL, the reading of the DRDs immediately following irradiation was the dose used for comparison; while the standard Martin Marietta Energy Systems, Inc. dose calculation algorithm was used to determine the reportable dose from the TLD readings. This algorithm first attempts to identify the radiation field components from ratios of the responses from the four thermoluminescent (TL) elements. Once the field components are identified, it calculates a correction factor for deep and shallow dose equivalent and applies it to the responses of the TLD's Elements 1 and 3, respectively. The correction factor calculation is based on calibration data, which can be averaged for a given component if the field is unknown (e.g., high-energy photons), or may be specified if the field is known (e.g., ^{137}Cs). For routine personnel dosimetry, the algorithm is run without specifying a particular calibration field. In order to determine the routine response of the TLDs, but also determine an optimal response, two versions of the dose calculation algorithm were run. For purposes of this report, running the algorithm without specifying the calibration field will be referred to as running the "TLD standard" algorithm, and running it using the known calibration field is referred to as running the "TLD optimal" algorithm.

In addition to this difference in the two versions, the TLD standard uses the routine average background subtraction, now used with all personnel dosimetry processing, while the TLD optimal uses the actual background values that were measured from a transit TLD dosimeter that was with each group of irradiated dosimeters. Another difference involved a new reader-output-to-dose-equivalent conversion factor (K-factor). In January 1993, this set of correction factors was redeveloped and implemented for Energy Systems, resulting in a change in ORNL's calculated dose. For the purpose of this report (which was to evaluate differences seen prior to the implementation of the new factors), the TLD standard runs use the older values, and the TLD optimal use the new.

Table 1 shows a summary of the DRD and TLD responses for the controlled exposures, using the average of ten dosimeters for each dose level. The values calculated show a fairly large negative bias for the TLD standard response and a

Table 1. Controlled exposures with ^{137}Cs at RaSCaL

Delivered dose from ^{137}Cs (mrem)		DRD	TLD standard[a]	TLD optimal[b]
40	Dose	41.1	33.9	39
	Bias[c]	*0.03*	*-0.15*	*-0.017*
80	Dose	81.0	70	79
	Bias[c]	*0.01*	*-0.12*	*-0.009*
130	Dose	130.9	109.5	125
	Bias[c]	*0.007*	*-0.16*	*-0.04*
Average of bias		0.02	-0.14	-0.02
Standard deviation		5.0	6.0	3.0

[a]TLD standard = default background, present K-factor, and no radiation field known.
[b]TLD optimal = actual background, new K-factor, and radiation field known.
[c]The TLD provided the reference dose: bias = [(TLD - DRD)/TLD].

small positive bias for the DRDs. Since the biases are in opposite directions and the "reference" TLD result is the smaller of the two, the relative bias appears even larger. By using the more accurate background and the known calibration field, the optimized TLD results are much improved over the TLD standard results.

Figure 2 shows similar data graphically. Again, the biases are in opposite directions with the TLDs' absolute bias larger than that of the DRDs'. Figure 3 shows how much the TLDs and the DRDs can vary over ten dosimeters. Here, the values range from 30 to 48 mrem when exposed to 40 mrem. Although the

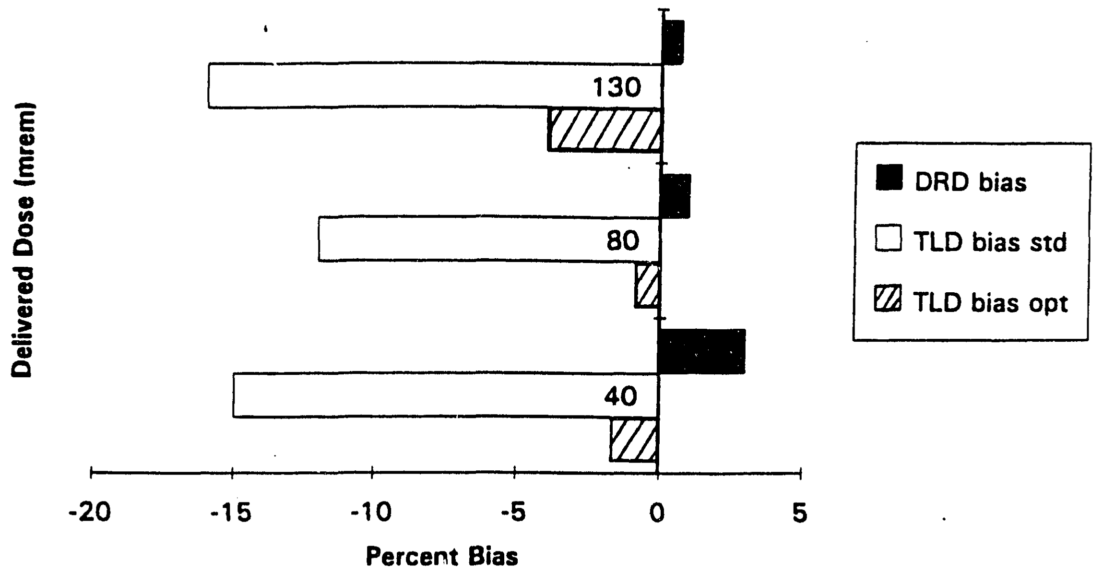

Fig. 2. Bias of both TLDs and DRDs for various levels.

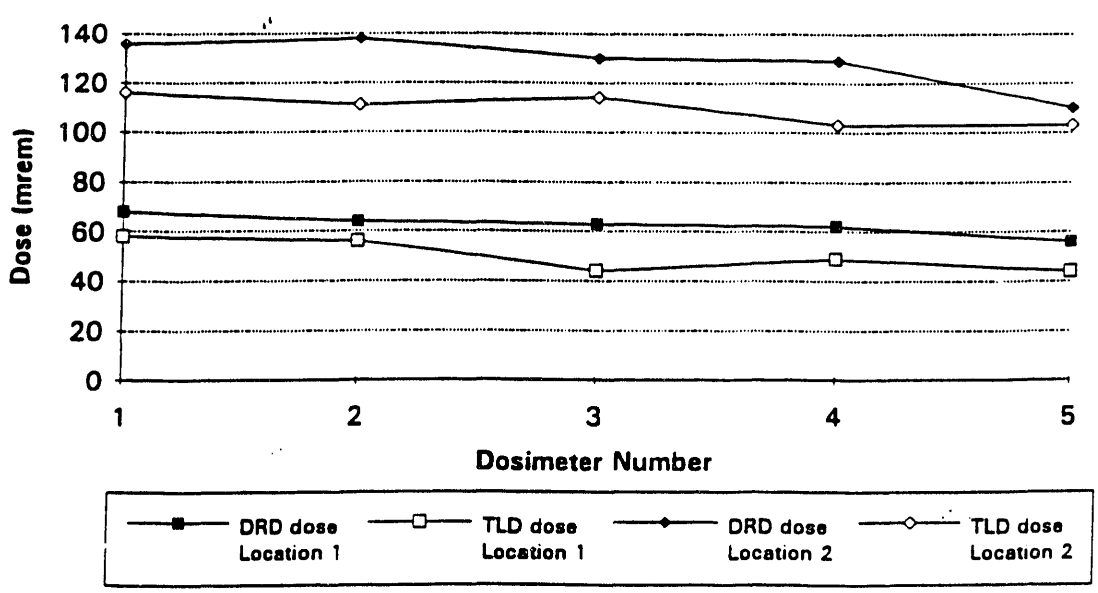

Fig. 3. Typical response of TLDs and DRDs.

average of each type of dosimeter is fairly close (37 mrem for the TLDs and 41 mR for the DRDs), the range is quite wide.

3.2 UNCONTROLLED EXPOSURES

Irradiations performed at HFIR were distributed over a 3-week period. Since the radiation type and the delivered dose equivalent were unknown in this part, only the results of the two dosimeters types could be compared to one another. These exposures better simulated real personnel exposures at ORNL because of the unknown radiation field and extended irradiation period.

Table 2 is a summary of the average DRD and TLD responses for the second set of exposures, where the percent difference is based on DRD vs TLD response. The TLD optimal in this case uses the new K-factor mentioned before, but the actual calibration factor and the background could not be input because both are unknown.

Table 2. Uncontrolled exposures at HFIR

DRD response (mR)		TLD standard response (mrem)	TLD optimal response (mrem)
62.6	Dose	50.2	46.8
	%diff[a]	*22*	*25*
122.0	Dose	110.2	105.8
	%diff[a]	*10*	*13*
128.6	Dose	109.6	102.4
	%diff[a]	*16*	*20*

[a]The DRD provided the reference dose: percent difference = [(DRD - TLD)/DRD] × 100 .

This optimal case does include a new background calculation method that was implemented in April 1993; therefore, the TLD optimal in Table 2 is actually the current dose calculation algorithm to be utilized by Energy Systems. This table shows that even in controlled (but unknown) conditions, errors between the TLD and DRD response still range from 10 to 25%.

Figure 4 shows graphically a comparison of the TLD and DRD responses from locations 1 and 2 at HFIR. The TLD is consistently lower than the DRD, and these relative differences are slightly larger than those seen at RaSCaL. It is assumed that the DRD's bias is slightly greater than at RaSCaL, because DRDs have been shown to perform better with a few large increments of dose (such as the one exposure at RaSCaL), rather than when the dose is delivered over many small increments (as at HFIR).[3]

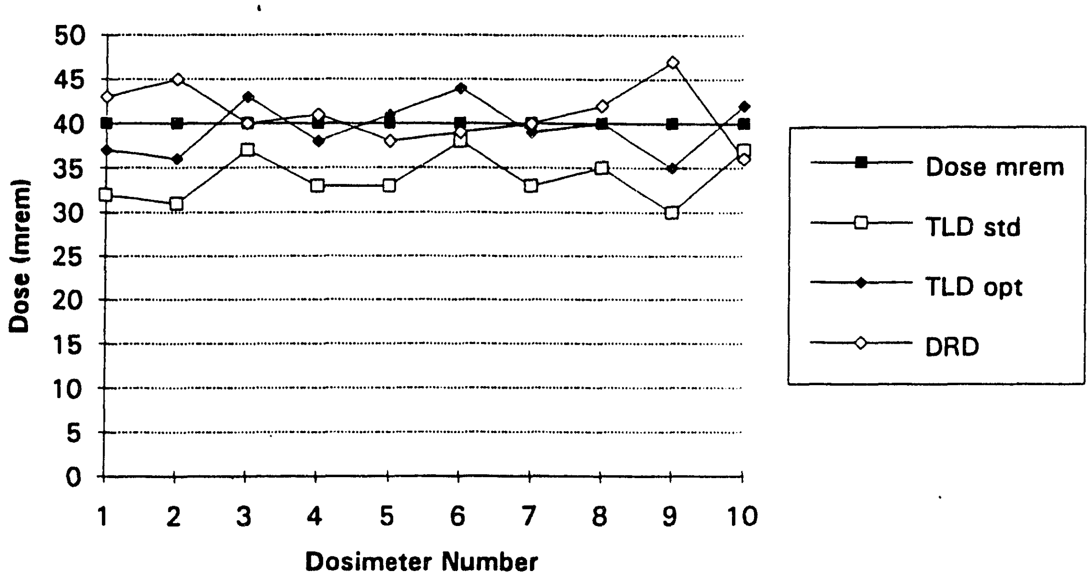

Fig. 4. Comparison of TLD and DRD responses in uncontrolled conditions.

3.3 HUMAN FACTORS

For the test involving various people reading DRDs, the responses ranged anywhere from 2 to 5 mR different for each DRD, with a standard deviation of 2 mR. The tilting of the DRD resulted in changes that averaged 6 mR. This is not enough information to substantiate any large errors due to the DRD, but it does show the variability of DRD dose recording among just a few different people.

While evaluating the DRD chargers used at various complexes, it was noted that most did not have a grounding circuit to prevent a "kick" in the DRD's fiber. For those that are careful and appropriately trained, this should not affect the response of the DRD; but for those that very quickly zero the DRD, or are inexperienced in doing so, this lack of the grounding circuit can result in an increase of the DRDs response up to 5 mR with each rezeroing.

When evaluating the TLD and DRD comparison done previously at HFIR, quite a few comparisons lead to discrepancies greater than 25%. Some of these differences were related back to certain people and/or certain groups of people. The differences in TLD and DRD readings are presented by division and quarter in Table 3.

It was thought that differences in TLD and DRD readings by division might occur due to different training received. This point seems to be obvious when looking at the results from the first quarter of 1992, but the second quarter is less clear. One thing that was apparent is that for generally larger average doses the

Table 3. Difference of TLD and DRD readings by division and quarter

Quarter	Division	Average TLD dose	Bias[a]	Standard deviation	|Bias| + std dev
1	ORP	93	-0.21	0.35	0.55
	PE	42	-0.26	1.25	1.51
	RRD	54	-0.23	0.33	0.56
	SS	27	-0.59	1.05	1.63
2	ORP	49	-0.48	0.65	1.13
	PE	14	-0.61	1.07	1.69
	RRD	24	-0.79	1.17	1.93
	SS	27	-0.37	0.86	1.23

[a]The TLD provided the reference dose: bias = [(TLD - DRD)/TLD].

average differences between dosimeters are smaller, and as the average doses decrease the differences become larger.

Another observation was made during the evaluation of the HFIR data. After reviewing each person's TLD and DRD response over two consecutive quarters, it was found that three-fourths of the people recording a DRD response read the DRD the same way over both of the quarters. They either overestimated the TLD dose both times, underestimated the TLD dose both times, or consistently read the DRD accurately.

Table 4 lists possible tolerance and threshold limits for the TLD and DRD comparisons and gives the percent of DRD results that would require investigation based on the sample of results analyzed in Sect. 2.4. The values used to generate this table were from personnel exposures obtained in the first and second quarters of 1992. Since changes in the TLDs' dose calculation algorithm have occurred since then, the data was recalculated using the current Energy Systems algorithm implemented in April 1993. This resulted in no changes to the data reported in Table 4.

The first tolerance and threshold limit from Table 4 is that required by the *DOE Radiological Control Manual*. It is the most lenient of the limits presented,

Table 4. Percent of measurable doses requiring investigation due to threshold and tolerance limits[a]

Threshold limit (mrem)	Tolerance limit (%)	Percent of doses requiring investigation (1992)	
		1st Quarter	2nd Quarter
100	±50[b]	0	0
50	±50	3	0
100	±25	1	0
50	±25	7	1
10[c]	±25	24	24

[a]Data from HFIR's first and second quarters 1992 TLD comparison; 123 TLD/DRD results evaluated per quarter.
[b]*DOE Radiation Control Manual* requirements.
[c]Essentially no threshold set (no reportable dose).

and there were no investigations required (mainly due to the threshold limit of the TLD response being greater than 100 mrem). The last limit presented in the table indicates the strictest possibility. It looks at all reportable doses and singles out discrepancies greater than 25%. This is what was to be investigated, as required by the recent audit finding. The three limits between the two extremes are possibilities for administrative limits that could be chosen depending on the results needed or the number of investigations wanted.

Tables 3 and 4 are expressed for 123 people evaluated during each quarter, but only half of those had a reportable dose in the first quarter and even less of those in the second quarter. Therefore, the percentages given in Table 4 are half of the actual percentage when only considering those that received a reportable dose.

4. DISCUSSION

4.1 TLDs—ERRORS DUE TO BACKGROUND SUBTRACTION

Our largest error (based on the results presented) is due to the fact that the standard algorithm frequently underestimates dose delivered by the ^{137}Cs source, while the DRD is biased slightly high. An average (though adjusted) background is subtracted from the TLDs for routine personnel dosimetry, because the background varies from home to home. A revised background subtraction method (which uses a lower background value than the previous method) was implemented in April 1993. This change improves the standard algorithm results during normal operations. However, this correction in the background subtraction method does not entirely eliminate the underestimation of dose, but decreasing the background accumulation rate causes significantly better agreement between TLD and DRD results for low doses.

4.2 TLDs—ERRORS DUE TO DOSE CALCULATION ALGORITHM

Most of the error found in the TLD response is due to the standard algorithm and the variability of Element 3 (L3). The algorithm criteria to determine the type of radiation field is based on six element ratios which are compared to each other. Often the criteria is just missed because of the variability of L3. This results in sending the algorithm to a less efficient step, rather than the best possible step. The algorithm is directed to certain steps that calculate a correction factor for a specific calibration field, depending upon the ratio of the chips in the dosimeter. For high-energy photons, the algorithm should go to Step 9 and apply the correction factor for intermediate- and high-energy photons, but if the ratio of L3/L2 or L3/L1 is above 1.10, the algorithm goes to Step 12 where a correction factor for photons of various energies is applied. If Step 9 is chosen, it applies a single correction factor, but Step 12 calculates the correction factor from the L3/L2 ratio. The calculated correction factor from Step 12 is about 13% lower than the single factor used in Step 9 when the ratio of L3/L2 is near 1.10 (ref. 4). The algorithm was forced through Step 9 to attain the optimal response. Since the radiation field was known, the dose was calculated from the proper step in the algorithm. Currently, a new version of the algorithm (which is expected to improve normal operational response) is being reviewed.

4.3 DRDs—ERRORS ASSOCIATED WITH DRIFT AND FREQUENCY OF READ

A DRD responds very well in controlled conditions (during calibrations and performance checks, the DRD must respond within 10% of the delivered ^{137}Cs dose). Errors are encountered when the DRD is taken out into the field, but these errors are difficult to test, although there are references to support the problems. Often the DRDs are not used or read correctly, but even when they are, more problems can exist when they are out in the field.

A few different kinds of chargers are used at ORNL, but most are battery-operated. The battery-operated ones do not have grounding circuits within the charger to remove residual charge on the DRD recharging pin. As determined before, this can result in a "kick" of 2 to 5% of the scale, as the charge is dissipated.[5] Also, the more frequently a DRD is read and recorded (and the size of the reading), the more likely it is to be in greater disagreement with the official dosimeter. This is due to round-off error, which frequents rezeroing compounds. This kind of disagreement usually results in a higher DRD response than the official dosimeter.[5]

Another factor contributing to the difference in the responses between DRDs and TLDs is the issue period. The longer the period for each, the worse the disagreement becomes. This is because the TLD is affected by fading, while the DRD is affected by additive reading and over-counting the longer it is out in the field. This problem is compounded at ORNL because the TLD and DRD are handled independently. The DRD's response is only recorded for certain time periods of the day at the discretion of the wearer. The total response of the DRD over a quarter is not recorded, although the total response of a TLD over a quarter is compared to it. Also, background is currently subtracted from the TLD's response, while it is not subtracted from the DRD's response.

4.4 DRDs—ERRORS ASSOCIATED WITH BACKGROUND AND DOSE RECORDING

The most accurate background subtraction for TLDs currently is approximately 0.75 mR/week, basing that on 24-h days. Although the total DRD response over 24 h is not used, there is background accumulated over the 8 h/d a person works. Therefore, approximately one-third of the background subtracted on TLDs should be applied to DRDs. This results in about 0.25 mR/week or 3 mR/quarter that should be subtracted from the gross response of the DRD. This background value is only accurate if the DRD was properly read and recorded over the quarter.

The way Pocket Meter Data Sheets (the sheets used to record DRD response) are designed, there is a tendency to record end doses incorrectly. A person records the reading of their DRD at the beginning of the day, and at the end of the day they are to record the reading of the DRD again. The difference of these two readings for each day is summed for the person's quarterly DRD response. If a person forgets to record an end dose at the finish of a day, the DRD reading at the beginning of the next work day is likely to be the response recorded for the missing reading. When this happens the background of the area in which the DRD is left is being recorded into the person's dose. This background can vary depending upon the location and is not subtracted from the DRD. It is also a different background than what the corresponding TLD is exposed to. This scenario results in a greater DRD response compared to the TLD. But the same situation could result in the DRD reporting lower than the TLD if no end dose was recorded at all, because the dose for the day would not be included in the persons quarterly comparison.

Another observation was that no conversion of milliroentgen (mR) to millirem (mrem) is accounted for in the comparison of TLDs and DRDs. Although this increases the response reported by the DRDs, it could be included. The Cx factor (a conversion factor of milliroentgen to mrem) is 1.03; therefore, all DRD responses should be multiplied by this factor in order to convert the DRD's response to millirem.

4.5 DRDs—ERRORS ASSOCIATED WITH HUMAN FACTORS

The interpretation of the reading itself is another problem encountered with the DRD. Everyone can read the DRD slightly different and, even if the difference is only a few milliroentgen, the summing of those errors can affect the dose greatly. The DRD should be read to the closest 1 to 2 mR, not to the closest scale or consistently rounding up or down. Most people tend to round up and, therefore, this yields a higher dose from the DRD than from the TLD.[5]

The effect of geotropism (gravity affecting the DRD fiber) should only vary within 5% of the DRD's scale, but small errors in reading the DRD add considerable errors over time.[3] A DRD can vary up to 6 mR at each reading (as shown from the data in Sect. 3.3), depending on the person reading it and how he is reading it.

When reviewing the HFIR data by division, the Office of Radiation Protection had the smallest average difference plus standard deviation of any of the other divisions evaluated during both quarters. This seems to relate to two things: (1) they generally receive the largest doses, and (2) they are also usually the most extensively trained in DRD and TLD dosimeters. This not only indicates that more training should be given to all employees wearing a DRD and TLD, but since the difference of the DRD and TLD is always negative (the DRD greater than the TLD), background and/or over-counting is added into the DRD doses. This would create a larger difference in the two dosimeters at low doses, but have less of an affect on the higher dose responses.

The observation made with the HFIR data that people do tend to read the DRDs consistently backs up other references mentioned in the report. This also demonstrates the need for increased training on the use of DRDs. Those people who consistently overestimate or underestimate their DRD response can be retrained on how to read the DRD more accurately.

The data presenting optional threshold and tolerance limits indicate the amount of work that might be required with each of the limits. However, more time will be required in investigating those TLD and DRD comparisons that fall outside the limit as the limit becomes more strict. It has to be determined what threshold and tolerance is needed within Energy Systems to be the most beneficial in investigating TLD and DRD response. Both the average dose and the dose range throughout the site should be considered, along with the limitations of the dosimetry systems used.

5. CONCLUSIONS

There are two main reasons why the TLD and DRD differ in comparisons. One of the reasons results largely from the way they are treated, mainly because the DRD has a less standardized method of use. Some DRDs are taken home and others are left at work, while all the TLDs are kept with the people they are assigned to. The DRDs are zeroed at varying times and response levels and are read at different times. More control should be added to the systems if a similar response is required between the two different dosimeter types.

The other reason for the differences is due to the TLD algorithm and the background subtraction method. It is believed that the implementation of the new background subtraction method will improve the ability of the algorithm to correctly determine the radiation field. The ratios of the chip responses should be slightly different after the modification of the background values for each chip. Only a small variation in the element ratios is needed, since usually the algorithm determines the wrong calibration field due to only a very small difference in the ratio and the limits.

Currently, improved methods of determining TLD results (as mentioned in this report) are being developed and implemented. Possible improvements for DRD results include standardizing policies for rezeroing, reading, and recording DRD responses. Some errors are inherent in the systems, and other problems may be due to the limitations of the systems. These errors are difficult to improve upon and, therefore, any preventable errors should be reduced until better resources are available.

The *DOE Radiological Control Manual* requirements for TLD and DRD comparison are very reasonable, and more stringent administrative limits could be set. A lower threshold between 50 and 100 mrem could be used at ORNL since occupational doses do not often exceed these values. The tolerance could reasonably vary from 25 to 50% depending on the limit of the threshold, because as the threshold increases, the tolerance can decrease due to generally better responses at higher doses.

REFERENCES

1. Procedure RP-3.3, "Personnel Monitoring," Rev. 2, *ORNL Health Physics Manual: Procedures and Practices for Radiation Protection and Radiation Monitoring*, Oak Ridge National Laboratory, Oak Ridge, TN, November 1991.

2. *U.S. Department of Energy Radiological Control Manual*, DOE/EH-0256T, U.S. Government Printing Office, Washington, D.C., June 1992.

3. *A Good Practice for the Comparison of Dosimetry Results,* REN/EPN-03, Institute of Nuclear Power Operations, Radiological Experience Notebook, 1982.

4. "Dose Calculation Algorithm for The Department of Energy Laboratory Accreditation Program," ALGM-D-U-0591-002, Solon Technologies, Inc. (Harshaw/Bicron), Solon, OH, May 1991.

5. *A Good Practice for Conduct of a Direct Reading Dosimeter Program (Quartz Fiber Pocket Dosimeter),* REN/EPN-02, Institute of Nuclear Power Operations, Radiological Experience Notebook, 1982.

INTERNAL DISTRIBUTION

1-6. A. B. Ahmed
7. R. V. Bishop
8. J. S. Bogard
9. R. S. Bogard
10. S. W. Croslin
11. E. Dixon
12. T. C. Dodd
13. B. D. Embleton
14. R. W. Fields, Jr.
15. J. E. Francis
16. E. L. Frome
17. W. R. Gorman
18. R. J. Gunter
19. J. B. Hunt
20. C. E. Maples
21. G. T. Mei
22. R. L. Mlekodaj
23. K. J. Nugent
24. K. G. Sanders
25. L. J. Schwanke
26-35. K. R. Shaw
36. C. S. Sims
37-40. M. L. Souleyrette
41. C. L. Sowder
42. M. Thein
43. Central Research Library
44-45. Laboratory Records
46. Laboratory Records-RC
47. ORNL Patent Section
48. ORNL Y-12 Technical Library

EXTERNAL DISTRIBUTION

49. Office of Assistant Manager for Energy Research and Development, Department of Energy, Oak Ridge Operations, P.O. Box 2001, Oak Ridge, TN 37831-8600
50-51. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831
52. J. J. Fix, Battelle-Pacific Northwest Laboratory, Battelle Boulevard, Richland, WA 99352
53. H. J. Monroe, Department of Energy, Oak Ridge Operations, P.O. Box 2001, Oak Ridge, TN 37831
54. J. W. Poston, Texas A&M University, Nuclear Engineering Department, College Station, TX 77843-6443
55. R. A. Tawil, Harshaw/Bicron Radiation Measurement Products, 6801 Cochran Road, Solon, OH 44139
56. C.-F. Wu, Waste Isolation Pilot Plant, P.O. Box 2078, Carlsbad, NM 88221

END

DATE
FILMED
9 / 24 / 93