QUALITY CONTROL PROGRAM FOR
THE HANFORD EXTERNAL DOSIMETRY
THERMOLUMINESCENT PROCESSING SYSTEM

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SUMMARY

The Hanford External Dosimetry Program is operated by Pacific Northwest Laboratory for the U.S. Department of Energy (DOE). The program records official external occupational radiation doses for all Hanford Site employees and visitors in compliance with DOE Order requirements. This report documents the quality control (QC) program for External Dosimetry's thermoluminescent dosimeter (TLD) processing system.

The focus of the External Dosimetry Program has been 1) to accurately calculate personnel radiation doses, and 2) to document the methods used to report doses in order to meet DOE Laboratory Accreditation Program (DOELAP) criteria. The purpose of this report is to describe the QC procedures used for dosimeters and processing equipment. Use of QC procedures allows for the prompt correction of unusual data before it is reported.

With minimal impact on routine processing, the External Dosimetry Program continues to provide quality dose results, meet DOELAP criteria, and pass DOELAP testing requirements. DOELAP test methodologies are used during each processing to ensure that the reported doses for the audit and control dosimeters meet DOELAP criteria and QC system goals. The lower limit of detection has been reduced; thus, increasingly lower doses can be reported.

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1.0 INTRODUCTION

The Hanford External Dosimetry Program is operated by Pacific Northwest Laboratory (PNL)^(a) for the U.S. Department of Energy (DOE), Richland Field Office (RL). The program is a multifaceted effort, involving all Hanford Site contractors and RL. Official external occupational radiation doses are recorded by External Dosimetry for all Hanford Site employees and visitors in compliance with the requirements of DOE Order 5480.15 (DOE 1987) and DOE Order 5480.11 (DOE 1988). Radiological protection services are also provided by PNL to Hanford contractors under the Internal Dosimetry Program, the Instrument Calibration and Evaluation Program, and the Hanford Radiological Records Program.

The Hanford External Dosimetry Program is technical in nature and involves significant quality control (QC) for the dosimeters and equipment used. The thermoluminescent dosimeter (TLD) reader processes dosimeter inserts by measuring the light photons released from the dosimeters' thermoluminescent chips. The light output from the thermoluminescent chips is proportional to the dose received, thereby determining the radiation dose received by the dosimeter wearer.

This report describes External Dosimetry's QC program for the TLD processing system. The system must meet the performance criteria described in the DOE Standard for the Performance Testing of Personnel Dosimetry Systems (DOE 1986a) and the Handbook for the DOE Laboratory Accreditation Program for Personnel Dosimetry Systems (DOE 1986b). As designed and modified by PNL, Hanford dosimeter readers and inserts provide maximum automation and have continued to be in compliance with Hanford performance criteria since 1970.

1.1 PNL EXTERNAL DOSIMETRY PERSONNEL

Technical direction for the design, calibration, processing, and dose determination of Hanford personnel dosimeters is provided by External Dosimetry staff. External Dosimetry staff include a technical program manager,

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several supporting technicians, and scientific and clerical staff. Senior personnel have many years of dosimetry experience and are responsible for the program's technical direction.

1.2 QUALITY CONTROL RESPONSIBILITIES

Specific quality control (QC) responsibilities for staff are identified in the program records. Staff responsibilities include the following program elements:

1. Equipment log books are maintained for all reader systems showing maintenance and calibration. Procedures are followed for each system's operation. Routine processing is automatically stopped whenever established limits are exceeded. It is the responsibility of the technical operating staff to ensure that the equipment is performing within established limits. If operation within limits cannot be established, the dosimeter processing group leader shall be contacted. It is the group leader's responsibility to obtain maintenance, calibration, and/or servicing prior to resuming routine processing.
2. A formal review of audit dosimeter results is performed to determine the adequacy of the routine dosimeter processing. For the results to be acceptable, the difference between reported and given doses for audit dosimeters must fall within predetermined criteria.
3. Maintaining and updating documentation for the External Dosimetry Program is an ongoing responsibility of program staff. Copies of the formal QC reports, dosimetry evaluations, and special study evaluations are provided for the program's historical file.
4. Copies of program correspondence involving methods and procedures for assessing personnel dose are provided to the Hanford Radiological Records for long-term storage. Copies of each Dosimeter Processing Acceptance form, which show the results of the audit dosimeters, are included. Records of all significant program activities are maintained.
5. Significant communication between External Dosimetry, Radiological Records, and Hanford contractor radiation protection staff is necessary to properly assign dosimeters, collect dosimeters for processing, and report dose. Much of the communication takes place through electronic means. The monthly cycle of External Dosimetry's audit and QC activities is shown in Figure 1.1.
6. Hanford contractor radiation protection staff communicate their needs for specific types of dosimeters and for the exchange

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FIGURE 1.1.1. Monthly Cycle of External Dosimetry's Audit and Quality Control Activities

frequency of personnel dosimeters by updating an electronic file maintained by Radiological Records. This file is retrieved monthly by External Dosimetry, and dosimeters are labeled with the appropriate information. Dosimeter assignments are communicated electronically back to Radiological Records, and External Dosimetry distributes dosimeters to Hanford contractor radiation protection staff for assignment to personnel.

7. Once old dosimeters have been exchanged for new dosimeters, Hanford contractors send the old dosimeters to External Dosimetry for processing and dose assessment. Following technical and QC evaluation, personnel dose records are sent to Radiological Records, where the information is made electronically available to Hanford contractor radiation protection staff.

Extensive analyses are performed to ensure that individual dose results comply with dose standards and that work with collective dose data is being conducted according to the "as low as reasonably achievable" requirement. The following QC features are incorporated into the program.

1. The responses of all personnel dosimeter holders and inserts, as well as the individual chips used in Hanford ring dosimeters, are evaluated based upon known levels of radiation exposure. All dosimeter inserts receive a unique identification number. A history is maintained for the exposure received by each personnel dosimeter. This history indicates the person to whom the dosimeter was assigned, as well as a summary of the dose results, time of exposure, etc. Control dosimeters (both zero dose and 1-R ¹³⁷Cs-irradiated) are included with all routine dosimeter processings.
2. The automated TLD reader, shown in Figure 1.2, is microprocessor-controlled with predetermined limits for reader sensitivity, dark current, and control dosimeters. Several other hardware parameters (e.g., high voltage to the photomultiplier tube [PMT], pneumatic pressure, flow of nitrogen gas, etc.) are monitored to ensure that the reader is functioning properly. If predetermined limits are exceeded, the reader stops processing and sounds an alarm. The Atlas hot gas reader has been automated and has a similar set of predetermined limits. For processing to continue, the operator is required to follow documented procedures for either the automated or manual reader system.
3. A formal procedure is followed to accept the results for a routine dosimeter processing. There are 17 dosimeter processings each year: 12 monthly, 4 quarterly, and 1 annual. Both audit and control dosimeters are included in each processing. The radiation type and dose levels used to irradiate the audit dosimeters are unknown to the processing staff; in some cases, processing staff are unaware that audit dosimeters are being processed.

FIGURE 1.2. Hanford Automated TLD Reader

4. A formal procedure is followed to determine the acceptability of audit dosimeter results. The differences between reported and given doses for each dosimeter type (i.e., basic, multipurpose, beta/photon, and ring dosimeters) and radiation category (e.g., 16-keV photons, ^{137}Cs gamma, total neutrons, etc.) are plotted. At least 80% of the results must fall within the predetermined limits. Dosimeter Results Acceptance forms (Figure 1.3) and Dosimeter Processing Quality Control forms (Figure 1.4) are used for each routine processing. Any abnormalities (e.g., adjustments to the calibration coefficients, processing controls not used, reader maintenance required, etc.) are noted on these forms. The Dosimeter Results Acceptance form is signed by the processing staff supervisor and the QC representatives conducting the dosimeter acceptance evaluation. A copy of the signed form is then sent to Radiological Records.
5. Each record generated by the Hanford automated readers is assigned a unique sequence number. Primary types of records include program records, dosimeter results, and individual dose evaluations. Individual dose records are maintained by Radiological Records on an interactive, computer-based Occupational Radiation Exposure (ORE) system. All records for each dosimeter processing are maintained by External Dosimetry. These records include the processing of audit and control dosimeters, internal light sources, dark-current readings, and personnel dosimeters. Similar records are maintained for ring dosimeters processed with the manual reader. External Dosimetry maintains a file of the reader log, which provides a hard-copy record of all results generated by each automated reader system.

The following sections contain the QC processes currently being used by External Dosimetry in the areas of 1) audit dosimeter evaluation, 2) reader processing tolerance, 3) reader maintenance, 4) detecting abnormal dosimetry data, 5) glow curve analysis, 6) statistical analysis of data, 7) dosimeter result acceptance, and 8) QC documentation.

Dosimeter Result Acceptance

Processing Review

Run: _____ Annual Quarterly Monthly
(Month/Year)

Reader # _____ Sequence Number: Beg. _____ End: _____

Ring Calibration Factors: B0: _____ C1: _____ C2: _____

Final Calibration Factors:

C ₀ _____	C ₃ _____	C ₆ _____
C ₁ _____	C ₄ _____	C ₇ _____
C ₂ _____	C ₅ _____	C ₈ _____

Blanks: B0: _____ B1: _____ B2: _____ B3: _____ B4: _____ B5: _____

Corrections to be applied to dose results*:

<u>Dosimeter</u>	<u>Shallow</u>	<u>Deep</u>	<u>Total Neutron</u>	<u>Eye</u>
Finger Rings	_____	_____		
Basics	_____	_____		
Multipurpose	_____	_____	_____	_____
Beta/Photon	_____	_____		

*Reported results X indicated factor.

Comments: _____

Processing Acceptance: _____ Date: _____

Technical Acceptance: _____ Date: _____

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FIGURE 1.3. Dosimeter Results Acceptance Form

Dosimeter Processing Quality Control Form					
a. Processing/Reader: _____					
b. Form Prepared by: _____					
c. Radiation Exposure: _____					
Have three days elapsed between exposure and readout for check dosimeters? (Y/N) _____					
Problems: _____					

d. Dosimeter Processing Controls					
Identify number, type of check or blank (1T, 0T, 7T, 2T) dosimeter results which exceed established reader control limits. Describe any actions taken to maintain dosimeter processing within established quality control tolerances.					
<u>Number</u>	<u>Dosimeter ID</u>	<u>Out of Limits</u>	<u>Not Used in Calibration</u>		
_____	_____	_____	_____		
_____	_____	_____	_____		
_____	_____	_____	_____		
e. Reader Maintenance					
Identify any unscheduled reader maintenance (1) or quality control limit (2) change which occurred during this processing					
<u>Sequence Number</u>	<u>Type</u>	<u>Description</u>	<u>Sequence Number</u>	<u>Type</u>	<u>Description</u>
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
f. Comments _____					

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FIGURE 1.4. Dosimeter Processing Quality Control Form

2.0 AUDIT DOSIMETER EVALUATION

Each month, computer codes are executed to randomly assign doses to a selected pool of field audit and open audit dosimeters, and the assigned doses are not disclosed to the processing staff. The open audit dose assignments are recognized as such by the processing staff and are spaced uniformly throughout the processing. Field audit dosimeters, however, are handled in the same manner as other personnel dosimeters and are processed as they come from the field. Currently, neither open audit nor field audit dosimeters are used to calibrate the automated reader system. Both types of audit dosimeters are used by QC staff to determine the acceptability of each run after results are complete and before electronically transferring the information to Radiological Records.

Basic and ring audit dosimeters are irradiated to ^{137}Cs only. Beta/photon audit dosimeters are irradiated to ^{137}Cs , $^{90}\text{Sr}/^{90}\text{Y}$, and 17-keV k-fluorescence x-ray (shallow). The multipurpose audit dosimeters are irradiated to ^{137}Cs , 17-keV x-ray, bare ^{252}Cf , and mixtures of bare ^{252}Cf and ^{137}Cs .

When data processing is complete, QC codes are executed to process the dose and ring files before they are electronically transferred to the ORE system at Radiological Records. Given doses are compared with reported doses for all audits, and plots are created showing the results for each type of irradiated dosimeter. Figure 2.1 shows an example of beta/photon audit dosimeters exposed to three types of radiation.

Audit dosimeter results exceeding predetermined limits are noted on the run acceptance forms with explanations for the deviations (if this can be determined at the time of the audit). Lists are created and printed to examine the results using methods similar to those used in DOELAP. These lists are used to determine result acceptance and the amount of system bias.

FIGURE 2.1. Results for Beta/Photon Audit Dosimeters Exposed to 16 keV X-ray, ^{137}Cs Gamma, and ^{90}Sr Beta Radiation

3.0 READER PROCESSING TOLERANCE

Many control dosimeters are involved in each automated reader processing run. The results from these control dosimeters are used to standardize the dosimeter results to predetermined levels. Automated reader sensitivity is maintained by an internal light source. The areas of reader sensitivity and chip sensitivity provide the majority of QC procedures for the automated readers.

To determine automated reader sensitivity, four different types of control dosimeters are used:

1. OT dosimeters - These multipurpose dosimeter inserts have not received radiation exposure.
2. 1T dosimeters - These multipurpose dosimeter inserts have been exposed in air to 1-R of ^{137}Cs gamma radiation.
3. 2T dosimeters - These basic dosimeter inserts have not received radiation exposure.
4. 7T dosimeters - These basic dosimeter inserts have been exposed in air to 1-R of ^{137}Cs gamma radiation.

The OT and 1T inserts are processed at the start of each run and again within every batch of 50 field dosimeters. The results of each control dosimeter are checked by the microprocessor controlling the reader, and the results must comply with predetermined limits for the processing to continue. If a control dosimeter is not found, processing will stop.

Limits are initially derived for each chip position, on every insert, from 20 insert readings of the OT, 1T, 2T, and 7T types on each reader. These initial limits are used to establish reader limits, which are set based upon the average +2 standard deviations for the upper limit and average -2 standard deviations for the lower limit.

The mean value of the control dosimeters is used to determine the calibration and reader sensitivity factors for dose calculation. The average result of the many 1T and 7T control dosimeters processed is standardized to a value of 1500 reader counts and is used to determine the calibration coefficients for basic, beta/photon, and multipurpose dosimeters.

During the reading process, each 1T and 7T check insert is automatically reread by the TLD reader to ensure that the radiation exposure signal was removed from the check insert chips. Upper limits are set in the reader, and chip results exceeding these limits cause the reader to stop.

The limits for 0T and 2T inserts are set in a manner similar to the 1T and 7T inserts, except that the lower limit is set at 6 counts. Light-source reader limits are set to the average ± 3 standard deviations for the light-source count. The reader background upper limit is set at 30 counts, and a lower limit is not set.

4.0 READER MAINTENANCE

To avoid excessive down time and minimize unsatisfactory data resulting from mechanical failure, routine maintenance procedures have been established. At the group leader's discretion, extensive maintenance may be scheduled with a department technician. Routine TLD reader maintenance is usually performed prior to the next scheduled dosimeter processing and includes the following tasks:

- cleaning the optics
- cleaning the slide mechanism
- checking the heater and verifying heater height
- lubricating moving parts
- checking the light seal
- ensuring that the light source is clean and contaminants do not interfere with the light output.

A decrease in the light-source count or in the 1T or 7T check insert readings (1-R of ^{137}Cs gamma exposure) is an indication that the PMT lens has contamination on it, possibly resulting from dirty inserts. The reader's sliding mechanism (on which the dosimeter is placed for processing) may also collect contaminants from dirty inserts, causing interference with mechanical function. Contamination can be removed with cotton swabs and acetone.

When the PMT lens is cleaned, the housing and cooler are removed, allowing the heater probe to be inspected for residual buildup. Lightly sanding the heater probe with 400-grit sand paper will remove contaminants. The heater probe should also be checked for proper positioning. During operation, the probe is raised to the insert position and heated up. The height to which the probe rises must be between 0.075 in. and 0.078 in. above the slide.

The light seal is constructed from a 0.125-in. inside diameter, black latex tube, which is found in the circular slot in the reader's base plate (the tube does not allow light to pass through it). The tube's diameter is expanded by forcing air into the tube, causing a portion of the tube's wall to

be pushed outside of the slot. This part of the tube presses against the slide, closing the gap between the slide and base plate. During processing, the latex tube may become contaminated with glue, oil, and parts of labels. Visual inspection of the tube reveals any contamination or wear of the tube wall. The light seal has a life of up to 6 months, and seal replacement takes 10 to 15 minutes. Wear of the tube results in high background readings.

The light source is found in a 0.5-in.-diameter slot approximately 5 in. from the slot holding the inserts. This location causes the light source to be highly susceptible to contamination, which can reduce light output. Dirt on the light source usually results in low light-source readings, causing the reader to stop. The light source is very fragile and cannot withstand chemical cleansing. Small hand-held cans of compressed air are used to remove contamination.

4.1 ACCEPTANCE FOLLOWING MAINTENANCE

After the TLD reader has been repaired and before it is returned to operation, External Dosimetry processing staff will process several light-source and dark-current readings to determine if the values are within predetermined limits. If the PMT housing has been removed from the plate and exposed to light, it may take from 20 minutes to 24 hours to obtain readings within the limits.

After the light-source and background readings are within limits, several sets of OT and IT check inserts are processed. If all of the values are within limits, the TLD reader is considered to be in compliance with established limits and can be used for routine processing.

4.2 MAINTENANCE RECORDS

When any type of maintenance is performed, repaired items are recorded in the External Dosimetry maintenance log. Any changes to settings, voltages, etc., must also be entered into the log before beginning routine processing. The person performing the repair and the group leader for External Dosimetry's processing section must sign and date the log before the reader can be

returned to operation. A QC representative must sign and date the log entry within five working days.

5.0 DETECTING ABNORMAL DOSIMETRY DATA

The computer code, TLD08D, has become a part of the routine processing for all dosimeters. TLD08D has been updated 28 times in order to monitor and compare routine processing results with general criteria. A description of the dosimeters is necessary to help explain how and why the TLD08D computer code operates.

5.1 DOSIMETER DESCRIPTION

The multipurpose dosimeter is used to monitor the shallow, deep, and total neutron dose components that may potentially be received by radiation workers in Hanford facilities. The multipurpose dosimeter insert consists of three TLD-700 chips and two TLD-600 chips suspended in an acrylonitrile-butadiene-styrene (ABS) plastic card. Figure 5.1 shows an example of the multipurpose dosimeter insert and Hanford security badge. The multipurpose dosimeter holder, shown in Figure 5.2, is injection-molded from ABS plastic and is designed to hold the dosimeter insert and the Hanford security badge. The metal filters are positioned in the holder's cavities. Because the dosimeter insert can be placed in the holder in only one direction, each TLD chip is held between the appropriate filters. The filter specifications for the materials in each holder position are summarized in Table 5.1.

The beta/photon dosimeter insert, shown in Figure 5.3, consists of three TLD-700 and two TLD-200 chips in a red ABS plastic card. The holder (also shown in Figure 5.3) is molded from ABS plastic and is lined with aluminized nylon to block light from entering the holder. The filtration specifications for the materials in each holder position are summarized in Table 5.2.

The basic dosimeter insert is composed of one TLD-700 chip in the insert's first position. The basic dosimeter insert holder is a plastic pouch that also holds the security badge.

Security Credential

Dosimeter

FIGURE 5.1. Hanford Multipurpose Dosimeter Insert and Security Badge

Plastic Holder

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FIGURE 5.2. Hanford Multipurpose Dosimeter Holder

TABLE 5.1. Filtration Specifications for the Hanford Multipurpose Dosimeter

Position	Filtration (mg/cm ²)						Total
	PTFE ^(a)	Security Badge	Aluminum	Tin	Cadmium	Plastic	
1	11.5	84					95.5
2	11.5	84	172			111	378.5
3	11.5	84		742		74	911.5
4	11.5	84		371	439	74	979.5
5	11.5	84		742		74	911.5

(a) PTFE = polytetrafluoroethylene.

FIGURE 5.3. Hanford Beta/Photon Dosimeter Insert and Holder (Front View)

TABLE 5.2. Filtration Specifications for the Hanford Beta/Photon Dosimeter

<u>Position</u>	<u>Filtration (mg/cm²)</u>					<u>Total</u>
	<u>PTFE</u>	<u>Aluminized Nylon</u>	<u>Aluminum</u>	<u>Tin</u>	<u>Plastic</u>	
1	11.5	1.4				12.9
2	11.5	1.4	172		111	295.9
3	11.5	1.4		742	74	828.9
4	11.5	1.4				12.9
5	11.5	1.4		742	54	66.9

5.2 TLD08D

Regardless of how carefully a dosimeter is handled, anomalous data values may occur. The TLD08D program is run against a dose file 1) to prevent erroneous data from becoming part of the official record, and 2) because it is impractical for External Dosimetry processing staff to look at every dose record by hand. TLD08D looks at the issue and return dates, shallow and deep dose, chip ratios, and high doses. As TLD08D is analyzing the results, two reports, a "High Dose Report" and a "Flyer Report," are generated.

The issue and return dates for the dosimeter are the first items examined. If the dosimeter insert has been in the field for 18 months or more, it is flagged and automatically added to the Flyer Report. Using this method, fading problems from extended-wear periods can be evaluated by External Dosimetry staff. If the dosimeter insert has been in the field for less than 7 days, it is also flagged and automatically added to the Flyer Report. This is usually an indication that the wrong dosimeter was returned to External Dosimetry by the contractor during the insert exchange.

Next, the code examines the dosimeter's measurement of shallow and deep dose. If the shallow dose is calculated to be less than the deep dose, these instances are flagged and automatically added to the Flyer Report. The program that calculates dose is designed such that if the shallow dose is calculated to be less than the deep dose, the shallow dose is set equal to the

deep dose. To ensure that this happens, TLD08D rechecks this condition and if it is found, it is added to the Flyer Report.

The third item examined, chip ratios, allows records to be flagged that appear to have anomalous chip values. The ratios of the five chips from both the multipurpose and beta/photon inserts are analyzed, and if any of these ratios exceed the values listed below, the record is automatically added to the Flyer Report.

For the multipurpose dosimeter, the following ratios are examined between Chips 1, 2, 3, 4, and 5:

$$2/1 \geq 2.0 \quad 5/4 \geq 2.0 \quad 5/1 \geq 2.0$$

$$5/3 \geq 2.0 \quad 5/2 \geq 2.0 \quad 5/3 \geq 2.0$$

$$(3-5)/(4-5) \geq 1.3$$

For the beta/photon dosimeter, the following ratios are examined between Chips 1, 2, 3, 4, and 5:

$$2/1 \geq 2.0 \quad 2/5 \geq 2.0 \quad 3/4 \geq 2.0$$

$$1/4 \geq 2.0 \quad 3/2 \geq 3.0$$

The final item that is examined by the TLD08D is the occurrence of high doses. Records that contain doses exceeding the following limits are flagged:

$$\text{Shallow whole-body} \geq 2000 \text{ mrem}$$

$$\text{Deep whole-body} \geq 1000 \text{ mrem}$$

$$\text{Total neutron} \geq 200 \text{ mrem}$$

$$\text{Basic dosimeter dose} \geq 100 \text{ mrem}$$

$$\text{Ring dose} \geq 3000 \text{ mrem}$$

$$\text{Eye} \geq 10 \text{ mrem}$$

High-dose occurrences are also automatically added to the High Dose Report. Any doses reaching these levels require independent review of the raw counts and glow curves.

All dose file changes are reviewed by the External Dosimetry processing supervisor. The High Dose Report and Flyer Report both require signatures and dates from the processing supervisor and the designated QC representative before changes can be made to the dose file.

6.0 GLOW CURVE ANALYSIS

During routine dosimeter processing, External Dosimetry processing staff run the TLD08D computer code against all dosimeter results. For any unusual results, glow curves are printed by the processing staff to determine the cause of these anomalies. A senior staff member runs a computer code, CK2GLW, to analyze the glow curves for unusual data.

The TLD08D and CK2GLW computer programs are generally run daily because of the amount of time required to evaluate and generate the output reports. The data are plotted and also presented in tabular form to facilitate evaluation of unusual results. Inspection of the output helps to determine the impact on the TLD results. Any modification of a reading requires the use of the Note Code 53 (NC53), which is a flag used to identify a record that has been changed. This causes a letter to be sent to the respective contractor stating the recommended dose. A copy of the letter is placed in the individual's exposure history file, indicating the radiation dose and which chip reading was modified. This section describes how glow curve analysis is used to determine the amount of correction that is necessary.

6.1 PLOTTED DATA

The plotted data reveal the cause of the abnormalities. All five of the TLD insert plots appear on one page in different colors, making problems easier to distinguish. Also included in the plots are the payroll number, reader sequence number, raw chip values, and other data. The plots also reveal electronic spikes, front-end noise, elevated tails, and any unusual increases during the read cycle.

6.2 REPORT FROM CK2GLW

The report from the CK2GLW program lists unusual data, payroll number, permanent identification number assigned to the insert, reader sequence number, date the TLD was read, integrated count, and type of error. An example of a report from CK2GLW is shown in Figure 6.1. The list may include any of the following items:

SPIKE 30	VALUE 700.00	CORR. 2.50	(L,M,U)= 29 30 31	
PAYROLL #TF854	PERM ID 86713	SEQUENCE #374528	CHIP #1 DATE 11-MAY-92	INTEGRAL 5007.
1) FRONT HIGH (DIRT): SUM(1...10)= 290.00 SUM(11...20)= 60.00				
PAYROLL #3E056	PERM ID 71525	SEQUENCE #490102	CHIP #4 DATE 09-APR-92	INTEGRAL 5994.
TAIL ELEVATED: SUM(290...300)= 115.00 SUM(215...230)= 57.00				
PAYROLL #91012	PERM ID 92991	SEQUENCE #490139	CHIP #5 DATE 09-APR-92	INTEGRAL 6907.
LOWER 25 NOT (50-110)	MIDDLE 33 NOT (88-140)	UPPER 52 NOT (85-155)		
PAYROLL #2T596	PERM ID 96194	SEQUENCE #203684	CHIP #1 DATE 27-APR-92	INTEGRAL 4187.
LOWER 114 NOT (50-110)	MIDDLE 155 NOT (88-140)	UPPER 300 NOT (85-155)		
PAYROLL #30196	PERM ID 87011	SEQUENCE #490262	CHIP #3 DATE 09-APR-92	INTEGRAL 33079.
LOWER 221 NOT (50-110)	MIDDLE 295 NOT (88-140)	UPPER 300 NOT (85-155)		
PAYROLL #TC437	PERM ID 2282	SEQUENCE #371154	CHIP #2 DATE 17-APR-92	INTEGRAL 63843.

39205126.5

FIGURE 6.1. Report from CK2GLW

1. spike - The count value of the spike and the value after correction is presented.
2. front-end noise - The sum of the first 10 channels exceeds the sum of channels 21 through 30; the amount of correction is represented.
3. elevated tail count - The total of the last 10 channels is compared with the total of the 10 channels from a earlier part of the read cycle.
4. noise throughout the read cycle - The entire count is elevated on every channel.
5. center of glow curve - The center and the full width at half-maximum (FWHM) must fall within limits; any values not falling within limiting values are indicated.
6. partial removal of signal - The entire signal is not released and an incomplete glow curve is created.

The CK2GLW report shows detailed spectrum data and indicates results requiring further analysis. Another computer code, PTGLOW, is run to produce columnar listings of all chip data for an insert in the glow curve files. The TLD-700 and TLD-200 chips are read for 15 seconds and TLD-600 chips for 27 seconds, and the glow curves are composed of 50-msec time intervals. Based on the glow curve data report from CK2GLW, each type of error and the amount

of error can be identified. Figure 6.2 shows an example of a normal glow curve plot.

6.2.1 Spike

A spike results from an unusually sharp increase in count followed by a rapid decrease. Generally, spikes are observed in one channel of the data (count period of 50 msec). Figure 6.3 contains an example of a spike found in a TLD glow curve.

A spike must meet the following criteria:

1. Spike > (value of previous) + 4 x SQRT (previous value) +100
2. Spike > (value of next) + 4 x SQRT (next value) + 100.

Statistically, a spike value greater than the calculated value would not occur under normal conditions. This method is based on Poisson statistics and assumes that the channel values will be <100,000 counts (doses <1000 mrem). Spikes are believed to be caused by the scaler's oscillation for short periods of time, and these counts are not due to fluorescence from the chip. In CK2GLW, the spikes are calculated and corrected using the channel value before the spike, plus the channel value after the spike, divided by 2. The resulting average is then subtracted from the recorded channel value, which results in the corrected value.

$$\frac{(\text{Channel Value Before}) + (\text{Channel Value After})}{2} = X$$

$$\text{Spike Value} - X = \text{Amount of Correction}$$

Values are generally not corrected if the resulting corrections are <500 counts because the total amount of change is <5 mrem. Doses reported to individuals' files are to the closest 10 mrem. When a correction is made, a copy of the NC53 letter is placed in that individual's exposure history file.

6.2.2 Front-End Noise

If the sum of channels 1 through 10 is higher than the sum for channels 11 through 20 by a factor of 2, the values are listed by CK2GLW. If the amount of correction is <500 counts, a correction is not necessary because the

FIGURE 6.2. Normal Glow Curve Plot

FIGURE 6.3. Spike in TLD Glow Curve

change is <5 mrem. If the correction is >500 counts, the correction amount is subtracted from the total count, and this new value becomes the chip count.

Dose is recalculated by processing staff using the computer code TLDB6. If the resulting value is different by 10 mrem or more, the new value is used and an NC53 is added to the insert data record. A letter will be placed in the individual's exposure history file indicating the changed chip and the new value.

A front-end noise error can be caused by 1) a spike within the first ten channels, or 2) the TLD insert not having been washed properly, resulting in contamination remaining on the chip's PTFE coating. This contamination may induce a short, early burst of light when the heater strikes the bottom of the TLD insert. Figure 6.4 shows an example of front-end noise.

6.2.3 Elevated Tail Count

The total count of the last 10 channels is compared with a previous total count of 10 channels. For Chips 1, 2, and 5, the integrated count for channels 290 through 300 are compared with the integrated count for channels 215 through 225. For Chips 3 and 4, the integrated count for channels 531 through 540 are compared with the integrated count for channels 336 through 345. If the count for the last 10 channels is twice the count for the earlier

FIGURE 6.4. Front-End Noise

10 channels, the result will appear in the CK2GLW output report. An increase in channel count can be caused by the following conditions: 1) the washing cycle was not completed and residue remains on a chip's PTFE coating, 2) signal residue could remain from a previous exposure, or 3) a spike may have occurred within the last 10 channels. Figure 6.5 shows an example of an elevated tail count.

Elevated tail counts can be corrected by using the values of a chip not exhibiting this effect. For example, the values of the last 50 channels can be added from a chip that doesn't exhibit the elevated-tail effect. If the net difference is >500 counts, a correction can be made. If the dose recalculation reduces the dose by 10 mrem or more, the corrected value should be used. The dosimeter record is marked with an NC53.

6.2.4 Noise Throughout the Read Cycle

Noise throughout the read cycle is the most difficult type of error to correct because the investigator's judgment determines the impact of the effect on the final reading. This type of error is generally caused by a hole in the chip's PTFE coating, resulting in impurities under the chip's coating.

FIGURE 6.5. Elevated Tail Count

The analysis of this error is a two-step process, and determining where the peak center is located may be difficult. To determine which channel number the peak value should be, the maximum peak value channel number is compared with the glow curve values and the channel numbers from a good chip. Aligning the good chip values with the bad chip values helps to determine where the corrected peak should be for the bad chip. Now that the location of the maximum peak value channel is known for the bad chip, the four highest channel values surrounding the peak are added to the maximum peak value channel. This is done for both the good chip and the bad chip. Two ratios can now be created and set equal to each other where the unknown is the total count of the bad chip.

$$\frac{\text{Total Counts for Good Chip}}{\text{Sum of Five Peak Channels (Good Chip)}} = \frac{X}{\text{Sum of Five Corrected Peak Channels (Bad Chip)}}$$

Some effects increase both the tail and peak regions, which requires the use of several techniques to obtain a more accurate estimate of the count from radiation only. If the correction is >10 mrem, a change is made, an NC53 is used, a letter is written to the respective contractor, and a copy of the letter is placed in the individual's exposure history file.

6.2.5 Center of Glow Curve

To ensure that TLD inserts have not been damaged, a set of empirically derived levels are used to check every glow curve. Ranges of channel values have been defined for maximum chip and FWHM values. The ranges are broad enough to allow for some stretching of the PTFE coating before the TLD insert would need to be removed from service. Each set of limits is checked separately, and any limitation failures are reported. Generally, all of the limits would need to be exceeded before removing the insert from service. Channel data investigations reveal that maximum chip and FWHM values may be caused by 1) a spike, 2) elevated tails, or 3) stretched PTFE coating. A list of stretched PTFE inserts to be removed from service is given to processing staff. Processing staff visually inspect all inserts that have been corrected to determine if the inserts have torn or stretched PTFE. An example of the late glow curve peak problem is shown in Figure 6.6.

6.2.6 Partial Removal of Signal

When viewing a glow curve, it is obvious when the radiation signal has not been completely removed. This occurrence is different than a spike because the peak center and the FWHM values are not adjacent channel numbers.

FIGURE 6.6. Late Glow Curve Peaks

The CK2GLW program detects this condition by indicating that the peak center and FWHM exceed acceptable limits; however, this method cannot always determine the true amount of signal in the chip.

In Figure 6.7, the back end of the peak has not returned to the baseline value, indicating that the entire radiation-induced signal was not released during the read cycle. Techniques have been developed to analyze where the peak is centered and to add the counts from the rising side of the curve to the height of the last curve value. If the peak has not reached a maximum, any estimate is questionable.

6.2.7 Negative Channel Values

The CK2GLW program looks for negative channel values, which are indicated in the output report. Negative values do not normally occur because the lowest physically possible value for an adjusted channel value is zero. This error is detected about 5 to 10 times per year and is an indication that the reader reset board requires maintenance. To correct the error, add the absolute value of the negative value to the total. If the new total is >500 counts, the new dose should be reported and an NC53 should be used.

FIGURE 6.7. Partial Removal of Signal

7.0 STATISTICAL ANALYSIS OF THE DATA

After completion of a run and before the dose reports are transmitted to Radiological Records, a statistical data review is conducted by the External Dosimetry senior staff member responsible for QC. The statistical review must be completed before the Dosimeter Result Acceptance form is signed; the review includes the following items:

1. statistical analysis code

- average and sigma of the 1T readings (multipurpose 1-R controls)
- average and sigma of the 7T readings (basic 1-R controls)
- average and sigma of the 0T readings (multipurpose zero-dose controls)
- average and sigma of the 2T readings (basic zero-dose control)

2. flow charts with means and sigmas

- light-source and direct-current readings for automatic reader
- light-source and direct-current readings for ring reader

3. histogram with the number of results and the doses received by personnel during the processing period

4. audit analysis similar to the DOELAP analysis

- performance index goals
 - basic TLD: <20% for ^{137}Cs gamma
 - multipurpose TLD: <15% for ^{137}Cs gamma, $^{90}\text{Sr}/^{90}\text{Y}$ beta, 16-keV x-ray, and ^{252}Cf neutron
 - beta/photon: <15% for ^{137}Cs , $^{90}\text{Sr}/^{90}\text{Y}$ beta, and 16-keV x-ray
- lower limit of detection (LLD) goal at 95%
 - basic TLD: deep dose <15 mrem
 - multipurpose TLD (deep dose, shallow dose, and total neutron dose): <10 mrem

- beta/photon TLD (deep dose and shallow dose):
<10 mrem.

8.0 DOSIMETER RESULT ACCEPTANCE

A formal procedure is followed to accept routine dosimeter processing results. Processing staff prepare a Dosimeter Result Acceptance form and a Dosimeter Processing Quality Control form at the completion of each processing cycle. These forms require the following information:

- the automatic reader used
- initial and final sequence numbers for each reader used
- ring calibration coefficients
- automatic reader final calibration factors
- radiation exposure of controls
- proper decay period for controls
- list of processing controls not used in developing calculation coefficients
- reader maintenance
- limits used for automatic reader
- limits used for ring reader
- comments.

In addition to the above-listed QC forms, processing staff also prepare the following:

- a statistical report on the number of dosimeters that were evaluated for different levels of shallow, deep, and total neutron doses received
- a list of dosimeters that were affected by data changes or special data calculations (NC53 records)
- a list of dosimeters processed
- plots of light-source and dark-current readings taken during the processing cycle
- a report containing a list of processing control dosimeter results (including calculation coefficients, position sensitivity factors, reader sensitivity factors, and statistical values such as means and sigmas for both zero dose results and 1-rem ¹³⁷Cs dose results).

The senior staff member in charge of QC will have staff prepare the following items:

- plots of audit dose result values
- lists of audit results by identification number with dose reported, dose given, amount of error, and amount of error allowed for that given dose
- DOELAP-type calculations for the various types of radiation
 - ^{137}Cs gamma
 - $^{90}\text{Sr}/^{90}\text{Y}$ beta
 - ^{252}Cf bare neutron
 - 17-keV x-ray
- LLD results for deep, shallow, and total neutron doses.

After review of the run is completed, the Dosimetry Result Acceptance form is signed by the processing staff supervisor and the representatives that conducted the QC acceptance evaluation. All QC acceptance evaluation records are maintained by External Dosimetry.

9.0 QUALITY CONTROL DOCUMENTATION

For each dosimeter data processing run (monthly, quarterly, and annual) that is sent electronically to Radiological Records, several Fortran codes are executed against this file in a batch-processing mode. These codes are used to pull control and audit dosimeter information into separate files and then perform routine statistical and numerical analyses on the data.

Flyer codes are also run against the input file. Ratios similar to those created in the TLD08D are used to flag results for further inspection by the QC evaluator. Other codes are also used to categorize and quantify the dosimeters for each contractor. Personnel cumulative dose totals for each contractor are made for the shallow, deep, and total neutron doses, as well as for the dose for basic dosimeter and shallow dose for ring dosimeters.

The QC documentation provides graphs showing dose distributions for each contractor. Under each graph, the total number of badges in each dose category and the percentages of the total number of dosimeters are listed. The total number of dosimeters being analyzed, the total doses in mrem, and the average doses for contractors are also included. The QC documentation and graphs of control dosimeter data are presented to the QC evaluator for review. This documentation is then filed with the External Dosimetry records.

10.0 CONCLUSION

Quality control practices for the Hanford External Dosimetry TLD system are constantly improving and have produced a reliable and efficient program. These improvements have been accomplished with minimal impact on the routine processing program. The QC computer programs are used to present anomalies, control charts, LLD, and DOELAP test results in a timely manner, ensuring that personnel dosimetry data are of excellent quality.

The use of DOELAP performance criteria and methodology is a critical part of the QC program's results. Table 10.1 shows an example of the performance indexes for DOELAP testing during 1989 and 1991. Comparing the results from 1989 with those from 1991, 1991 showed that results for 19 categories had improved, 6 categories had remained the same, and 2 categories had declined. The analyses were based upon the following criteria: 1) a difference of <0.05 caused the categories to be considered the same, and 2) a difference of >0.05 was considered to be either improved or declined. During 1991, only two of the results reached 50% of the allowable limit, and both of these were at 61% of the allowed maximum.

TABLE 10.1. Performance Indexes for DOELAP Testing
(1989 and 1991)

<u>Index</u>	<u>1989</u>	<u>1991</u>
0-5%	1	6
6-10%	6	8
11-15%	5	9
16-20%	4	4
>20%	11	0

11.0 REFERENCES

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