JLAB-TN-05-010
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# Operational Fade Study for TLD-760

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## *Introduction*

The Jefferson Lab Radiation Control Group (RCG) has been utilizing subcontractor dosimetry processors for external dosimetry since the inception of radiation producing activities at Jefferson Lab (then known as CEBAF). The reasoning behind the selection of the type of external dosimeter is contained in the Jefferson Lab External Dosimetry Technical Basis Document (available from the Jefferson Lab RCG.) Jefferson Lab is required under 10 CFR 835.402 to monitor individuals meeting a certain set of conditions, the most applicable for Jefferson Lab being "radiological workers who, under typical conditions, are likely to receive....(1) An effective dose equivalent to the whole body of 0.1 rem (0.001 sievert) or more in a year.....(5) Individuals entering a high or very high radiation area."[1] Additionally, the dosimetry used for monitoring these individuals must be (according to 10 CFR 835.402(b)) "Accredited, or excepted from accreditation, in accordance with the DOE Laboratory Accreditation Program for Personnel Dosimetry (DOELAP)"[1].

The various dosimeter models used at Jefferson Lab over the years (as well as the current models) have been DOELAP accredited. Among other tests, DOELAP tests external dosimetry processors in different irradiation categories (e.g, Category IV High Energy Photons in the range of 0.03-10 rem) to ensure that the dosimetry tested in each respective testing category has "approximately 70% confidence that a dosimeter response would be within 30% of a conventionally true value[2]." Additionally, the DOELAP accreditation process requires an analysis of the Lower Level of Detection (LLD) (the minimum evaluated dose equivalent for which the readout value of a dosimeter is significantly different (at the 95% confidence level) from the readout value at the detection threshold)), and angular dependence (the response of a dosimeter as a function of angle of incidence of the radiation detected compared to its response at normal incidence (non-perpendicular incidence)).[2] Additionally, due to the nature of TLDs, the dose recorded in the TLD elements decreases or "fades" over time. The extent of this "fading" over time has been studied and analyzed by the respective TLD processors, and is accounted for in the processors' dose algorithm. Each of these factors is studied and analyzed **independently**, in order to provide data useful in selecting a useful badge type, and a useful TLD badge period.

Previously, Jefferson Lab radiation workers were wearing TLD badges for approximately 3 month wear periods with LLDs for neutron and gamma radiation of less than 10 mrem quarter (varying in LLD from 4 to 8 mrem). However, the minimum reportable dose was 10 mrem per quarter. In this case, it is feasible for a person performing maintenance on activated accelerator components on a fairly

routine basis to accumulate a gamma radiation dose of 9 mrem per quarter for a collective annual dose of 36 mrem, **but** the actual recorded dose for the year would likely be reported as "zero".

For this reason, the RCG recently decided to increase the wear period for personnel TLDs. Although wearing a TLD for a longer period (six months) can slightly elevate the LLD (e.g. 8 mrem DDE for photon), the minimum reportable dose stays as 10 mrem for a six month period. The "fade" is also slightly increased (as delineated in the ICN Fade Study of Attachment 1), but this is more than counteracted by the lower "effective" minimum reported dose. In the example of the previous paragraph, the same radiation worker would likely register a radiation dose of at least 15 mrem for each period, for a total of 30 mrem reported annual dose. Because the aforementioned scenario is indicative of the typical exposure conditions for radiation workers at Jefferson Lab (based on approximately 10 years of operational experience and process knowledge), the increased wear period makes more sense in order to "capture and record" more of the dose.

Measurement and "accurate" recording of dose is a complicated process containing many variables (many of which cannot be easily tracked, such as angle at which a dose was received, or day on which the dose was received.) In order to verify that the badge issue period and badge type selected for radiation workers at Jefferson Lab was appropriate, we decided to set up a number of test scenarios in the RCG Calibration range that more closely approximate typical exposure conditions encountered during radiation work performed at Jefferson Lab. This would allow the analysis of **several** sources of error, **in the actual dose range of interest at Jefferson Lab**. By contrast, the DOELAP tests are conducted, by and large, at higher doses than are expected at Jefferson Lab. Additionally, there is no direct requirement for a "Fade" study.

## Initial Assumptions (based on years of Jefferson Lab specific process knowledge):

- Personnel exposure at Jefferson Lab is due primarily to photon radiation received by persons working near activated components during shutdown periods of which there are on average 2 shutdown periods per year (or one per six month dosimetry issuance period.)
- Typical dose received is less than 100 mrem per year.
- Dose is usually collected in (at most) a few discrete events.
- Because fading algorithms assume that dose is received in the middle of a TLD issue period, and normalized to that, challenging scenarios were chosen such that 15 mrem dose was received either at the beginning of the issue period, or at the end of the issue period. This would adequately model a radiation worker performing work on an activated piece of equipment during the maintenance period.
- To approximate a number of low-dose exposures typical of someone working generally in one of the Experimental Halls, a challenging scenario of 4 discrete 5 mrem doses throughout the issue period was chosen.

- A review of individual dose history indicates that it was rare for individuals to receive "approximately the same dose on each dosimeter"[2] when badged quarterly (unless zero dose is included)
- The vast majority of Jefferson Lab employees are not required to be monitored per 10 CFR 835.402 (typically one or two individuals receive 100 mrem each year, and fewer than 30 enter High Radiation Areas)
- Individuals who enter High Radiation Areas are easily tracked (per sign-in sheet of the Self Reading Pocket Dosimeter (SRPD) log of specific Radiation Work Permits (RWPs) which are required to enter High Radiation Areas). Thusly, if dose that is below the reportable threshold but above the LLD is noted on the TLD for a particular individual, that dose can be requested of and provided by the dosimetry processing subcontractor, when asked by a cognizant RCG member.

## Test Scenario

Utilizing the RCG calibration range, and a phantom meeting the DOELAP criteria, and following the RCG procedure for TLD Quality Assurance Testing, HPP-QAP-021, three different groups of TLD-760 badges from Global Dosimetry Solutions, Inc. (Jefferson Lab's current dosimetry subcontractor) were exposed to a Cs-137 source at different periods and doses, as delineated below, and shown on the respective attachments:

Group 1: Sixteen TLD badges held over from the 4$^{th}$ quarter of 2003 (approximately October 1, 2003) were exposed to 15 mrem gamma dose on 1/8/04, and held until May 2004 when the badges were processed. Details and results are contained in Attachment 2. Of the sixteen badges, three initially were returned with zero dose reported. However, upon further inquiry with the GDS, Inc. technical representatives, the raw data for the badges was determined to yield doses in the neighborhood of 15 mrem. Using this corrected data yielded a tolerance level of L = 0.0821, which is well within the DOELAP tolerance criterion[2] of 0.30. This indicates that fade from low dose that occurs early in a badging period is adequately accounted for.

Group 2: Eight TLD badges from the initial six months of 2004 were held for the entire badging period, and then exposed to 15 mrem gamma dose on 6/8/04 (immediately before the badges were shipped to be processed). Details and results are contained in Attachment 3. Of the eight badges, two initially were returned with zero dose reported. However, upon further inquiry with the GDS, Inc. technical representatives, the raw data for the badges was determined to yield doses in the neighborhood of 15 mrem. Using this corrected data yielded a tolerance level of L = 0.14697, which is well within the DOELAP tolerance criterion[2] of 0.30. This indicates that fade from low dose that occurs late in a badging period is adequately accounted for.

Group 3: Ten TLD badges from the initial six months of 2004 were exposed to a total of 20 mR each, in 4 separate 5 mrem doses spaced throughout the badging period on 1/12/04, 2/27/04, 3/15/04, and 4/20/04, and then turned in for processing at the normal time (i.e., mid-June). Details and results are contained in Attachment 4. Of the ten badges, two initially were returned with zero dose reported. However, upon further

inquiry with the GDS, Inc. technical representatives, the raw data for the badges was determined to yield doses in the neighborhood of 12 -13 mrem. Using this corrected data yielded a tolerance level of L = 0.3864, which is outside the DOELAP tolerance criterion[2] of 0.30. However, this is not outside the recommendations of critical documents for monitoring doses at low exposure, which are summarized in the following paragraphs.

NCRP 57 recommends that for reported values less than ¼ of the Maximum Permissible Dose (MPD), an accuracy of a factor of 2 is acceptable[3]. Under today's definitions, this ¼ of a MPD translates to a dose less than 625 mrem for a six month period (conservatively taking the MPD to be ½ of the annual whole body dose limit of 5 rem). The 20 mrem dose received is more than an order of magnitude lower than the "equivalent MPD". The "factor of 2" translates to a tolerance of L = 2.0. Clearly this test met the recommendations of NCRP 57.

ICRU 20 recommends that, at the level of 0.1 of the maximum permissible dose, a maximum allowable uncertainty of a factor of three is suggested[4]. The 0.1 of the MPD translates to 62.5 mrem for a six month period (based on the MPD assumption of the previous paragraph). The "factor of three" translates to a tolerance level of L = 3.0. The statistical analysis of the test from Group 3 met this tolerance by almost an order of magnitude.

ICRP 35 recommends a minimum level of accuracy within a factor of two at the 95% confidence level when the annual reported dose is less than 1 rem[5]. Again, the "factor of two" correlates to a tolerance of L = 2.0, and 40 mrem per year is clearly less than 1000 mrem. Thusly, the tolerance level of L = 0.3864 meets the recommendations of ICRP 35.

Furthermore, although these blind audit exposures were outside of the 0.03 to 10 rem range specified by DOELAP test criteria (at an ambitiously low level), the overall results were somewhat consistent with the desire for "approximately 70% confidence that a dosimeter response would be within 30% of a conventionally true value[2]." In each test scenario, at least 75% of the dosimeter results registered as a positive dose above the minimum reportable level upon first analysis, and (with the exception of test scenario 3 which was analyzed in the preceding paragraphs) were within 30% of the conventionally true value.

## Comments:

Although a percentage of TLDs at a dose above the minimum reportable dose were initially reported as zero during the test scenarios, this is not a significant concern. Because all people who truly meet 10 CFR 835.402 monitoring criteria for a monitoring period are logged into a Radiological Work Permit with a SRPD, these individuals' badges (if reported with no dose) can easily be identified and re-evaluated. For people who are **not** monitored in accordance with 10 CFR 835.402, and not listed on a RWP, a distinct possibility exists of sporadically receiving a dose in the neighborhood of 20 mrem in a six month period that goes unreported. Even in the unlikely event that this

occurred in consecutive monitoring periods for the same individual, this would result in a total of 40 mrem of received dose that would go unreported. This is still significantly below the limit of 100 mrem for members of the public entering a controlled area as delineated in 10 CFR 835.208[1]. In other words, even individuals who are not employed at Jefferson Lab are legally allowed to receive up to 100 mrem dose in a year from radiation producing activities directly resulting from Jefferson Lab. Furthermore, monitored individuals who are concerned with their reported dose can always request the RCG to investigate their reported dose, which would include a re-analysis of the raw data at GDS, Inc.

Additionally, it is interesting to note that it appears that there is a less than 10% increase in number of people with reported doses over those from quarterly monitoring. It is difficult to draw hard and fast conclusions or complete a statistical analysis due to the variables involved including: different maintenance activities engaged in by monitored individuals from monitoring period to monitoring period, changes in dose investigation procedures for the new wear period, and the fact that only two semiannual TLD monitoring periods have been utilized at the time of writing of this document. That being said, one can infer that: 1) Jefferson Lab may be conservatively capturing and recording slightly more dose than that which was recorded with quarterly monitoring periods, and 2) Jefferson Lab has properly characterized and mitigated radiation hazards, as well as properly identified the population of individuals requiring dosimetry.

## Conclusion:

The blind audit tests of the Jefferson Lab dosimetry processor subcontractor using the current TLD (TLD-760) and a six month badge wear period corroborate that, for the type of radiation exposure relevant for Jefferson Lab workers (gamma exposure resulting in doses of 15 – 20 mrem semiannually), the combination of TLD type and badge wear period meets the needs of Jefferson Lab for effectively documenting low dose with "accuracy."

Endnotes

[1] 10 CFR 835 Code of Federal Regulations, Occupational Radiation Protection, 2004 edition.
[2] DOE/EH-0027, Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems, Washington, DC, 1986.
[3] National Council on Radiation Protection and Measurements (NCRP) *Instrumentation and Monitoring Methods for Radiation Protection*, NCRP 57, Washington, DC, 1978.
[4] International Commission on Radiation Units and Measurements (ICRU), *Radiation Protection Instrumentation and Its Application*, ICRU Report No. 20, Washington, DC, 1971.
[5] International Commission on Radiological Protection (ICRP), *General Principles of Monitoring for Radiation Protection of Workers*, ICRP 35, Pergamon Press, Oxford, United Kingdom, 1982.

# 2000-2001 ICN Worldwide Dosimetry Fade Study

## Summary

ICN Worldwide Dosimetry Service conducted a yearlong fade study April 2000-2001. Fade is the degradation of a TLD's thermoluminescence (TL) overtime between anneal and irradiation (pre-fade), and/or irradiation and readout (post-fade). Since the signal degrades, it is important that a TLD processor identifies the rate of TL reduction to avoid underreporting the radiation dose delivered to a TLD.

The ICN study tested the ICN TLD 760. The 760 is composed of four sensitive elements, three $^{7}$LiF and one $^{6}$LiF chips. These elements exhibit distinct pre-fade and post-fade effects.

## Procedure

The test period was 365 days, breaking them into two groups to separately evaluate the pre-fade and post-fade effects. 760 ICN TLD 760 badges were ordered from ICN's Client Services in accordance with standard ICN Standard Operating Procedure (SOP) the Account Numbers and Location ID Numbers listed in Table 2. ICN's Production Staff in accordance with SOP then assembled the badges except Production was delivered badges with controlled anneal dates as outlined in appendix of this study.

### Pre-Irradiation Fade Study

All badges were annealed at the same time. Then, in groups of 10, the badges were delivered a dose of 300 mrem per the schedule in Table 3 and processed seven days after irradiation followed by a review looking for suspicious results and statistical outliers. Each group of irradiated badges had ten control badges added during processing.

### Post-Irradiation Fade Study

The post-fade badges, in groups of 20, were annealed at varying times. Then 10 of the 20 badges were delivered a dose of 300 mrem 7 days after anneal. All groups were processed at the same time as shown in Table 4 followed by a review looking for suspicious results and statistical outliers.

Attachment 1

# Results

## ICN TLD 760

After evaluating all of the data for the ICN TLD 760 badge the fade equations listed in Table 1 were developed using regression techniques. Figures 1, 2, and 3 of the appendix contain graphical representations of the fade equations. To derive the "Combined" equation an equal number of fade days, pre and post irradiation was assumed.

**Table 1 ICN TLD 760 Fade Equations**

| Study | Fade Equation |
|---|---|
| Pre-Fade | -0.0535 Ln(Days) + 1.1041 |
| Post-Fade | -0.0539 Ln(Days) + 1.1049 |
| Combined | -0.1046 Ln(Days) + 1.2814 |

# Conclusions

After a review of the results it has been determined that, all of the results are within statistical agreement with prior internal ICN fade studies and externally published articles. Therefore, there is no reason to change the current fade equations. This study should be performed again to try to reduce the variability within the individual groups. The data from this study can also be used to generate background accumulation for the Harshaw badges.

# Appendix

**Table 2-Account Listing**

**Account: 68319**

| Test | IGNITE [redacted] 760 |
|---|---|
| 365 Pre-Fade | 00015LOC |
| 365 Post-Fade | 00014LOC |

Figure 1-ICN TLD 760 Pre-Fade Study

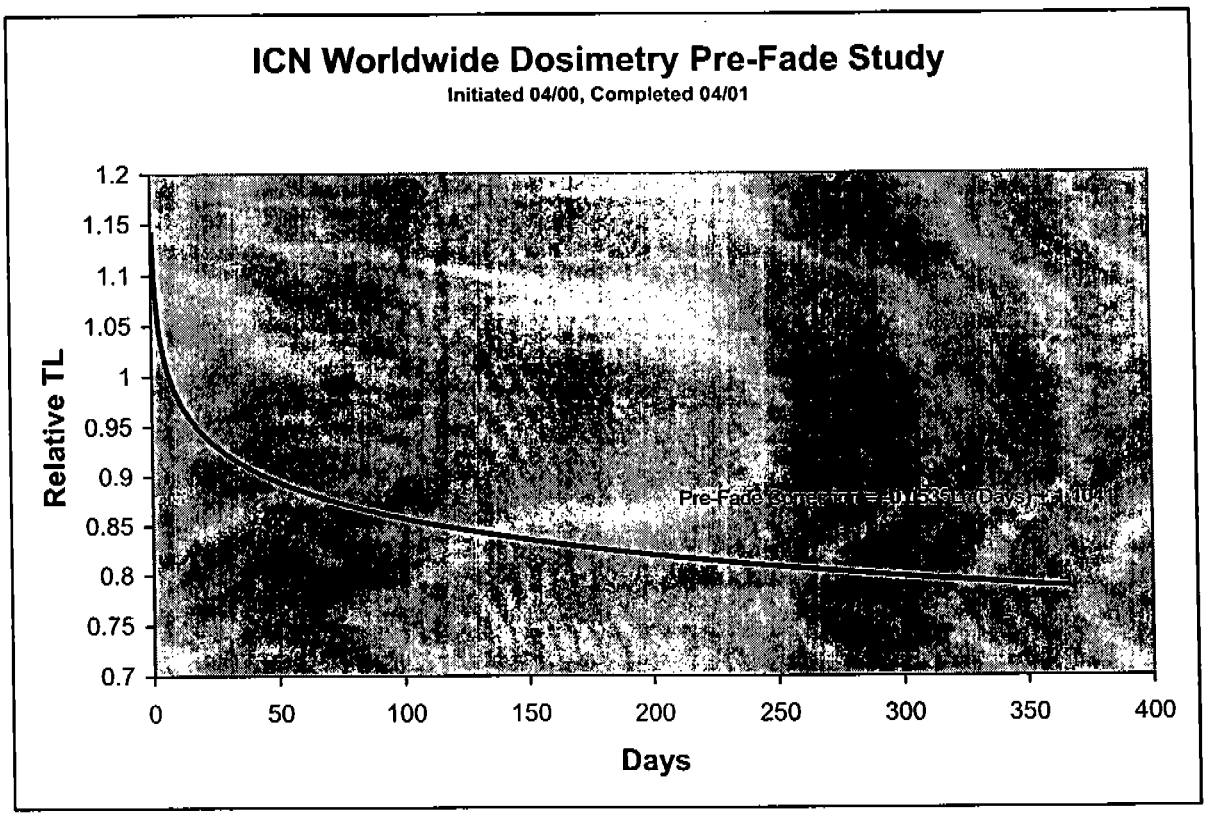



Figure 2-ICN TLD 760 Post Fade Study

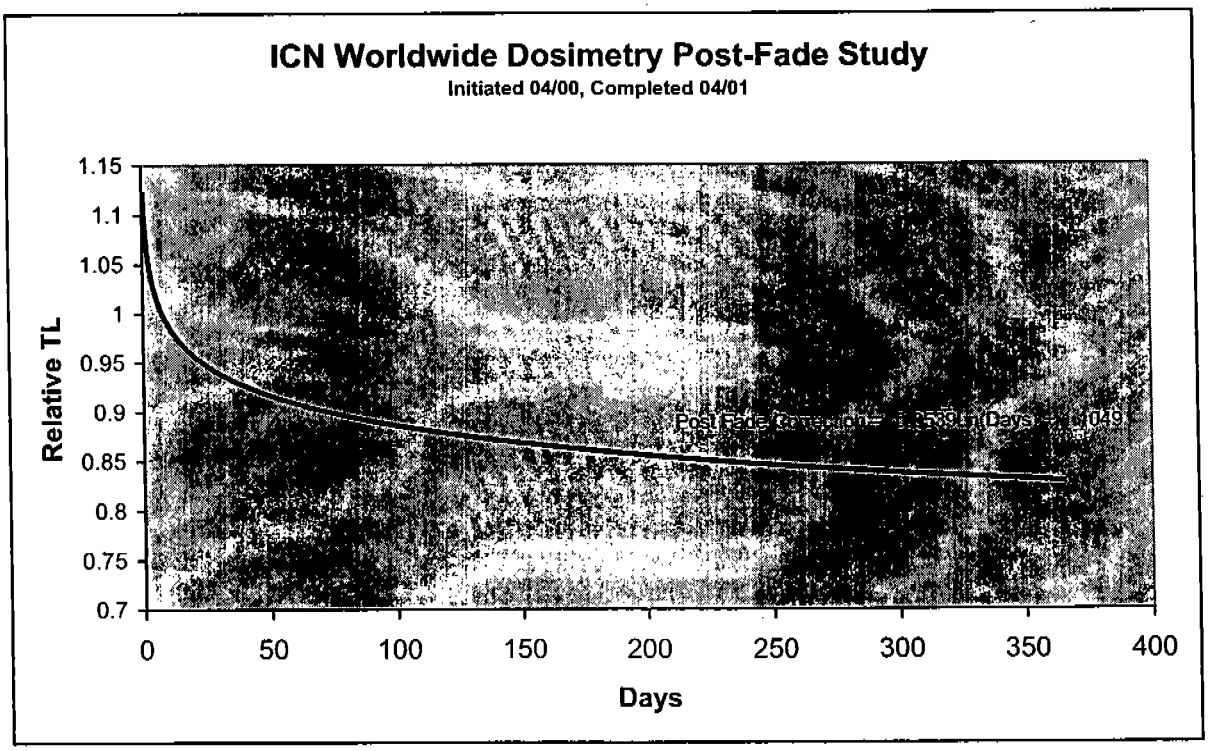
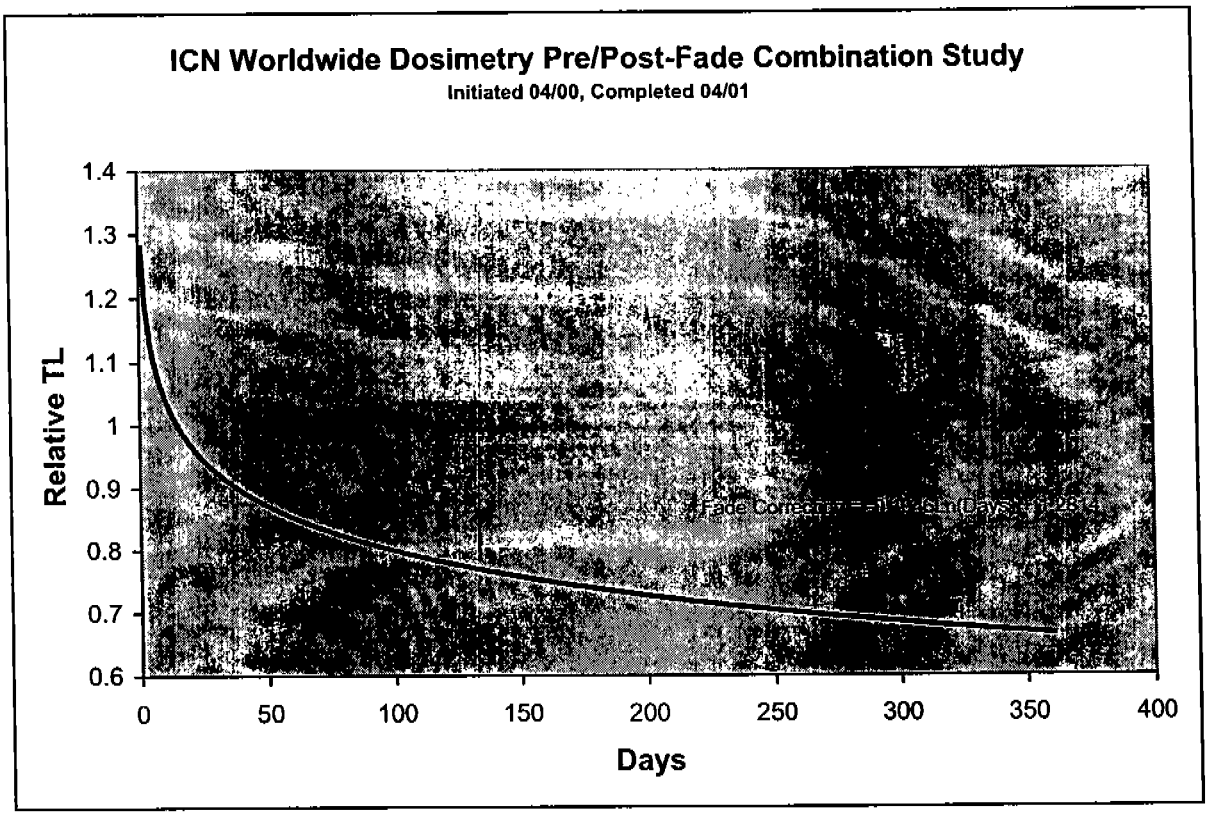


Figure 3-ICN TLD 760 Combination of Pre- and Post-Irradiation Fade Study



| Form: HPF-QAP-006<br>Revision: 3<br>Date: 2/10/03 | Radiation Control Group<br>TLD Badge Quality Assurance Data Sheet | Applicable to procedure:<br><br>HPP-QAP-021 |
|---|---|---|

Date(s) of exposure: 1/8/04 4TH QUARTER '03 BADGES
Total exposure time: 3 HOURS

Source: Cs-137 #27 Distance: 2.51 m
Exposure Rate: 5 MR/HR How determined: CAL RANGE
Instrument(s): Model: RADCAL 1515 Ser. RADCAL 1515
Detectors: _____
Modifying factors: 1.63
Calculations used: N/A
Total Dose Delivered: 15mR (15.45 mR - MODIFIED)
DOELAP Catagory(s): 7
Special Tests: _____

Comments: 1ST EXPOSURE 1/8/04;
4th Qtr '03 Badges held until 1st Qtr, exposed on Date above, then held until 5/04 until processing.

Phantom Location Chart

| | | | |
|---|---|---|---|
| SMITH Z 723<br>14mR | QUACKENBUSH 726<br>15mR | STEARN 730<br>11 mR (Corrected) | ROHER 734<br>12mR |
| TOMPKINS, P 729<br>12 mR (Corrected) | VILLIS, J 728<br>11 mR | VANSER, J 722<br>13 mR | BAILEY, M 731<br>15 mR |
| HOWARD, D 409<br>14 | ROBERTS, O. 724<br>13mR | UNGER, C 725<br>14mR | SPENCER, A 733<br>13 mR (Corrected) |
| LYNCH, J 410<br>12mR | COOK, P 721<br>15mR | CARPENTER, S 732<br>11mR | ZELINSKI 727<br>11mR |

Unirradiated TLDs: PASQUALICCHIO, MCCLINTON
Exposure performed by: [signature]
Reviewed by: [signature]

Attachment 2

# Occupational Radiation Exposure Report

Accredited by the "National Institute of Standards and Technology through NVLAP for the specific scope of accreditation under lab code 100555-0"

REPORT NO: 03542 ACCOUNT NO: 48663S LOCATION: 75041P

| | |
|---|---|
| DATE BADGES RECEIVED: | 05/12/2004 |
| DATE BADGES REPORTED: | MAY 21, 2004 |
| PAGE: 1 OF: 1 | |
| LICENSE NO: | |
| PURCHASE ORDER NO: 03 C1377 | |

NOTIFICATION LEVELS

| DEEP | SHALLOW | EXTREMITY |
|---|---|---|
| 250 | 2500 | |

S/I: 11

REPORT TO:
JEFFERSON LAB
BECKY MOSBRUCKER
12000 JEFFERSON AVE
NEWPORT NEWS, VA 23606

SHIP TO:
JEFFERSON LAB
BECKY MOSBRUCKER
12000 JEFFERSON AVE
NEWPORT NEWS, VA 23606

DOSE EQUIVALENT IN MILLIREMS FOR PERIODS INDICATED BELOW

| WEARER NUMBER | SLOT NUMBER | PROCESS CONTROL NUMBER | NAME (LAST) OR OTHER DESIGNATION | FI | MI | ID TYPE | SSN / ID | BIRTH DATE | SEX | BADGE TYPE | BODY REGION | BODY PART | SERVICE | MONITORING PERIOD FIRST DAY | MONITORING PERIOD LAST DAY | CURRENT DEEP | CURRENT EYE | CURRENT SHALL | CURRENT NEUT. | CURRENT PROC. NOTES | QUARTER TO DATE DEEP | QUARTER TO DATE EYE | QUARTER TO DATE SHALL | YEAR TO DATE DEEP | YEAR TO DATE EYE | YEAR TO DATE SHALL | YEAR TO DATE NO. RPTS | LIFETIME TO DATE DEEP | LIFETIME TO DATE DOSE HISTORY ADJUSTMENTS | LIFETIME TO DATE INCEPTION DATE LIFETIME TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 409 | | 0036504 | HOWARD | D | | 1 | 223709562 | 19580122 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 14 | 14 | 14 | | | 14 | 14 | 14 | 431 | 434 | 434 | 4 | 2801 | | 01/01/1998 |
| 410 | | 0036504 | LYNCH | J | | 1 | 334568377 | 19621023 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 12 | 12 | 16 | | | 12 | 12 | 16 | 510 | 510 | 517 | 4 | 2287 | | 01/01/1998 |
| 721 | | 0036504 | COOK | P | | 1 | 123700998 | 19501105 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 15 | 17 | 18 | | | 15 | 17 | 18 | 458 | 460 | 462 | 4 | 1607 | | 01/01/1998 |
| 722 | | 0036504 | WAMSER | J | | 1 | 373461987 | 19480309 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 13 | 13 | 13 | | | 13 | 13 | 13 | 452 | 465 | 472 | 4 | 2130 | | 01/01/1998 |
| 723 | | 0036504 | SMITH | Z | | 1 | 283149672 | 19400501 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 14 | 14 | 14 | | | 14 | 14 | 14 | 427 | 427 | 427 | 4 | 2699 | | 01/01/1998 |
| 724 | | 0036504 | ROBERTS | O | | 1 | 524356284 | 19620909 | F | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 13 | 14 | 19 | | | 13 | 14 | 19 | 505 | 506 | 516 | 4 | 3738 | | 01/01/1998 |
| 725 | | 0036504 | UNGER | C | | 1 | 127461256 | 19450804 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 14 | 14 | 25 | | | 14 | 14 | 25 | 508 | 516 | 535 | 4 | 3278 | | 01/01/1998 |
| 726 | | 0036504 | QUACKENBUSH | J | | 1 | 095216887 | 19550128 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 15 | 15 | 17 | | | 15 | 15 | 17 | 153 | 153 | 155 | 4 | 3015 | | 01/01/1998 |
| 727 | | 0036504 | ZELINSKI | F | | 1 | 012623765 | 19520621 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 11 | 11 | 11 | | | 11 | 11 | 11 | 514 | 514 | 518 | 4 | 3083 | | 01/01/1998 |
| 728 | | 0036504 | WILLIS | J | | 1 | 307709220 | 19601231 | F | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 11 | 11 | 11 | | | 11 | 11 | 11 | 500 | 500 | 517 | 4 | 2548 | | 01/01/1998 |
| 729 | | 0036504 | TOMPKINS | D | | 1 | 100000035 | 19491201 | F | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 12* | 12* | 12* | | | 0 | 0 | 0 | 132 | 132 | 132 | 4 | 3013 | | 01/01/1998 |
| 730 | | 0036504 | STEARN | R | | 1 | 031444312 | 19600101 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 11* | 11* | 11* | | | 0 | 0 | 0 | 492 | 494 | 494 | 4 | 3238 | | 01/01/1998 |
| 731 | | 0036504 | BAILEY | M | | 1 | 422856124 | 19550409 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 15 | 15 | 15 | | | 15 | 15 | 15 | 453 | 453 | 456 | 4 | 2329 | | 01/01/1998 |
| 732 | | 0036504 | CARPENTER | S | | 1 | 572303498 | 19570704 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 11 | 11 | 14 | | | 11 | 11 | 14 | 513 | 513 | 522 | 4 | 2362 | | 01/01/1998 |
| 733 | | 0036504 | SPENCER | A | | 1 | 230558104 | 19440830 | F | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 13* | 13* | 13* | | | 0 | 0 | 0 | 436 | 438 | 439 | 4 | 2189 | | 01/01/1998 |
| 734 | | 0036504 | ROHRER | A | | 1 | 564695259 | 19610801 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | 12 | 14 | 19 | | | 12 | 14 | 19 | 431 | 433 | 438 | 4 | 2962 | | 01/01/1998 |
| 735 | | 0036504 | PCSOLINSKI | D | | 1 | 452931647 | 19701009 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | | | | | | 0 | 0 | 0 | 491 | 513 | 517 | 4 | 2874 | | 01/01/1998 |
| 736 | | 0036504 | MCCLINTON | J | | 1 | 227426654 | 19521225 | M | 16 | WB | | Q | 10/01/2003 | 12/31/2003 | | | | | | 0 | 0 | 0 | 500 | 500 | 505 | 4 | 1866 | | 01/01/1998 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |

15 mrem
Exposed 1-8-04 (2003 badges)

SEE REVERSE SIDE FOR COMPLETE REPORT DETAILS BY COLUMN NUMBER
IT IS RECOMMENDED THAT YOU KEEP THIS REPORT FOR YOUR RECORDS

GLOBAL DOSIMETRY SOLUTIONS, INC.
Formerly ICN Dosimetry Service
3300 Hyland Avenue, Costa Mesa, CA 92626
U.S./Canada: (800) 251-3331 Worldwide: (714) 545-0100 x6925
http://www.globaldosimetry.com e-mail: info@globaldosimetry.com

JLAB Blind Spike Dosimeter Test Badges for Calendar Quarter: 4th Quarter 2003

Category: IV | Source ID: Cs-137 | Configuration: Phantom at 2.51m

Del. Dose: Calc. ___ Meas. ___ | Detector S/N: | Last Cal.

Del. dose(mrem)=(Meas. Exp Rate) (Exp. Time) (Cal. Cor. Factor) (Cxd)

15 | 5 X | 3 X | 1 X | 1.03

| Dosimeter # | Exp. Date(s) | D | R | Qi | (Qi-B)^2 |
|---|---|---|---|---|---|
| 723 | 1/8/2004 | 15 | 14 | -0.0667 | 0.00141 |
| 726 | 1/8/2004 | 15 | 15 | 0 | 0.01085 |
| 734 | 1/8/2004 | 15 | 12 | -0.2 | 0.00918 |
| 728 | 1/8/2004 | 15 | 11 | -0.2667 | 0.02641 |
| 722 | 1/8/2004 | 15 | 13 | -0.1333 | 0.00085 |
| 731 | 1/8/2004 | 15 | 15 | 0 | 0.01085 |
| 409 | 1/8/2004 | 15 | 14 | -0.0667 | 0.00141 |
| 724 | 1/8/2004 | 15 | 13 | -0.1333 | 0.00085 |
| 725 | 1/8/2004 | 15 | 14 | -0.0667 | 0.00141 |
| 410 | 1/8/2004 | 15 | 12 | -0.2 | 0.00918 |
| 721 | 1/8/2004 | 15 | 15 | 0 | 0.01085 |
| 732 | 1/8/2004 | 15 | 11 | -0.2667 | 0.02641 |
| 727 | 1/8/2004 | 15 | 11 | -0.2667 | 0.02641 |
| * 729 | 1/8/2004 | 15 | 12 | -0.2 | 0.00918 |
| * 730 | 1/8/2004 | 15 | 11 | -0.2667 | 0.02641 |
| * 733 | 1/8/2004 | 15 | 13 | -0.1333 | 0.00085 |

N= 16

sumQi = -1.6667 | s = 0.09524

sumQi/N = B = -0.1042

Total Error = 0.117

<0.067 systematic error due to reporting resolution

0.05 measurement accuracy

Result |B| + s - |E| = 0.08241

Criterion: |B| + s - |E| < 0.30

Comments: Fading Studies

Performed by: David Hamlette

Reviewed by: Keith Welch

* Corrected exposure. Initially read '0'. GDS Re-Ran using $Cs^{137}$ Path.

| Form: HPF-QAP-006<br>Revision: 2<br>Date: 1/26/01<br>RA 01/29/01 | Radiation Control Group<br>TLD Badge Quality Assurance Data Sheet | Applicable to procedure:<br><br>HPP-QAP-021 |
|---|---|---|

Date(s) of exposure: 6/8/04 (1st Half Badges)
Total exposure time: 1hour

Source: Cs-137 (source # 27 Distance: 1.45m
Exposure Rate: 15mR/hr How determined: CAL RANGE
Instrument(s): Model: RADCAL 1515 Ser. _____
Detectors: _____
Modifying factors: 1.03
Calculations used: N/A
Total Dose Delivered: 15mR
DOELAP Catagory(s): 7
Special Tests: 15mR DELIVERED RIGHT BEFORE DELIVERING BADGES FOR READING
Comments: _____

Phantom Location Chart

| | | | |
|---|---|---|---|
| SMITH, Z (723)<br>13mR | VIAMSER, J (722)<br>11mR | _____ | _____ |
| ROBERTS, O (724)<br>0mR<br>(12mR corrected) | COOK, P (721)<br>12mR | VILLIS, J (728)<br>11mR | _____ |
| HOWARD, D (409)<br>12mR | CARPENTER, S (732)<br>11mR | TOMPKINS, P (729)<br>0mR<br>(13mR Corrected) | _____ |
| _____ | _____ | _____ | |

Unirradiated TLDs: _____
Exposure performed by: [signature]
Reviewed by: [signature]

Attachment 3

# Occupational Radiation Exposure Report

Accredited by the "National Institute of Standards and Technology through NVLAP for the specific scope of accreditation under lab code 100555-0"

REPORT NO: 03580 ACCOUNT NO: 48663S LOCATION: 75041P

| | |
|---|---|
| DATE BADGES RECEIVED: | 06/07/2004 |
| DATE BADGES REPORTED: | JUN 15, 2004 |
| PAGE: 1 OF: 1 | |
| LICENSE NO: | |
| PURCHASE ORDER NO: 03 C1377 | |

| NOTIFICATION LEVELS | | |
|---|---|---|
| DEEP | SHALLOW | EXTREMITY |
| 250 | 2500 | |

S/I:1I

REPORT TO:
JEFFERSON LAB
BECKY MOSBRUCKER
12000 JEFFERSON AVE
NEWPORT NEWS, VA 23606

SHIP TO:
JEFFERSON LAB
BECKY MOSBRUCKER
12000 JEFFERSON AVE
NEWPORT NEWS, VA 23606

DOSE EQUIVALENT IN MILLIREMS FOR PERIODS INDICATED BELOW

| WEARER NUMBER | SLOT NUMBER | PROCESS CONTROL NUMBER | NAME (LAST) OR OTHER DESIGNATION | FI | MI | ID TYPE | SSN / ID | BIRTH DATE | SEX | BADGE TYPE | BODY REGION | BODY PART | SERVICE | MONITORING PERIOD FIRST DAY | MONITORING PERIOD LAST DAY | CURRENT DEEP | CURRENT EYE | CURRENT SHALL. | CURRENT NEUT. | CURRENT PROC. NOTES | QUARTER TO DATE DEEP | QUARTER TO DATE EYE | QUARTER TO DATE SHALL. | YEAR TO DATE DEEP | YEAR TO DATE EYE | YEAR TO DATE SHALL. | YEAR TO DATE NO. RPTS | LIFETIME TO DATE DEEP | LIFETIME TO DATE DOSE HISTORY ADJUSTMENTS | LIFETIME TO DATE INCEPTION DATE LIFETIME TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 409 | | 0036705 | HOWARD | D | | 1 | 223709562 | 19690122 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12 | 12 | 12 | * | | 12 | 12 | 12 | 12 | 12 | 12 | 1 | 2813 | | 01/01/1998 |
| 721 | | 0036705 | COOK | P | | 1 | 123700998 | 19501105 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12 | 13 | 13 | * | | 12 | 13 | 13 | 12 | 13 | 13 | 1 | 1819 | | 01/01/1998 |
| 722 | | 0036705 | WAMSER | J | | 1 | 373481987 | 19480309 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 11 | 11 | 11 | * | | 11 | 11 | 11 | 11 | 11 | 11 | 1 | 2141 | | 01/01/1998 |
| 723 | | 0036705 | SMITH | Z | | 1 | 283149872 | 19400501 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 13 | 13 | 13 | * | | 13 | 13 | 13 | 13 | 13 | 13 | 1 | 2712 | | 01/01/1998 |
| 724 | | 0036705 | ROBERTS | O | | 1 | 524366284 | 19620909 | F | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12* | * | * | * | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3738 | | 01/01/1998 |
| 728 | | 0036705 | WILLIS | J | | 1 | 307709220 | 19501231 | F | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 11 | 11 | 11 | * | | 11 | 11 | 11 | 11 | 11 | 11 | 1 | 2569 | | 01/01/1998 |
| 729 | | 0036705 | TOMPKINS | D | | 1 | 100000035 | 19491201 | F | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 13* | * | * | * | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3013 | | 01/01/1998 |
| 732 | | 0036705 | CARPENTER | S | | 1 | 572303498 | 19570704 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 11 | 11 | 11 | * | | 11 | 11 | 11 | 11 | 11 | 11 | 1 | 2373 | | 01/01/1998 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |

15 mrem
Exposed 6-4-04

SEE REVERSE SIDE FOR COMPLETE REPORT DETAILS BY COLUMN NUMBER
IT IS RECOMMENDED THAT YOU KEEP THIS REPORT FOR YOUR RECORDS


GLOBAL DOSIMETRY SOLUTIONS, INC.
Formerly ICN Dosimetry Service
3300 Hyland Avenue, Costa Mesa, CA 92626
U.S./Canada: (800) 251-3331 Worldwide: (714) 545-0100 x6925
http://www.globaldosimetry.com e-mail: info@globaldosimetry.com

JLAB Blind Spike Dosimeter Test Badges for Semi-Annual Calendar : 1st Half 2004 2nd Batch

Category: IV | Source ID: Cs-137 | Configuration: Phantom at 1.45m

Del. Dose: Calc. ___ Meas. ___ | Detector S/N: | Last Cal.

Del. dose(mrem)=(Meas. Exp Rate) (Exp. Time) (Cal. Cor. Factor) (Cxd)

15 | 15 X 1 X 1 X 1.03

| Dosimeter # | Exp. Date(s) | D | R | Qi | (Qi-B)^2 |
|---|---|---|---|---|---|
| 723 | 6/8/2004 | 15 | 13 | -0.1333 | 0.005625 |
| 722 | 6/8/2004 | 15 | 11 | -0.2667 | 0.003402778 |
| * 724 | 6/8/2004 | 15 | 12 | -0.2 | 6.94444E-05 |
| 721 | 6/8/2004 | 15 | 12 | -0.2 | 6.94444E-05 |
| 728 | 6/8/2004 | 15 | 11 | -0.2667 | 0.003402778 |
| 409 | 6/8/2004 | 15 | 12 | -0.2 | 6.94444E-05 |
| 732 | 6/8/2004 | 15 | 11 | -0.2667 | 0.003402778 |
| * 729 | 6/8/2004 | 15 | 13 | -0.1333 | 0.005625 |

N= 8

sumQi = -1.6667 | s = 0.055634864

sumQi/N = B = -0.2083

Total Error = 0.117

<0.067 systematic error due to reporting resolution

Result |BI + s - |EI = 0.14697

Criterion: |BI + s - |EI < 0.30

0.05 measurement accuracy

Comments: Fading Studies

Performed by: David Hamlette

Reviewed by: Keith Welch

* Badges originally reported as '0'. GDS re-ran raw data forced down Cs137 Path.

| Form: HPF-QAP-006<br>Revision: 3<br>Date: 2/10/03 | Radiation Control Group<br>TLD Badge Quality Assurance Data Sheet | Applicable to procedure:<br><br>HPP-QAP-021 |
|---|---|---|

Date(s) of exposure: 1/12/04
Total exposure time: 1ST 1 hr; 2ND 1hr, 3RD 1hr, 4TH 1hr

Source: Cs-137 #27 Distance: 2.51m (2.637 ACT)
Exposure Rate: 5mR/hr How determined: CAL RANGE
Instrument(s): Model: RADCAL 1515 Ser. _____
Detectors: _____
Modifying factors: 1.03
Calculations used: N/A
Total Dose Delivered: 5mR/5mR/5mR/5mR
DOELAP Catagory(s): 7
Special Tests: 1ST EXP 5mR; 2ND EXP 5mR; 3RD EXP 5mR; 4TH EXP 5mR
1/12/04 2/27/04 3/15/04 4/20/04
Comments: _____

Phantom Location Chart

| | | | |
|---|---|---|---|
| | ROHRER, A 734 | UNGER, C 725 | LYNCH J 410 |
| PISOLINSKI 735 | BAILEY, M 731 | MCCLINTON, J 736 | STEARN 730 |
| | QUACKENBUSH 726 | ZELINSKI, F 727 | SPENCER, A 733 |
| | | | |

Unirradiated TLDs: _____
Exposure performed by: [signature]
Reviewed by: [signature]

Attachment 4

# Occupational Radiation Exposure Report

Accredited by the "National Institute of Standards and Technology through NVLAP for the specific scope of accreditation under lab code 100555-0"

REPORT NO: 03564 ACCOUNT NO: 48663S LOCATION: 75041P

| | |
|---|---|
| DATE BADGES RECEIVED: | 05/21/2004 |
| DATE BADGES REPORTED: | JUN 2, 2004 |
| PAGE: 1 OF: 1 | |
| LICENSE NO: | |
| PURCHASE ORDER NO: 03 C1377 | |

| NOTIFICATION LEVELS | | |
|---|---|---|
| DEEP | SHALLOW | EXTREMITY |
| 250 | 2500 | |

S/I:1I

REPORT TO:
JEFFERSON LAB
BECKY MOSBRUCKER
12000 JEFFERSON AVE
NEWPORT NEWS, VA 23606

SHIP TO:
JEFFERSON LAB
BECKY MOSBRUCKER
12000 JEFFERSON AVE
NEWPORT NEWS, VA 23606

DOSE EQUIVALENT IN MILLIREMS FOR PERIODS INDICATED BELOW

| WEARER NUMBER | SLOT NUMBER | PROCESS CONTROL NUMBER | NAME (LAST) OR OTHER DESIGNATION | FI | MI | ID TYPE | SSN/ID | BIRTH DATE | SEX | BADGE TYPE | BODY REGION | BODY PART | SERVICE | MONITORING PERIOD FIRST DAY | MONITORING PERIOD LAST DAY | CURRENT DEEP | CURRENT EYE | CURRENT SHALL. | CURRENT NEUT. | CURRENT PROC. NOTES | QUARTER TO DATE DEEP | QUARTER TO DATE EYE | QUARTER TO DATE SHALL. | YEAR TO DATE DEEP | YEAR TO DATE EYE | YEAR TO DATE SHALL. | YEAR TO DATE NO. RPTS | LIFETIME TO DATE DEEP | LIFETIME TO DATE DOSE HISTORY ADJUSTMENTS | LIFETIME TO DATE INCEPTION DATE LIFETIME TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 410 | | 0036587 | LYNCH | J | | 1 | 334566377 | 19821023 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 22 | 22 | 22 | * | | 22 | 22 | 22 | 22 | 22 | 22 | 1 | 2309 | | 01/01/1998 |
| 725 | | 0036587 | UNGER | C | | 1 | 127491256 | 19450804 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12 | 12 | 21 | * | | 12 | 12 | 21 | 12 | 12 | 21 | 1 | 3280 | | 01/01/1998 |
| 726 | | 0036587 | QUACKENBUSH | J | | 1 | 095216897 | 19550128 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12 | 12 | 18 | * | | 12 | 12 | 18 | 12 | 12 | 18 | 1 | 3027 | | 01/01/1998 |
| 727 | | 0036587 | ZELINSKI | F | | 1 | 012623765 | 19520821 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 10 | 10 | 13 | * | | 10 | 10 | 13 | 10 | 10 | 13 | 1 | 3093 | | 01/01/1998 |
| 730 | | 0036587 | STEARN | R | | 1 | 031444312 | 19600101 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 11 | 11 | 22 | * | | 11 | 11 | 22 | 11 | 11 | 22 | 1 | 3249 | | 01/01/1998 |
| 731 | | 0036587 | BAILEY | M | | 1 | 422856124 | 19650409 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12 | 12 | 19 | * | | 12 | 12 | 19 | 12 | 12 | 19 | 1 | 2341 | | 01/01/1998 |
| 733 | | 0036587 | SPENCER | A | | 1 | 230559104 | 19440630 | F | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 12* | * | * | * | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2189 | | 01/01/1998 |
| 734 | | 0036587 | ROHRER | A | | 1 | 564695259 | 19610901 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 14 | 17 | 22 | * | | 14 | 17 | 22 | 14 | 17 | 22 | 1 | 2976 | | 01/01/1998 |
| 735 | | 0036587 | PCSOLINSKI | D | | 1 | 452931647 | 19701009 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 13* | 13 | 28 | * | | 0 | 13 | 28 | 0 | 13 | 28 | 1 | 2874 | | 01/01/1998 |
| 736 | | 0036587 | MCCLINTON | J | | 1 | 227428654 | 19621225 | M | 16 | WB | | S | 01/01/2004 | 06/30/2004 | 15 | 15 | 36 | * | | 15 | 15 | 36 | 15 | 15 | 36 | 1 | 1870 | | 01/01/1998 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |

20 mrem LN 4 Exposures

1/12/04 2/27/04 3/15/04 4/20/04

SEE REVERSE SIDE FOR COMPLETE REPORT DETAILS BY COLUMN NUMBER
IT IS RECOMMENDED THAT YOU KEEP THIS REPORT FOR YOUR RECORDS


GLOBAL DOSIMETRY SOLUTIONS, INC.
Formerly ICN Dosimetry Service
3300 Hyland Avenue, Costa Mesa, CA 92626
U.S./Canada: (800) 251-3331 Worldwide: (714) 545-0100 x6925
http://www.globaldosimetry.com e-mail: info@globaldosimetry.com

JLAB Blind Spike Dosimeter Test Badges for Calendar Quarter: 1st Half 2004 1st Batch

Category: IV Source ID: Cs-137 Configuration: Phantom at 2.51m

Del. Dose: Calc. ___ Meas. ___ Detector S/N: Last Cal.

Del. dose(mrem)=(Meas. Exp Rate) (Exp. Time) (Cal. Cor. Factor) (Cxd)

20 = 5 X 3 X 1 X 1.03

| Dosimeter # | Exp. Date(s) | D | R | Qi | (Qi-B)^2 |
|---|---|---|---|---|---|
| 734 | 1/12/2004 | 20 | 14 | -0.3 | 0.0012 |
| 725 | 1/12/2004 | 20 | 12 | -0.4 | 0.0042 |
| 410 | 1/12/2004 | 20 | 22 | 0.1 | 0.1892 |
| * 735 | 1/12/2004 | 20 | 13 | -0.35 | 0.0002 |
| 731 | 1/12/2004 | 20 | 12 | -0.4 | 0.0042 |
| 736 | 1/12/2004 | 20 | 15 | -0.25 | 0.0072 |
| 730 | 1/12/2004 | 20 | 11 | -0.45 | 0.0132 |
| 726 | 1/12/2004 | 20 | 12 | -0.4 | 0.0042 |
| 727 | 1/12/2004 | 20 | 10 | -0.5 | 0.0272 |
| * 733 | 1/12/2004 | 20 | 12 | -0.4 | 0.0042 |

N= 10

sumQi = -3.35 s = 0.1684

sumQi/N = B = -0.335

Total Error = 0.117 0.1

Result |B| + s - |E| = 0.3864 <0.067 systematic error due to reporting resolution

Criterion: |B| + s - |E| < 0.30 0.05 measurement accuracy

Comments: Fading Studies

Performed by: David Hamlette

Reviewed by: Keith Welch

* Badges initially reported as '0'. GDS Re-ran using Cs137 Path.