Draft White Paper

SC&A REVIEW OF LAWRENCE BERKELEY NATIONAL LABORATORY SITE PROFILE MATRIX ISSUES #6, #7, AND #8

Contract Number 200-2009-28555

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September 2012

S. COHEN & ASSOCIATES: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No.: White Paper – SC&A Review of LBNL Issues #6, #7, and #8 Effective Date: Draft – September 5, 2012 Revision No. 0 (Draft)
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Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	09/05/2012	Initial issue

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ABBREVIATIONS AND ACRONYMS

DCAS	Division of Compensation Analysis and Support
DL	detection limit
DR	dose reconstruction
eV	electron volt
HEP	high energy physics
ICRP	International Commission on Radiation Protection
keV	kilo electron volts
LBNL	Lawrence Berkeley National Laboratory
LOD	limit of detection
MDL	minimum detectable limit
MeV	million electron volts
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
n/p	neutron-to-photon ratio
NTA	Neutron Track A
ORAUT	Oak Ridge Associated Universities Team
R/wk	Roentgen per week
rem	Roentgen equivalent man
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
TBD	Technical Basis Document
TIB	Technical Information Bulletin
TLD	thermoluminescent
WB	Whole Body
WG	Work Group

1.0 INTRODUCTION

This evaluation is based on the following documents:

- On April 2, 2007, the National Institute for Occupational Safety and Health (NIOSH) issued the Lawrence Berkeley National Laboratory (LBNL) Site Profile, Rev. 01, ORAUT-TKBS-0049 (ORAUT 2007).

- On January 20, 2010, NIOSH issued the LBNL Special Exposure Cohort Petition Evaluation Report SEC-00160 for August 13, 1942, through December 31, 1961, Rev. 0, (NIOSH 2010), based on lack of bioassay records through 1961 and external dosimetry records through 1947.

- On May, 10, 2010, NIOSH issued the LBNL Site Profile, Rev. 02, ORAUT-TKBS-0049 (ORAUT 2010b), herein referred to as the Technical Basis Document (TBD).

- On January 27, 2012, SC&A issued the LBNL Site Profile Issues Matrix (SC&A 2012).

- On February 1, 2012, NIOSH issued preliminary responses to SC&A's LBNL Site Profile Issues Matrix (NIOSH 2012).

- On February 3, 2012, a LBNL Work Group (WG) meeting was held to discuss the LBNL site profile issue. SC&A and NIOSH were each assigned a list of action items by the WG.

The following is a summary of SC&A's action items for Issues #6, #7, and #8, and the resulting SC&A response.

2.0 LBNL SITE PROFILE ISSUES AND FINDINGS

2.1 SC&A's Initial Issue #6: Insufficiency of Neutron Dosimetry Treatment

NTA Film Energy Threshold Determination: As has been the case in a number of site profiles prepared by NIOSH, there is an inconsistent approach to the energy cut-off for the NTA neutron dosimeter. Callout "c" in Table 6.5 references NIOSH 2002 as listing the NTA lower energy threshold at 500 keV. Yet attribution number 47 discusses 800 keV as the threshold, and this is used as the basis for neutron energy threshold in ORAUT-TKBS-0049, Rev. 01 (ORAUT 2007). Other sources list 1,000 keV as the threshold for NTA response. The assumption that NTA film responds down to 500 keV is not justified by the technical data and is not claimant favorable.

Failure to Adjust Recorded Doses to Correct for Lack of Response of NTA and CR-39 in the Intermediate and Thermal Neutron Energy Range: Table 6.6 of TKBS-0049 (ORAUT 2007), "Adjustments to Recorded Dose," defines the corrections for photon and neutron dosimeters to adjust the measured quantity. However, no adjustment is indicated for the failure of NTA film to respond to intermediate energy neutrons. As presented, a significant part of the spectrum is inappropriately monitored and uncorrected.

There is virtually no discussion of the potential neutron fields that may have existed throughout the history of this facility. Given that LBNL was a world leader in accelerator development, and given the leading-edge high energies developed by the machines, it is likely that there was the potential for unanticipated radiation fields and possible neutron exposures across a range of energies, especially in the early decades.

The site profile document is silent as to thermal and/or slow neutron exposure. A search of the "O" drive revealed only a single document that mentioned slow or thermal neutrons. Clearly, there was the potential for exposure to slow neutrons, as slow neutron electroscopes were in use in 1956 and readings were documented for several individuals.

It is unclear from ORAUT-TKBS-0049 (ORAUT 2007) how and when albedo thermoluminescent (TLD) data were merged with CR-39 results. The gap in neutron response from above the cadmium cutoff (nominally 0.5 eV) to the lower energy threshold for CR-39 (also not mentioned, but assumed to be around 150 keV) is not discussed. NIOSH should evaluate the neutron program and determine how missed intermediate energy neutron dose should be determined for this period, as well as intermediate and thermal energy neutrons for the NTA and pre-NTA years.

Selection of Minimum Detectable Dose for CR-39 Dosimeters: Table 6-1 of TKBS-0049 (ORAUT 2007) shows that the minimum detectable level (MDL) for CR-39 is 10 mrem, with no attribution provided. The Los Alamos TBD shows an MDL for CR-39 of 20 mrem. The current commercial service available from Landauer, Inc., also shows an MDL of 20 mrem. It is likely that the MDL for CR-39 is higher than 10, and more likely around 20 mrem. This number is important in terms of assessing missed dose from exposure below the detection limit (DL). It should be noted that the MDL value does not encompass the dose not registered because of the inability of CR-39 to detect neutrons of energies less than approximately 150 keV.

Use of Neutron-Gamma Ratios for Situations Where Neutron Data are Lacking – Seeming Inconsistency between the Environmental and External Dose Sections: Table 4.1 of the Environmental Occupational Dose section (Section 4.0) of TKBS-0049 (ORAUT 2007) contains estimates of annual environmental dose throughout the history of the facility. The values provided are totals of neutron and photon exposure.

In TKBS-0049 (ORAUT 2007), the Environmental Dose section utilizes a ≥70% factor and the External Dose section utilizes a 42% factor. This significant difference in the average site-wide neutron-to-photon ratio is surprising. It is possible that the environmental dose includes more skyshine and other factors; however, this issue needs to be addressed and the large difference explained.

The present section in TKBS-0049 (ORAUT 2007) on the determination of missed and missing neutron exposure needs a thorough review. Both the source terms and the dosimeter response specifications need to be addressed.

NIOSH's Preliminary Response to Issue #6:

> *Regarding NTA film, Section 6.3 of Revision 2 of the LBNL Site Profile indicates that a neutron to photo ratio can be applied for the LBNL film era which was up through 1994. The LBNL Site Profile includes neutron to photon ratios based on site specific information.*
>
> *Section 6.2.3 of Revision 2 of the LBNL Site Profile provides a correction factors to account for angular dependence, and fast neutron energy for NTA film and CR-39 dosimeters.*
>
> *Peer-reviewed data indicate an* [CR-39] *LOD of 15 mrem (http://rpd.oxfordjournals.org/content/55/4/285.abstract). Table 6-4 of Revision 2 of the LBNL Site Profile will be revised accordingly.*
>
> *Regarding the NP ratio for environmental doses and personnel dosimetry, the footnote (b) of Table 4-1 does point out that these numbers are impacted by skyshine and shielding. Therefore, NIOSH feels that the difference in environmental geometry and shielding scenarios and occupational exposure geometry and shielding scenarios account for the differences in NP ratios.*

SC&A's Current Evaluation of Issue #6: Insufficiency of Neutron Dosimetry Treatment

SC&A finds that some of the items in this original site profile issue have been addressed, or were negated, by the revised TKBS-0049 (ORAUT 2010b), or the Special Exposure Cohort (SEC). However, a number of important items still remain, and several new items have been introduced by the revisions in TKBS-0049; these items are discussed below.

Neutron Radiation Fields Not Characterized

The following statement is found on page 54 of TKBS-0049 (ORAUT 2010b):

> *Evaluations of potential neutron radiation hazards in LBNL workplaces have also been done on numerous occasions, as noted in Attachment A. Table 6-6 lists neutron radiation sources potentially encountered at LBNL over the years, the approximate energy category, and the associated dose fraction. Workplace neutron radiation energies of potential external radiation exposure significance to workers are between 10 keV and 20 MeV.*

Then, in Table 6-6, the last line lists **Cyclotrons and Accelerators** in Buildings 51 and 71 as having **50% 0.1–2.0 MeV** and **50% 2.0–20 MeV** neutron dose fields. SC&A has reviewed the material and some of the references in Attachment A of ORAUT 2010b and found that this historical account is a useful tool. We note, however, that the pertinent data have not been extracted and brought forth into the main text of the TBD to provide a technically sound basis for comparing the dosimeters, which were calibrated using PoBe or PuBe neutron standards (ORAUT 2010b, pg. 53), to the various neutron fields present in the work areas and environmental areas of the numerous LBNL accelerators over a wide time span.

There is need for greater detail and benchmark measurements characterizing the neutron fields workers could have been exposed to over time, and operating conditions at the various facilities. For example, were there measurements to show that some workers were, or were not, exposed to significant neutron fields below the cut-off energy of NTA film, TLDs, and CR-39? Additionally, were there measurements to show that some workers were, or were not, exposed to neutron fields with significant dose above the range that these dosimeters could register with reasonable accuracy (i.e., >10–20 MeV)? Although some of this information may be present in the references contained in Attachment A of ORAUT 2010b (i.e., BNS 1957; Moyer 1960; Patterson 1965; Stephens and Miller 1969; and especially Sun 1991), this information should be brought forth into the text of the TBD. The TBD should provide summaries of the different accelerators' operating periods, neutron energy spectra and dose equivalent measures made in the work areas and environmental areas, and the response of the NTA film and CR-39 neutron dosimeters, along with any correction factors. For example, the 1987 article concerning NTA film and CR-39 response comparisons (Greenhouse 1987), discussed on pages 107–108 of Attachment A of the TBD, indicates that NTA film and CR-39 dosimeters only responded to approximately 50% of the total neutron dose equivalent; this could indicate an issue with the recorded neutron doses, and perhaps a need for correction factors to be applied.

Use of TLDs and CR-39

It is unclear from the TBD how/when/if TLD neutron data were merged with CR-39 results. According to Tables 6-3 and 6-4 of the revised TKBS-0049 (ORAUT 2010), since 1995, TLDs are only used for beta/photon dosimetry and CR-39 is the only neutron dosimeter. If this is true, how is the dose below the threshold (~0.1 MeV) of CR-39 detected? Are any neutron-sensitive TLDs used, and if so, how are the data from the TLD and CR-39 compiled for recorded dose?

CR-39 MDL
Table 6-4 of the revised TKBS-0049 lists the MDL for CR-39 as 10 mrem; this is to be changed to 15 mrem, as per the LBNL WG meeting of February 3, 2012. SC&A has found that the Los Alamos National Laboratory uses a CR-39 MDL value of 20 mrem (ORAUT 2009), and Brookhaven National Laboratory recommends a value of <20 mrem (ORAUT 2010a). SC&A finds that an MDL of 15 mrem may be reasonable, but not necessarily claimant favorable.

Environmental versus Facility n/p Values
The Environmental Dose section utilizes a ≥70% factor (n/p of 2.33 =>2.33/3.33 = 0.70) as per footnote "c" of Table 4-1, page 32, of the revised TKBS-0049, and the External Dose section utilizes a 44% factor (n/p of 0.77 => 0.77/1.77 = 0.44) as per Table 6-10, page 56, of the revised TKBS-0049. This indicates that the neutron-to-photon doses were, on the average, 2.33/0.77 = 3.0 times greater in the environmental areas than in the facilities. While some of this difference could come from neutron skyshine in the early years, SC&A believes that if the environmental doses were measured using survey instruments, such as rem-balls, (as indicated in annotation [15][1] on page 62 of the TKBS-0049 2010 where it mentions "portable instrument readings"), then it is feasible that the NTA film personnel badges may have missed some of the lower/higher energy neutron dose in the work areas around the accelerators. Table 4-1 on page 31 should provide greater granularity by tabulating annual gamma and neutron doses and then n/p values. Footnote "c" to Table 4-1 states that, "Neutron component of dose is typically ≥70% of total [16][2]." SC&A believes that this statement is too general and that greater clarity would be realized by a breakdown on an annual basis. We also note that if skyshine is a contributor to the greater environmental n/p values compared to the personnel monitoring n/p values, then the environmental n/p values should show a decrease as a function of time as the tops of the accelerators became better shielded around the 1960s (Moyer 1960).

Revised TKBS-0049 used Under-responsive NTA Film to Correct for Under-responsive NTA Film In Sections 6.4.3 and 6.4.3.1 of the revised TKBS-0049, NIOSH used 876 NTA film results from 1947–1987 (which originally missed part of the dose because of the lack of low-energy neutron response below ~800 keV) to derive n/p values to replace these very neutron dose readings that are faulty, because they missed the doses below ~800 keV (circular reasoning). If the NTA film readings can be adjusted by applying the appropriate correction factors for fading, angular dependence, low-energy cut off, decreased response at high energies, etc., then the corrected recorded results can be used directly in dose reconstruction (DR), and n/p values would only be needed to assign neutron doses to workers who were not monitored for neutrons, but who were potentially exposed to neutrons.

[1] [15] East, James. ORAU Team, Task 3. May, 2006. Summary statement based on facts reported in the Environmental Reports over the years. The portable instrument readings were converted from hourly rates to annual for consistency. [Annotation from ORAUT 2010b.]

[2] [16] East, James. ORAU Team, Task 3. May, 2006. This statement is drawn from notations in many of the Environmental Reports and represents the capabilities of the monitoring at the time observations were made. [Annotation from ORAUT 2010b.]

Revised TKBS-0049 - Neutron and Photon Doses are **Not** Correlated

It is stated on page 57 of TKBS-0049 (ORAUT 2010b) that, "Figure 6-2 illustrates a scatter plot of the measured neutron and photon dose. It is evident that the measured neutron and photon doses are well correlated with a Pearson Correlation of 0.09." However, an examination of Figure 6-2 (reproduced below as Exhibit A) shows that there appears to be very little correlation between neutron and photon doses in this plot. A **Pearson Correlation of 0.0913** and a **Spearman Correlation of 0.0923** indicates a **poor** correlation between the variables.

Exhibit A: Plot of Neutron Dose vs. Photon Dose

(From ORAUT 2010b, Figure 6-2, page 59)

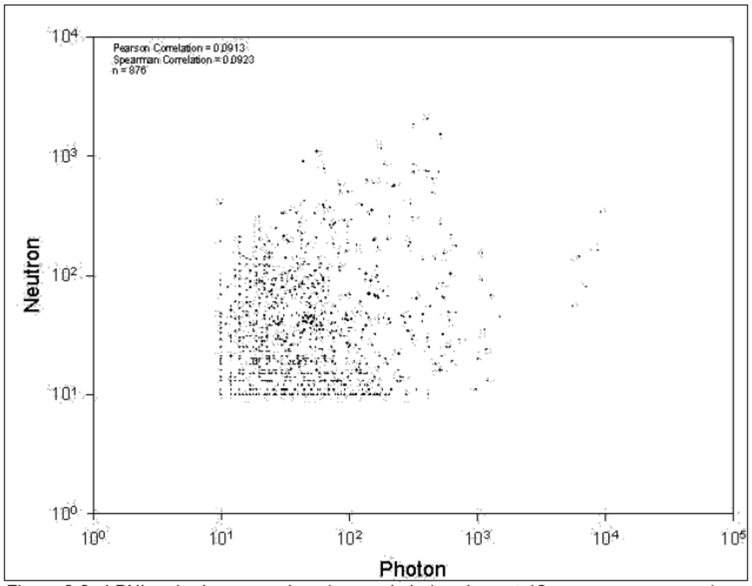

Figure 6-2. LBNL paired personnel neutron and photon doses ≥10 mrem measurements.

Text Errors in Revised ORAUT-TKBS-0049

- The scales in Figure 6-1 and 6-3 are backwards and need to be corrected.
- Table 6-6, page 54, *ICRP 60 correction factors* are actually "adjusted" *ICRP 60 correction factors*, because they are a combination of the ICRP 60 correction factor and the energy fraction.

Summary of Issue #6

The revised TKBS-0049 (ORAUT 2010b), page 55, addressed the angular dependence of neutron dosimetry (both NTA film and CR-39) and recommends a correction factor of 1.3, which is acceptable. However, there are no explicit recommendations for correction of the lack of response below the lower-energy cut off or lack of sensitivity at higher energies or the mention of correction factors for NTA film fading. The following is stated on page 55 of the TBD:

> *Considering that NTA has a lower energy response limit of about 0.5 MeV, it is likely that neutron doses were under-estimated in general workplace areas with highly scattered neutron fields and accurately measured in less scattered neutron fields with higher energy neutrons. As such, consideration can be given to*

> *estimating the neutron dose using a neutron-to-photon dose (NP) ratio which is described in Section 6.4.3.* [Emphasis added.]

This does not explicitly direct the dose reconstructor to use the n/p method. Section 6.3 on page 56 states that the dose reconstructor "*should*" use the n/p method to determine the missed neutron dose, and on page 58 it is stated that "*Table 6-10 may be*" used to assign measured and missed neutron doses. However, Table 6-11 on page 60 provides a table of uncertainties, which include <u>NTA film</u> for 1940s–1994 (i.e., apparently not using the n/p method); additionally, as previously discussed, the n/p values that were derived to replace deficient recorded neutron dose values, were themselves based on deficient recorded neutron dose values (which did not correlate well to the paired photon dose values).

It is not clear if the uncertainties in Table 6-11 are assumed to encompass the angular dependence, lack of low-energy response, decreased response at high energies, and fading correction factors (which were not all quantified in ORAUT 2010b), as well as the variability in measurement uncertainty, or just the variability in measurement uncertainty; i.e., is the dose reconstructor to apply this uncertainty factor in addition to the 1.3 angular correction factor as given in Table 6-8, as well as the other correction factors that have not yet been quantified?

2.2 SC&A's Initial Issue #7: Failure to Justify the Shallow to Deep Dose Ratio Assumption

TKBS-0049 (ORAUT 2007) provides guidance concerning the doses to be assigned in the "early" years (pre-1979) for which there is no record of beta exposure. In the general case, there is an assumption that a factor of three for the ratio of shallow to deep dose is reasonable and claimant favorable. However, as discussed below, SC&A believes that for some personnel, the 3:1 ratio may not be claimant favorable.

However, LBNL had a broad mandate. In most cases, the site description does not provide sufficient detail as to the quantities, forms, and methods under which these materials were handled. What is known is that the levels of protection in the 1940s, 1950s, and 1960s fell far short of what would be considered good practice today.

There is no mention of skin, head and eye, or non-uniform whole-body irradiation in the site profile. Typically, workers handling beta emitters and those performing maintenance inside accelerators can be exposed to significant non-uniform fields. Likewise, there is no mention in TKBS-0049 (ORAUT 2007) of potential skin and clothing contamination and resultant exposure.

It is unclear from TKBS-0049 (ORAUT 2007) if workers were exposed to significant shallow dose with possibly little deep dose to be used as an indicator. Possible activities that may have been conducted include fume hood operations, maintenance of accelerators, ventilation and plumbing systems, waste disposal operations, and spill cleanup. The lists of nuclides are extensive and include beta emitters, including some pure beta and low-energy X-ray emitters. For some personnel, the 3:1 ratio may not be claimant favorable. NIOSH should identify the workers who could have received exposure from these beta or low-energy X-ray emitters, or provide an alternative method of estimating the shallow dose in a claimant-favorable manner.

NIOSH's Preliminary Response to Issue #7:

> *Non-uniform exposure can be addressed using the guidance in DCAS-TIB-0010[a)] [DCAS 2011] and DCAS-TIB-0013[b)] [DCAS 2010], or, if necessary be addressed on a case-by-case basis using modeling. Section 6.6 of Revision 2 of the LBNL Site Profile provides claimant-favorable guidance on the assignment of shallow dose because it is based on a comparison of the historical dose limits used by LBNL.*

SC&A's Current Evaluation of Issue #7: Failure to Justify the Shallow to Deep Dose Ratio Assumption

SC&A finds that some of the items in this original site profile issue have been addressed, or were negated, by the revised TKBS-0049 (ORAUT 2010b), or the SEC. However, a number of important items still remain, and several new items have been introduced by the revisions in TKBS-0049 2010; these items are discussed below.

SC&A's Review of DCAS-TIB-0010, DCAS-TIB-0013, and ORAUT-OTIB-0017
SC&A concurs that the use of these documents provides for resolution of some of the geometry and shallow dose issues when shallow doses were measured. However, as per TKBS-0049 (ORAUT 2010b), page 51, Table 6-2, there was no shallow dose measured or recorded prior to 1982. Therefore, the issue of the lack of shallow dose measurements is pertinent for the period 1948–1981. SC&A's review of Nielsen 1951 indicates that the beta-to-gamma ratio for a uranium slab 12 inches thick is 3:1; however, it is 5:1 at closer distances. Therefore, the 3:1 ratio may not be claimant favorable at close distances. Additionally, working with pure beta emitters such as P-32 and Sr-90 (listed in Tables 2-1 and 6-5 of ORAUT 2010b) would result in exposures that would not register any gamma dose on the dosimeters to be used to derive the shallow dose.

Extremity Doses
TKBS-0049 (ORAUT 2010b) states on page 61 that the extremity dose can be assigned by using 3 times the WB (Whole Body) photon dose based on the comparison of the dose limits at the time, as provided on page 61:

Whole body–0.3 rem/wk;
Skin–0.5 rem/wk; and
Extremity–1.5 R/wk.

However, the extremity dose limit is 5 times the WB dose limit (i.e., [1.5 R/wk] / [0.3 R/wk] = 5); therefore, 3 times the WB dose could underestimate the extremity dose.

2.3 SC&A's Initial Issue #8: Uncertainty in Beta-Gamma Dosimeter Response to Radiation Types and Energies

The Use of Early Electroscope Data Needs Greater Definition: Page 39 of TKBS-0049 (ORAUT 2007) describes the use of electroscope data as follows:

> *… Exposure data were recorded by film badges and thermoluminescent dosimeters (TLDs). Early exposure records also provided electroscope (or at times, electrometer or E was used) results, which supplemented the results measured by film. Dose reconstructors should use the electroscope results in a qualitative manner because no data were found on the calibration or energy response of these devices; they should use the film or TLD results to estimate the actual exposure or the electroscope reading if no corresponding dosimeter reading exists.*

A search of the "O" drive found that, anecdotally at least, there were significant problems with electroscopes. A study performed November 23, 1953, by Jim Bennett (Bennett 1953) showed that readings from the three electroscopes tested were widely divergent from the film that was exposed with them. Two gave a 10% response compared with the film, and the third was "off scale." No details are provided as to the energy of the gamma source used for the exposure. However, the memo provides a cautionary statement as to using electroscope data, even in a qualitative manner.

Dosimeter Response to Very High Energy Photons and Charged Particles: LBNL was a pioneer in the development of high energy physics (HEP) and in the search for exotic particles. The film and electroscopes in use in the early decades will likely not have been calibrated for energies above 1 or 2 MeV. NIOSH should evaluate the dosimetry and potential for exposure to radiation at energies above that commonly produced by radioisotopes. The detectors will have responded to some degree, but the correction factor magnitude and sign are unknown and not mentioned in the 2010 version of TKBS-0049. The response of the detector element or film, for example, will depend greatly on the composition of the holder and filters.

NIOSH's Preliminary Response to Issue #8:

> *The period prior to 1961 is covered under the SEC. Section 6.1.1 of Revision 2 of the LBNL Site Profile has been revised to read," Dose reconstructors should use the electroscope results cautiously to assign exposure because no data were found on the calibration or energy response of these devices; they should use preferentially the film or TLD results to estimate the actual exposure. The electroscope results include daily readings in tables captioned "dosimeter," "slow neutron," and "electroscope." The three readings, which occurred on the same dates, were evidently used to measure exposure at the end of work shifts [42][3].*
>
> *Presently any claims from 1948 and later that have electroscope data also have film and/or TLD data, which the dose reconstructor is directed to use according to the LBNL Site Profile.*

[3] [42] Guido, Joseph, ORAU Team, Task 5. June 5, 2006. Mr. Guido reviewed the original data from multiple claims and made the observation that the readings represented the end of work shifts. [Annotation from ORAUT 2010b.]

SC&A's Current Evaluation of Issue #8: Uncertainty in Beta-Gamma Dosimeter Response to Radiation Types and Energies

SC&A finds that some of the items in this original site profile issue have been addressed, or were negated, by the revised TKBS-0049 (ORAUT 2010b), or the SEC. However, a number of important items still remain, and several new items have been introduced by the revisions in TKBS-0049; these items are discussed below.

External Dose is Not Covered under the SEC After 1947

The NIOSH response to this issue of "The period prior to 1961 is covered under the SEC." appears to be incorrect, because the SEC only covers external dose through 1947; therefore, this issue is still pertinent for the year 1948 and forward.

Electroscope Issue

This issue was discussed during the February 3, 2012, LBNL WG meeting. This item would not be an issue for the year 1948 and forward because film or TLD data are available along with the electroscope data; therefore, the electroscope data are not needed for dose reconstruction. According to NIOSH, this change will be noted in the next revision of TKBS-0049. **This issue can be closed**.

Dosimeters Calibration Compared to Measured Workplace Photon Energies

As with neutron dosimeter, photon dosimetry needs to be evaluated in view of the dosimetry calibration sources and experimentally measured photon energy fields (benchmarks) around the occupied areas of the accelerators as a function of operating conditions and time. If this information is available in the references in Attachment A of TKBS-0049 (ORAUT 2010b), it should be summarized and documented in the main text of the TBD.

3.0 SUMMARY

SC&A finds that some of the items in the original site profile issues have been addressed or were negated by the revised TKBS-0049 (ORAUT 2010b) or the SEC. However, a number of important items still remain and several new items have been introduced by the revisions in TKBS-0049; these items were discussed in the Section 2 of this report. Important benchmark information in Attachment A of the TBD needs to be extracted and summarized and applied in the main body of the TBD.

4.0 REFERENCES

Bennett 1953. Bennett, J., of LBNL, Letter to Nolan, W., of LBNL, dated December 2, 1953, entitled "*Film Badge Testing Program*," University of California, Lawrence Berkeley National Laboratory, Berkeley, California. [SRDB Ref ID: 21337]

BNS 1957. *Bevatron Neutron Survey of 12/5/1957*, University of California, Radiation Laboratory, Berkeley, California. December 5, 1957 [SRDB Ref ID: 21549, pdf. pp. 23–26].

DCAS 2010. *Technical Information Bulletin: Selected Geometric Exposure Scenario Considerations for External Dose Reconstruction at Uranium Facilities*, DCAS-TIB-0013, Rev. 0. National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio. November 23, 2010.

DCAS 2011. *Technical Information Bulletin: Best Estimate External Dose Reconstruction Considerations for Glovebox Workers*, DCAS-TIB-0010, Rev. 4. National Institute for Occupational Safety and Health, Division of Compensation Analysis and Support, Cincinnati, Ohio. November 28, 2011.

Greenhouse, N.A., T.M. de Castro, J.B. McCaslin, A.R. Smith, R.K. Sun, and D.E. Hankins, 1987. *An Evaluation of NTA Film in an Accelerator Environment and Comparisons with CR-39*, Radiation Protection Dosimetry (1987) 20 (3): 143-147.

ICRP (International Commission on Radiological Protection) 1991. *1990 Recommendations of the International Commission on Radiological Protection*, Publication 60, Pergamon Press, Oxford, England.

Moyer, B.J., 1960. *Radiation Fields of High-Energy Accelerators*, Presented at the Thirteenth International Congress on Occupational Health during July 25–29, 1960, [SRDB Ref ID: 13990].

Nielsen 1951. Nielsen, E., of LBNL, Letter to Garden, N., of LBNL, dated September 20, 1951, entitled "*Radiation from Uranium Block*," University of California, Lawrence Berkeley National Laboratory, Berkeley, California. [SRDB Ref ID: 21143]

NIOSH 2002. *External Dose Reconstruction Implementation Guideline*, OCAS-IG-001, Rev. 1, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. August, 2002.

NIOSH 2010. *Special Exposure Cohort, Petition Evaluation Report Petition SEC-00160 for the Lawrence Berkeley National Laboratory*, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. January 20, 2010.

NIOSH 2012. *NIOSH preliminary responses to issues have been added on Feb 1, 2012 prior to the work group discussion on Feb 3, 2012*. National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. February 1, 2012.

ORAUT 2005. *Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose*, ORAUT-OTIB-0017, Rev. 01. Oak Ridge Associated Universities Team, Cincinnati, Ohio. October 11, 2005.

ORAUT 2007. *Site Profile for the Lawrence Berkeley National Laboratory*, ORAUT-TKBS-0049, Rev. 01. Oak Ridge Associated Universities Team, Cincinnati, Ohio. April 2, 2007.

ORAUT 2009. *Technical Basis Document for the Los Alamos National Laboratory – Occupational External Dose*, ORAUT-TKBS-0010-6, Rev. 02. Oak Ridge Associated Universities Team, Cincinnati, Ohio. November 23, 2009.

ORAUT 2010a. *Site Profile for the Brookhaven National Laboratory*, ORAUT-TKBS-0048, Rev. 01. Oak Ridge Associated Universities, Cincinnati, Ohio. April 26, 2010.

ORAUT 2010b. *Site Profile for the Lawrence Berkeley National Laboratory*, ORAUT-TKBS-0049, Rev. 02. Oak Ridge Associated Universities, Cincinnati, Ohio. May 10, 2010.

Patterson, H.W., 1965. *Accelerator Radiation Monitoring and Shielding*, UCRL-16445 Rev, Lawrence Berkeley Laboratory, University of California, Berkeley, California. Academic Press, New York [SRDB Ref ID: 21691].

SC&A 2012. *SC&A's Issues Matrix for the Lawrence Berkeley National Laboratory Site Profile Technical Basis Document.* SC&A, Inc., Vienna, Virginia, and Saliant, Inc., Jefferson, Maryland. January 2012.

Stephens, L.D., and A.J. Miller, 1969. *Radiation Studies at a Medium Energy Accelerator*, UCRL-19386, Lawrence Berkeley Laboratory, University of California, Berkeley, California. October 1969 [SRDB Ref ID: 72354].

Sun, Rai-Ko S., 1991. *Review of Measurement at Accelerators and Application to Dosimeter Calibration*, LBL-30883, Lawrence Berkeley Laboratory, University of California, Berkeley, California [SRDB Ref ID: 20875].