7 DIRECT RADIATION: TLD PROGRAM

CHAPTER CONTENTS

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THERMOLUMINESCENT DOSIMETERS (TLDS)

DQO START DATE January 1, 2003

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SUMMARY OF PROPOSED CHANGES

From March 14 through April 11, 2003, DOE's Brookhaven Site Office conducted an assessment of BNL's compliance with DOE Order 5400.5 (1990), Radiation Protection of the Public and the Environment (now replaced by DOE Order 458.1). During the review, assessors discovered that a "technical basis document" for the placement of TLDs at BNL had never been prepared (Finding F-HP-0403-04). This DQO is a response to that finding.

There are no proposed changes for calendar year (CY) 2014.

DESCRIPTION AND TECHNICAL BASIS

The regulatory dose limit set for the members of the public is an effective dose equivalent (EDE) of 100 mrem (1mSv) in a year from all DOE activities and all environmental pathways. The Environmental Protection Agency (EPA) dose limit for airborne emissions under the Clean Air Act (CAA) for members of the public is 10 mrem (0.1 mSv) in a year. The EDE includes the deep dose equivalent from yearly exposures to radiation sources external to the body (measured with TLDs), plus the committed effective dose equivalent from radionuclides taken into the body (via inhalation, ingestion, and skin absorption).

BNL measures environmental background radiation through a network of on- and off-site TLDs placed approximately 1 meter above the ground. These devices measure direct, penetrating beta/gamma radiation originating from cosmic and terrestrial sources, as well as any contribution from Laboratory operations. The off-site exposures are assumed to be true natural background doses with no contribution from Laboratory operations. On-site and off-site external doses are compared with each other (using a statistical t-test) to estimate the contribution, if any, from BNL operations above the natural background level of radiation.

The scientific principle on which TLDs function is that when certain crystals contained in the TLD holder are exposed to penetrating gamma radiation, the impurities in the crystals' low-temperature trapping sites for electrons are excited to higher energy states. These electrons remain in a high-energy state at normal ambient temperatures.

Processing TLDs at the contract analytical laboratory consists of three phases: the TLD is heated, causing the electrons to be released from the trapping sites and drop to a lower energy state, resulting in the emission of photons proportional to the original absorbed dose of radiation; the photons are measured with a photomultiplier tube and the light intensity measurement is recorded; and after the TLD is read, it is heated and read a second time for any residual dose to ascertain

that all of the gamma-radiation-induced stored energy has been released. This second heat treatment is referred to as "annealing" and verifies that the TLD is ready for reuse in the field.

The environmental TLDs used at BNL are composed of calcium fluoride (CaF_2: Dy) doped with Dysprosium and lithium fluoride (LiF: Mg, Ti), doped with magnesium/titanium. The accuracy of the TLD is verified using known sources of radiation exposures. For quality control, the Laboratory also participates in inter-comparison programs with other sites. The personnel monitoring dosimetry group in the Radiological Control Program process environmental TLDs at BNL. The DOE Laboratory Accreditation Program accredits that laboratory.

The environmental TLDs proposed for neutron measurement would be the Harshaw badge 8814, which contains the neutron chip for measurement. Personnel monitoring would be able to supply and read the TLDs after exposure, and subsequently report the results to the Environmental Protection Division (EPD) on a quarterly basis.

DRIVERS FOR MONITORING BEING CONDUCTED UNDER THIS CHANGE

___ Compliance
_X_ Support Compliance
_X_ Surveillance
___ Restoration

DATA QUALITY OBJECTIVE ANALYSIS

This technical basis document was developed based on the EPA's Data Quality Objective (DQO) process. The DQO process is used to clarify objectives, define the type of data, and specify levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decision-making.

Step 1: State the Problem

Radioactive materials and/or emission sources can contribute to external radiation exposure. These sources include routine facility emissions and effluents, equipment and machines that generate radiation, environmental restoration activities, and on-site vehicle transport of sources or radioactive wastes. The environmental air and surface water pathways may also transport radionuclides from emission or effluent sources (point or diffuse) to locations near the public and/or aquatic biota. Many of these released radionuclides produce penetrating particles and photons (i.e., beta and gamma radiation) during decay processes in media that is external to an organism.

The primary purpose of monitoring direct radiation is to measure the dose, if any, to members of the public from gamma radiation sources at BNL. The main objectives are to:

- Obtain ambient external dose measurements from potential sources at the BNL site
- Obtain ambient external background dose measurements from full occupancy locations inhabited by the members of the public and uninvolved workers
- Verify that the potential dose to the members of the public from external pathways remains as low as reasonably achievable (the ALARA principle)

- Obtain radiation exposure data near facilities with radiation-generating machines or equipment and near radioactive waste sites to assess the integrated effect of the operations on overall exposures

- Obtain dose measurements at the site perimeter and adjacent communities to ensure that external exposure from BNL operations is known at various distances and to confirm that exposure is in the range of background levels.

- Measure on- and off-site external radiation exposures to assess the environmental dose from unplanned releases, if any, and for comparison/assessment purposes.

- Document and maintain a record of exposure to show compliance with DOE and EPA dose limits.

Step 2: Identify the Decision

The primary decision to be made using data from direct radiation monitoring is whether the dose, if any, to members of the public is originating from BNL sources and, if so, whether the dose is well below the regulatory dose limits set by DOE and EPA. The following questions are considered in support of the decision-making:

- Are the external exposure measurements that were taken at locations with public or noninvolved worker access higher than historical measurements and survey results?

- Is the dose below the regulatory compliance limit of EPA and DOE?

- Are the site perimeter external doses reasonable and in the range of natural background?

- Is the potential dose to members of the public from the external dose pathway as low as reasonably achievable?

- Is the radiation exposure near specific facilities or waste sites contributing to the cumulative dose?

- Are all emission/source terms taken into consideration during placement of TLDs?

- Does the placement of background TLDs accurately portray background levels of radiation?

- What is the dose contribution from thermal neutrons?

Step 3: Identify Inputs to the Decision

From 1949 until 1972, the perimeter sampling stations at locations P-2, P-4, P-7, and P-9 were monitored to determine ambient external radiation levels from weapons test fallout using continuous chart-recorded background radiation measurements taken with pressurized ion chambers and dynamic condenser electrometers (DCEs) mounted on each station's roof. In 1972, TLDs were placed in the field to monitor natural background radiation. During that same year, the S-13 and S-6 locations were incorporated into the ambient monitoring network to measure external radiation near the Sewage Treatment Plant (STP) and the former Hazardous Waste Management

Facility (HWMF). The average dose equivalent rate in 1972 from naturally occurring background radiation at the site perimeter was measured at 65.3 mrem.

In 1981, additional TLDs were placed at on- and off-site locations to monitor the standard 16 wind sectors. The 1986 Site Environmental Report lists the average dose equivalent rate at the site boundary as 70.2 mrem.

In 1994, the numbering system for TLDs was changed to a grid system; however, the physical locations for background radiation measurements remained the same during all the years of environmental surveillance. The only difference noted between past and present TLD programs was that in earlier years the standard practice was for TLDs to be exchanged monthly; since 1994, they have been exposed for three months at a time.

In 1998, new TLD locations were added in the central portion of the BNL site in an effort to address worker health concerns. The following locations were added after surveying the area with Bicron microRem instruments: BERA ball field (4 μrem/hr), across from the previous Teacher‘s Federal Credit Union (2 to 3 μrem/hr) which has since been relocated, tennis courts (4 μrem/hr), Building 356 (4 μrem/hr), Building 914 (4 μrem/hr), and the Upton gas station (3 to 6 μrem/hr).

At present, on- and off-site areas are divided into grids and the TLD numbers are assigned based on these grids. For more detailed information, refer to Environmental Monitoring Standard Operating Procedure (EM-SOP 202), Sample Location Identification. In 2002, the TLD location identifiers were modified to accommodate the new Environmental Information Management System (EIMS). The grid numbers were retained to preserve the historical link to previously collected TLD data; however, the suffixes were changed to “TLD” followed by a sequential identification number. For example, 011-401 was changed to 011-TLD1.

As part of a voluntary program implemented by BNL employees, TLDs are placed in 16 off-site wind sectors to monitor for external dose. Evaluation of the placement of TLDs showed that TLDs needed to be placed in wind sectors 6 and 7. In 2007, a new TLD, #900-TLD2, was placed in wind sector 7 at a BNL employee’s residence. TLDs were also posted in wind sector 6 at the site boundary.

The Alternating Gradient Synchrotron (AGS) accelerates protons to energies up to 30GeV and heavy ion beams to 15 GeV/amu. The Relativistic Heavy Ion Collider (RHIC) has two beams circulating in opposite directions and is capable of accepting either protons or heavy ions up to gold. Protons are accelerated up to a final energy of 250 GeV and gold ions to 100 GeV per nucleon. Facilities such as AGS and RHIC have the potential to generate high energy neutrons ranging from 0.025eV to >100 MeV. Passive monitoring devices for neutrons will provide retrospective indication of any change in radiological conditions to protect the environment and residents within the BNL vicinity. Therefore, to confirm and ascertain that there is no neutron dose contribution to the public, 12 new TLDs were placed in close proximity to the Laboratory boundary on the west side starting in the first quarter of 2009.

The following inputs are required to support decision-making based on TLD data:

- Review of analytical results by project managers in accordance with EPD data review procedures to ensure data is of acceptable quality.

- TLD doses measured at BNL monitoring locations are compared to both recent and historical background measurements to determine the contribution, if any, from BNL operations.

- TLD doses measured at off-site monitoring locations are compared to both recent and historical background measurements to spot long-term trends in the data.
- Evaluate dose contribution from neutron TLDs.

- TLDs are read, annealed, and reported by the personnel monitoring dosimetry group within BNL's Radiological Control Program.

- TLDs are calibrated annually at Pacific Northwest National Laboratory, utilizing sources traceable to the National Institute of Standards and Technology (NIST).

- Environmental TLDs are exchanged quarterly and read using Harshaw TLD readers using associated EM-SOPs and quality control.

- The dose units are reported in rem/day or rem/quarter with the number of exposure days documented in the report prepared by the personnel monitoring dosimetry group.

- The personnel monitoring dosimetry group corrects the TLD for any residual dose during the annealing process.

- Processing (annealing, calibration, reading, and testing) of the environmental dosimeters is done in accordance with the American National Standards Institute (ANSI) N13.29 standard.

Step 4: Define the Study Boundaries

The frequency for exchanging TLDs deployed in the field is determined based on the potential for detecting elevated external radiation levels above natural background radiation and the characteristics of the crystal used in the TLDs. For the environmental TLDs in use on site, a quarterly exchange frequency is considered optimal (so "fading" is minimal). This interval is determined as the approximate exposure time needed to generate statistically confident results above the limit of detection.

External radiation exposures are measured with consideration for the types and levels of exposure expected from the various pathways, transport media, and other direct radiation sources. Some of the critical environmental media or sources causing potential external radiation exposure are airborne cloud passage and exposure to contaminated surface water, vegetation, sediment, or soil. Important factors that have influenced the decision to keep the TLD locations the same (in alignment with the old regime) were the capability to look at the long-term trend analysis from previously collected historical data, the comparability of the recent TLD data with the enormous quantity of baseline data, the population distribution around the site, the site-specific meteorological conditions, and the recreational activities of the community adjacent to the site. The types of radiation causing most of the external exposures are gamma photons and beta particles. Because the site is large and there are no longer any large-scale potential sources such as reactors, the maximum predicted exposure or concentration would typically be to on-site receptors rather than off-site receptors. Historical data support the approach of designing the measurement methods mainly for photon sources, but pure beta emitters can exist in the environment unaccompanied by gamma emitters (e.g., strontium-90).

After the shutdown of the High Flux Beam Reactor (HFBR) and the Evaporator Facility, the number of possible sources of emissions that can contribute to total effective dose has been reduced. However, the regulatory dose limits have not changed and the burden to show regulatory

compliance with ALARA considerations is still required of BNL's environmental surveillance program. At present, the major facilities at the Laboratory that can contribute to ambient external exposure are the AGS, Tandem Van de Graaff, Booster Storage Ring, RHIC, the former HWMF, the Target Processing Laboratory (TPL), and the National Light Synchrotron Light Source (NSLS).

In an accelerator environment (e.g., AGS, RHIC), when a high-energy charged particle leaves the vacuum confines of the accelerator, nuclear fragments may be produced along the path of the energy particle or when it collides with other matter. TLD locations are selected in the vicinity of the accelerators to fulfill the surveillance objectives. Also, the radioactive source information is used to determine the potential location for placement of TLDs and the timely detection of exposures, if any. Two other facilities that release airborne gaseous products and therefore are significant from an environmental monitoring point of view are the Radiation Therapy Facility and the Brookhaven Linear Isotope Producer (BLIP) facility.

Meteorological factors also play a part in the selection of TLD locations. At BNL, the ground-level winds are from the southwest during the summer, from the northwest in the winter, and with equal frequency from these two directions during the spring and fall. There is an ongoing need for dosimeters that provide background monitoring for public assurance, as well as dosimeters that would only be used in emergencies, to confirm emission controls or for dose modeling. Fulfilling these needs requires TLD placement in off-site locations that are generally upwind (for the background locations) and in population centers located within the prevailing wind directions.

Currently, 58 environmental TLDs are deployed on the BNL site and 14 are deployed off-site. An additional 30 control TLDs are stored in a lead-shielded container in Building 490. The average dose of the control TLDs is reported annually in the BNL Annual Site Environmental Report as a reference dose measure, labeled "075-TLD1."

Of the 58 TLDs on site, 28 were selected and posted as natural background locations within the BNL site boundary for comparison with the off-site TLDs (Table 7.1-1).

Table 7.1-1. Ambient Background TLD Locations at BNL

TLD Number	Location	Rationale for Placement
011-TLD1	North Firebreak	Measure natural background dose
013-TLD1	North Firebreak	Measure natural background dose
025-TLD1	NE Firebreak	Measure natural background dose
037-TLD1	S-13	Measure natural background dose
043-TLD1	North Access Road	Measure natural background dose
043-TLD2	North of Met Station	Measure natural background dose
049-TLD1	East Firebreak	Measure natural background dose
053-TLD1	West Firebreak	Measure natural background dose
063-TLD1	West Firebreak	Measure natural background dose
066-TLD1	New HWM Facility	Measure natural background dose
073-TLD1	West of Met/ Bldg. 51	Measure natural background dose
080-TLD1	East Firebreak	Measure natural background dose
081-TLD1	Wind Sector 6	Measure natural background dose
081-TLD2	Wind Sector 6	Measure natural background dose
082-TLD1	West Firebreak	Measure natural background dose
084-TLD1	Tennis Court	Measure natural background dose
085-TLD1	TFCU	Measure natural background dose
085-TLD2	Upton Gas Station	Measure natural background dose
086-TLD1	BERA Ball Field	Measure natural background dose
105-TLD1	South Firebreak	Measure natural background dose

TLD Number	Location	Rationale for Placement
108-TLD1	Water Tower	Measure natural background dose
111-TLD1	Trailer Park	Measure natural background dose
122-TLD1	South Firebreak	Measure natural background dose
126-TLD1	South Gate	Measure natural background dose
P-2, P-4, P-7, and S-5	Perimeter Blockhouses	Measure natural background dose and compare with historical data

The remaining on-site TLDs are posted at various facility monitoring locations and are categorized as Facility Area Monitors (FAM). The FAM dosimeters are deployed in locations where there is a known possibility of higher external radiation dose, such as the skyshine phenomenon, possible beam loss, loss of shielding, or in the vicinity of beam stops. These dosimeters do not represent the true environment background dose but could have elevated dose contributions from operations, any of the above-stated causes, or from an emergency scenario. If data from the FAM dosimeters were used to calculate the annual on-site average dose, the value would be incorrect. The primary purpose of the FAM TLDs is to measure dose emanating from known sources or due to unplanned releases.

Five TLDs are located in the vicinity of the AGS to monitor the ambient external dose rates in that area (Table 7.1-2).

Table 7.1-2. AGS TLD Locations

TLD Number	Location	Rationale for Placement
074-TLD1	Bldg. 197	Occupied area/background
074-TLD2	Bldg. 907	Occupied area/background
054-TLD1	Bldg. 914	Beam stop/Sky shine
054-TLD2	Northeast of Bldg. 913B	Beam stop/Sky shine
054-TLD3	Northwest of Bldg. 913B	Beam stop/Sky shine

Radiation external to the RHIC tunnel is generated by facility operations. The radiation field consists mainly of neutrons, muons, and gamma radiation. The beam stops are expected to account for 85 percent of the total beam loss energy. Eighteen TLDs are deployed in the vicinity of the RHIC Ring, beam stops, and occupied buildings (Table 7.1-3).

Table 7.1-3. RHIC TLD Locations

TLD Number	Location	Rationale for Placement
025-TLD1	Bldg. 1010 Beam Stop 1	Beam Stop/shielding
025-TLD4	Bldg. 1010 Beam Stop 4	Beam Stop/Shielding
027-TLD1	South of Bldg. 1002A	Occupied areas/study
027-TLD2	East of Bldg. 1002D	Occupied areas/study
034-TLD1	Bldg. 1008 Collimator 2	Beam Collimator
034-TLD2	Bldg. 1008 Collimator 4	Beam Collimator
036-TLD1	East side of Bldg. 1004B	Occupied area/study
036-TLD2	East corner of 1004	Occupied area
044-TLD1	Bldg. 1006	Occupied area
044-TLD2	South of Bldg./near Bldg. 1000E	Occupied area
044-TLD3	South of Bldg. / east of Bldg. 1000P	Occupied area
044-TLD4	South of Bldg. 1006/ NE of Bldg. 1000P	Occupied area
044-TLD5	South of Bldg. 1006/ N of Bldg. 1000P	Occupied area
045-TLD1	Bldg. 1005S	Occupied area
045-TLD2	East of Bldg. 1005S	Occupied area
045-TLD3	SE of Bldg. 1005S	Occupied area
045-TLD4	SW of Bldg. 1005S	Occupied area
045-TLD5	WSW of Bldg. 1005S	Occupied area

Data from the S-6 location, near the former HWMF, together with previously collected TLD external dose data suggest that there are radiation sources in the vicinity of the S-6 blockhouse location. The potential sources in this area could be contaminated materials stored within the fenced yard, materials being repackaged for disposal at an off-site licensed location, or contaminated media (e.g., soils). To investigate the extent of contamination as well as the external dose rate at this location, four additional devices (TLDs 088-TLD1 thru 4) are posted at the S-6 ambient air sampling location, equidistant from each other, on the enclosure fence of the former HWMF.

Building 356 houses one cobalt-60, one cesium-137, and one neutron (Am-Be) source. This building is being monitored because previous TLD readings were higher than the natural background dose. The original TLD (075-TLD3) has been supplemented with a new TLD, 075-TLD5, which was located at the corner of Building 356 to record the dose rate there.

Twelve TLDs that contain the neutron chip are were posted 2010 to evaluate neutron dose from the AGS and RHIC facilities (Table 7.1.4).

Table 7.1-4. Neutron TLD Locations

TLD#	Location	Rational for Placement
025-TLD-N1	Bldg. 1010 Beam Stop	Beam Stop/shielding
025-TLD-N2	Bldg. 1010 Beam Stop	Beam Stop/shielding
034-TLD-N1	Bldg. 1008 Collimator	Beam Collimator
034-TLD-N2	Bldg. 1008 Collimator	Beam Collimator
043-TLD-N1	Upton Road /North Gate	Occupied Area
043-TLD-N2	White Pine Path /Canopy Road	Proximity to Site Boundary
044-TLD-N1	RHIC W-line Beam Stop	Beam Stop/Shielding
052-TLD-N1	West 5th/Canopy Road	Proximity to Site Boundary
054-TLD-N1	J-10 beam Stop	Beam Stop/Shielding
054-TLD-N2	LINAC to Booster transition (EBIS)	Beam Stop/Shielding
054-TLD-N3	BLIP Area	Soil Activation
064-TLD-N1	Booster Stop	Beam Stop/Shielding

Step 5: Develop the Decision Rules

The BNL Annual Site Environmental Report shall be used as the reporting method and as a record of dose for members of the public.

If the annual average dose for an off-site TLD is statistically outside the range of 64 to 80 mrem at the 2σ confidence interval, **then** an investigation into the cause of higher/lower dose at the off-site location would be completed.

If the annual dose for on-site TLDs is statistically outside the range of 66 to 85 mrem at the 2σ confidence interval, **then** an investigation into the cause of higher/lower dose at the on-site location would be completed and corrective action taken to reduce the dose to normal background levels.

Perform a statistical test to determine whether the variability in the on-site, off-site, and natural background exposures is statistically different. **If** the variability is higher than normal (based on historical data), **then** notify the facility manager of the need to implement corrective actions.

If the TLD readings continue to remain above normal background, **then** access to radiological areas may be restricted, radiological postings may be necessary, or other corrective actions will

be taken. The Radiological Control Division Manager and the Environmental Protection Division Manager shall be informed about the above-background exposure from the facility or area.

If a TLD is missing, **then** the annual dose is calculated as four times the average quarterly dose, determined from available data.

If TLDs are wet, damaged, or found on the ground, **then** they are not accepted for use in reporting monitoring data.

If an unplanned release occurs, **then** the TLDs in the upwind and downwind directions shall be immediately retrieved and processed to estimate the dose to members of the public.

If the quality control program does meet the ANSI standard, **then** the dose data shall be evaluated for usability and reportability.

Step 6: Specify Acceptable Error Tolerances

The TLD readings' arithmetical average, normalized to 365 days, would be acceptable at 72 ± 8 mrem/year at 2σ. Sampling frequencies for on-site TLDs may require adjustments to reflect changes, such as the potential for elevated exposure rates due to modifications in operations or the transportation of radiation sources. If intermittent or sporadic operations have a significant potential for elevating environmental exposures, survey frequencies shall be increased.

Step 7: Optimize the Design

The TLD data will be evaluated on a quarterly basis to upgrade the monitoring program until dose rates are at normal background levels or until a radiological boundary sign is posted. BNL's personnel dosimetry program participates in the DOE Laboratory Accreditation Program (DOELAP) every two years and must meet specified inter-laboratory comparison performance goals. The accreditation program is specifically for dosimeters worn by personnel to monitor the dose they receive. Although no comparable DOE accreditation program exists for environmental monitoring, the Laboratory has participated in the field-testing of a proposed comparable program and has incorporated the key features of that program into the BNL environmental dosimetry program.

The quality control features in this program are:

- Calibration, maintenance, and audits of the TLD reading/recording system
- Anomalous data evaluation
- Personnel training
- Procedures and records maintenance.

The quality control program within the personnel monitoring group achieves routine quality control of the TLD process cycle. The quality control program provides a measure of the quality of the complete TLD processing cycle. Intercomparison studies are conducted to determine and document TLD processing performance.

Anomalous TLD results are evaluated promptly to confirm or dismiss unusual results. Investigation into an anomalous result includes, as necessary, verification of the quality of the result (sampling and analytical aspects), questioning staff at facilities near the location with anomalous re-

sults about unusual situations, reviewing nearby air sampling results, and following up with immediate portable instrument measurements and/or gamma spectroscopy.

The TLDs are handled carefully during transport to keep them away from significant external radiation fields that would generate false positive data. Comments describing any unusual handling of TLDs or any findings that may affect TLD results are recorded in the BNL Field Sampling Team's field notebook. Sample collection and handling procedures are documented in EM-SOP 502, Placement and Collection of Thermoluminescent Dosimeters.

Cost of TLD Program:

Fixed Costs:

Total Number of qualified TLDs presently in the program = 405
Purchase price of each TLD = $43.13
Purchase price of TLD holder = $24.25
Total cost of TLDs = $67.38 x 402 = $27,289

TOTAL SAMPLING AND ANALYSIS COST FOR MONITORING PROGRAM

Analysis	No. of Samples Per Year	Turnaround time (calendar days)	Cost per Analysis	Total Cost
TLD Analysis	58 x 4: On site 19 x 4: Off site 30 x 4: QA	30 days after each quarter	$103.90	$44,469
TLD Neutron	12x 4	30 days after each quarter	$103.90	$4,987.20
TLD Sampling	Post 58 TLDs Post 12 neutron TLDs	1 day	$41.85 per half hour	$669.60
			Total Cost of TLD Program	$11,128

CY 2012 Costs $50,126.00
CY 2013 Costs $50,126.00
CY 2014 Costs $50,126.00

See Appendix B for the monitoring program for this DQO.