Collider-Accelerator Department

BROOKHAVEN NATIONAL LABORATORY

Building 911B – P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344 7124
Fax 631 344 5568
beavis@bnl.gov
www.bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

Date: *May 13, 2015*

To: *C. Schaefer (ERL IRR* Team Leader), RSC, D. Kayran, and I. Ben-Zvi*

From: *D. Beavis (RSC Chair)*

Subject: *Review of Shielding Policy for ERL (ATS #8310.1.2)*

This memorandum reviews the design documentation for ERL for radiation exposure and concludes that the design satisfies the C-AD's shielding policy. However, there have not been sufficient beam operations to verify that the design actually satisfies the C-AD shielding policy. This is achieved when fault studies and routine operations are conducted and compared to design estimates.

It is recommended that the IRR pre-start 2.3.2 be changed to: Review and document that the initial ERL shielding, posting, and radiation monitors have been designed to satisfy the C-AD shielding policy. **This memorandum is intended to close this modified version of IRR finding 2.3.2.**

It is recommended that a post-start finding be added-2.4.1: Review the beam operations and beam fault studies to verify that the radiological design of ERL satisfies the C-AD shielding policy.

The C-AD uses radiation shielding to reduce radiation levels in occupied areas to acceptable levels. The C-AD shielding policy is described in formal terms in Chapter 4 of the current C-AD SAD, and in OPM 9.5.1 C-A ALARA Policy and Responsibilities. The relevant policy statements are summarized as follows:

1. Annual site-boundary dose equivalent is less than 5 mrem.
2. Annual on-site dose equivalent to inadvertently exposed people in non-Collider-Accelerator Department facilities is less than 25 mrem.
3. Maximum dose equivalent to any area where access is not controlled is limited to less than 20 mrem during a fault condition.
4. For continuously occupied locations, the dose equivalent rate is ALARA but in no case greater than 0.5 mrem in one hour or 20 mrem in one week.
5. Dose equivalent rates where occupancy is not continuous is ALARA, but in no case exceeds 1 rem in one year for whole body radiation, or 3 rem in one year for the lens of the eye, or 10 rem in one year for any organ.

The C-AD conducted periodic radiation surveys of the ERL experimental areas prior to

*Instrument Readiness Review Committee (**IRR**)

operations,[1] as well as calculated and simulated low-intensity, credible beam faults.[2, 3] Radiation surveys were conducted during gun and cavity testing without beam and limited surveys with beam from the gun. No external radiation has been measured for any mode of operation presently achieved. These independent surveys and studies help assure the adequacy of the shielding design and radiological controls to achieve ALARA goals. C-AD has a strong program of using monitor TLDs in the field to monitor that ALARA goals are achieved.

The ALARA design objective is less than 500 mrem per year; viz., assuming 100% occupancy at known locations and a 2000-hour per year residence time yielding the design goal of 0.25 mrem/hr in continuously occupied areas. This objective is one-half the design objective stated in the federal regulation 10CFR835 § 835.1002 (b).

It is noted that ERL plans to be run only about 25% of a year (500 hours). Since there are many ways to control access and residence-time by area designation, training and signage and since dose rate declines with distance from the shield face, significantly higher dose rates are acceptable at the shield-face provided C-AD controls access and plans work in and around the ERL accelerator enclosure.

The following summarizes specifics of this review of ERL shielding against the C-AD shielding policy:

1. Annual site-boundary dose equivalent is less than 5 mrem.

The mechanism that will typically transport radiation to the site boundary is known as skyshine. Shielding enclosures often have thinner shielding on the roof than the side walls as the occupancy is intended to be lower, more restrictive, or not allowed. The leakage of radiation out the roof will scatter in the materials above the roof shielding and a small portion will be scattered to distant ground locations.

The Monte Carlo program MCNPX was used to calculate the dose to the building 940. At the time this was considered a non-C-AD area. The results are presented in the ERL Archival Safety Assessment Document . The site boundary is 1200 meters for the ERL facility. If the building 940 numbers are scaled by $(1/r)^2$ then the dose at the site boundary for 500 hours of operations would be 0.004 mrem/hr. The attenuation due to air has been ignored which would reduce the results substantially.

2. Annual on-site dose equivalent to inadvertently exposed people in non-Collider-Accelerator Department facilities is less than 25 mrem.

The nearest on-site non-C-AD facility is Building 703, which is about 400 m from ERL.

[1] ALARA Committee Documents

[2] ERL RSC Documents

[3] ERL Archival Safety Assessment Document

*Instrument Readiness Review Committee (**IRR**)

Scaling[4] the Building 940 results provides a yearly[5] skyshine dose estimate of 0.038 mrem/yr. This is much less than 25 mrem annually.

3. Maximum dose equivalent to any area where access is not controlled is limited to less than 20 mrem during a fault condition.

Maximum sustained beam losses are 1.2 MW for 3.5 MeV injection electrons and 60 kW for electrons in the 25 MeV ring. Credible routine losses are expected to be 1 W at beam injection and 50 W for the 25 MeV beam.[6]

The accessible areas contiguous to and nearby to the outside of the ERL shielding enclosure are protected by radiation monitor interlocks. There are no uncontrolled areas contiguous to the shielding enclosure. The closest uncontrolled areas are outside the building approximately twenty feet from the shielding enclosure. The radiation monitors have both an alarm setting and an interlock setting. The interlock setting is established to ensure that the dose received during a beam fault will not exceed 20 mrem in any uncontrolled area. For large dose rates at the radiation monitor the beam will be turned off within 3 seconds[7]. The operators respond to radiation alarms and interlocks using a C-AD OPM procedure[8]. ERL operation would be stopped by the ERL Operator following a radiation interlock trip, and the fault condition would be investigated and corrected.

A 20 mrem dose near the shielding enclosure would correspond to a maximum fault dose rate of 24,000 mrem/hr for 3 seconds. Review of the maximum dose rates outside the penetrations[9] and walls of ERL, as indicated in the ERL Archival Safety Assessment Document and by other independent reviewers, shows the maximum sustainable fault-dose-rate is less than 100,000 mrem h^{-1} in accessible, contiguous, Controlled Areas adjacent to the ERL enclosure. Some Controlled Areas may have a dose in an MCI approach 100 mrem. However, uncontrolled areas surrounding ERL, which are further away from Controlled Areas, would receive less than 20 mrem in a fault.

For sustainable fault dose rates, see Tables 4.1.2.a and 4.1.2.b in the ERL Archival Safety Assessment Document. It is noted that constant continuous loss of full-power 25-MeV beam pulses is not sustainable after the first lost beam pulse because energy would not be recovered and transferred to the next beam pulse. Also, it is noted the radiation monitor interlocks were assumed to respond after 9 seconds in the ERL Archival Safety Assessment Document.

4. For continuously occupied locations, the dose equivalent rate is ALARA but in no case greater than 0.5 mrem in one hour or 20 mrem in one week.

---

[4] Similar to the site boundary estimate the scaling will not include the additional air attenuation.
[5] Assumes 500 hours of operations in a year.
[6] ERL Archival Safety Assessment Document, Page 85, June 30, 2008
[7] This time includes 0.75 seconds for the radiation monitor to generate an interlock and 2.25 seconds for the access control system to turn the beam off.
[8] OPM 18.6.1 Responding to Chipmunk Alarms and Interlocks
[9] For an Updated Table of Penetrations see http://www.c-ad.bnl.gov/esfd/RSC/Memos/5_13_15_ERL.pdf

The ERL Control Room is the only continuously occupied area during operation of ERL. That area is designed to be a Controlled Area. The ERL Archival Safety Assessment Document, Table 4.1.2.b, indicates that for a sustainable loss of 50 W the annual dose to an individual in the Prototype ERL control room will be 41 mrem."

Table 4.1.2.b indicates a sustainable routine loss causes 0.082 mrem h^{-1} in the Control Room, which is less than 0.5 mrem in one hour and less than 20 mrem in one week. That table also shows the maximum sustainable loss would cause 98 mrem h^{-1} in the Control Room, which will trip the radiation monitor interlocks. The estimated dose in Table 4.1.2.b is 0.25 mrem per interlock trip. It is highly unlikely C-AD management and ERL Operators would allow 80 interlock trips per week, which would result in 20 mrem in one week.

5. Dose equivalent rates where occupancy is not continuous is ALARA, but in no case exceeds 1 rem in one year for whole body radiation, or 3 rem in one year for the lens of the eye, or 10 rem in one year for any organ.

Monitor TLDs are placed around the facility to measure the integrated dose for operations periods. Typically at C-AD the monitor TLDs are changed quarterly. The ERL facility is expected to operate on and off for brief periods throughout the year. The monitor TLDs will provide indications if ERL operations is producing excessive dose in external areas.

To help personnel avoid unnecessary dose, the radiation monitors that are located at the weakest ERL shielding locations were set up like a street light with red, yellow and green indicators. In addition to interlocks, a monitor will display a red blinking light for radiation levels greater than 20 mrem h^{-1}, and a yellow blinking light for levels from 2.5 to 20 mrem h^{-1}. Normally, radiation monitors operate in the green range indicating nominal radiation levels. Personnel are trained that if a radiation monitor is indicating in the red range or an unexpected yellow range, then they must leave the immediate area, and notify collaborators and co-workers to leave the immediate area. Thus, for the case of maximum beam losses, it is extremely unlikely that annual dose could exceed 1 rem for whole body radiation, 3 rem for lens of the eye, or 10 rem for any organ.

Copy to:

I. Ben-Zvi
P. Bergh
D. Kayran
D. Passarello
T. Roser
C. Schaefer

*Instrument Readiness Review Committee (**IRR**)