Exemption Request for Low-Power Testing of ERL SC Gun and 5-Cell Cavity

Introduction

The Collider-Accelerator Department (C-AD) Chairman is requesting the Laboratory ESH Committee (LESHC), the Assistant Laboratory Director for ESH (ALD for ESH) and Head of DOE Area Office (BHSO) approve or recommend for approval, as applicable, a low-power beam test of the ERL. To do these tests, C-AD management requests exemption from paragraph (4).(b) of the DOE Order 420.2C and corresponding SBMS Accelerator Safety Subject Area requirements, and allow the test described below. Specifically, please allow the tests prior to conducting an Accelerator Readiness Review (ARR) for the full ERL accelerator facility. C-AD bases the exemption request on the limited power and the low-level radiation hazard allowed for the test.

Background

DOE Order 420.2C, Safety of Accelerator Facilities, Paragraph 3.c.(2) indicates DOE may approve accelerator exemptions, in addition to those examples listed in paragraph 3.c.(1). An exemption would result in not requiring the ERL superconducting gun and 5-cell cavity test to meet the provisions of paragraph 5 of the Order. This opportunity to request an exemption is also in the SBMS Accelerator Safety Subject Area. Such a request requires a review and recommendation for approval by the Laboratory Environmental, Health and Safety Committee (LESHC) and the approval of the BNL ALD for ESH prior to DOE approval.

Low-Power Testing Plan

C-AD will conduct the following low-power tests:

1) Beam out of the gun, and
2) Beam through the 5-cell accelerating cavity.

In both cases, the beam power will be limited to less than 70 watts. The control of the beam power will be done through the setting of the photocathode drive laser, pulse energy and repetition rate.

The photocathodes to be used in these tests are multi-alkali, mostly cesium potassium antimonide. The bunch charges will be less than one nanoCoulomb (nC) with the repetition rate adjusted to maintain the maximum beam power with the given beam energy.

1) The gun maximum beam energy would be 3 MeV, and
2) The beam through the 5-cell cavity will be less than 25 MeV.

The pulse repetition frequency will be under 3 kHz for the maximum charge of 1 nC and maximum energy of 25 MeV. At lower pulse charges, the repetition frequency may be increased accordingly.

In the initial test (1), the diagnostic equipment will be a Faraday Cup (FC), an Integrating Current Transformer (ICT), and beam loss monitors (BLM). See Figure 1.

In the latter test (2), additional diagnostics will be beam position monitors, and beam profile monitors. See Figure 2.

Both tests will have a large array of radiation detectors, ion chambers and photomultiplier tubes (seen in Figures 1 and 2)

C-AD will conduct tests intermittently over a period of 7 months after the onset of approved low-power testing.

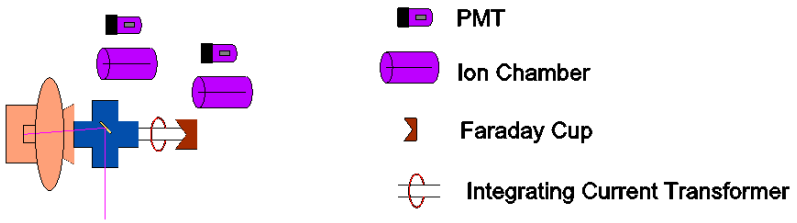

Figure 1 – Initial Test. Gun is on the left.

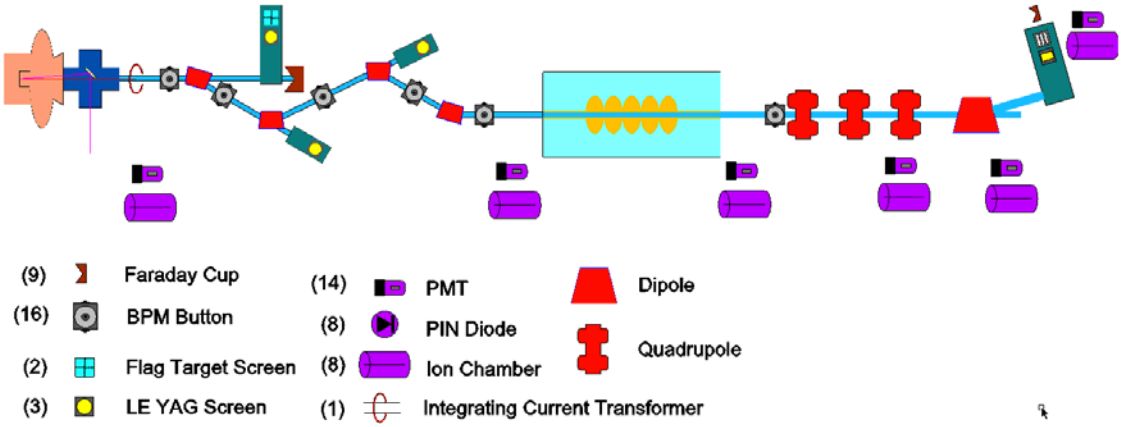

Figure 2 – Later Test

Safety Basis for Exemption Request for Low-Power Testing

To test the ERL Superconducting Gun and 5-cell cavity at low power, C-AD management will adhere to an approved ERL CASE for ERL Superconducting Gun and 5-Cell Cavity Test (see Appendix 1). With exception of Credited Controls for the Maximum Credible Incident, C-AD adopts all Credited Controls and Supports associated with the approved June 6, 2012 ERL ASE, and reproduces them in the ERL CASE for this test. However, C-AD defines a different set of Credited Controls for the Maximum Credible Incident in Section 2:

Credited Controls for Maximum Credible Incident

2.1. Electron kinetic energy must be limited to 3.5 MeV for the superconducting RF gun.
2.2. The electron beam power leaving the ERL Superconducting Gun or the five-cell cavity must be limited to 70 W averaged over 1 hour.
2.3. Electron kinetic energy limit must be limited to 25 MeV to the dump.

The bases for these Credited Controls are that shielding calculations show that a maximum 70 W beam power will allow C-AD to maintain the outside of the ERL enclosure as a Controlled Area under Maximum Credible Incident conditions.

Method to Limit Beam Power during Low-Power Testing

The electron beam power will be limited by using alarming and interlocking radiation monitors inside the ERL enclosure. The alarm and interlock set points inside the ERL enclosure will be set such that no more than 70 W of beam power is possible without interlocking the beam off. C-AD will place alarming and interlocking radiation monitors outside the enclosure too. The alarm and interlock set points outside the ERL enclosure will be set such that outside the enclosure, C-AD maintains radiation exposure no greater than that allowed for a Controlled Area.

Estimated Dose Rate during Low-Power Testing

The ERL enclosure uses bulk shielding for radiation protection. The enclosure has side walls composed of between four- and eight-feet of light concrete. The thin sections of wall are shadowed from the potential sources with inner supplemental shield walls located appropriately. The inner supplemental shields subtend any angle for any energy electron-beam bent by dipole magnets. The entire enclosure has a single layer of light concrete roof beams four feet thick, except for a transition region where the roof is two layers of beams. This transition region is where the 4.3 m ceiling height in the center falls to 3 m at both ends.

In order to determine the effectiveness of the shielding at ERL, the maximum sustained beam loss assumed in the safety analyses (2011 C-AD SAD) was 1.2 MW for 3.5 MeV injection electrons. In Table 4.13.b. from the C-AD SAD, the experts who did the shield safety analyses assumed that credible sustainable beam losses were 1 W of electron beam at beam injection energy of 3.5 MeV and 60 kW at 25 MeV. The C-AD SAD shielding experts listed estimates of absorbed dose rates at the outside surface of the ERL's shielding for these assumed losses. Their Table in the C-AD SAD is as follows:

Table 4.13.b Dose Outside Prototype ERL Enclosure for 3.5- and 25-MeV Electrons

Condition	Instantaneous Dose Rate From Maximum Beam Loss[a]	Dose Rate From Sustainable Loss[b]	Dose From Sustainable Loss Assuming Interlock Occurs[d]
3.5MeV@ 0 degrees, γ	88,000 mrad/h	0.073 mrad/h	0.0002 mrad
3.5MeV@ 90 degrees, γ	18,000 mrad/h	0.015 mrad/h	0.00004 mrad
25 MeV@ 0 degrees, γ	65,000 mrad/h[c]	4000 mrad/h[c]	10 mrad[c]
25 MeV @ 90 degrees, γ	13,000 mrad/h	800 mrad/h	2.0 mrad
25 MeV neutrons	120 mrem/h	6.0 mrem/h	0.015 mrem

[a] The maximum instantaneous beam loss is 1.2 MW at 3.5 MeV, and 10 MW at 25 MeV, which would terminate after a small fraction of a second.
[b] The sustainable loss is 1 W for 3.5 MeV, and 60 kW for 25 MeV electrons is assumed.
[c] The forward-direction gamma-dose rates were reduced by a factor of 0.005 by the adding 2-feet of heavy concrete in the electron ring.
[d] As with all C-AD interlocking area-dose-rate monitors, a 9-second delay from sensing the trip point's dose rate to stopping of beam is conservatively assumed in SAD analyses.

Using columns 3 and 4 from Table 4.13.b, and 0-degree beam, and assuming 70 W maximum sustained beam loss with alarming radiation monitors, then C-AD estimates the maximum sustainable dose rate outside the ERL enclosure at about 5 mrad/h (70 W x 0.073 mrad/h-W). Since C-AD will use both alarming and interlocking radiation monitors, the beam will shut within 9 seconds after reaching a set point of 2.5 mrem/h, and a maximum a 0.014 mrad absorbed-dose is expected (70 W x 0.0002 mrad/W) in such a fault. For 25 MeV beam, 70 W also results in 5 mrad/h and about 0.014 mrad absorbed-dose in a fault. Based on this estimate of absorbed dose in a fault, C-AD concludes no need for a Radiation Area in accessible locations adjacent to the ERL enclosure, and a Controlled Area will suffice for the test. This maximum radiological consequence is the safety basis for an exemption request from requirements in Section 5 of DOE O 420.2C for this specific low-power beam test. This level of hazard produces only local work area impacts and can be safely managed under the provisions of Title 10, Code of Federal Regulations (CFR), Part 835 and Part 851.

Specific Assurance Methods for Low-Power Testing

C-AD management for this test has employed the following assurance methods specific to this test:

1) The C-AD RSC has reviewed the use of alarming and interlocking radiation monitors for this proposed low-power beam test,
2) The C-AD RSC inspected the ERL enclosure shielding prior to operations with low power beam to ensure all inner shields intercepted all possible beam energies,
3) The C-AD RSC inspected and approved the locations of alarming and interlocking radiation area monitors inside and outside the ERL enclosure,
4) The C-AD RSC prepared a Radiation Safety Check-off list for the low-power tests that helps ensures the ERL access control system is operational and that alarming and interlocking radiation monitors are in place
5) Qualified operators and the engineered-safety-system owners must sign the Radiation Safety Check-off list prior to enabling beam,
6) The ERL Operations Coordinator qualified each operator to respond to alarming and interlocking Chipmunk radiation monitors by observing their performance when executing the procedure,
7) The ERL Operations Coordinator qualified each operator to enable the ERL enclosure for beam by observing their performance in executing the sweep procedure,
8) One qualified ERL operator is required to be present during any period of testing with low-power electron beam,
9) The C-AD FSS Representative will schedule radiation surveys near the external penetrations to the ERL enclosure and for the general areas outside the ERL enclosure during the tests,
10) The Chair of the Radiation Safety Committee and the Head of the ESSHQ Division will review radiological surveys and e-log radiation monitor data with the FSS Representative at the end of each day of tests.

Request for DOE O 420.2C Exemption in Order to Perform Low-Power Testing

C-AD management requests exemption from paragraph (4).(b) of the DOE Order 420.2C and corresponding SBMS Accelerator Safety Subject Area requirements to allow testing of the ERL superconducting gun and 5-cell cavity at low power. Specifically, C-AD management requests low-power tests be allowed prior to conducting an Accelerator Readiness Review (ARR) for the full ERL accelerator facility. C-AD bases the exemption request on the limited power and the low-level radiation hazard allowed for the test, the review by the Radiation Safety Committee, the use of qualified operators, the implementation or alarming and interlocking radiation monitors, and daily oversight by C-AD managers.