C-AD

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Radiation

Safety Minutes of RSC Subcommittee of Sept. 8, 2016

Committee

Subject: LEReC Gun Testing and Penetrations for Full Operations

Present: J. Tuozzolo, D. Beavis, M. Benmerrouche, W. Fischer, J. Reich, D. Kayran, A. Fedotov, H. Kahnhauser, E. Lessard, P. Sampson, L. Hammonds, C. Montag, P. Cirnigliaro, and C. Schaefer

An agenda[1] was distributed before the meeting which provided a list of topic for LEReC and also links for the supporting radiation analysis. The following topics were discussed:

- Conducting initial gun tests as an exempt accelerator
- HV conditioning of the gun (no cathode)
- Radiation out penetrations for full LEReC Operations

The LEReC schedule has the gun arriving at BNL in Oct. with HV conditioning in Nov. to a maximum voltage of 0.5 MV. Gun testing at 0.4 MeV electron beam is expected to start in Jan. 2017 if allowed as an exempt accelerator. Gun testing with beam accelerated to 2.5 MeV will not occur until FY2018.

Gun Testing as an Exempt Accelerator

The committee recommended that the Department proceed with the exemption request for testing the gun at 0.4 MeV without a beam power limit.

The committee was given a draft of the exemption request. A limited discussion occurred during the RSC meeting of April 15, 2016[2]. The draft request has a power limit of 25 kW of electron power at 0.5 MeV. There was discussion on how this number was arrived at and what will prevent the power limit from being exceeded. The maximum exterior dose rate outside the enclosure was estimated to be 9 mrad/hr for 50 kW of 0.5 MeV beam. The logic of the draft exemption request was to limit the exterior dose rate to 5 mrads/hr[3], which implies a limit of 25 kW.

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[1] D. Beavis, Agenda and references for Sept. 8, 2016 RSC Meeting; http://www.c-ad.bnl.gov/esfd/RSC/GeneralReferences/Agenda_090816.pdf

[2] RSC Minutes of April 15, 2016; http://www.c-ad.bnl.gov/esfd/RSC/Minutes/04_15_16Minutes.pdf

[3] A dose rate of 5 mrads/hr is one of the characteristics that define a device as an accelerator in the ASO.

The committee requested an explanation of what limits of the gun beam power[4]. The gun has a series of modules that are limited to a maximum of 100 mA of current. Lowering the voltage does not change the maximum beam current. The gun will be conditioned to 0.5 MV and operated to 0.4 MV. The analysis has used 0.5 MeV at 50 kW or 100 mA. It is unlikely that the gun can operate with beam to the maximum voltage that it was conditioned. The maximum voltage that the gun can achieve is 0.6 MV.

The dose rate for penetrations near the area of the gun test were provided in a memo[5] for 0.5 MeV beam with a power of 25 kW relevant for the gun test. The results below have been scaled to 50 kW. Only the dose rate at the gate can exceed 5 mrads/hr. This estimate is expected to be conservative. However, the potential dose rate in the future from the full LEReC could be higher. Chipmunk MON265 will be moved to the gate[6] and have an alarm level of 5 mrem/hr. Operators will respond to the alarms via OPM 6.1.3. The chipmunk will be installed with a quality factor[7] of 2.5. The dose rate from x-rays are overestimated by that amount. The chipmunk will have a dose rate that is a factor of two higher than the average dose rate at gate 2GE1. An alarm level of 5 mrem/hr coupled with operators responding to the alarm will prevent the dose in an hour from the gun test to exceed 5 mrads in an hour.

Dose Rates for 50 kW of 0.5 MeV Electrons

Penetration	**Dose Rate (mrad/hr)**	**Comments**
2GE1 Labyrinth Gate	18	Chipmunk moved to gate
Cryoport-high above shielding	3.	Not accessible
Cryoport at head level	0.02	accessible
Laser Port	2	Not constructed yet-averaged over a 10 cm radius around the laser tube
Cableway-at top of chimney	<< 1	2.5 MeV beam at 130 kW
704 MHz coaxial waveguide	<<2	Not constructed 2.5 MeV at 130 kW Inside shielding chimney

(CK-RHIC&LEReC-Oct. 15, 2015-IG-1052) Chipmunk moved with qf=2.5 and alarm=5.

The chipmunk alarms are generated in MCR. LEReC gun test with beam will be operated from MCR and trained personnel will be on duty to respond to the chipmunk alarms. Based on this and the conservative nature of the calculations the committee recommended that the 25 kW power limit be removed from the draft exemption request.

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[4] This was provided after the meeting.
[5] D. Beavis, August 18, 2016; http://www.c-ad.bnl.gov/esfd/RSC/Memos/8_18_16_LEReC.pdf
[6] It will be located on the end wall of the labyrinth inside the gate. The small height of the initial labyrinth prevents it from being placed inside the long main section of the labyrinth.
[7] This is used instead of 1 since it will also monitor for neutrons from RHIC beam losses.

The gun test will be conducted in a phased approach to reduce the risk of machine damage. The initials operations of gun beam will occur at power levels of the order of 1 Watt, which is sufficiently low to prevent equipment damage. The instrumentation will be commissioned including the Machine Protection System (MPS). RCTs will conduct surveys outside the shielding to ensure that there is no unexpected x-ray leakage.

The shielding designed for RHIC and the LEReC gun test must be in place. The final shield design for the laser port, cableway, and co-axial port must be reviewed before beam tests. **(CK-RHIC&LEReC-Oct. 15, 2015-IG-1053)**

Since the gun test with beam is close to the RHIC run schedule it is assumed that the complete shielding required for RHIC will be in place for the gun test. Any exceptions will be reviewed and documented.

All operations of the gun with beam and HV conditioning of the gun will be conducted only after an appropriate RSC check-off list has been reviewed, approved and completed.

The LEReC and RHIC may be simultaneously operating with their respective beams. The chipmunk at the gate could detect losses from either machine. The OPM should be examined and modified appropriately.
(CK-RHIC&LEReC&CeCPoP-Oct. 15, 2015-MCRGL-1054)Review OPM 6.1.3 for chipmunk alarms with multiple sources.

The beam dump will be the copper beam dump constructed for CeCPoP. A smaller base and thinner shielding will be used for the diagnostic beam dump. A discussion of shielding and other issues for the gun diagnostic dump are presented in a memo[8]. Shielding for the beam dump is not required for the gun test and there are no expected issues. The amount of hydrogen generated in the cooling water should be small and there will be no induced activity. The ozone production was estimated in footnote 8 and is not a concern. The engineering and review of the dump is near completion. The dump is expected[9] to be able to routinely handle 1-10 kW of 0.5 MeV beam.

The committee did not recommend a sunset date for the exemption. The project expects to need access for additional installation as soon as the RHIC run is over. A few weeks after the RHIC run ends would be a natural time to terminate the gun test exemption or request an extension. The gun can operate when RHIC is not operational since it is a room temperature device not requiring cryogenic fluid from RHIC.

HV Conditioning of the GUN

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[8] D. Beavis, May 23, 2016; http://www.c-ad.bnl.gov/esfd/RSC/Memos/5_23_16_LEReC.pdf
[9] This is dependent on the actual beam parameters achieved in addition to the engineering analysis that is in progress.

The Project expects to begin conditioning the gun with HV in November. There will still be substantial activities in IR2 both for LEReC and CeCPoP. Both projects would like access for equipment to be kept as convenient as possible. It is expected that the area will be open for workers during normal hours and then swept and secured for HV conditioning of the gun.

A possible temporary system of a local Pb shield and a barrier at the truck door was presented[10]. If 10% of the maximum current[11] is in field emission electrons at 0.5 MeV then the dose rate at a foot will be 5,000,000 mrads/hr at one meter. This was presented as the basis for the analysis unless there is sufficient controls and documentation on the means to limit the current during HV conditioning below this level. It is expected that there will be a resistor chain to limit the current during HV conditioning. The committee has often given substantial reduction in dose rate if there are appropriate controls on this current limiting device. It was learned after the meeting that the PS has a knob that can be used to limit the current to values less than 100 mA. This could also be used with reviewed and approved controls to limit the current. The Project is encouraged to provide details on both schemes to limit the current so that the shielding and restrictions during the HV conditioning can be as flexible as possible.
(CK-LEReC-Oct. 15, 2015-A. Fedotov & J. Sandberg-1055)Review any hardware or processes to limit the maximum gun current.

The committee and guests were reminded that typically credit is not given to machine protection systems and other means to prevent escalation of dose rates unless there are specific configuration management controls related to the devices to prevent inadvertent alteration.

The committee did not feel there was a sufficiently strong case to support the temporary system of local shielding and barriers for the HV conditioning. **The committee recommends that a thinner shield wall be used at the truck door to shield for the x-rays and to force personnel through the gates that are monitored by the access control system.** If a clear need is demonstrated then the committee will reconsider. It was noted that the effort to remove the shielding may not be any more cumbersome than removing a temporary barrier after RS LOTO of devices.

Footnote 10 noted that 50 cm of light concrete would be sufficient to reduce the dose rate during HV conditioning to 0.8 mrads/hr. The thin blocks that are used as the second layer of the truck door shielding are 75 cm thick and would be more than sufficient. The issue of potential cracks would need to be reviewed.
(CK-LEReC-Oct. 15, 2015-D. Phillips & D. Beavis-1056) Review final truck door shield and associated cracks for the HV gun test.

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[10] D. Beavis, August 26, 2016; http://www.c-ad.bnl.gov/esfd/RSC/Memos/8_26_16_LEReC_Gun.pdf
[11] 10% was "pulled out of the air" as a conservative assumption. In reality it would not be possible for the gun to absorb this much power without failing in a short time.

Radiation measurements were provided[12] after the meeting for the conditioning of a gun at Cornell. There are not sufficient details for the committee to give credit for the low radiation rates. It is instructive to note that the typical rates during HV commission are less than a few hundred mrads/hr. However, there are some periods of elevated rates. One short burst has a dose rate of 90 rads/hr but still far less than the 5,000 R/hr estimated at 10% of the power supply current. During the conditioning shown at Cornell there were probably machine protection devices to limit the current and subsequent dose rate.

LEReC Full Operations

Several references were provided to discuss the potential dose through penetration when LEReC is operating at full energy and power. The calculations were not discussed in detail. There is sufficient time to review the calculations and there will most likely be minor changes between now and when the machine is closer to operating. Several independent calculations will be conducted to verify selected calculations. A few items that were discussed.

The issue of access to the berm inside the fence during LEReC operations was discussed[13]. C-AD OPM 4.56.ca section 1.3 authorizes the RSC Chair to allow access into the locked fences at RHIC with an appropriate work permit and/or radiation work permit. A similar process at other C-AD facilities is allowed in OPM 4.46 with the approval of the RSC Chair and concurrence from the RCD Representative. These exception clauses are used on an infrequent basis for C-AD facilities. The potential dose due to the ventilation shafts and the survey shaft were examined for LEReC beam faults in case such a request was made in the future for work on the berm at IR2. The fault dose rate for full LEReC beam can be 200 rads/hr near the survey shaft. The dose rate falls off quickly with transverse distance from the shaft. Most work on the berm would likely be at the base of the berm far away from the survey shaft. There was discussion on the risk of executing this exception clause if there are less experienced personnel in the future. The committee did not come to a conclusion but if there are concerns on allowing access with the beam on then the regular steps in the procedure can be executed, which requires all beams to be turned off. The exception clauses provide for infrequent conditions to be handled without machine interruptions provided that appropriate reviews and work permits are conducted.

There are several of these survey shafts around the RHIC ring. For RHIC beam losses[14] the maximum dose for a fault is 1 rem. The maximum dose from an electron loss is 200 times larger but in reality will be limited by the duration the machine can survive the energy deposition. Although, there is concern about all the survey shafts the committee was concerned about this specific shaft for the electron beam. **Investigate it this shaft can either be permanently shielded of an improved shield be added to reduce the potential fault dose. (CK-LEReC-e-Nov. 1, 2016-J. Tuozzolo& D. Beavis-1057)**

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[12] C. Gulliford Powerpoint slides provided to A. Fedotov, http://www.c-ad.bnl.gov/esfd/RSC/GeneralReferences/Cornell_rad_cond.pdf
[13] D. Beavis, August 26, 2016; http://www.c-ad.bnl.gov/esfd/RSC/Memos/8_26_16_LEReC.pdf
[14] D. Beavis, July 7, 2012; http://www.c-ad.bnl.gov/esfd/RSC/Memos/Survey_Shift_07132012.pdf

Footnote 8 provides an initial recommendation for shielding the full power beam dump in the tunnel. The shielding will need to reduce ozone production and also protect machine components. The conservative estimate of ozone concentration was 100 times the TLV (Threshold Level Value). A more detailed estimate can be done but it was noted that the dose rate is too high for some of the machine components in the area. A shield to reduce the dose to nearby magnets and cables will also reduce the ozone production. A minimum of 10 cm of Pb shielding between the dump and the magnets and machine utilities was recommended as well as 15 to 20 cm of Pb in the forward direction. This recommendation was based on reducing the integrated absorbed dose at 90 cm to 1 Mrad assuming 3 years of operations at 2.5 MeV.

There are several issues related to the beam dump and associated shielding in the tunnel. The space is limited and the ability to get equipment by the shielded beam dump is a concern. Egress requirements will need to be accommodated by the final design. The placement of heavy equipment in the tunnel can also be problematic. **The project needs to provide the design team a specification that satisfies life safety code requirements and equipment moving requirements. Then a final shield and dump location can be designed. (CK-LEReC-e-Nov. 1, 2016-J. Tuozzolo-1058)**

The report (footnote 8) also addressed issues of radiation to penetrations and hydrogen generation in the cooling water.

CC:

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RSC Minutes File
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