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Memo

Date: *July 14, 2014*

To: *RSC, D. Phillips, and D. Kayran*

Cc: *I. Ben-Zvi, S. Belomestnykh, and W. Xu.*

From: *D. Beavis*

Subject: *Examination of Miscellaneous Shielding Changes at ERL*

The shielding designs for several areas of ERL have changed since the original shielding estimates were conducted. The ones that are not previously described are discussed in this note.

Changes to the 1 MW Waveguide Port

The shielding surrounding the top portion of the waveguide is now steel rather than heavy concrete. This change decreases the photon dose for direct punch through. A narrow area on the side of the port has 15 inches of steel with the rest having two feet. The section with 15 inches of steel would allow 1.4 R/hr to enter the waveguide port over a small area. The photons would require a reflection (bounce) to exit the port creating a dose rate of 50 mrads /hr for a 1 megawatt loss of 3.5 MeV electrons.

There are potential rays that can cut through the heavy concrete side wall and into the port. These rays are estimated to produce 20 mrads of dose for 1 megawatt of 3.5 electrons.

The port needs to be examined for 25 MeV beam loss and especially the neutrons. A loss just backwards of 90 degrees can illuminate the thin steel block. The estimated dose out the port is 50 mrads/hr for a 50 kW beam loss at 25 MeV. Heavy concrete on the side of the port can also be illuminated and result in 5.7 rads/hr exiting the port. A location in the ring farther away can illuminate the exit of the port through the 3.2 feet of heavy concrete at a production angle of 30 degrees. The estimated dose rate is 25 rads/hr for photons.

The dose rate due to neutrons can be estimated using an attenuation length of 45 g/cm^2 for heavy concrete. The neutron dose rate for 50 kW of 25 MeV beam losses is 200 mrem/hr for the section where the neutrons transverse 3.2 feet of heavy concrete. The steel is not as effective in shielding the neutrons from the 25 MeV electron beam losses as the photons. The neutrons can transverse 2 feet of steel (attenuation length of 100 g/cm^2) and then scatter to the exit of the port. A crude estimate of 300 mrem/hr is obtained for 50kW of beam loss.

1 MegaWatt Port Summary

Source	Source location	loss	Dose rate (mrem/hr)
3.5 MeV e^-		1000 kW	50 photons
25 MeV e^-	In last leg of ring—90 deg.	50 kW	5,700 photons
25 MeV e^-	South leg-30 degrees	50 kW	25,000 photons
25 MeV e^-	In last leg of ring—90 deg.	50 kW	300 neutron

Dump to ODH Port

The geometry of the beam dump shielding to the ODH port has changed. The initial design philosophy stated that the beam dump shield should be thick enough so that the radiation exiting the beam dump shield would be no higher than that of routine losses. The present shield has only 3 inches of steel on top so that this has a potential impact for dose to the ODH port. The beam dump has five inches of steel on the bottom and both sides. The end of the shield has an additional five inches that acts as a counter weight but also provide additional shielding.

A simple calculation using TVLs will provide an estimate of the dose out the top concrete cover of the ODH port. The x-rays must go through 3 inches of steel, a total of 3.6 feet of light concrete and travel a distance of 4.3 meters. One megawatt of 3.5 MeV beam into the beam dump results in a dose rate out the top of 220 mrads/hr.

A simple calculation was conducted for a loss in the beam transport before the beam dump. A source dose rate of 10^4 rad/(hr-kW) at one meter was used. A one MW beam loss would result in a dose of 75 rads/hr out the top of the 1.5 foot thick cap block. There are potential rays that can penetration the north shielding blocks of the vent port. These blocks are two feet thick and the angle would have the photons penetrating 2.6 feet of light concrete. One megawatt beam loss would create 100 rads/hr for a small portion of the block. Angles in the transport can illuminate the four thick side blocks which would produce less than 4 rads/hr.

Miss-steering by Dipole in Front of Beam Dump

The last dipole in the extraction channel does not presently have an interlock that requires the magnet current to match the beam energy. If the dipole is turned off the beam will strike Pb, then the steel shielding, and finally the concrete wall. The electromagnetic shower would have 20 cm of Pb, 25 cm of steel and 2.4 meters of light concrete. This shielding (19 TVLs) would be more than sufficient to terminate the radiation. If the dipole bends at an intermediate angle to miss the lead shield the beam will enter the beam dump. The side shield at such an angle is equivalent to 40 inches of steel . Followed by the concrete wall the shielding is more than sufficient.

The cast steel block behind the beam dump is two feet thick with an approximate density of 7 g/cm^3. The dose rate at the distance of the gate would be 570 mrads/hr without taking credit for the concrete wall and would be reduced to 0.03 mrads/hr by the concrete wall. The heavy concrete on top and below the iron block does not provide as much attenuation as the steel block but are not located at zero degrees. The dose rate at the gate assuming the iron block is heavy concrete would be 42 mrads/hr to one MW of 3.5 MeV electrons. The heavy concrete should be sufficient for the vertically inclined radiation going over or under the steel block.

Miss-steering By the First Extraction Dipole

The first dipole for extracting the beam provides a 30 degree bend to the 3.5 MeV beam. The maximum bend will be assumed to be 45 degrees[1]. Allowing the 3.5 MeV beam to directly strike the concrete wall would create 11 rads/hr into the klystron power supply building and somewhat smaller dose rates in the area adjacent to the locked building.

Shielding Over the Beam Dump

The dose rate through the roof was examined for the beam dump as the source. The section of roof over the beam dump has two layers of roof beams providing a total of eight feet of light concrete. The dump shield has three inches of steel. Ignoring any possible seams in the roof the dose rate on the roof would be 0.03 mrad/hr for 1 MW of beam. The roof becomes one layer just after the beginning of the beam dump end shield. There is a vertical angle where radiation would need to penetrate 3.5 inches of steel and 4.6 feet of light concrete to escape the enclosure with an estimated dose rate of 620 mrads/hr. The addition of another roof beam would decrease this to 2 mrads/hr. The roof is not allowed to have personnel on it during operations of ERL with radiation sources.

The dose through the nearby side wall will be 40 mrads/hr. A more detailed estimate[2] was provided by K. Yip with a dose rate was 0.1 mrad/hr at a location slightly upstream of the beam dump and four feet from the wall[3]. The use of empirical techniques with TVLs often overestimates the dose rates, which may partially explain the difference between the two estimates. The klystron power supply house cannot be occupied with beam operations at ERL and the dose rate would decrease substantially to the areas that are allowed to be occupied.

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[1] At the time of this report the maximum bend angle had not been confirmed for 3.5 MeV.
[2] http://www.c-ad.bnl.gov/esfd/RSC/Memos/kin_dump.pdf
[3] This is the closest location that can be occupied by personnel.

The decreased shielding around the beam dump may increase the difficulty of using radiation detectors at weak locations to limit beam losses to low levels. The one MW of beam into the dump appears like a 10kW loss in north east corner assuming the 5 inches of shielding. If radiation detectors are placed to limit losses at the 10-100 Watt level it may be difficult to filter out the beam dump. The beam dump may need to have shielding added to allow the radiation monitors to limit the losses at arbitrary locations. Fault studies and low power routine operations should help in establishing the final configuration.