Date: March 2, 2016

To: RSC, D. Phillips, I. Pinayev, and V. Litvinenko

From: D. Beavis

Subject: CeCPoP High Power Beam Dump Shielding

The end of the CeC beam line has a water cooled copper beam dump. This brief report gives a few details of the shield. A more detailed analysis may be provided in the future. The beam dump shielding has four primary purposes listed in the order of importance:

1. Reduce dose rates near the beam dump from residual activity to keep dose ALARA and compliant with regulations.
2. Reduce the air activation to allow either immediate access at the end of bombardment (EOB) or have a reasonably short waiting time.
3. Reduce the dose rate to surrounding instrumentation and materials.
4. Reduce the production of ozone in the tunnel air.

The dump shield and beam activities will evolve with time. This report provides the criteria that a subgroup of the RSC will use to limit both the maximum beam power on the high power beam dump and any potential wait times before access to IR2 is allowed after EOB.

A temporary access procedure\(^1\) was developed to allow flexibility in the access and whether radiation surveys are requested. Naturally, the Operations Coordinator can request surveys based on his knowledge of running conditions in IR2. This TPL will also be modified to contain specification for a minimum waiting period before IR2 is entered. The waiting period, if any, will be used to decrease potential risk of exposure to residual radiation, air activation, and ozone. This process is to allow flexibility for the changing conditions that may occur at IR2 and allow as much progress for CeCPoP as is prudent.

The dump shield is shown in Figure 1. The shielding in the forward direction is 15 cm of Pb followed by 15 cm of steel. The side walls are 5 cm of Pb and 15 inches of steel. The top is covered with 15 cm of Pb. The Pb on the top captures all the shielding when the assembly is complete. The top layer of Pb weighs 1450 #. The other top Pb pieces weigh 450 # each and the steel blocks are too heavy to lift by hand. Lifting equipment will be used to construct the beam dump shielding. The bottom support plate/shield is 15 cm thick. The thickness of the bottom plate was chosen to allow electronics under the beam dump to survive at least two years of operations (1000 hours at full power).

The water cooled beam dump will have saturation activities at the end of a long bombardment (more than 2 days) for 8500W of 25 MeV electron beam of:

- 3.15 Ci $^{61}$Cu
- 73. Ci $^{62}$Cu
- 35.7 Ci $^{64}$Cu

All the radionuclides are assumed to be at a point and the dose rate is estimated at a distance of 45 cm from the source point. The bottom support plate has a half width of 40 cm so the 45 cm is a reasonable distance to use. Microshield$^2$ was used with the source in air and different shielding layers were placed between the source and the detection point. The dose rate is 243,000 mrem/hr with no shield present and no self-shielding.

To establish shielding and entry conditions to keep dose ALARA and compliant with area posting some criteria have been established, which couples the installed shielding configuration with allowed maximum beam power. The maximum allowed beam power will have an initial limit of 1 Watt averaged over one hour. This limit will be established on the RSC check-off list for CeCPoP operations. Changes to the limit will be incorporated using a change form$^3$ for the check-off list. After initial commissioning the following shielding conditions establish the maximum beam power allowed $^4$to keep levels below 100 mrads/hr for 25 MeV beam.

- No shielding—3.5 Watts
- 5 cm Pb – 360 Watts
- 5 cm Pb followed by 6 inches of steel—No limit on beam power (4.4 mrads/hr)
- 15 cm steel (bottom) 3600 Watts --A simple barrier can prevent access for higher beam current.
- 15 cm Pb and 15 cm steel No limit. (26 microrads/hr)

Note, if it is decided to create a high radiation area around the dump and beam transport before the beam dump then dose rates to 1,000 mrem/hr could be allowed and the beam power could be increased by a factor of 10. Entry into such an area would require an RWP sign in and an SRD. This should be avoided unless unusual conditions arise.

The shield implementation is expected to occur in one to three steps depending on the machine conditions and the availability of the steel shielding. The shielding cannot be placed before bake-out is complete$^5$. The steps are:

1. No shielding. This allows testing of the beam dump and beam dump instrumentation before it is buried in shielding.
2. Install all the Pb shielding except the top 3 inches. This option would allow for higher beam power and testing and may be necessary if the steel shielding blocks are not ready.

---

$^2$ Grove Software, Inc.; Microshield 7.02 was used to the simple shielding analysis.
$^4$ These beam current limits can change when based on actual RCT radiation measurements in the field.
$^5$ This is likely to be 2-4 weeks from March 2, 2016.
3. The complete shield is installed. If the shielding is available and the project engineers judge that the dump has no issues then the shielding assembly will be completed.

The shielding design for the beam dump has 5 inches of Pb on the sides of the beam dump. There will be 15 cm of Pb in the forward direction and 15 cm of Pb over the top of the dump. The Pb bricks are “captured” by large Pb pieces of the top. Large 15 cm thick steel blocks exist on the sides and front of the dump. There is Pb and steel paced in the backward direction. Additional shielding is expected to be needed but field measurements will be used to integrate the shielding into the beam line components. There is also Pb blocks behind the 45 degree dipole. The dose rate through the Pb after the diploe will be 0.3 mrad/s/hr at EOB with full beam. The albedo off the Pb will be 3 mrad/s/hr one foot in front of the Pb (and to the side).

The air activation can be sufficiently high that a waiting time may be appropriate to allow decay. The $^{13}\text{N}$ immersion dose is 123 times larger than the DAC value for operations at 25 MeV and 8500 Watts if there is no dump shielding. This would provide an external immersion dose of 300 mrad/s/hr. Therefore, without shielding the beam current on the beam dump should be limited to a beam power to reduce the immersion dose to less than 100 mrad/s/hr. A reasonable initial immersion dose rate would be 10 mrad/s/hr which would limit the power on the unshielded beam dump to 280 Watts. The threshold for $^{13}\text{N}$ production is 10.55 MeV and for $^{15}\text{O}$ is 15.67 MeV. The energy absorption coefficient for Pb of $3.48\times10^{-2}$ cm$^2$/gm and 8.6 cm of Pb is needed to decrease the immersion dose of $^{13}\text{N}$ to below 10 mrad/s/hr after EOB.

Figure 1: Plan view of the last segment of the CeCPoP beam transport with the beam dump and associated shielding. Steel and Pb show the backward direction and there is a four inch Pb shield at the back of the dipole.

Figure 2: Side view of the shielding and transport. The red boxes are steel and the green Pb.

---

6 There is conservatism in these estimates and the actual air activation will be measured.
Acknowledgement: I would like to thank R. Karol for checking the Microshield numbers and suggesting using the immersion dose for the activated air.