Memo

date: December 6, 2006

to: RSC

from: D. Beavis

subject: Estimate of the Radiation Exiting Penetrations for the ERL 50 KW Wave Guide, Cable Buss Block, and Water Pipes

A simple estimate is made to support changes in the shielding configuration for the ERL test area. This note will address changes for the 50kW wave guide, a cable buss block, and water pipes. The penetrations associated with these items will have the potential to leak radiation under routine operations and fault conditions.

A maximum beam fault of 50kW at 25 MeV will generate a gamma dose rate of $4 \times 10^5$ rads/hr at a meter and $2.1 \times 10^4$ rem/hr for neutrons (Ref. 1). The radiation entering the penetrations is assumed to be that of transverse radiation. Forward angle photon radiation is assumed to be shadowed by an interior shield wall, which will reduce the dose rates to or lower than the transverse radiation. Routine losses are expected to be at least a 1000 times lower than the 50 kW loss.

The 50 kW wave-guide penetration is assumed to have a cross-sectional area of 588 cm$^2$. The source is assumed to be 3.1 meters away and have a 45-degree angle to the penetration opening. The 4-foot section of the penetration through the shield wall is expected to have attenuation 0.1 (Ref 2). Coupled with the solid angle to the source the expected maximum dose rates exiting the penetration are 4000 rads/hr gamma and 210 rem/hr neutron. The distance to the electronics room is 244 cm. The neutrons can reflect off the shadow block in the forward direction. Using reflection coefficients (Ref. 3) of 0.1 for the neutrons and 0.01 for the photons the dose rates in the electronics building are expected to be 400 mrem/hr gamma and 207 mrem neutrons.

The reflection of the photons and neutrons are shadowed by an 18 inch concrete shield which is part of the wave guide labyrinth. The neutrons have a TVL in concrete of 80 gm/cm$^2$ (Ref. 4) and the photons have a TVL of 80 gm/cm$^2$ (Ref. 5). This provides an additional attenuation of 0.045. The dose into the electronic building is reduced to 18 mrem/hr gamma and 9 mrem/hr neutron for a 50 kW loss.
The dose rates for the cable ports can be calculated in a similar fashion. The ports are a series of 4-inch diameter circular holes in buss blocks. There are a total of 24 holes. The 12 smaller 2-inch diameter holes will be ignored. The holes are distributed with a minimum distance of 91cm from the support building and have a spacing of 20 cm. There are four holes in a vertical column. A single hole will have a dose rate exiting the buss block of 280 rem/hr gamma and 15 rem/hr neutron. The radiation can be reflected off the shadow block, which is in the forward direction. The dose rates from a single port reflected into the building 91 cm away will be 26 mrem/hr gamma and 15 mrem/hr neutron. Taking into account the spacing pattern of the holes the estimated fault dose rates for the 24 cable holes are of 315 mrem/hr gamma and 160 mrem/hr neutron.

A single chipmunk could easily protect the fault-dose rates of 500 mrem/hr. Although these calculations are crude estimates, this configuration would appear to be reasonable. Provision to block unused ports and the addition of a thin shadow shield could be incorporated into the design to lower the potential dose into the building. The routine losses are expected to be 1000 times lower and should not be an issue. The building is not expected to have a high-personnel occupancy.

The wave-guide penetration is actually a three-legged labyrinth. The first leg was treated above and has a cross-sectional area of 588 cm**2. 60 cm thick concrete shadows the first leg in the forward direction. The neutron and photon doses are reduced by a factor of 0.017 using the broad beam TVL. The gamma (neutron) dose rate would be 68 rem/hr (3.6 rem/hr) outside the shadow block. This calculation ignores two factors that would further reduce the dose. The first is the dispersion of the radiation emerging from the first leg of the penetration. The second factor is the scattering in the concrete. The broad beam TVL assumes that the radiation is uniformly distributed on the inside surface of the concrete.

MCNPX (Ref. 6) can be used to estimate the reduction of dose due to the two-feet thick shadow block. For this estimate fixed energy gammas and neutrons will be used with energies above and below the expected mean energy. Figure 1 displays the results for the neutrons as a function of radius. The hole is treated as a circular source of neutrons and the direction of the neutrons are perpendicular to the concrete block. The 3.0 MeV neutrons are above the mean energy and have an attenuation of 0.0047, which is about 3.6 times lower than the result from the broad beam TVL. The 0.1 MeV neutrons are nearly 100 times lower than the TVL result. It is reasonable to assume that a 50 kW beam loss will produce a neutron dose rate of less than 1 rem/hr outside the shadow block.
The gamma dose rate as a function of radius is shown in Figure 2. The dose is reduced from 4000 rem/hr to 28 rem/hr by the shadow block for 2 MeV gammas. The result for 0.3 MeV gammas is about 1000 times lower than the 2 MeV gammas and is not shown in the figure. The dose rate for routine losses is expected to be a few $10$’s of mrem/hr.
Two 6-inch diameter penetrations for 4-inch diameter water pipes are adjacent to the wave guide penetration. Each 6-inch diameter penetration would have an exiting gamma dose rate of 400 rads/hr for a 50 kW/hr beam loss. The discussion above can be applied to get a gamma (neutron) dose rate outside the shadow block of 2-3 rem/hr (100 mrem/hr). The contribution of the water pipe penetrations will be ignored for the calculation of the gap under the shadow block.

The dose exiting the gap under the shadow block can be estimated using the labyrinth formula of reference 7 for neutrons or reflection coefficients for the gammas. The estimated neutron dose rate exiting under the shadow block is 0.1 rem/hr for a 50kW loss. The gamma dose estimated by using two albedo coefficients of 0.01 for the first scatter and 0.1 for the second is 4 rem/hr for a 50 kW loss.

Conclusions

Simple techniques have been used to estimate of the expected dose rates exiting several penetrations. It is expected that at least one chipmunk will be able to limit the fault potential near these penetrations. The penetrations are approximately 12 feet above the floor. Access to the floor area under the penetrations could have additional controls if warranted.

References

2) A.H. Sullivan, A Guide to Radiation and Radioactivity Levels Near High Energy Particle Accelerators, 1992, see Figure 2.25,2.26, and 2.27.
3) NCRP Report No. 144, Figure 4.12 and 4.13.
4) W.P. Swanson, Radiological Safety Aspects of the Operation of Electron Linear Accelerators, 1979, Figure 46.
5) NCRP Report No. 144, Table 4.2.
6) D. B. Pelowitz,Ed. “MCNPX User’s Manual, Version 2.5.0”, April 2005; version 2.5f was used for these calculations
7) K. Goebel et. al., “Evaluating Dose Rates Due to Neutron Leakage Through the Access Tunnels of the SPS”, CERN LABII-RANote/75-10(1975). It is noted that the aspect ratio for this problem exceeds that which the formula is tested for.