Memo

Date: September 28, 2016

To: RSC, S. Pontieri, A. Zaltsman, and A. Drees

From: D. Beavis

Subject: Utility Penetrations for 9 MHz Cavities in 3 O’clock Sector

A group of 5 and 3 inch-diameter penetrations are being installed in the berm for cables to be routed from support Building 1004D to the RHIC arc for the 9 MHz cavities. Figure 1 displays the layout of the penetrations. This memorandum documents calculations for the potential dose out the 5 inch-diameter penetrations in the event of a RHIC beam loss and x-rays from the 9 MHz cavities. The 3 inch-diameter penetrations have a much smaller dose than the 5 inch-diameter penetrations and are not calculated.

Figure 1: Side view of the penetrations being installed into the RHIC tunnel on the 3 O’clock side of IR4. The penetrations are being used to deliver utilities to the 9 MHz cavities that will be installed in the tunnel. The support building is shown on the left-hand side of the figure.
A quick estimate can be made using the curves provided by Sullivan\(^1\). The parameters for the calculation are:

- Penetration diameter – 12.7 cm
- Penetration Length in soil – 990 cm
- Height of penetration above beam – 225 cm
- Horizontal distance to wall – 290 cm
- Beam Loss – \(2.5 \times 10^{13}\) 250 GeV protons

Using the curve from Figure 2.25 of Footnote 1 the attenuation for neutrons is \(1.65 \times 10^{-5}\). The dose at the penetration opening inside the ring was obtained from the MCNPX calculation. The exit dose for a maximum credible beam fault is 20 mrem. The utility pipes exit the berm where access is permitted and the area is posted as a Controlled Area for RHIC beam operations. The dose for a beam fault satisfies the C-AD Shielding Policy.

A more detailed estimate was conducted using MCNPX\(^2\). The penetration is assumed to be empty. Using the method discussed in footnote 2 the neutron dose for a full beam fault can be calculated along the penetration. A factor of 2.1 has been applied to account for other hadrons as a simple approximation. The last points in the MCNPX calculations have large errors. However, the dose is sufficiently low where the errors are sufficiently good that the dose in a beam fault would be of the order 1 mrem per fault. The estimates from MCNPX are shown in Figure 2. The curve from Footnote 1 is shown as the blue curve. The results using the first leg labyrinth formula of Goebel et al. is shown as the red curve.

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**Figure 2:** Dose as a function of longitudinal distance from the source inside the penetration. The penetration starts at \(z=290\) cm. The green points are the MCNPX results. The blue points are from the curves in Sullivan (footnote 1) and the red curve is the result using Goebel et al.

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The 9 MHz cavities can be a source of x-rays for the penetrations. The cavities are assumed\(^3\) to have a maximum voltage of 80 kV and a maximum possible power of 16 kW. The assumption of 16 kW going into emission electrons is very conservative\(^4\). MCNPX was used to estimate the x-rays from 80 keV electrons striking a 4mm diameter copper rod. The x-rays were binned in 10 keV increments and the energy distribution was used to illuminate the 5 inch-diameter penetration. It was assumed that 16 kW of 80 keV electrons were striking the copper rod. In addition a 1 cm thick aluminum shell was placed around the rod to simulate the attenuation of the vacuum box. Figure 3 displays the results of the MCNPX calculations. The dose in the penetration is quickly reduced to acceptable levels inside the penetration and well below the potential fault doses from RHIC beam losses.

![Graph](image.png)

**Figure 3:** Dose rate along the axis of one of the 5 inch-diameter penetrations for the 9 MHz cavities with 80 keV electrons striking a copper rod at the maximum power from the power supply.

There will be a total of six 9 MHz cavities inside the tunnel. The number of cavities is not a concern for dose outside the tunnel. The cavities will be connected to the access control system with dual contactors to prevent access into the tunnel with the cavities on. Ventilation shaft 3EF3 & 4XEF1 are on the outside of the ring and exit the berm inside the locked fence. There are two 12 inch-diameter penetrations\(^5\) for beam cooling. These nearby penetrations should be check for x-ray leakage due to the 9 MHz cavities. (CK-RHIC-Nov. 15, 2016-S. Pontieri&D. Beavis-1059)

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\(^3\) E-mail from A. Zaltsman to D. Beavis on April 27, 2016, which stated 80 kV at 15 kW.

\(^4\) S. Polizzo e-mail to D. Beavis on March 13, 2015 had more than 99% of the power going into resistive losses in the warm cavity.