Collider-Accelerator Department

BROOKHAVEN NATIONAL LABORATORY

Building 911B – P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344 7124
Fax 631 344 5568
beavis@bnl.gov
www.bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

date: *January 14, 2010*

to: *RSC*

from: *D. Beavis*

subject: *RHIC Labyrinths*

Introduction

The RHIC personnel labyrinths will be examined for the potential maximum credible incidents (MCI) and for low energy operations. These estimates will be performed in a simple manner and compared to the RHIC SAD and other documents. The analysis is crude and most likely overly conservative. Additional work can be done to provide more accurate estimates if needed. For routine operations the largest uncertainty is the actual chronic beam loss and not the method of treating attenuation of radiation in the labyrinth. The labyrinths are not considered a concern for low energy operations when considered by themselves.

Labyrinth Estimations

The potential dose to a person outside a labyrinth can be estimated using simple labyrinth formulas and a source term. Similar to the treatment in the RHIC SAD[1] an MCI will be defined as either one-half or all the beam in one ring lost at a point near the labyrinth entrance. The full beam in a ring used for the source term is $2.28*10^{13}$ protons at 250 GeV. The estimated dose at a foot from a full beam fault is:

$D = (38{,}800 \text{ rem})* e^{-(d/att)}/(r_t*r_t)$ where,

D is the dose in rem, r_t is the transverse distance in feet, d is the shield thickness in feet, and att is the attenuation length of the shielding in feet. This formula incorporates a factor of 2 that the RHIC project used for increased neutron equivalent dose.

For the treatment of labyrinths the reader is encouraged to read the notes[2] in the RHIC SAD and the references contained therein. Several differences exist between the simple method I will use and the treatments of appendix 16. Firstly, I do not double the dose into the labyrinth[3]. In addition, sometimes a different source term is used (full verses half beam loss). A "punch-through" contribution[4] for some of the labyrinths was neglected in the RHIC SAD. It is estimated using the attenuation formula above with the distance to the gate. This contribution is then added to the labyrinth formula and given in parenthesis. This is a very simplistic treatment and could be improved via Monte Carlo methods to obtain a more appropriate evaluation. Most of the differences when comparing the dose estimates calculated and those presented in the RHIC SAD

can be accounted for by these systematic differences in method. However, in a couple cases, it is possible the wrong leg length was used in the attenuation formula.

Dose from Maximum Credible Incidents (MCI)

The estimated dose out the passage ways is given in the table below for an MCI. The estimates given here are in reasonable agreement with those contained in the RHIC SAD. Most of the access labyrinths would have a dose lower than a typical location of the RHIC berm resulting from the occurrence of an MCI. The archival drawings were used to obtain the dimensions of the labyrinths and minor differences can be due to extracting dimensions, if the dimensions were not explicitly on the drawing. All RHIC personnel labyrinths exit into Controlled Areas. The labyrinths that exit near the Intersection Region (IR) support buildings have radiation monitors (chipmunks) near the exit. TLDs are placed near many labyrinth exits to measure the integrated dose from an access way during operations. The numbers in the Table I can be used to estimate the chronic dose[5] once a chronic beam loss condition is assumed.

Table I: Dose from a Maximum Credible Incident (MCI) Near an Access Portal

Location	Type	Dose mrem	Dose in RHIC SAD mrem	Source/Comments
B Alcove (typical)	P-3	.7,3	7	Half, ref. 19
A&C Alcove (typical)	P-4	49	70	Half
Emergency exit (7B)	P-5	2,16	33	Half, ref. 20
2 O'clock to support bldg.-2GE2	P-6	46(136)	19	Full ,ref. 10
4 O'clock to support bldg.-4GE2	P-7	6(34)	16	Half
Ring to 1005-4GE3	P-8	16	13	Half, ref. 14
Injection to 1007 & 1005-5GE1	P-9	1.5(22)	3.6,36	Half, ref. 11
10 O'clock to berm	P-10	3	2	Full
10 O'clock to support bldg-10GE1	P-11	3	270	Full, ref. 12
12 O'clock to berm	P-12	23	3	Full, ref. 18
12 O'clock support bldg.-12GE1	P-14	30	11	Full
8 O'clock to support bldg.-8GE2	P-15	9	21	Half, ref. 13
6 O'clock to support bldg.-6ED1	P-17	21 (82)	24	Full
Emergency exit near 1005	P-19	9	60	Half, ref. 15
STAR Exp.-6GE1,2			50	Half
PHENIX escape-8GE1			24	Half,With poly door, ref. 16
2GE1			23	Half, ref. 17
4GE1		160(2000)		Half, inside secured area

Energy and intensity upgrades would increase these potential doses up to a factor of 2.5. Most labyrinths would not be considered an area of concern with this increase. However, the labyrinths at STAR could exceed 100 mrem for a local MCI with beam upgrades. However, at STAR it should be noted the dose through the shield wall is estimated to be substantially higher. This exceeds the design criteria[6] of 100 mrem that the committee has recommended for

experimental areas. These are the areas where personnel are most likely to be gathered during beam operations.

Dose from Chronic Beam Losses

The RHIC SAD did not consider chronic dose near the access portals since chronic losses were not considered an issue. All evidence points to the fact that for full energy operations there is not an issue with chronic doses. The results of TLD monitor badges that have been near many of the facility personnel labyrinths have demonstrated that the integrated dose is essentially consistent with background. Therefore, chronic losses are not anticipated to be an issue for high-energy operations.

Low energy operations are expected to have a much higher percentage of the beam lost during injection and store. For low energy operations we will assume[7] that 25 % of the injected beam is lost at the injection region, 25% is lost on the IR triplets, 25% is lost on the abort kickers, 25% on the collimators, and 10% is lost at a "typical hot spot".

The injection losses are close to the P-9 labyrinths listed in Table I. For each fill the labyrinth could have a dose of 0.0174 of an MCI for 3.85 GeV. Three such fills[8] per hour would create a possible dose rate[9] of 1.1 mrem/hr. Surveys should be able to provide necessary information to change posting near the exit of the injection labyrinths if the losses are this high.

The collimator for the blue beam is near the labyrinth 8GE1. There is 3 feet of heavy concrete on the side of this collimator which reduces the dose into the labyrinth and the punch-through by a factor of ten. The estimated dose per hour is 0.05 mrem/hr. The yellow collimator is not near a labyrinth.

Most of the labyrinths near IRs would see much less than $1/20^{th}$ of a MCI in an hour. Escape labyrinths which are near typical sections of the berm would see substantially less. An appropriate approach would be to conduct radiation surveys to insure that areas near the exits do not have undesired dose rates.

The abort kickers are downstream of the labyrinths so that if they have large losses the dose will be much smaller than estimated in Table I.

Recommendations and Comments

It is recommended that for low energy operations none of the labyrinths requires additional protection at startup. Rather, labyrinths near high loss points should be surveys in the commissioning process and local posting be upgrade as needed.

The labyrinths that exit the ring near the two operating experiments are candidates for careful surveys since they are near areas where there is substantial occupancy.

Labyrinths that have a large contribution from punch-though should have an improved analysis conducted to provide a more accurate estimate.

References

1. M. Harrison and A. J. Stevens, "Beam Loss Scenario in RHIC", AD/RHIC/RD-52, January 1993.
2. RHIC SAD Appendix 16. Notes by A.J. Stevens and P. Gollon.
3. A.J. Stevens, "Scaling Gollon's Duct and Labyrinth Calculations", in RHIC SAD appendix 16.
4. The values calculated in this note use a different attenuation factor and in some cases a different source term for the punch through than that treated in D. Beavis, "
5. See for example D. Beavis memorandum, "Potential Dose on the RHIC Berm", Dec. 30, 2009.
6. RSC Minutes of August 25, 2009, "Fault Dose Design Criteria for RHIC Intensity Upgrades".
7. This follows the assumptions of reference 5 above.
8. T. Satogata, "RHIC Low Energy Beam Loss Projections", Sept. 9, 2005.
9. The conservative punch-through value has been used.
10. This is one of several labyrinths where it was decided to use the full beam rather than half beam for the fault.
11. The 36 mrem is calculated outside where the berm allows the access tunnel to be uncovered.
12. The 270 mrem was before the shielding was placed inside building 1010B to make an additional turn to the personnel labyrinth.
13. The value calculated ignores the shielding on the side of the collimator, which shadows losses on the collimator but not losses in other locations. The RHIC SAD value has a factor of 0.53 to account for the poly-door, which was not used in the recalculated number.
14. The value calculated here has ignored the extra reduction caused by the stacked concrete blocks in the labyrinth. The value is to the interlocked gate and not the door that defines the transition from the building to a Controlled Area., where the dose would be about 1 mrem.
15. This is a B alcove exit that is unusually short because of building 1005. The labyrinth concrete of the last leg becomes uncovered about half-way to the door.
16. The poly door accounts for a factor of 16 in dose reduction based on S. Kahn and A.J. Stevens, "Estimates of Dose Equivalence Associated with Penetrations in the PHENIX Shield Wall", June 1998.
17. Requires a more detailed approach than used in this note.
18. The attenuation of the last leg is a factor of ten too small in the RHIC SAD, probably due a slipped decimal point.
19. The 0.7mrem is at the door. The 3 mrem is inside the tunnel where the soil coverage may end. It appears this is the location used for the RHIC SAD. There should however be an additional reduction for any potential exposure outside the tunnel. The 1B, 3B,9B, and 11B alcove exits are all nearly identical. The other two B alcove exits are listed separately in the table.

CC: A. Drees, W. Fischer, A. Pendzick, T. Satogata