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Memo

date: *November 14, 2008*

to: *RSC*

from: *D. Beavis* DB

subject: *Proposed Changes for U/W Beam Line*

Introduction

Operating conditions have changed for the use of the U line over the last 15 years. The committee minutes and fault studies have been reviewed for the portion of the AtR where the U line and W line split to evaluate whether some of the chipmunks can be removed. The exterior chipmunks on the U berm can be difficult to service and are susceptible to environmental conditions that make them more likely cause downtime. Recommendations, historical background, and justification will be given based on the review of the records.

Recommendations

It is proposed that the following four exterior chipmunks be removed:

NMON82 U/S U line-1
NMON83 U/S U line-2
NMON84 U/S U Blockhouse
NMON85 D/S U Blockhouse

It is proposed that the chipmunk on top of WD7, NMON219, downstream of the headwall be removed.

It is proposed that the chipmunk at gate UGE2 have the interlock level remain at 20 mrem/hr and the alarm level to 5.0 mrem/hr. The interlock or alarm level could be decreased in the future to provide additional sensitivity for scrapping in the U line.

It is proposed that a positive means to terminate beam in the U line spur be added before UGE2. This could be accomplished by a small steel block or by locking the collimator in the closed position. The chipmunk at UGE2 would be sensitive to beam on the terminating material.

It is recommended that an administrative alarm program be instituted to limit potential beam losses and/or their duration. The program could use the beam current measuring devices, magnet monitors, and/or loss monitors to alarm operators for abnormal conditions. It is

suggested that the beam be allow to operate should a component of this alarm program fail provided it is repaired within a specified time window.

It is recommended that a few TLDs be placed along the perimeter fence to monitor the integrated exposure during operations.

History

The chipmunks NMON82-84 were added to the U line for experiments E938 and E939, which targeted protons on materials in the upstream U spur[1]. At that time, there was concern that high intensity AGS pulses could be mistakenly transported past the 8 degree bend. The radiation from one pulse of 60 TP 24 GeV protons was estimated to be 6 mrem at the edge of the berm at an elevation of 11 feet. A positive means to quickly stop the beam was desired. Based on these concerns and the targeting of protons for the experiments the chipmunks were installed partway down the U line berm on the west side. The concern for high intensity pulses and purposely targeting beams in the U line is not expected to be an issue for the immediate future.

The RSC reviewed some issues with the operation of E938 in the meeting[2] of July 28, 1998. The relevant part of these minutes is the discussion of estimated radiation levels on the berm, at the berm fence, and at penetrations on the west side. Radiation levels will be discussed below when the fault studies are reviewed.

Later in 1998 it was noted that the logic for placing the chipmunks upstream of the U line Block house could be applied to a thin section of the U line downstream of the block house and the UGE3 labyrinth. No intentional targets were planned for these areas but the beam could induce radiation at these weak locations and therefore chipmunks NMON85 (D/S of U blockhouse) and NMON86 (UGE3 labyrinth) were added.

The question of whether some of these chipmunks were required for ion operations was addressed in a memo in August of 2000. The conclusion was based on the estimates discussed in reference 1 and stated that each cycle of $4*10^9$ Au ions could produce 0.039 mrem at the berm fence on the west side (11 feet above the ground). **There are three aspects to reconsider as to why this conclusion can be changed**. First, all fault studies conducted have always shown measured radiation levels below the conservative estimates. Secondly, examination of the sensitivity of the chipmunk located at UGE2 shows it is more sensitive to faults than the berm chipmunks for most fault locations. Thirdly, the RSC has taken more credit in recent times for administrative controls of beam losses. The analysis[4] for the W line conducted for RHIC[5] does not consider beam faults continuing for more than a few AGS cycles.

The chipmunks were relocated to the top of the U line berm to reduce the risk to personnel that service the chipmunks. The U line was also discussed in several other minutes but most of the issues are not relevant other than the concern about penetrations on the west side, including downstream of the U blockhouse.

The chipmunk at WD7 was placed in the W line in 1995 to protect workers in the W line while beam was operated to the upstream U line. To enter the W line the 8 and 20 degree bends must be off.

Justification of Proposed Changes

The positive termination of beam in the U line spur in the vicinity of WD2 will prevent beam close to any penetrations downstream of the U line block house or the weak section of the berm near the block house. Thus NMON85 and NMON84 can be removed. This also implies that NMON86 could be removed, but this chipmunk can be used for other purposes if needed and therefore is not recommended for removal. NMON86 was recently relocated close to the tunnel and therefore is not subject to adverse environmental conditions.

For beam in the U line the UGE2 chipmunk will be sensitive to beam striking the terminating material. Two fault studies were conducted with a proton beam striking a 4-inch thick iron brick located in the U-line. The kinetic energy of the protons was[6] 24 GeV. The dose rates measured by the chipmunks are summarized in the table below with a factor of 2.2 to scale to 100% beam interactions and scaling to full Au beam intensity of $8*10^9$ Au ions every 3 seconds:

Chipmunk	**Dose rate mrem/hr Fault Study 25**	**Dose rate mrem/hr Fault Study 29**
NMON 82	<2.6 (7)	<2 (7)
NMON 83	9.4	14
NMON84	9.4	5
NMON85	<2.6 (7)	<2 (7)
NMON81	240	120

The chipmunk at UGE2 has a dose rate typically more than 10 times higher than the berm chipmunks. The 4-inch brick appears to have been located about halfway between WD1 and WD2 for fault study 25, although the indications on the survey map are not clear. NMON82 is approximately 10 feet downstream of the end of WD1 and NMON83 is between WD2 and WD3. Based on these numbers it would be expected that the chipmunk at UGE2 is more sensitive to faults in the U line than the berm chipmunks. A fault study[8] no. 29 was conducted approximately 2 years later with an iron brick about 10 feet downstream of the end of WD2 and similar conclusions can be drawn. Depending on the actual location of the brick in fault study 25, there may be some concern as to the sensitivity of NMON81 to faults locations upstream of WD2.

The sensitivity of NMON81 to beam faults will decrease as the scrapping is moved towards the 8-degree bend. It is not expected that hard beam faults can be created easily upstream of WD1 where the berm is thin. To prevent the risk of exposure due to faults lasting for substantial time a program to monitor beam conditions could be used to alert operators to unexpected conditions. It should be noted that operating with Au ions at $8*10^9$ions per cycle at 10.8 GeV every 4 seconds correspond to $4.2*10^{12}$ nuc.-GeV per hour and an expected maximum dose rate on the U line berm of a 3-6 mrem/hr if chipmunk, NMON81, does not interlock (based on the fault studies). For the fault studies considered, the alarm level of NMON81 would correspond to a dose rate on the U line berm of 0.2 mrem/hr during a full Au beam fault.

No radiation was detected at any of the penetrations along the west side of the beam line upstream of the U line blockhouse in fault study 25. The penetrations have cables and pipes in them that may reduce the radiation. The dose rates measured by the chipmunks are lower than predicted in the minutes. This is a result of the conservative nature of the initial calculations, which assume a nearly optimum target. Many of the penetrations downstream of the blockhouse on the east side are presently empty. With the termination of the beam upstream of UGE2 and the sensitivity of the chipmunk at UGE2 this should not be a concern.

The chipmunk on top of WD7,NMON219, is ignored by the interlock system if the 8 and 20 degree bends are off. The AGS no longer extracts high intensity beam into the upstream U line. Should the interlock on the 8 degree bend fail in a manner not detected by the reachback checks then the beam could be transported to the front end of the W line at WD1. The 4-inch thick brick located in the U line spur between WD2 and WD3 generated 4 mrem/hr at NMON219 and 3 mrem/hr at NMON81. When scaled to $8*10^9$ Au ions every 3 seconds and a factor of 2.2 is used for 100% beam loss then the dose rates would be 51 mrem/hr at NMON219 and 39 mrem/hr at NMON81. The alarm level of NMON81 is presently set at 5 mrem/hr and this would respond to a dose rate of 6.5 mrem/hr at WD7. This is acceptable considering a hardware interlock had to fail to create this dose.

There are penetrations on the west side of the tunnel. Most of the penetrations upstream of UGE2 have been abandoned and do not fully penetrate the berm. Inside the tunnel the upstream penetrations are often used for flag cameras. One penetration near WD2 is open to the outside berm, but is well within the fence, unlike the west penetrations.

There are four penetrations on the west side of the W line before the head wall located near WD5 to WD6. The two downstream penetrations were examined in RHIC/ATR Fault Study no. 17 with Au beam. These penetrations were not discussed as part of the RHIC reports since they are upstream of the headwall. When scaled to a gold beam of $8*10^9$ Au ion the highest radiation level would be 710 mrem/hr at the exit of the penetration. In this location the beam pipe is close to the penetration both in distance and elevation so the the angle from the source to the opening of the pipe is small (about 10 degrees). Using figure 2.25 of reference 9 and the MCNPX estimates from reference 10 the dose for this fault is calculated to be 1470 mrem/hr. These penetrations are the same diameter and length as the ones on the east side which saw no detectable radiation. The differences include the fact that the west penetrations were empty, the angle to a portion of the source is smaller, and the beam fault is created differently. The two downstream penetrations were blocked with 8 inches of light concrete in tunnel and 14 inches outside the berm. The upstream two penetrations are blocked on the inside with eight inches of light concrete and the outside is blocked by a ventilation duct, since they are used for ventilation. Based on the RHIC beam loss scenario with a maximum chronic local loss of 0.05% these penetrations would be estimated to less than 0.3 mrem/hr for the maximum chronic loss used for the W line in reference 2 without the added concrete.

The west penetrations are down stream of UGE2 and the chipmunk in the labyrinth is not expected to be sensitive to fault at WD5-6. A program to reduce losses or their duration would add additional protection for these penetrations.

There are several penetrations on the berm which are not discussed since the berm can only be accessed with special precautions. The chipmunks were not installed to provide protection for access to the berm with beam on, although in a localized region they can serve this function.

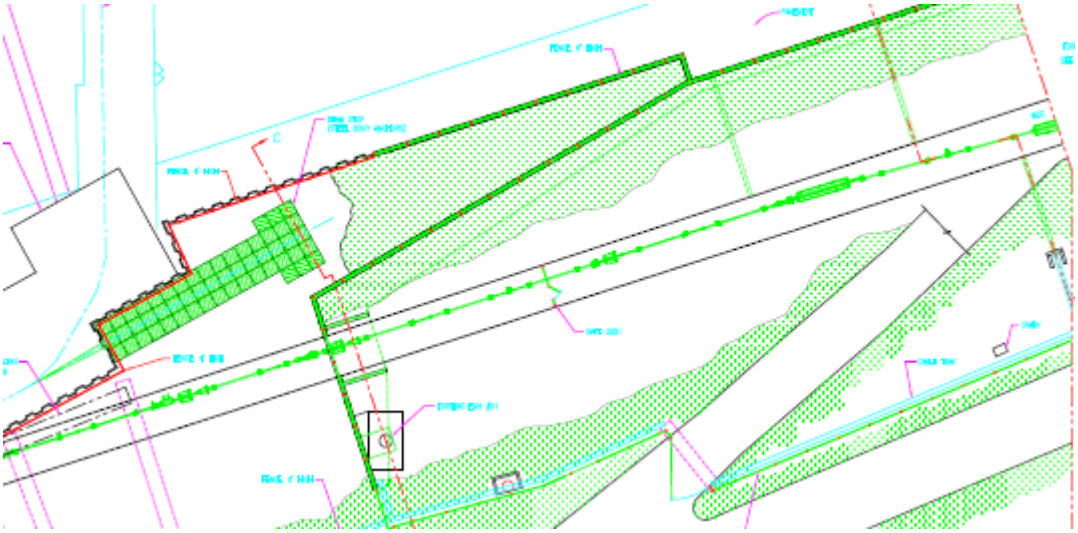

Fig. 1 Section of the U line berm in plan.

The thin section of the berm starts from just upstream of the four foot fence shown of the left of the drawing. Magnets WD1 and part of WD2 are visible in the drawing. Some penetrations are evident.

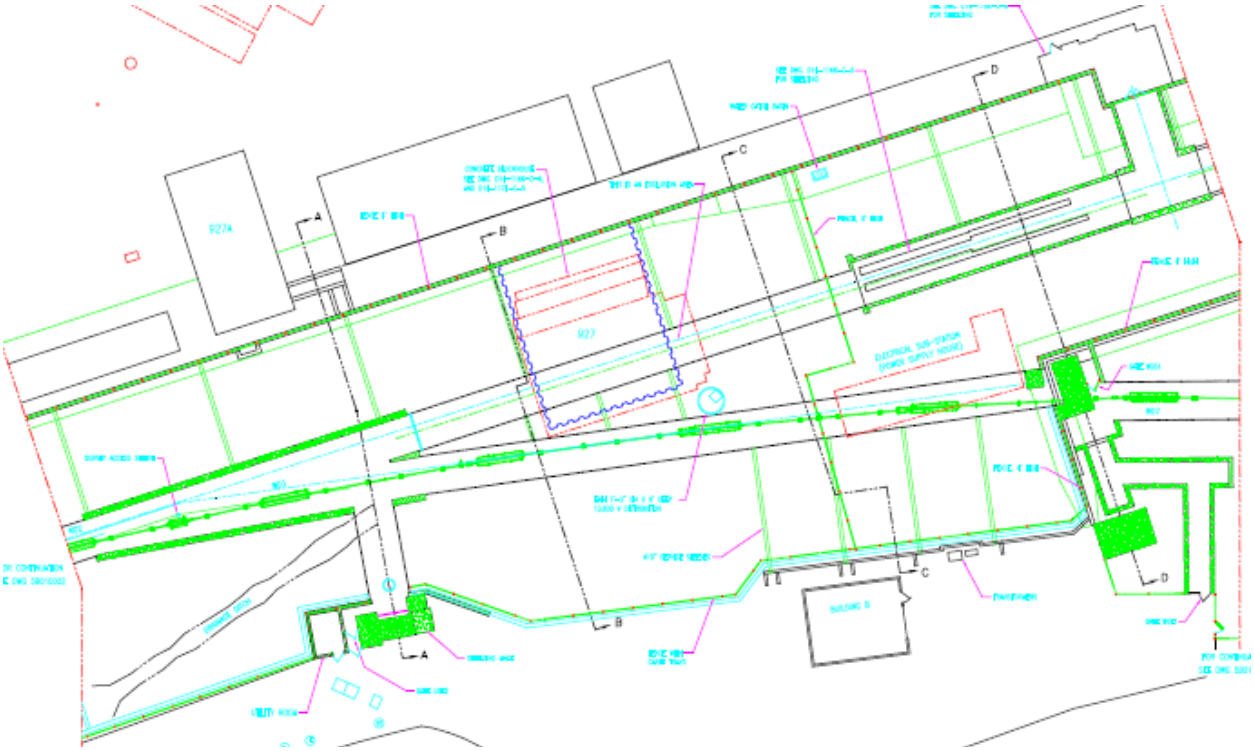

Fig. 2 Plan view of the U/W line from WD2 to WD7

The labyrinths on the west side, UGE2 and WGE1, are visible. The block house and UGE3 labyrinth area are shown on the west side. Penetrations are displayed on both sides. This drawing does not reflect the current configuration but is sufficient to illustrate locations.

The beam loss scenario[4] for routine operations for the W line had $8.28*10^8$ Au ions lost in a hour with half being a localized arbitrary point loss. For protons the loss assumption was $9.39*10^{10}$ protons lost per hour with half at an arbitrary localized location. These assumptions did not include losses on stripping foils in the upstream U line where the berm is thick. The beam loss scenario can be used for Au to project the dose rate at the berm fence for the thin potion of the U line, where it is proposed that the chipmunks be removed. Using the results[10] of MCNPX, scaling by $1/r^2$, and using an attenuation length of 114 gm/cm^2 for the soil, the dose rate is 0.017 mrem/hr. A person standing at the fence for 2000 hours of operations would receive a total estimated dose of 34 mrem. A conservative occupancy time would be 1/16 of 2000 hours which would reduce this to 2.1 mrem.

The results of the fault studies can be used to achieve a more realistic although less conservative estimate of the chronic dose to the adjacent uncontrolled areas outside the berm fence. The dose rate measured by NMON83 during AtR/RHIC fault study no. 29 would correspond to a dose rate at the fence of 0.0097 mrem/hr for the loss used in the operations scenario. For a person present for 2000 hours of operations this would correspond to 19 mrem. For a 1/16 occupancy factor for 2000 hours of operations the dose would be 1.2 mrem.

The losses for routine operations are not expected to create an issue for the dose to personnel in the areas adjacent to the U line berm fence.

The dose that can be received in a fault will depend on the duration of the fault and the beam intensity. Reference 4 used a fault duration for the W line of 2 AGS cycles. This is not a realistic time for an operator to respond to an alarm and determine the cause and appropriate course of action. A fault duration of 2 minutes (about 30 AGS cycles) will be used. The two examples above at 100% of the Au beam faulting for two minutes would give a dose of 1.1 mrem for the estimated thick target dose and 0.65 mrem for the dose scaled from the fault study. A portion of the thin section of the U line is monitored by chipmunk NMON81 at UGE2. U line areas that may not be effectively monitored by NMON81 should be supplemented with an active monitor system that will allow operators to terminate large beam faults with a few minutes.

Protons extracted at the AGS transformer limit of $2.5*10^{12}$ per cycle (assume 4 seconds) would generate a dose rate at the fence of 273 mrem per hour or a dose of 9 mrem in two minutes with a full beam fault (based on the fault study).

One full intensity pulse of $30*10^{12}$ protons would produce 3.6 mrem at the fence. This should be prevented by the dual current transformers.

Options for additional fault studies, chipmunks paced in more sensitive areas, changing the adjacent area posting along the fence, and more details Monte Carlo evaluations could be requested but are not recommended here.

References

1. RSC Minutes of Nov. 2, 1998," U-Line Operation: Runs for E938 and E939".
2. RSC Minutes of July 28, 1998, "U Line Operations-E938 Revisit".
3. E-mail from A. Carroll to D. Beavis, A. Stevens, and J.W. Glenn, "Calculation Regarding Need for West Berm U-Line Chipmunks during HI Running", August 16, 2000.
4. A. J. Stevens, "Analysis of Radiation Levels Associated with Operation of the RHIC Transfer Line", AD/RHIC/RD-83, Dec. 1994.
5. It should be noted that the analysis of reference 4 did not include any sections of the W line before the isolating shield wall between WD6 and WD7.
6. AtR fault study no. 25 and 29. See pages 46 to 62 of RHIC/AtR Fault Studies Logbook Vol. 2 for fault study 25 and pages 132 to 139 for fault study 29.
7. At the fault study intensity the dose rate was below the detectable level.
8. See RHIC/AtR Fault Study No. 29 which was used to verify the U beam dump after steel was removed.
9. A.H. Sullivan, A Guide to Radiation Protection and radioactivity Levels Near High Energy Accelerators, Nuclear technology Publishing, 1992.
10. A. Stevens to D. Beavis (see RSC file)

CC: RSC U Line File
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