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Memo

date: *December 11, 2008*

to: *RSC*

from: *D. Beavis*

subject: *Proposed Changes to the AGS North Gate and WGE2*

Motivation

The circular labyrinth for WGE2 has had increased dose rates outside the doors associated with the increased beam into the W beam dump. It is desirable to reduce or eliminate the area outside the labyrinth doors that has been posted as a Radiation Area. The simplest means to shield the labyrinth would be to add shield blocks that are made to be moved by forklift. Shield blocks that can be moved by forklifts are usually in short supply.

When this issue was discussed with A. Pendzick, he suggested that it would be helpful if the shielding could be removed from inside the AGS North and South Plug door tunnels. The shielding used in the AGS plug door tunnels was constructed to be moved by forklifts. Removing the shielding from the labyrinths would reduce the time spent every year during shutdown. Any removed shielding could be used at WGE2 to reduce the glow out of the gate.

Fault studies, memorandum, and reports were reviewed to provide the basis of the material reported below.

Recommendations

It is proposed that the shielding walls in the AGS North Plug door labyrinth be removed. In addition some of the barriers and postings near the plug door can be removed or modified. The orange fencing posted as a high radiation area could be removed. The metal fence, which prevents access to the side of the plug, could have the Radiation Area posting removed and instead be posted as no entry without HP or the equivalent.

It is proposed that the removed shielding or a portion of it be placed at the beginning of WGE2 labyrinth. A minimum thickness of two feet should be used for the shield walls. Four feet would make the levels lower but may reduce the convenient access of the area with large objects.

It is proposed that an administrative limit be placed on the AGS beam. The limit proposed is $1.25*10^{17}$ nucleon-GeV per hour. This corresponds to about twice the B15 transformer limit for 22 GeV protons per cycle. The present AGS ASE is $1.1*10^{19}$ nucleons-GeV per hour.

It is proposed that studies can be approved with higher limits on a case-by-case basis.

It is recommended that the configuration at the AGS South Plug remain unchanged until additional consideration is given to other types of beam faults in this area.

History

P. Bergh had the RCTs conduct surveys last year for both the Au beam on the W dump[1] and the deuteron beam on the W dump[2] (also see figure 1 and 2). A substantial area outside the doors of WGE2 required posting. The amount of beam delivered to the W beam dump has been increasing over the years causing the levels at WGE2 to correspondingly increase. This increase has necessitated increasing the interlock level of the chipmunk at WGE2 and posting the area outside the WGE2 doors.

The shielding in the south plug door entrance way was placed in February 1995. The primary reasoning given[3] for adding shielding in the AGS South Plug Door tunnel was that chronic injection losses in the ring was causing elevated levels in the area outside the plug door. Increasing the proton intensity was problematic because of the associated increase in dose rates outside the South Plug Door.

The shielding inside of the AGS North Plug door was placed in February 1996. The only justification found in the records was a comment that since the North Gate tunnel is shorter than the South Plug door tunnel that the North gate should have shielding similar to the South Gate. This conclusion is not correct since it does not take into account the fact that the plug door is thicker at the north gate. It was previously calculated[4] that the dose rate out the north plug door should be more than a factor of seven below that of the south plug door for the equivalent beam fault.

Fault studies were conducted for several AGS areas from 1994 to 1996. The South plug door was examined with fault studies at injection energy (1.5 GeV protons) in AGS Fault Study (FS) 19 and 28. Shielding was added to the south tunnel during the maintenance day on Feb. 28, 1995. The modified area was examined with AGS FS no. 43, which was conducted with injection energy on Feb. 26, 2006. All three of these fault studies used the E13 vacuum valve as a target. No fault studies were conducted in this area at higher energy or on other targets.

The results of FS 19 and 43 are listed in the table below. Since these fault studies were conducted at injection energy they are scaled to a maximum which is the Booster ASE, 10^{14} 1.5 GeV protons per second.

Location	**AGS FS no. 19 (no shielding) mrem/hr for 10^{14} p/s**	**AGS FS no. 43 (shielding) mrem/hr for 10^{14} p/s**
Crack on left of plug	3800	45
Chipmunk	320	2
Center of plug	360	<8 (FS below .2 mrem/hr)
45 feet from plug door	44	No measurement

The results demonstrate that the shielding reduced the levels outside the plug door a factor of 45 or more depending on the location. The chipmunk has an interlock level at 2.5 mrem/hr and an alarm level at 1.0 mrem/hr. It is noted that the chipmunk does little to limit injection losses at injection energy with the shielding in place. This will be examined again when full energy beam faults are considered.

The North Plug Door was examined with AGS FS no. 45 with 24.5 GeV protons. A shield wall similar in design to the South Plug Door was in place but the shielding was constructed from two layers of two-feet thick instead of one layer of four-foot thick light concrete. This would imply a reduction in radiation as measured at the South Plug Door of 45 compared to no shielding in place at the North Plug Door. FS no. 45 used an orbit bump to drive the beam into apertures near H12, which is close to the north tunnel entrance. The results have been scaled to a maximum of 10^{14} protons per second at 24.5 GeV. This corresponds to $8.8*10^{18}$ nucleon-GeV per hour, which is almost at the AGS ASE of $1.1*10^{19}$ nucleon-GeV per hour. The FS results are given in the table below scaled to the 100 TP operating maximum at 24.5 GeV, scaled for no shielding in place, and scaled with no shielding and an operating limit of $1.25*10^{17}$ nucleon-GeV per hour.

North Plug Door and Associated Areas

Location	**mrem/hr 10^{14}p/s at 24.5 GeV Shielding in place**	**mrem/hr 10^{14}p/s at 24.5 GeV Shielding removed**	**mrem/hr $1.25*10^{17}$ nuc-GeV/hr Shielding removed**
Chipmunk (NMON22)	507	22800	320
At Gate	1304	58700	830
Plug Door	362	16300	230
Crack on right side	6665	300000	4200
Fence at opening	870	39200	560
H10 Left sleeve	4640	4640	70
Chipmunk (NMON76)	2430	2430	35
Chipmunk (MNON32)	116	116	2

The North gate chipmunk, NMON22, has an interlock level of 20 mrem/hr and an alarm level of 16 mrem/hr. MNON76 is the Northwest Corner chipmunk and has an interlock level of 2.5 mrem/hr and an alarm level of 1.6 mrem/hr. NMON32 is the Target Building N. Catwalk chipmunk and has an interlock level 20 mrem/hr and an alarm level of 16 mrem/hr.

Justification

RHIC is the only external physics program for the AGS. This is expected to remain the case for several years except some potential small beam requests for the U line. When the AGS to RHIC (AtR) is used with protons the B15 dual transformers are used to limit the beam to $2.5*10^{12}$ protons per cycle. A typical cycle time is 3.6 seconds and the typical beam energy is 22 GeV.

The B15 transformer limit corresponds to $5.5*10^{16}$ nucleon-GeV per hour, about one half of the proposed administrative limit of $1.25*10^{17}$ nucleon-GeV per hour. The maximum intensity for Au ions is $8*10^{9}$ ions per 3.6 second cycle corresponding to $1.7*10^{16}$ nucleon-GeV per hour. This is nearly a factor of ten below the proposed administrative limit for the AGS.

It is not credible that the AGS will need to operate with intensities above the proposed administrative limit for the immediate future, except for possible short machine tests. Short tests could be handled on a case-by-case basis. It is not recommended that the B15 current transformer interlocks be used to limit the AGS beam internal to the AGS. The transformers could be used in an alarm mode if desired, however this is not recommended here since the potential higher intensity running will be small or nil.

The dose rates near the North Gate and associated areas with 24.5 GeV beam faulting at the chipmunk interlock level is given in the table below. The entire area outside the North gate is posted as a Radiation Area. The dose rate for the crack does not represent a whole body exposure and has a metal fence that prevents access. The metal fence posting is presently Radiation Area. Since this is already inside a Radiation Area the posting should be changed to no entry without HP or the equivalent. The orange fence at the front of the plug door is posted as a High Radiation Area. The orange fencing should be removed along with the High Radiation Area posting. The wheel at the bottom of the plug door may have an elevated level relative to the plug door. For the south Plug door the wheel was a factor of five higher than the door. The ratio could be larger for the North Plug door but it is not considered an issue.

For beam faults causing dose rates just above the chipmunk interlock level, the chipmunk would terminate the beam in 9 seconds. The dose at the gate for the nine seconds would be 0.05 mrem. For beam faulting at the administrative limit the dose in 9 seconds at the gate would be 0.6 mrem. The actual interlock time is expected to be shorter for larger dose rates.

North Plug Door and Associated Areas
At NMON22 interlock level

Location	**mrem/hr** **$1.25*10^{17}$ nuc-GeV/hr** **Shielding removed**
Chipmunk (NMON22)	20
At Gate	51
Plug Door	14
Crack on right side	260
Fence at opening	34
H10 Left sleeve	4
Chipmunk (NMON76)	2
Chipmunk (MNON32)	1

The fault studies (at 1.5 GeV) at the South Plug door can be scaled to the proposed administrative limit of $1.25*10^{17}$ nucleons-GeV per hour. The results are given in the table below:

South Plug Door

Location	AGS FS no. 19 (no shielding) mrem/hr for $1.25*10^{17}$ nuc-GeV/hr	AGS FS no. 43 (shielding) mrem/hr for $1.25*10^{17}$ nuc-GeV/hr
Crack on left of plug	880	10
Chipmunk (NMON48)	75	0.5
Center of plug	84	<2 (FS below 0.2 mrem/hr)
45 feet from plug door	10	No measurement
Chipmunk (NMON47)	No Measurement (80)	80

The interlock level on the chipmunk (NMON48) is 2.5 mrem/hr and the alarm level is 1.0 mrem/hr. The E Fan House chipmunk, NMON47, and the E Fan House were measured in FS 40. NMON47 reads between a factor of 4 to 12 higher than NMON48 during FS40, so a factor of 8 is used. The E Fan House chipmunk does not interlock but has an alarm at 40 mrem/hr. The associated dose rates with the South Plug Door chipmunk, NMON48, operating at the interlock and alarm levels can be scaled from the table above and are:

South Plug Door—NMON48 at interlock level of 2.5 mrem/hr

Location	AGS FS no. 19 (no shielding) mrem/hr for $1.25*10^{17}$ nuc-GeV/hr	AGS FS no. 43 (shielding) mrem/hr for $1.25*10^{17}$ nuc-GeV/hr
Crack on left of plug	30	10
Chipmunk (NMON48)	2.5	0.5
Center of plug	3	<0.2 (FS below .2 mrem/hr)
45 feet from plug door	0.333	No measurement
Chipmunk (NMON47)	No measurement (0.3)	80

South Plug Door—NMON48 at Alarm level of 1.0 mrem/hr

Location	AGS FS no. 19 (no shielding) mrem/hr for $1.25*10^{17}$ nuc-GeV/hr	AGS FS no. 43 (shielding) mrem/hr for $1.25*10^{17}$ nuc-GeV/hr
Crack on left of plug	12	10
Chipmunk (NMON48)	1.0	0.5
Center of plug	1	<0.2(FS below .2 mrem/hr)
45 feet from plug door	0.13	No measurement
Chipmunk (NMON47)	No measurement (1)	80

It can be seen that based on these scaling that NMON48 serves little function with the shielding in place with the proposed administrative intensity limit. The present fence is about 30 feet from the plug door so that the location 45 feet away is an uncontrolled area, a road and parking area. For a 9 second duration fault (terminated by the chipmunk) at the proposed administrative limit the dose at 45 feet would be 0.025 mrem. This does not seem to be an issue.

There are two concerns that should be considered before this area is potentially changed. The administrative limit is in nucleon-GeV per hour and to first order this takes care of 1.5 GeV verses 24.5 GeV beam faults. However, it is probably worthwhile to consider this scaling more carefully. The H10 region is designed for having bumps to allow for extraction in the U line. It is not clear if the area near the south plug door can have such an orbit excursion at high energy. If orbit excursions at high energy are not possible then the numbers above are conservative for high energy beams.

The second and potentially more serious consideration is that a vacuum valve (E13) was used for the FS at the South Gate and valves represent rather thin targets. Vacuum valves are typically 0.5 to 1 cm thick and the interaction length of iron is 17 cm. It may be possible that an orbit bump at some energy can cause a substantially larger dose rate in the tunnel than striking a valve, even at injection energy. The FS results for the North Plug Door can be scaled to the South Plug Door using the calculations of Reference 4. The predicted values of the North gate and Plug Door will also be compared to the calculation in the table below:

Dose Rates for high Energy Beam faults of $1.25*10^{17}$ nuc-GeV/hr

location	Predicted (mrem/hr)	Measured (mrem/hr)
North Plug Door	400	320
North Gate	400	830
South Plug Door	2700	Not measured

The agreement at the AGS North Plug Door and gate are probably better than should have been expected. The scaled calculation for the South Plug Door is about thirty times higher than the fault study results using the vacuum valve. More than likely the combination of the chipmunks would be sufficient to protect the uncontrolled area. However, if there are chronic losses in the area it may be difficult to limit the yearly integrated dose in the Uncontrolled Area to appropriate levels. This should be examined further before the shielding is modified.

Figures 1 and 2 show the dose rates in the area of WGE2 for Au and deuterons on the W beam dump. Dose rates outside the doors are as high as 30 mrem/hr. For the deuterium beam the dose rate 10 feet from the outside doors is 4.5 mrem/hr. Based on fault studies 19 and 43 at the South Plug Door a reduction factor of 6.5 can be achieved with two feet of light concrete and a factor of 45 with four feet. It is recommended that a minimum of two feet of light concrete be added and preferably four feet. The arrangement of the shielding has several potential options which shadow the labyrinth and at the same time allow reasonable access with equipment.

A 100TP proton pulse at 24.5 GeV faulting at H12 could produce a dose of 60 mrem at the North Gate. This type of fault is not considered credible without a high intensity program running in either the booster or AGS. This high an intensity has never been achieved in the AGS and it is

not expected that either the Booster or AGS could accelerate an entire errant bunch intended for BLIP.

There are uncertainties in the scaling and some of the interpretations of the numbers from the logbooks. However, for the North Plug door an uncertainty of a factor of four does not change the conclusion.

References

1. P Bergh, Survey around WGE2 area with Au beam on the W beam dump, Dec. 20, 2007.
2. P Bergh, Survey around WGE2 area with D beam on the W beam dump, Dec. 20, 2007.
3. RSC Minutes of Subcommittee and Memorandum, February 23, 1995.
4. D. Beavis, "Ring Me: Potential Radiation Levels from Beam Faults in the AGS Ring", AGS/EP&S/Tech Note 138, Sept. 30, 1991.

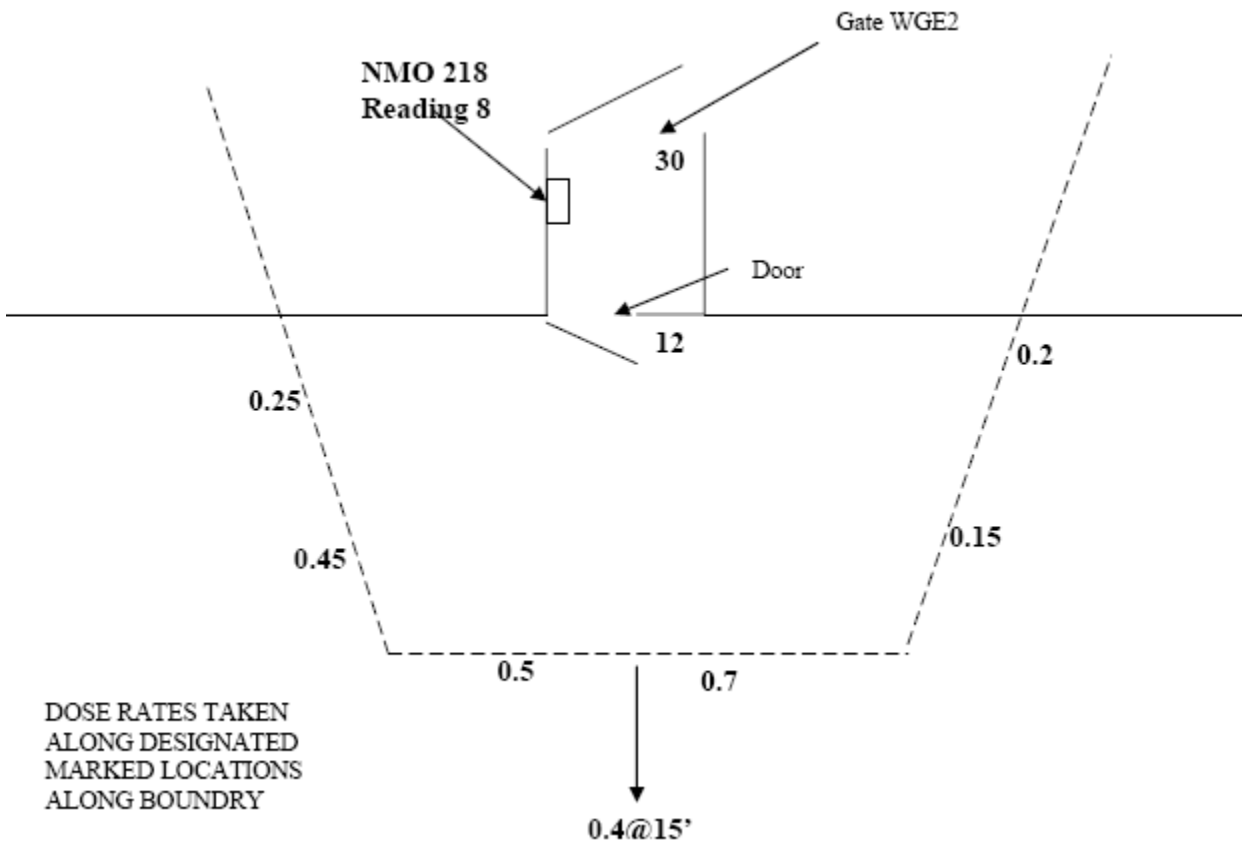

Figure 1: Dose rates in mrem/hr for $5*10^9$ Au ions per cycle on the W beam dump.

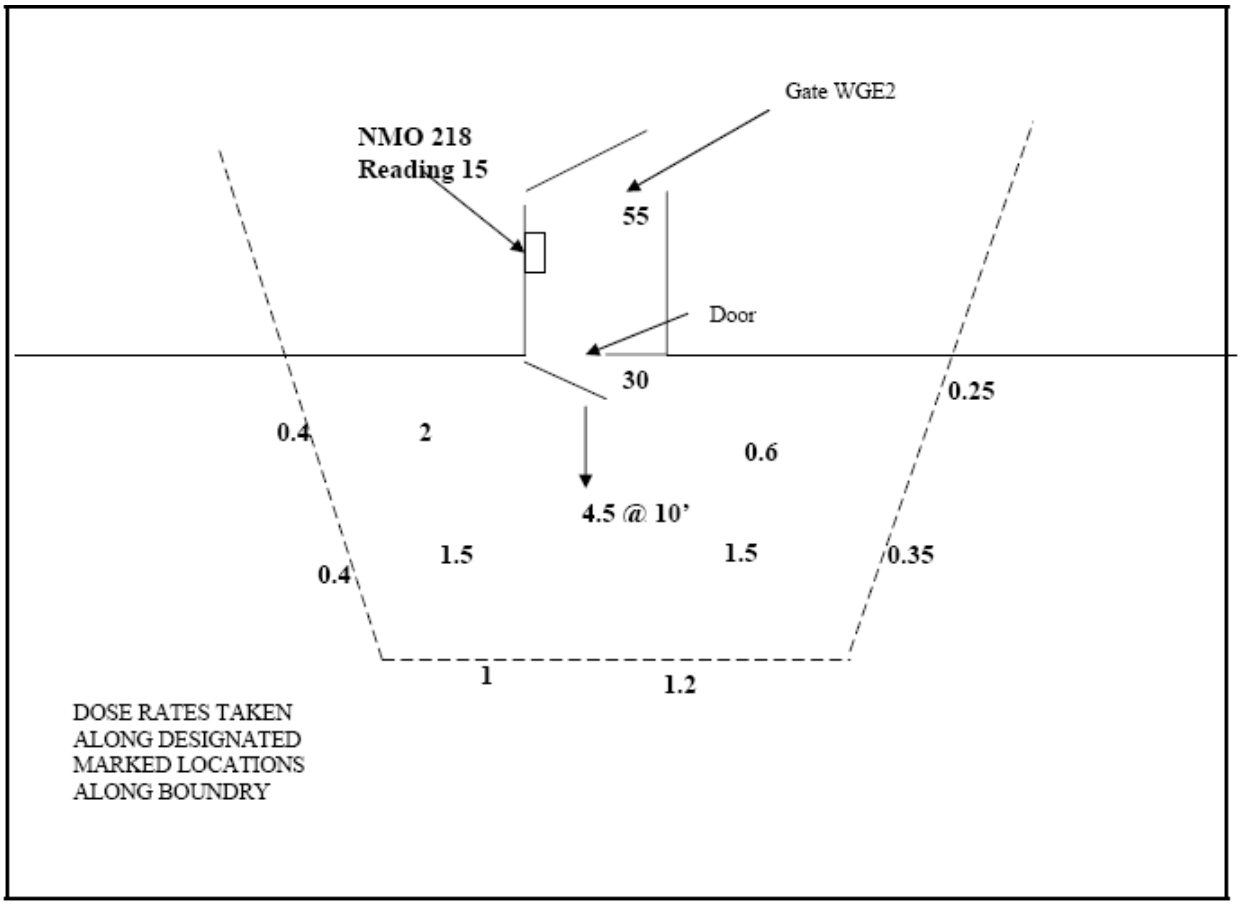

Figure 2: Dose rate in mrem/hr for 7*10^{11} deuterons per cycle on the W beam Dump.

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