Booster Fault Study for the BAF Penetration Site

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Study Period: December 9, 1999

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Reported by: C. J. Gardner

Machine: Booster

Beam: Protons

Tools: RLM System, Current Transformer, Orbit Bumps, etc.

Aim: BAF Penetration Fault Study

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Following is a report on the Booster Fault Study carried out December 9, 1999. The original Fault Study Plan is reproduced here followed by results, conclusions, actions taken, and recommendations.

1 Fault Study Plan

1.1 Goal

The berm in the D6 through E2 region of the Booster ring was penetrated and reconstructed this Fall to provide a tunnel for the BAF transport line. This modification requires measurements of the radiation levels in the penetration region to ensure that the new configuration of shielding is adequate under normal running and fault conditions. The goal of this study, then, is to produce a primary beam loss fault in the BAF Penetration region of the Booster ring, and to measure the resulting prompt radiation in this region on the top and sides of the Booster berm and along the Booster perimeter fence. The study is to be conducted in accordance with AGS OPM 9.1.9.

1.2 Original (non-fault) Beam Conditions

1. Establish clean injection and acceleration to full energy (1.74 GeV) in Booster. Intensity at full energy should be 1–5 TP per Booster cycle.
2. Record output (both tabular and graphical) from Ring Loss Monitor program at desired "fault time".
3. Record beam current transformer trace for complete magnetic cycle.

1.3 Method

1. Reduce intensity to 1 TP at full energy. (Intensity may have to be increased to achieve observable fault levels.)
2. Pick a "fault time" in the magnetic cycle close to (and before) extraction. Put in a radial shift toward the inside or outside of the vacuum chamber at this time. Adjust the magnitude of the shift until beam loss is seen on the ring loss monitors and/or the beam current transformer. Reduce the magnitude of the shift just to the point where the beam loss disappears.
3. Put in a local distortion of the equilibrium orbit centered on desired fault time and position. This can be done with a correction-dipole three-bump or with a bump produced by pole-tip windings on the main dipoles. The desired fault locations in the ring are the beam dump at D6 and any ring elements in the region from D5 through E2.
4. Observe loss on beam current transformer and ring loss monitors. Adjust the bump to localize the loss at the desired fault time and position.
5. Record loss on beam current transformer and ring loss monitors. Record Radius and Bump parameters.
6. Measure levels on and around berm (see Survey Location below). Record BAF Penetration Chipmunk (NM066 and NM067) levels.

1.4 Survey and Chipmunk Locations

1. All surveys are done using the HP1010 meter unless otherwise noted.
2. Chipmunk NM066 is located at the Penetration headwall approximately 1 Foot off the floor and approximately 2 Feet to the right of the beamline (looking upstream). Chipmunk NM067 is currently centered on the beamline at the downstream face of the concrete beamplug. For the fault study, we will move NM067 approximately two feet downstream of this location.
3. Survey top and sides of the Booster Berm over region from D5 through E2.
4. Survey top and sides of BAF Tunnel Berm.

5. Survey region at end of BAF Tunnel.
6. Survey along Booster Perimeter Fence in BAF Penetration Region.

1.5 Radiation Estimates

The following formula for the Radiation Dose at the downstream end (Chipmunk NM067) of the concrete beamplug due to a loss in the D6 straight section of the Booster was provided by Alan Stevens:

$$D = Ke^{-S/43.3} \tag{1}$$

where $K = 8.4 \times 10^{-13}$ Rem per proton, and S is the length of the concrete beamplug in cm. The proton kinetic energy assumed here is 2.0 GeV. Applying the formula with $S = 365$ cm, one finds that the dose at the downstream end of the beamplug is 0.2 mrem per 10^{12} protons lost at D6. Assuming a repetition period of 3 seconds with 10^{12} protons lost at D6 per cycle, the dose rate would be 220 mrem/hour. This is, in fact, an overestimate of the actual dose because the formula does not take into account the shielding in place at the D6 dump—an empty straight-section is assumed.

To obtain a better estimate of the dose, Chipmunk NM066 (at the penetration headwall) was set to inhibit the beam when the dose rate exceeds 2.5 mrem/hour. With this beam-inhibit mechanism in place, we produced a pre-study loss of 10^{12} protons at the D6 dump and saw a dose rate of approximately 2.5 mrem/hour at Chipmunk NM066. The dose rate on the berm over this point is estimated to be down by a factor of eight.

For the fault study, we will raise the level at which NM066 inhibits the beam to 50 mrem/hour.

2 Results

2.1 Loss Setup

1. A Radial Shift and the Dump Bump were used to create a localized loss at the D6 beam dump 75 ms from BT0 in the Booster magnetic cycle. The proton kinetic energy is approximately 1.74 GeV at this time. The Radius and Dump Bump functions were programmed as follows:

   (a) Radial Shift of -0.07 cm at 65 ms from BT0, ramped down to -0.8 cm at 75 ms from BT0, and then back up to -0.07 at 85 ms from BT0.
   (b) Dump Bump current ramped from 0 A at 65 ms from BT0 down to -40 A at 75 ms from BT0, and then back up to 0 A at 85 ms from BT0.

2. This setup moved the equilibrium orbit to the **inside** at the dump and produced a 100% loss there at the desired time in the Booster magnetic cycle. (We were unable to produce any loss at the dump by moving the equilibrium orbit to the **outside**.)

3. Using horizontal and vertical three-bumps, we attempted—but were unable—to produce localized losses at D5, D7, D8, E1, and E2.

2.2 Measurements

1. The Repetition Period was 4.2 seconds.

2. 4.5×10^{12} protons at 1.74 GeV were lost on D6 Dump per Booster Cycle. This is 1.07×10^{12} protons lost per second at 1.74 GeV.

3. Ring Loss Monitors D5 through E7 registered the following counts in the window from 65 to 85 ms from BT0 under the fault condition. (All other monitors registered essentially zero counts in this window.)
   (a) D5(2200); D6(11000); D7(5500); D8(22000)
   (b) E1 through E7 (2200)

4. 7.5 mrem/hour was seen on chipmunk NM066; 0.6 mrem/hour was seen on NM067.

5. Figure 1 is a map of the survey region which shows the measurements obtained by Health Physics. Figure 2 is a map showing the depth of the soil cover in the BAF Penetration region.

6. 10 mrem/hour was seen on the berm over the point where the BAF beamline pierces the Booster Tunnel. This was the maximum dose rate observed in the survey region.

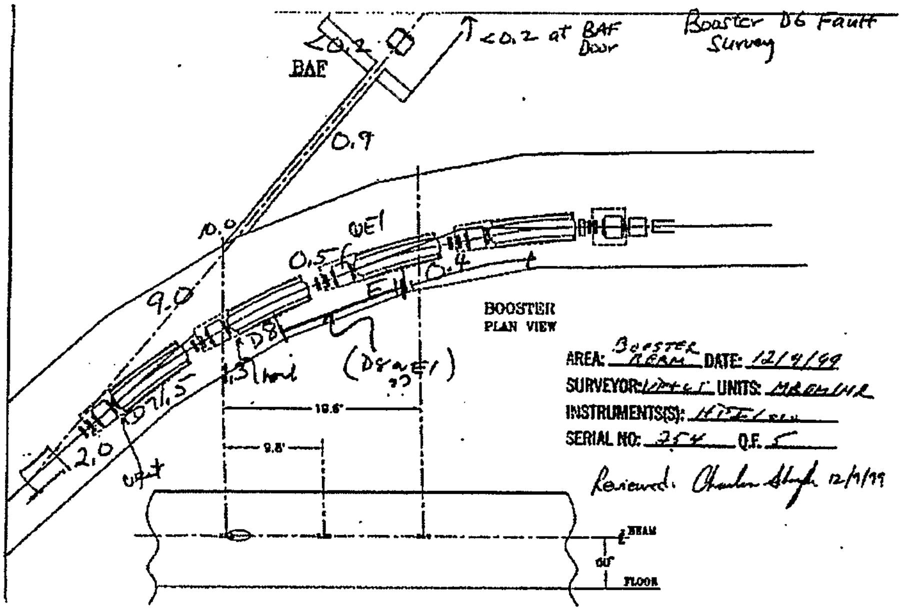

Figure 1: Map of survey region showing radiation measurements.

7. 2 mrem/hour was seen on the berm over the dump; 1.5 mrem/hour was seen over D7; 1.3 mrem/hour was seen over D8; 0.5 mrem/hour was seen over E1.

8. 0.9 mrem/hour was seen in the region over Chipmunk NM066.

9. All other survey locations, including the door at the downstream end of the BAF Tunnel, showed less than 0.2 mrem/hour under fault conditions.

3 Conclusions

1. Assume the following maximum intensity situation: 6 Booster cycles per 2 second AGS period with 24×10^{12} protons at 1.74 GeV per Booster cycle.

2. This gives a maximum possible loss on the D6 Dump of 72×10^{12} protons per second at 1.74 GeV.

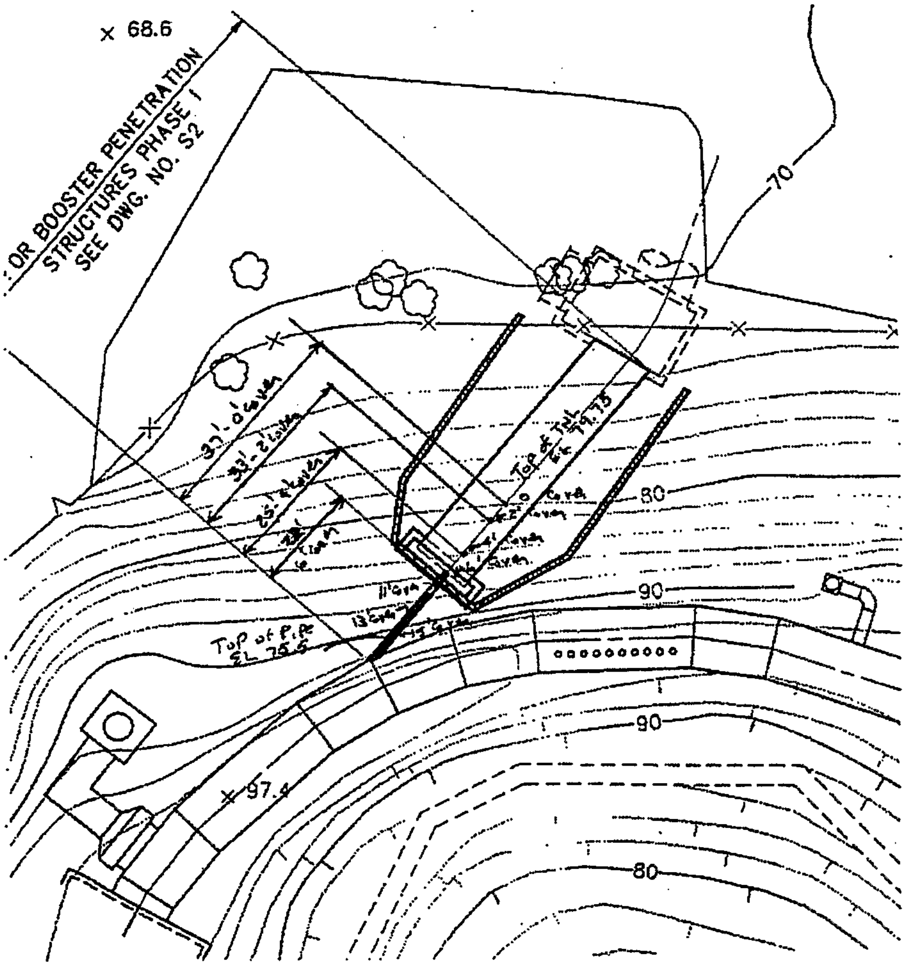

Figure 2: Map of BAF Penetration region showing depth of soil cover.

3. The dose rate, which was 7.5 mrem/hour at Chipmunk NM066 during the study, would then be (72/1.07) × 7.5 = 505 mrem/hour. The dose rate at NM067 would be (72/1.07) × 0.6 = 40 mrem/hour.
4. The dose rate at the point where 10 mrem/hour was measured during the study, would be (72/1.07) × 10 = 673 mrem/hour.
5. The dose rate at the point on top of the berm where 2 mrem/hour was measured, would be (72/1.07) × 2 = 135 mrem/hour.
6. The dose rate at points where less than 0.2 mrem/hour was measured during the study would be less than 14 mrem/hour.

4 Actions Taken and Recommendations

1. Chipmunk NM066 was left in its nominal position and set to inhibit beam at a dose rate of 20 mrem/hour. This means that the dose rate (under the fault conditions) will not exceed (20/7.5) × 10 = 27 mrem/hour at the point where 10 mrem/hour was measured during the study.
2. Chipmunk NM067 was left at the fault-study position approximately two feet downstream of the downstream face of the beam plug. It is set to inhibit beam at a dose rate of 2.5 mrem/hour.
3. The Booster berm is currently classified and posted as a Radiation Area during proton running; the maximum dose rate for this classification is 100 mrem/hour. The results of this study indicate that we should re-assess the current classification. Previous Booster fault studies will be reviewed and additional studies will be done if necessary in order to establish the best classification for this area.