1985 Particle Accelerator Conf., Vancouver, Canada, 5/13-16/85.

RECEIVED BY OSTI JUN 06 1985

BNL 36485

CONF-850504--139

BNL--36485

DE85 012522

BEAM CATCHER/DUMP*

Y. Makdisi, E. Rodger, J.W. Glenn, K. Brown
AGS Department, Brookhaven National Laboratory
Upton, New York 11973

Introduction and Synopsis

A simple, low cost aperture limiting device with an absorber block has been developed and installed in the AGS ring at Brookhven National Laboratory. The device intercepts injection tails, transition losses, and the inward spiraling beam of an aborted acceleration or extraction cycle. The resultant consolidation of losses at one point reduces activation of components around the ring and radiation exposure to personnel.

Design Parameters

Aperture

The β function in the AGS changes rapidly through the 10-ft. straight section in which the scrapper is installed. The apertures of the device were calculated using the following formula:

$$A = A_{max} \left(\frac{\beta}{\beta_{max}}\right)^{1/2} + \frac{\Delta p}{p}\,\alpha_p$$

where α and β are the beam phase ellipse parameters[1] for the AGS and $\frac{\Delta p}{p}$ is the momentum spread. For the vertical aperture there is no momentum spread to consider. In addition, for ease of construction, the aperture circumferences at the upstream and downstream ends were required to be the same. This allowed the use of a single properly deformed tube.

The resulting apertures are ellipses with a horizontal axis of 11.9 cm and a vertical axis of 7.0 cm at the upstream end, and 12.9 cm and 5.4 cm respecitvely at the downstream end. The downstream aperture is actually slightly restrtictive to increase the capture efficiency of scattered particles. These aperture calculations were checked by measuring the beam size at the E-10 location using the ionization profile monitor. Profiles were taken at 500 μsec and 60 msec into the cycle. The x and y beam profiles were then scaled using the relative β functions to the E-20 position. The resulting spreads were well within the calculated design apertures.

Choice of Material

For efficient scattering of protons and containment, the absorber block material should be chosen with a short absorption length, low mean free path and high mean scattering angle of the incident protons. Since the amount of deposited energy could be considerable (20 kW), the material should have good heat capacity and conductivity. Copper was the first choice due to ease of machining and satisfaction of the above requirements; however, attempts to have it casted to a specific form failed and thus it was rejected. Lead or a lead alloy was the second choice. Solder (40% lead, 60% tin) was eventually used.

*Work done under the auspices of the U.S. Department of Energy.

Length and Width

Hadronic cascades resulting from a 28 GeV beam impinging on a solid absorber block were simulated using a Monte Carlo program.[2] The integrated energy distributions for a geometry of 25 x 25 x 200 cm[3] copper block are shown in Figure 1(a,b). This represents an upper limit since full beam dumping is not envisaged.

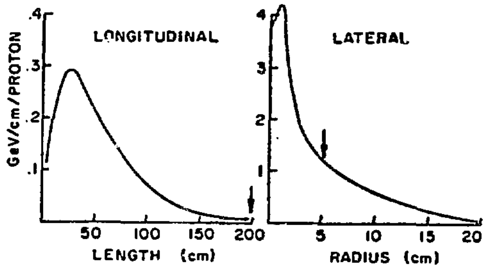

Fig. 1 - Integrated energy deposition of a 28 GeV beam.

The chosen dimensions of 200 cm long and 5 cm wide seem to provide adequate containment with some side leakage. The latter is expected to increase with the substitution of 60-40 solder for copper with an effective increase of 25% in abosrption length. A future unit will have its lateral dimension increased by a factor of two.

Thermal Loads

The kinetic energy in a beam of 10^{13} protons at 28 GeV is approximately 40 kJ. This energy dumped suddenly into the absorber every second yields approximately 40 kilowatts. If the energy is abosrbed as a result of an inward spiraling beam due to premature rf turn off, about 20 kW could be deposited on average. The cooling water flow of 3 gal/min results in a water temperature rise of 28°C.

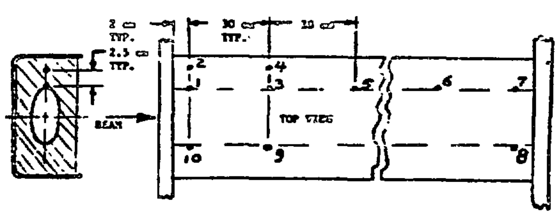

Fig. 2 - Thermocouple locations in the absorber block.

Thermocouples were buried in the body of the abosrber at various locations (Figure 2). A test was run by turning off the rf, allowing the beam to spiral into the abosrber, and measuring the temperature rise at various locations. By spiraling a 25 GeV/c beam repeatedly into the device every 3 seconds, a maximum temperature rise of 13°C was observed at the Ø1 location. The temperature rise stabilized after 13 pulses indicating good thermal conductivity within the absorber. Earlier tests with a 1 KW torch directed at the inside of the beam tube wall directly opposite a thermocouple showed a maximum ΔT of 38°C which stabilized within 1-1/2 minutes.

In conclusion, there is no problem to date with hot spots or cooling capacity.

Escaping Particles

Since the abosrber block surrounds the beam pipe, this inside aperture allows for the escape of particles scattered through small angles. The lower the dump momentum, the larger the scattering angle and the better the containment. Also, as might be expected, the containment goes up with the distance away from the inside aperture edge. The confinement efficiency with grazing angle is not as straightforward; however, a CERN study modeling a combination of elastic, inelastic and cascade effects shows that proper alignment is important. Skew angle studies are now under way to minimize the radiation to the "F" region just downstream of the dump.

Due to betatron oscillations, particles, scattering in the E-20 region should show peak deflection at 1/4 λ and 3/4 λ wave lengths downstream. A future improvement might be the addition of scrapers inside the vacuum chamber near these downstream locations to further absorb the escaping particles, without restricting the aperture.

Mechanical Construction

Proper selection of materials for this device is important for several reasons. First, the thermal coefficients of expansion of the absorber and beam tube must be closely matched to prevent high stress during cool down after casting. Second, the beam tube and absorber should have high thermal conductivity to reduce local beam heating of the tube wall. For the same reason, a relatively low "z" material is preferable for the beam tube to reduce localized beam energy deposition. Third, the absorber material should have a significantly lower melting temperature than the beam tube and container walls. Copper was initially chosen as the absorber material with a stainless steel beam pipe. Casting difficulties finally lead to the selection of common 60-40 solder for the absorber and aluminum (6061-T6) for the beam tube. The 10 cm o.d. x 0.16 cm wall beam

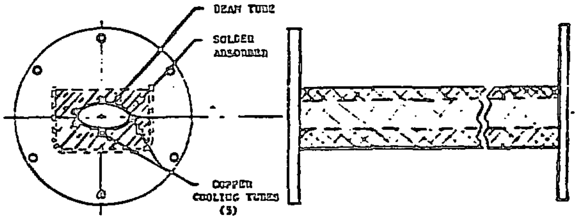

Fig. 3 - A cross section of the scraper/dump.

tube is first welded to aluminum end flanges which are then welded to an open alumiunum trough, Figure 3. This forms a container for the molten solder.

The 200°C melting temperature of the solder is well below the annealing temperature of the aluminum. It was necessary to machine circumferential convolutions around the beam tube weld (Figure 4) in one of the end flanges to allow for differential expansion. The trough which is 0.63 cm thick is welded to the same flanges as the 0.16 cm thick beam tube. As molten solder is poured into the trough and around the beam tube, differential expansion takes place between the two because of the different thermal time constants. This expansion can be large enough to crack the welds. The convolutions permit sufficient motion to prevent this.

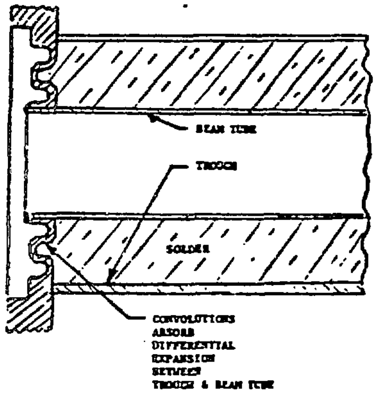

Fig. 4 - Detail of the end flange construction.

The copper cooling tube is pre-tinned so that solder to copper "wetting" takes place during the casting operation and a good thermal contact is made. In addition, close thermal contact is developed between the beam tube and absorber because the solder has a slightly higher thermal coefficient of expansion (contraction in this case) and thus grips the beam pipe as it cools.

The entire device can be translated by ± 3.8 cm and skewed ± 1.4°. This is controlled remotely.

Activation and Personnel Protection

As expected, the absorber block activation reached levels of 2.5-4 R measured at a 30 cm distance from the block. This constitutes a hazard to personnel passing by or working in the vicinity. A 1" thick lead shroud was fabricated to cover the scraper/dump on maintenance days. The decrease in measured activation by an order of magnitude made it comparable with other components in the machine.

Operating Experience and Performance

The beam scraper/dump was installed in the AGS at the E-20 location in October, 1984. It was first determined that the scraper aperture as designed was not limiting the beam intensity of the machine. The AGS has since reached a new record intensity of 1.64 x 10^{13} protons per spill with the scraper in place.

Early beam orbit measurements showed the beam at E-20 to be shifted outward instead of the reverse. In addition, a strong ninth harmonic caused large and unacceptable orbit shifts. This was corrected by moving the appropriate magnets. The catcher was moved radially outward to shadow the other apertures in the machine and dump studies were carried out to assess its effectiveness. The beam was aborted at 7 GeV/c and radiation loads around the ring were measured versus scraper position. Figure 5 shows the total integrated radiation around the machine with the exclusion of the E-20 and F-2 monitors immediately surrounding the dump. The graph shows a drop in the distributed radiation around the ring by a factor of 3. In addition, periodic surveys around the ring show a drop in activation of components since the installation of the device at E-20.

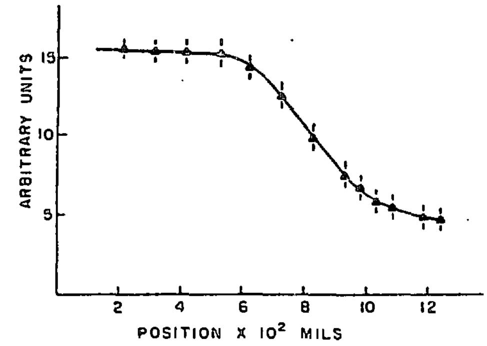

Fig. 5 - Total ring radiation Vs the scraper radial position.

The F region receives most of the forward leakage. Figure 6 shows the radiation monitor levels in F4 versus the scraper position as it is moved to intercept the beam. The maximum levels are reached when the scraper/dump shadows all other apertures in the machine. The plateau is due to the 7 GeV beam energy which is low enough for the absorber to contain most of the energy.

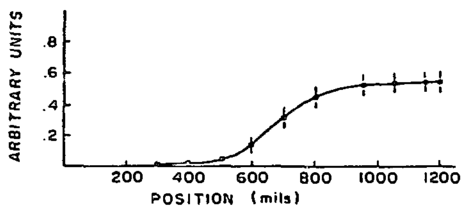

Fig. 6 - Radiation levels Vs scraper position in the F4 region.

References

1. E.D. Courant, Precision Computation of AGS Orbit Parameters, Accelerator Department Internal Report, EDC-28, December, 1958.
2. A. van Ginekea, CASIM, Program to Simulate Transport of Hadronic Cascades in Bulk Matter, FNAL FN-272, 1975.
3. W.C. Middlekoop, B. deRaad, G. Schroder, P. Sievers, Beam Dumping in the SPS, CERN, LABII/BT/Int/72-5.