THE RHIC BEAM ABORT KICKER SYSTEM*

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Abstract

The energy stored in the RHIC beam is about 200 kJ per ring at design energy and intensity. To prevent quenching of the superconducting magnets or material damage, the beam will be safely disposed of by an internal beam abort system, which includes the kicker magnets, the pulsed power supplies, and the dump absorber. Disposal of heavy ions, such as gold, imposes design constraints more severe than those for proton beams of equal intensity. In order to minimize the thermal shock in the carbon-fiber dump block, the bunches must be laterally dispersed. The nominal horizontal beam deflection angle is required to vary from ~1.7 to 2.5 mrad, which is obtained from five 1.22 m long kicker modules operating at a magnetic field of ~3.5 T. The kickers are constructed as window frame magnets with an 50.8 by 76.2 mm aperture and are operated in the ring vacuum. The pulsed power supplies run at 33 kV and deliver the 12.8 μs long pulse. The peak current required is ~21 kA and the 50% modulation is generated by means of a pulse forming network with non-uniform characteristic impedance.

1 INTRODUCTION

The Relativistic Heavy Ion Collider, RHIC, is a machine with two superconducting magnet rings capable of accelerating and storing particles at energies from 10 to 100 GeV/u in each beam. There are nominally 60 beam bunches with a total stored energy of ~200 kJ at top energy and design intensity of 10^9 ions in the case of gold. This energy is large enough to quench the superconducting magnets or cause material damage if lost in an uncontrolled manner but it is small enough to be disposed of in an economical internal dump.

The stored beam energy can be disposed of within the constraints of the lattice without damage to the machine equipment or operation, provided that certain precautions are taken. Disposal of gold beams imposes more severe constraints on the dump block design than protons due to the large, Z^2 dependent, dE/dx and short interaction length of the Au ions. This problem is handled by adopting at the dump entry a special carbon-carbon absorber material having extremely high thermal shock resistance.[1] The absorber is located in the beam vacuum, but properly pumped. Minimizing the thermally induced stress is achieved by lateral dispersion of the beam on the face of the C-C block.

The beam abort systems are located in the 34-m long warm straight sections of the outer rings down stream of the 10 o'clock intersection point. At this location, the lattice properties favor horizontal deflection. In addition to the dump absorber proper, the beam abort system includes the kicker magnet and the pulsed power supply subsystems. The principle requirements and design features of the kicker magnets and the pulsed power supplies are presented in this paper.

2 DESIGN REQUIREMENTS

The kick strength is determined by the transverse dimensions of the CC block and the distance between kicker and dump face. The C-C block is 0.5 m long with a cross section of 58 × 58 mm. Its distance from the nominal closed orbit is 19 mm. In order to fully use the C-C block, and given the limited distance of 23.7 m between kicker center to dump face, the deflection angle of a single ion can cover the range from of 0.82 to 3.22 mrad. The deflection is provided by 5 separate kickers; allowing for malfunction of one unit and to accommodate a ~7π mm.mrad (unnormalized) dump aperture, the beam center is scanned over the range from 1.68 to 2.52 mrad, thereby spreading ions laterally over ~42 mm.

One kicker unit is 1.22 m long and has an aperture of 50.8-mm horizontal × 76.2-mm vertical. Deflecting the beam at full energy of 100 GeV/u by 2.52/5 mrad is achieved with a magnetic field of 0.35 T, corresponding to a current of 21 kA. The pulsed power unit generates the current pulses with a voltage of 33 kV.

The beam structure imposes several basic design constraints on the abort system. The rotation time of the bunches is 12.8 μs which determines the length of the deflecting pulse. The spacing of bunches is 0.213 μs and the total bunch length is expected to be ≤16 ns under normal operating conditions. Thus, allowing for a gap in the beam created by 4 missing bunches, the rise time of the deflecting kick must be <1 μs. Spreading of the beam over the C-C block could be achieved by a wiggler; a more economical solution is obtained by adopting a pulse forming network with non uniform characteristic impedance.

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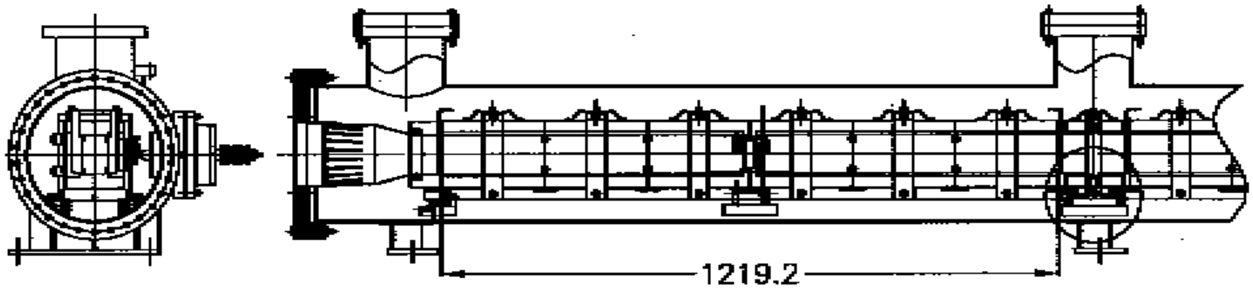

Fig. 1. Abort kicker vessel (in mm).

3 KICKER MAGNETS

The series of five kicker magnets is mounted in one common vacuum vessel. A partial side view and its cross section with the magnets installed are shown in Fig. 1. Also shown are the shields to reduce the coupling impedance of the device. The vessel with the magnets is part of the ring vacuum, the required vacuum levels being maintained by six sputter ion pumps placed atop the structure. To achieve the required vacuum, the entire unit is bakeable to 250 °C.

The kicker is constructed as a window frame magnet employing Ceramics Magnetics CMD 5005 ferrite blocks as shown in Fig. 2. The magnetic field in the return path is kept below 0.32 T. Finite element analysis has been performed showing a field uniformity of better than 5% over the full aperture of the magnet in spite of a local saturated spot. The mechanical construction of the magnets is straight forward, with the exception of the busbar. Arcing problems in a model were eliminated in the final units by using a highly polished stainless steel bus bar. The bus bar is electrically isolated from the vacuum vessel and connected to the pulser via the feedthrough, specially developed for this application and shown in Fig. 3.

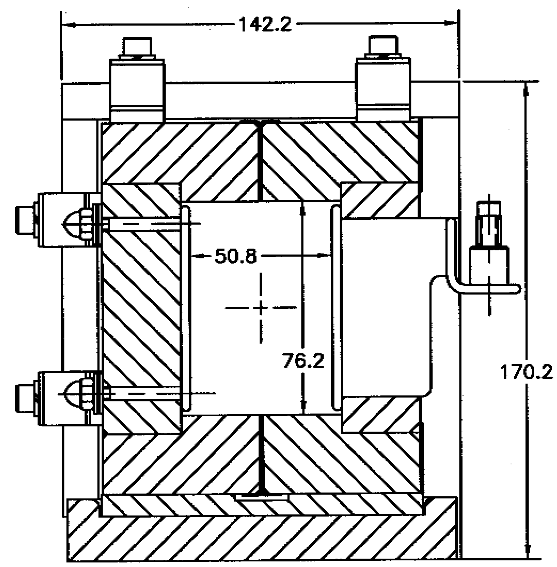

Fig. 2. Abort kicker cross section (in mm).

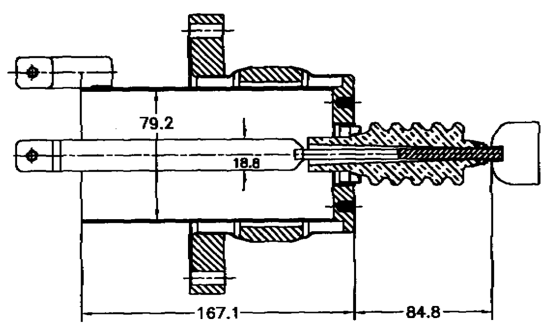

Fig. 3. Feedthrough by ISI (in mm).

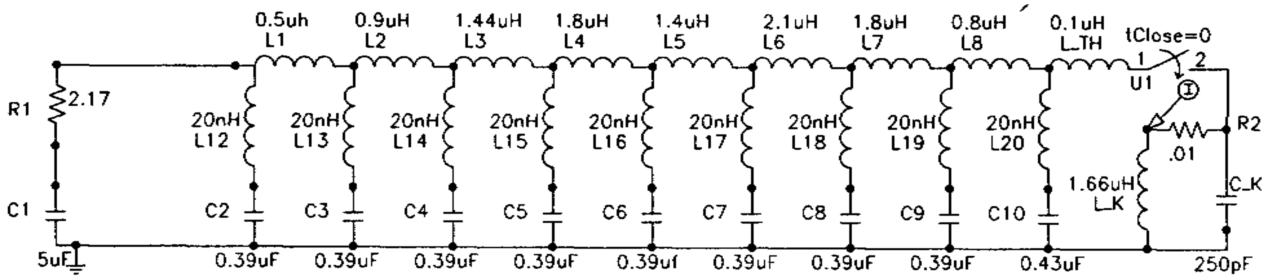

Fig. 4. Pulse forming network.

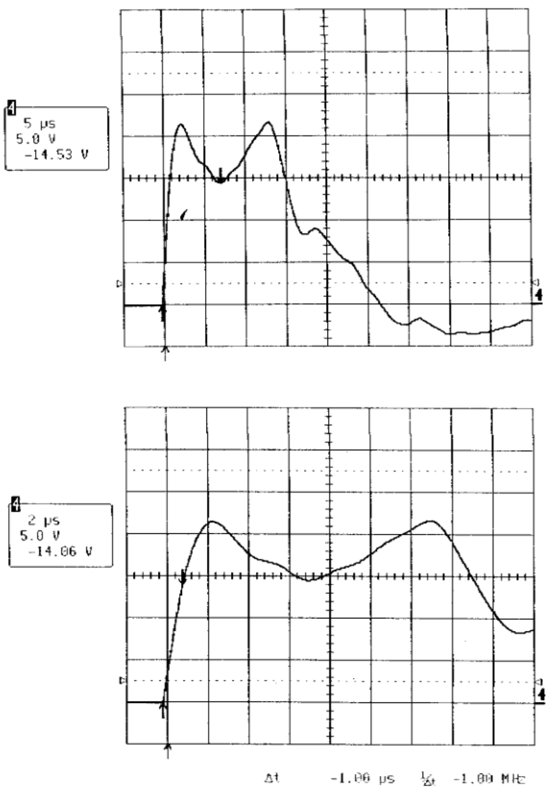

Fig. 5. Abort kicker current pulse shape at 33 kV (5 kA per unit).

4 PULSED POWER SUPPLY

A separate power modulator powers each abort kicker magnet. The main components of the modulator are the Pulse Forming Network, the deuterium thyratron EEV CX1575C to hold off voltage, the DC power supply, and the trigger circuitry. The ceramic 4.5-in. diameter hollow anode tube was selected in view of its reverse current capabilities and is operated in air. The measured inductance of the kicker magnet with feedthrough is 1.67 µH. In order to achieve the 1 µs rise time, a PFN impedance of ~2 Ω is required, which brings the voltage into the 30 - 40 kV range. Dispersing the beam on the dump block is achieved by modulating the current during the pulse between 14 and 21 kA at top energy. This is accomplished by using a PFN in which the impedance of the network is mismatched and tapered from one end to the other (Fig. 4). The observed current pulse at 33 kV is shown in Fig. 5. Although relatively conventional in its design, pre-fire problems plagued the units. Holding the voltage during the 10-hour store time was finally demonstrated after careful conditioning of the thyratron and proper choice of the trigger circuitry. The latter design was complicated by the broad operating range from RHIC injection energy to storage energy or ~3 to 33 kV.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] A. J. Stevens, *Conceptual Design of the RHIC Dump Core*, Report AD/RHIC/RD-94 (BNL 1995).