Magnetic Septa Design and Performance For Injection And Extraction To And From The MIT-Bates South Hall Ring(SHR)*

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Abstract
This report discusses the design, construction, testing and installation of 2 magnetic septa in the South Hall Ring Lattice for the injection and extraction of an electron beam of energies from 0.3 to 1.0 GeV. The report covers: magnetic design and performance of the following; steel return frame, electrical coil design, power supply, vacuum vessel, supports, fiducialization, and magnetic measurements.

I. GENERAL

The magnetic septa specifications are to horizontally bend an electron beam of up to 1.0 GeV energy through 60 mr. The septum width must be less than 8 mm to allow sufficient clearance for the injected and extracted beam and the circulating beam. Multi-turn injection and resonant extraction are planned. The magnet gap, window, and length dimensions were determined to be 1.44 cm, 7.0 cm, and 99 cm respectively. The final configuration for the core was modelled on POISSON[1,2]. The low external side fields outside the septa were reduced further by the addition of a 80% nickel, 0.75 mm thick, cylindrical magnetic shield. The shield tube also acts as a shield for the S-band electron bunches and reduces the beam/tank structure interaction. The watercooled
C-frame septa are mounted on flanges to allow the units to be installed on the vacuum side of the large UHV tanks. Flange mounted support bars support the septum 110 lbs. weight. All connections for electrification and cooling water are external to the vacuum and there are no electrical/water joints inside the vacuum envelope.

II. STEEL ALLOY RETURN FRAME

The return iron material is 4750 forged alloy obtained from Scientific Alloys Inc. of Westerly, RI. The material was machined to within 1/16" of final dimensions and then annealed at 2150° F for 4 hours and oven cooled to reduce the coercive force of the material. Final dimensions were achieved by Blanchard grinding with water based coolants and then a 0.5 mil thick electroless-nickel plating was applied for corrosion protection and for reduction of surface vacuum outgassing rates. The septum steel consists of 2 plates for top and bottom with dimensions 39.0"x4.53"x1.092" LxWxH. The gap is set by 2 ground bars which allow a space for rear access at the mid point for coil lead passage. The bars dimensions are 19.18"x1.429"x0.567" LxWxH. The frame is bolted together

by 2 parallel rows of bolts to provide clamping of the core assembly. A cross section of the septa is shown in Figure 1. A photograph of the septum assembly mounted on the beam line is shown in Figure 2.

III. ELECTRICAL COIL DESIGN

Several designs were considered using square OD hollow copper conductor, but the available profiles did not fill the gap with enough copper to maintain the design temperature rise and to help reduce the stray field outside the septum. Consideration was given to rolling a square conductor down to a rectangular profile to obtain more copper in the gap and lower the temperature rise. Our designers, through persistence, located a Finnish supplier, Otukumpu, with the desired profile listed in their catalog. Engineers were able to obtain from the vendor's US offices a small quantity (200 lbs.), which more than supplied our conductor needs. The conductor, an OFHC CDA 102 copper alloy, has dimensions of 6mm x 5mm OD/ 3mm RD-ID. This conductor provides an excellent match to the design gap and septum width specifications.

The conductor has a resistance per foot of 229.1 micro-ohms. The coil length for 2 turns is 20 feet, resulting in a magnet resistance of 4.58 milli-ohms at 20C. To drive the gap to 2000 Gauss requires a current of about 1150 amperes, a voltage of about 6.00 volts and a power consumption of 6.8 kW. Each turn conductor carries 1 GPM of water at 80 psid; such that the temperature rise of the water is less than 13.0C at the maximum current of 1150A for 1.0 GeV operation.

Insulation designs considered for the conductor were: ceramic clips, hard coated aluminum sheets, to flame sprayed alumina. Information from G. Fischer of SLAC[3] on a qualified flame spray vendor, BBC of San Jose,CA. resulted in the selected insulation design of 10 mils (± 3) mils of Al_2O_3 being flame sprayed onto the conductor. The coil ends are saddled, turned up/down, to allow the beam to pass through. Early designs called for field clamps/supports for the coil ends, but assembly and

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testing determined that the coil ends were self-supporting. The coil/frame assembly was high potential tested to 1000 volts DC and no leakage was noted. The four end conductors for the windings come out of the vacuum via a flange with 4 insulating feedthroughs. The conductors slide out through the feedthroughs and are brazed via a matching interface copper disc to the feedthrough after final fit up is achieved. From then on the magnet is tied to the vacuum tank large rectangular flange and is handled as a flanged assembly.

The 2 turns are connected, outside vacuum, in series to produce the required magnetic field and are connected with fittings for parallel turn water cooling supply and return. Temperature sensors are installed on the water outlet conductors and with flow switches are part of the septum interlock protection system. Large tabs are connected to the input terminals so that 6-4/0 AWG flexible cables can be connected to each terminal. The 12 cables for supply and return are interleaved in the path from the power supply to reduce stray fields and couplings to other circuits.

IV. VACUUM TANK DESIGN

A rectangular design was chosen based on the availability of a suitable 8"x10"x½" wall 304 stainless steel rectangular pipe. Various ports and flangements were provided for; beam entry and exit, vacuum pump port, windows for a beam monitor screen, support and fiducial mounts, and the large side flange for the septum magnet assembly. Articulation of the septum is accomplished over the motion of the entrance and exit bellows and by adjustment of the 6 strut support system, which allows vertical, horizontal and azimuthal motion in an independent way.

The tanks were built by Mill Lane Engineering, Lowell, MA and no problems were noted in fabrication. Cleaning and bakeout processes performed allowed a base pressure 10*exp(-9) Torr to be achieved with an O-ring seal. A Helicoflex Delta Seal is planned to be used for the final assembly sometime in the future.

V. POWER SUPPLY

The design of the power supply was specified and an order was placed with Bruker Inc., Billerica, MA. for 2 units rated at 12 Volts and 1300 Amperes DC, with current regulated to 10 ppm/°C long term. The units were delivered, installed, tested and determined to be within specifications without any problems. The power supplies are a distance from the septa due to the radiation associated with the electron beam injection, storage and extraction activities planned.

VI. MAGNETIC MEASUREMENTS

The magnetic measurements on the septa were made out of the vacuum tank to allow access to the septum gap and external stray fields using the Bates X-Z table with precision Hall probe. Measurements of the end field, internal gap field, and septum external field were taken versus distance and excitation. The reduction of the stray septum field when the magnetic shield was installed was also measured. Plots of the vertical magnetic fields versus axial distance (z); in the septum for the injected/extracted beam, in the shield for the circulating beam are presented in Figure 3. A photograph of the septum mounted on the main flange is shown in Figure 4.

VII. FIDUCIALIZATION

The completed assembly of septum/flange was measured to allow use of external fiducial points on the flange to set the horizontal and vertical position of the septum with respect to the beam position at the septum beam entrance and exit points. The success of this program allowed the beam to be directed through the septum on the first attempt to inject the electron beam.

VIII. CONCLUSIONS

The septa were constructed and tested on the injection side of the SHR. Both units performed well with electron injection at about 330 MeV. The first unit was removed to modify some tank dimensions. There are some mechanical improvements in the second unit based on the experience gained with the construction of the first unit.

IX. ACKNOWLEDGEMENTS

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X. REFERENCES

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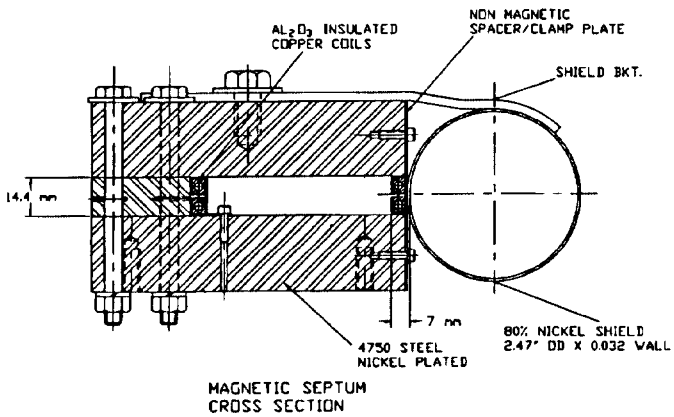

Figure 1. Septum Cross-section.

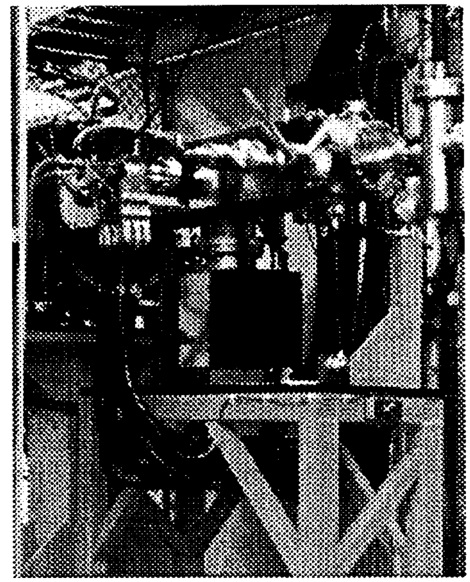

Figure 2. Injection septum installed in Ring.

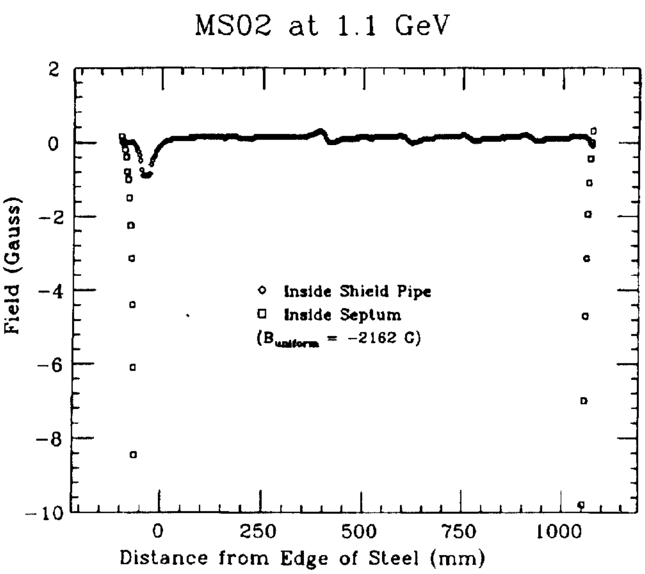

Figure 3. B_y (X_m,O,Z), {+ X_1 inside septum; +X_2 inside shield} - $100^{mm} \leq Z \leq + 1050^{mm}$. Note: Injected beam along (X_1,Z); circulating beam along (X_2,Z).

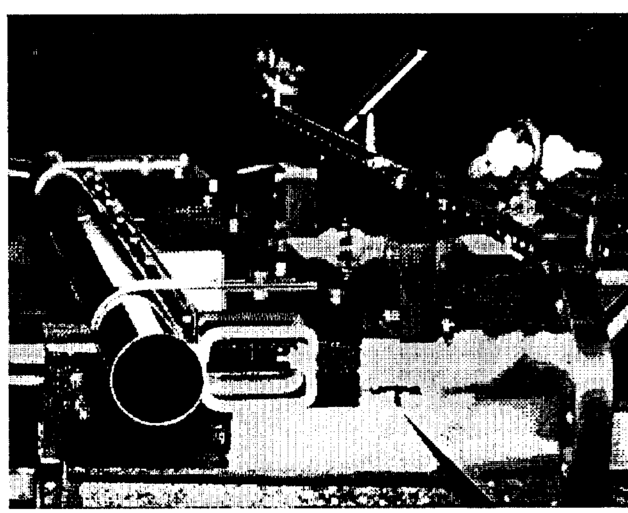

Figure 4. Septum/Shield/Flange Assembly.