June 30, 1997 *CBN 97-28*

BENDING MAGNETS FOR DUAL APERTURE STORAGE RING[1]

Alexander Mikhailichenko, David Rubin
Cornell University, Wilson Laboratory, Ithaca, NY 14850

The design of the bending magnet for dual aperture storage ring is described

1. Introduction

In the dual aperture storage ring [1, 2], the counterrotating beams are focused by side-by-side quadrupoles and share a common dipole bending field. An H-shaped dipole was designed to be light weight, simple and inexpensive to manufacture. The compact magnet can be placed above the synchrotron in the CESR tunnel as shown in Fig. 1.

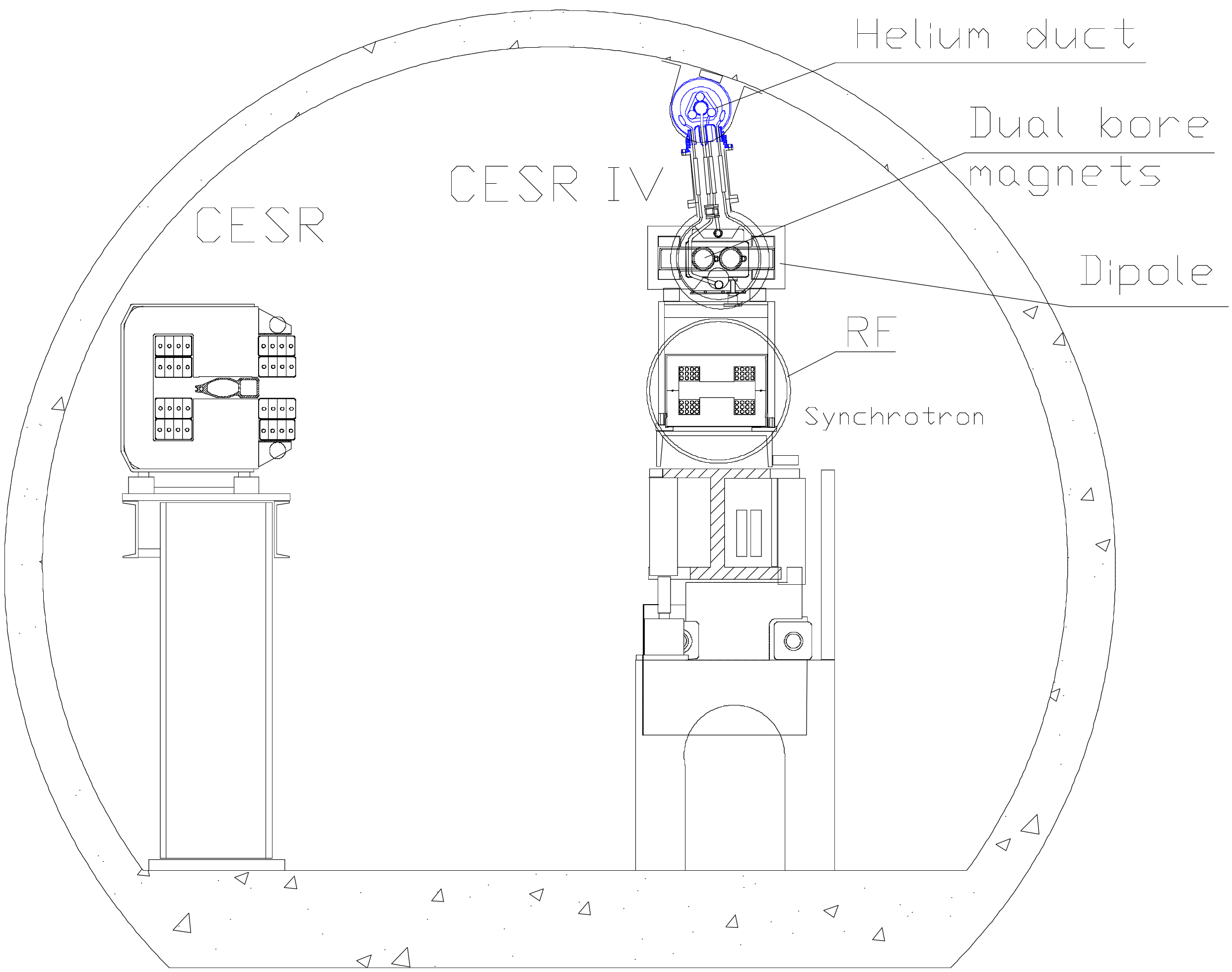

Fig. 1. The layout of the CESR tunnel with dual bore machine on the top of the Synchrotron.

[1] Supported by National Science Foundation.

2. Magnet

Good field quality is required over the full aperture of both beams of about 135 *mm*. The yoke must be mechanically stable so that the machining tolerances and magnetic properties are preserved. The magnet is designed so that it can be split into an upper and lower half in order to simplify installation and alignment of the vacuum chambers.

The yoke is solid iron. The filling factor is higher for a solid yoke than for a laminated yoke. And it is straightforward to machine the solid iron to the requisite 0.015 *mm* accuracy.

The outer diameter of the vacuum chamber is 60 *mm*. The gap between the poles is chosen to be 65mm, since that is the gap in the existing CESR dipoles. The extra 5mm allowed for chamber misalignment. The vacuum chamber was installed in the existing CESR C-magnets through the gap. In the new split H-magnet, the chambers can be set into the lower half of the magnet and forced to conform when the upper half is set in place. There may be a possibility of reducing the gap by as many as 5mm, which would have some advantage since the magnet power consumption scales as the square of the gap. The design presented has a conservative 65 *mm* gap. Any reduction of the gap could be easily done later. The reduction can be of the order of 150 *kW* for all 140 magnets.

The magnet is shown in Fig. 2, and the field lines are indicated in Fig. 3. The field in the midplane is represented in Fig. 4. The thickness and shape of the yoke was optimized to minimize weight. The 25.4 *mm* thickness of the yoke yields a reasonable magnetic field of 10 *kG* in the iron.

A one inch long section of yoke was manufactured to measure the deformations generated by magnetic field pressure. If the field strength is 0.2 *T*, the pressure is about 0.1 kg/cm^2. Lead bricks were used to simulate the magnetic pressure. The deflections were measured with an array of micrometers. The deflection was less than 0.015mm and the pole faces remained parallel.

The magnet is supported at a distance from each end, that is the fraction 0.223 of its full length. This arrangement yields minimum vertical deflection of the magnet along its length. The design allows access to the midplane via the 4 grooves located 650 *mm* from each end. This access is critical to the alignment of the magnets.

The area available for the coil is about 60×26 mm^2. The coil has 8 turns of rectangular cross section. The filling coefficient is about 70%. The cross section of the wire is about 13×13 mm^2.

The power consumption depends only on the cross section of the coil. The number of turns may be adapted to match the available power supply. A single layer 4 turn coil could be used with a high current supply.

The water flow required to limit temperature rise to 10°C is $Q \cong 0.17[L/s] = 0.17 \cdot 10^{-3}[M^3/s]$.

With an additional input in the middle of the winding the length of the water channel is $L \cong 26.5m$.

The cross section of the water channel is 19.6 mm^2.

The pressure drop Δp according to Hagen-Poiseuile equation equal to

$$\Delta p = Q\frac{8\mu_f}{\pi}\frac{L}{r^4},$$

where $\mu_f \cong 8 \cdot 10^{-4} [N \cdot s / M^2]$ is dynamic viscosity of water with temperature around 40°C.

This gives $\Delta p = 2 \cdot 10^5 N / M^2$ or about 2 *atm* .

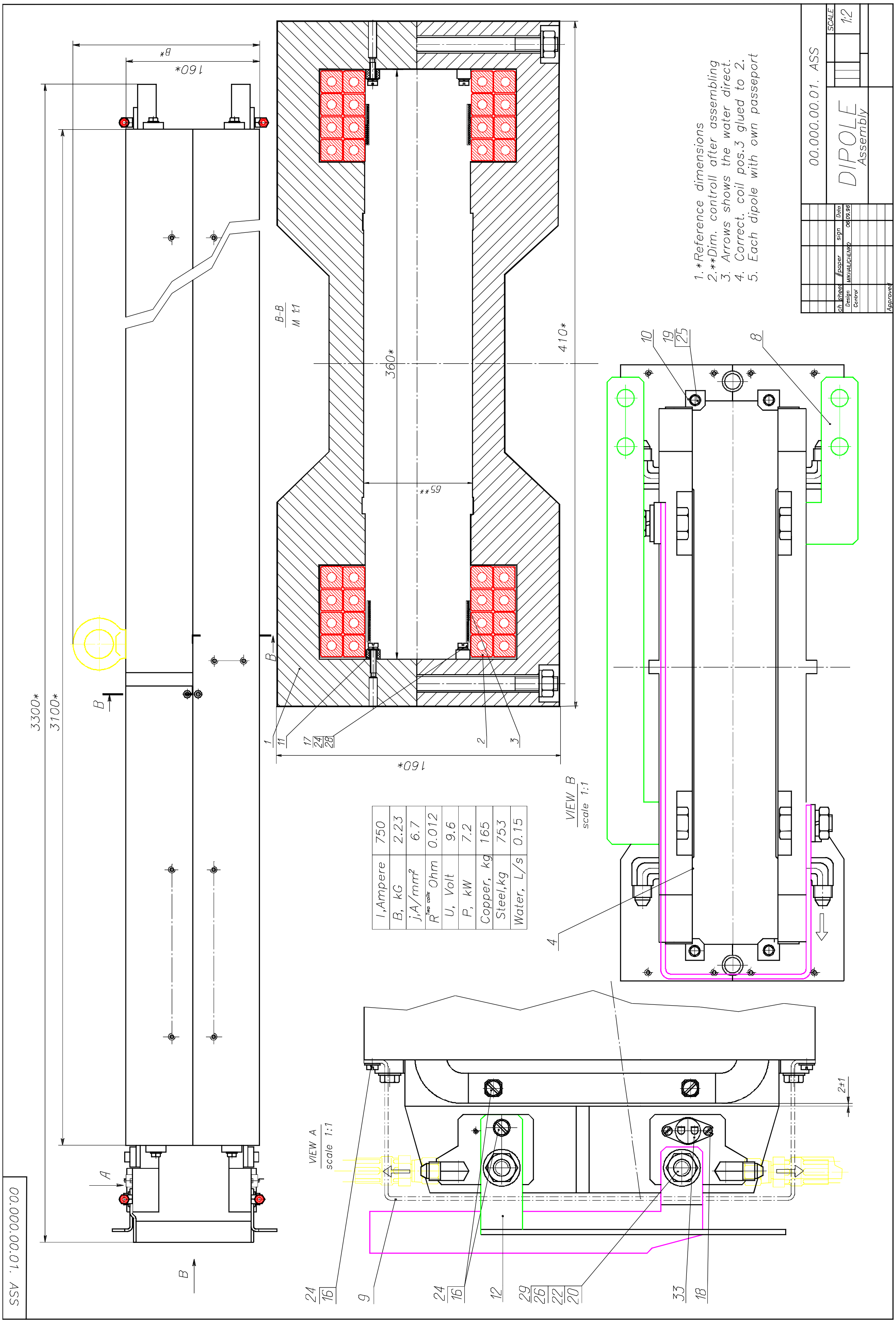

Fig. 2. The basic model.

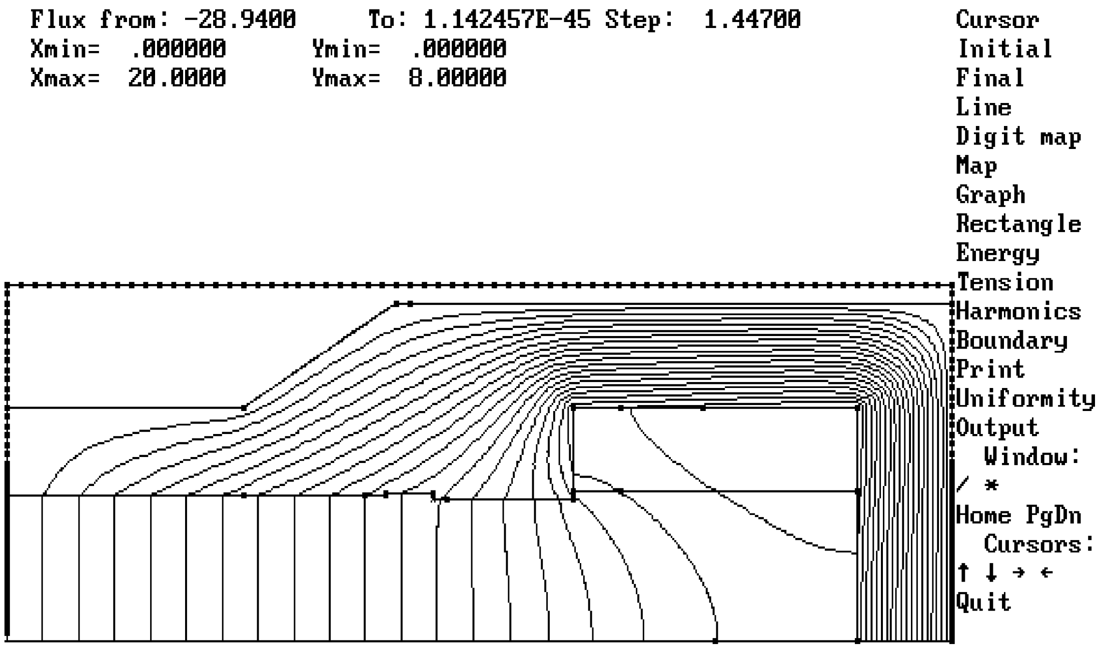

Fig. 3. The magnetic lines. Print out from MERMAID. Shown is ¼ of the magnet.

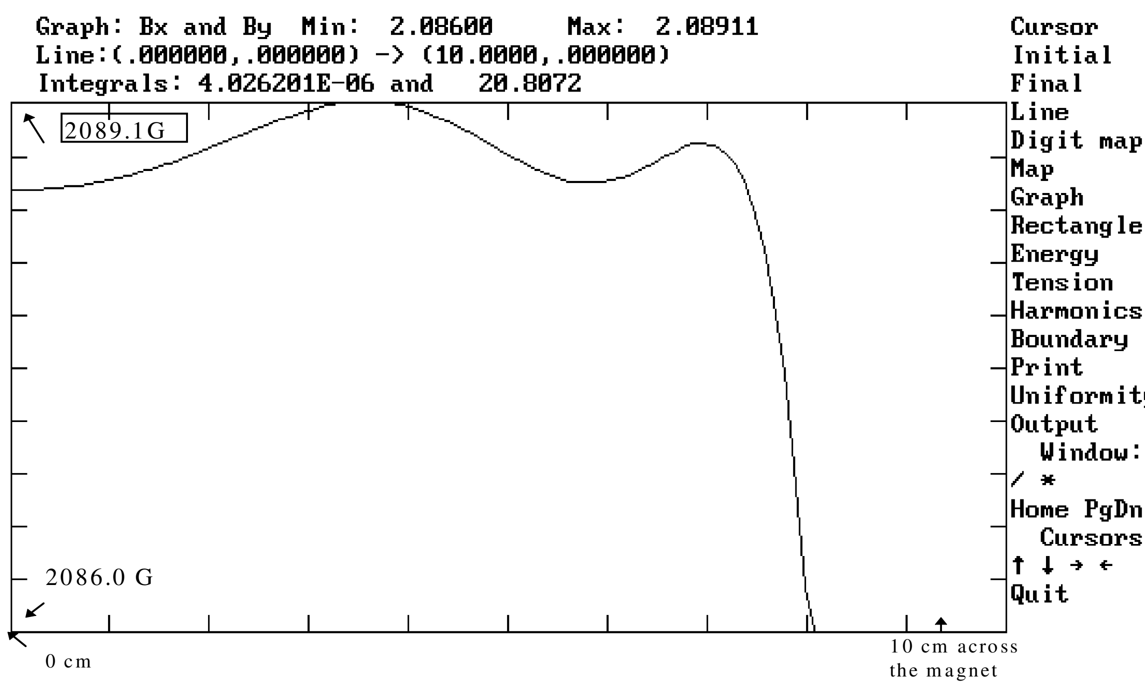

Fig. 4. An example of the field behavior across the gap of the magnet. Zero transverse coordinate corresponds to the magnet center. One division on vertical scale corresponds to $1.5 \cdot 10^{-4}$ of relative variations. So, the good region is about ± 7.5 *cm*. The relative field variations here are within $\pm 1.5 \cdot 10^{-4}$. Print out from MERMAID.

The center of each beam is located +-40 *mm* from the center of the magnet and the aperture of each of the vacuum chambers is +-27 *mm* [2]. The 360 *mm* wide and 65 *mm* high gap can easliy accommodate the two chambers.
The magnet parameters are summarized in Table 1.

Table 1.

Gap, *mm*	65
I, *A*	750
B, *kG*	2.2
j, A/mm^2	6.7
$R^{\text{two coils}}$, *Ohm*	0.012
U, *Volt*	9.6
P, *kW*	7.2
Steel, *kg*	753
Copper, *kg*	165
Water flow, *L/sec*	0.15
Pressure drop, *atm*	2

3. Conclusion

A compact, H-shaped dipole magnet that can accommodate a pair of side-by-side vacuum chambers is described. There is flexibility in the choice of conductor cross section. The profile is economic and the magnet is relatively light weight. The split yoke permits precise placement of the vacuum chambers. The yoke is solid so that the poles can be precisely machined. Access to the pole allows the possibility of using shims to adjust the field distribution. This design may serve as a reference point for a cost estimation.

4. References

[1] D. Rubin, M.Tigner, Shared Bends and Independent Quadrupoles, CON 94-28, Cornell, December 2, 1994.

[2] A. Mikhailichenko, D. Rubin, Concentric Ring Colliding Beam Machine with Dual Aperture Quadrupoles, EPAC96, Sitges (Barcelona), June 10-14, 1996, Proceedings, p.433.

[3] A.N. Dubrivin, E.A. Simonov, **MERMAID**- **ME**sh-oriented **R**outine for **MA**gnet **I**nteractive **D**esign, Novosibirsk, BINP, 1990.