REVISED CROSS SECTION FOR RHIC DIPOLE MAGNETS*

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Abstract

Using the experience gained in designing and building Relativistic Heavy Ion Collider[1] (RHIC) dipole prototype magnets an improved cross section has been developed. Significant features of this design include the use of only three wedges for field shaping and wedge cross sections which are sectors of an annulus. To aid in the understanding of the actual magnets, one has been sectioned, and detailed mechanical and photographic measurements made of the wire positions. The comparison of these measurements with the magnetic field measurements will is presented.

Introduction

The proposed RHIC will be capable of storing colliding beams of ions as heavy as ^{179}Au for periods of as long as ten hours. Intrabeam scattering causes significant growth in the beam emittance at these long storage times. This large emittance puts stringent limits upon the field quality of the 360 "standard" superconducting dipoles (bore=80 mm, design field=3.45 T, Length 3.6 to 9.5 m) which are a major part of the storage rings. The field quality is a function of the superconducting persistent currents, iron saturation effects and the turn placement in the coils. This paper discusses the turn placement; saturation effects are discussed in the adjacent paper[2]. It is practical to make these dipoles with coils consisting of a single layer of superconducting cable. This simplifies construction, but reduces the freedom available for optimizing the coil design. RHIC has a very short cell consisting of two dipoles,two quadrupoles and two chromaticity correcting sextupoles. These sextupoles can also be used to compensate for the systematic sextupole produced by the dipoles. There are also two decapole correctors but because of the phase advance between the dipoles and correctors, only partial compensation is possible. Hence the emphasis is upon minimizing the systematic b4' (Where bn' = C_{n+1}(@25mm)/B_o X 10^4, with C_{n+1} the field coefficient for cos(n+1)θ).

Yoke and Mechanical Details

An overall cross section of the assembled cold mass is given in Figure 1. The RHIC dipoles use the iron yoke as the collaring system to compress the coils. The interleaved yoke halves are pinned together in pairs. The assembly is then compressed with a press until it is possible to insert the keys on the outer periphery. Not visible in the figure is the taper of the midplane. This assures that there is contact at the inner radius of the midplane. At the pole, there is a 5x5 mm notch in the inner radius. This precisely positions the molded insulator, which in turn positions the coil. Thus the coil position is referenced to the survey notches on the outside of the iron.

Coil Design

The RHIC is most sensitive to field quality at a central field Bo=1.0 Tesla. The coil cross section is optimized so that the geometric field coefficients will cancel the rest of the terms. The dominant effect for this design is the harmonics produced by the indexing notch at the pole. The cable used has the following parameters.

1. Wire diameter 0.648 mm
2. Number of wires 30
3. Cable width (over insulation) 10.06 mm
4. Cable mean thickness (over insulation,in magnet) 1.337 mm
5. Cable keystone 1.2°

Possible coil designs containing 31 to 33 total turns and 4 or 5 separate current blocks were optimized with the program PAR2DOPT. Several four current block solutions were found with excellent field quality. (In all cases, the coil spacing wedges are forced to be symmetric. This removes one possible assembly error.) Additional parameters considered in the final selection are:

1. **POLE ANGLE** , the further the top turn is from 90°, the larger the bend radius of this turn.
2. **WEDGE SIZES** , it is not practical to make a separating wedge less than 0.4 mm thick. It is desireable that the wedges be conspicuously different in size to minimize the possibilities of mistakes in construction.
3. **THREE or MORE TURNS in TOP BLOCK** , for quench protection reasons.

Figure 2 is a cross sectional drawing of this coil design, and Table 1 lists its salient parameters.

Figure 3 shows the predicted field quality as a function of central field for this design.

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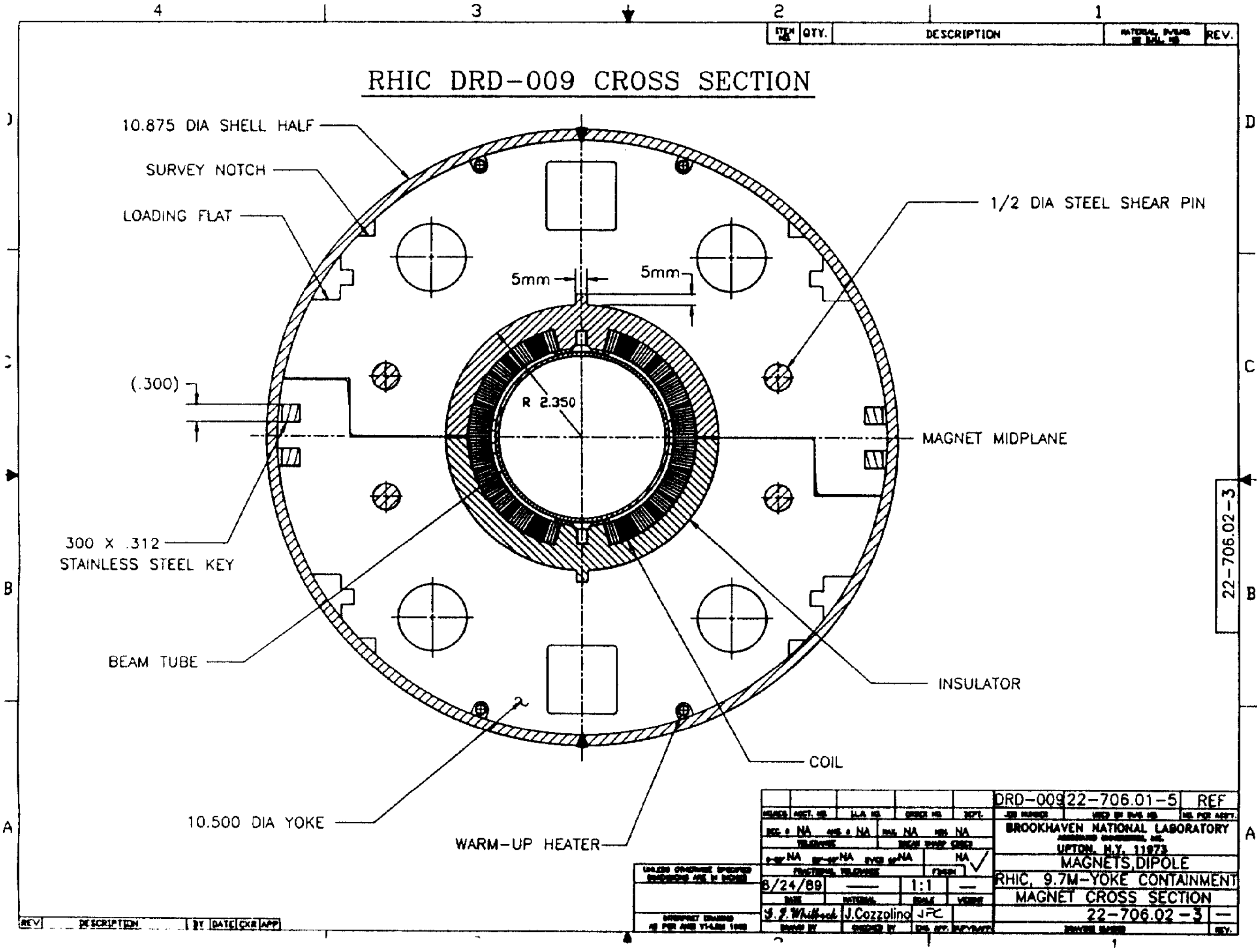

Figure 1: RHIC Cold Mass

Examination of Actual Magnet

Because the field quality is sensitive to coil distortions of 50 μm, one magnet, DRB006, was sectioned after assembly and testing. Photographs of these sections were digitized on a Vanguard scanner, and one section was digitized directly. Table 2 summarizes these measurements. There are two sections which were measured with the Vanguard scanner, labeled R1 and R4. The third section,labeled CROSS2 was digitized directly. This coil was design DRB with a 0.009" shim on the pole(labeled DRB-9). The best fit to the calculation was to assume that this shim was only 0.003"(Hence the label DRB-3). The difference between the calculated and measured pole angles are a clear symptom of this effect. The measured radius is 100 μm larger than calculated. Detailed examination of the measured positions versus predicted showed some turns, particularly near the midplane displaced inward as much as 250 μm; there were no other systematic displacements. The second portion of the table gives the harmonics computed from the measured turn positions for the three sections. The DRB-3 values are those expected from an otherwise perfect coil with the smaller shim. The actual harmonics are measured with a 600 mm

N	bn-calc	bn-design
2	-2.128	-2.060
4	+0.946	+0.950
6	-0.225	-0.232
8	+0.066	+0.055

Turns	Wedge Size
9	...
..	0.81^0
11	...
..	5.27^o
8	...
..	10.52^o
4	...

Transfer Function	Pole Angle
7.09G/A	73.18^o

Table 1: Details of DRE 4 Block Coil

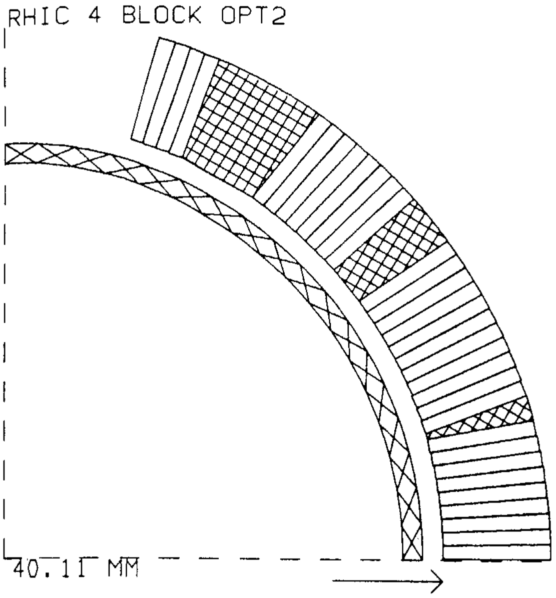

Figure 2: Quadrant of DRE 4 Block Coil

coil. (The sections are less than 200 mm apart; the cable twist pitch is 74 mm)

References

1. "Conceptual Design of the Relativistic Heavy Ion Collider", Brookhaven National Laboratory, BNL 51932 (1986)
2. P.A.Thompson et al.,"Iron Saturation Control in RHIC Dipole Magnets", this conference,(1991)

Section	Radius(mm)	Pole Angle
DRB-9	44.977	74.82°
R1	45.07	75.03°
R4	45.02	75.09°
CROSS2	45.16	75.10°

	bn'				
n	R1	C2	R4	DRB-3	Msr
0	7.075	7.068	7.071	7.068	7.075
1	-0.653	-0.525	-0.460	.....	-1.0
2	7.138	10.024	9.311	4.4	5.9
3	-1.409	0.160	-0.008	.....	-0.4
4	-0.199	1.734	2.096	-0.45	2.0
5	-1.052	0.074	0.031	.....	0.1

Table 2: Comparison of DRB006 Sections

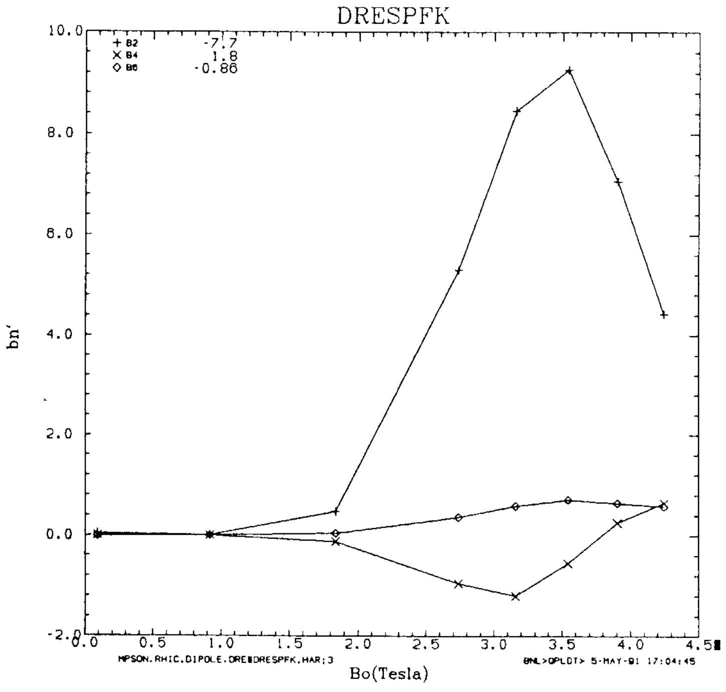

Figure 3: Field Dependence of DRE Harmonics