xiii. 180 mm Insertion Dipole

Immediately on each side of the six intersection regions is a dipole, "DX", through which both beams pass; there are 12 of these magnets. The strength of DX determines the collision angle. The spacing between the two beams at the end of the magnet away from the intersection determines the aperture required. A coil diameter of 180 mm ensures adequate field uniformity in the case of asymmetric operation, provided that the dipole can be moved sideways to be centered on the beam trajectories. The axial space available necessitates a somewhat higher field, 4.3 T, than is needed for the arc dipoles. To achieve this field with an adequate margin in a single layer coil, a wider cable is used. The cable chosen is similar to the 36-strand cable used in the 130 mm aperture insertion quadrupole, differing only in the keystone angle, 0.6^o vs. 1.0^o in the cable for the quadrupole, see Tables 2-3 and 2-4. The insulation is the same, all Kapton CI, but the design value of the insulated cable mid-thickness is slightly less, 1.341 mm (0.0528 in.).

Basic Design Parameters

Table 13-1 lists the design parameters. A six-block coil design is needed to achieve good field uniformity at low field; all wedges are mechanically symmetric. Unlike all of the other RHIC magnets, the DX uses a stainless steel collar around the coils, similar to that used in the SSC dipoles. This is because the press available can accommodate a moderately thick collar, but not the large diameter of the steel yoke if it were used as a collar. To minimize deflections and thus aid in assembly, a 40.1 mm thick collar is used. Iron saturation is controlled by a series of holes in the iron, near and at the yoke inner radius. Figure 13-1 shows one quadrant of the DX dipole design. Figure 13-2 shows the full cross section. The magnet is considered to be part of the blue ring for cryogenic purposes. The bus cutout is the same size as in the arc magnets, but the helium flow channel is slightly larger (3.175 cm) to assist in the control of iron saturation; there is an additional, smaller hole solely for saturation control.

The rather large stored energy and modest ratio of copper to superconductor in the cable may result in a damaging hot spot temperature during a worst-case quench with passive (double-diode) protection, and active protection consisting of quench detection and firing of heaters was incorporated. A diode was also installed across each of the two coils.

Table 13-1. Design Parameters for the 18 cm Aperture RHIC Insertion Dipole

Parameter	Value
Coil aperture	180 mm
Number of turns per pole	70
Number of magnets in machine	12
Magnetic length	3.7 m
Iron inner diameter	(11.3 in) 287.0 mm
Collar thickness	40.1 mm
Iron outer diameter	(24.5 in.) 622 mm
Shell thickness	9.52 mm
Operating temperature	4.6 K
Design current	6.7 kA
Design field	4.3 T
Computed quench current	8.5 kA
Computed quench field	5.2 T
Inductance	49 mH
Stored energy @ design current	1.1 MJ
Field margin	22%
Transfer function	
@ low current	0.664 T/kA
@ design field	0.643 T/kA
Allowed Design harmonics @ 60 mm	
$b_{n'}$ @ low field (geometric)	< 1
maximum saturation (in operating range) $b_{2'}$	3
$b_{4'}$	0.6

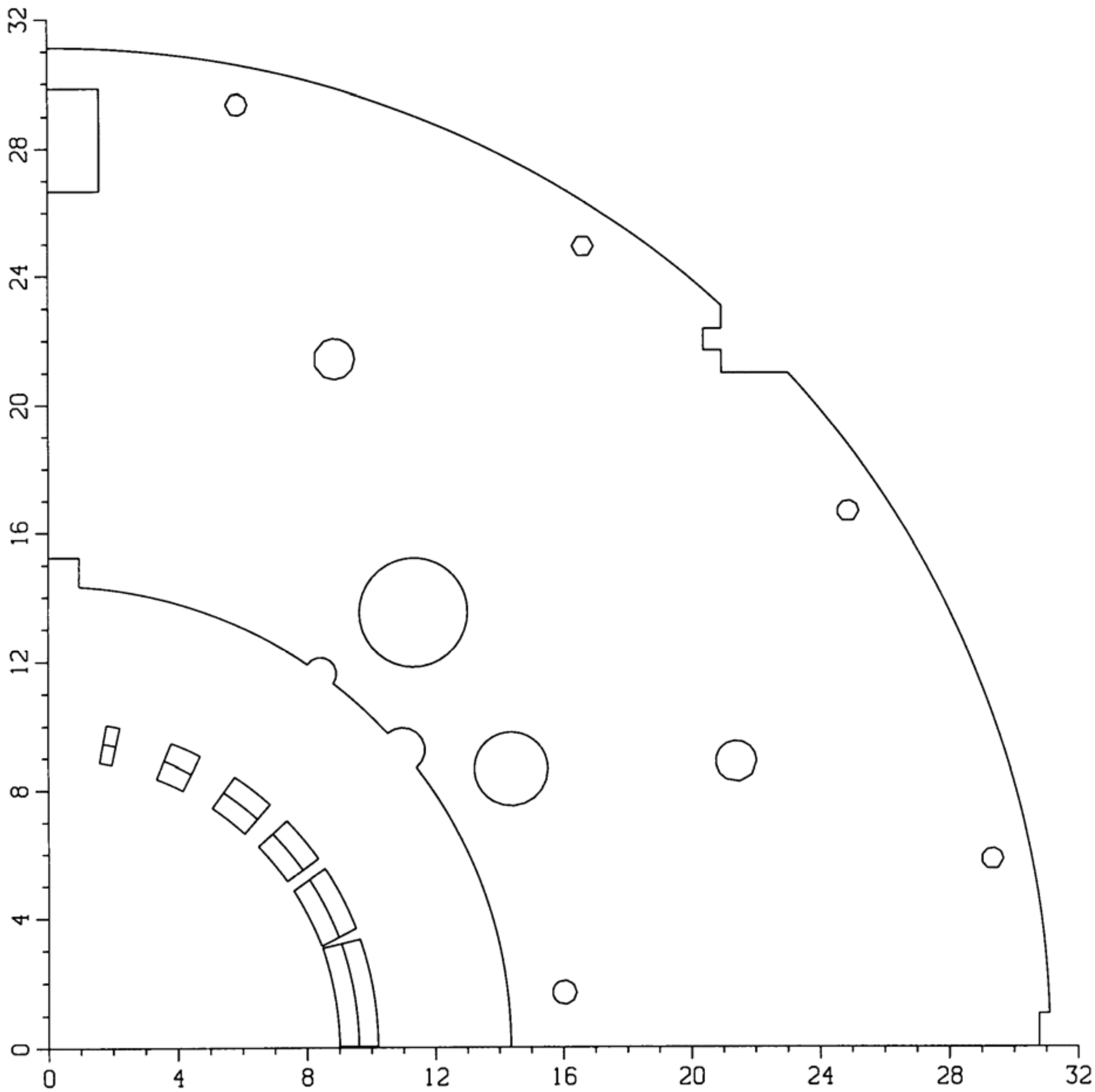

Fig. 13-1. One quadrant of the DX dipole design DXM8A (dimensions in cm).

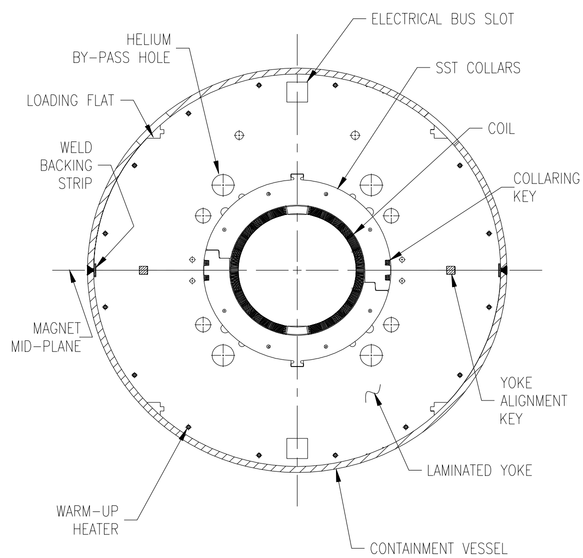

Fig. 13-2. Cross section of the 180 mm DX dipole magnet.

The quench performance of the twelve DX's installed in RHIC is summarized in Fig. 13-3. The dipoles required between one and three quenches to reach operating current. All were trained to at least 10% above the operating current of 6.6 kA. After installation in RHIC, six of the magnets required one quench each to reach operating current after the first cool-down, in agreement with the thermal cycle data obtained during production.

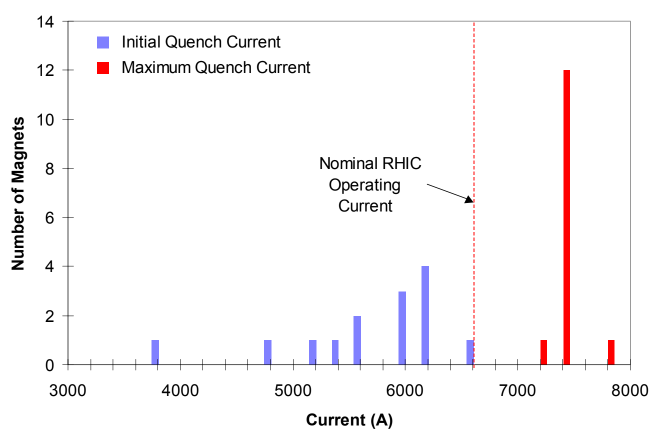

Fig. 13-3. Quench performance of 14 large aperture (180 mm) dipoles, tested at 4.5 K.

Warm integral measurements were made on all 13 magnets. The mean value of the transfer function was 2.5053 T•m/kA with rms variation of 0.03%. Measurements of the integral transfer function and the first two allowed harmonics versus current are shown for a representative magnet in Figs. 13-4 through 13-6. Cold measurements of the harmonics were made on all the magnets, but integral measurements were made on only six. Warm – cold correlations were used to estimate integral values for the remaining six. Warm – cold correlations for several low order terms are shown in Figs. 13-7 and 13-8. The field quality data for warm and cold measurements are given in Table 13-2.

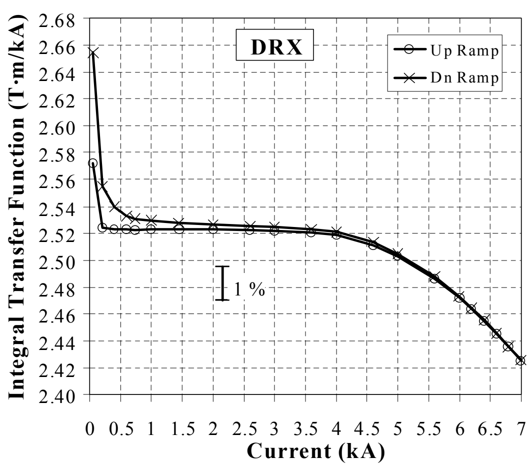

Fig. 13-4. Integral transfer function in DRX110.

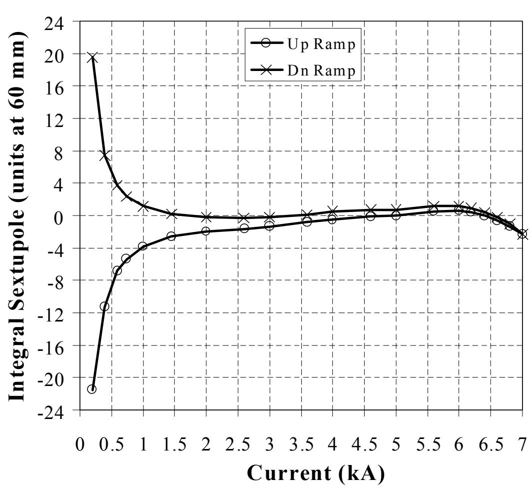

Fig. 13-5. Integral normal sextupole harmonic in DRX110.

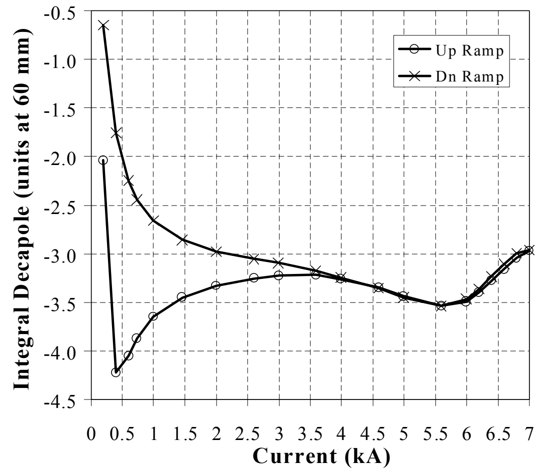

Fig. 13-6. Integral normal decapole harmonic in DRX110.

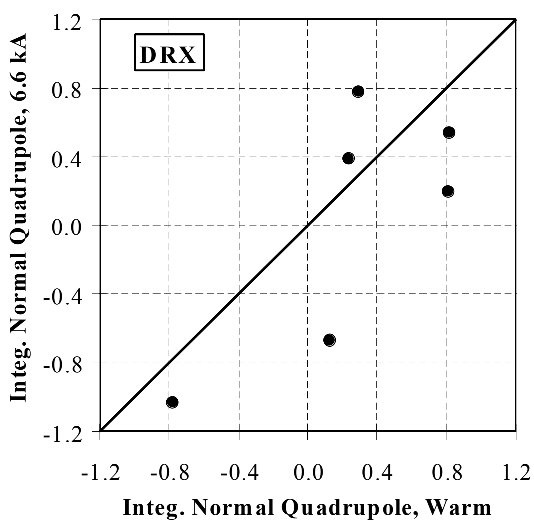

Fig. 13-7. Warm-cold correlation of b_1 in DRX magnets.

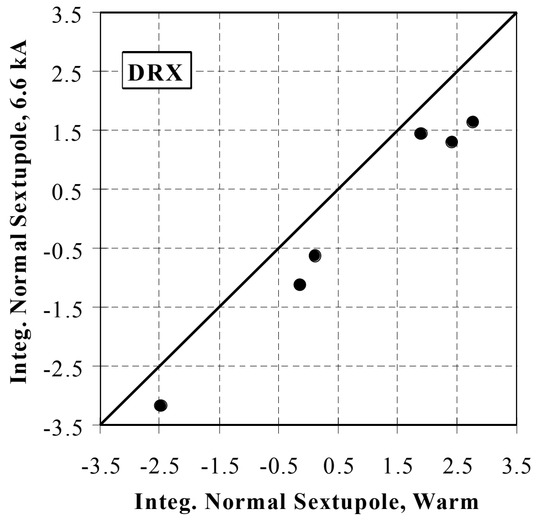

Fig. 13-8. Warm-cold correlation of b_2 in DRX magnets.

Table 13-2. Summary of integral field quality in DX dipoles.

Harmonic at 60 mm	Mean		Standard Deviation	
	30 A (13 magnets)	6600 A (6 magnets)	30 A (13 magnets)	6600 A (6 magnets)
b_1	0.04	0.03	0.63	0.72
b_2	0.53	-0.09	2.09	1.90
b_3	0.00	-0.03	0.19	0.22
b_4	-2.68	-2.95	0.57	0.41
b_5	0.03	-0.05	0.10	0.15
b_6	-1.91	-1.76	0.17	0.12
b_7	0.01	0.01	0.04	0.06
b_8	-1.09	-1.15	0.07	0.07
b_9	0.00	0.01	0.02	0.02
b_{10}	-1.13	-1.15	0.02	0.02
a_1	-1.00	-2.33	2.37	0.96
a_2	-2.54	-2.70	0.53	0.32
a_3	0.38	-0.06	0.99	1.10
a_4	0.30	0.34	0.25	0.16
a_5	0.34	0.19	0.37	0.38
a_6	-0.21	-0.15	0.15	0.08
a_7	0.19	0.15	0.11	0.11
a_8	-0.04	-0.05	0.04	0.04
a_9	0.09	0.08	0.04	0.05
a_{10}	0.03	0.06	0.02	0.02