BROOKHAVEN NATIONAL LABORATORY

MAGNET DIVISION NOTES

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Title: Reducing b_3 with a Cutout in Iron Aperture

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List Revised 3/93

Reducing b_3 with a Cutout in Iron Aperture

Ramesh Gupta

A large b_3 ($\sim$ 7 unit) has been observed in both RHIC 8 cm quadrupoles and 13 cm quadrupoles. An experiment was performed to move the pole angle of the coil[1] in the 13 cm aperture insertion quadrupoles to remove this b_3 empirically. However, it did not produce the required magnitude of b_3 to offset the large values observed in those quadrupoles. In this note we propose modifying the iron to cancel the measured b_3 in the arc quadrupoles.

The following modifications (shown in figure 1) in iron yoke should significantly reduce the observed magnitude of b_3 in the entire design range of operation :

1. **Cutouts in the aperture :** 2 mm deep cutouts are proposed in iron aperture from 18 degree to 24 degree. The iron will have a 4-fold symmetry. Therefore, the cutouts will also be present from -18° to -24°, from 156° to 162° and from 198° to 204°. This breaks the eight-fold quadrupole symmetry and produces a b_3 of about -7.2 unit at low current.
2. **Holes in the yoke :** The above cutout produces a b_3 which has a strong current dependence due to iron saturation. To reduce this we propose the holes of a radius of 2 mm located at a radius of 60 mm and at an angle of 60 degree from the center of the magnet. There will be four such holes to maintain the four fold symmetry. The other three holes will be at the angular locations of 120, 240 and 300 degree. These holes have a b_3 symmetry and reduce the current dependence in b_3 produce by the above cutout. The computed change in b_3 versus current is under 1 unit till a current of 5800 Amp (design current 5000 Amp).
3. **Elimination of 90° notch in aperture :** The 90° and 270° notches in the iron aperture maintains a quadrupole symmetry in the iron since the locating notches are present at 0° and 180°. If 90° and 270° notches are eliminated a b_3 of < 0.2 unit will be generated. This is a small number as compared to the observed b_3 of $\sim$7 unit. Therefore, these notch may be eliminated for the ease of construction and savings.

The computed additional b_3 by the modified iron described above is given in table 1 and plotted in figure 2. When it is superimposed on the observed b_3 of $\sim$7 unit a b_3 of under 1 unit is expected till 5800 Amp. It may be noted that the measured b_3 did not have any significant current dependence. The measured value of b_7 in the arc quadrupoles was $\sim$+0.1 unit in the straight section. This location of cutout will also remove most of that harmonic till the design value of current.

Table 1: Additional b_3 and b_7 harmonics generated by the cutouts and holes as a function of current in the 80 mm aperture arc quadrupoles. The computer model is shown in figure 1.

I(kA)	b_3	b_7
1.00	-7.121	-0.10
3.00	-7.146	-0.10
4.00	-7.420	-0.10
4.50	-7.936	-0.10
4.75	-8.085	-0.11
5.00	-8.027	-0.13
5.25	-7.347	-0.16
5.50	-7.095	-0.20
5.80	-6.247	-0.23
5.90	-5.980	-0.24
6.00	-5.738	-0.24
6.50	-4.493	-0.24

References:

1. Memo to Mike Anerella from R. Gupta and P. Thompson, 3/8/93.

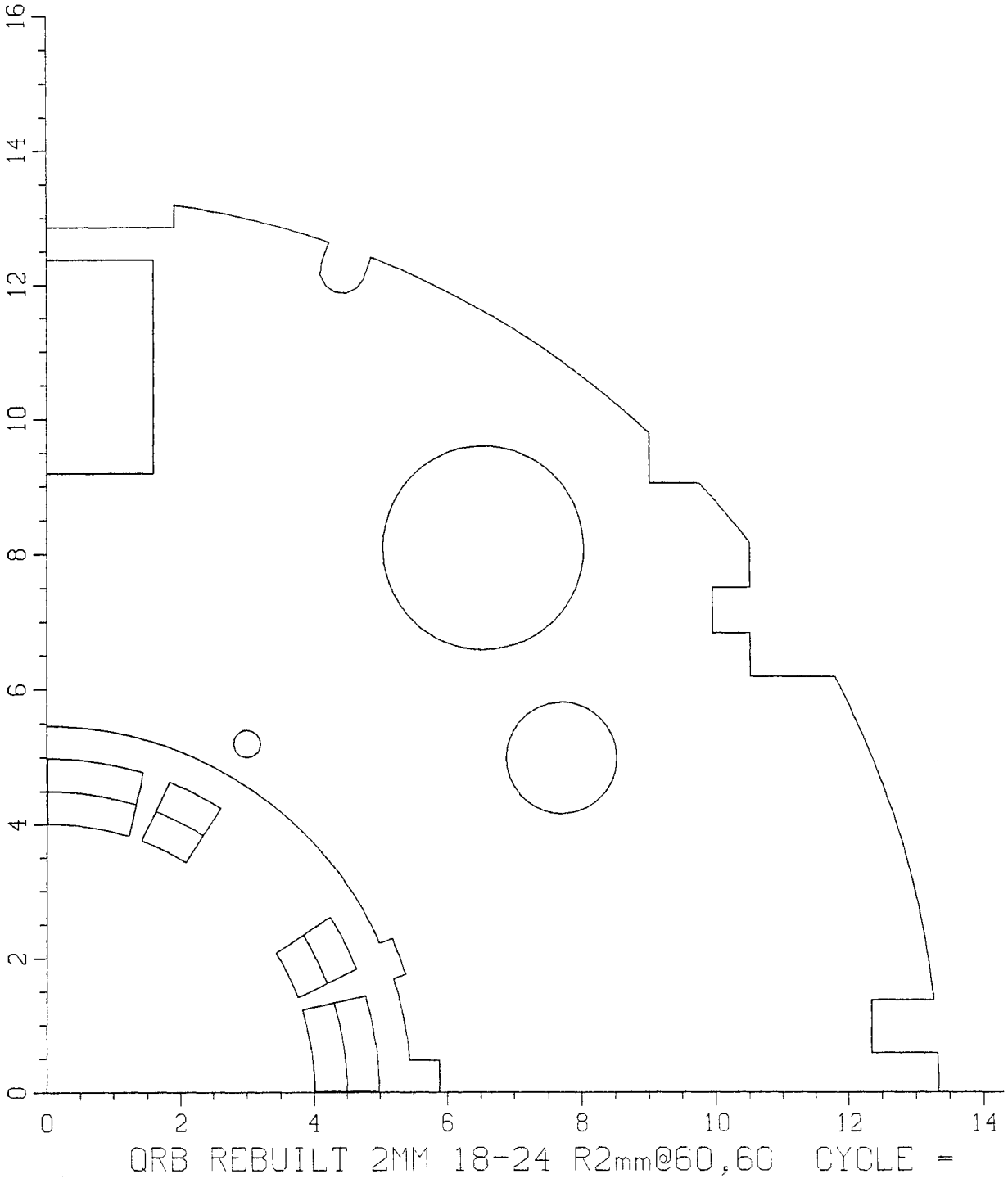

Figure 1: Modified yoke to remove measured b_3 in the arc quadrupoles. A cutout, an additional hole and a missing notch at 90° are the proposed modifications.

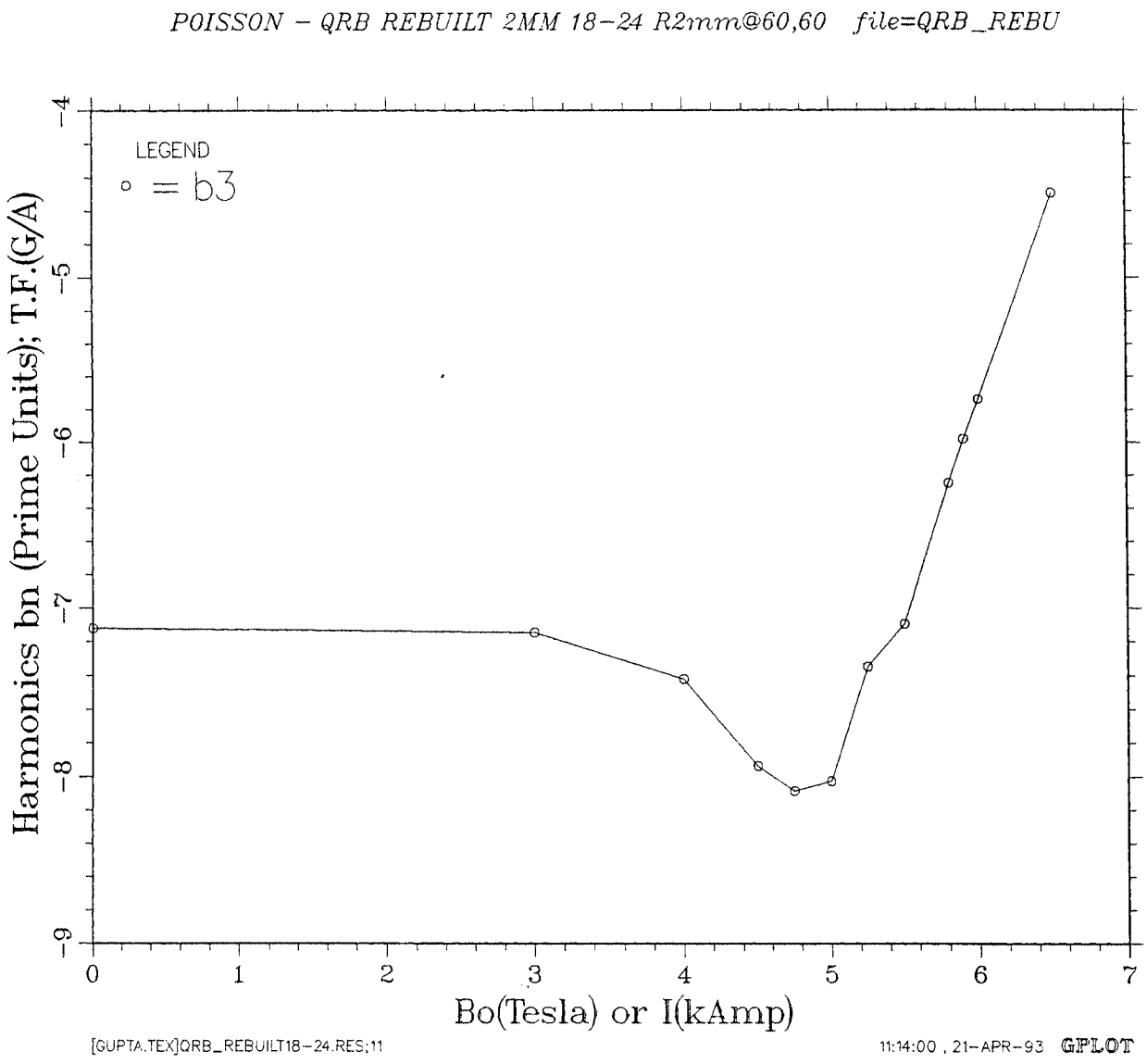

Figure 2: Additional b_3 as a function of current in the arc quadrupoles due to a cutout, a hole and a missing notch.