# BROOKHAVEN NATIONAL LABORATORY

## MAGNET DIVISION NOTES

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**Title:** Possibility of Reducing Iron Saturation in RHIC Arc Dipole by Slightly Changing the Location of Stainless Steel Shear Pins

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# Possibility of reducing iron saturation in RHIC arc dipole by slightly changing the location of stainless steel shear pins

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The maximum measured change in the saturation induced $b_4$ harmonic between 2 kA and 5 kA in the straight section of ARC dipole DRD009 is $\sim$ -1.4 unit ($\sim$ -1.5 unit when end effects are included). The design goal was to keep $b_4$ saturation within 1 unit. The observed differences between the calculations and measurements are in part due to a series of small effects like a 20 mil gap between the mating plane of top and bottom yoke halves, an undersize key not completely filling the iron at the outer radius, the effect of cryostat wall, etc.,etc. Though, each one of them gives a small individual effect of the order of 0.2 unit in $b_4$ saturation, they all add up to become significant. These were either not part of the original design or were not included in the original model for simplicity and reliability of the computer model. Moreover, there is always a limit to what the calculations can predict and therefore a small difference between the calculations and measurements is always to be expected. It has been found that in earlier RHIC magnets, starting from DRA001, the calculations and measurements have differed in the same range. The agreement between the calculations and measurements is much better when the computer model is made for *"as built"* magnets and when all little details are taken care of. That will not be discussed here and is the subject of another note to be published later.

The conceptual design of arc dipole included a feature for an easy tuning of the saturation induced harmonics to empirically compensate for such differences after the design. This involves either changing the material type of steel key (magnetic) or stainless steel shear pin (non-magnetic) or changing the size or location of them slightly. This change must be small so that the mechanics of the cross section remains practically unchanged. Now that harmonics has been measured in several short dipoles and one long dipole (namely DRD009), we present the results of such exercise. We would like to point out that it

has been consistently observed that there is a very little magnet to magnet variation in the measured saturation characteristic of any cross section. This was also the case in the recent short magnets DRS005 through DRS008, which were made with the same iron cross section as DRD009. Therefore, we feel quiet confident that this correction can be adopted and the results would come close to what is intended.

The measured $b_2$ saturation till design is $\sim$ 7.5 unit in the straight section section and $\sim$ 8 unit when end effects are included. The measured $b_6$ saturation is $<$ 1 unit. All harmonics in this note are reported at 25 mm reference radius.

We make a small change in the location of shear pin in a direction which is preferable both magnetically and mechanically. In these calculations we have used the original model which predicted $b_2$ saturation 7 unit (measured 8 unit), $b_4$ saturation -0.6 unit (measured -1.5 unit) and $b_6$ saturation 0.8 unit (measured 0.8 unit). In the present cross section the $\frac{1}{2}''$ dia shear pin is located at ($3.375''$, $1.062''$). In the reduced saturation cross section the location of the pin would be ($3.15''$, $1.5''$), every thing else remains identical. The original model was modified only to change the location of the shear pin. The results of calculations are shown in table 1. For reference, we have also given the results of calculations for the present cross section and the results of measurements in the magnet DRD009. The computed saturation in $b_2$, $b_4$ and $b_6$ harmonic in the new location of pin is 5.8, 0.5 and 1.1 unit respectively. Since there is a noticeable difference between the calculations and measurements in $b_4$ saturation, one must look at the differences. Therefore, we expect the $b_4$ saturation to be about -0.7 unit. Obviously any value between -0.7 to +0.5 for $b_4$ saturation would be an improvement on the present value of -1.5 unit. The $b_2$ saturation reduces by 1 unit.

This is an option which can, if desired, be implemented to improve the field quality in RHIC arc dipoles. The new location of the pin is very close to the old one (about a diameter – $\frac{1}{2}''$ – away) and it takes hole in the yoke away from the corner.

**Table 1:** Measured (in DRD009), computed and expected values of saturation induced harmonics in the arc dipole for a 25 mm reference radius. These are the maximum change in the 2 kA values of these harmonics up to the design current (5 kA). The harmonics are computed for two locations of stainless steel shear pins (a) for the present location X = $\pm 3.375''$ and Y = $\pm 1.062''$ and (b) for the reduced saturation location X = $\pm 3.15''$ and Y = $\pm 1.5''$ . The last row is what we should expect to be the measured values in the reduced saturation cross section. (Please see text for a brief explanation of the difference between the computed and measured values of $b_4$ saturation.

| | $\delta b_2$ | $\delta b_4$ | $\delta b_6$ |
|---|---|---|---|
| Measured in DRD009 | 8.0 | -1.5 | 0.8 |
| Computed for the present location of shear pin | 6.8 | -0.7 | 0.8 |
| Computed for the new location of shear pin | 5.8 | +0.5 | 1.1 |
| Expected measured values in new location | 7.0 | -0.7 | 1.1 |