BROOKHAVEN NATIONAL LABORATORY

MAGNET DIVISION NOTES

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Title: Reduction in the Current Dependence Increase in the Effective Length between Short and Long Dipoles

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Reduction in the Current Dependence Increase in the Effective Length between Short and Long Dipoles

Ramesh Gupta

The magnetic field in the ends of the magnet is smaller than that in the body of the magnets. In RHIC type dipole and quadrupole magnets where the ends are enclosed by the yoke, the iron at the two ends saturates much slower than that in the body of the magnets. This has also been seen in the measured data for RHIC arc dipoles which at 5 kAmp show about a 10 mm increase in the effective length (defined as the integral transfer function divided by the body transfer function). In long dipoles, such as those used in RHIC, this current dependence increase is expected to be independent of the length of the magnet. The expected relative increase is 1 part in 1000 in the arc dipoles ($\sim$ 9.45 meter long) and 3 part in 1000 in D6 and D9 dipoles ($\sim$ 2.95 meter long). In other words, *D6 and D9 dipoles would become 7 mm too long at 5 kAmp even if they had the ideal mechanical length matched to give correct bend angle at low current.* Since these magnets are connected in series to the same power supply, they would not track[1] at high current.

Here, we propose a method for *reducing current dependence change in effective length by adjusting the nominal value of iron packing factor* between the short and long magnets. A smaller packing factor forces a faster saturation in the body of the magnet which is used to compensate for a slower saturation in the ends. This means that the packing factor (or total iron weight for the given length) should be reduced in shorter magnets. It may be pointed out that this compensation is both required and effective only at high fields and makes no difference at lower currents. The parameter to be minimized is the current dependence of the $\int B.dl$ ratio between the long and short magnets.

In Fig. 1, we plot the drop in transfer function as a function of current for the nominal (97.55%) and 1% lower (96.55%) packing factor. The results of magnetic field calculations are given in Table 1 and Table 2. One can see that a 1% drop in packing factor reduces field by 0.0064 Tesla at 5 kA or causes a 0.187% drop in transfer function. There is a very small effect on other field harmonics.

The calculations show that the required drop in iron weight of 6.91 m long D5I dipole is 0.15% (or 10.7 mm). Since each lamination pair is $\frac{1}{2}''$(12.7 mm) long, this means that one

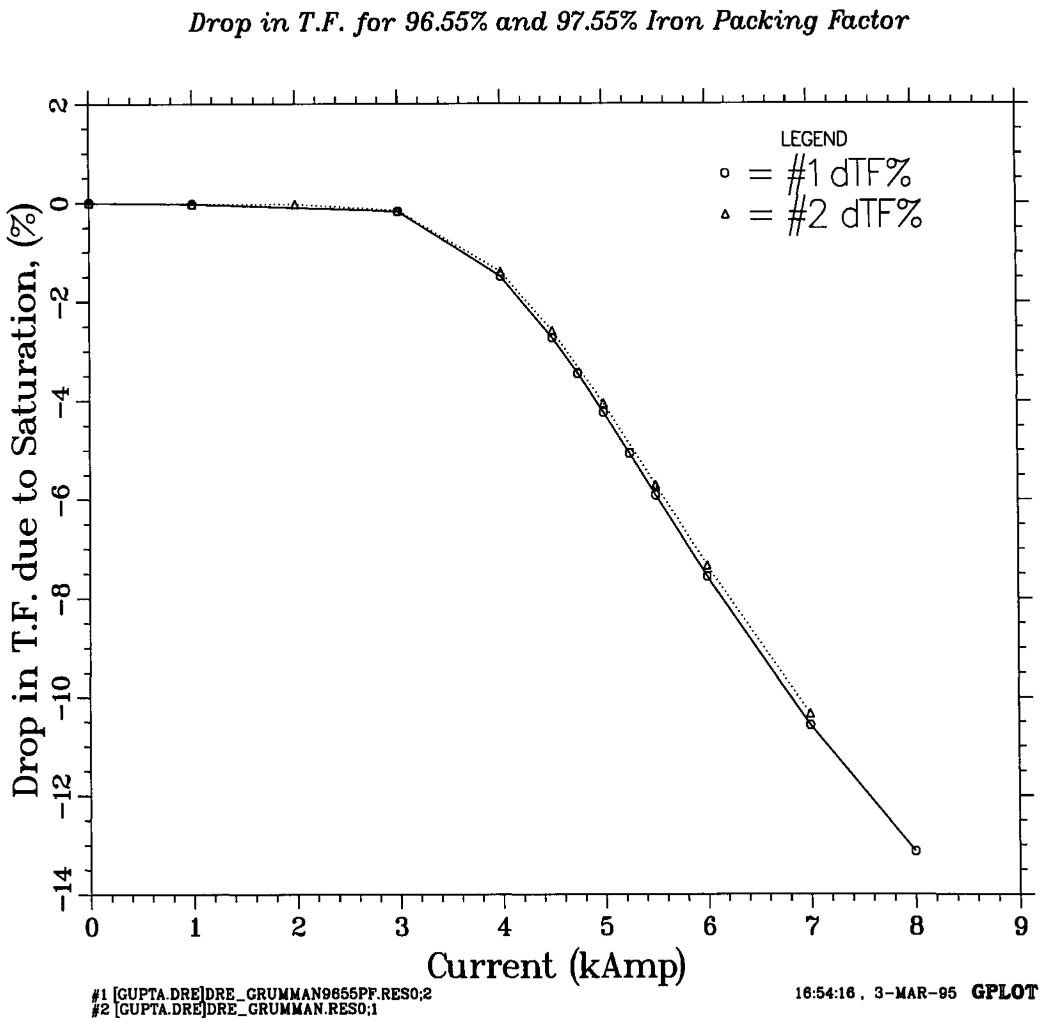

Figure 1: The variation of the drop in Transfer Function as a function of current for 96.55% and 97.55% values of Iron packing factor.

pair of laminations would be missing. In the shortest 2.95 m long D6 and D9 dipole, the required drop in iron is 1.3% (or 38.5 mm). This mean that three pair of laminations would be missing. These are modest changes and are not expected to otherwise influence the performance, in particular because the iron packing factor is being reduced (not increased) and the new value in D6/D9 magnets would be closer to that in arc quadrupoles.

[1] Memo from Steve Tepikian, et.al. to Art Greene and Mike Harrison on Jan 24, 1995.

Table 1: POISSON - GRUMMAN YOKE CROSS SECTION with a 97.55% iron packing factor. These calculations are good for tracking transfer function only. file=DRE_GRUMMAN.LOG;1

I kAmp	B_o Tesla	T.F. T/kA	b_2' 10^{-4}	b_4' 10^{-4}	b_6' 10^{-4}	b_8' 10^{-4}	b_{10}' 10^{-4}	b_{12}' 10^{-4}
0.000	0.0000	0.70857	1.108	-0.123	0.077	0.076	-0.559	-0.212
1.000	0.7084	0.70837	1.157	-0.110	0.081	0.077	-0.560	-0.212
3.000	2.1222	0.70741	1.349	0.025	0.160	0.071	-0.560	-0.212
4.000	2.7947	0.69867	0.739	0.914	0.680	0.046	-0.571	-0.217
4.500	3.1060	0.69022	0.289	1.119	1.114	0.039	-0.581	-0.221
5.000	3.3991	0.67983	-1.492	0.655	1.380	0.062	-0.595	-0.224
5.500	3.6746	0.66811	-5.714	-0.017	1.349	0.081	-0.608	-0.228
6.000	3.9393	0.65656	-9.582	-0.358	1.202	0.089	-0.620	-0.232
7.000	4.4472	0.63532	-12.817	-0.490	0.939	0.100	-0.638	-0.238

Table 2: POISSON calculations for GRUMMAN YOKE with 96.55% iron packing factor. These calculations are good for tracking transfer function only. file=DRE_GRUMMAN9655PF.LOG;1

I kAmp	B_o Tesla	T.F. T/kA	b_2' 10^{-4}	b_4' 10^{-4}	b_6' 10^{-4}	b_8' 10^{-4}	b_{10}' 10^{-4}	b_{12}' 10^{-4}
0.000	0.0000	0.70857	1.108	-0.123	0.077	0.076	-0.559	-0.212
1.000	0.7084	0.70837	1.157	-0.109	0.081	0.077	-0.559	-0.212
3.000	2.1219	0.70731	1.375	0.038	0.168	0.071	-0.560	-0.212
4.000	2.7920	0.69799	0.676	0.959	0.718	0.045	-0.572	-0.218
4.500	3.1015	0.68923	0.204	1.095	1.154	0.040	-0.583	-0.221
5.000	3.3927	0.67854	-1.814	0.576	1.394	0.064	-0.596	-0.225
5.500	3.6665	0.66663	-6.139	-0.085	1.339	0.083	-0.610	-0.228
6.000	3.9300	0.65500	-9.873	-0.397	1.187	0.091	-0.621	-0.232
7.000	4.4357	0.63368	-12.729	-0.500	0.922	0.101	-0.639	-0.239