MAGNETIZATION IN BORE-TUBE CORRECTION WINDINGS

M.A. Green and J.M. Peterson
December 1986

Bore-tube correction windings are planned for the SSC dipoles. The current design[1] has one-layer sextupole, octupole, and decapole windings, as listed in the following Table I.

Table I. Bore-Tube Correction Windings

	6-Pole	8-Pole	10-Pole
Turns per pole	19	14	11
B(1cm)/I (gauss/amp)	6.7	3.7	2.0
Winding radius (mm)	17.7	17.7	17.7
Length (m)	8	3	5
Operating Current (Amp)	3.9	3.7	4.2
$(B(1cm)\cdot L)/(BL)_{dip}$, 20 TeV	2×10^{-4}	0.4×10^{-4}	0.4×10^{-4}

The windings are formed with 0.008-inch diameter wire that consists of a copper jacket with a solid, 120-micron Nb-Ti core. The questions addressed here are the strengths of the multipole distortions produced by magnetization in these correction windings that are induced by the dipole field.

The fields due to the magnetization currents in the 120-micron filament were calculated using the program SC MAG 04[2]. The critical-current density was assumed to vary as shown in Table II.

Table II
Critical-Current Density vs. Ambient Magnetic Field at 4.4K

B(T)	0	0.05	0.10	0.30	0.50	1.0	2.0	3.0	5.0	7.0	9.0
J_c(kA/mm^2)	18.0	15.3	12.6	9.55	7.95	5.24	3.49	2.80	1.85	1.03	0.21

The dipole was cycled from 0 to 5.5 tesla, back to 0, and back up to various induction levels up to 2.5 tesla. Magnetization currents in the dipole coils were suppressed in order to isolate the effects produced in the trim coil alone.

Several types of single-layer trim-coil windings were examined. Each was of the 60°/(n+1) type, where the multipole number is 2(n+1) -- i.e., each pole had a winding in which the positive-current winding, the negative-current winding, and the central hole each subtended an angle of 60°/(n+1). Ideally, this rule eliminates the first allowed multipole, which is 6(n+1). The quadrupole winding case was included in the calculations although such a bore-tube corrector is not planned for the SSC.

Table III
Coil Geometries That Were Calculated

Winding Multipole	n	60°/(n+1)	# Turns Per Pole	1st Allowed Multipole
quadrupole	1	30°	28	12-pole
sextupole	2	20°	19	18-pole
octupole	3	15°	14	24-pole
decapole	4	12°	11	30-pole

The resulting multipole fields produced by persistent currents in each of the basic multipole windings <u>all</u> followed excitation curves of the same shape, shown in Figure 1. Each went through zero at a dipole field of about 0.35 tesla (very close to injection), and each rose to a maximum at about 0.70 tesla. (The change in magnetic induction required to penetrate a 120-micron filament that has been completely penetrated in the opposite sense is about 0.7 tesla.) The maximum multipole coefficients are listed in Table IV. The b_n coefficient represents the strength of the 2(n+1) multipole at 1 cm relative to the dipole field strength and is usually expressed in units of 10^{-4}.

Table IV
Maximum Strength of Multipoles Produced at 0.70 Tesla Dipole Field in Different Bore-Tube Windings.

Type of Winding	Max Strength of Magnetization Multipole Coef. b_n			
	b_2 sextupole	b_4 decapole	b_6 14-pole	b_8 18-pole
normal quadrupole	1.33×10^{-4}	0*	-0.16×10^{-4}	0
skew quadrupole	-1.33	0	-0.16	0
normal sextupole	0	0.70×10^{-4}	0	0
skew sextupole	0	-0.71	0	0
normal octupole	0	0	0.31	0
skew octupole	0	0	-0.32	0
normal decapole	0	0	0	0.13×10^{-4}

*Note: The "zero" entries represent strengths $\leq 0.01\times10^{-4}$

To judge the relative importance of the multipoles produced by magnetization in the bore-tube windings, consider the multipole coefficients at injection produced by magnetization in the main dipole windings for the case of 5-micron filaments, as listed in Table V: (Note: Proximity coupling between filaments is not considered here.)

Table V
Multipole Coefficients at Injection (0.33 Tesla)
Produced by Magnetization in the Dipole Windings with 5-micron filaments

b_2	b_4	b_6	b_8
-5.4	0.36	0.08	0.06

Comparison of Tables IV and V shows that the magnetization decapole produced in the sextupole bore-tube winding, the magnetization 14-pole in the octupole winding, and the magnetization 18-pole in the decapole winding at 0.7 tesla are all considerably larger than those produced in the fine filaments in the main dipole windings at injection. Since the sextupole bore-tube windings will extend only over about half of the dipole magnet length, and the octupole and decapole windings each about one quarter of the dipole magnet length, the relative magnetization multipole strengths are correspondingly reduced.

However, from comparing these reduced values with the multipole tolerances of the 90-degree lattice, as shown in Figure 14 of SSC-SR-1024, it seems clear that the magnetization decapole produced in the bore-tube sextupole winding and probably the magnetization 14-pole produced in the octupole bore-tube winding will require correction if the bore-tube windings use 120-micron filaments.

[1] P.A. Thomson, SSC-226, Aug 86.

[2] M.A. Green, LBL Eng. Note M-5692, Feb 1981, "Magnetic Field Programs, Instructions for the Use of SCMAG01, SCMAG02, SCMAG03, and SCMAG04".

1989S

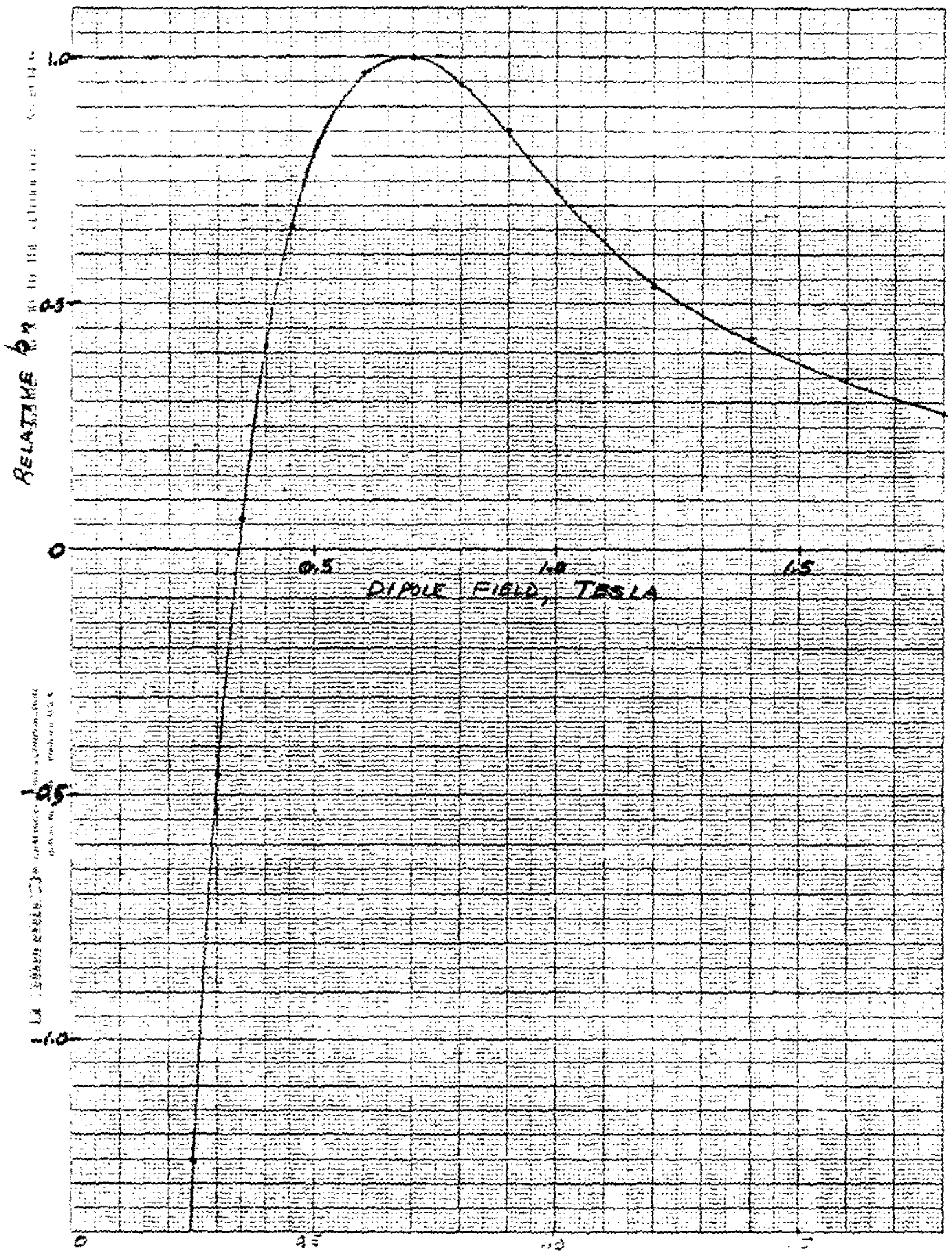

Fig. 1 Relative strength of each magnetization multipole versus rising dipole strength. The peak multipole strengths at 0.7 tesla are given in Table IV.