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SSC Technical Note No. 4

COIL DESIGN FOR THE PROTOTYPE SSC DIPOLE

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The coil cross section for the prototype SSC dipole is a graded, two layer, four block design. It is assumed that both layers are wound from CBA type cable with a mean thickness of 55 mils and the appropriate keystone. The room temperature coil geometry is given in Table I and Figure 1. A wedge is used in each layer to separate the coil blocks. The coil angles listed include the cable insulation, but the radii do not. It is assumed that an extra 2 mils of insulation per quadrant is used at the midplane.

The SSC design philosophy calls for "graded" conductors, in which the current density in each block can be different. In the eventual accelerator this would be done by using cables with different thicknesses per turn. For the prototype, however, it is more convenient and instructive to use the same cable but different currents. Since the peak fields in the outer blocks are smaller than those in the inner blocks, increasing the current in the outer blocks can result in a higher central field and more uniform quench propagation. For constructional convenience the currents in blocks 1 and 2 were required to be equal. There were thus 3 independent currents to be determined.

The coil design program (MAG2) incorporated a J_c vs B_p subroutine (DENS) for Nb_3Sn provided by G. Morgan.[1] A graph of the data is shown in Fig. 2. The curve assumes a copper to elements ratio of 1.25 and a temperature of 4.5 K.

Table II shows the central fields and multipoles obtained with two different sets of currents. In solution 43A the current in block 2 was required to equal its critical current. The currents in blocks 3 and 4 were larger, but below their critical values. The allowed multipoles are all small and the infinite permeability value of the central field is 89.5 kG. In solution 43B both blocks 2 and 3 are at their critical currents. This design achieves an additional 5 kG of central field with slightly worse values for the multipoles.[2] At any rate it is clear that the availability of 3 independently adjustable currents allows considerable freedom in obtaining an acceptable result from the magnetic measurements.

These designs should achieve saturated fields of 8 T, unless of course the production Nb_3Sn has worse J_c characteristics, or the stress involved in forming and assembling the coil causes serious degradation in performance.

Even so two additional factors that have not been included in the design act in our favor. The actual cable that is being ordered has a copper to elements ratio of 1/1, instead of 1.25/1, and the temperature can be lowered below 4.5 K.

References

1. G. Morgan, Magnet Division Analysis Section Note No. 42 (1983).

2. It is possible to achieve both the higher field and good multipoles by slightly altering the wedge and post angles (SSC-52), but it was felt that such fine tuning is premature at this point.

TABLE I
SSC-43 Coil Cross Section

Layer	Block #	Turns	ϕ_{start}	ϕ_{end}	r_i (cm)	r_i (cm)
Inner	1	15	0.15°	60.14	1.610	2.393
	2	3	64.20	76.20	1.610	2.393
Outer	3	12	0.10	33.92	2.449	3.231
	4	5	40.37	54.46	2.449	3.231

TABLE II
Multipoles, $b_n \times 10^4$ @ 1 cm

Solution	$I_1 = I_2$ (kA)	I_3 (kA)	I_4 (kA)	B_0 (kG)	b_2	b_4	b_6	b_8	b_{10}
SSC-43A	5.05	8.85	6.39	89.5	0.0	-0.1	-0.1	-0.1	0.1
SSC-43B	5.05	9.56	7.56	94.8	0.7	-1.4	0.1	0.0	0.1

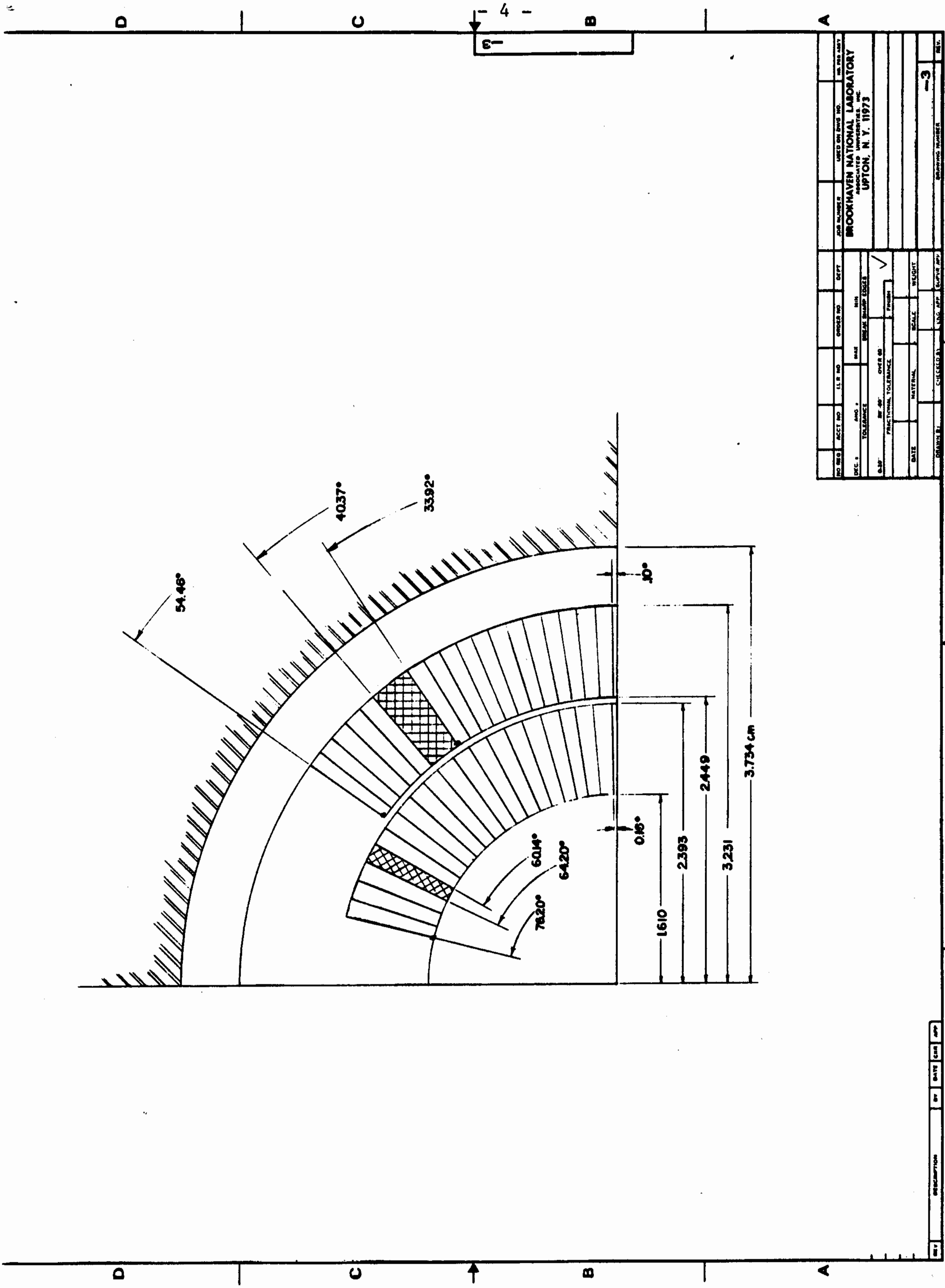
54.46°
40.37°
33.92°
.10°
0.18°
60.14°
64.20°
78.20°
1.610
2.393
3.231
2.449
3.734 cm
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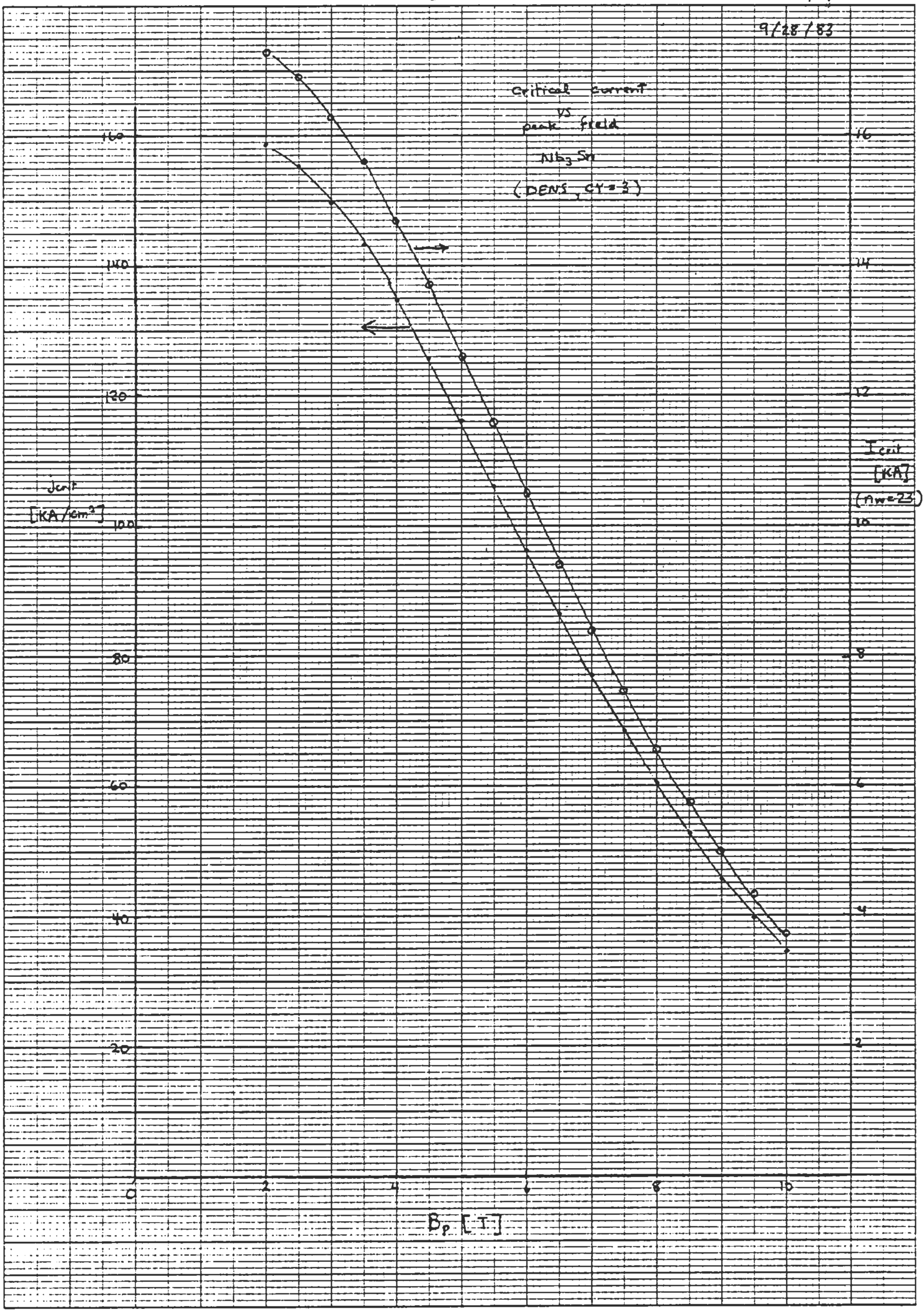
Figure 1

Fig. 2


9/28/83
Critical current vs peak field
Nb_3Sn
(DENS, CY=3)
Jcrit [KA/cm²]
Icrit [KA] (nw=23)
Bp [T]
0
2
4
6
8
10
20
40
60
80
100
120
140
160
2
4
6
8
10
12
14
16

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