A 5cm Dipole for the SSC - DE-1*

S. Caspi

**Lawrence Berkeley Laboratory
Accelerator & Fusion Research Division
1 Cyclotron Road
Berkeley, CA 94720**

April 30, 1990

***This was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division, U. S. Department of Energy, under Contract No. DE-AC03-76SF00098.**

MASTER

Abstract

A 5cm SSC superconducting dipole that develops 6.6 tesla at 5790 A is proposed. The two layer magnet has 12% more transfer function than the present design as a result of using thin collars and "close in" iron. The thin collars provide precise positioning of the coils ; they also provide minimum prestress (perhaps 2000 psi) as aid for magnet assembly. A welded skin around the iron provides the final prestress and shapes the coil geometry. A prestressed aluminum bar placed between the vertically split iron yokes provides precise control of the gap between yokes halves and is designed to allow the gap to close tightly during cooldown so that there is no decrease of prestress¹.

In order to reduce the effect of iron saturation on the field multipoles the iron ID has been optimised to an elliptical shape. The coil inner layer is a 30 strand cable with 1.3:1 cu/sc. The outer layer is a 36 strand cable with 1.8:1 cu/sc. At the operating field of 6.6 tesla the current density in the copper is 666 A/mm² and 760 A/mm² in the inner and outer layers respectively.

The magnet short sample performance is limited by the inner layer. Operating at 4.35 K the maximum current and central field are 6896 A and 7.95 tesla. The calculated operating short sample temperature at 6.6 tesla and 5798 A is 5.17 K (0.82 K temperature margin). The magnet stored energy is 100.0 (KJ/m) at the 5790 A operating current.

A mechanically similar 5cm bore two layer dipole for the cable test facility (D-16B-1) has been recently built and tested². The magnet had no collars and the iron was placed directly on the coil OD. The magnet's first quench was at 7 tesla with 6000 A and it reached 7.6 tesla at 6600 A.

Following are tables and Figures associated with the design.

¹ "Design of Coil Containment Structure for Cable Test Facility Dipole Magnet" — C.Peters., SC-MAG-265, November 15, 1989.

² "Design and Construction of a 5-cm Bore , 7.5 T Dipole for SSC Short Sample Testing", SC-MAG-269; LBL-28086a, March 1990.

SSC 5cm dipole

Transfer Function

Figure 1 Transfer function.

	Cu/SC	Bo(T)	Io (A)	Jcu(Io) A/mm ²	Bc(T)	To(K) F=1.0	To(K) F=0.95	Iss(A) F=1.0	Iss(A) F=0.95	Bc_ss(T) F=1.0	Bc_ss(T) F=0.95	Tss(K)
DE-1	1.0:1	6.6	5790	753	6.86	5.29	5.24	7111	7034	8.16	8.09	4.35
DE-1	1.3:1	6.6	5790	666	6.86	5.17	5.12	6896	6814	7.956	7.87	4.35
BNL		6.6	6500	748	6.91	5.03	5.03	7460	-	7.8	-	4.35
DE-1	1.5:1	6.6	5790	628	6.86	5.09	5.04	6762	6677	7.82	7.74	4.35
BNL		6.6	6500	705	6.91	4.94	4.94	7300	-	7.65	-	4.35

Table 1 Operating and short sample values for the 30 strand inner layer (see nomenclature in Fig. 2).

	Cu/SC	DT(K)	DT/Tss%	DI(A)	DI/Io%	DB(T)	DB/Bo%
DE-1	1.0:1	0.94	21.6	1321	22.8	1.30	18.95
DE-1	1.3:1	0.82	18.9	1106	19.1	1.10	16.0
BNL		0.68	15.6	960	14.8	0.89	12.9
DE-1	1.5:1	0.74	17.0	972	16.8	0.96	14.0
BNL		0.59	13.6	800	12.3	0.74	10.7

Table 2 Temperature , Current and Field Margins for the 30 strand inner layer (F=1.0).

$$DT = T_o - T_{ss} \quad DI = I_{ss} - I_o$$

$DB = B_{c_ss} - B_c$; $F=1.0$ (no degradation = 2750 (A/mm²) at 5 T, 4.2K) ; $F=0.95$ corresponds to a 5% degradation.

Figure 2 Nomenclature

LAYER	N strands	Diameter inch	CU:SC	Asc/turn (mm ²)	Acu/turn (mm ²)	Jc(4.2K,5T) (A/mm ²)
INNER	30	0.0318	1.3:1	6.684	8.689	2750
OUTER	36	0.0255	1.8:1	4.236	7.625	2750

Table 3 Cable parameters for the two layer dipole.

Figure 3 Top - 30 strand inner layer cable and bottom - 36 strand outer layer cable :

Figure 4 Coil closeup.

Figure 5 Magnet cross section

Figure 6 Load lines and short sample curves

SSC 5cm DIPOLE

Harmonics

Figure 7 Harmonics

Wed Apr 4 11:16:34 1990
/home/floenn/magi/coapl/magnetz/asc_dipole/5cm/30_36_strand/poisson/elll/withiron

March 29 1990 , 5 cm bore! <8705 CYCLE = 7910

Figure 8 Flux plot at 6.6 tesla , from POISSON.

Wed Apr 4 11:20:18 1990
/home/flann/mag/caspl/magnets/ssu..dipole/5cm/30_36_stre.d/poiseon/ell/wilhiren

March 29 1990 , 5 cm bore! <8705 CYCLE = 7910

Figure 9 Fringe field.

Training of D-16B-1

Figure 10 Performance of a 5cm bore dipole with, two layers of 28 and 36 strands , 4 wedges and close in iron.

Appendix A PK input and output.

INPUT

```

NEW SSC DIPOLE 30 strands inner 36 outer march 29 1990
  1 N1      .7000E+01 .2000E+01 .4000E+01 .1000E+02
  2 W2      .7200E+00 .1000E-06 .7200E+00 .3000E+01
  3 N3      .5000E+01 .2000E+01 .5000E+01 .1000E+01
  4 W4      .2706E+01 .2360E-06 .3500E+00 .9000E+01
  5 N5      .5000E+01 .2000E+01 .4000E+01 .9000E+01
  6 W6      .7614E+01 .1000E-06 .7500E+00 .9000E+01
  7 N7      .3000E+01 .2000E+01 .2000E+01 .5000E+01
 11 N11     .7000E+01 .3000E+01 .3000E+01 .1300E+02
 12 W12     .7975E+00 .4984E-06 .7200E+00 .4000E+01
 13 N13     .2200E+02 .3000E+01 .1300E+02 .2500E+02

SFCNIN RFE=5.575 ,ROPT=1.0,QUAD=.false.,DIPOLE=.true.,LSYM=4
align=.false. AMP=6000.0 $
Scrit t0 = 4.35 nstrands(1) = 30 nstrands(2)= 36
ds(1) = 0.0318 ds(2) = 0.0255
rcusc(1) = 1.3 rcusc(2) = 1.8 f(1) = 1.0 f(2) = 1.0
jm(1) = 2750.0 jm(2) = 2750.
tbm(1) = 4.2 tbm(2) = 4.2
bm(1) = 5.0 bm(2) = 5.0 $

1      4
2      -21.64      1.  <----- required at ROPT=1.25 cm
4      -0.4985      1.  <----- required at ROPT=1.25 cm
6      0.0          1.
8      0.0          1.

2
1 4.0 7.      2.5247      3.7439      1.      63.40      10.3
2 4.0 3.      3.8049      4.9733      1.      51.77      7.95
STWIST pb(5) = 16.0      pb(3) = 17.0 pb(7)=13.8672 $
SKEY $
SWIDTH $
FIX      1
FIX      3
FIX      5
FIX      7
FIX      11
FIX      13
CALL FCN      3
CALL FCN      6
PUNCH
EXIT
END

```

OUTPUT

```

-----
Transfer function = 12.463572
0  N      BN/BO      BPR      BEFF      AN/BO      APR      AEFF
0  0.1000E+01  10000.00  18.13  0.0000E+00  0.00  0.00
2  -0.1385E-02  -13.85  -0.03  0.0000E+00  0.00  0.00
4  -0.1991E-04  -0.20  0.00  0.0000E+00  0.00  0.00
6  0.2155E-05  0.02  0.00  0.0000E+00  0.00  0.00
8  0.3247E-05  0.03  0.00  0.0000E+00  0.00  0.00
10 -0.2881E-06  0.00  0.00  0.0000E+00  0.00  0.00
12 0.3178E-07  0.00  0.00  0.0000E+00  0.00  0.00
14 0.1265E-07  0.00  0.00  0.0000E+00  0.00  0.00
16 -0.5316E-08  0.00  0.00  0.0000E+00  0.00  0.00
18 0.2715E-09  0.00  0.00  0.0000E+00  0.00  0.00
OB EVALUATED AT R = 1.00000

```

ONEXT COMMAND...

```

*****
*** 8****CALL FCN      6.00000
*****

```

Peak fields and critical currents

```

Layer 1: Bpeak = 7.7743 T at ( 0.5423, 2.5806 ) on the Top
Superconducting cable geometry:
Operating temperature is 4.35 K
# strands = 30 strand dia = 0.031800 in , Cu:SC = 1.30 degradation factor = 1.00
Jc = 2750.0 A/mm^2, Bm = 5.00 T @ 4.20 K
Area-SC = .6684E-01 cm^2/turn; Area-Cu = .8689E-01cm^2/turn;
Jcu = 690.5624 A/mm^2/turn

```

b[t]	ic@pl[a]	-or+100a/mm2	
4.00000000	20987.2431	-763.172477	763.172477
4.20000000	20267.7228	-737.008100	737.008100
4.40000000	19548.5807	-710.857478	710.857478
4.60000000	18829.8496	-684.721804	684.721804
4.80000000	18111.5663	-658.602410	658.602410
5.00000000	17393.7719	-632.500796	632.500796
5.20000000	16675.5128	-606.418649	606.418649
5.40000000	15959.8416	-580.357877	580.357877
5.60000000	15243.8178	-554.320647	554.320647
5.80000000	14528.5092	-528.309426	528.309426
6.00000000	13813.9937	-502.327043	502.327043
6.20000000	13100.3606	-476.376748	476.376748
6.40000000	12387.7133	-450.462301	450.462301
6.60000000	11676.1720	-424.588073	424.588073
6.80000000	10965.8773	-398.759175	398.759175
7.00000000	10256.9946	-372.981624	372.981624
7.20000000	9549.72008	-347.262548	347.262548
7.40000000	8844.28773	-321.610463	321.610463
7.60000000	8140.97950	-296.035618	296.035618
7.80000000	7440.13789	-270.550469	270.550469
8.00000000	6742.18323	-245.170299	245.170299
8.20000000	6047.63710	-219.914076	219.914076

8.40000000	5357.15475	-194.805627	194.805627
8.60000000	4671.57093	-169.875307	169.875307
8.80000000	3991.96579	-145.162392	145.162392
9.00000000	3319.76223	-120.718626	120.718626

$I_{cp}/I_o = 1.2550$ $B_{co}/E_p = 1.0565$, $B_{ss} = 8.1337$ T @ 6277.3671 A
 Layer 2: $B_{peak} = 6.7297$ T at (2.3372, 3.1847) on the Top
 Superconducting cable geometry:
 Operating temperature is 4.35 K
 # strands = 36 strand dia = 0.025500 in , Cu:SC = 1.80 degradation factor = 1.00
 $J_c = 2750.0$ A/mm², $B_m = 5.00$ T @ 4.20 K
 $Area-SC = .4236E-01$ cm²/turn; $Area-Cu = .7625E-01$ cm²/turn;
 $J_{cu} = 786.8585$ A/mm²/turn

b[t]	ic@pl[a]	-or+100a/mm2	
4.00000000	13302.4785	-483.726490	483.726490
4.20000000	12846.4203	-467.142556	467.142556
4.40000000	12390.6019	-450.567340	450.567340
4.60000000	11935.0440	-434.001598	434.001598
4.80000000	11479.7638	-417.446176	417.446176
5.00000000	11024.8056	-400.902023	400.902023
5.20000000	10570.1808	-384.370209	384.370209
5.40000000	10115.9284	-367.851944	367.851944
5.60000000	9662.08648	-351.348599	351.348599
5.80000000	9208.69788	-334.861741	334.861741
6.00000000	8755.81193	-318.393161	318.393161
6.20000000	8303.48529	-301.944920	301.944920
6.40000000	7851.78350	-285.519400	285.519400
6.60000000	7400.78275	-269.119373	269.119373
6.80000000	6950.57212	-252.748077	252.748077
7.00000000	6501.25649	-236.409327	236.409327
7.20000000	6052.96013	-220.107641	220.107641
7.40000000	5605.83143	-203.848416	203.848416
7.60000000	5160.04908	-187.638148	187.638148
7.80000000	4715.83017	-171.484733	171.484733
8.00000000	4273.44110	-155.397858	155.397858
8.20000000	3833.21248	-139.389545	139.389545
8.40000000	3395.55965	-123.474896	123.474896
8.60000000	2961.01167	-107.673152	107.673152
8.80000000	2530.25320	-92.0092072	92.0092072
9.00000000	2104.18612	-76.5158588	76.5158588

$I_{cp}/I_o = 1.1848$ $B_{co}/E_p = 1.0734$, $B_{ss} = 7.0830$ T @ 6315.0385 A

poisson stuff for CIRCULAR high density high μ iron

Thu Mar 28 16:28:12 1990
/home/leon/r-r-1/naupl/magnets/sea_dipole/5cm/38_38_x-road/poisson

March 29 1990 , 5 cm bore! <8705 CYCLE = 890

Figure 11 High density POISSON output for circular iron at r=5.575 cm.

AUTOMESH

```

March 29 1990 , 5 cm bore! <870527.0922>
$geo NREG=8 XMAX=5.5750 YMAX=6.3565
dx=0.05 $
$reg npoint=9 mat=1 $
SPO X=0.0 Y=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=2.5247 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=3.7439 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=3.8049 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=4.9733 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=5.5750 theta=0.0 $
SPO nt=4 x0=0.0 y0=0.0 r=6.3565 theta=90.0 $
SPO nt=1 x0=0.0 y0=0.0 r=5.575 theta=90.0 $
SPO x=0.0 y=0.0 $
$REG mat=1 NPOINT=4 $
SPO nt = 1 x0=0.0 y0=0.0 r= 5.5750 theta=0.0 $
SPO NT=4 X0=0.0 Y0=0.0 R=6.3565 THETA=90.0 $
SPO NT=1 X0=0.0 Y0=0.0 R=5.5750 THETA=90.0 $
SPO NT=2 X0=0.0 Y0=0.0 R=5.5750 THETA=0.0 $
$REG mat=1 cur=-42000.0 NPOINT=5$
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=0.0 $
SPO NT=1 X0=0.0 Y0=0.0 R=3.7439 THETA=0.0 $
SPO NT=2 X0=0.0 Y0=0.0 R=3.7439 THETA=18.7505 $
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=23.5518 $
SPO NT=2 X0=0.0 Y0=0.0 R=2.5247 THETA=0.0 $
$REG mat=1 cur=-30000.0 NPOINT=5$
SPO NT=1 x0=0.0 y0=0.0 r= 2.5247 THETA= 24.62795 $
SPO NT=1 x0=0.0 y0=0.0 r= 3.7439 THETA=24.9473 $
SPO NT=2 x0=0.0 y0=0.0 r= 3.7439 theta=38.0432 $
SPO NT=1 x0=0.0 y0=0.0 R= 2.5247 THETA=41.05246 $
SPO NT=2 x0=0.0 y0=0.0 R=2.5247 THETA=24.62795 $
$REG mat=1 cur=-30000.0 NPOINT=5$
SPO NT=1 x0=0.0 y0=0.0 r= 2.5247 THETA=44.12712 $
SPO NT=1 x0=0.0 y0=0.0 r= 3.7439 theta=45.3070 $
SPO NT=2 x0=0.0 y0=0.0 r= 3.7439 theta=58.3948 $
SPO NT=1 x0=0.0 y0=0.0 R=2.5247 THETA=60.55156 $
SPO NT=2 x0=0.0 y0=0.0 R=2.5247 THETA= 44.12712 $
$REG mat=1 cur=-18000.0 NPOINT=5$
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=68.50 $
SPO NT=1 X0=0.0 Y0=0.0 R=3.7439 THETA=68.2611 $
SPO NT=2 X0=0.0 Y0=0.0 R=3.7439 THETA=76.02156 $
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=78.2147 $
SPO NT=2 X0=0.0 Y0=0.0 R=2.5247 THETA=68.50 $
$REG mat=1 cur=-42000.0 NPOINT=5$
SPO NT=1 x0=0.0 y0=0.0 r=3.8049 THETA=0.0 $
SPO NT=1 x0=0.0 y0=0.0 r=4.9733 theta=0.0 $
SPO NT=2 x0=0.0 y0=0.0 r=4.9733 theta=11.4562 $
SPO NT=1 x0=0.0 y0=0.0 R= 3.8049 THETA=12.8409 $
SPO NT=2 x0=0.0 y0=0.0 R= 3.8049 THETA=0.0 $
$REG mat=1 cur=-132000.0 NPOINT=5$
SPO NT=1 X0=0.0 Y0=0.0 R= 3.8049 THETA=13.81276 $
SPO NT=1 X0=0.0 Y0=0.0 R= 4.9733 THETA=15.9473 $
SPO NT=2 X0=0.0 Y0=0.0 R= 4.9733 THETA=51.7280 $
SPO NT=1 X0=0.0 Y0=0.0 R=3.8049 THETA= 53.861588 $
SPO NT=2 X0=0.0 Y0=0.0 R= 3.8049 THETA= 13.81276 $

```

POISSON INPUT

```

0 dump
*6 -2

```

```
*66 1.0
*46 6
*43 21
*45 21
*54 0.5 0.6 2.55 2.65
*110 10 19 1.0 90. 1.0 0.0 S COUNT
-l dump
```

POISSON OUTPUT

April 17 1990 , 5 cm bore! <8705

XJFACT = 1 , Mu infinite

	0	13	62	-4.385105E+04	0.58000	2.63000	2805.587	78119.888	78170.252	-8.4374E+03	1.4692E+04
OPole Pairs				N(AN)/R	N(An)/R/Al	N(BN)/R	N(Bn)/R/Bl	ABS(N(CN)/R)		Units	
Dipole				-7.4794E+04	1.0000E+04	0.0000E+00	0.0000E+00	7.4794E+04		10000.0000	
Sextupole				9.8284E+01	-1.3141E+01	0.0000E+00	0.0000E+00	9.8284E+01		-13.1406	
Decapole				1.2792E+00	-1.7104E-01	0.0000E+00	0.0000E+00	1.2792E+00		-0.1710	
14-pole				-1.2291E-01	1.6433E-02	0.0000E+00	0.0000E+00	1.2291E-01		0.0164	
18-pole				-1.6972E-01	2.2631E-02	0.0000E+00	0.0000E+00	1.6972E-01		0.0227	
22-pole				6.0490E-02	-8.0876E-03	0.0000E+00	0.0000E+00	6.0490E-02		-0.0081	
26-pole				-7.0624E-03	9.4425E-04	0.0000E+00	0.0000E+00	7.0624E-03		0.0009	
30-pole				-7.0823E-03	9.4691E-04	0.0000E+00	0.0000E+00	7.0823E-03		0.0009	
34-pole				4.2967E-02	-5.7447E-03	0.0000E+00	0.0000E+00	4.2967E-02		-0.0057	
38-pole				5.4120E-02	-7.2359E-03	0.0000E+00	0.0000E+00	5.4120E-02		-0.0072	

poisson stuff for ELLIPTICAL high density high μ iron

The Mar 29 17:23:56 1990
/home/ilean/mag/comp/magneto/one_dipole/5cm/38_38_strand/poisson/ell

March 29 1990 , 5 cm bore! <8705 CYCLE = 990

Figure 12 High density POISSON output for elliptical iron at $x=5.575$ cm. $y=6.3565$ cm

AUTOMESH

```

March 29 1990 , 5 cm bore! <870527.0922>
$geo NREG=8 XMAX=5.5750 YMAX=6.3565
      dx=0.05 $
$reg npoint=5 mat=1 $
SPO X=0.0 Y=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=2.5247 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=3.7439 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=3.8049 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=4.9733 theta=0.0 $
SPO nt=1 x0=0.0 y0=0.0 r=5.5750 theta=0.0 $
SPO nt=4 x0=0.0 y0=0.0 r=6.3565 theta=90.0 $
SPO nt=1 x0=0.0 y0=0.0 r=5.575 theta=90.0 $
SPO x=0.0 y=0.0 $
$REG mat=1 NPOINT=4 $
SPO nt = 1 x0=0.0 y0=0.0 r= 5.5750 theta=0.0 $
SPO NT=4 X0=0.0 Y0=0.0 R=6.3565 THETA=90.0 $
SPO NT=1 X0=0.0 Y0=0.0 R=5.5750 THETA=90.0 $
SPO NT=2 X0=0.0 Y0=0.0 R=5.5750 THETA=0.0 $
$REG mat=1 cur=-42000.0 NPOINT=5$
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=0.0 $
SPO NT=1 X0=0.0 Y0=0.0 R=3.7439 THETA=0.0 $
SPO NT=2 X0=0.0 Y0=0.0 R=3.7439 THETA=18.7505 $
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=23.5518 $
SPO NT=2 X0=0.0 Y0=0.0 R=2.5247 THETA=0.0 $
$REG mat=1 cur=-30000.0 NPOINT=5$
SPO NT=1 x0=0.0 y0=0.0 r= 2.5247 THETA= 24.62795 $
SPO NT=1 x0=0.0 y0=0.0 r= 3.7439 THETA=24.9473 $
SPO NT=2 x0=0.0 y0=0.0 r= 3.7439 theta=38.0432 $
SPO NT=1 x0=0.0 y0=0.0 R= 2.5247 THETA=41.05246 $
SPO NT=2 x0=0.0 y0=0.0 R=2.5247 THETA=24.62795 $
$REG mat=1 cur=-30000.0 NPOINT=5$
SPO NT=1 x0=0.0 y0=0.0 r= 2.5247 THETA=44.12712 $
SPO NT=1 x0=0.0 y0=0.0 r= 3.7439 theta=45.3070 $
SPO NT=2 x0=0.0 y0=0.0 r= 3.7439 theta=58.3948 $
SPO NT=1 x0=0.0 y0=0.0 R=2.5247 THETA=60.55156 $
SPO NT=2 x0=0.0 y0=0.0 R=2.5247 THETA= 44.12712 $
$REG mat=1 cur=-18000. NPOINT=5$
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=68.50 $
SPO NT=1 X0=0.0 Y0=0.0 R=3.7439 THETA=68.2611 $
SPO NT=2 X0=0.0 Y0=0.0 R=3.7439 THETA=76.02156 $
SPO NT=1 X0=0.0 Y0=0.0 R=2.5247 THETA=78.2147 $
SPO NT=2 X0=0.0 Y0=0.0 R=2.5247 THETA=68.50 $
$REG mat=1 cur=-42000. NPOINT=5$
SPO NT=1 x0=0.0 y0=0.0 r=3.8049 THETA=0.0 $
SPO NT=1 x0=0.0 y0=0.0 r=4.9733 theta=0.0 $
SPO NT=2 x0=0.0 y0=0.0 r=4.9733 theta=11.4562 $
SPO NT=1 x0=0.0 y0=0.0 R= 3.8049 THETA=12.8409 $
SPO NT=2 x0=0.0 y0=0.0 R= 3.8049 THETA=0.0 $
$REG mat=1 cur=-132000.0 NPOINT=5$
SPO NT=1 X0=0.0 Y0=0.0 R= 3.8049 THETA=13.81276 $
SPO NT=1 X0=0.0 Y0=0.0 R= 4.9733 THETA=15.9473 $
SPO NT=2 X0=0.0 Y0=0.0 R= 4.9733 THETA=51.7280 $
SPO NT=1 X0=0.0 Y0=0.0 R=3.8049 THETA= 53.861588 $
SPO NT=2 X0=0.0 Y0=0.0 R= 3.8049 THETA= 13.81276 $

```

POISSON INPUT

```

0 dump
*6 -2

```

```

*66 1.0
*46 6
*43 21
*45 21
*54 0.5 0.6 2.55 2.65
*110 10 19 1.0 90. 1.0 0.0 S COUNT
-1 dump

```

POISSON OUTPUT

April 17 1990 , 5 cm bore! <8705

XJFACT = 1 , Mu infinite

0 13 62 -4.113954E+04 0.58000 2.63000 3057.824 73451.639 73515.261 -8.8891E+03 1.4697E+04

	N(AN)/R	N(An)/R/A1	N(BN)/R	N(Bn)/R/B1	ABS(N(CN)/R)	Units
OPole Pairs						
Dipole	-7.0752E+04	1.0000E+04	0.0000E+00	0.0000E+00	7.0752E+04	10000.0000
Sextupole	-4.3237E+00	6.1111E-01	0.0000E+00	0.0000E+00	4.3237E+00	0.6111
Decapole	-1.7004E-01	2.4034E-02	0.0000E+00	0.0000E+00	1.7004E-01	0.0240
14-pole	-1.2690E-01	1.7936E-02	0.0000E+00	0.0000E+00	1.2690E-01	0.0179
18-pole	-1.8256E-01	2.5803E-02	0.0000E+00	0.0000E+00	1.8256E-01	0.0258
22-pole	6.8101E-02	-9.6253E-03	0.0000E+00	0.0000E+00	6.8101E-02	-0.0096
26-pole	3.0965E-02	-4.3766E-03	0.0000E+00	0.0000E+00	3.0965E-02	-0.0044
30-pole	9.6226E-03	-1.3600E-03	0.0000E+00	0.0000E+00	9.6226E-03	-0.0014
34-pole	2.9262E-02	-4.1358E-03	0.0000E+00	0.0000E+00	2.9262E-02	-0.0041
38-pole	3.9711E-02	-5.6127E-03	0.0000E+00	0.0000E+00	3.9711E-02	-0.0056

poisson stuff for ELLIPTICAL low density real μ iron

AUTOMESH

Wed Apr 4 17:21:38 1990
/hema/flonn/magi/cospl/magnets/esc_dipoles/Ecm/30_38_strand/pelaaen/ell/wilhiren

March 29 1990 , 5 cm bore! <8705 CYCLE = 0

Figure 13 Low density DUMP 0

```

March 29 1990 , 5 cm bore! <870527.0922>
$geo NREG=17 XHAX=18.1 YMAX=18.1
      xreg1=6.0 xreg2=7.0
      yreg1=7.0 yreg2=7.5
      dx=0.12 $
$reg npoint=12 mat=1 $
$PO X=0.0 Y=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=2.52491 theta=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=3.7439 theta=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=3.8049 theta=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=4.9733 theta=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=5.5750 theta=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=17.30 theta=0.0 $
$PO nt=1 x0=0.0 y0=0.0 r=18.0 theta=0.0 $
$PO nt=2 x0=0.0 y0=0.0 r=18.0 theta=90.0 $
$PO nt=1 x0=0.0 y0=0.0 r=17.3 theta=90.0 $
$PO nt=1 x0=0.0 y0=0.0 r=6.3565 theta=90.0 $
$PO x=0.0 y=0.0 $
$REG MAT=2 NPOINT=7 $
$PO NT=1 X0=0.0 Y0=0.0 R=5.575 THETA=0.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=16.51 THETA=0.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=16.51 THETA=70.2648 $
$PO NT=1 X0=0.0 Y0=0.0 R=14.6752 THETA=67.673 $
$PO NT=1 X0=0.0 Y0=0.0 R=13.575 THETA=90.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=6.3565 THETA=90.0 $
$PO NT=4 X0=0.0 Y0=0.0 R=5.575 THETA=0.0 $
$REG MAT=1 NPOINT=5 $
$PO NT=1 X0=8.0514 Y0=11.0410 R=1.6256 THETA=0.0 $
$PO NT=2 X0=8.0514 Y0=11.0410 R=1.6256 THETA=90.0 $
$PO NT=2 X0=8.0514 Y0=11.0410 R=1.6256 THETA=180.0 $
$PO NT=2 X0=8.0514 Y0=11.0410 R=1.6256 THETA=270.0 $
$PO NT=2 X0=8.0514 Y0=11.0410 R=1.6256 THETA=360.0 $
$REG MAT=1 NPOINT=4 $
$PO NT=1 X0=0.0 Y0=0.0 R=5.575 THETA=0.0 $
$PO NT=4 X0=0.0 Y0=0.0 R=6.3565 THETA=90.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=5.575 THETA=90.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=5.575 THETA=0.0 $
$REG mat=513 NPOINT=5 $
$PO nt=1 x0=0.0 y0=0.0 r= 17.3 theta=0.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=18.0 THETA=0.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=18.0 THETA=90.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=17.3 THETA=90.0 $
$PO nt = 2 x0=0.0 y0=0.0 r= 17.3 theta=0.0 $
$REG MAT=1 CUR=21000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52491 THETA=0.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=0.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=20.8868 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52485 THETA=24.2159 $
$PO NT=2 X0=0.0 Y0=0.0 R=2.52491 THETA=0.0 $
$REG MAT=1 CUR=21000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=0.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=0.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.77442 THETA=18.7062 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=20.8868 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=0.0 $
$REG MAT=1 CUR=15000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52485 THETA=24.2159 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=24.6585 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=39.2464 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52491 THETA=41.1243 $
$PO NT=2 X0=0.0 Y0=0.0 R=2.52485 THETA=24.2159 $
$REG MAT=1 CUR=15000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=24.6585 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=24.9517 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.77442 THETA=38.0065 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=39.2464 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=24.6585 $

```



```

$REG MAT=1 CUR=15000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52491 THETA=44.1083 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=44.8347 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=59.2386 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52491 THETA=60.5712 $
$PO NT=2 X0=0.0 Y0=0.0 R=2.52491 THETA=44.1083 $
$REG MAT=1 CUR=15000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=44.8347 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=45.3158 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.77442 THETA=58.3572 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=59.2386 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=44.8347 $
$REG MAT=1 CUR=9000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52491 THETA=68.5087 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=68.3611 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=76.8962 $
$PO NT=1 X0=0.0 Y0=0.0 R=2.52491 THETA=78.2545 $
$PO NT=2 X0=0.0 Y0=0.0 R=2.52491 THETA=68.5087 $
$REG MAT=1 CUR=9000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=68.3611 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=68.2633 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.77442 THETA=75.9978 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.15263 THETA=76.8962 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.15263 THETA=68.3611 $
$REG MAT=1 CUR=21000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=0.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.38818 THETA=0.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=4.38818 THETA=12.0664 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=12.9042 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.77442 THETA=0.0 $
$REG MAT=1 CUR=21000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.38818 THETA=0.0 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.9733 THETA=0.0 $
$PO NT=2 X0=0.0 Y0=0.0 R=4.9733 THETA=11.4609 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.38818 THETA=12.0664 $
$PO NT=2 X0=0.0 Y0=0.0 R=4.38818 THETA=0.0 $
$REG MAT=1 CUR=66000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=13.741 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.38818 THETA=15.0442 $
$PO NT=2 X0=0.0 Y0=0.0 R=4.38818 THETA=52.7275 $
$PO NT=1 X0=0.0 Y0=0.0 R=3.77442 THETA=54.0307 $
$PO NT=2 X0=0.0 Y0=0.0 R=3.77442 THETA=13.741 $
$REG MAT=1 CUR=66000.0 NPOINT=5 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.38818 THETA=15.0442 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.9733 THETA=15.9845 $
$PO NT=2 X0=0.0 Y0=0.0 R=4.9733 THETA=51.7872 $
$PO NT=1 X0=0.0 Y0=0.0 R=4.38818 THETA=52.7275 $
$PO NT=2 X0=0.0 Y0=0.0 R=4.38818 THETA=15.0442 $

```

POISSON INPUT

```

0 dump
*6 -2
*66 1.23
*46 6
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*110 8 10 1.0 90. 1.0 0.0 S COUNT
1 dump
*6 0
*126 21
*129 1
*66 1.23

```

```

*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
2 dump
*6 0
*126 21
*129 1
*66 1.5
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
3 dump
*6 0
*126 21
*129 1
*66 1.077
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
4 dump
*6 0
*126 21
*129 1
*66 1.0
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
5 dump
*6 0
*126 21
*129 1
*66 0.923076923
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
6 dump
*6 0
*126 21
*129 1
*66 0.769230769
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
7 dump
*6 0
*126 21
*129 1
*66 0.6153846
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
8 dump
*6 0

```

```

*126 21
*129 1
*66 0.4615384
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
9 dump
*6 0
*126 21
*129 1
*66 0.307692
*43 21
*45 21
*54 0.4 0.8 2.4 2.8
*46 6
*110 8 10 1.0 90. 1.0 0.0 S COUNT
-1 dump

```

Edited POISSON output

13:1 cu/sc

```

../out_edit.pois
baseline
9 dumps
72 separate harmonics

```

I[A]	x[cm]	y[cm]	Smax [T]
2769.2	0.56000	2.52000	3.38577
3692.3	0.56000	2.52000	4.51012
4615.4	0.56000	2.52000	5.59327
5538.5	0.56000	2.52000	6.59992
6000.0	0.56000	2.52000	7.07462
6462.0	0.56000	2.52000	7.53449
6900.0	0.56000	2.52000	7.95931
7380.0	0.56000	2.52000	8.41798
7380.0	0.56000	2.52000	9.02532

I[A]	Bo[T]	Tf [T/A]	b2	b4	b6	b8			
2769.2	-3.2650	-11.7903	-0.00986	0.01217	0.005274	0.004749	0.002971	0.002756	0.00
3692.3	-4.3489	-11.7783	-0.01583	0.02599	0.005193	0.00475	0.002945	0.002741	0.002
4615.4	-5.3910	-11.6805	-.1016	.1024	0.005181	0.004987	0.002881	0.002733	0.002
5538.5	-6.3544	-11.4732	-.2877	.1672	0.006191	0.005186	0.002508	0.002498	0.001
6000.0	-6.8046	-11.341	-1.197	.1807	0.006674	0.005532	0.002352	0.002473	0.001
6462.0	-7.2380	-11.2009	-2.529	.1766	0.006801	0.006025	0.002245	0.002516	0.001
6900.0	-7.6362	-11.067	-3.998	.1638	0.006714	0.00654	0.002156	0.002581	0.001
7380.0	-8.0654	-10.9287	-5.527	.1503	0.006978	0.007383	0.002246	0.002822	0.001
7380.0	-8.7037	-11.7936	0	0	0	0	0	0	0

Mu infinite iron point

Deleted B = 9.0253200

Operating temperature is 4.35 K

strands = 30 strand dia = 0.031800 in , Cu:SC = 1.30 degradation factor = 1.00

Jc = 2750.0 A/mm², Bm = 5.00 T @ 4.20 K

Area-SC = .6684E-01 cm²/turn; Area-Cu = .8689E-01cm²/turn;

Jcu = 666.4232 A/mm²/turn

True Jc = 866.35016

Bore = 6.600000 [T] 5790.264549 [A] 5.292875 [K]

Conductor = 6.858886 [T] 5790.264549 [A] 5.167384 [K]

Short sample 7.955758 [T] 6896.337524 [A] 4.349992 [K]

Bore maximum 7.632870 [T] 6896.337524 [A] 4.559254 [K]

1.5:1 cu/sc

```
../out_edit.pois
baseline
9 dumps
72 separate harmonics
```

I[A]	x[cm]	y[cm]	Bmax [T]
2769.2	0.56000	2.52000	3.38577
3692.3	0.56000	2.52000	4.51012
4615.4	0.56000	2.52000	5.59327
5538.5	0.56000	2.52000	6.59992
6000.0	0.56000	2.52000	7.07462
6462.0	0.56000	2.52000	7.53449
6900.0	0.56000	2.52000	7.95931
7380.0	0.56000	2.52000	8.41798
7380.0	0.56000	2.52000	9.02532

I[A]	Bo[T]	If [T/A]	b2	b4	b6	b8				
2769.2	-3.2650	-11.7903	-0.00986	0.01217	0.005274	0.004749	0.002971	0.002756	0.00	
3692.3	-4.3489	-11.7785	-0.01583	0.02599	0.005193	0.00475	0.002945	0.002741	0.002	
4615.4	-5.3910	-11.6805	.1016	.1624	0.005181	0.004987	0.002881	0.002733	0.002	
5538.5	-6.3544	-11.4732	-.2877	.1672	0.006191	0.005186	0.002508	0.002498	0.001	
6000.0	-6.8046	-11.341	-1.197	.1807	0.006674	0.005532	0.002352	0.002473	0.001	
6462.0	-7.2380	-11.2009	-2.529	.1766	0.006801	0.006025	0.002245	0.002516	0.001	
6900.0	-7.6362	-11.067	-3.998	.1638	0.006714	0.00554	0.002156	0.002581	0.001	
7380.0	-8.0654	-10.9287	-5.527	.1503	0.006978	0.007383	0.002246	0.002822	0.001	
7380.0	-8.7037	-11.7936	0	0	0	0	0	0	0	

```
Mu infinite iron point
Deleted B = 9.0253200
Operating temperature is 4.35 K
# strands = 30 strand dia = 0.031800 in, Cu:SC = 1.50 degradation factor = 1.00
Jc = 2750.0 A/mm^2, Bc = 5.00 T @ 4.20 K
Area-SC = .6149E-01 cm^2/turn; Area-Cu = .9223E-01cm^2/turn;
Jcu = 627.7900 A/mm^2/turn
True Jc = 941.68496
Bore = 6.600000 [T] 5790.264549 [A] 5.213945 [K]
Conductor = 6.858886 [T] 5790.264549 [A] 5.086287 [K]
Short sample 7.825698 [T] 6762.242798 [A] 4.350007 [K]
Bore maximum 7.510960 [T] 6762.242798 [A] 4.550897 [K]
```

1.0:1 cu/sc

```
../out_edit.pois
baseline
9 dumps
72 separate harmonics
```

I[A]	x[cm]	y[cm]	Bmax [T]
2769.2	0.56000	2.52000	3.38577
3692.3	0.56000	2.52000	4.51012
4615.4	0.56000	2.52000	5.59327
5538.5	0.56000	2.52000	6.59992
6000.0	0.56000	2.52000	7.07462
6462.0	0.56000	2.52000	7.53449
6900.0	0.56000	2.52000	7.95931
7380.0	0.56000	2.52000	8.41798
7380.0	0.56000	2.52000	9.02532

I[A]	Bo[T]	If [T/A]	b2	b4	b6	b8				
2769.2	-3.2650	-11.7903	-0.00986	0.01217	0.005274	0.004749	0.002971	0.002756	0.00	

3692.3	-4.3489	-11.7783	-0.01583	0.02599	0.005193	0.00475	0.002945	0.002741	0.002
4675.4	-5.3910	-11.6805	.1016	.1024	0.005181	0.004987	0.002881	0.002733	0.002
5538.5	-6.3544	-11.4732	-.2877	.1672	0.006191	0.005186	0.002508	0.002498	0.001
6000.0	-6.8046	-11.341	-1.197	.1807	0.006674	0.005532	0.002352	0.002473	0.001
6462.0	-7.2380	-11.2009	-2.529	.1766	0.006801	0.006025	0.002245	0.002516	0.001
6900.0	-7.6362	-11.067	-3.998	.1638	0.006714	0.00654	0.002156	0.002581	0.001
7380.0	-8.0654	-10.9287	-5.527	.1503	0.006978	0.007383	0.002246	0.002822	0.001
7380.0	-8.7037	-11.7936	0	0	0	0	0	0	0

Mu infinite iron point

Deleted B = 9.0253200

Operating temperature is 4.35 K

strands = 30 strand dia = 0.031800 in, Cu:SC = 1.00 degradation factor = 1.00

Jc = 2750.0 A/mm², Bm = 5.00 T @ 4.20 K

Area-SC = .7686E-01 cm²/turn; Area-Cu = .7686E-01cm²/turn;

Jcu = 753.3480 A/mm²/turn

True Jc = 753.34797

Bore = 6.600000 [T] 5790.264549 [A] 5.411088 [K]

Conductor = 6.858886 [T] 5790.264549 [A] 5.288693 [K]

Short sample 8.160818 [T] 7110.878906 [A] 4.350007 [K]

Bore maximum 7.824761 [T] 7110.878906 [A] 4.573660 [K]