

Jan-7-1991

EFFECT OF MANUFACTURING ERRORS ON HARMONICS
IN 5cm SSC MAGNETS

Jim,

Enclosed are computer runs showing the effect of manufacturing errors on harmonic coefficients. The results are from Alan Riddiford's code with some modifications to account for errors.

Each run has a comment section for that run followed by the type of errors used in the coil geometry. The first table shows the skew and normal field component for inner and outer coils (in KGauss) and the ratios of these component to the principal moment in units of 10^{-4} . The second table shows the total coefficients and the ratios.

Third table contains the dipole field variation as a function of X along the x-axis. The errors are all taken to be 10 mils and the insulation is taken as part of the cable cross section.

Note that the current density is assumed to change for cables under compression, i.e., the cross section area is reduced for these cables. The wedge sizes are also changed slightly in each case.

Akbar Mokhtarani

NSEGS = 45 SEGMENTS; DIPOLE SYMMETRY

RIRON = 6.7820 CM
 RIRON = 2.6701 INCHES
 RREF = 1.0000 CM
 RREF = 0.3937 INCHES
 ROFF = 0.0000 CM
 ROFF = 0.0000 INCHES
 CURRENT = 5.0000 KAMPS/TURN
 SEGMENT AREA = 0.0319 SQINS
 CDENSE = 156.7836 KAMPS/SQIN
 FACTOR = 2.4302 KGAUSS*INCH
 SEGMENT AREA = 0.0249 SQINS
 CDENSE = 200.5953 KAMPS/SQIN
 FACTOR = 3.1092 KGAUSS*RREF

comments for this run:
 original cross section

Multipole coefficients for inner and outer coils
 higher coefficients (n>1) are in 10**-4

pole	a(in)	b(in)	a(out)	b(out)	a(in)/b1	b(in)/b1	a(out)/b1	b(out)/b1
1	0.0000000	22.4493844	0.0000000	29.7782447	0.0000000	4298.3732473	0.0000000	5701.6267527
2	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
3	0.0000000	-0.2820305	0.0000000	0.2832381	0.0000000	-54.0002515	0.0000000	54.2314762
4	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
5	0.0000000	0.0153110	0.0000000	-0.0150151	0.0000000	2.9315996	0.0000000	-2.8749305
6	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7	0.0000000	-0.0000452	0.0000000	-0.0000810	0.0000000	-0.0008483	0.0000000	-0.0155033
8	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
9	0.0000000	0.0001722	0.0000000	0.0000393	0.0000000	0.00329717	0.0000000	0.0075249

Multipole coefficients (total). Skew, Normal, ratios

	a(out)	b(out)	RATIO	DIFF
1	0.0000000	10000.000	10000.000	0.000
2	0.0000000	0.000	10000.002	0.002
3	0.001207632	0.231	10000.009	0.009
4	0.0000000	0.000	10000.021	0.021
5	0.00295989	0.057	10000.038	0.038
6	0.0000000	0.000	10000.061	0.061
7	0.000126138	-0.024	10000.090	0.090
8	0.0000000	0.000	10000.126	0.126
9	0.000211505	0.040	10000.172	0.172

units	BOTH	AIR	IRON	RATIO	DIFF
X =	0.000	39.56729081	12.660333608	10000.000	0.000
X =	0.100	52.227641187	12.660503193	10000.002	0.002
X =	0.200	52.227677852	12.661011735	10000.009	0.009
X =	0.300	52.227740087	12.661858602	10000.021	0.021
X =	0.400	52.227829501	12.663042738	10000.038	0.038
X =	0.500	52.227948342	12.664562665	10000.061	0.061
X =	0.600	52.228099853	12.666416481	10000.090	0.090
X =	0.700	52.228289236	12.668601861	10000.126	0.126
X =	0.800	52.228525613	12.671116057	10000.172	0.172
X =	0.900	52.228825459	12.673956895	10000.229	0.229
X =	1.000	52.229218049	12.677117778	10000.304	0.304
X =	1.100	52.229735662	12.680597682	10000.407	0.407
X =	1.200	52.230514577	12.684391158	10000.552	0.552
X =	1.300	52.231631760	12.688493334	10000.766	0.766
X =	1.400	52.233304635	12.692988911	10001.087	1.087
X =	1.500	52.235828436	12.697602167	10001.570	1.570
X =	1.600	52.239628088	12.702569666	10002.297	2.297
X =	1.700	52.245300479	12.707876712	10003.384	3.384
X =	1.800	52.253668258	12.713434450	10004.985	4.985

X = 1.900 1.900 52.265832463 39.546559693 12.719262769 10007.315 7.315
X = 2.000 2.000 52.283267441 39.557913581 12.725353880 10010.653 10.653
X = 2.100 2.100 52.307899466 39.576189964 12.731699503 10015.367 15.367
X = 2.200 2.200 52.342170714 39.603679633 12.738291081 10021.931 21.931
X = 2.300 2.300 52.389268207 39.644138623 12.746119684 10030.947 30.947
X = 2.478 2.478 52.517934827 39.760084960 12.757849867 10055.585 55.585

5 cm SSC magnet, new coil geometry, No

NSEGS = 45 SEGMENTS; DIPOLE SYMMETRY

RIRON = 6.7825 INCHES CM
RIRON = 2.6701 INCHES CM
RREF = 1.0000 INCHES CM
RREF = 0.3937 INCHES CM
ROFF = 0.0000 INCHES CM
ROFF = 0.0000 INCHES CM
CURRENT = 5.0000 KAMPS/TURN
CURRENT AREA = 0.0319 KAMPS/SQIN
CDENSE = 156.7836 KAMPS/SQIN
FACTOR = 2.4302 KGAUSS*INCH
SEGMENT AREA = 0.0249 KAMPS/SQIN
CDENSE = 200.5853 KAMPS/SQIN
FACTOR = 3.1092 KGAUSS*RREF

comments for this run:
run on case 1

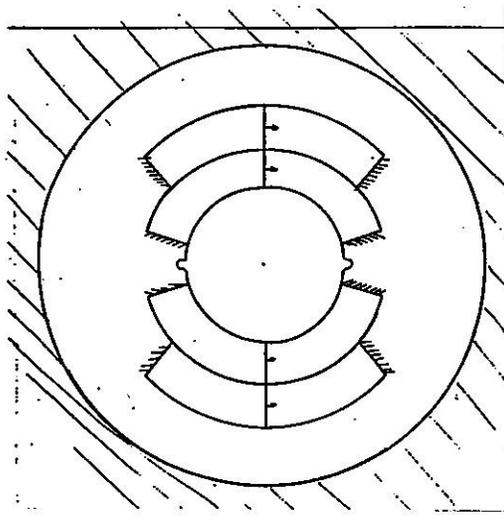
case: 1 L/R symmetric, vertical displacement of the coil mid-plane (poles fixed)

Multipole coefficients for inner and outer coils

higher coefficients (n>1) are in 10**4

Table with 9 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(in)/b1, a(out)/b1, b(out)/b1. Contains numerical data for poles 1 through 9.

Table with 9 columns: RREF, units, cm, BOTH, AIR, IRON, RATIO, DIFF. Contains numerical data for poles 1 through 9.



1.444
2.146
3.202
4.767
7.053
10.338
14.989
21.475
30.397
54.813

10001.444
10002.146
10003.202
10004.767
10007.053
10010.338
10014.989
10021.475
10030.397
10054.813

12.697487477
12.702480760
12.707758900
12.713314909
12.719141384
12.725230511
12.731574069
12.738163436
12.744989600
12.751716381

39.537174724
39.535647462
39.536082595
39.538702004
39.544812986
39.555882860
39.573827266
39.601113684
39.640882025
39.755673464

52.234682201
52.238328222
52.243841495
52.252016912
52.263954370
52.281113371
52.305401326
52.339277120
52.386871625
52.513388845

1.500 1.500
1.600 1.600
1.700 1.700
1.800 1.800
1.900 1.900
2.000 2.000
2.100 2.100
2.200 2.200
2.300 2.300
2.478 2.478

X =
X =
X =
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X =
X =
X =
X =
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X =

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(-SNOW2E)

5 cm SSC magnet, new coil geometry, No

NSEGS = 45 SEGMENTS; DIPOLE SYMMETRY

RIRON = 8.7820 CM
RIRON = 2.6701 INCHES
RREF = 1.0000 CM
RREF = 0.3937 INCHES
ROFF = 0.0000 CM
ROFF = 0.0000 INCHES
CURRENT = 5.0000 KAMPS/TURN
CURRENT AREA = 0.0319 SQINS
CDENSE = 156.7836 KGAUSS*INCH
FACTOR = 2.4302 SQINS
SEGMENT AREA = 0.0249 KAMPS/SQIN
CDENSE = 200.5953 KGAUSS*REF
FACTOR = 3.1092

comments for this run:

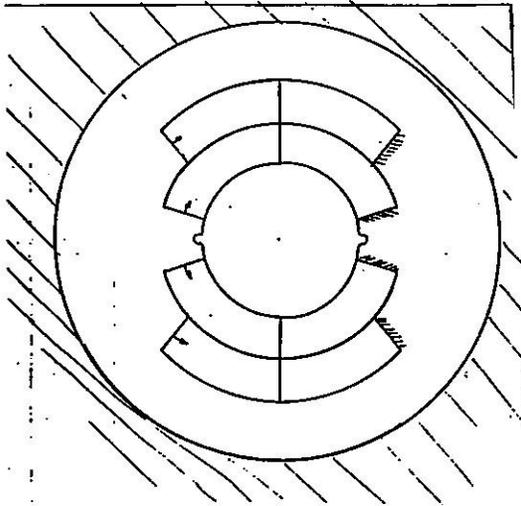
run on case 2

***** case: 2 L/R symmetric, vertical displacement of the pole only (lower pole fixed) *****
error= 10.00 mils

***** Multipole coefficients for inner and outer coils *****
higher coefficients (n>1) are in 10**4

Table with 9 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(in)/b1, a(out)/b1, b(out)/b1. Rows 1-9 contain numerical data for various multipole coefficients.

Table with 9 columns: RREF units, cm, BOTH, AIR, IRON, RATIO, DIFF. Rows X-X contain numerical data for various ratios and differences.



X =	1.500	1.500	52.325448998	39.611782293	12.713667706	10005.456	5.456
X =	1.800	1.800	52.331591794	39.612814354	12.718777440	10006.630	6.630
X =	1.700	1.700	52.339594187	39.615414606	12.724179580	10008.161	8.161
X =	1.800	1.800	52.350217614	39.620350475	12.729867139	10010.192	10.192
X =	1.900	1.900	52.364489433	39.628666726	12.736832709	10012.921	12.921
X =	2.000	2.000	52.383773198	39.641704726	12.742068472	10016.608	16.608
X =	2.100	2.100	52.409866547	39.661284348	12.748566199	10021.595	21.595
X =	2.200	2.200	52.445017159	39.689699901	12.755317257	10028.319	28.319
X =	2.300	2.300	52.492194287	39.729881669	12.762312618	10037.340	37.340
X =	2.478	2.478	52.618118614	39.842760057	12.776368657	10061.419	61.419

5 cm SSC magnet, new coil geometry, No

NSEGS = 45 SEGMENTS; DIPOLE SYMMETRY

RIRON = 6.7820 CM
RIRON = 2.6701 INCHES
RREF = 1.0000 CM
RREF = 0.3937 INCHES
ROFF = 0.0000 CM
ROFF = 0.0000 INCHES
CURRENT = 5.0000 KAMPS/TURN
CDENSE = 156.7836 KAMPS/SQIN
FACTOR = 2.4302 KGAUSS*INCH
SEGMENT AREA = 200.5953 KAMPS/SQIN
FACTOR = 3.1092 KGAUSS*RREF

comments for this run:
run on case 3

Vertical displacement of the coil with respect to the yoke
error= 10.00 mils

Multipole coefficients for inner and outer coils
higher coefficients (n>1) are in 10**4

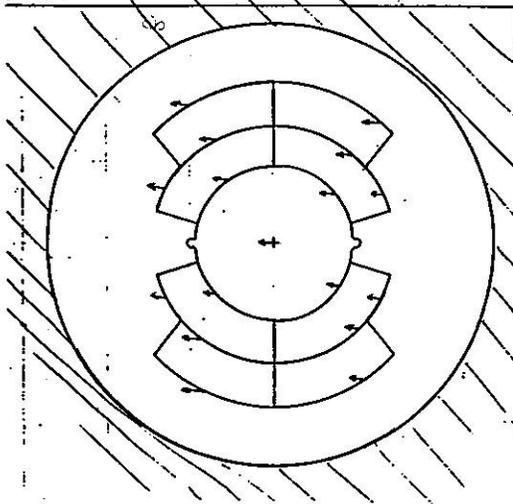
Table with 9 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(in)/b1, a(out)/b1, b(out)/b1. Contains numerical data for poles 1 through 9.

Multipole coefficients (total). Skew, Normal, ratios

Table with 9 columns: pole, ATR, IRON, RATIO, DIFF. Contains numerical data for poles 1 through 9.

RREF

Table with 9 columns: units, cm, BOTH, ATR, IRON, RATIO, DIFF. Contains numerical data for units 1 through 9.



X = 1.500 1.500 52.235714202 39.538138344 12.697575857 10001.548 1.548
X = 1.600 1.600 52.239452585 39.536885580 12.702566985 10002.262 2.262
X = 1.700 1.700 52.245035231 39.537192398 12.707842834 10003.331 3.331
X = 1.800 1.800 52.253271852 39.539875235 12.713398418 10004.908 4.908
X = 1.900 1.900 52.265254157 39.546033821 12.719229336 10007.282 7.282
X = 2.000 2.000 52.282431996 39.557125221 12.725396775 10010.491 10.491
X = 2.100 2.100 52.306898992 39.575051477 12.731847515 10015.138 15.138
X = 2.200 2.200 52.340496338 39.602262399 12.738239939 10021.609 21.609
X = 2.300 2.300 52.386932205 39.641875172 12.745057033 10030.500 30.500
X = 2.478 2.478 52.513873594 39.756098651 12.757777043 10054.805 54.805

5 cm SSC magnet, new coil geometry, No

45 SEGMENTS; DIPOLE SYMMETRY

NSEGS = RIRON = 6.7820 INCHES CM
RIRON = 2.6701 INCHES CM
RREF = 1.0000 INCHES CM
RREF = 0.3937 INCHES CM
ROFF = 0.0000 INCHES CM
ROFF = 0.0000 INCHES CM
CURRENT = 5.0000 KAMPS/TURN
SEGMENT AREA = 0.0319 KAMPS/SQIN
CDENSE = 156.7838 KGAUSS*INCH
FACTOR = 2.4302 SQINS
SEGMENT AREA = 0.0249 KAMPS/SQIN
CDENSE = 200.5953 KGAUSS*RREF
FACTOR = 3.1092

comments for this run:

run on case 4

***** case: 4 U/D symmetric, displacement of the pole on the right side only *****

***** error= 10.00 mils *****

***** Multipole coefficients for inner and outer coils *****

***** higher coefficients (n>1) are in 10**4 *****

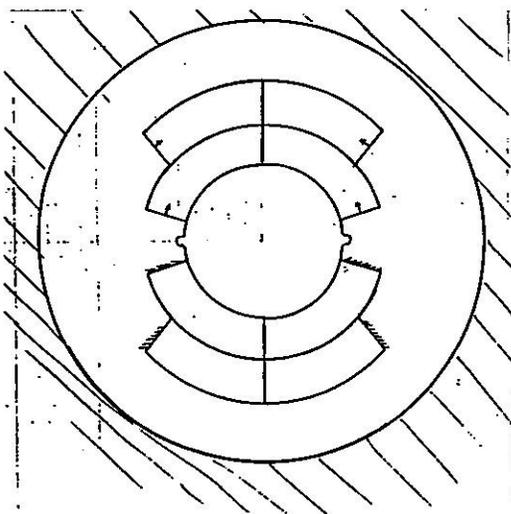
Table with 9 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(in)/b1, a(out)/b1, b(out)/b1. Rows 1-9 contain numerical data for various multipole coefficients.

Multipole coefficients (total). Skew, Normal, ratios

Table with 9 rows and 4 columns: pole, a(out), b(out), ratio. Rows 1-9 contain numerical data for skew, normal, and ratio coefficients.

RREF units cm

Table with 9 rows and 4 columns: X, units, cm, ratio. Rows 1-9 contain numerical data for RREF units and ratios.



X =	1.500	1.500	39.671367400	12.718925991	10017.853	17.853
X =	1.800	1.600	39.876178384	12.724397735	10019.821	19.821
X =	1.700	1.700	39.682520366	12.730164032	10022.137	22.137
X =	1.800	1.800	39.691139988	12.736218006	10024.942	24.942
X =	1.900	1.900	39.703058045	12.742652357	10028.433	28.433
X =	2.000	2.000	39.719828053	12.749159368	10032.864	32.864
X =	2.100	2.100	39.742617347	12.756090997	10038.574	38.574
X =	2.200	2.200	39.774302139	12.763158430	10045.996	45.996
X =	2.300	2.300	39.817578062	12.770532993	10055.681	55.681
X =	2.478	2.478	39.935400182	12.784261913	10080.836	80.836

5 cm SSC magnet, new coil geometry, No

45 SEGMENTS; DIPOLE SYMMETRY

NSEGS = RIRON = 6.7820 CM
RIRON = 2.6701 INCHES
RREF = 1.0000 CM
RREF = 0.3937 INCHES
ROFF = 0.0000 CM
ROFF = 0.0000 INCHES
CURRENT = 5.0000 KAMPS/TURN
SEGMENT AREA = 166.7836 KAMPS/SQIN
CDENSE = 2.4302 KGAUSS*INCH
FACTOR = 0.0249 SQINS
SEGMENT AREA = 200.5953 KAMPS/SQIN
CDENSE = 3.1092 KGAUSS*RREF
FACTOR =

comments for this run:
run on case 5

case: 5 Horizontal displacement of the coil with respect to the yoke
error= 10.00 mils

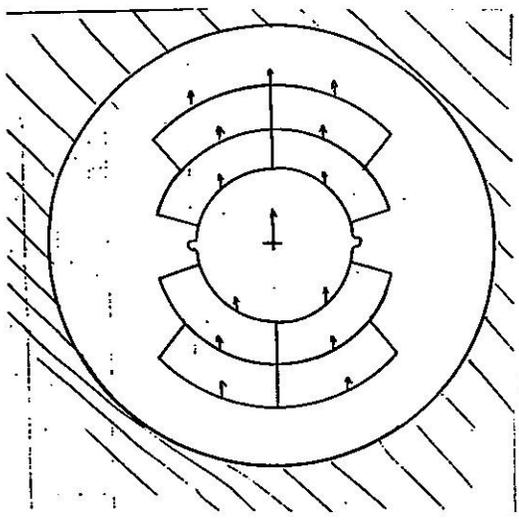
Multipole coefficients for inner and outer coils
higher coefficients (n>1) are in 10**4
pole a(in) b(in) a(out) b(out) a(in)/b1 b(out)/b1 a(out)/b1 b(in)/b1

Table with 8 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(out)/b1, a(out)/b1. Rows 1-9 contain numerical data for various multipole coefficients.

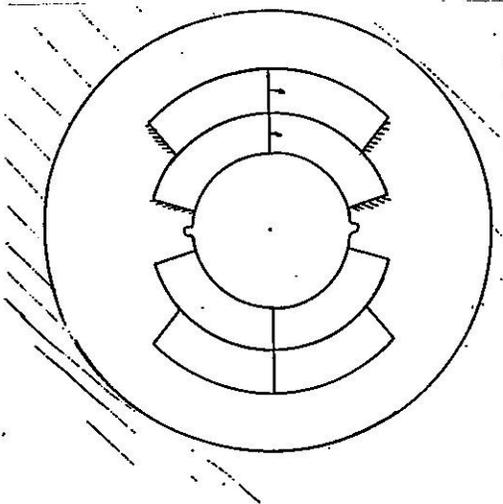
Multipole coefficients (total). Skew, Normal, ratios

Table with 8 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(out)/b1, a(out)/b1. Rows 1-9 contain numerical data for skew, normal, and ratio coefficients.

Table with 8 columns: RREF units, cm, BOTH, AIR, IRON, RATIO, DIFF. Rows 1-9 contain numerical data for various ratios and differences.



X =	1.500	1.500	39.538760478	12.718724666	10005.718	5.718
X =	1.800	1.800	39.537302675	12.725146718	10008.688	6.688
X =	1.700	1.700	39.537280686	12.731857099	10007.950	7.950
X =	1.800	1.800	39.539488680	12.738848953	10009.707	8.707
X =	1.900	1.900	39.544913610	12.746114998	10012.141	12.141
X =	2.000	2.000	39.555007845	12.753647524	10015.516	15.516
X =	2.100	2.100	39.571674894	12.761438408	10020.180	20.180
X =	2.200	2.200	39.596970515	12.769479108	10026.582	26.582
X =	2.300	2.300	39.634200428	12.777760675	10035.298	35.298
X =	2.478	2.478	39.742344600	12.793091053	10058.938	58.938



5 cm SSC magnet, new coil geometry, No
 NSEGS = 45 SEGMENTS; DIPOLE SYMMETRY
 RIRON = 6.7820 CM
 RIRON = 2.6701 INCHES
 RREF = 1.0000 CM
 RREF = 0.3937 INCHES
 ROFF = 0.0000 CM
 ROFF = 0.0000 INCHES
 CURRENT = 5.0000 KAMPS/TURN
 AREA = 0.9319 KAMPS/SQIN
 CDENSE = 156.7836 KGAUSS*INCH
 FACTOR = 2.4302 KAMPS/SQIN
 SEGMENT AREA = 200.5953 KAMPS*INCH
 CDENSE = 3.1092 KGAUSS*REF

comments for this run:
 run on case 6

 case: 6 Vertical displacement of the coil mid-plane on one side only (poles fixed)

 error= 10.00 mils

 Multipole coefficients for inner and outer coils
 higher coefficients (n>1) are in 10***-4
 pole a(in) b(in) a(out) b(out) a(in)/b1 b(out)/b1 a(out)/b1 b(out)/b1

	a(in)	b(in)	a(out)	b(out)	a(in)/b1	b(out)/b1	a(out)/b1	b(out)/b1
1	0.0541238	22.4492227	0.0462102	29.7781513	10.3631105	4298.3632806	8.8478909	5701.6367194
2	0.0209383	-0.0001499	0.0146362	-0.0000842	4.0090693	-0.0286980	2.8023952	-0.0122998
3	0.0951878	-0.2821089	0.0033433	0.2832125	0.9933083	-54.0155177	0.6401380	54.2268254
4	0.0009268	0.0000308	0.0000308	-0.0000080	0.1774232	-0.0059022	0.1155795	-0.0015315
5	0.0001961	0.0153003	0.0000843	-0.0150172	0.0375413	2.9295504	-0.0161423	-2.8753509
6	0.0000834	-0.0000039	0.0000091	-0.0000005	0.0159611	-0.0007521	0.0017452	-0.0000974
7	0.0000393	-0.0000468	0.0000013	-0.0000011	0.0075333	-0.0008953	0.0002558	-0.0155258
8	0.0000174	-0.0000007	0.0000005	0.0000000	0.0033303	-0.0001405	0.0001049	-0.0000054
9	0.0000082	0.0001719	0.0000002	0.0000393	0.0015764	0.00329075	0.0000453	0.0075236

Multipole coefficients (total). Skew, Normal, ratios
 1 0.108334015 52.22733974 19.211 10000.000
 2 0.035574490 -0.000214121 6.811 -0.041
 3 0.008631061 0.001103604 1.633 0.211
 4 0.001530276 -0.000038825 0.293 -0.007
 5 0.000280375 0.000283070 0.054 0.054
 6 0.000092476 -0.000004437 0.018 -0.001
 7 0.000040679 -0.000127880 0.008 -0.024
 8 0.000017941 -0.000000782 0.003 0.000
 9 0.000008470 0.000211161 0.002 0.040

units	BOTH	AIR	IRON	RATIO	DIFF
cm	52.227373974	39.567092419	12.660281555	10000.000	0.000
0.100	0.100	39.568913958	12.660449030	9999.998	-0.002
0.200	0.200	52.227373527	12.660956014	10000.000	0.000
0.300	0.300	52.227410216	12.661801875	10000.007	0.007
0.400	0.400	52.227469232	12.662984353	10000.018	0.018
0.500	0.500	52.227554335	12.664502569	10000.035	0.035
0.600	0.600	52.227668313	12.666354620	10000.056	0.056
0.700	0.700	52.227815823	12.668538177	10000.085	0.085
0.800	0.800	52.228005342	12.671050492	10000.121	0.121
0.900	0.900	52.228262557	12.673886387	10000.168	0.168
1.000	1.000	52.228585785	12.677048263	10000.232	0.232
1.100	1.100	52.229054035	12.680528095	10000.322	0.322
1.200	1.200	52.229738440	12.684317430	10000.453	0.453
1.300	1.300	52.230767885	12.688417393	10000.650	0.650
1.400	1.400	52.232110000	12.692820682	10000.951	0.951

X = 1.500 1.500 52.234746392 39.537224819 12.697521573 10001.412 1.412
X = 1.600 1.600 52.238409558 39.535895840 12.702513916 10002.113 2.113
X = 1.700 1.700 52.243921970 39.538130926 12.707791143 10003.168 3.168
X = 1.800 1.800 52.252099249 39.538752984 12.713346265 10004.734 4.734
X = 1.900 1.900 52.264042308 39.544870431 12.719171878 10007.021 7.021
X = 2.000 2.000 52.281212041 39.555951875 12.725260166 10010.308 10.308
X = 2.100 2.100 52.305517722 39.573914813 12.731602909 10014.962 14.962
X = 2.200 2.200 52.339420693 39.601229209 12.738191484 10021.454 21.454
X = 2.300 2.300 52.386055005 39.641038128 12.745016876 10030.383 30.383
X = 2.478 2.478 52.513687909 39.756946576 12.757741335 10054.821 54.821

NSEGS = RIRON = 45 SEGMENTS; DIPOLE SYMMETRY

RIRON = 6.7820 CM
RIRON = 2.6701 INCHES
RREF = 1.0000 CM
RREF = 0.3937 INCHES
ROFF = 0.0000 CM
ROFF = 0.0000 INCHES
CURRENT = 5.0000 KAMPS/TURN
SEGMENT AREA = 0.0319 SQINS
CDENSE = 160.7836 KAMPS/SQIN
FACTOR = 2.4302 KGAUSS*INCH
SEGMENT AREA = 0.0249 SQINS
CDENSE = 200.5953 KAMPS/SQIN
FACTOR = 3.1092 KGAUSS*RREF

comments for this run:
run on case 7

***** Mid-plane insulation increased by twice the error
error= 4.00 mils

***** Multipole coefficients for inner and outer coils
higher coefficients (n>1) are in 10**4

Table with 9 columns: pole, a(in), b(in), a(out), b(out), a(in)/b1, b(in)/b1, a(out)/b1, b(out)/b1. Contains numerical data for poles 1 through 9.

Table with 9 columns: RREF, units, cm, BOTH, AIR, IRON, RATIO, DIFF. Contains numerical data for poles 1 through 9.

X =	1.500	1.500	52.174041594	39.483081999	12.690959595	9995.361	-4.639
X =	1.600	1.600	52.171820833	39.475951095	12.695869737	9994.935	-5.065
X =	1.700	1.700	52.170630747	39.469472034	12.701058712	9994.688	-5.312
X =	1.800	1.800	52.170822783	39.464303380	12.706519403	9994.744	-5.256
X =	1.900	1.900	52.173599065	39.461354799	12.712244266	9995.276	-4.724
X =	2.000	2.000	52.180080460	39.461856122	12.718225338	9998.518	-3.482
X =	2.100	2.100	52.191887346	39.467433108	12.724454239	9998.780	-1.220
X =	2.200	2.200	52.211134528	39.480212353	12.730922176	10002.467	2.467
X =	2.300	2.300	52.240541860	39.502921907	12.737619953	10008.101	8.101
X =	2.478	2.478	52.329491498	39.579392488	12.750099011	10025.142	25.142