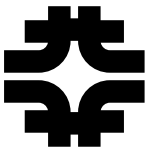

Fermi National Accelerator Laboratory

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MINOS Detector Steel Magnetic Measurements

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MINOS DETECTOR STEEL MAGNETIC MEASUREMENTS

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ABSTRACT

Magnetic measurements were made on one steel plate of the MINOS far detector. The conventionally used technique of measuring sense coil voltage induced by step changes in excitation current voltage was successful in providing stable, repeatable measurements. Measurements were made at several locations on the steel and the results are presented.

MINOS DETECTOR STEEL MAGNETIC MEASUREMENTS

Some characteristics of the magnetic properties of iron or steel can be determined by measuring the fields induced in a sense coil by step current changes in a magnetizing coil. In the MINOS detector, a variety of sense coils with a judiciously chosen number of turns were installed on the steel detector plate located in NMS (see Figure 2). The sense coils were readout by the integrator shown schematically in Figure 1 below.

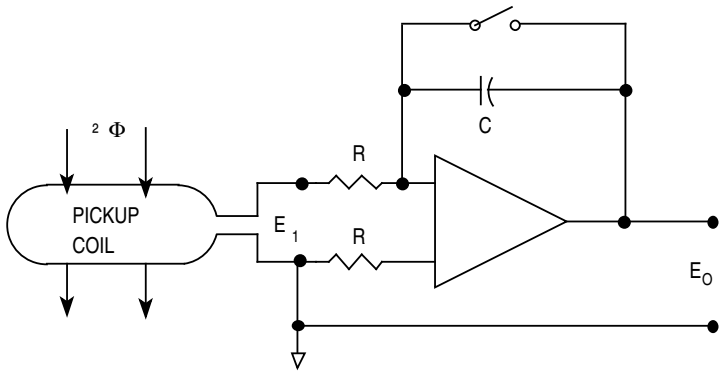


Figure 1

For this circuit,

$$E_0 = \frac{-1}{RC}\int_0^T E_1 dt \qquad \text{(a)}$$

where E_1 is the induced voltage at the winding caused by the change in magnetizing current. From the Faraday induction law:

$$E_1 = -N\frac{d\Phi}{dt}$$

where,

$$\Delta\Phi = \text{change of flux}$$
$$\text{N} = \text{number of turns}$$

Also, the magnetic flux is related to the magnetic flux density by:

$$\Phi = \int_S B \bullet dS$$

$$B = \frac{\Delta\Phi}{S} \qquad \text{(b)}$$

For (a) we can write:

$$\int_0^T E_1 dt = -N \int_0^T d\Phi / dt = -N(\Delta\Phi)$$

and from (b) the output of the voltage integrator is related to the change in the flux density as follows:

$$E_0 = \frac{N}{RC} \Delta\Phi$$

$$E_0 = \frac{NS}{RC} B$$

$$B = \frac{RC}{NS} E_0$$

Since the product of R and C determines the final accuracy of the integrator, it was measured by applying a precisely known (amplitude and width) pulse to the amplifier input and measuring the output. Based upon this calibration, a value of RC = 4.945 x 10^{-2} was determined and will be used throughout the subsequent discussion.

A series of induction measurements were made on a single plane of the MINOS detector steel to evaluate the efficacy of the measurement scheme and to compare the measurements to those determined by FEA. Initially, five coils were installed on the plane; one single turn coil from center to outside and four additional five turn coils placed equally on radius. As a result of the measurements using these coils, it was decided to add several additional coils in an attempt to better understand the field non-uniformity and the apparent effect of the plane support steel on the field shape. Figure 2 shows the final coil arrangement and identification setup. Figure 3 shows the schematic of the setup for the WHT coil.

As was stated above, several simplifying assumptions were made to evaluate the data; among them uniform flux through the steel volume and no air gaps was assumed. Clearly this is not the case for the MINOS detector plate. Furthermore, the non-uniformity of the flux in the MINOS plate makes it difficult to make a precise estimate of H. Consequently, the plots that follow are of B versus I in amperes. In spite of these limitations, the discussion that follows was used to determine the relative measures of the magnetic flux density versus the exciting current and plot the BI curves shown on pages 5 through 9.

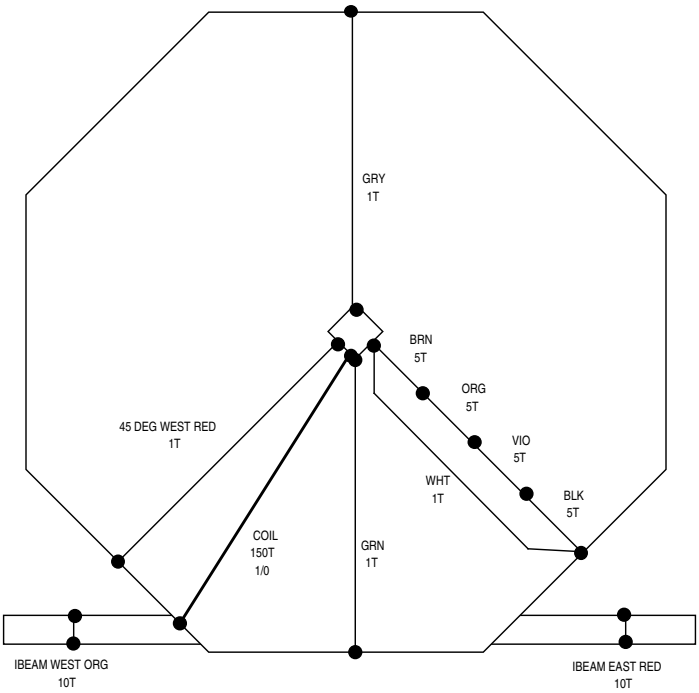


Figure 2

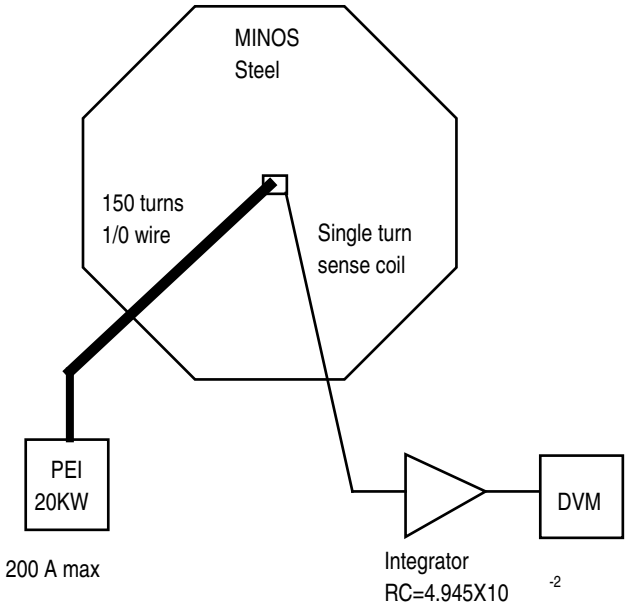


Figure 3

For the integrator used and the area of the MINOS detector plate sense coils:

$R = 10^4$ ohms
$C = 4.945 \times 10^{-6}$ farads
WHT, GRN, GRY and 45 DEG WEST RED coils
$N = 1$
$S = 0.074$ m^2
BRN, ORG, VIO and BLK coils
$N = 5$
$S = 0.018$ m^2
IBEAM WEST ORG and IBEAM EAST RED
$N = 10$
$S = 0.011$ m^2

Based upon the simplifying assumptions and for these values,

$$\Delta B = \frac{4.945 \times 10^{-2}}{(N)(S)} E_0$$

$\Delta B = 0.6682 E_0$ tesla for the WHT, GRN, GRY and 45 DEG WEST RED coils

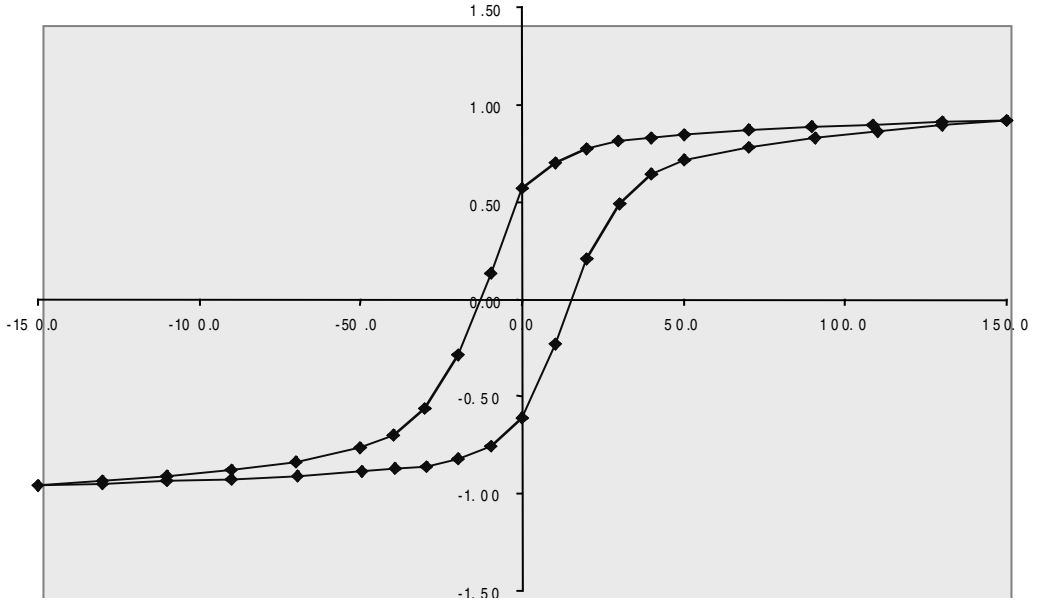
$\Delta B = 0.5369 E_0$ tesla for BRN, ORG, VIO and BLK coils

$\Delta B = 0.4495 E_0$ tesla for IBEAM WEST ORG and IBEAM EAST RED coils

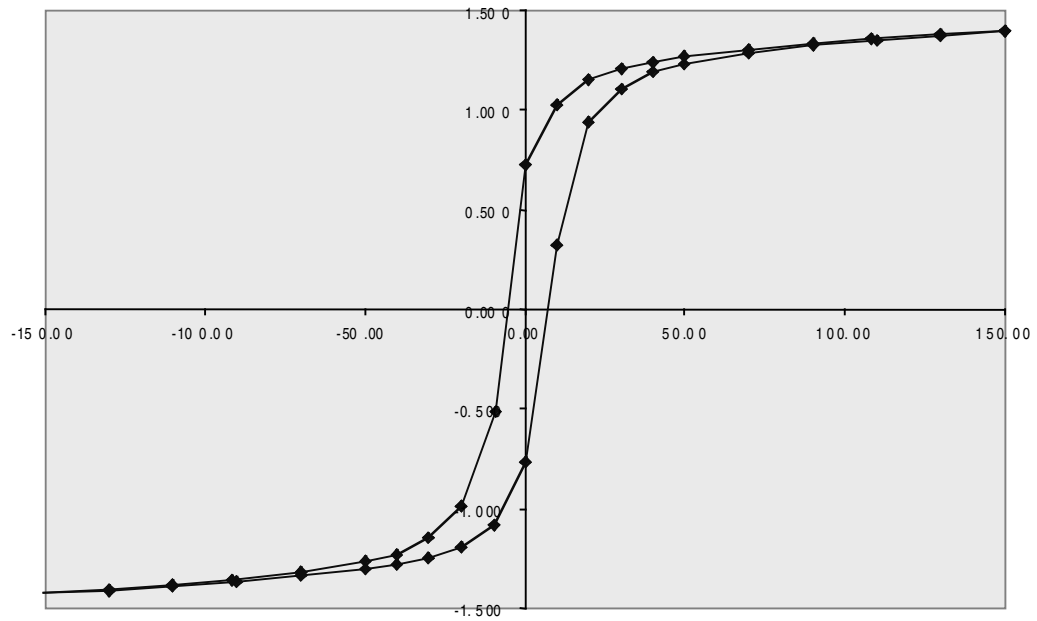
Table 1 and 2 are the direct results from the measurements for full cycle runs. At the start of each run, the current was run up to a maximum of 150 amperes to fully saturate parts of the steel (100 amperes is the expected maximum operating current). The current was then reduced in steps to zero. The power supply was reversed and the current was run up in steps to a maximum 150 amperes and then run down to zero current. The power supply polarity was once again reversed and the current was increased in steps to 150 amperes (the starting current value and polarity). The step sizes are shown in the Tables and were chosen merely to improve the data plots. The data was then adjusted to minimize the effect of integrator drift and to ensure symmetry. The results are shown on pages 4 through 9.

Several observations can readily be made; the energizing coil placement is not optimal and the steel support structure strongly affects the field lines in the detector steel. Several measurements were taken in an attempt to quantify the effect of the support steel and the IBEAM sense coils show the results of these measurements. It is clear that a significant field exists and to some extent short circuits the flux in the detector plate.

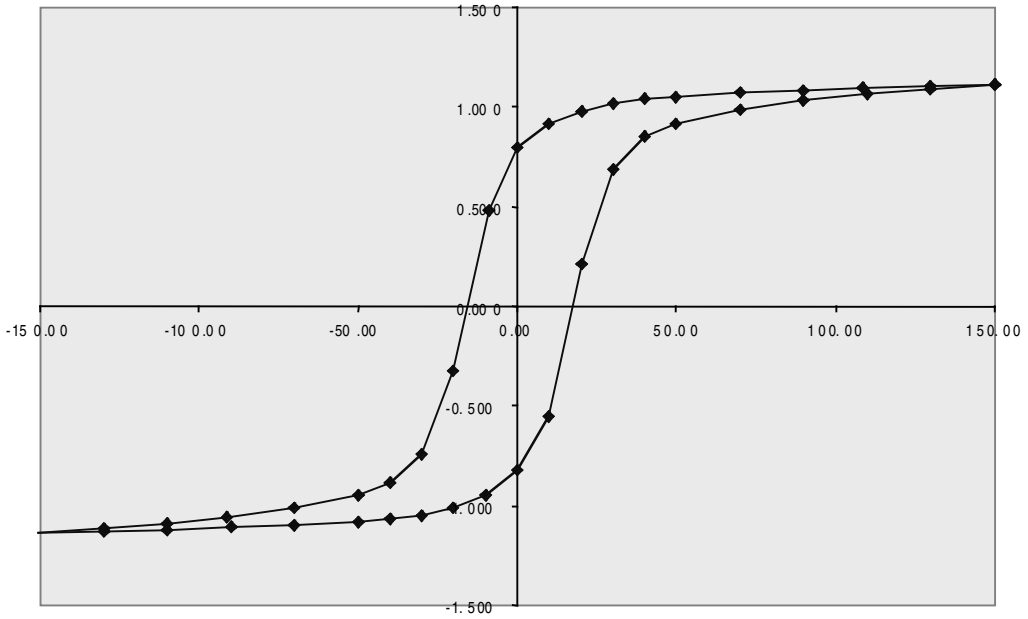
WHT CAL



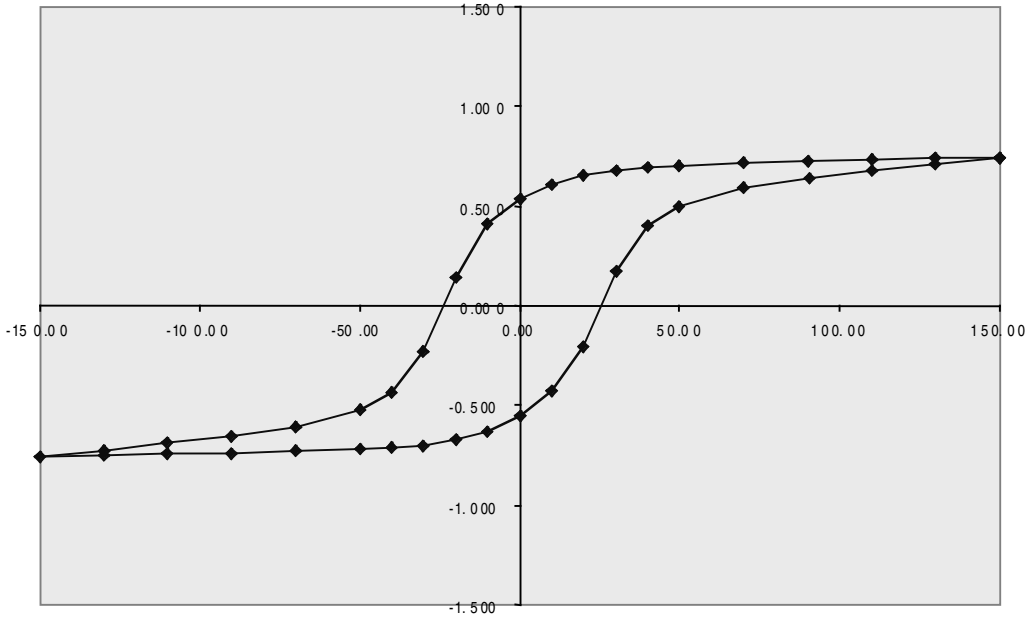
BRN CAL

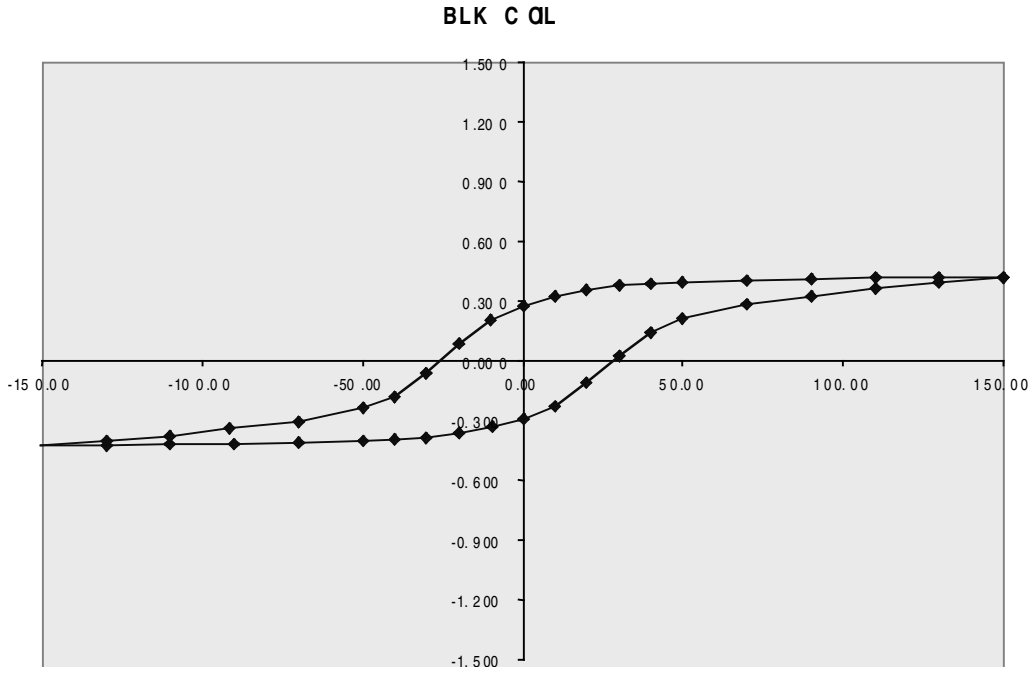


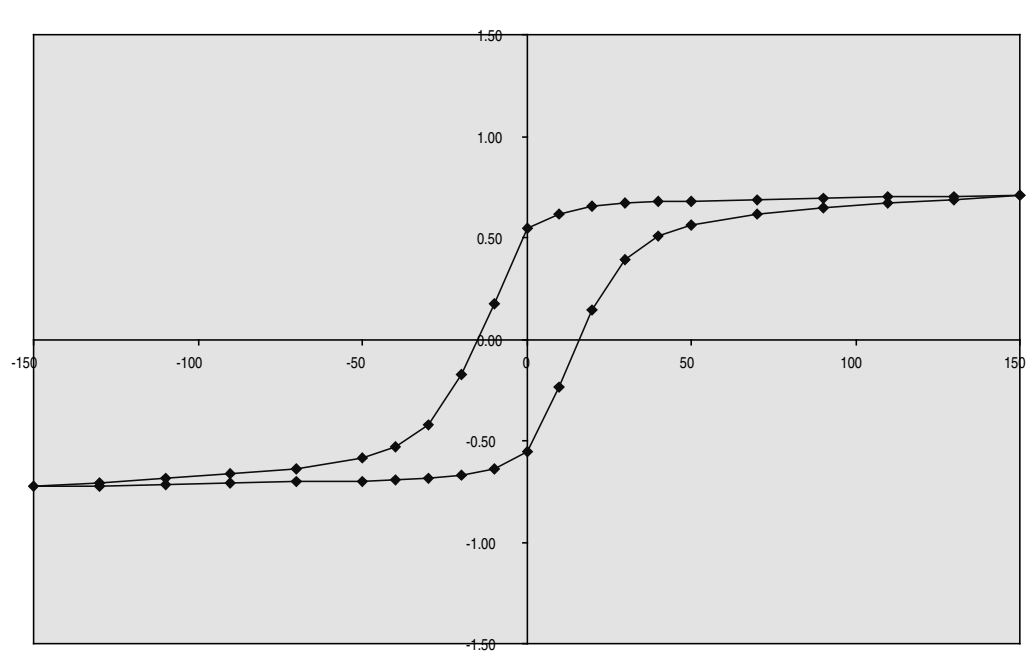
ORG CAL



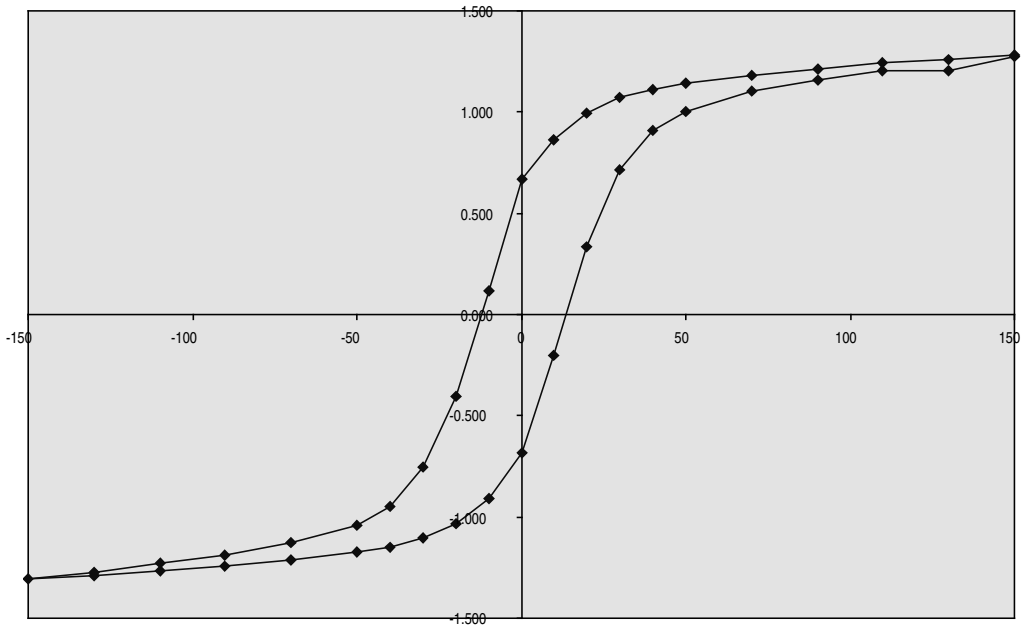
VIO CAL



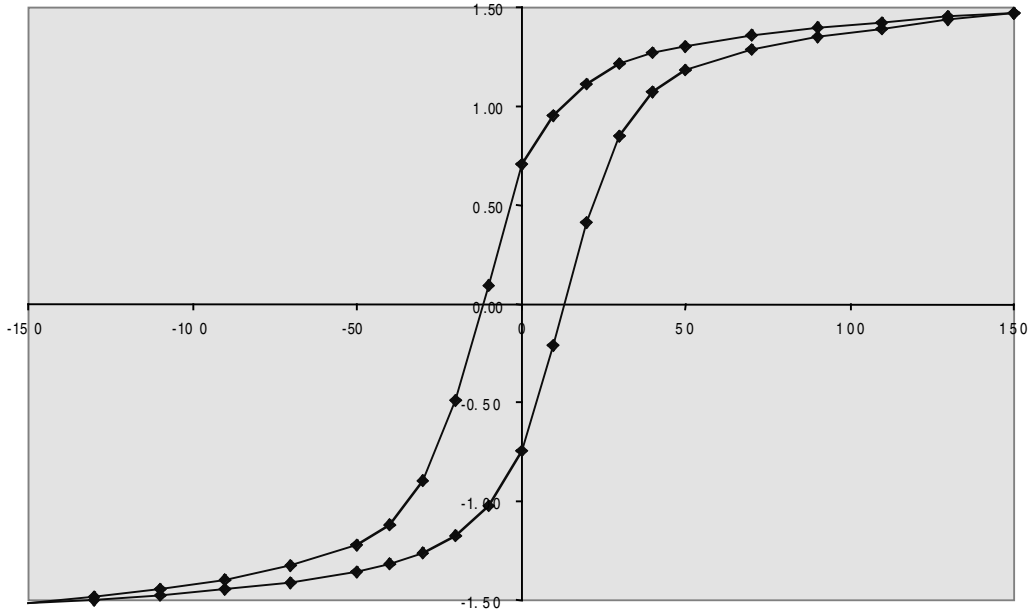

BLK CAL
1.500
1.200
0.900
0.600
0.300
0.000
-0.300
-0.600
-0.900
-1.200
-1.500
-150.00
-100.00
-50.00
0.00
50.00
100.00
150.00


TOP GRY
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-150
-100
-50
0
50
100
150

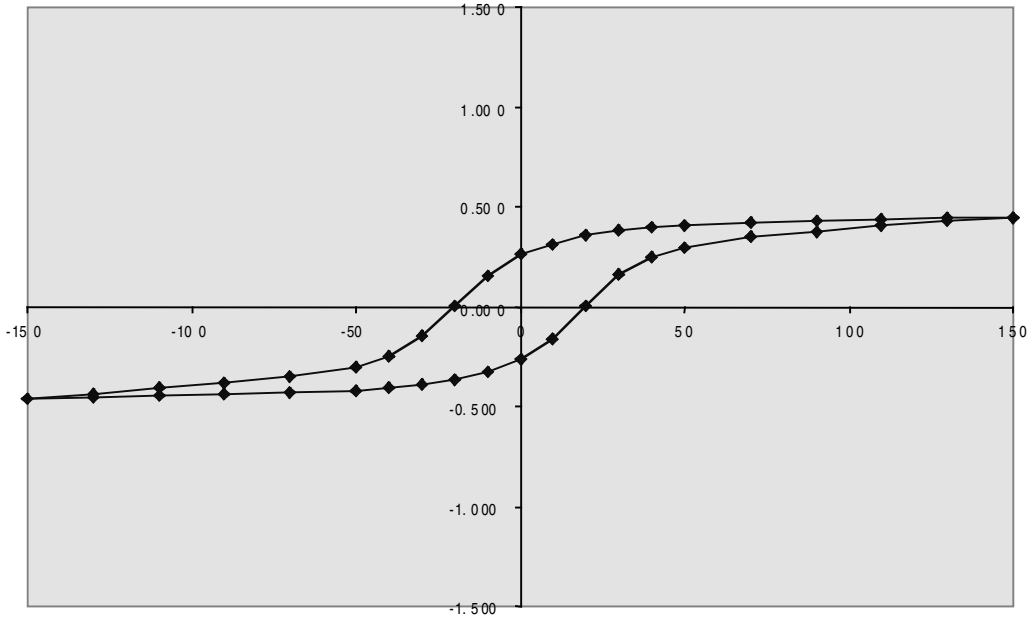
BOTTOM GRN



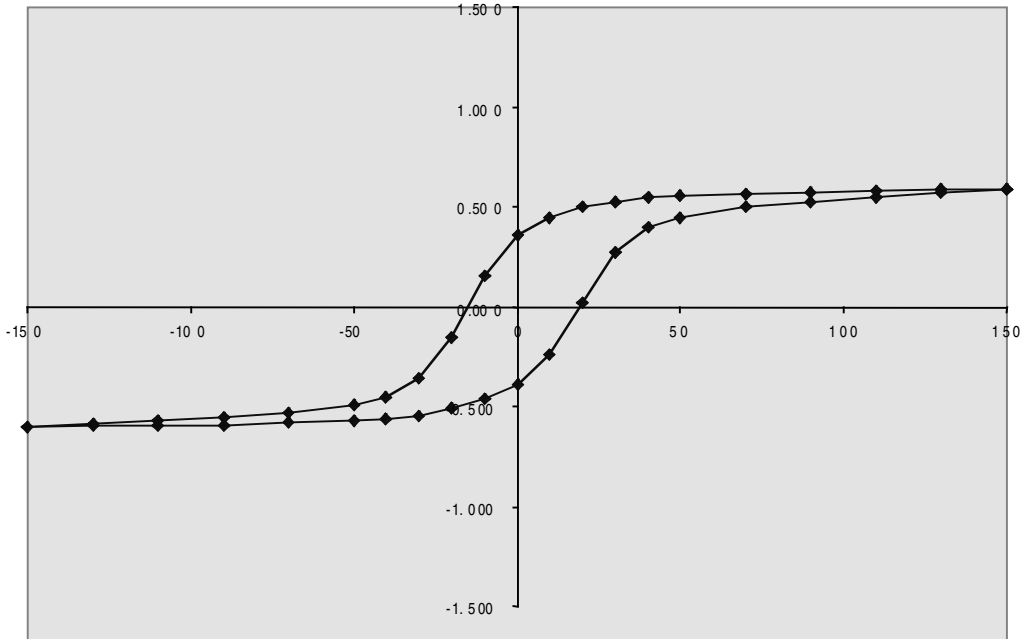
WEST 45 DEG RED



IBEAM EAST RED



IBEAM WEST ORG



Integrator: R=10K, C=4.945 uF					Current: 1V = 20A				Date:	12/1/98
Temperature @ start=		67 deg F							Name:	
Sensor	WHT				Sensor	BRN			Sensor	ORG
# of turns	1				# of turns	5			# of turns	5
Area=	0.0737	sq meters			Area=	0.018425	sq meters		Area=	0.01843
Polarity	I	I	Integrator	Polarity	I	I	Integrator	Polarity	I	I
(Reset)	amps	volts	volts		amps	volts	volts		amps	volts
F (reset)	150.0	7.50	0.00	F (reset)	150.0	7.50	0	F (reset)	150.0	7.50
67 degF	130.0	6.50	-0.01		130.0	6.50	-0.031		130.0	6.50
	108.4	5.42	-0.03		108.4	5.42	-0.067		108.4	5.42
	89.8	4.49	-0.04		90.0	4.50	-0.109		90.0	4.50
	70.0	3.50	0.06		70.0	3.50	-0.1604		70.0	3.50
	50.0	2.50	-0.09		50.0	2.50	-0.227		50.0	2.50
	40.0	2.00	-0.11		40.0	2.00	-0.27		40.0	2.00
	29.8	1.49	-0.14		30.0	1.50	-0.336		30.0	1.50
	20.0	1.00	-0.19		20.0	1.00	-0.44		20.0	1.00
	10.0	0.50	-0.29		10.0	0.50	-0.663		10.0	0.50
	0.0	0.00	-0.49		0.0	0.00	-1.22		0.0	0.00
R	-10.0	-0.50	-0.48	R	-9.0	-0.45	-3.53	R	-9.0	-0.45
	-20.0	-1.00	-1.14	95 degF	-20.0	-1.00	-4.41		-20.0	-1.00
	-30.0	-1.50	2.17		-30.0	-1.50	-4.7	106 degF	-30.0	-1.50
	-40.0	-2.00	2.38		-40.0	-2.00	-4.85		-40.0	-2.00
	-50.0	-2.50	2.47		-50.0	-2.50	-4.92		-50.0	-2.50
	-70.0	-3.50	-2.57		-70.0	-3.50	-5.01		-70.0	-3.50
	-90.0	-4.50	-2.63		-91.4	-4.57	-5.08		-91.4	-4.57
	-110.0	-5.50	-2.67		-110.0	-5.50	-5.13		-110.0	-5.50
	-130.0	-6.50	-2.71		-130.0	-6.50	-5.17		-130.0	-6.50
77 degF	-150.0	-7.50	-2.74		-150.4	-7.52	-5.2		-150.4	-7.52
	-130.0	-6.50	-2.72		-130.0	-6.50	-5.17		-130.0	-6.50
	-110.0	-5.50	-2.70		-110.0	-5.50	-5.13		-110.0	-5.50
	-90.0	-4.50	-2.68		-90.0	-4.50	-5.08		-90.0	-4.50
	-69.8	-3.49	-2.65		-69.8	-3.49	-5.027		-70.0	-3.50
	-49.8	-2.49	-2.62		-49.8	-2.49	-4.96		-50.0	-2.50
	-39.4	-1.97	-2.59		-40.0	-2.00	-4.91		-40.0	-2.00
	-29.8	-1.49	-2.57		-30.0	-1.50	-4.85		-30.0	-1.50
	-20.0	-1.00	-2.51		-20.0	-1.00	-4.75		-20.0	-1.00
	-9.8	-0.49	-2.41	98 degF	-9.8	-0.49	-4.54		-10.0	-0.50
	0.0	0.00	-2.19		0.0	0.00	-3.95		0.0	0.00
F	10.0	0.50	-1.61	F	10.0	0.50	-1.91	F	10.0	0.50
84 degF	20.0	1.00	-0.96		20.0	1.00	-0.77	110 degF	20.0	1.00
	30.0	1.50	-0.53		30.0	1.50	-0.45		30.0	1.50
	40.0	2.00	-0.30		40.0	2.00	-0.29		40.0	2.00
	50.0	2.50	-0.19		50.0	2.50	-0.204		50.0	2.50
	70.0	3.50	-0.08		70.0	3.50	-0.102		70.0	3.50
	90.6	4.53	-0.01		90.0	4.50	-0.033		90.0	4.50
	110.0	5.50	0.04		110.0	5.50	0.02		110.0	5.50
	130.0	6.50	0.09		130.0	6.50	0.068		130.0	6.50
86 degF	150.0	7.50	0.14	100 degF	150.0	7.50	0.11		150.0	7.50

Table 1

Integrator: R=10K, C=4.945 uF						Current: 1V = 20A			
Temperature @ start=		67 deg F							
Sensor	VIO					Sensor	BLK		
# of turns	5					# of turns	5		
Area=	0.018425	sq meters				Area=	0.018425	sq meters	
Polarity	I	I	Integrator		Polarity	I	I	Integrator	
(Reset)	amps	volts	volts			amps	volts	volts	
F (reset)	150.0	7.50	0.000		F (reset)	150.0	7.50	0.000	
114 degF	130.0	6.50	-0.007		125 degF	130.0	6.50	-0.005	
	110.0	5.50	-0.017			110.0	5.50	-0.012	
	90.0	4.50	-0.030			90.0	4.50	-0.022	
	70.0	3.50	-0.046			70.0	3.50	-0.033	
	50.0	2.50	-0.070			50.0	2.50	-0.050	
	40.0	2.00	-0.086			40.0	2.00	-0.060	
	30.0	1.50	-0.113			30.0	1.50	-0.080	
	20.0	1.00	-0.160			20.0	1.00	-0.120	
	10.0	0.50	-0.244			10.0	0.50	-0.176	
	0.0	0.00	-0.366			0.0	0.00	-0.256	
R	-10.0	-0.50	-0.610		R	-10.0	-0.50	-0.396	
	-20.0	-1.00	-1.100			-20.0	-1.00	-0.610	
120 degF	-30.0	-1.50	-1.800			-30.0	-1.50	-0.888	
	-40.0	-2.00	-2.170			-40.0	-2.00	-1.110	
	-50.0	-2.50	-2.340			-50.0	-2.50	-1.220	
	-70.0	-3.50	-2.490			-70.0	-3.50	-1.340	
	-90.0	-4.50	-2.580			-91.4	-4.57	-1.410	
	-110.0	-5.50	-2.640			-110.0	-5.50	-1.470	
	-130.0	-6.50	-2.710			-130.0	-6.50	-1.520	
	-150.0	-7.50	-2.770			-150.4	-7.52	-1.570	
	-130.0	-6.50	-2.760			-130.0	-6.50	-1.560	
	-110.0	-5.50	-2.740			-110.0	-5.50	-1.550	
	-90.0	-4.50	-2.730			-90.0	-4.50	-1.540	
	-70.0	-3.50	-2.710			-69.8	-3.49	-1.530	
	-50.0	-2.50	-2.690			-49.8	-2.49	-1.510	
	-40.0	-2.00	-2.670			-40.0	-2.00	-1.500	
	-30.0	-1.50	-2.650			-30.0	-1.50	-1.480	
	-20.0	-1.00	-2.590			-20.0	-1.00	-1.440	
	-10.0	-0.50	-2.520		127 degF	-9.8	-0.49	-1.380	
	0.0	0.00	-2.370			0.0	0.00	-1.300	
F	10.0	0.50	-2.140		F	10.0	0.50	-1.180	
124 degF	20.0	1.00	-1.720			20.0	1.00	-0.970	
	30.0	1.50	-1.020			30.0	1.50	-0.710	
	40.0	2.00	-0.590			40.0	2.00	-0.490	
	50.0	2.50	-0.410			50.0	2.50	-0.360	
	70.0	3.50	-0.240			70.0	3.50	-0.230	
	90.6	4.53	-0.150			90.0	4.50	-0.150	
	110.0	5.50	-0.073			110.0	5.50	-0.083	
	130.0	6.50	-0.007			130.0	6.50	-0.024	
	150.0	7.50	0.055			150.0	7.50	0.033	

Table 2

Integrator: R=10K, C=4.945 uF								Current: 1V = 20A				
Temperature @ start=	67 deg F											
Sensor	TOP GRY					Sensor	BOTTOM GRN					
# of turns	1					# of turns	1					
Area=	0.0737	sq meters				Area=	0.0737	sq meters				
Polarity	I	I	Tesla	Int adj	Integrator	Polarity	I	I	Tesla	Int adj	Integrator	
(Reset)	volts	amps	0.6682		volts		volts	amps	0.6682		volts	
F (reset)	7.5	150	0.71	1.060	0.000	F (reset)	7.5	150	1.280	1.915	0.000	
	6.5	130	0.70	1.055	-0.004		6.5	130	1.262	1.888	-0.025	
	5.5	110	0.70	1.048	-0.009		5.5	110	1.240	1.856	-0.055	
	4.5	90	0.70	1.041	-0.015		4.5	90	1.215	1.819	-0.090	
	3.5	70	0.69	1.031	-0.023		3.5	70	1.184	1.772	-0.135	
	2.5	50	0.68	1.020	-0.033		2.5	50	1.142	1.710	-0.195	
	2.0	40	0.68	1.012	-0.040		2.0	40	1.111	1.663	-0.240	
	1.5	30	0.67	0.998	-0.052		1.5	30	1.070	1.602	-0.299	
	1.0	20	0.65	0.976	-0.073		1.0	20	0.995	1.489	-0.410	
	0.5	10	0.62	0.928	-0.120		0.5	10	0.866	1.297	-0.600	
	0.0	0	0.55	0.816	-0.230		0.0	0	0.665	0.994	-0.900	
	-0.5	-10	0.18	0.265	-0.780		-0.5	-10	0.115	0.172	-1.720	
	-1.0	-20	-0.18	-0.267	-1.31		-1.0	-20	-0.407	-0.610	-2.500	
	-1.5	-30	-0.42	-0.628	-1.670		-1.5	-30	-0.756	-1.132	-3.020	
	-2.0	-40	-0.53	-0.799	-1.840		-2.0	-40	-0.945	-1.414	-3.300	
	-2.5	-50	-0.59	-0.881	-1.920		-2.5	-50	-1.040	-1.556	-3.440	
	-3.5	-70	-0.64	-0.961	-1.999		-3.5	-70	-1.128	-1.688	-3.570	
	-4.5	-90	-0.66	-0.994	-2.030		-4.5	-90	-1.189	-1.780	-3.660	
	-5.5	-110	-0.68	-1.025	-2.060		-5.5	-110	-1.231	-1.842	-3.720	
	-6.5	-130	-0.71	-1.056	-2.090		-6.5	-130	-1.272	-1.904	-3.780	
	-7.5	-150	-0.73	-1.088	-2.120		-7.5	-150	-1.307	-1.956	-3.830	
	-6.5	-130	-0.72	-1.079	-2.110		-6.5	-130	-1.288	-1.928	-3.800	
	-5.5	-110	-0.72	-1.070	-2.100		-5.5	-110	-1.270	-1.900	-3.770	
	-4.5	-90	-0.71	-1.062	-2.090		-4.5	-90	-1.244	-1.862	-3.730	
	-3.5	-70	-0.70	-1.053	-2.080		-3.5	-70	-1.212	-1.814	-3.680	
	-2.5	-50	-0.70	-1.045	-2.070		-2.5	-50	-1.174	-1.756	-3.620	
	-2.0	-40	-0.69	-1.036	-2.060		-2.0	-40	-1.148	-1.718	-3.580	
	-1.5	-30	-0.69	-1.027	-2.050		-1.5	-30	-1.103	-1.650	-3.510	
	-1.0	-20	-0.67	-1.009	-2.030		-1.0	-20	-1.031	-1.542	-3.400	
	-0.5	-10	-0.64	-0.960	-1.980		-0.5	-10	-0.912	-1.364	-3.220	
	0.0	0	-0.56	-0.832	-1.850		0.0	0	-0.686	-1.027	-2.880	
	0.5	10	-0.24	-0.353	-1.370		0.5	10	-0.200	-0.299	-2.150	
	1.0	20	0.14	0.216	-0.800		1.0	20	0.334	0.499	-1.350	
	1.5	30	0.39	0.584	-0.430		1.5	30	0.713	1.067	-0.780	
	2.0	40	0.51	0.763	-0.250		2.0	40	0.912	1.365	-0.480	
	2.5	50	0.56	0.842	-0.170		2.5	50	1.004	1.503	-0.340	
	3.5	70	0.61	0.920	-0.090		3.5	70	1.100	1.646	-0.195	
	4.5	90	0.65	0.969	-0.040		4.5	90	1.159	1.735	-0.104	
	5.5	110	0.67	1.000	-0.007		5.5	110	1.205	1.803	-0.034	
	6.5	130	0.69	1.031	0.025		6.5	130	1.208	1.808	-0.027	
	7.5	150	0.71	1.059	0.054		7.5	150	1.278	1.913	0.080	

Table 3

Integrator: R=10K, C=4.945 uF							Current: 1V = 20A											
Temperature @ start=	67 deg F																	
Sensor	WEST 45 DEG RED						Sensor	IBEAM EAST RED					Sensor	IBEAM WEST ORG		from 12/8/98 data		
# of turns	1						# of turns	10					# of turns	10				
Area=	0.0737	sq meters					Area=	0.011	sq meters				Area=	0.011	sq meters			
Polarity	I	I	Tesla	Int adj	Integrator		Polarity	I	I	Tesla	Int adj	Integrator	Polarity	I	I	Tesla	Int adj	Integrator
(Reset)	volts	amps	0.6682		volts			volts	amps	0.6682		volts		volts	amps	0.4495		volts
F (reset)	7.5	150	1.47	2.200	0.000		F (reset)	7.5	150	0.448	-0.670	0.000	F (reset)	7.5	150	0.589	1.310	0.000
	6.5	130	1.45	2.170	-0.026			6.5	130	0.442	-0.661	0.008		6.5	130	0.585	1.303	-0.006
	5.5	110	1.42	2.132	-0.061			5.5	110	0.435	-0.652	0.017		5.5	110	0.581	1.292	-0.015
	4.5	90	1.39	2.085	-0.104			4.5	90	0.428	-0.640	0.028		4.5	90	0.575	1.279	-0.027
	3.5	70	1.36	2.029	-0.156			3.5	70	0.418	-0.625	0.042		3.5	70	0.566	1.260	-0.044
	2.5	50	1.30	1.953	-0.229			2.5	50	0.405	-0.607	0.060		2.5	50	0.554	1.232	-0.071
	2.0	40	1.27	1.895	-0.283			2.0	40	0.395	-0.592	0.074		2.0	40	0.543	1.209	-0.092
	1.5	30	1.22	1.818	-0.356			1.5	30	0.381	-0.570	0.095		1.5	30	0.527	1.172	-0.128
	1.0	20	1.11	1.664	-0.507			1.0	20	0.357	-0.534	0.130		1.0	20	0.497	1.105	-0.193
	0.5	10	0.95	1.427	-0.740			0.5	10	0.310	-0.464	0.200		0.5	10	0.442	0.984	-0.313
	0.0	0	0.71	1.058	-1.105			0.0	0	0.262	-0.392	0.271		0.0	0	0.357	0.795	-0.500
	-0.5	-10	0.09	0.140	-2.020			-0.5	-10	0.155	-0.232	0.430		-0.5	-10	0.150	0.334	-0.960
	-1.0	-20	-0.49	-0.734	-2.890			-1.0	-20	0.001	-0.002	0.660		-1.0	-20	-0.152	-0.338	-1.630
	-1.5	-30	-0.89	-1.338	-3.490			-1.5	-30	-0.146	0.219	0.880		-1.5	-30	-0.359	-0.799	-2.090
	-2.0	-40	-1.12	-1.671	-3.820			-2.0	-40	-0.247	0.370	1.030		-2.0	-40	-0.450	-1.001	-2.290
	-2.5	-50	-1.22	-1.833	-3.978			-2.5	-50	-0.301	0.450	1.110		-2.5	-50	-0.491	-1.092	-2.380
	-3.5	-70	-1.33	-1.989	-4.130			-3.5	-70	-0.348	0.521	1.180		-3.5	-70	-0.528	-1.174	-2.460
	-4.5	-90	-1.40	-2.092	-4.230			-4.5	-90	-0.382	0.572	1.230		-4.5	-90	-0.555	-1.235	-2.520
	-5.5	-110	-1.45	-2.166	-4.300			-5.5	-110	-0.409	0.612	1.270		-5.5	-110	-0.574	-1.277	-2.560
	-6.5	-130	-1.48	-2.220	-4.350			-6.5	-130	-0.436	0.653	1.310		-6.5	-130	-0.588	-1.308	-2.590
	-7.5	-150	-1.52	-2.273	-4.400			-7.5	-150	-0.457	0.684	1.340		-7.5	-150	-0.602	-1.340	-2.620
	-6.5	-130	-1.50	-2.247	-4.370			-6.5	-130	-0.451	0.675	1.330		-6.5	-130	-0.598	-1.331	-2.610
	-5.5	-110	-1.48	-2.211	-4.330			-5.5	-110	-0.445	0.665	1.320		-5.5	-110	-0.595	-1.323	-2.600
	-4.5	-90	-1.45	-2.164	-4.280			-4.5	-90	-0.438	0.656	1.310		-4.5	-90	-0.591	-1.314	-2.590
	-3.5	-70	-1.41	-2.108	-4.220			-3.5	-70	-0.425	0.637	1.290		-3.5	-70	-0.582	-1.296	-2.570
	-2.5	-50	-1.36	-2.032	-4.140			-2.5	-50	-0.419	0.627	1.280		-2.5	-50	-0.574	-1.277	-2.550
	-2.0	-40	-1.32	-1.975	-4.080			-2.0	-40	-0.406	0.608	1.260		-2.0	-40	-0.566	-1.259	-2.530
	-1.5	-30	-1.26	-1.889	-3.990			-1.5	-30	-0.393	0.589	1.240		-1.5	-30	-0.548	-1.220	-2.490
	-1.0	-20	-1.17	-1.753	-3.850			-1.0	-20	-0.367	0.549	1.200		-1.0	-20	-0.509	-1.132	-2.400
	-0.5	-10	-1.02	-1.526	-3.620			-0.5	-10	-0.327	0.490	1.140		-0.5	-10	-0.464	-1.033	-2.300
	0.0	0	-0.74	-1.110	-3.200			0.0	0	-0.261	0.391	1.040		0.0	0	-0.393	-0.875	-2.140
	0.5	10	-0.21	-0.314	-2.400			0.5	10	-0.161	0.241	0.890		0.5	10	-0.241	-0.536	-1.800
	1.0	20	0.41	0.613	-1.470			1.0	20	0.005	-0.008	0.640		1.0	20	0.024	0.052	-1.210
	1.5	30	0.85	1.269	-0.810			1.5	30	0.165	-0.247	0.400		1.5	30	0.275	0.611	-0.650
	2.0	40	1.07	1.605	-0.470			2.0	40	0.252	-0.376	0.270		2.0	40	0.395	0.879	-0.380
	2.5	50	1.18	1.768	-0.304			2.5	50	0.299	-0.448	0.198		2.5	50	0.449	0.998	-0.260
	3.5	70	1.28	1.922	-0.146			3.5	70	0.347	-0.519	0.126		3.5	70	0.497	1.106	-0.150
	4.5	90	1.35	2.014	-0.050			4.5	90	0.378	-0.565	0.079		4.5	90	0.527	1.173	-0.082
	5.5	110	1.39	2.084	0.023			5.5	110	0.403	-0.603	0.041		5.5	110	0.550	1.223	-0.030
	6.5	130	1.43	2.144	0.087			6.5	130	0.426	-0.637	0.006		6.5	130	0.572	1.272	0.020
	7.5	150	1.47	2.196	0.143			7.5	150	0.447	-0.669	-0.027		7.5	150	0.588	1.309	0.058

Table 4