General Quadrupole Information

We had four quads here at UK for some time: NTQM 02, NTQM 03 (Jackie and Patsy) and NTQM 01, NTQM 04 (Felicia and Tessa).

Information on Jackie and Patsy

- Dimensions: 14 1/8" x 14 1/8" x 16"
- Aperature: 4.0" (10.2cm)
- Effective Length: 17.5" (44.0cm)
- Gradient: 3.7 kG/in
- Rated Power: 11.1 kW
- Rated Current: 300 amps
- Operating Temperature: 50 C
- Resistance @ 20 C: 0.11 ohms
- Water Flow: 1.48 GPM
- Pressure Drop: 40 psi
- Water Temperature Rise: 30 C
- Approximate Weight: 700 lbs (320 kg)

Information on Felicia and Tessa

- Dimensions: 22 1/8" x 22 1/8" x 12"
- Bore: 4.0"
- Length: 12.0"
- Field (Pole Tip): 5.9 kG

F2Q II

- Turns/Pole: 50
- Current: 280 amps
- Voltage: 21.5 V
- Resistance: 0.077 ohms at operating temperature
- Flow: 1.0 GPM
- Pressure Drop: 35 psi
- Temperature Rise: 40 F
- Weight: 1350 lbs

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Quadrupole Information

Table II
Pole Tip Field Measurements

Magnet	Patsy	Jackie	Tessa	Felicia
Measurement Radius	49.6 mm	49.6 mm	50.0 mm	50.0 mm
Current (A)	Field (G)	Field (G)	Field (G)	Field (G)
300.0	5801.5	5809.0	5029.5	6135.0
250.0	4912.0	4927.0	5418.5	5533.5
200.0	3954.0	3691.5	4530.0	4634.0
150.0	2976.0	2983.0	3450.0	3528.5
100.0	1997.0	2000.0	2329.5	2379.0
50.0	1014.5	1016.0	1187.0	1208.0
0.0	32.0	29.5	31.0	30.0

140A

3,3A

Rotating Coil Measurements
A ~4" OD rotating coil was used to measure the integral quadrupole field and higher order multipoles as a function of the excitation current. The axis of the coil was aligned to within ±0.5 mm of the mechanical axis of the quad. The coil was slowly rotated to generate a voltage signal that was read by a digital voltage integrator. The digitized signal was Fourier analyzed to determine the multipole components. Knowledge of the coil's geometry was used to convert the Fourier components into an absolute measurement of the quadrupole gradient length product (GL) and relative measurements of the higher order components. The coil's measurement of the GL has a relative uncertainty of ±0.25%, and absolute uncertainty of ±2%. The measurement of the higher order multipoles, listed in % of the quadrupole at a reference radius of 40 mm (80% of the clear aperture), should be good to ±0.05% of the quadrupole. The excitation current was measured with an uncertainty of ±0.01 A by a "zero-flux" current transducer. The results of the rotating coil measurements are listed in Tables IIIa through IIId. The GL as a function of current for each of the magnets is shown in Figs. 2a-d. The original (circa 1972) GL measurements for Tessa and Felicia are shown in Figs. 2c and 2d respectively.

Tessa
Tessa has a ding in one of the coils that was repaired with clear epoxy. During testing the temperature rise of the damaged coil was monitored and found to be no different than the undamaged coils, indicating that the ding has not affected the coolant flow significantly. Furthermore the fact that the n=3 component of this magnet is about the same as its counterpart is an indication that the damage did not cause any turn to turn shorts.

Table IIIa
Rotating Coil Results for Patsy

Current	GL	Multipoles in % of n=2 at R = 40 mm			
(A)	(T)	n=3	n=4	n=5	n=6
299.15	5.204	0.18	0.08	0.02	0.31
249.93	4.435	0.16	0.05	0.02	0.26
200.09	3.571	0.15	0.04	0.02	0.21
150.14	2.691	0.15	0.02	0.02	0.18
100.24	1.807	0.16	0.02	0.02	0.18
49.94	0.9143	0.12	0.02	0.02	0.19
0.06	0.0250	0.11	0.06	0.01	0.52

Table IIIb
Rotating Coil Results for Jackie

Current	GL	Multipoles in % of n=2 at R = 40 mm			
(A)	(T)	n=3	n=4	n=5	n=6
299.02	5.194	0.33	0.02	0.01	0.23
249.82	4.428	0.34	0.03	0.01	0.19
200.09	3.561	0.33	0.03	0.01	0.17
150.03	2.687	0.34	0.03	0.01	0.16
100.48	1.810	0.37	0.02	0.01	0.17
50.21	0.9180	0.43	0.02	0.00	0.18
0.00	0.0279	1.30	0.05	0.10	0.56

Table IIIc
Rotating Coil Results for Tessa

Current	GL	Multipoles in % of n=2 at R = 40 mm			
(A)	(T)	n=3	n=4	n=5	n=6
299.04	4.308	0.35	0.02	0.02	0.33
250.20	3.975	0.39	0.02	0.02	0.31
200.04	3.325	0.42	0.02	0.02	0.28
150.03	2.534	0.40	0.02	0.01	0.27
100.25	1.714	0.37	0.03	0.01	0.28
50.56	0.8789	0.29	0.01	0.02	0.27
0.00	0.0228	0.59	0.04	0.07	0.65

Table IIId
Rotating Coil Results for Felicia

Current	GL	Multipoles in % of n=2 at R = 40 mm			
(A)	(T)	n=3	n=4	n=5	n=6
299.03	4.424	0.25	0.02	0.01	0.35
249.99	4.002	0.25	0.02	0.02	0.32
199.95	3.354	0.25	0.02	0.01	0.29
150.07	2.557	0.25	0.02	0.01	0.26
100.28	1.729	0.25	0.01	0.01	0.25
50.11	0.8783	0.25	0.01	0.01	0.26
0.00	0.0229	0.84	0.11	0.11	0.68

.017996 T/A 300
.017745 ~250
.017847 200
.018027 100

.01737 T/A 300
.017797 200
.018014 100

1.0003
Patsy/Jackie ~ 1.0007 ← ?
1.0017

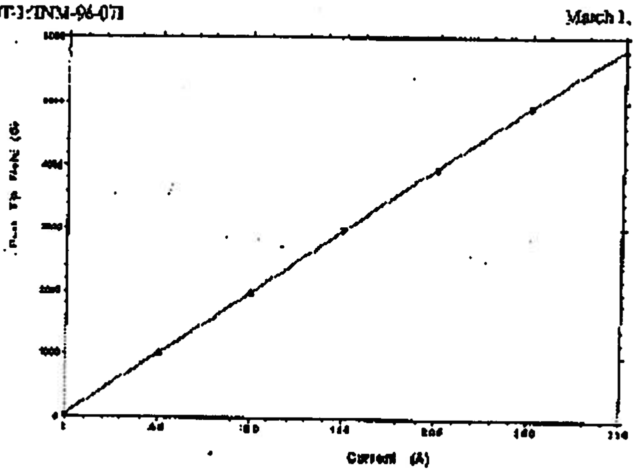

Fig. 1a Pole tip field measurements for PATSY. The measurement radius is 46.6 mm.

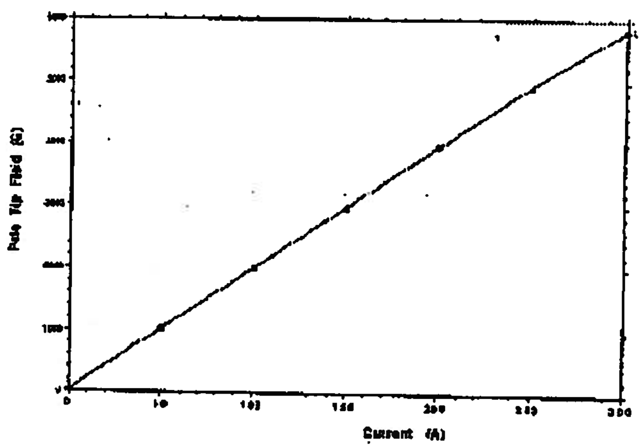

Fig. 1b Pole tip field measurements for JACKIE. The measurement radius is 45.6 mm.

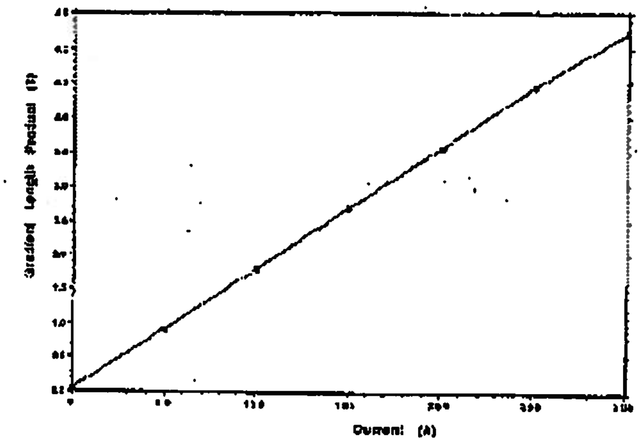

Fig. 2a. GL vs current measured for PATSY.

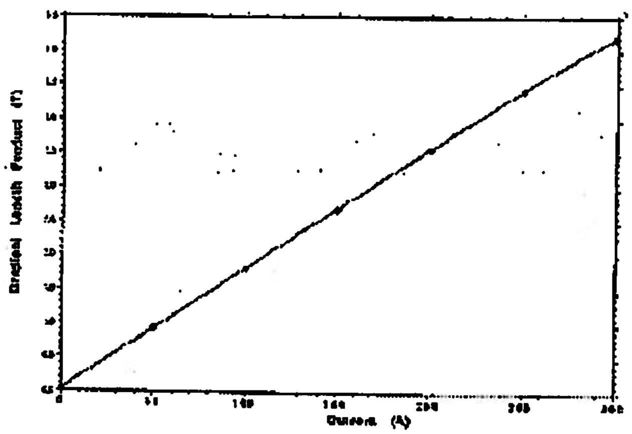

Fig. 2b. GL vs current measured for JACKIE.

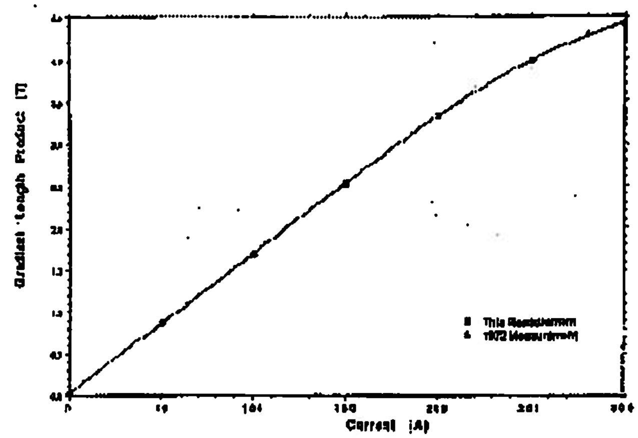

Fig. 2c. GL vs current measured for TESSA. Also shown are the results of a previous measurement made in 1972.

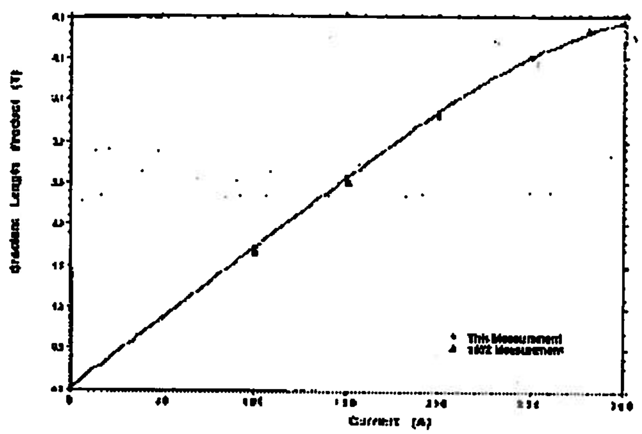

Fig. 2d. GL vs current measured for FELICIA. Also shown are the results of a previous measurement made in 1972.

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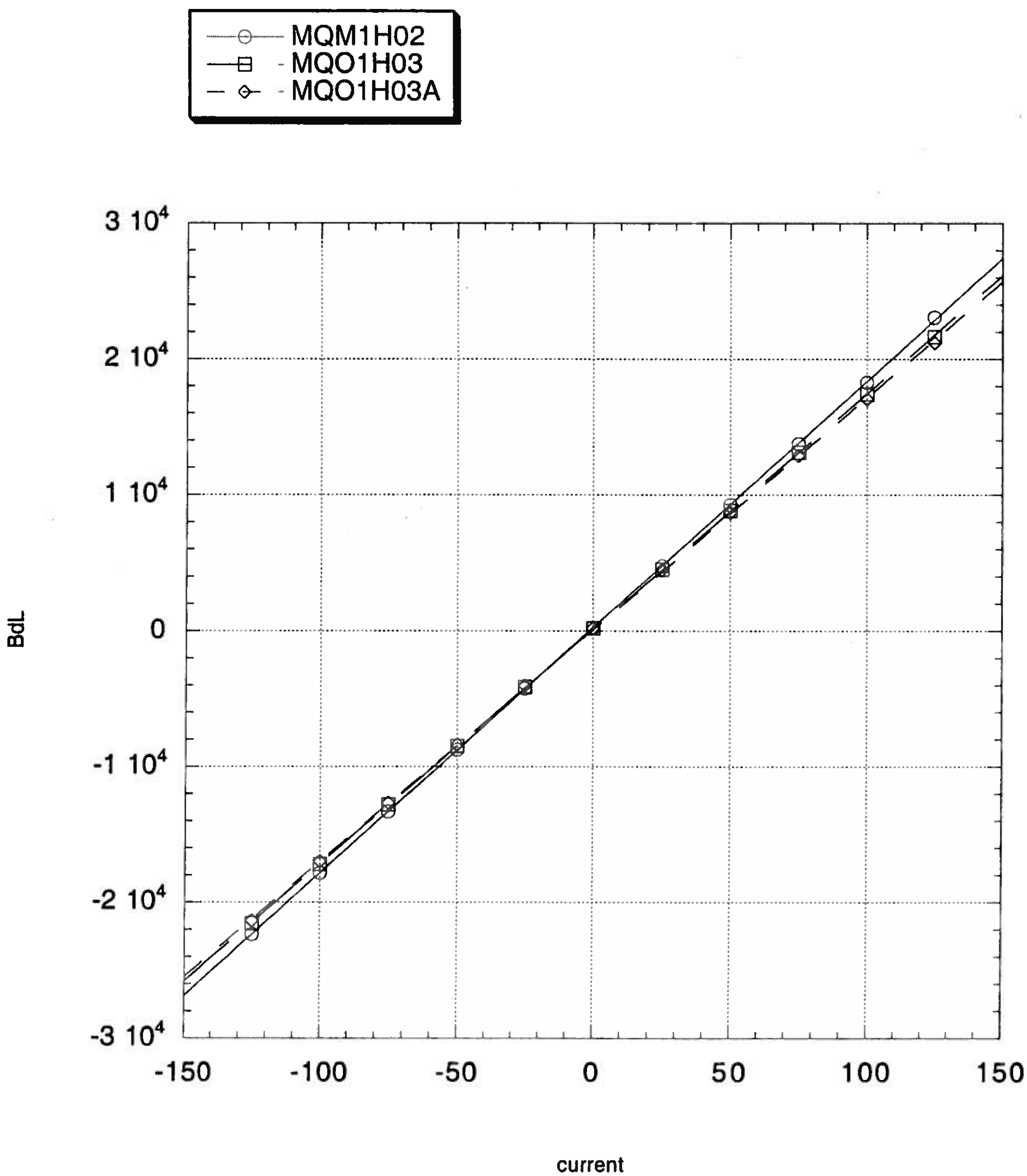
EPICS field map



1H02 fit includes bad 125A point

$Y = M0 + M1*X$

M0	260.37
M1	180.95
R**2	0.99998

1H03 fit

$Y = M0 + M1*X$

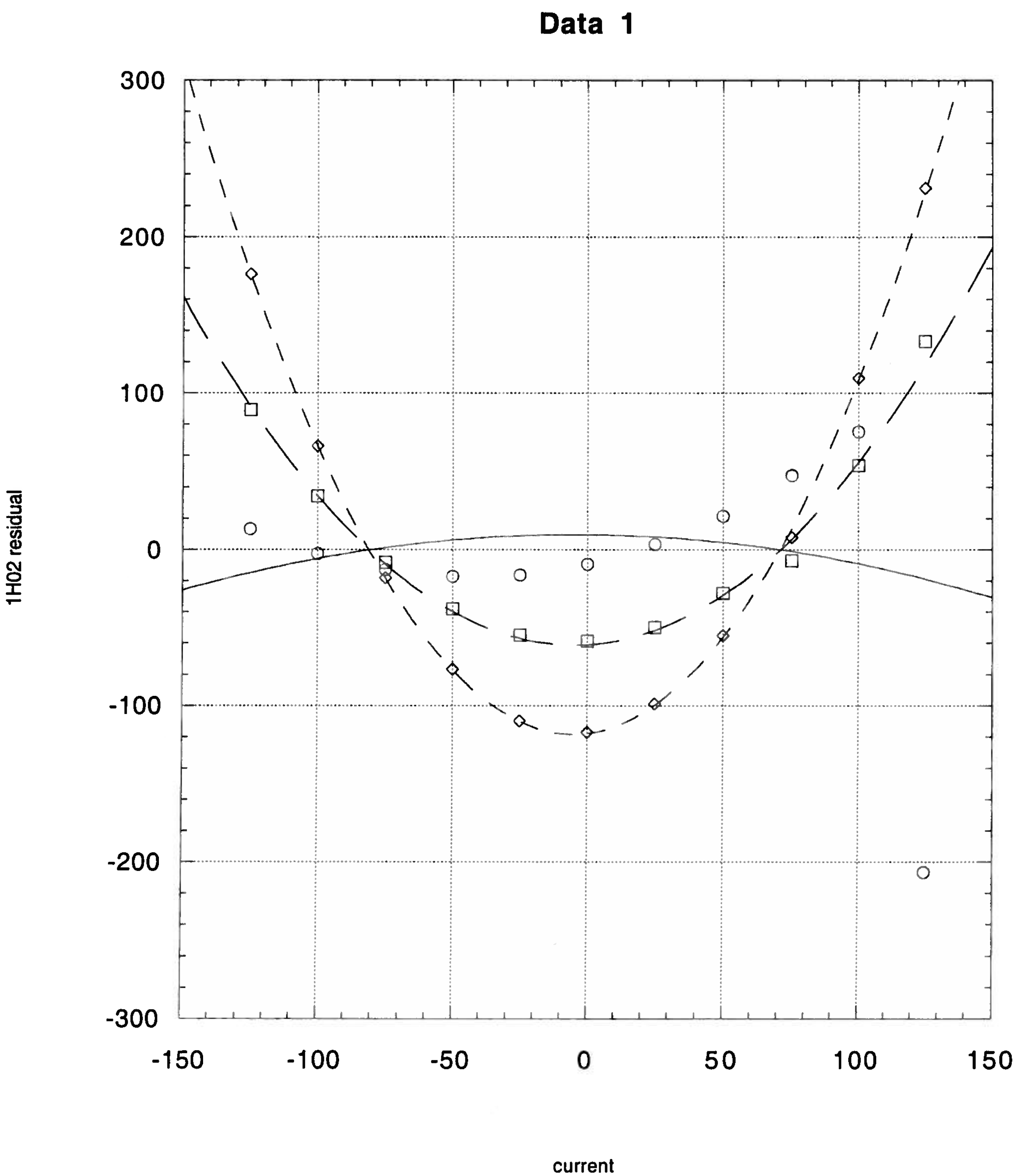
M0	161.07
M1	173.07
R**2	0.99998

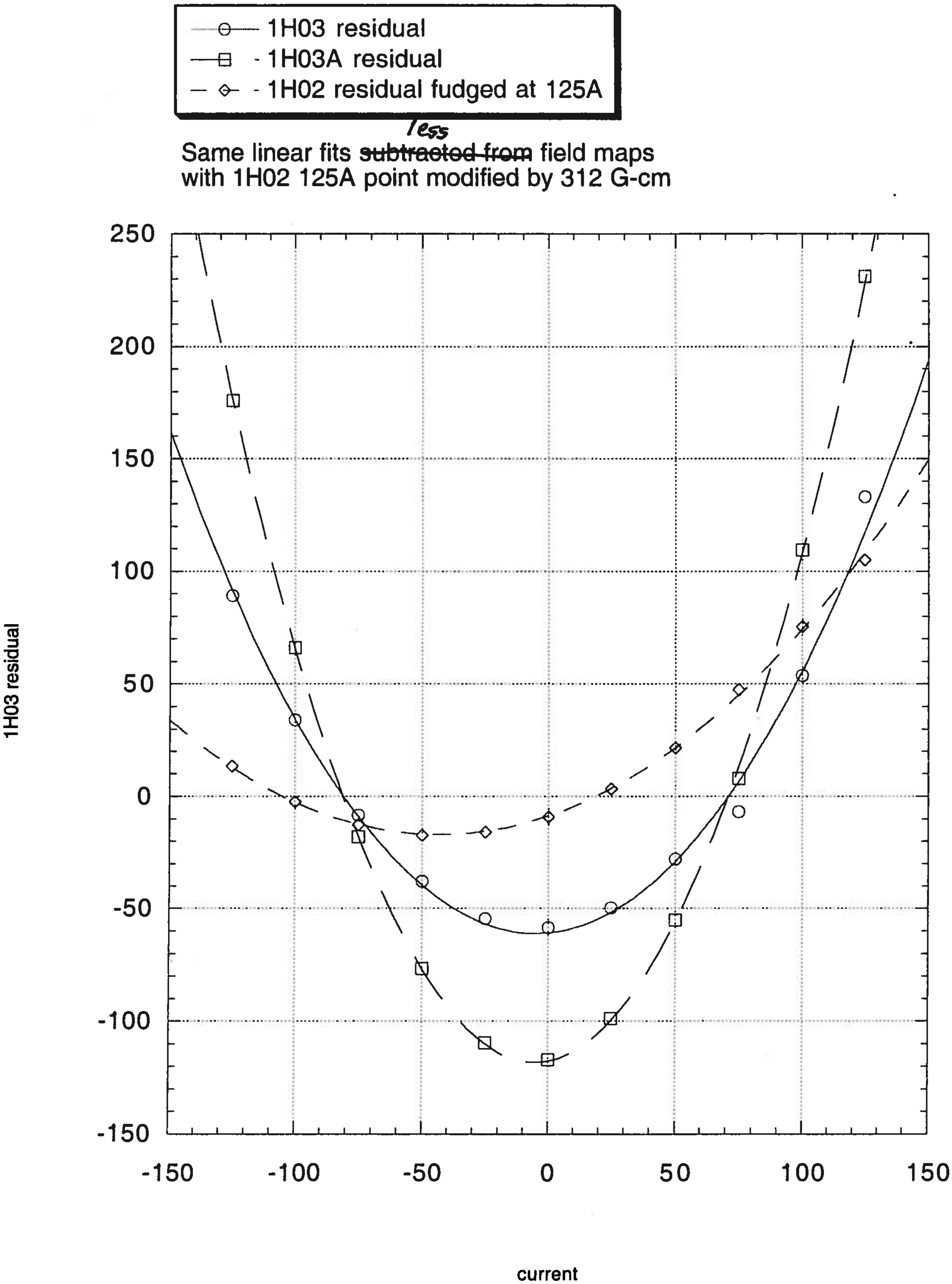
1H03A fit

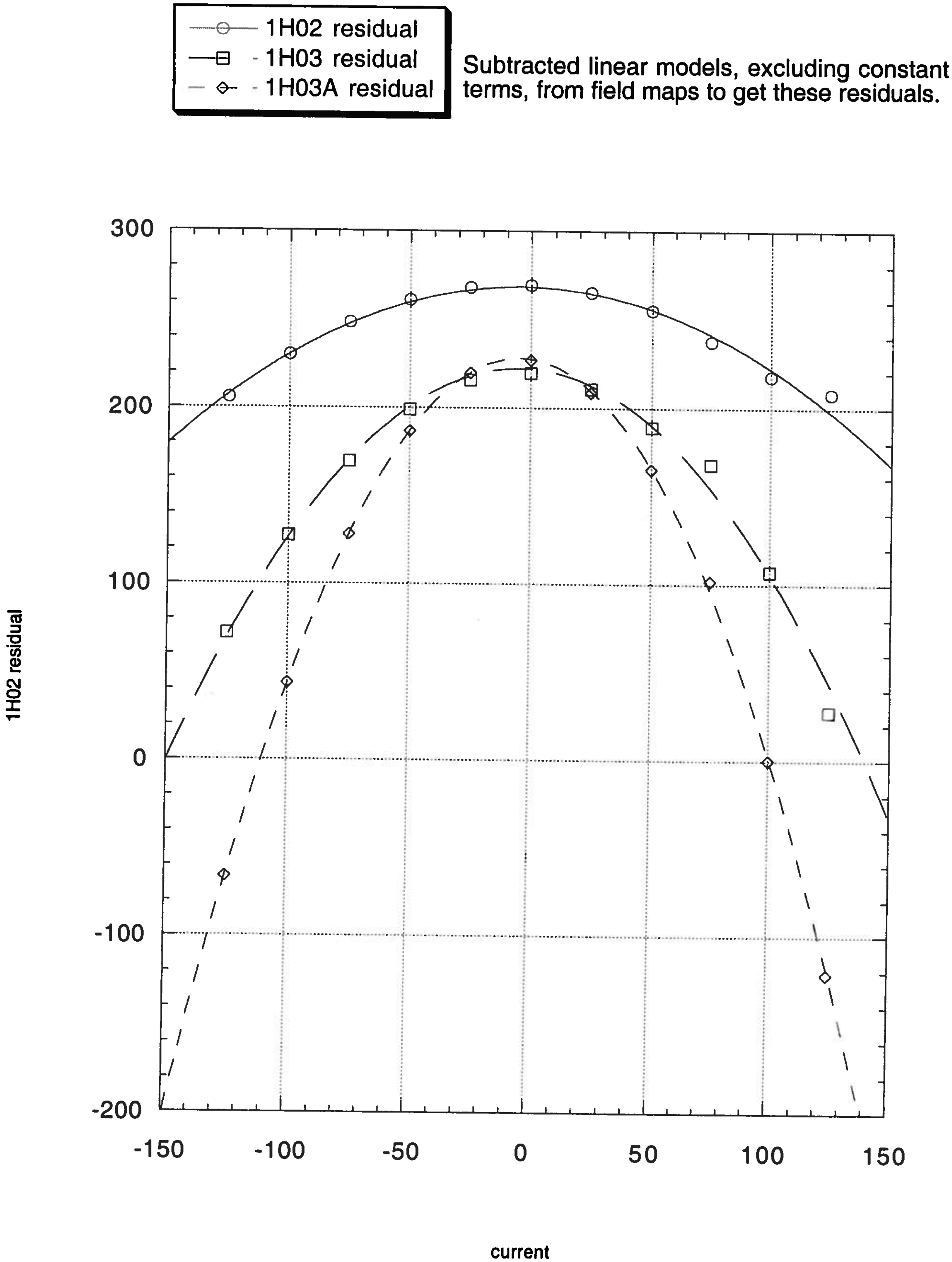
$Y = M0 + M1*X$

M0	109.82
M1	170.48
R**2	0.99993

Linear fit less ~~subtracted from~~ field maps. Residuals are shown. Clearly the 125A point of 1H02 is bogus. Further, there is no difference in the values dependent on current history/direction

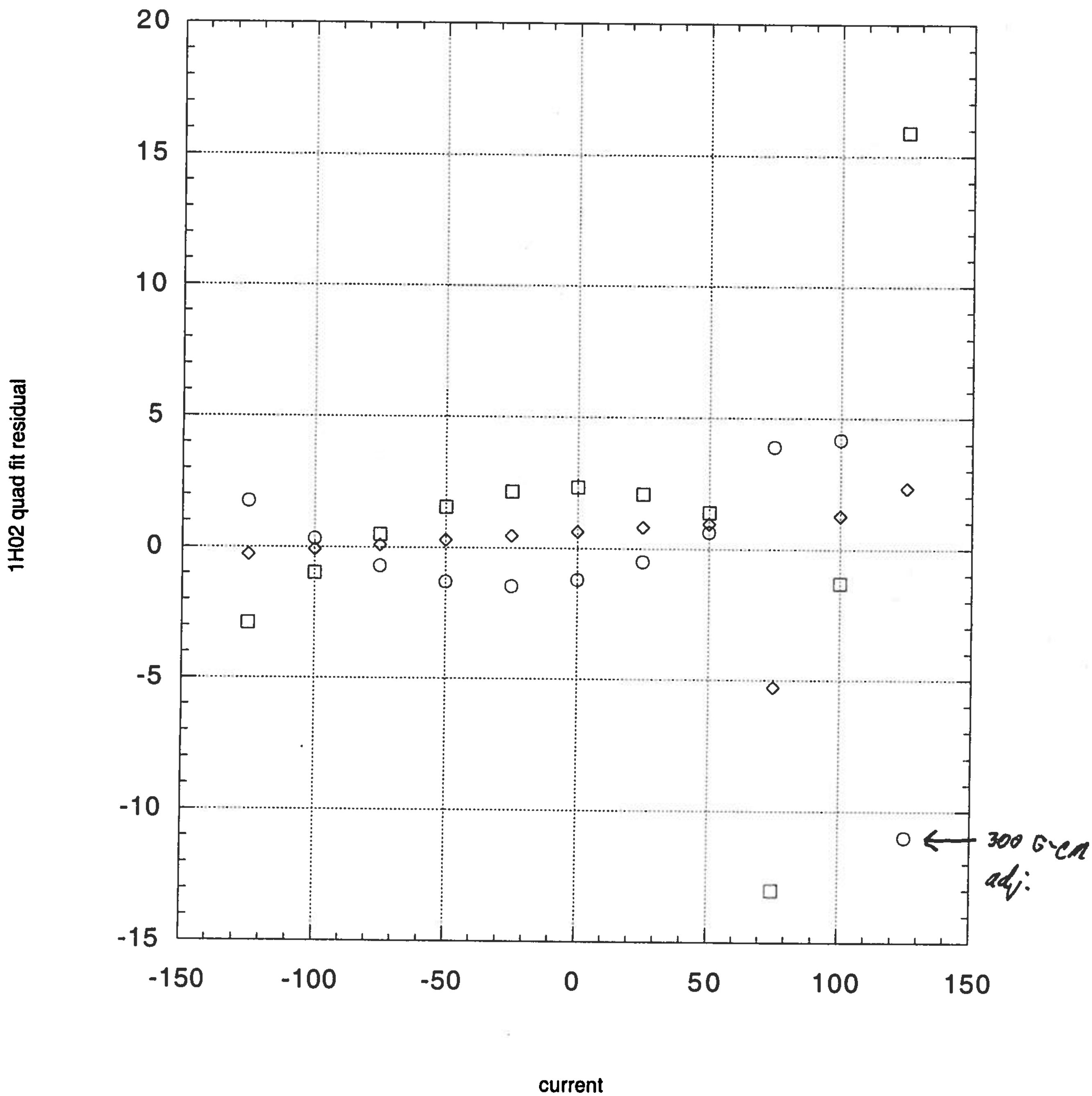



1H03 residual
1H03A residual
1H02 residual fudged at 125A
Tess
Same linear fits ~~subtracted from~~ field maps
with 1H02 125A point modified by 312 G-cm
250
200
150
100
50
0
-50
-100
-150
-150
-100
-50
0
50
100
150
1H03 residual
current


1H02 residual
1H03 residual
1H03A residual
Subtracted linear models, excluding constant terms, from field maps to get these residuals.
300
200
100
0
-100
-200
1H02 residual
-150
-100
-50
0
50
100
150
current

○ 1H02 quad fit residual
□ 1H03 quad fit residual
◇ 1H03A quad fit residual

Field maps were subtracted from quad fits of the field maps to give these residuals, which are at the part per thousand level.



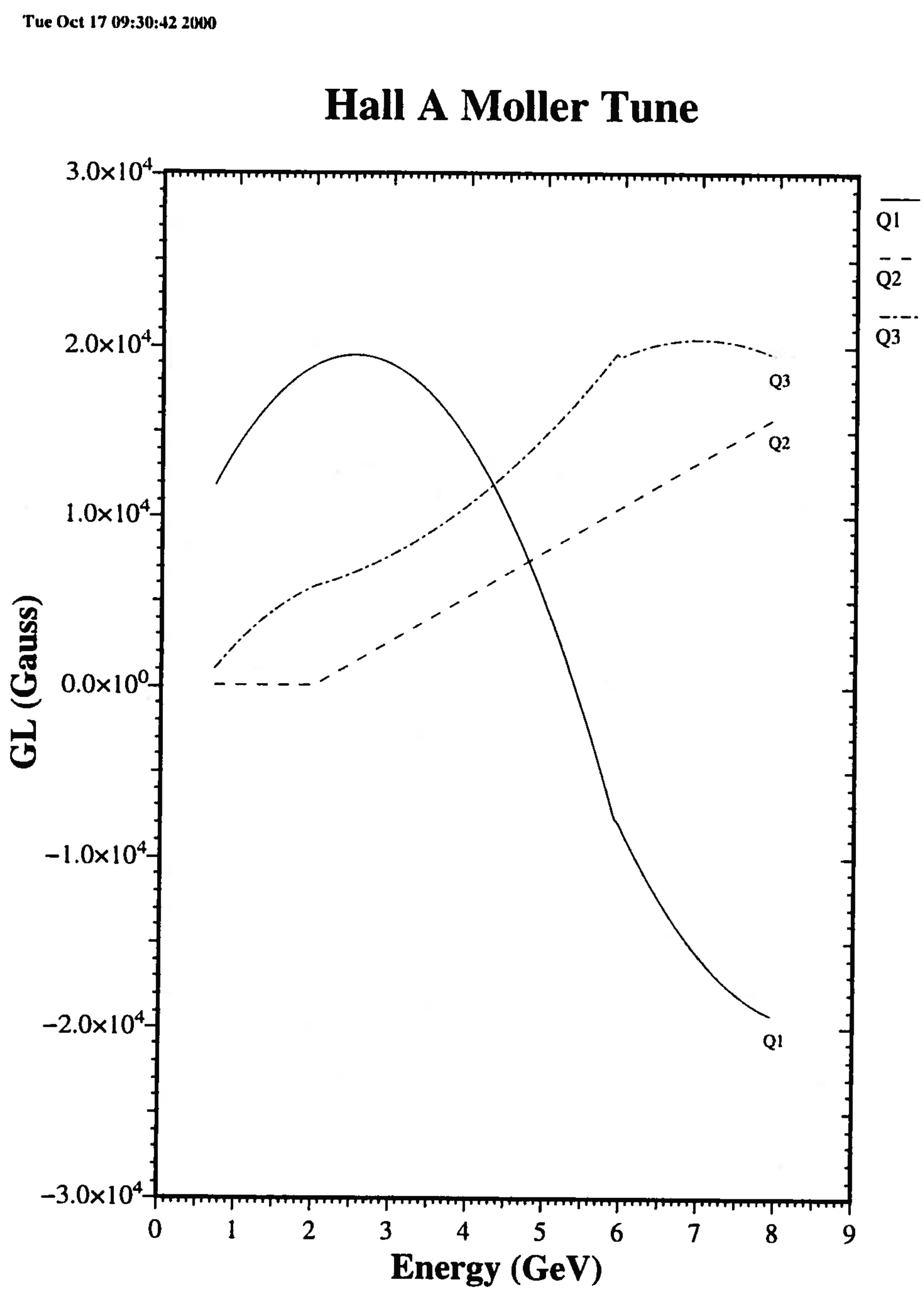


Figure 4: *Moller Quadrupole Tune*

Table 1: Hall A Moller Quadrupole Parameters

Quad 1 Radius= 4.96 cm Length= 44.77 cm						
Current	B_{pole}	$\int G.dl$ (Gauss)				
(A)	(Gauss)	Quadrupole	Sextupole	Octupole	Decapole	Dodecapole
0.00	32.00	290.00	0.32	0.17	0.03	1.51
49.94	1014.50	9143.00	10.97	1.83	1.83	16.46
100.24	1997.00	18070.00	28.91	3.61	3.61	32.53
150.14	2976.00	26910.00	40.36	5.38	5.38	48.44
200.09	3954.00	35710.00	53.57	14.28	7.14	74.99
249.93	4918.00	44350.00	70.96	22.17	8.87	115.31
299.15	5801.50	52040.00	98.88	26.02	10.41	161.32
Quad 2 Radius= 5.00 cm Length= 36.74 cm						
Current	B_{pole}	$\int G.dl$ (Gauss)				
(A)	(Gauss)	Quadrupole	Sextupole	Octupole	Decapole	Dodecapole
0.00	31.00	228.00	1.35	0.09	0.16	1.48
50.56	1187.00	8789.00	25.49	0.88	1.76	23.73
100.26	2329.50	17140.00	63.42	5.14	1.71	47.99
150.08	3450.00	25340.00	101.36	5.07	2.53	68.42
200.04	4530.00	33250.00	139.65	6.65	6.65	93.10
250.20	5418.50	39750.00	155.03	7.95	7.95	123.22
299.04	6029.50	43980.00	153.93	8.80	8.80	145.13
Quad 3 Radius= 5.00 cm Length= 36.50 cm						
Current	B_{pole}	$\int G.dl$ (Gauss)				
(A)	(Gauss)	Quadrupole	Sextupole	Octupole	Decapole	Dodecapole
0.00	30.00	229.00	1.92	0.25	0.25	1.56
50.11	1208.00	8783.00	21.96	0.88	0.88	22.84
100.28	2379.00	17290.00	43.23	1.73	1.73	43.23
150.07	3528.50	25570.00	63.92	2.56	2.56	66.48
199.95	4634.00	33540.00	83.85	6.71	3.35	97.27
249.99	5533.50	40030.00	100.08	8.01	8.01	128.10
299.03	6135.00	44240.00	110.60	8.85	4.42	154.84

Table 2: Moller Quads Hysteresis Curves

Current	$\int G.dl$		
	Q1	Q2	Q3
(A)	(Gauss)	(Gauss)	(Gauss)
-300.00	-51585.45	-43586.39	-43843.80
-270.00	-47006.78	-41258.47	-41546.90
-240.00	-42059.79	-38089.24	-38396.81
-210.00	-36859.13	-34199.61	-34506.46
-180.00	-31596.50	-29658.79	-29933.35
-150.00	-26305.22	-24870.97	-25100.47
-120.00	-20992.48	-19953.56	-20130.77
-90.00	-15671.83	-14965.26	-15093.55
-60.00	-10347.58	-9924.10	-10006.52
-30.00	-5028.18	-4851.71	-4892.13
0.00	290.00	228.00	229.00
30.00	5606.97	5315.68	5357.00
60.00	10929.70	10388.31	10472.99
90.00	16253.97	15430.00	15560.28
120.00	21576.40	20426.34	20608.17
150.00	26885.27	25327.08	25558.59
180.00	32187.58	30249.26	30532.12
210.00	37496.32	34714.48	35021.31
240.00	42697.07	38605.17	38911.40
270.00	47586.78	41714.47	42004.90
300.00	52165.45	44042.39	44301.80

Table 3: Moller Quads Hysteresis Curves

Current	$\int$G.dl		
	Q1	Q2	Q3
(A)	(Gauss)	(Gauss)	(Gauss)
270.00	47529.38	41669.04	41959.53
240.00	42581.04	38513.54	38819.70
210.00	37322.11	34577.41	34883.85
180.00	31955.34	30066.81	30348.95
150.00	26595.00	25098.96	25329.48
120.00	21228.03	20152.48	20333.08
90.00	15847.56	15110.33	15239.26
60.00	10465.63	10022.76	10106.33
30.00	5085.13	4904.61	4944.71
0.00	-290.00	-228.00	-229.00
-30.00	-5573.30	-5280.95	-5322.77
-60.00	-10811.53	-10289.76	-10373.13
-90.00	-16078.12	-15285.05	-15414.52
-120.00	-21340.96	-20227.42	-20405.94
-150.00	-26595.49	-25099.09	-25329.58
-180.00	-31828.70	-29841.25	-30116.53
-210.00	-37033.26	-34336.49	-34643.78
-240.00	-42175.74	-38180.67	-38488.36
-270.00	-47064.17	-41303.90	-41592.27
-300.00	-51583.77	-43584.88	-43842.28

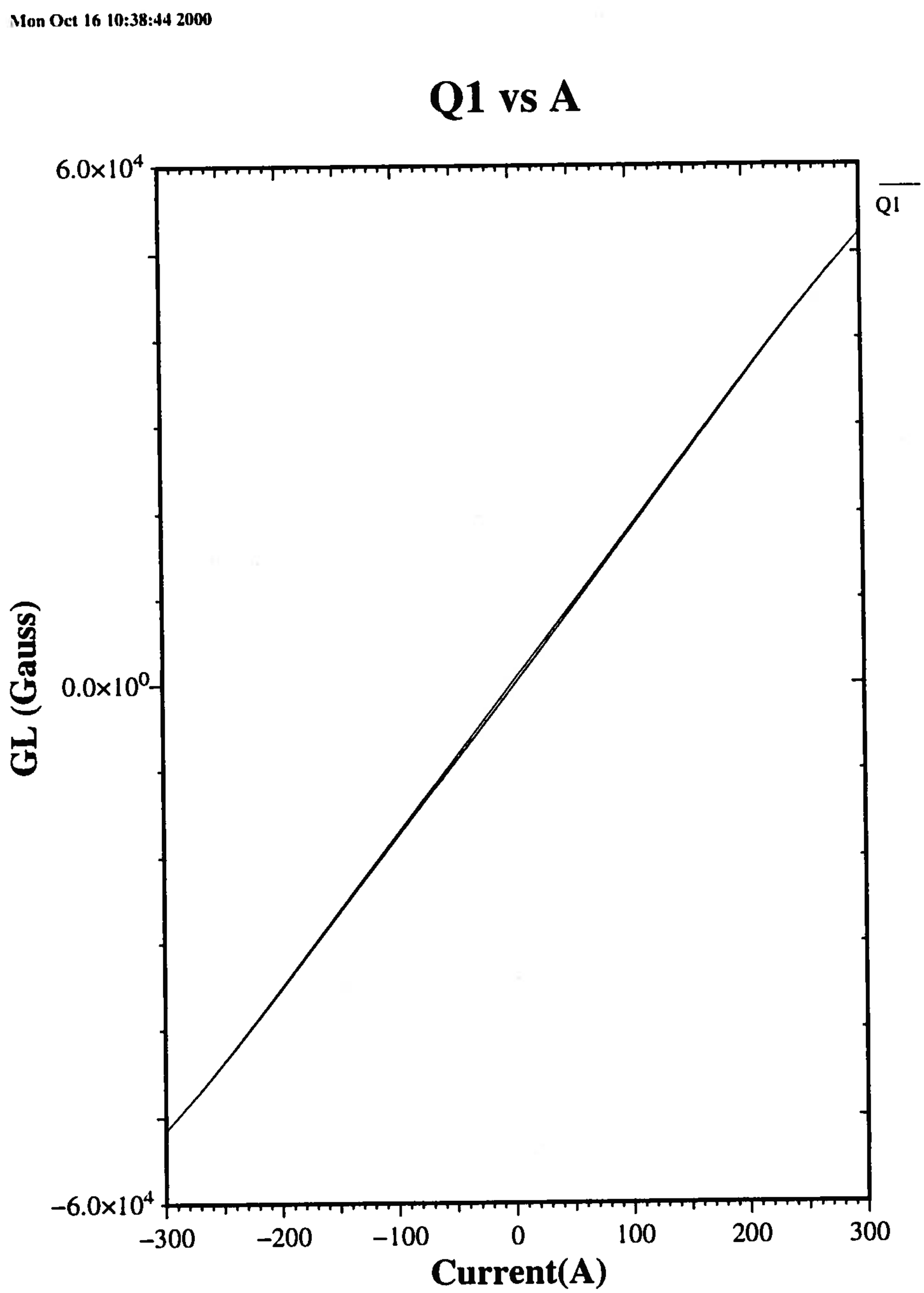


Figure 1: *Quad 1 Hysteresis Curve*

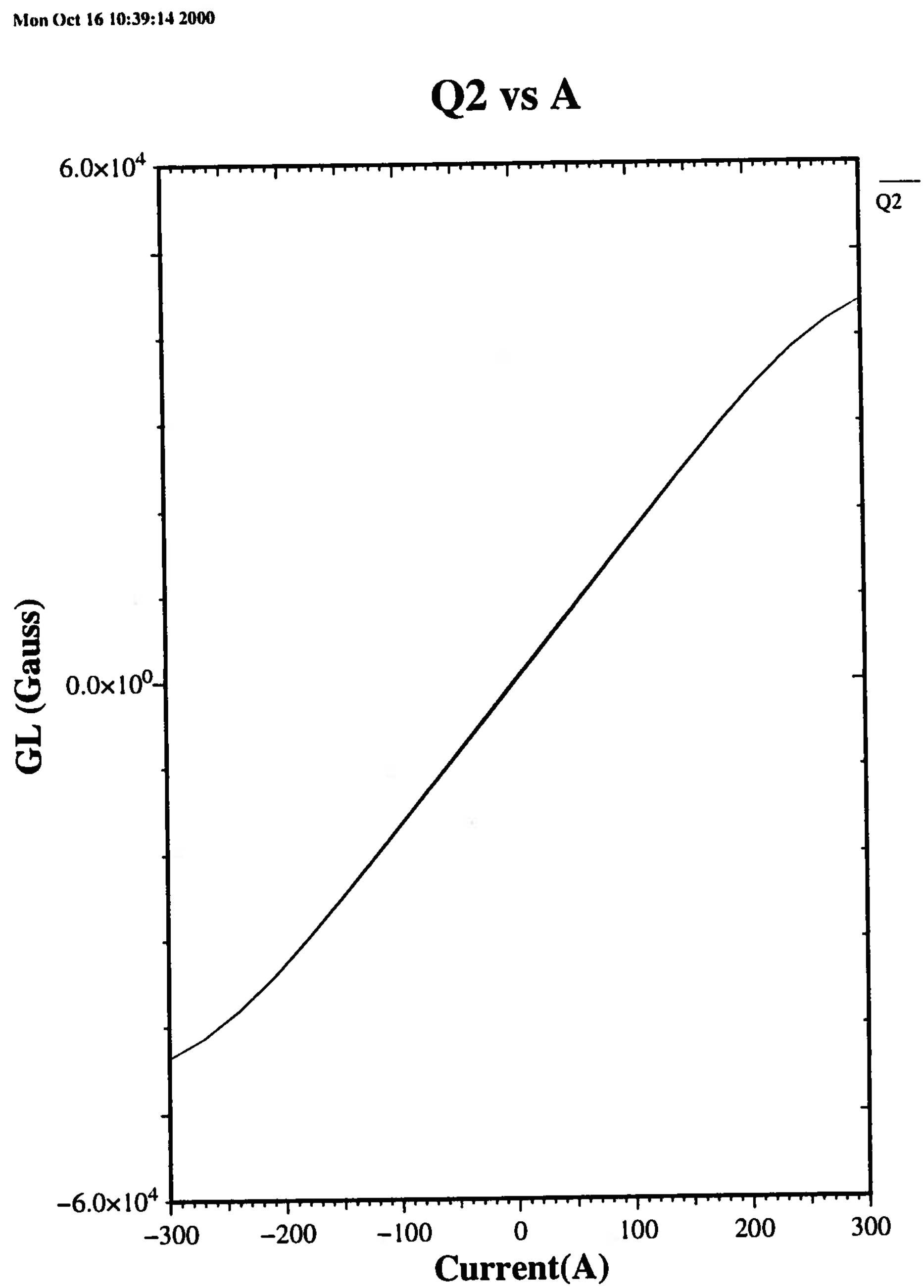


Figure 2: *Quad 2 Hysteresis Curve*

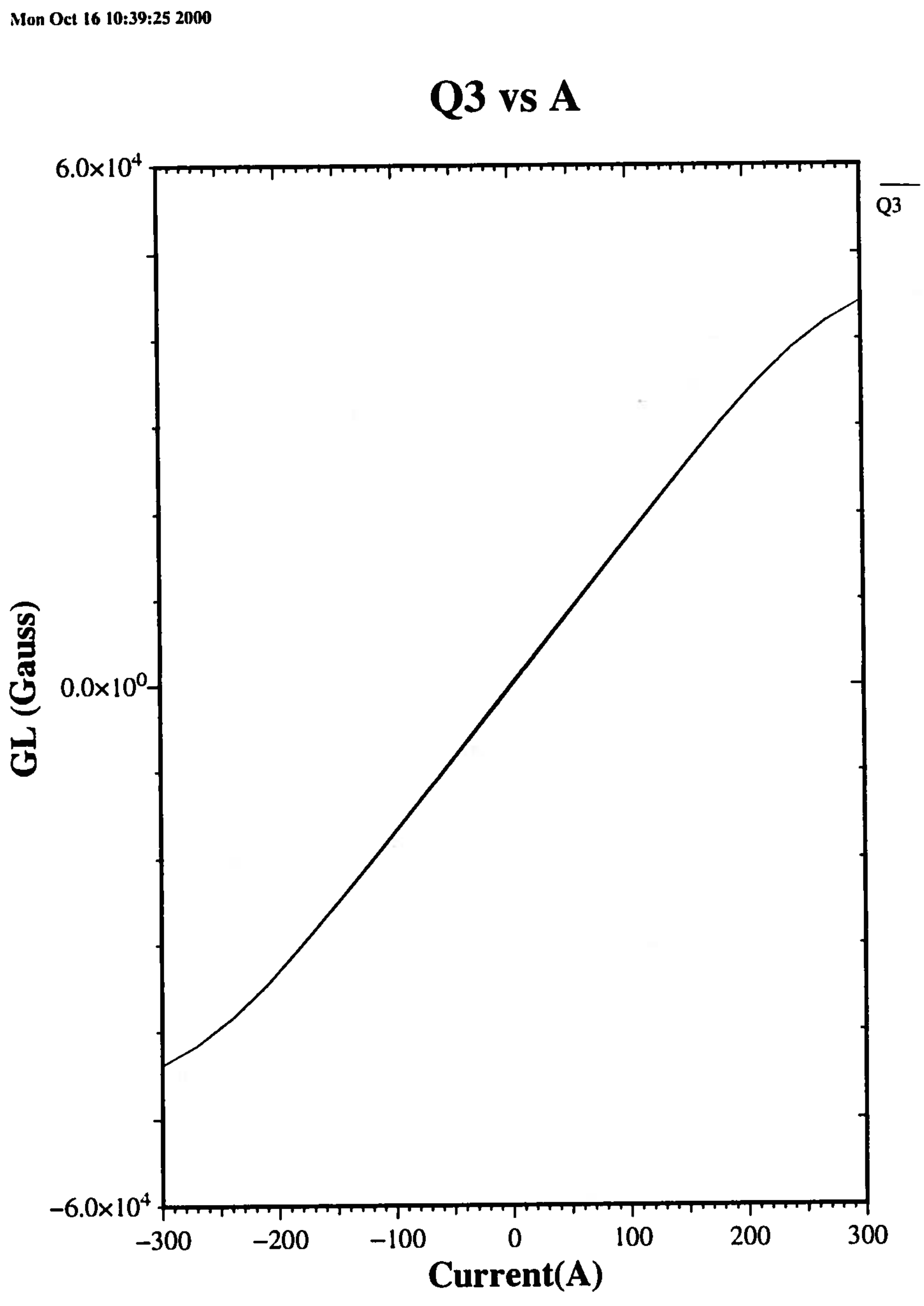


Figure 3: *Quad 3 Hysteresis Curve*