ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY **ENGINEERING NOTE** **Mechanical Engineering Department**			**BaBar Detector**
WBS#: 1.3.1.1	LBNL Serial # M7687	DIRC Note # 103	
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First Line:
BaBar Detector

Second Line:
DIRC PID

Title:
Strong Support Tube Strain Gage Measurements

MPG

INTRODUCTION

During the month of April 1998 measurements were made of the stresses in the DIRC Strong Support Tube (SST) caused by magnetic forces. The objective of these measurements was to confirm the safety of the DIRC Support Structure which was designed to withstand approximately 210 tons of magnetic loading with the solenoid at a field strength of 1.5 tesla. The measurements focused on the forward end of the SST in the thinnest regions of the steel which we refer to as "septa." Twelve of these septa, each less than 0.6 in. thick and 45 in. long, transfer the majority of the axial magnetic force on the DIRC and the Backward Endplug. During the Preliminary and Final Engineering Reviews, concerns were raised about the stress in the SST septa as failure in one septum could catastrophically increase the stress in other septa.

Finite Element Analysis (FEA) of the structure predicted a maximum static stress of 11,000 psi (in 36,000 psi yield material) with ideal, symmetric loading (FEA Stress Analysis of the DIRC Structure, MCR Associates, Inc.). No measurement was taken at the location of this maximum stress value of 11,000 psi because the SOB Magnetic Shield prevented access to the septa in the Horse Collar where the stresses were predicted to be highest.

Because the DIRC Support Structure contains many bolted connections and a complicated interface with the Backward Endplug, we found it necessary to confirm the stress level and stress distribution in the SST experimentally.

MEASUREMENTS

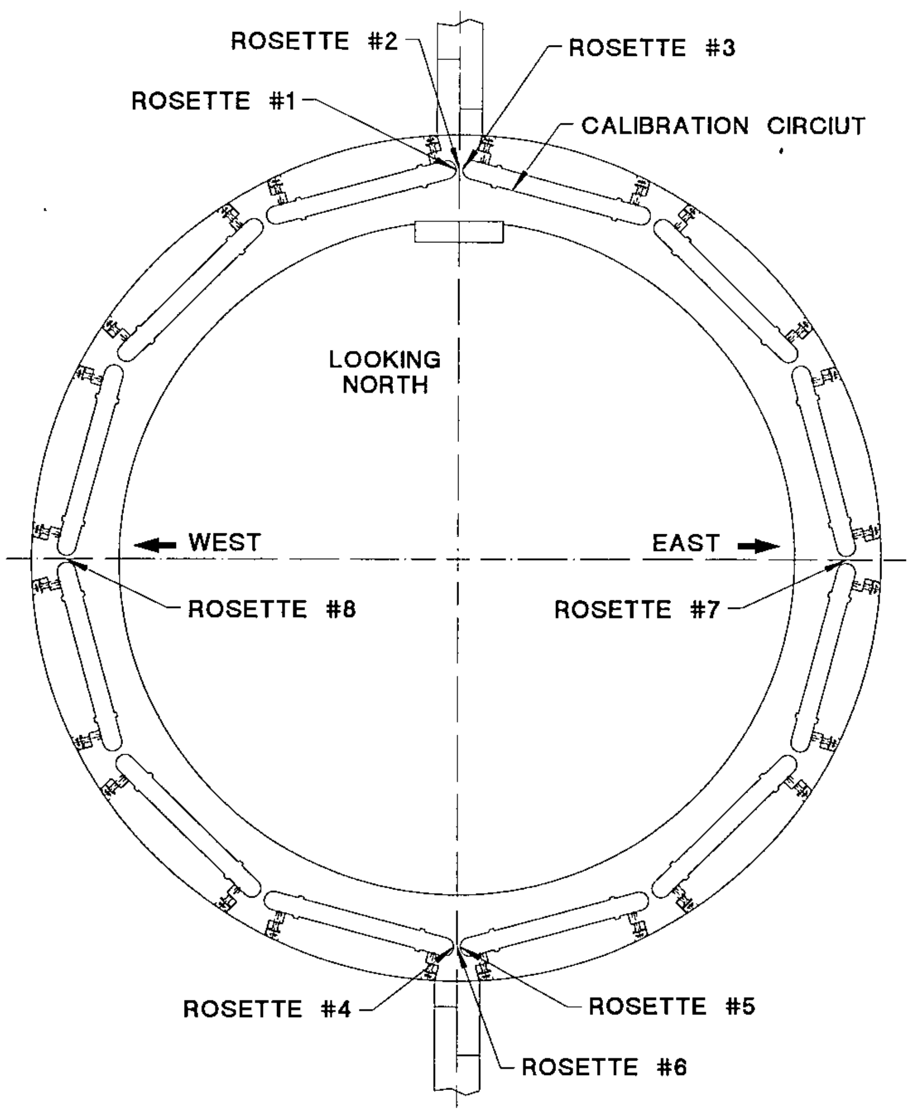
Strain Gages were adhered to 4 of the septa on the forward end of the DIRC SST (at 0, 90, 180, and 270 degrees). In the sample areas FEA predicted Von Mises stresses of approximately 2500 psi in the top and bottom septa and approximately 1200 psi in the zero and 180 degree septa.

Rosettes (each containing three strain gages at 0, 45, and 90 degree angles) were used to determine the principle stresses at each measurement location.

Measurements were taken on three separate days (4/15, 4/16, and 4/27/98). Measurements were made at five solenoid current levels: zero, 460, 2300, 3450, and 4600 amperes.

Twenty-four strain gages (350 ohm) were monitored: three rosettes on the top and bottom septa and one on each of the 0 and 180 degree septa.

STRAIN GAGE ROSETTE LOCATIONS



RESULTS

Location	Ave. Measured Stress	FEA Predicted Stress
90 degrees (top)	1300 psi	2500 psi
270 degrees (bottom)	3000 psi	2500 psi
0 degrees (right)	-1000 psi	-1200 psi
180 degrees (left)	-2000 psi	-1200 psi

A measurement uncertainty of plus or minus 300 psi is attributed to these values due to fluctuations in the last digit of the voltage meter which had microvolt resolution.

DISCUSSION

The primary challenges in collecting meaningful strain gage data were as follows:

magnetic field:
Strain gage manufacturers (Omega Engineering, Inc., and Micro Measurements Division Measurements Group, Inc.) would not guarantee the accuracy of the gages when used in the presence of a 1.5 tesla DC magnetic field. This challenge was overcome by utilizing a calibration circuit (a nearly balanced precision Wheatstone Bridge circuit) inside the SST with the measurement circuits. During measurements there was negligible fluctuation in this circuit which implied that the magnetic field had no adverse affect on the results.

multi-channel data acquisition:
We were hard pressed to devise a cost effective technique for monitoring 25 channels of voltage data at a distance of forty feet from the measurement locations with an accuracy in the microvolt range. We overcame this challenge by building a custom data acquisition box which kept all strain gages contiuously energized (2 volt excitation) and allowed us to switch a high accuracy digital volt meter between signal channels. Connections were made to insulated lead wires with aircraft-type Cannon connectors containing gold plated pins. Any change in the resistance in a circuit caused by connecting and disconnecting lead wires would introduce error into the results.

lead wire length:
Lead wires were approximately 50 feet in length. In order to avoid errors caused by temperature fluctuations (i.e. resistance changes) in the lead wires, a complete Wheatstone Bridge circuit for each strain gage was located inside the SST. Three bridge circuits were located at each rosette location.

zero fluctuation:

Fluctuations in the zero values of the Wheatstone Bridge circuits were observed over time periods of more than four hours. These fluctuations were avoided by re-zeroing each circuit as close as possible to the time when a measurement was taken. In order to track changes in zero values we took all data on days when the magnet was ramped up from zero current, stopping long enough at each current level to take measurements (approximately 30 minutes). Two out of eight of the rosettes appear to have been affected by zero fluctuations. The results for these two rosettes, located on the right and left side of the top septum, have been omitted from the report of these measurements. The other six rosettes produced results which fell predictably on a second order curve plotting stress as a function of magnet current (magnetic force is proportional to the square of the magnetic field).

nickel plating:
The SST is made of a low carbon steel and has a .001 in. thick electroless nickel plating. Because the nickel plating is necessary for corrosion protection of the steel we were hesitant to remove the plating in the areas in which strain gages would be applied. In order to test the effect of the nickel plating we constructed a test stand comprised of a cantilevered beam deflected by a micrometer head. We applied rosettes to both a plated and non-plated beam and found strain results to agree to better than five percent. Based on this result we adhered the strain gages to the SST without removing the nickel plating.

CONCLUSION

The measured values of stress at maximum magnetic field were all within less than a factor of two of the predicted FEA values.

The maximum average principal stress measured (4234 psi) was 1.7 times higher than predicted. If all stresses in the structure were multiplied by this factor the maximum predicted stress value in the structure of 11,000 psi would increase to 18,600 psi, still well below the yield strength of the steel (36,000 psi).

Given our safety factor (based on yield strength) on the FEA predicted stress of approximately three during static loading, these results give us confidence that the DIRC Support Structure will be able to withstand magnetic and seismic loading with no plastic deformation.

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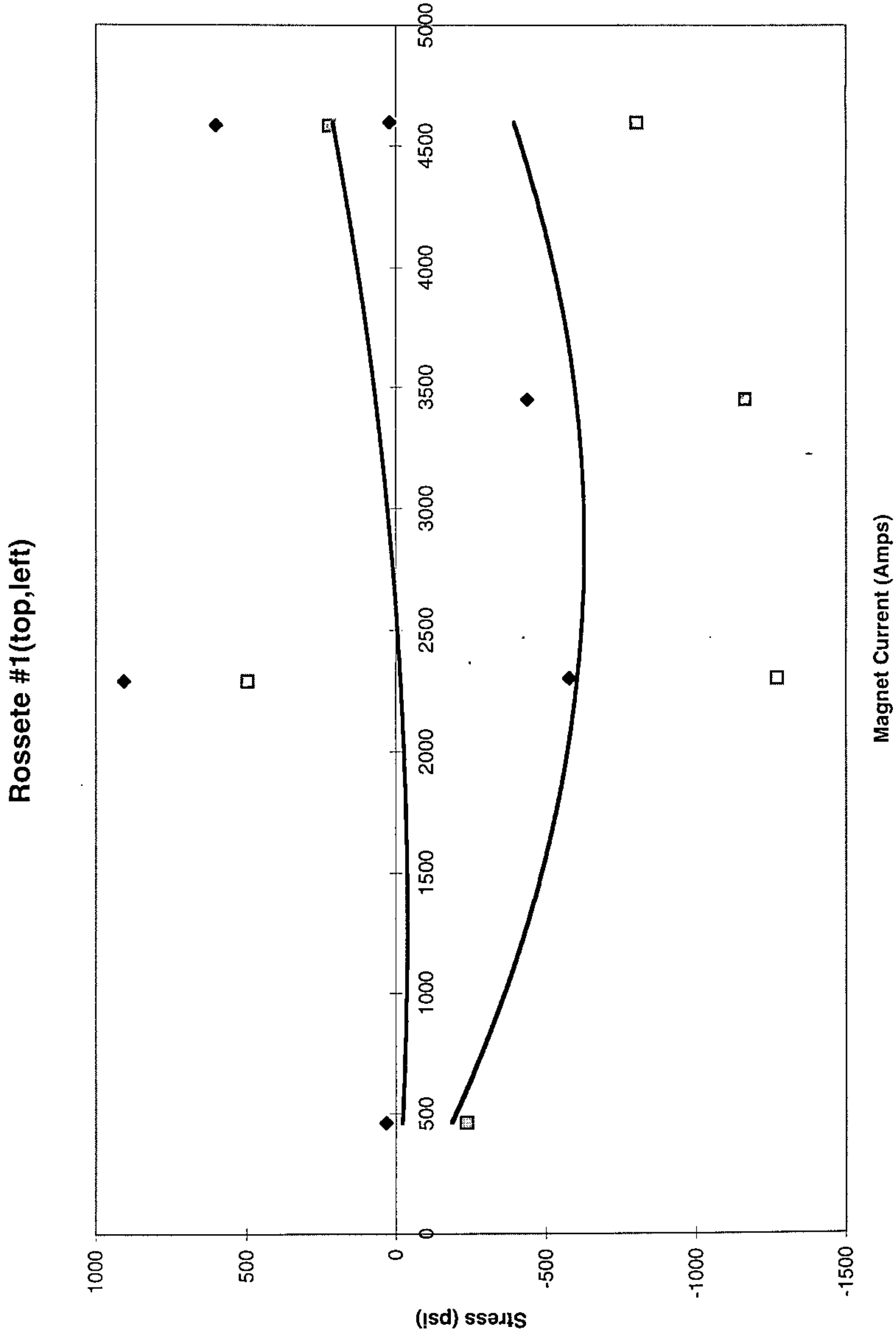
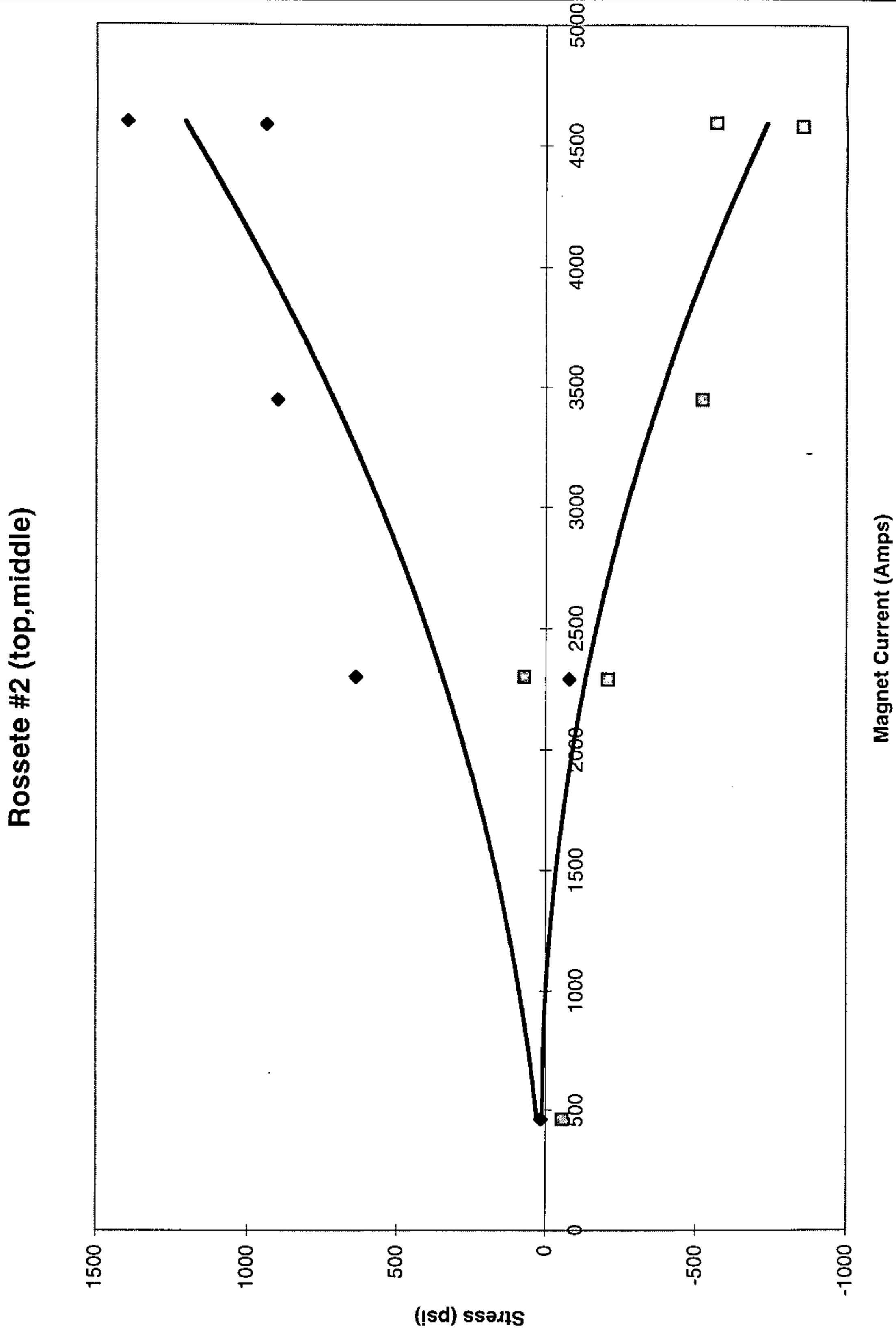
SST Strain Gage Measurements Appendix

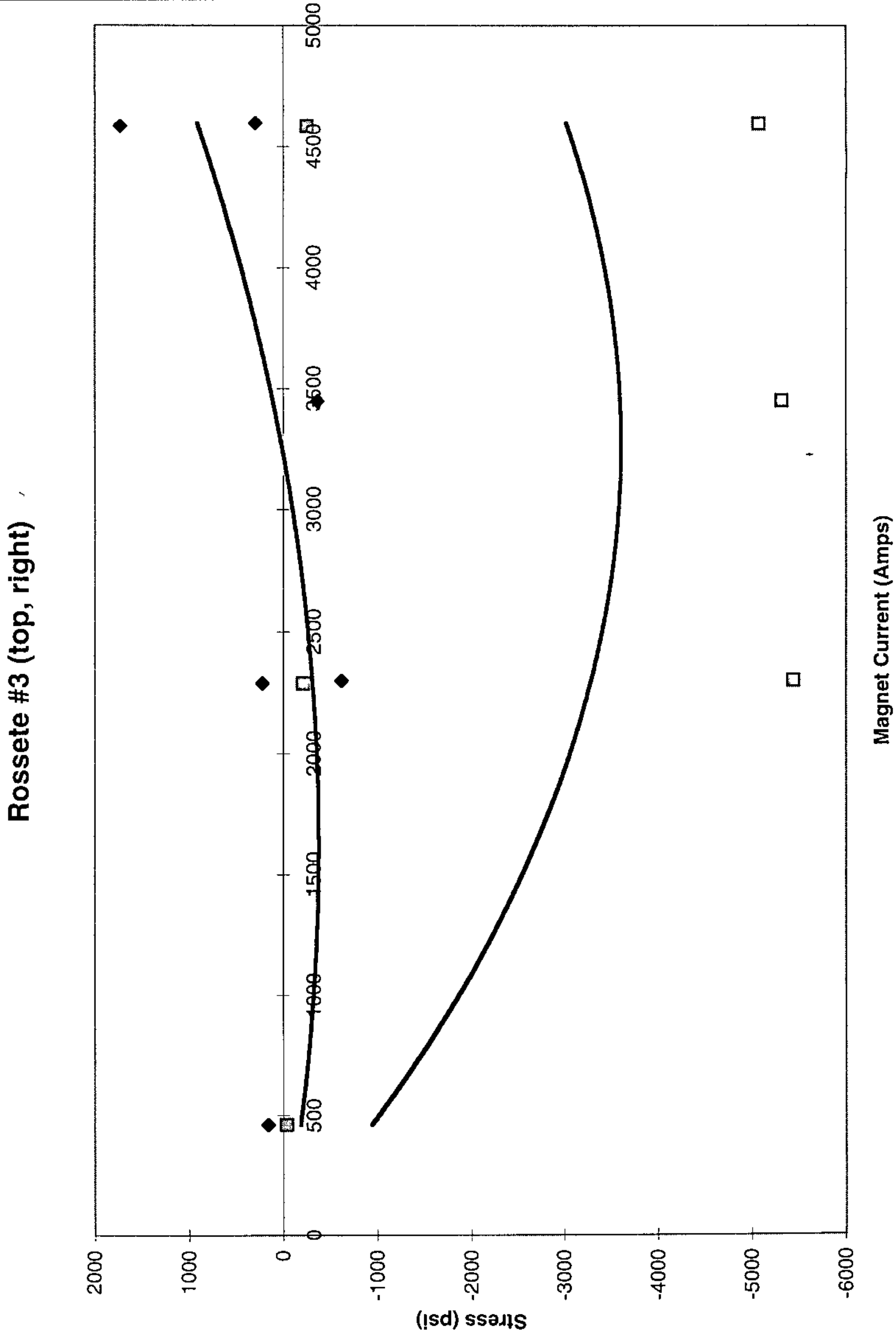
Daryl Oshatz
Steve Martinez

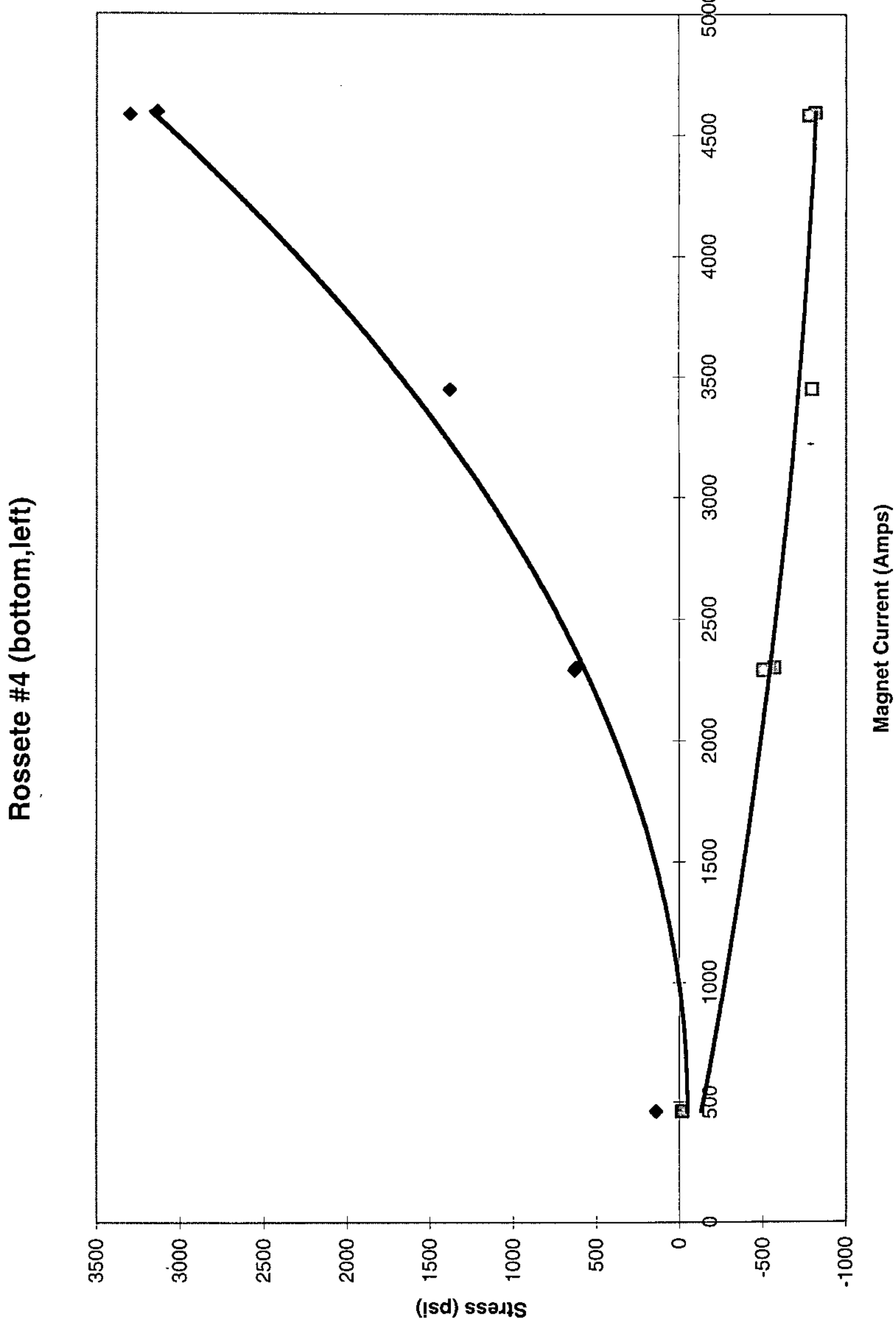
Location on SST	Rossete Number	Magnet Current (Amps)	1st Princ Stress (psi)	2nd Princ Stress (psi)	Max Average Stress (psi)	FEA Predicted Value (psi)	Fraction of Predicted Value
top,left	1	460	31	-237			
	1	2291	905	496			
	1	4587	600	224			
	1	2300	-580	-1273			
	1	3450	-440	-1166			
	1	4600	20	-805	**NA**	2500	NA
top,middle	2	460	14	-56			
	2	2291	-80	-209			
	2	4587	940	-857			
	2	2300	637	71			
	2	3450	899	-522			
	2	4600	1397	-572	**1300**	2500	0.52
top,right	3	460	157	-34			
	3	2291	223	-209			
	3	4587	1730	-247			
	3	2300	-619	-5444			
	3	3450	-366	-5325			
	3	4600	294	-5081	**NA**	2500	NA
bottom, left	4	460	140	-17			
	4	2291	630	-507			
	4	4587	3297	-784			
	4	2300	620	-575			
	4	3450	1381	-799			
	4	4600	3134	-822	**3200**	2500	1.28
bottom,right	5	460	176	-12			
	5	2291	1476	90			
	5	4587	4234	422			
	5	2300	1128	32			
	5	3450	2139	94			
	5	4600	4098	402	**4100**	2500	1.64
bottom, middle	6	460	119	87			
	6	2291	951	326			
	6	4587	1964	55			
	6	2300	835	-4			
	6	3450	1212	-174			
	6	4600	1971	-31	**1900**	2500	0.76
right	7	460	31	-31			
	7	2291	83	-454			
	7	4587	-502	-1105			
	7	2300	274	-389			
	7	3450	-146	-836			
	7	4600	-486	-1165	**-1100**	-1200	0.92
left	8	460	-102	-227			
	8	2291	639	226			
	8	4587	-660	-2883			
	8	2300	-164	-1109			
	8	3450	-363	-1489			
	8	4600	-338	-1478	**-2000**	-1200	1.67


Rossete #1(top,left)
Stress (psi)
1000
500
0
-500
-1000
-1500
Magnet Current (Amps)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

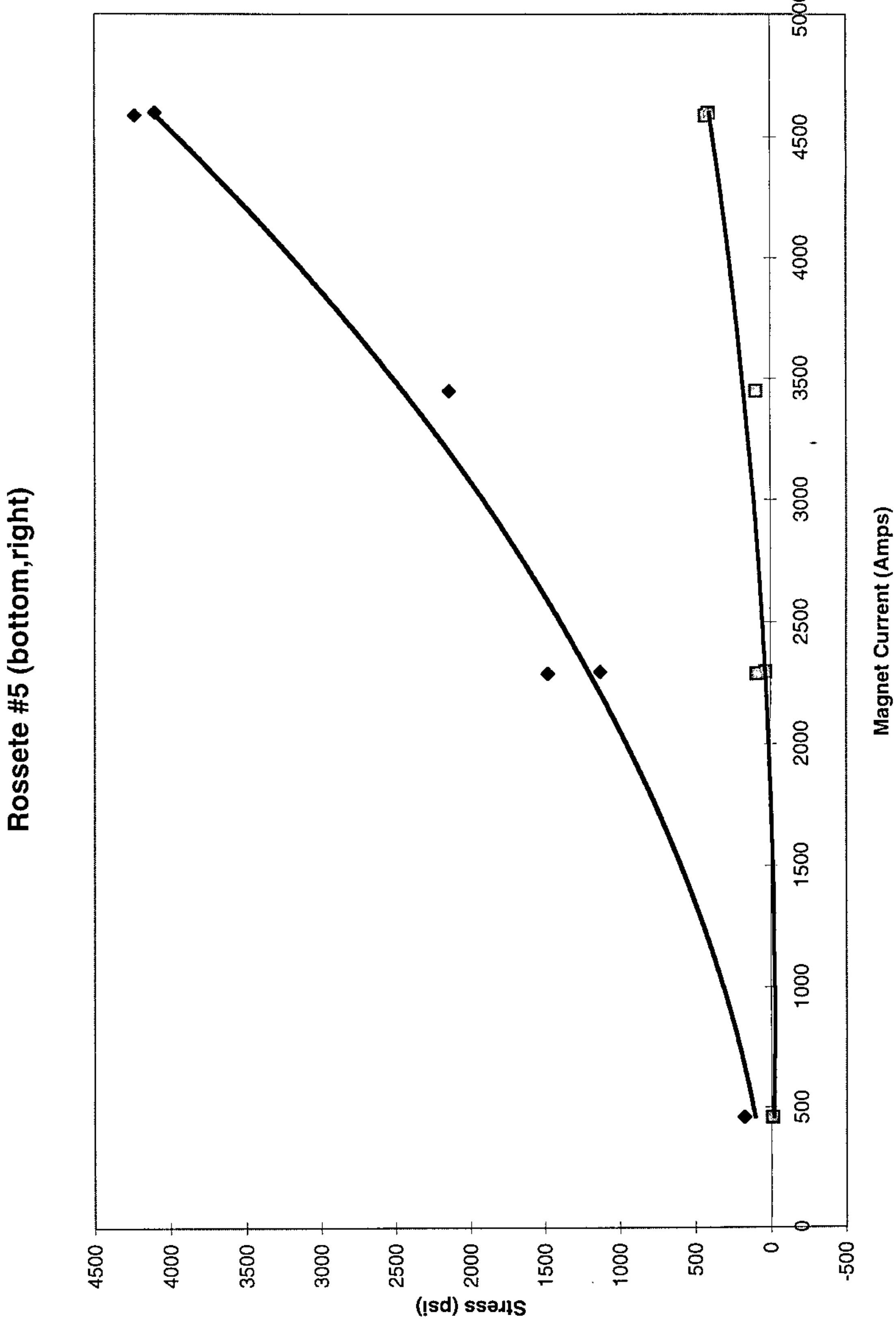


Rossete #2 (top,middle)
Stress (psi)
1500
1000
500
0
-500
-1000
Magnet Current (Amps)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

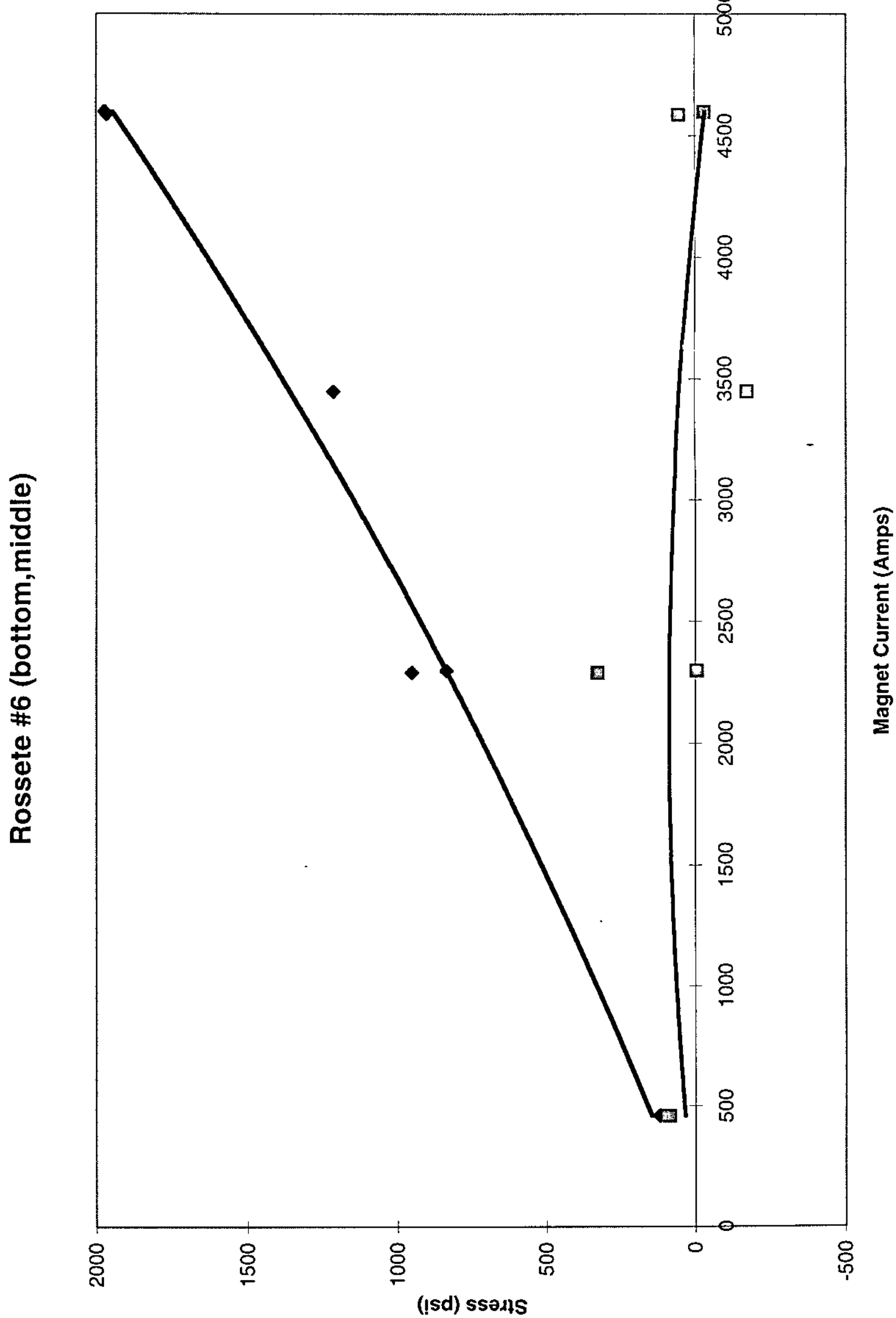

Rossete #3 (top, right)
Stress (psi)
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
Magnet Current (Amps)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000



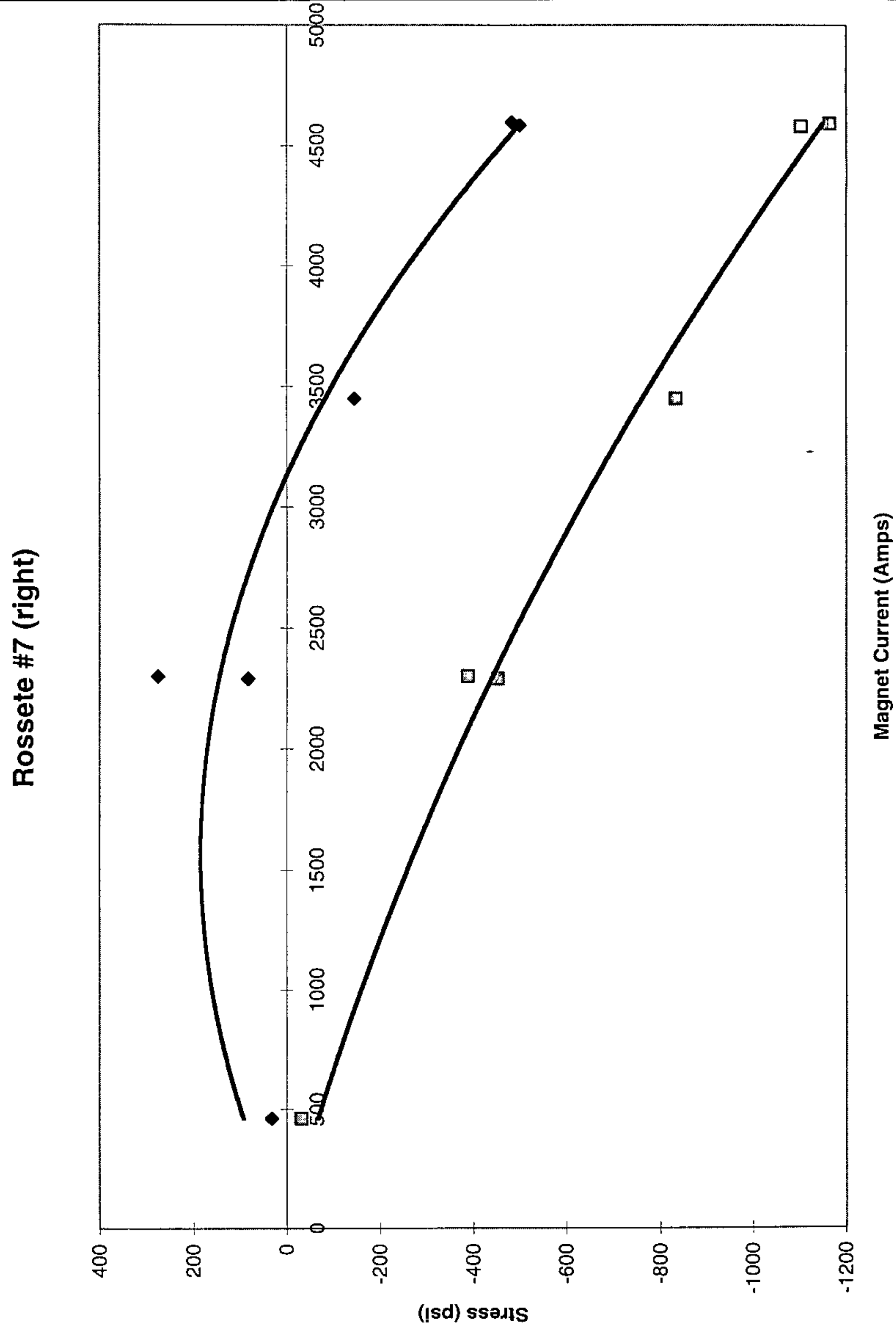
Rossete #4 (bottom,left)
Stress (psi)
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
Magnet Current (Amps)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000



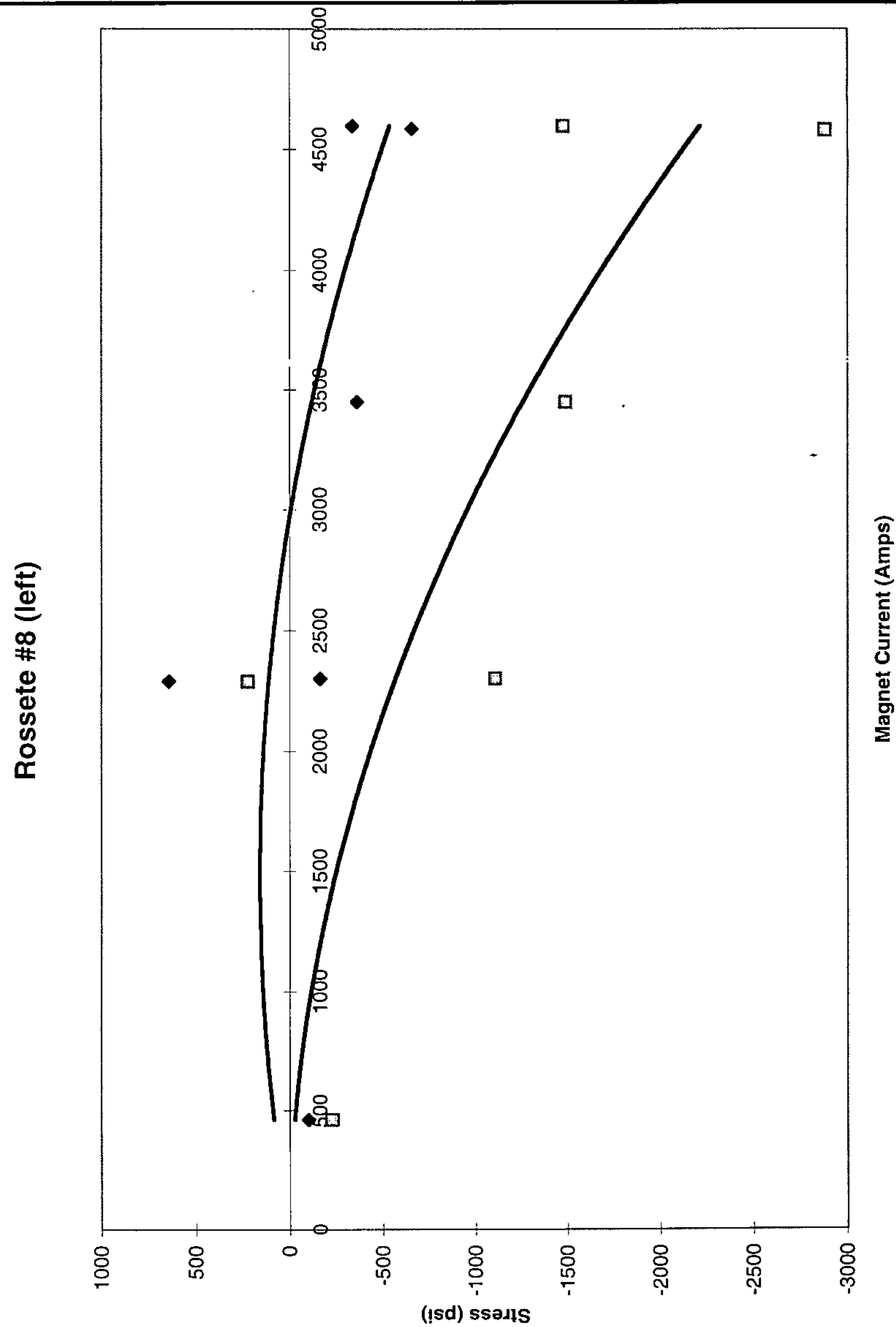
Rossete #5 (bottom,right)
Stress (psi)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
Magnet Current (Amps)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000



Rossete #6 (bottom,middle)
Stress (psi)
2000
1500
1000
500
0
-500
Magnet Current (Amps)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000



Rossete #7 (right)
Magnet Current (Amps)
Stress (psi)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
400
200
0
-200
-400
-600
-800
-1000
-1200


Rossete #8 (left)
Stress (psi)
Magnet Current (Amps)
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

Strain Gage Data Sheet

Excitation Voltage = Vin0
Vin0 = -2003 mV
Gage Factor = GF
GF = 2.08
Modulus of Specimen = E
E = 3.0E+07 psi

Equations:
Vr = ((Vout/Vin)strained-(Vout/Vin)unstrained)
e = -4*Vr/(GF*(1+2*Vr))
ep = (e1+e3)/2+(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
eq = (e1+e3)/2-(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
sp = E/1e6/2*((e1+e3)/(1-.3)+(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))
sq = E/1e6/2*((e1+e3)/(1-.3)-(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))

DATA: Oshatz/Martinez 4/15/97, Magnet at 460 Amps = 1/10th field

Rosette	Gage	Vout1 (mV)	Vout2 (mV)	Vr (V/V)	e1 (1e-6 in/in)	e2 (1e-6 in/in)	e3 (1e-6 in/in)	ep (1e-6 in/in)	eq (1e-6 in/in)	sp 1st princ. (psi)	sq 2nd princ. (psi)
1	1	-1.060	-1.065	2.5E-06	-5						
	2	-1.571	-1.568	-1.5E-06		3					
	3	-0.973	-0.973	0.0E+00			0	3	-8	31	-237
2	4	-1.840	-1.84	0.0E+00	0						
	5	-1.315	-1.314	-5.0E-07		1					
	6	-1.093	-1.094	5.0E-07			-1	1	-2	14	-56
3	7	-0.403	-0.404	5.0E-07	-1						
	8	-1.925	-1.927	1.0E-06		-2					
	9	-1.544	-1.54	-2.0E-06			4	6	-3	157	-34
4	10	-0.762	-0.763	5.0E-07	-1						
	11	-1.289	-1.29	5.0E-07		-1					
	12	-1.092	-1.088	-2.0E-06			4	5	-2	140	-17
5	13	-0.688	-0.683	-2.5E-06	5						
	14	-1.533	-1.534	5.0E-07		-1					
	15	-1.327	-1.328	5.0E-07			-1	6	-2	176	-12
6	16	-1.233	-1.23	-1.5E-06	3						
	17	-1.281	-1.278	-1.5E-06		3					
	18	-1.590	-1.588	-1.0E-06			2	3	2	119	87
7	19	-2.307	-2.306	-5.0E-07	1						
	20	-2.050	-2.049	-5.0E-07		1					
	21	-2.250	-2.251	5.0E-07			-1	1	-1	31	-31
8	22	-1.743	-1.749	3.0E-06	-6						
	23	-1.298	-1.3	1.0E-06		-2					
	24	-1.352	-1.354	1.0E-06			-2	-1	-7	-102	-227
Calib.	25	0.004	0.01	-3.0E-06	6						
Test Stand	26	-0.950	-0.936	-7.0E-06	13						
Vin	27	-2003		-1							

Strain Gage Data Sheet

Excitation Voltage = Vin0
Vin0 = - mV
Gage Factor = GF
GF = 2.08
Modulus of Specimen = E
E = 3.0E+07 psi

Equations:
Vr = ((Vout/Vin)strained-(Vout/Vin)unstrained)
e = -4*Vr/(GF*(1+2*Vr))
ep = (e1+e3)/2+(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
eq = (e1+e3)/2-(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
sp = E/1e6/2*((e1+e3)/(1-.3)+(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))
sq = E/1e6/2*((e1+e3)/(1-.3)-(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))

DATA: Oshatz/Martinez 4/15/97, Magnet at 2291 Amps = 1/2 field

Rosette	Gage	Vout1 (mV)	Vout2 (mV)	Vr (V/V)	e1 (1e-6 in/in)	e2 (1e-6 in/in)	e3 (1e-6 in/in)	ep (1e-6 in/in)	eq (1e-6 in/in)	sp 1st princ. (psi)	sq 2nd princ. (psi)
1	**1**	-1.056	-1.032	-1.2E-05	23						
	2	-1.543	-1.532	-5.5E-06		11					
	3	-0.957	-0.947	-5.0E-06			10	25	7	905	496
2	**4**	-1.806	-1.812	3.0E-06	-6						
	5	-1.293	-1.298	2.5E-06		-5					
	6	-1.073	-1.074	5.0E-07			-1	-1	-6	-80	-209
3	**7**	-0.393	-0.393	0.0E+00	0						
	8	-1.889	-1.893	2.0E-06		-4					
	9	-1.518	-1.514	-2.0E-06			4	8	-4	223	-58
4	**10**	-0.747	-0.770	1.1E-05	-22						
	11	-1.264	-1.270	3.0E-06		-6					
	12	-1.064	-1.038	-1.3E-05			25	26	-23	630	-507
5	**13**	-0.673	-0.630	-2.1E-05	41						
	14	-1.503	-1.504	5.0E-07		-1					
	15	-1.307	-1.312	2.5E-06			-5	48	-12	1476	90
6	**16**	-1.184	-1.175	-4.5E-06	9						
	17	-1.259	-1.231	-1.4E-05		27					
	18	-1.560	-1.538	-1.1E-05			21	28	1	951	326
7	**19**	-2.265	-2.262	-1.5E-06	3						
	20	-2.010	-2.024	7.0E-06		-13					
	21	-2.210	-2.222	6.0E-06			-12	7	-16	83	-454
8	**22**	-1.713	-1.697	-8.0E-06	15						
	23	-1.272	-1.269	-1.5E-06		3					
	24	-1.326	-1.321	-2.5E-06			5	19	1	639	226
Calib.	**25**	0.009	0.010	-5.0E-07	1						
Test Stand	**26**	-0.909	-0.919	5.0E-06	-10						
Vin	**27**	-2001	-2001	0.0E+00							

Strain Gage Data Sheet

Excitation Voltage = Vin0
Vin0 = - mV
Gage Factor = GF
GF = 2.08
Modulus of Specimen = E
E = 3.0E+07 psi

Equations:
Vr = ((Vout/Vin)strained-(Vout/Vin)unstrained)
e = -4*Vr/(GF*(1+2*Vr))
ep = (e1+e3)/2+(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
eq = (e1+e3)/2-(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
sp = E/1e6/2*((e1+e3)/(1-.3)+(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))
sq = E/1e6/2*((e1+e3)/(1-.3)-(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))

DATA: Oshatz/Martinez 4/27/97, Magnet at 2300 Amps = 1/2 field

Rosette	Gage	Vout1 (mV)	Vout2 (mV)	Vr (V/V)	e1 (1e-6 in/in)	e2 (1e-6 in/in)	e3 (1e-6 in/in)	ep (1e-6 in/in)	eq (1e-6 in/in)	sp 1st princ. (psi)	sq 2nd princ. (psi)
1	1	-0.963	-0.975	6.0E-06	-12						
	2	-1.423	-1.434	5.5E-06		-11					
short ?0	3	-0.878	-0.911	1.7E-05			-32	-7	-37	-580	-1273
2	4	-1.789	-1.789	-4.5E-08	0						
	5	-1.284	-1.266	-9.0E-06		17					
	6	-1.061	-1.044	-8.5E-06			16	21	-4	637	71
3 ?zero	7	-0.220	-0.376	7.8E-05	-150						
	8	-1.863	-1.866	1.5E-06		-3					
	9	-1.501	-1.492	-4.5E-06			9	34	-175	-619	-5444
4	10	-0.735	-0.761	1.3E-05	-25						
	11	-1.247	-1.251	2.0E-06		-4					
	12	-1.050	-1.023	-1.4E-05			26	26	-25	620	-575
5	13	-0.657	-0.622	-1.8E-05	34						
	14	-1.475	-1.474	-5.4E-07		1					
	15	-1.288	-1.295	3.5E-06			-7	37	-10	1128	32
6	16	-1.145	-1.151	3.0E-06	-6						
	17	-1.246	-1.226	-1.0E-05		19					
	18	-1.546	-1.520	-1.3E-05			25	28	-8	835	-4
7	19	-2.248	-2.238	-5.1E-06	10						
	20	-1.995	-2.006	5.5E-06		-10					
	21	-2.193	-2.206	6.5E-06			-12	13	-16	274	-389
8	22	-1.591	-1.626	1.7E-05	-34						
	23	-1.219	-1.226	3.5E-06		-7					
	24	-1.309	-1.305	-2.0E-06			4	6	-35	-164	-1109
Calib.	25	0.008	0.008	2.0E-10	0						
Test Stand	26	-0.924	-0.917	-3.5E-06	7						
Vin	27	-1996.7	-1997	-1.0E-04							

Strain Gage Data Sheet

Excitation Voltage = Vin0
Vin0 = - mV
Gage Factor = GF
GF = 2.08
Modulus of Specimen = E
E = 3.0E+07 psi

Equations:
Vr = ((Vout/Vin)strained-(Vout/Vin)unstrained)
e = -4*Vr/(GF*(1+2*Vr))
ep = (e1+e3)/2+(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
eq = (e1+e3)/2-(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
sp = E/1e6/2*((e1+e3)/(1-.3)+(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))
sq = E/1e6/2*((e1+e3)/(1-.3)-(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))

DATA: Oshatz/Martinez 4/27/97, Magnet at 3450 Amps = 3/4 field

Rosette	Gage	Vout1 (mV)	Vout2 (mV)	Vr (V/V)	e1 (1e-6 in/in)	e2 (1e-6 in/in)	e3 (1e-6 in/in)	ep (1e-6 in/in)	eq (1e-6 in/in)	sp 1st princ. (psi)	sq 2nd princ. (psi)
1	1	-0.963	-0.968	2.5E-06	-5						
	2	-1.423	-1.435	6.0E-06		-11					
short ?0	3	-0.878	-0.912	1.7E-05			-33	-3	-34	-440	-1166
2	4	-1.789	-1.799	5.0E-06	-10						
	5	-1.284	-1.251	-1.7E-05		32					
	6	-1.061	-1.042	-9.5E-06			18	35	-26	899	-522
3 ?0	7	-0.220	-0.383	8.2E-05	-157						
	8	-1.863	-1.872	4.5E-06		-9					
	9	-1.501	-1.476	-1.3E-05			24	41	-174	-366	-5325
4	10	-0.735	-0.774	2.0E-05	-38						
	11	-1.247	-1.257	5.0E-06		-10					
	12	-1.050	-0.997	-2.7E-05			51	54	-40	1381	-799
5	13	-0.657	-0.592	-3.3E-05	63						
	14	-1.475	-1.474	-5.4E-07		1					
	15	-1.288	-1.299	5.5E-06			-11	70	-18	2139	94
6	16	-1.145	-1.153	4.0E-06	-8						
	17	-1.246	-1.210	-1.8E-05		35					
	18	-1.546	-1.513	-1.7E-05			32	42	-18	1212	-174
7	19	-2.248	-2.245	-1.6E-06	3						
	20	-1.995	-2.011	8.0E-06		-15					
	21	-2.193	-2.220	1.3E-05			-26	4	-26	-146	-836
8	22	-1.591	-1.638	2.3E-05	-45						
	23	-1.219	-1.235	8.0E-06		-15					
	24	-1.309	-1.307	-1.0E-06			2	3	-46	-363	-1489
Calib.	25	0.008	0.008	2.0E-10	0						
Test Stand	26	-0.924	-0.917	-3.5E-06	7						
Vin	27	-1996.7	-1997	-1.0E-04							

Strain Gage Data Sheet

Excitation Voltage = Vin0
Vin0 = - mV
Gage Factor = GF
GF = 2.08
Modulus of Specimen = E
E = 3.0E+07 psi

Equations:
Vr = ((Vout/Vin)strained-(Vout/Vin)unstrained)
e = -4*Vr/(GF*(1+2*Vr))
ep = (e1+e3)/2+(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
eq = (e1+e3)/2-(1/2^.5)*((e1-e2)^2+(e2-e3)^2)^.5
sp = E/1e6/2*((e1+e3)/(1-.3)+(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))
sq = E/1e6/2*((e1+e3)/(1-.3)-(2^.5/(1+.3)*((e1-e2)^2+(e2-e3)^2)^.5))

DATA: Oshatz/Martinez 4/27/97, Magnet at 4600 Amps = full field

Rosette	Gage	Vout1 (mV)	Vout2 (mV)	Vr (V/V)	e1 (1e-6 in/in)	e2 (1e-6 in/in)	e3 (1e-6 in/in)	ep (1e-6 in/in)	eq (1e-6 in/in)	sp 1st princ. (psi)	sq 2nd princ. (psi)
1	**1**	-0.963	-0.954	-4.5E-06	9						
	2	-1.423	-1.431	4.0E-06		-8					
short ?0	**3**	-0.878	-0.906	1.4E-05			-27	9	-27	20	-805
2	**4**	-1.789	-1.800	5.5E-06	-11						
	5	-1.284	-1.235	-2.5E-05		47					
	6	-1.061	-1.030	-1.6E-05			30	52	-33	1397	-572
3 ?0	**7**	-0.220	-0.389	8.5E-05	-163					-	
	8	-1.863	-1.873	5.0E-06		-10					
	9	-1.501	-1.448	-2.7E-05			51	61	-172	294	-5081
4	**10**	-0.735	-0.786	2.6E-05	-49						
	11	-1.247	-1.260	6.5E-06		-13					
	12	-1.050	-0.943	-5.4E-05			103	113	-59	3134	-822
5	**13**	-0.657	-0.535	-6.1E-05	118						
	14	-1.475	-1.469	-3.0E-06		6					
	15	-1.288	-1.301	6.5E-06			-13	133	-28	4098	402
6	**16**	-1.145	-1.139	-3.0E-06	6						
	17	-1.246	-1.181	-3.3E-05		63					
	18	-1.546	-1.505	-2.1E-05			39	66	-21	1971	-31
7	**19**	-2.248	-2.253	2.5E-06	-5						
	20	-1.995	-2.012	8.5E-06		-16					
	21	-2.193	-2.228	1.8E-05			-34	-5	-34	-486	-1165
8	**22**	-1.591	-1.637	2.3E-05	-44						
	23	-1.219	-1.232	6.5E-06		-13					
	24	-1.309	-1.307	-1.0E-06			2	3	-46	-338	-1478
Calib.	**25**	0.008	0.008	0.0E+00	0						
Test Stand	**26**	-0.924	-0.915	-4.5E-06	9						
Vin	**27**	-1996.7	-1996.7	0.0E+00							