TS-SSC 90-058

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Summary of DS0310 Quenches

The 40 mm aperture, 1 m long Fermilab magnet DS0310 experienced 51 quenches during its first thermal cycle and 29 during its second for a total of 80 quenches. These quenches occurred at three temperatures: 4.3°K, 4.2°K and 3.8°K. The first section of this report summarizes the quench history of DS0310, the second section discusses the analysis of these quenches, and the third section discusses the ramp rate studies performed. A summary table is attached and figure 1 is a map of the voltage taps used to determine the quench origins.

Quench History of DS0310

The following is a brief description of the sequence of tests performed on DS0310 and their relationship to its quenches. DS0310 was cooled to 4.2°K degrees while all gages were monitored at 10 minute intervals. Upon reaching 4.2°K degrees, the dewar was pressurized to approximately 850 Torr which produced a temperature at the magnet skin of 4.3°K. This temperature represents an average of three thermometers located at the top, middle and bottom of the magnet. Typical readings of these thermometers were 4.33, 4.29 and 4.28°K, top to bottom. The average fluctuated a maximum of 0.025 degrees, and these fluctuations did not appear to affect the quench current. The thermometer readings for each quench can be seen in the quench summary. Ramp rates to quench were at 16 A/s unless stated otherwise. Figure 2 displays a plot of quench current and origination position as a function of quench number.

There were two training quenches at 4.3°K, both at about 6600 A. The first was in the lead end of the upper inner coil at turn 14 and terminated the fifth strain gage run. The second was in the lead end of the lower inner coil at turn 11. The plateau current of 6850 A was reached on the third quench. Plateau quenches tended to be in the upper inner straight section of turn 16 (the pole turn) opposite the ramp splice. This is the same location as the plateau quenches in DS0309. Following four plateau quenches, a ramp rate study was initiated, with rates of 25, 50, 75, 100, 125, and 150 A/s. During an attempt to ramp at 175 A/s power supply problems were encountered which tripped the safety circuit. This occurred twice, the safety circuit tripping at 5000 A the first time and 2476 A the second time. It was later discovered that the ramp rate apparently jumped to about 700 A/s and 6000 A/s respectively, for a period of about 30 ms prior to these trips. A ramp rate of 16 A/s was then tried and a quench occurred at 6580 A originating in the uninstrumented section of the lower inner coil between turns 1 and 9. It is unknown whether this quench, which was almost 300 A below the plateau, was as a consequence of the power supply problem. It was followed by two quenches originating in the upper inner straight section opposite the ramp splice. The first of these was about 25 A below plateau current and the second was at the plateau current.

Three training quenches were required to reach plateau when the temperature was dropped to 4.2°K. Two of these were again in the lead end of the lower inner coil turn 11, while the third was in the return end of the upper inner turn 16. The quenches in turn 11 were very similar to the training quench at 4.3°K. Five plateau quenches were then observed. The warm bore was inserted into the magnet and a series of harmonic measurements were made during which 3 more quenches occurred. All of these were slightly above the plateau current. One of these quenches was in the upper outer coil, one was in the upper inner turn 16 about 30 cm from the ramp splice and the third was in the typical plateau quench location. The harmonic measurements were completed in the evening and the following morning two more quenches were produced at 4.2°K. The first of these was in the upper inner return end of turn 16 and was about 50 A below plateau, the second was a plateau quench.

The temperature was then lowered to approximately 3.8°K (typically the average of the thermometers was 3.76°K). Three training quenches were required to obtain the plateau. The first was in the inner lower straight section of turn 10, the second was in the upper inner turn 16 straight section opposite the splice, and the third was in the upper inner turn 16 return end. The first and third training quenches were 250 A below plateau,the second was 30 A below plateau. Four plateau quenches at 7500 A were then observed followed by strain gage runs. The goal of the strain gage run was to obtain measurements at 7400 A, however runs were aborted twice at about 7000 A due to heating in the copper leads to the magnet. On the second aborted attempt, the inner strain gages were lost. It was subsequently discovered that a ground short had developed in one of the gages in the string. During the third attempt at the strain gage run, the magnet quenched 140 A below plateau in the upper inner turn 16 straight section opposite the splice. Another simple 16 A/s ramp quenched 250 A below plateau, however the shut down procedure for the evening had already begun and the temperature in the dewar was rising so this was not considered a reliable measurement. The following day, two quenches were required to regain the plateau at 3.8 K, both in the upper inner turn 16 return end. These quenches will be discussed further in the analysis section. Three quenches at the plateau value of 7515 A were then produced, one of which was in the lower inner turn 11 lead end. Another low quench followed again in upper inner turn 16 return end, followed by a quench at plateau. A strain gage run followed and then 4 high ramp rate quenches which were used to warm the magnet to 4.2°K. Three quenches at the plateau value were obtained at 4.2°K The magnet was then warmed to room temperature.

DS0310 experienced 29 quenches during the second thermal cycle. The first quench at 4.3°K occurred during the strain gage runs and was a training quench about 50 A below plateau. It was in the lower inner turn 10 straight section on the right side. Four plateau quenches were observed at 4.3°K and then the magnet temperature was dropped to 4.2°K where the plateau current was immediately reached. After three quenches at this temperature, the magnet was again brought to 4.3°K and a ramp rate study was initiated to confirm the results obtained during the first thermal cycle. The magnet temperature was then brought to 3.8°K. Two training quenches occurred before the plateau was reached. The first was in the upper outer coil and the second was in the upper inner turn 12 straight section on the right side. Two apparent plateau quenches were then observed, followed by three lower current quenches. The lowest of these (200 A below plateau) was again in the lead end of turn 11. The other two were in the upper inner turn 13 straight section right side and in the upper inner turn 16 return end. These were followed by three quenches at the plateau. It should be noted that the plateau at 3.8 in the second thermal cycle was about 50 A below the plateau in the first thermal cycle.

Quench Analysis

In this section a more detailed analysis of some of quenches referred to above will be given. The general characteristics of the plateau quenches will also be discussed.

The first training quench at 4.3°K was located near the center of the lead end of the upper inner turn 14. The time required for the quench to propagate to the straight sections on either side of the end was 5 ms. The second training quench was in the lower inner turn 11 lead end. Since turn 11 is not fully instrumented, the location of the quench must be inferred from the time of the resistive rise of neighboring segments. A map of these times is shown for this quench in figure 3. Since the time for the quench to reach tap 11B was approximately 5.8 ms and the time to reach tap 14B in the first training quench was 5 ms, one may conclude that the origin of the second quench was near the center of the end. All quenches which originated in the lead end of turn 11 were very similar to this quench.

The plateau quenches at a ramp rate of 16 A/s and 4.3°K were either 28.5±4 cm (4 quenches) or 44±4 cm (2 quenches) from the lead end of turn 16 opposite the ramp splice. (Distances are quoted from the boundary of the wedges and the lead end spacers.) Most plateau quenches were located in the range 27-30 cm from the lead end of turn 16 opposite the ramp splice, with measurement errors of ±4 cm. These will be referred to as standard plateau quenches (SPQs) for the remainder of this note. The quench velocity as measured using the time of flight technique was 80±5 m/s.

The three training quenches at 4.2°K were approximately 75 A below the plateau of 7025 A. Two of these were again in the lead end of turn 11, approximately in the same location as the training quench at 4.3°K. The third quench was near the center of the return end of turn 16. The plateau quenches were all SPQs.

The first of the three training quenches at 3.8°K was in the lower left inner straight section of turn 10 about 8±4 cm from the return end. It was 250 A below the eventual plateau. The second training quench was only about 30 A below plateau and was about 28.5±4 cm from the lead end of turn 16 opposite the splice. The third training quench was again about 250 A below plateau and was near the center of the return end of turn 16. The four plateau quenches were at about 7500 A. The first and third of these were SPQs and the second and fourth were 64±4 cm from the lead end of turn 16 opposite the ramp splice. The two low quenches in turn 16 which followed the 4 plateau quenches were very near the center of the magnet and therefore in the region of the strain gages. The quench velocity of these quenches was anomalously high, about 105 m/s and 95 m/s, respectively. Immediately prior to these two quenches a short had developed in the upper inner strain gage assembly against which this coil rests. The two events may be related. The subsequent two quenches were also low but were near the center of the return end of turn 16 and occurred the following day. The next three quenches were at the plateau current and two of them were SPQs. The third was near the center of the lead end of turn 11. The following quench was at the center of the turn 16 return end and it was about 200 A below the plateau. It was followed by an SPQ.

The final three quenches of the first thermal cycle were at 4.2°K and were all at the plateau current. Two of them were SPQs and the last was 40±4 cm from the lead end of upper inner turn 16 opposite the ramp splice.

The first quench of the second thermal cycle was in the lower inner right straight section of turn 10 at tap D about 8±4 cm from the return end. It was about 50 A below plateau. The next four quenches were at the plateau current. The first, second and fourth were SPQs and the third was about 53±4 cm from the lead end in the upper inner turn 16 straight section opposite the splice.

The next three quenches were at 4.2°K and all were SPQs. The following set of quenches were part of a ramp rate study which will be discussed later.

The first quench at 3.8°K was in the upper outer coil probably near the ramp splice. It was 275 A below plateau. The second training quench was in the upper inner turn 12 right side and was at the lead end tap, about 6.4 cm from the end. It was approximately 100 A below plateau. The next two quenches were SPQs. There then followed three quenches which were off the plateau. The first of these was in the upper inner turn 13 right side very near the return end tap and was about 40 A below the plateau. The next was in the lower inner return end of turn 11 and was about 180 A below plateau. The next was near the center of the return end of upper inner turn 16 and was 30 A below plateau. The following three quenches were on plateau. The first two were SPQs and the third was about 44±4 cm from the lead end of upper inner turn 16 opposite the ramp splice. The plateau quenches at 3.8°K ranged from 7480 A to 7469 A with no corresponding variation in temperature as monitored by the thermometers. This is to be compared with plateau quenches at 3.8°K during the first thermal cycle which ranged from 7495 A to 7519 A.

The relation between quench current and temperature of the magnet (as determined by the average of the three thermometers) is plotted in figure 4 for all quenches with dI/dt less than 75 A/s and stable temperature conditions. The line shown is the critical current as predicted using Chris Quigg's program. The table below summarizes the plateau quench currents for the various temperatures at which data was taken. For the purpose of this table, a plateau quench is defined to be one which occurs when the ramp rate is 16 A/s and originates in the pole turn opposite the ramp splice, and which is part of a sequence of at least 2 quenches near the maximum current for a given temperature.

Temperature	Thermal Cycle	Predicted Icrit	Measured Iquench	Difference
4.31°K	1	6617 A	6846±10 A	229±10
4.16°K	1	6795 A	7022±5 A	227±5
3.78°K	1	7210 A	7509±9 A	299±9
4.31°K	2	6617 A	6856±9 A	239±9
4.17°K	2	6783 A	7023±8 A	240±8
4.76°K	2	7230 A	7468±8 A	238±8

Ramp Rate Dependence

Figure 5 shows the ramp rate dependence of the quench current for magnet DS0310 compared to magnets DS0309 and DS0308. A ramp rate study was done during each of the two thermal cycles for DS0310. It can be seen that the quench current begins dropping between ramp rates of 50 and 75 A/s for DS0310 whereas there is no drop in quench current until the ramp rate exceeds 100 A/s for magnets DS0309 and DS0308. The quench at 25 A/s during the first thermal cycle was in the upper inner turn 16 on the side of the ramp splice 43±4 cm from the lead end. It was 75 a above plateau. The quench at 50 A/s was near the middle of the upper inner turn 16 straight section opposite the ramp splice about 59±4 cm from the lead end. The quenches at 25 and 50 A/s during the second thermal cycle were in the upper inner turn 16 opposite the ramp splice 66±4 and 72±4 cm from the lead end respectively.

The location of the quenches below plateau is in the upper inner ramp splice for all three magnets, indicating that the mechanism for quench initiation during high ramp rates is resistive heating in the solder filled splice. From the difference in ramp rate dependence, one may conclude that resistive heating in the ramp splice of DS0310 is greater than that in DS0309 although the reason for this difference is not known. Figure 6 is a plot of voltage versus current across the upper ramp splice, from which a splice resistance of 1.5 nΩ can be derived. As discussed in TS-SSC 90-026, the SSC dipole magnets must be able to ramp down at an initial rate of -325 A/s without quenching. As with DS0309, DS0310 was ramped from 6500 A to 4000 A at -100, -200,-300, and -400 A/s without quenching, indicating adequate stability despite the indication that resistive heating was greater in DS0310 than in DS0309.

Quench File Summary
DS0310

Q#	File	I-m	Idot	I-t	Idot	QDC	MIITs	t-Q	V-max	Coil	t(H)	V(H)	T(t)	T(m)	T(b)	P	LL	Location
	0	983.	0.	0.0	0.0	U-L	0.1	0.000	-6.	LI	0.000	0.	4.34	4.30	4.29	859.	0.	
1	1	6608.	0.	0.0	0.0	U-L	4.2	-.009	21.	UI	0.000	0.	4.33	4.29	4.28	852.	28.	IU14LE 5 ms from taps
2	2	6603.	16.	0.0	0.0	U-L	4.1	-.007	19.	LI	0.000	0.	4.33	4.29	4.28	849.	22.	IL11LE
3	3	6853.	-16.	0.0	0.0	U-L	4.3	-.006	22.	UI	0.000	0.	4.33	4.29	4.28	851.	27.	IU16SL 2.2 ms from lead tap
4	4	6848.	16.	0.0	0.0	U-L	4.3	-.005	22.	UI	0.000	0.	4.33	4.29	4.28	852.	29.	IU16SL 2 ms from lead tap
5	5	6848.	16.	0.0	0.0	U-L	4.5	-.007	18.	UI	0.000	0.	4.33	4.29	4.28	850.	25.	IU16SL 4.2 ms from lead tap
6	6	6853.	16.	0.0	0.0	U-L	4.3	-.005	22.	UI	0.000	0.	4.33	4.29	4.28	853.	24.	IU16SL 2 ms from lead tap
7	7	6922.	0.	0.0	0.0	U-L	4.5	-.007	-20.	UI	0.000	0.	4.33	4.30	4.28	856.	33.	IU16SR 4 ms from return tap
8	8	6868.	50.	0.0	0.0	U-L	4.5	-.007	-17.	UI	0.000	0.	4.33	4.29	4.28	852.	23.	IU16SL 5.4 ms from lead tap
9	9	6731.	75.	0.0	0.0	U-L	4.4	-.012	-22.	UI	0.000	0.	4.33	4.29	4.28	851.	20.	IU Rmp Spl 1.8 ms from tap 16A
	10	5634.	100.	0.0	0.0	Vtot	3.2	0.000	-32.	LI	0.000	0.	4.33	4.29	4.28	851.	17.	
10	11	6599.	0.	0.0	0.0	U-L	4.4	-.013	-22.	UI	0.000	0.	4.33	4.29	4.28	852.	18.	IU Rmp Spl 3 ms from tap 16A
11	12	6486.	125.	0.0	0.0	U-L	4.3	-.013	-22.	UI	0.000	0.	4.33	4.29	4.28	850.	13.	IU Rmp Spl 3.6 ms from tap 16A
12	13	6403.	150.	0.0	0.0	U-L	4.2	-.013	-22.	UI	0.000	0.	4.33	4.30	4.29	855.	17.	IU Rmp Spl 3.8 ms from tap 16A
	14	5007.	175.	0.0	0.0	V-dI	2.6	0.000	-29.	LI	0.000	0.	4.33	4.29	4.28	851.	16.	
	15	2476.	175.	0.0	0.0	V-dI	0.7	-.001	-14.	LI	0.000	0.	4.33	4.29	4.29	850.	29.	
13	16	6579.	16.	0.0	0.0	U-L	4.1	-.010	23.	LI	0.000	0.	4.32	4.28	4.27	848.	20.	IL Multi Turn
14	17	6824.	16.	0.0	0.0	U-L	4.4	-.008	20.	UI	0.000	0.	4.34	4.30	4.28	864.	21.	IU16SL 2.6 ms from lead tap
15	18	6848.	16.	0.0	0.0	U-L	4.4	-.007	19.	UI	0.000	0.	4.35	4.32	4.30	869.	34.	IU16SL 4.2 ms from lead tap
16	19	6966.	16.	0.0	0.0	U-L	4.4	-.008	22.	LI	0.000	0.	4.19	4.16	4.15	746.	27.	IL11LE
17	20	6936.	16.	0.0	0.0	U-L	4.6	-.009	21.	UI	0.000	0.	4.19	4.15	4.14	744.	29.	IU16RE 4 ms from taps
18	21	6951.	16.	0.0	0.0	U-L	4.3	-.007	22.	LI	0.000	0.	4.19	4.16	4.15	745.	33.	IL11LE
19	22	7020.	16.	0.0	0.0	U-L	4.5	-.007	22.	UI	0.000	0.	4.19	4.16	4.14	744.	35.	IU16SL 2 ms from lead tap
20	23	7029.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.15	4.15	744.	22.	IU16SL 1.8 ms from lead tap
21	24	7029.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.15	4.15	745.	28.	IU16SL 1.8 ms from lead tap
22	25	7015.	0.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.16	4.15	747.	27.	IU16SL 2 ms from lead tap
23	26	7025.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.16	4.15	748.	27.	IU16SL 2 ms from lead tap
24	27	7069.	16.	0.0	0.0	U-L	4.3	-.008	-26.	UI	0.000	0.	4.19	4.16	4.15	749.	24.	OU
25	28	7039.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.16	4.15	750.	27.	IU16SL 2 ms from lead tap
26	29	7078.	16.	0.0	0.0	U-L	4.6	-.007	-19.	UI	0.000	0.	4.19	4.16	4.15	750.	28.	IU16SR 4.2 ms from return tap
27	30	6976.	16.	0.0	0.0	U-L	4.6	-.008	22.	UI	0.000	0.	4.19	4.15	4.14	745.	31.	IU16RE 4.2 ms from taps
28	31	7025.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.16	4.15	745.	33.	IU16SL 2.2 ms from lead ta
29	32	7240.	16.	0.0	0.0	U-L	4.7	-.009	23.	LI	0.000	0.	3.78	3.75	3.74	488.	24.	IL10SL at tap 10C
30	33	7470.	16.	0.0	0.0	U-L	4.6	-.004	27.	UI	0.000	0.	3.78	3.75	3.74	490.	25.	IU16SL 2.2 ms from lead tap
31	34	7240.	16.	0.0	0.0	U-L	4.8	-.009	22.	UI	0.000	0.	3.78	3.75	3.73	488.	23.	IU16RE 5.4 ms from 16C
32	35	7495.	16.	0.0	0.0	U-L	4.6	-.004	27.	UI	0.000	0.	3.81	3.80	3.77	502.	19.	IU16SL 2 ms from lead tap
33	36	7500.	16.	0.0	0.0	U-L	4.7	-.004	26.	UI	0.000	0.	3.78	3.75	3.74	488.	18.	IU16SL 5.2 ms from return tap
34	37	7509.	16.	0.0	0.0	U-L	4.7	-.005	27.	UI	0.000	0.	3.78	3.76	3.76	492.	16.	IU16SL 2.2 ms from lead tap
35	38	7504.	16.	0.0	0.0	U-L	4.7	-.004	27.	UI	0.000	0.	3.79	3.76	3.76	495.	15.	IU16SL 5.2 ms from return tap
	39	7000.	0.	0.0	0.0	Cu L	18.7	0.000	0.	LI	0.000	0.	3.78	3.75	3.74	490.	15.	
	40	6990.	0.	0.0	0.0	Cu L	18.7	0.000	0.	LI	0.000	0.	3.78	3.75	3.74	498.	16.	
36	41	7338.	16.	0.0	0.0	U-L	4.6	-.004	23.	UI	0.000	0.	3.81	3.77	3.76	555.	29.	IU16SL 4 ms from lead tap
37	42	7264.	16.	0.0	0.0	U-L	4.8	-.007	24.	UI	0.000	0.	3.85	3.82	3.81	852.	24.	IU16SL 4.4 ms from return tap
38	43	7211.	0.	0.0	0.0	U-L	4.9	-.009	23.	UI	0.000	0.	3.78	3.74	3.73	495.	18.	IU16RE 5 ms from 16C
39	44	7392.	16.	0.0	0.0	U-L	4.9	-.008	25.	UI	0.000	0.	3.78	3.77	3.75	492.	12.	IU16RE4.2 ms from 16D
40	45	7519.	16.	0.0	0.0	U-L	4.7	-.005	28.	UI	0.000	0.	4.00	3.82	3.77	610.	11.	IU16SL 2 ms from lead tap
41	46	7519.	16.	0.0	0.0	U-L	4.6	-.007	25.	LI	0.000	0.	3.78	3.76	3.76	491.	10.	IL11LE
42	47	7514.	16.	0.0	0.0	U-L	4.7	-.005	28.	UI	0.000	0.	3.77	3.74	3.73	486.	16.	IU16SL 2.2 ms from lead tap
43	48	7309.	16.	0.0	0.0	U-L	4.8	-.008	24.	UI	0.000	0.	3.76	3.73	3.72	486.	11.	IU16RE 4.5 ms from taps
44	49	7519.	16.	0.0	0.0	U-L	4.6	-.004	27.	UI	0.000	0.	3.78	3.76	3.77	492.	13.	IU16SL 2 ms from lead tap
	50	6990.	-16.	0.0	0.0	Cu L	18.7	0.000	0.	LI	0.000	0.	3.78	3.75	3.74	488.	19.	
45	51	6946.	16.	0.0	0.0	U-L	4.7	-.011	18.	UI	0.000	0.	3.95	3.91	3.90	748.	25.	
46	52	6873.	100.	0.0	0.0	U-L	4.5	-.011	-19.	UI	0.000	0.	4.19	3.97	3.91	748.	22.	
47	53	6501.	150.	0.0	0.0	U-L	4.3	-.013	-22.	UI	0.000	0.	4.19	4.15	3.94	748.	17.	
48	54	6364.	0.	0.0	0.0	U-L	4.3	-.015	-22.	UI	0.000	0.	4.19	4.16	4.07	748.	22.	
49	55	7020.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.15	4.14	748.	27.	IU16SL 2.2 ms from lead tap
50	56	7020.	16.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.19	4.15	4.14	748.	32.	IU16SL 2 ms from lead tap
51	57	7015.	0.	0.0	0.0	U-L	4.6	-.006	23.	UI	0.000	0.	4.19	4.16	4.15	748.	26.	IU16SL 5 ms from return tap
	58	1002.	0.	0.0	0.0	U-L	0.1	0.000	-6.	LI	0.000	0.	4.34	4.30	4.29	507.	63.	
52	59	6809.	0.	0.0	0.0	U-L	4.3	-.008	21.	LI	0.000	0.	4.35	4.31	4.30	458.	73.	IL10SR at tap 10D
53	60	6853.	16.	0.0	0.0	U-L	4.5	-.007	19.	UI	0.000	0.	4.35	4.31	4.30	492.	72.	IU16SL 4 ms from lead tap
54	61	6853.	16.	0.0	0.0	U-L	4.5	-.008	19.	UI	0.000	0.	4.35	4.31	4.29	491.	69.	IU16SL 4 ms from lead tap

55	62	6848.	16.	0.0	0.0	U-L	4.5	-.008	18.	UI	0.000	0.	4.34	4.30	4.29	523.	64.	IU16SL 4.7 ms from return tap
56	63	6853.	16.	0.0	0.0	U-L	4.4	-.007	19.	UI	0.000	0.	4.34	4.30	4.29	523.	69.	IU16SL 2 ms from lead tap
57	64	7034.	16.	0.0	0.0	U-L	4.4	-.005	24.	UI	0.000	0.	4.20	4.16	4.15	292.	72.	IU16SL 2 ms from lead tap
58	65	7015.	0.	0.0	0.0	U-L	4.4	-.005	22.	UI	0.000	0.	4.21	4.17	4.16	344.	69.	IU16SL 2.4 ms from lead tap
59	66	7020.	16.	0.0	0.0	U-L	4.5	-.005	24.	UI	0.000	0.	4.20	4.16	4.15	337.	68.	IU16SL 2 ms from lead tap
60	67	6873.	16.	0.0	0.0	U-L	4.5	-.008	19.	UI	0.000	0.	4.35	4.30	4.29	856.	69.	IU16SL 3.8 ms from lead tap
61	68	6858.	25.	0.0	0.0	U-L	4.5	-.007	18.	UI	0.000	0.	4.34	4.30	4.29	850.	62.	IU16SL 5.2 ms from return tap
62	69	6883.	50.	0.0	0.0	U-L	4.5	-.007	21.	UI	0.000	0.	4.34	4.30	4.29	850.	62.	IU16SL 4.1 ms from return tap
63	70	6765.	75.	0.0	0.0	U-L	4.5	-.013	-20.	UI	0.000	0.	4.34	4.30	4.29	853.	63.	IU Rmp Spl 3.2 ms from tap 16A
64	71	6594.	100.	0.0	0.0	U-L	4.4	-.012	-21.	UI	0.000	0.	4.34	4.30	4.29	853.	63.	IU Rmp Spl 3.5 ms from tap 16A
65	72	6457.	125.	0.0	0.0	U-L	4.3	-.014	-21.	UI	0.000	0.	4.34	4.30	4.29	853.	53.	IU Rmp Spl 3.3 ms from tap 16A
66	73	6305.	150.	0.0	0.0	U-L	4.2	-.015	-22.	UI	0.000	0.	4.35	4.31	4.30	859.	64.	IU Rmp Spl 3.0 ms from tap 16A
67	74	6070.	200.	0.0	0.0	U-L	4.1	-.018	-23.	UI	0.000	0.	4.35	4.31	4.30	859.	64.	IU Rmp Spl 3.0 ms from tap 16A
68	75	6873.	16.	0.0	0.0	U-L	4.3	-.005	23.	UI	0.000	0.	4.30	4.25	4.24	844.	72.	IU16sl 2ms from lead tap
69	76	6437.	125.	0.0	0.0	U-L	4.3	-.014	-22.	UI	0.000	0.	4.34	4.29	4.28	855.	64.	IU Rmp Spl 3.5 ms from tap 16A
70	77	7206.	16.	0.0	0.0	U-L	4.6	-.009	-26.	UI	0.000	0.	3.79	3.76	3.75	494.	67.	OU
71	78	7377.	16.	0.0	0.0	U-L	4.5	-.005	25.	UI	0.000	0.	3.79	3.76	3.75	494.	67.	IU12 at tap 12A
72	79	7480.	16.	0.0	0.0	U-L	4.5	-.005	22.	UI	0.000	0.	3.79	3.76	3.75	494.	67.	IU16SL 2 ms from lead tap
73	80	7475.	16.	0.0	0.0	U-L	4.7	-.006	27.	UI	0.000	0.	3.79	3.76	3.75	494.	67.	IU16SL 2.2 ms from lead tap
74	81	7436.	16.	0.0	0.0	U-L	4.6	-.007	26.	UI	0.000	0.	3.79	3.76	3.75	494.	67.	IU13RE 1 ms from tap 13C
75	82	7294.	16.	0.0	0.0	U-L	4.6	-.007	26.	LI	0.000	0.	3.79	3.76	3.75	494.	67.	IL11LE
76	83	7446.	16.	0.0	0.0	U-L	4.8	-.007	27.	UI	0.000	0.	3.77	3.74	3.73	506.	63.	IU16RE 4ms from taps
77	DATA LOST - DATA LOGGER PROBLEM																	
	84	1002.	0.	0.0	0.0	U-L	0.1	-.001	-6.	LI	0.000	0.	3.78	3.75	3.74	487.	68.	
78	85	7465.	16.	0.0	0.0	U-L	4.6	-.004	27.	UI	0.000	0.	3.79	3.75	3.74	494.	68.	IU16SL 2 ms from lead tap
79	86	7460.	16.	0.0	0.0	U-L	4.5	-.004	27.	UI	0.000	0.	3.78	3.74	3.73	491.	71.	IU16SL 2 ms from lead tap
80	87	7460.	0.	0.0	0.0	U-L	4.6	-.004	26.	UI	0.000	0.	3.78	3.75	3.75	488.	66.	IU16SL 5 ms from return tap
	88	6109.	0.	0.0	0.0	Cu L	14.3	0.000	0.	LI	0.000	0.	3.78	3.75	3.74	485.	67.	

----- QSUMARY V03.13 -----

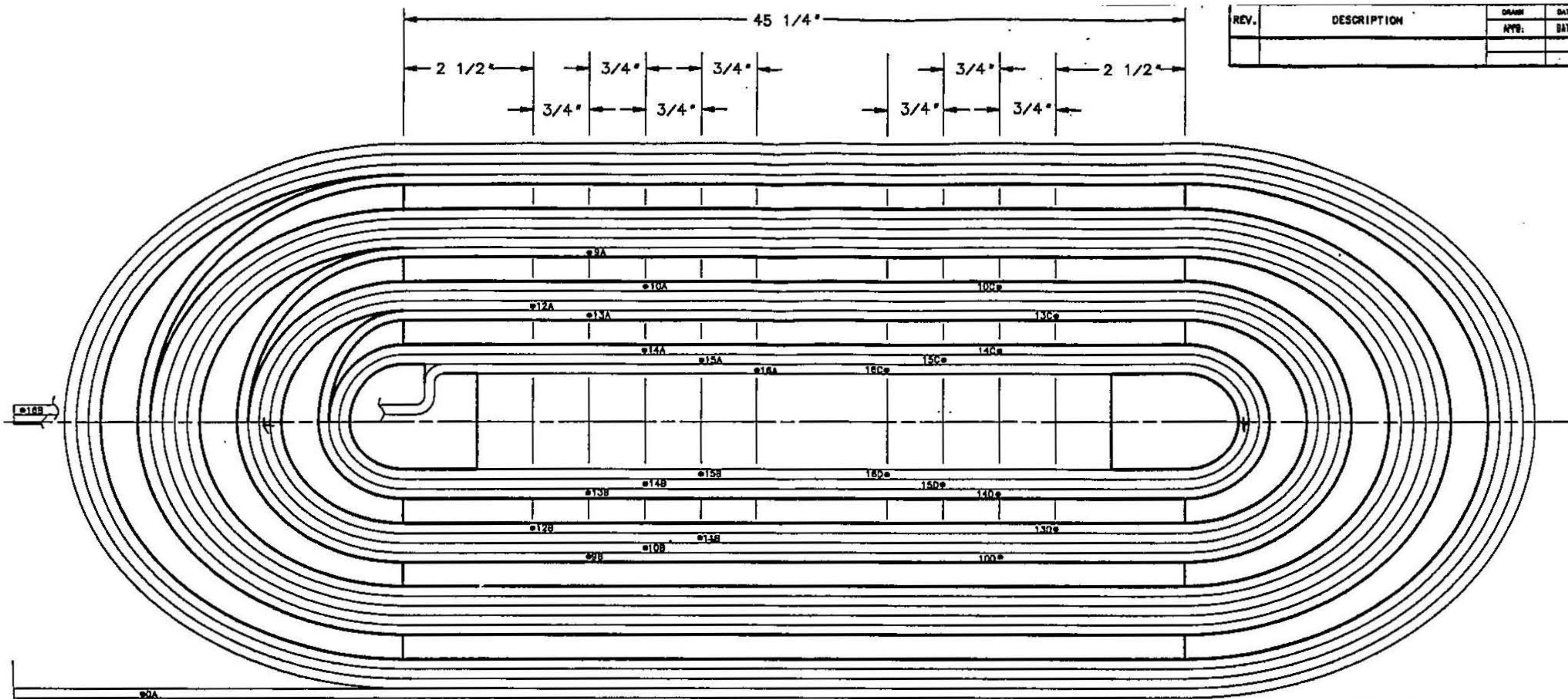
FORMAT:

Q#	File	I-m	Idot	I-t	Idot	QDC	MIITs	t-Q	V-max	Coil	t(H)	V(H)	T(t)	T(m)	T(b)	P	LL	Location
A5,	I5,	F8.0,	F5.0,	F5.1,	F5.1,	A5,	F5.1,	F6.3,	F6.0,	A4,	F6.3,	F5.0,	F5.2,	F5.2,	F5.2,	F5.0,	F5.0,	2X,A30

NOTATION KEY

Q#	Quench number or Spot heater number (e.g. s4 is spot heater 4)
File	Quench file number
I-m	Main coil current at quench
Idot	Main coil dI/dt at quench
I-t	Trim coil current at quench
Idot	Trim coil dI/dt at quench
QDC	Name of quench detection circuit which tripped:
	1) U-L Upper - Lower Coil
	2) V-dI Magnet - Idot
	3) SC L SC Pwr Leads - Idot
	4) Vtot Magnet
	5) Trim Trim Coil
	6) Cu L Cu Pwr Leads - IR
	7) GndI Ground Fault Monitor
	8) Thru Through Bus - Idot
MIITs	Integral of (I**2)dt from t-Q to "infinity"
t-Q	Time first voltage appears in V(Upper) - V(Lower) (relative to quench detection time)
V-max	Maximum voltage across any quarter coil
Coil	Coil corresponding to V-max

t(H)	Protection heater firing time (relative to quench detection time); -.999 if heater did not fire
V(H)	Protection heater firing voltage; -999. if heater did not fire
T(t)	Temperature at top of magnet
T(m)	Temperature at middle of magnet
T(b)	Temperature at bottom of magnet
P	Dewar pressure (Torr)
LL	Liquid level (%)
Location	Quench or spot heater location



REV.	DESCRIPTION	DRAWN / APPD.	DATE

NOTE:

1. VOLTAGE TAP WIRES FOR TAPS 0A, 16B, AND THE HALF COIL TAP ARE #22 AWG TEFLON INSULATED.
2. THE REMAINING VOLTAGE TAP WIRES ARE #32 AWG TEFLON INSULATED.
3. TAP WIRES WITH THE SAME NUMBER AT EACH END SHOULD FORM A TWISTED PAIR (A-B AND C-D).
4. VOLTAGE TAP WIRE SHOULD FOLLOW THE CABLE TO WHICH THEY ARE SOLDERED UNTIL THEY MEET AND ARE TWISTED WITH THEIR "MATE".
5. COIL AS VIEWED FROM INSIDE.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED: .XX ± | .XXX ± | ANGLES ±

1. BREAK ALL SHARP EDGES .02 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982
4. MAX. ALL MACH. SURFACES

ORIGINATOR: STRAIT/KOSKA
DRAWN: R. DIXON 1/5/90
CHECKED
APPROVED
USED ON
MATERIAL

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DS0308
VOLTAGE TAPS
INNER COIL

SCALE: NONE | FILMED | DRAWING NUMBER | REV.

CREATED WITH I-DEAS 4.1 | USER NAME: SPUD

INCHES 0 1 2 3 4 5 6 METRIC 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Figure 1

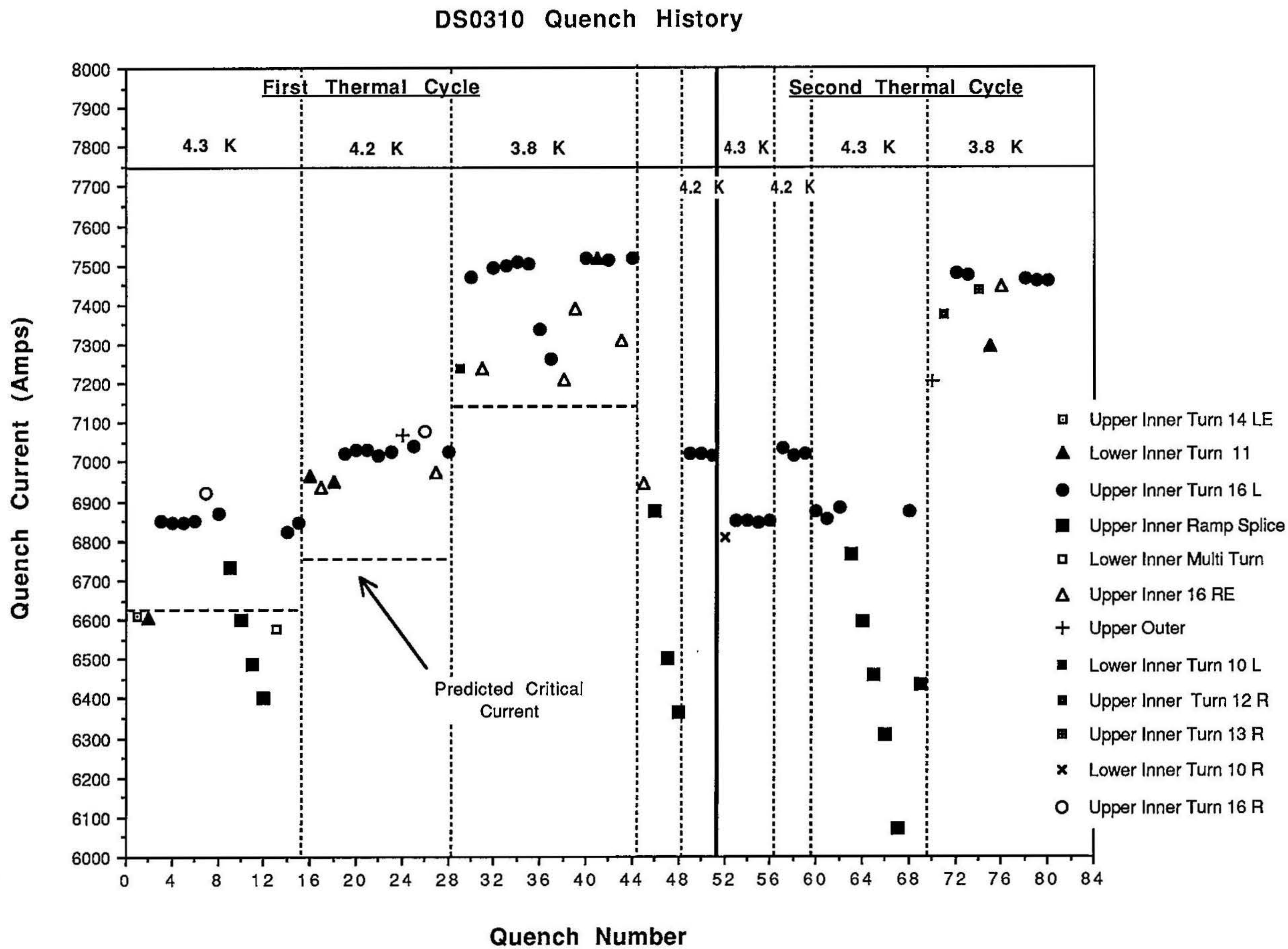

DS0310 Quench History
First Thermal Cycle
Second Thermal Cycle
4.3 K
4.2 K
3.8 K
4.3 K
4.3 K
3.8 K
4.2 K
4.2 K
Predicted Critical Current
Quench Current (Amps)
Quench Number
Upper Inner Turn 14 LE
Lower Inner Turn 11
Upper Inner Turn 16 L
Upper Inner Ramp Splice
Lower Inner Multi Turn
Upper Inner 16 RE
Upper Outer
Lower Inner Turn 10 L
Upper Inner Turn 12 R
Upper Inner Turn 13 R
Lower Inner Turn 10 R
Upper Inner Turn 16 R

Figure 2

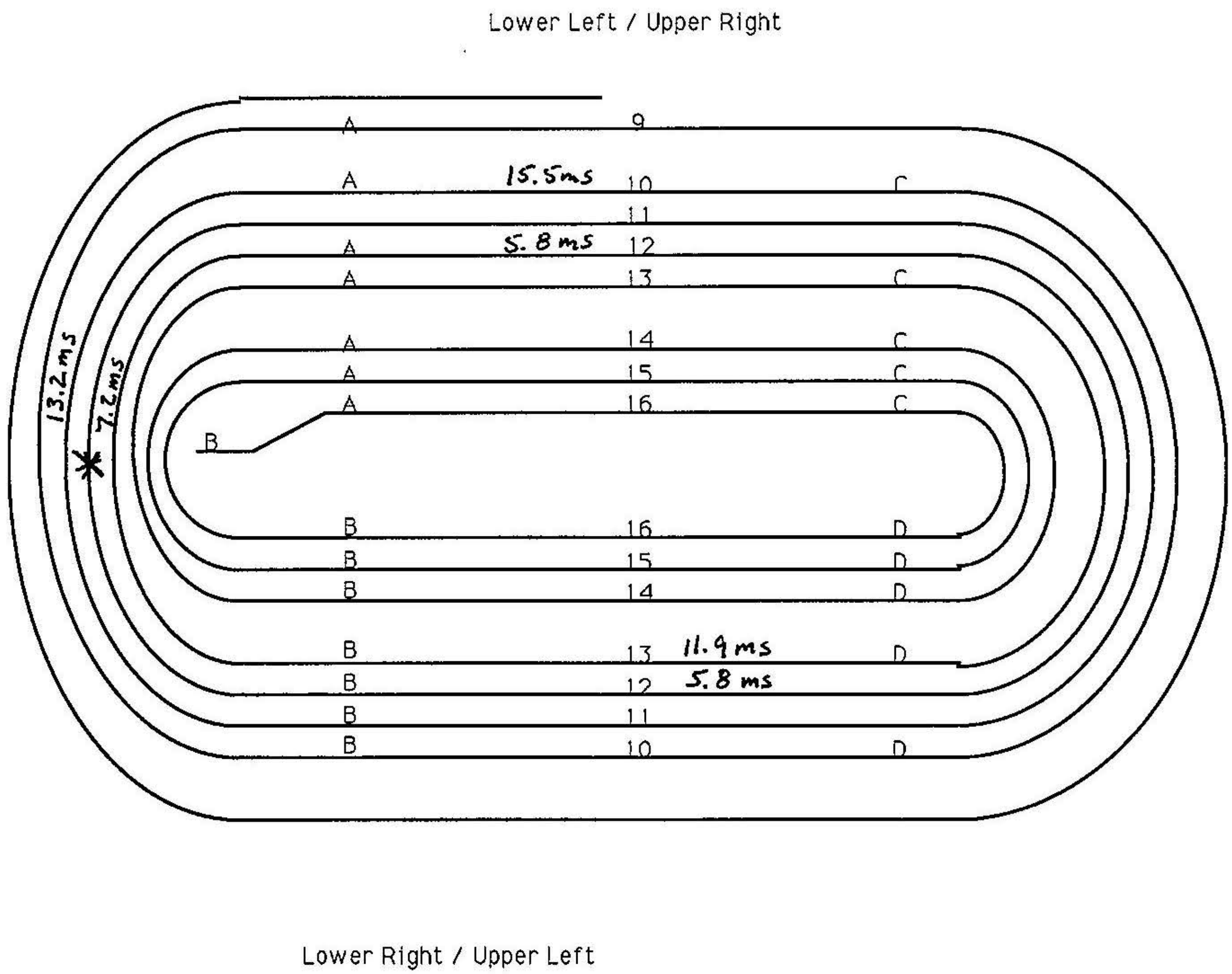
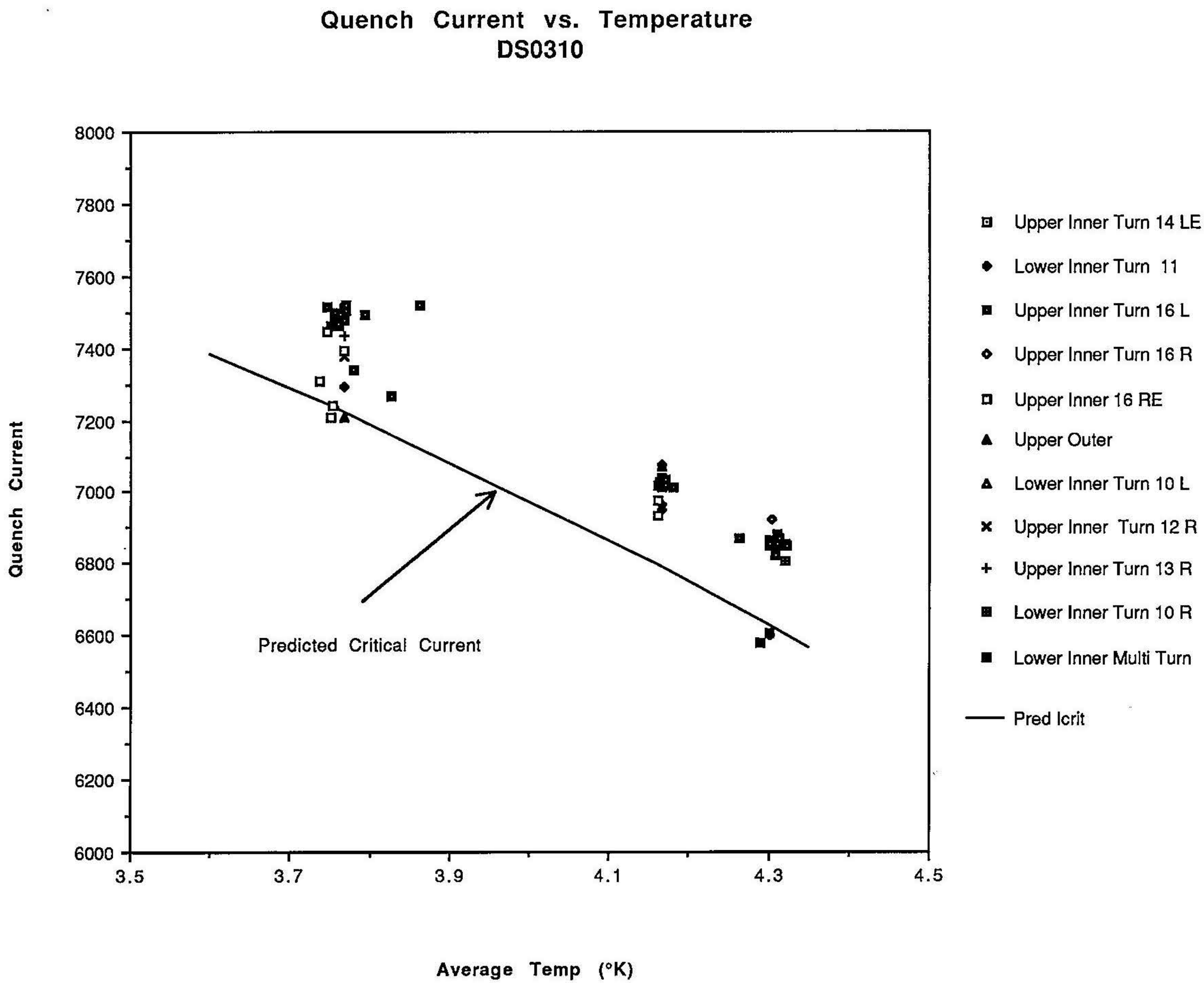

Lower Left / Upper Right
A
9
A
15.5ms
10
C
11
A
5.8ms
12
A
13
C
A
14
C
A
15
C
A
16
C
B
13.2ms
7.2ms
B
16
D
B
15
D
B
14
D
B
13
11.9ms
D
B
12
5.8ms
B
11
B
10
D
Lower Right / Upper Left

Figure 3



Quench Current vs. Temperature
DS0310
8000
7800
7600
7400
7200
7000
6800
6600
6400
6200
6000
Quench Current
3.5
3.7
3.9
4.1
4.3
4.5
Average Temp (°K)
Predicted Critical Current
Upper Inner Turn 14 LE
Lower Inner Turn 11
Upper Inner Turn 16 L
Upper Inner Turn 16 R
Upper Inner 16 RE
Upper Outer
Lower Inner Turn 10 L
Upper Inner Turn 12 R
Upper Inner Turn 13 R
Lower Inner Turn 10 R
Lower Inner Multi Turn
Pred Icrit

Figure 4

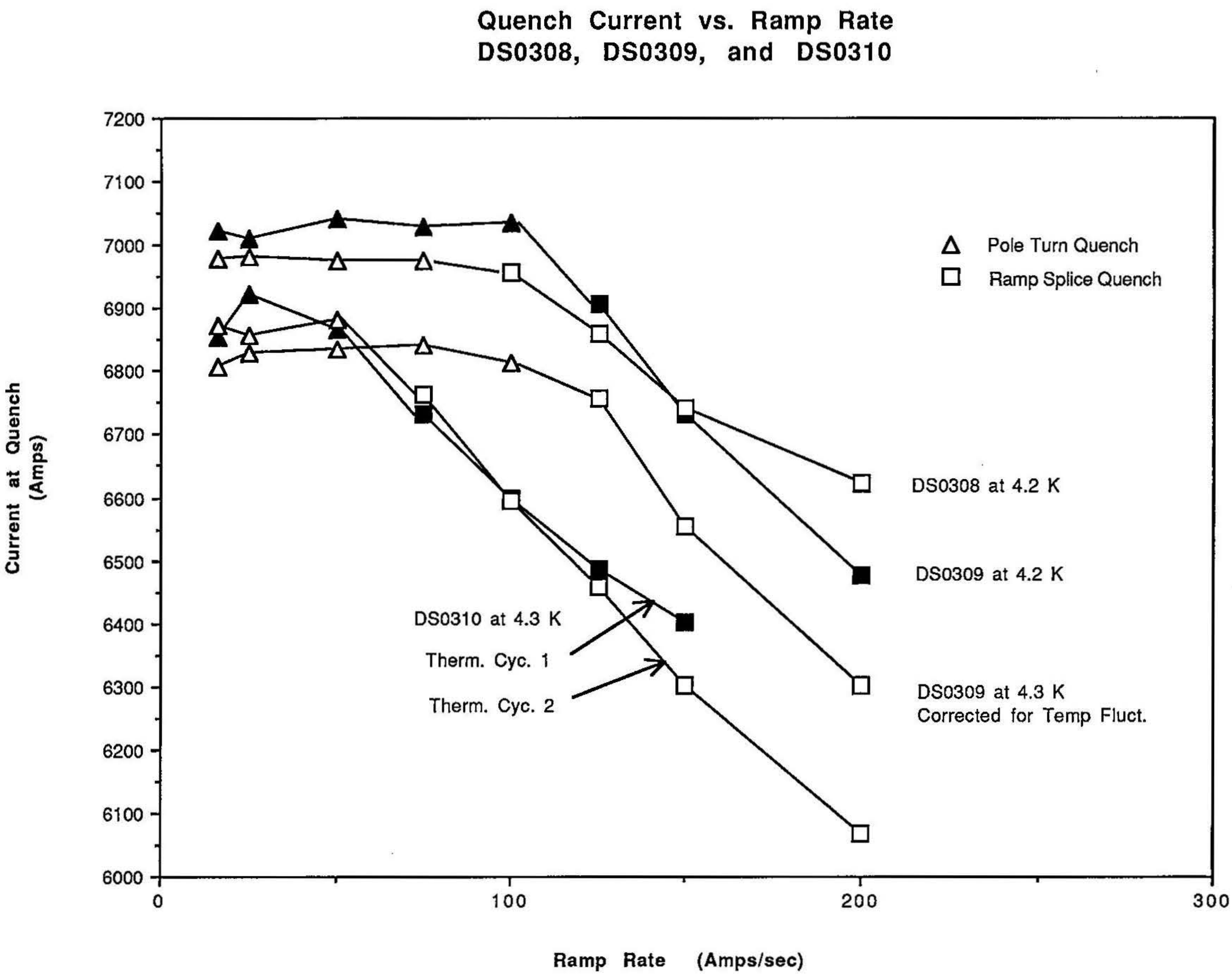

Quench Current vs. Ramp Rate
DS0308, DS0309, and DS0310
Pole Turn Quench
Ramp Splice Quench
DS0308 at 4.2 K
DS0309 at 4.2 K
DS0309 at 4.3 K
Corrected for Temp Fluct.
DS0310 at 4.3 K
Therm. Cyc. 1
Therm. Cyc. 2
Current at Quench (Amps)
Ramp Rate (Amps/sec)
7200
7100
7000
6900
6800
6700
6600
6500
6400
6300
6200
6100
6000
0
100
200
300

Figure 5

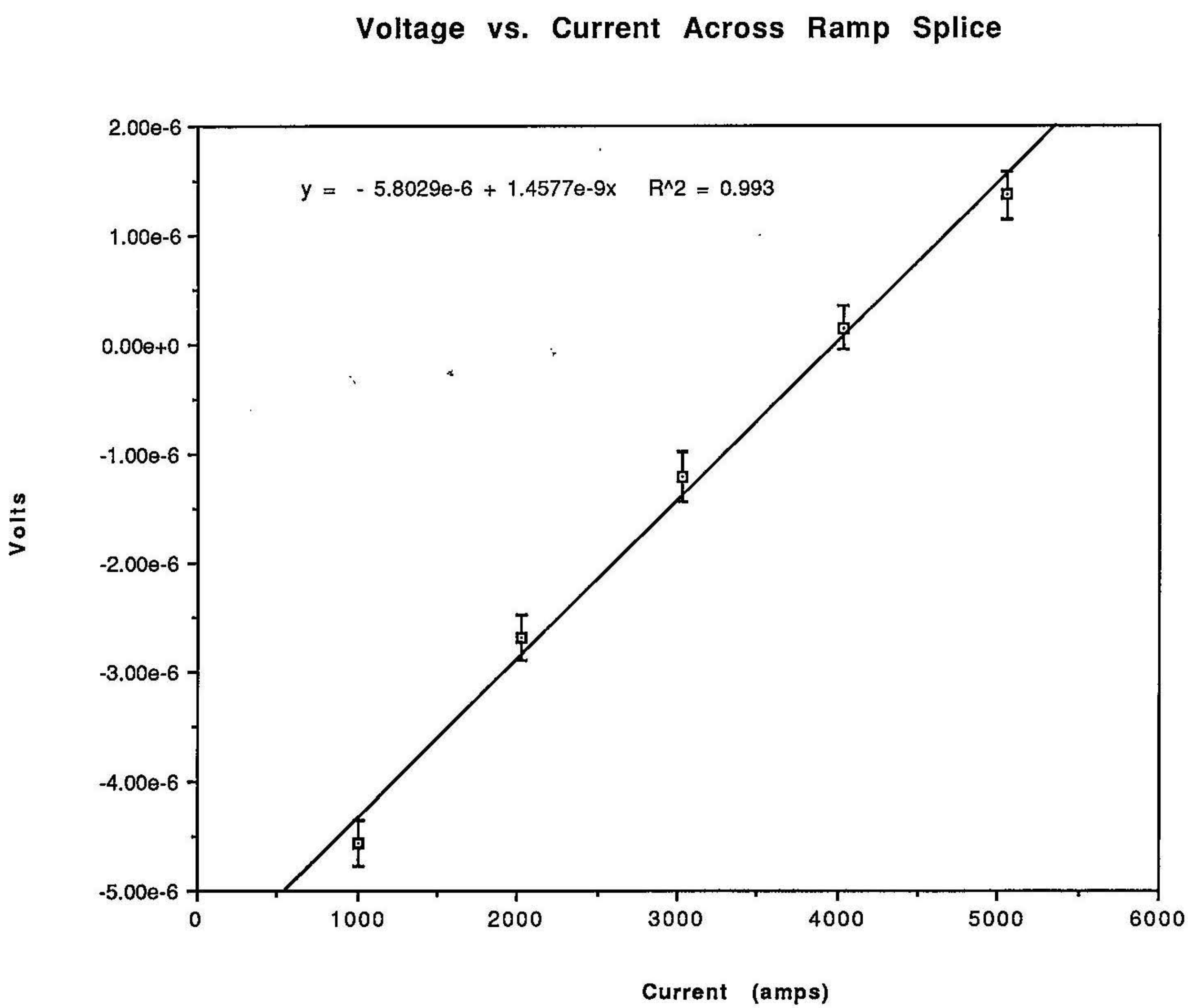

Voltage vs. Current Across Ramp Splice
y = - 5.8029e-6 + 1.4577e-9x R^2 = 0.993
2.00e-6
1.00e-6
0.00e+0
-1.00e-6
-2.00e-6
-3.00e-6
-4.00e-6
-5.00e-6
Volts
0
1000
2000
3000
4000
5000
6000
Current (amps)

Figure 6

Distribution:

FNAL
Rodger Bossert
John Carson
Tariq Jaffery
Mike Lamm
Paul Mantsch
Peter Mazur
Ray Hanft
Gale Pewitt
Jim Strait

KEK
Arnaud Devred

SSCL
Tom Bush
Roger Coombes
Jay Jayakumar
Phil Sanger
John Tompkins