Fermilab

TS-SSC 90-026

May 30, 1990

MEMO TO: Distribution

FROM: Jim Strait

SUBJECT: Summary of DS0309 Quenches on the First Cooldown

Tests of DS0309 on the first cooldown included quench training at 4.3 K and 3.8 K, ramp rate dependence of quench current at 4.3 K, tests ramping down from 6500 A at rates up to 400 A/sec, strain gage runs to 6740 A at 4.3 K and 7350 A at 3.8 K, and harmonics measurements as a function of z at 5000 A and as a function of current at the center of the magnet. The quench results are summarized here. A summary table of all quench files is attached and the quench history is plotted in Figure 1.

There was one training quench (6316 A) at 4.3 K, located in lower inner turn 10 on the right side near the return end. Figure 2 shows the time, relative to the quench origin of the quench onset in the segments near the quench location. Turn 10 was fully instrumented with 4 voltage taps. During insertion of the warm finger prior to cooldown one of the turn 10 taps taps was broken. The training quench occurred near this broken tap, so the precise quench location cannot be determined. My best estimate is that the quench occurred in the straight section about 25± 5 cm from the broken tap.

All plateau quenches originated in the straight section of the upper inner pole turn on the side opposite the ramp-splice. Quenches with a ramp rate less than or equal to 25 A/sec were at the identical location about 35± 5 cm from the lead end. Figure 3 shows the voltages in the three earliest segments for a typical plateau quench. Quenches at 50, 75 and 100 A/sec were about 55, 80 and 80 cm from the lead end respectively. (Distance are quoted from the boundary of between the wedges and the lead end spacers.) Quenches at 100 A/sec and above were in the upper inner ramp splice; this behavior is the same as in DS0308. Quenches at ramp rates less than or equal to 100 A/sec are, after correcting for temperature differences, at the same current. The quench current drops by 60 A at 125 A/sec, 260 A at 150 A/sec and 500 A at 200 A/sec.

When a magnet quenches in the SSC ring, the rest of the magnets in that half-cell are quenched by heaters and the remainder of the ring is ramped down through dump resistors with a 20 second time constant. The magnets must be able to ramp down at the initial rate -325 A/sec without quenching. DS0309 was ramped from 6500 A to 4000 A at -100, -200, -300, and -400 A/sec without quenching, indicating adequate stability.

There were three training quenches at 3.75 K before a plateau at an average current of 7430 A was established. The first two training quenches were at 7388 A in the upper outer coil and propagated into the outer coil ramp splice in 17 ms. There is a tap at the point where the outer pole turn enters the ramp splice region; otherwise the outer coil is uninstrumented. The voltage trace for the upper outer coil for one of these quenches is shown in Figure 4 and the earliest three inner coil segments are shown in Figure 5. Because the quench reaches the ramp-spice relatively promptly, the quench origin is most likely in the pole turn towards the return end. The third training quench was at 7275 A, about 100 A lower current than the first two, and in the upper inner coil turn 11 at the lead end. Turn 11 is not fully instrumented so the quench location is deduced from the quench arrival time in segments in adjacent turns. The voltages in the earliest 6 segments are shown in Figure 6 and the times relative to the quench origin are shown on a coil pattern in Figure 7. The plateau quenches were at the same location as those at 4.3 K. To check that the temperature dependence matched that expected for conductor limited quenches, one quench was taken at 3.71 K.

The relation between quench current and temperature is plotted in Figure 8 for all quenches with dI/dt less than or equal to 100 A/sec. The table below summarizes the plateau quench currents at 4 temperatures and compares them to that calculated using Chris Quigg's program. (This program, I believe, uses Gerry Morgan's parametrization of the critical surface.) The error bars on the measured values are the standard deviation divided by the square root of the number of quenches for the 4.30 K and 3.75 K data. The error bars for the 4.16 K and 3.71 K quenches are gotten assuming the same standard deviation as measured at 4.30 and 3.75 K. The listed temperatures are the average of all plateau quenches and the average of the three thermometer readings for each quench.

Temperature	Predicted Icrit	Measured Iquench	Difference
4.30 K	6629 A	6830± 7 A	201± 7 A
4.16 K	6795 A	7001± 14 A	206± 14 A
3.75 K	7240 A	7432± 10 A	192± 10 A
3.71 K	7279 A	7496± 20 A	217± 20 A

The plateau quench currents have a standard deviation of about 20 A at both 4.3 K and 3.75 K and at 4.3 K the full range of quench currents is almost 80 A. This is larger than one might expect for conductor limited quenches at constant temperature. The system for controlling dewar pressure and therefore helium bath temperature is rather crude: a technician adjusting a hand valve while monitoring a pressure gauge. The dewar is filled from 500 l dewars supplied by Airco through a transfer line with a hand operated throttling valve which is set to balance the boiloff rate. It is conceivable that this results in significant temperature fluctuations that could explain the range of quench currents, although there is no evidence for this from the thermometer data. On the second cooldown it is planned to take enough quenches at 4.2 K, allowing atmospheric pressure to control the dewar pressure, to see if a similar range of quench currents occurs there as well.

Distribution:

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

KEK
Arnaud Devred

SSCL
Tom Bush
Rodger Coombes
Jay Jayakumar
Phil Sanger
John Tompkins

Quench File Summary
DSØ3Ø9

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
	Ø	979.	Ø.	Ø.Ø	Ø.Ø	U-L	Ø.1	-.ØØ2	-6.	LI	Ø.ØØØ	Ø.	Ø.ØØ	Ø.ØØ	Ø.ØØ	Ø.	Ø.	
	1	979.	Ø.	Ø.Ø	Ø.Ø	U-L	Ø.1	Ø.ØØØ	-6.	LI	Ø.ØØØ	Ø.	4.32	4.27	4.26	839.	56.	
	2	43.	Ø.	Ø.Ø	Ø.Ø	U-L	Ø.Ø	Ø.ØØØ	Ø.	LI	Ø.ØØØ	Ø.	4.23	4.18	4.16	832.	8Ø.	
1	3	6316.	Ø.	Ø.Ø	Ø.Ø	U-L	4.Ø	-.Ø1Ø	22.	LI	Ø.ØØØ	Ø.	4.31	4.27	4.25	842.	74.	IL1Ø Right near Return End
	4	974.	Ø.	Ø.Ø	Ø.Ø	U-L	Ø.1	Ø.ØØØ	-6.	LI	Ø.ØØØ	Ø.	4.34	4.29	4.28	854.	78.	
	5	983.	Ø.	Ø.Ø	Ø.Ø	U-L	Ø.1	Ø.ØØØ	-6.	LI	Ø.ØØØ	Ø.	4.34	4.29	4.28	849.	78.	
2	6	6835.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	22.	UI	Ø.ØØØ	Ø.	4.35	4.3Ø	4.29	862.	76.	IU16SL 3ms from lead tap
3	7	6835.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	22.	UI	Ø.ØØØ	Ø.	4.33	4.28	4.28	846.	72.	IU16SL 3ms from lead tap
4	8	683Ø.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ7	22.	UI	Ø.ØØØ	Ø.	4.29	4.25	4.24	82Ø.	71.	IU16SL 3ms from lead tap
5	9	6825.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	22.	UI	Ø.ØØØ	Ø.	4.34	4.29	4.28	854.	79.	IU16SL 3ms from lead tap
6	1Ø	68ØØ.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	22.	UI	Ø.ØØØ	Ø.	4.35	4.3Ø	4.29	862.	82.	IU16SL 3ms from lead tap
7	11	681Ø.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	23.	UI	Ø.ØØØ	Ø.	4.34	4.3Ø	4.29	856.	78.	IU16SL 3ms from lead tap
8	12	683Ø.	25.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	22.	UI	Ø.ØØØ	Ø.	4.35	4.3Ø	4.29	861.	77.	IU16SL 3ms from lead tap
9	13	6859.	5Ø.	Ø.Ø	Ø.Ø	U-L	4.3	-.ØØ7	22.	UI	Ø.ØØØ	Ø.	4.33	4.28	4.27	847.	77.	IU16SL 6ms from lead tap
1Ø	14	69Ø3.	75.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ7	23.	UI	Ø.ØØØ	Ø.	4.3Ø	4.25	4.24	839.	69.	IU16SL 8ms from lead tap
11	15	6874.	1ØØ.	Ø.Ø	Ø.Ø	U-L	4.5	-.Ø16	-17.	UI	Ø.ØØØ	Ø.	4.29	4.25	4.24	822.	71.	IU16SL 8ms from lead tap
12	16	683Ø.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	22.	UI	Ø.ØØØ	Ø.	4.33	4.28	4.27	846.	76.	IU16SL 3ms from lead tap
13	17	6771.	125.	Ø.Ø	Ø.Ø	U-L	4.6	-.Ø13	-19.	LI	Ø.ØØØ	Ø.	4.33	4.29	4.27	846.	76.	IL Rmp Spl 3ms from tap 16A
14	18	659Ø.	15Ø.	Ø.Ø	Ø.Ø	U-L	4.5	-.Ø13	-2Ø.	LI	Ø.ØØØ	Ø.	4.32	4.27	4.26	837.	75.	IL Rmp Spl 3ms from tap 16A
15	19	6325.	2ØØ.	Ø.Ø	Ø.Ø	U-L	4.2	-.Ø14	-21.	LI	Ø.ØØØ	Ø.	4.33	4.28	4.27	841.	77.	IL Rmp Spl 3ms from tap 16A
16	2Ø	6839.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	23.	UI	Ø.ØØØ	Ø.	4.34	4.3Ø	4.29	859.	79.	IU16SL 3ms from lead tap
17	21	6879.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	23.	UI	Ø.ØØØ	Ø.	4.34	4.3Ø	4.25	86Ø.	82.	IU16SL 3ms from lead tap
18	22	6815.	16.	Ø.Ø	Ø.Ø	U-L	4.4	-.ØØ8	23.	UI	Ø.ØØØ	Ø.	4.34	4.29	4.27	857.	79.	IU16SL 3ms from lead tap
19	23	7ØØ1.	16.	Ø.Ø	Ø.Ø	U-L	4.6	-.ØØ8	23.	UI	Ø.ØØØ	Ø.	4.19	4.15	4.14	746.	83.	IU16SL 3ms from lead tap
2Ø	24	7ØØ1.	16.	Ø.Ø	Ø.Ø	U-L	4.6	-.ØØ8	23.	UI	Ø.ØØØ	Ø.	4.2Ø	4.15	4.14	749.	81.	IU16SL 3ms from lead tap
21	25	7388.	16.	Ø.Ø	Ø.Ø	U-L	4.8	-.Ø11	-23.	UI	Ø.ØØØ	Ø.	3.79	3.75	3.74	494.	72.	OU, 17 ms from ramp splice
22	26	7388.	16.	Ø.Ø	Ø.Ø	U-L	5.Ø	-.Ø11	-31.	UI	Ø.ØØØ	Ø.	3.79	3.75	3.74	494.	79.	OU, 17 ms from ramp splice
23	27	7275.	16.	Ø.Ø	Ø.Ø	U-L	4.6	-.ØØ7	31.	UI	Ø.ØØØ	Ø.	3.78	3.74	3.73	493.	82.	IU11EF
24	28	7447.	16.	Ø.Ø	Ø.Ø	U-L	4.9	-.ØØ8	26.	UI	Ø.ØØØ	Ø.	3.78	3.74	3.73	495.	86.	IU16SL 3ms from lead tap
25	29	7412.	16.	Ø.Ø	Ø.Ø	U-L	4.8	-.ØØ7	26.	UI	Ø.ØØØ	Ø.	3.78	3.74	3.73	537.	76.	IU16SL 3ms from lead tap
26	3Ø	7437.	16.	Ø.Ø	Ø.Ø	U-L	4.8	-.ØØ7	27.	UI	Ø.ØØØ	Ø.	3.78	3.74	3.73	499.	82.	IU16SL 3ms from lead tap
27	31	7496.	16.	Ø.Ø	Ø.Ø	U-L	4.9	-.ØØ7	27.	UI	Ø.ØØØ	Ø.	3.74	3.7Ø	3.69	474.	74.	IU16SL 3ms from lead tap
	32	5273.	Ø.	Ø.Ø	Ø.Ø	Cu L	1Ø.6	Ø.ØØØ	Ø.	LI	Ø.ØØØ	Ø.	3.79	3.75	3.74	499.	75.	

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 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/m/b)	Temperature at top/middle/bottom of magnet
P	Dewar pressure (Torr)
LL	Liquid level (%)
Location	Quench or spot heater location

DS0309.QB003 (Q#1, 6316A, 4.3K)

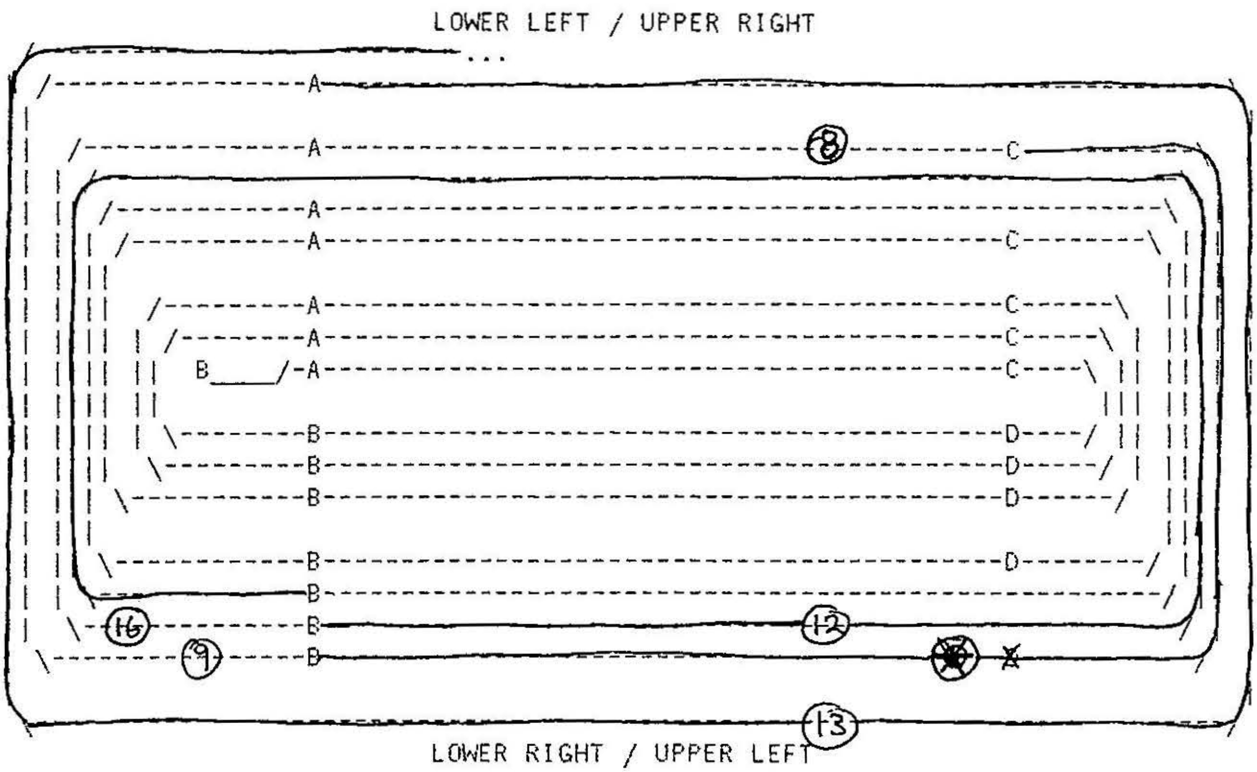


Figure 2

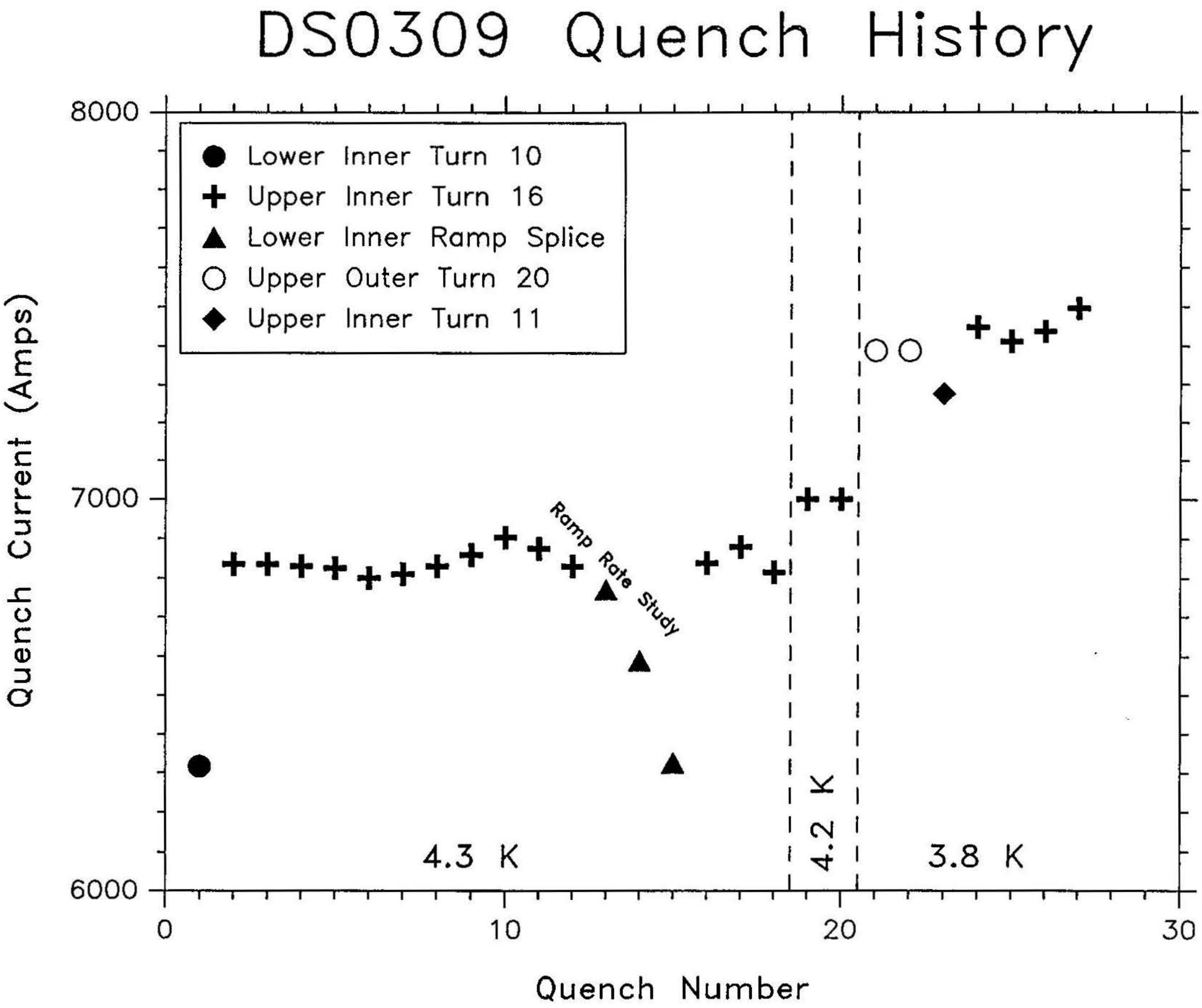

DS0309 Quench History
8000
7000
6000
0
10
20
30
Quench Current (Amps)
Quench Number
Lower Inner Turn 10
Upper Inner Turn 16
Lower Inner Ramp Splice
Upper Outer Turn 20
Upper Inner Turn 11
Ramp Rate Study
4.3 K
4.2 K
3.8 K

Figure 1

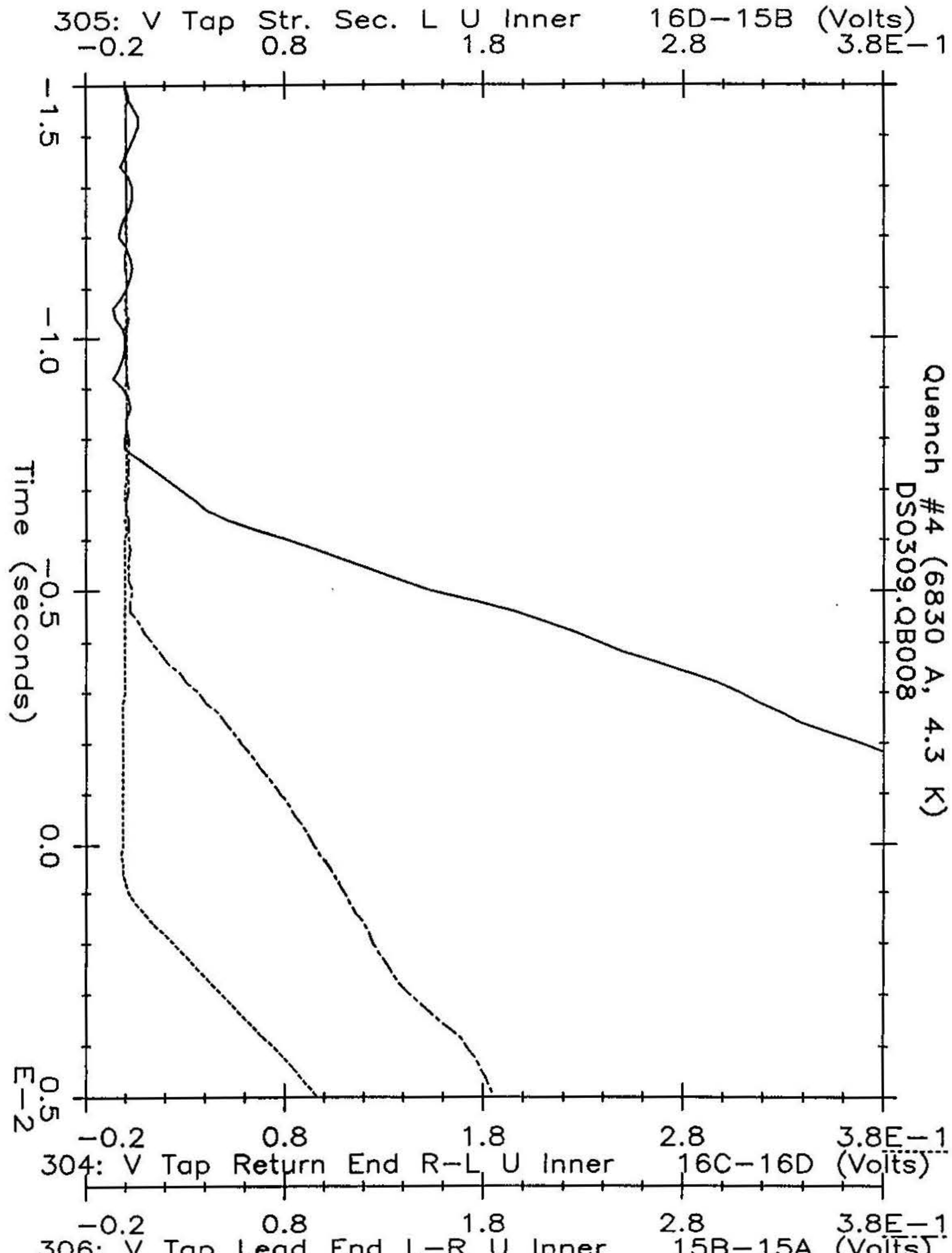
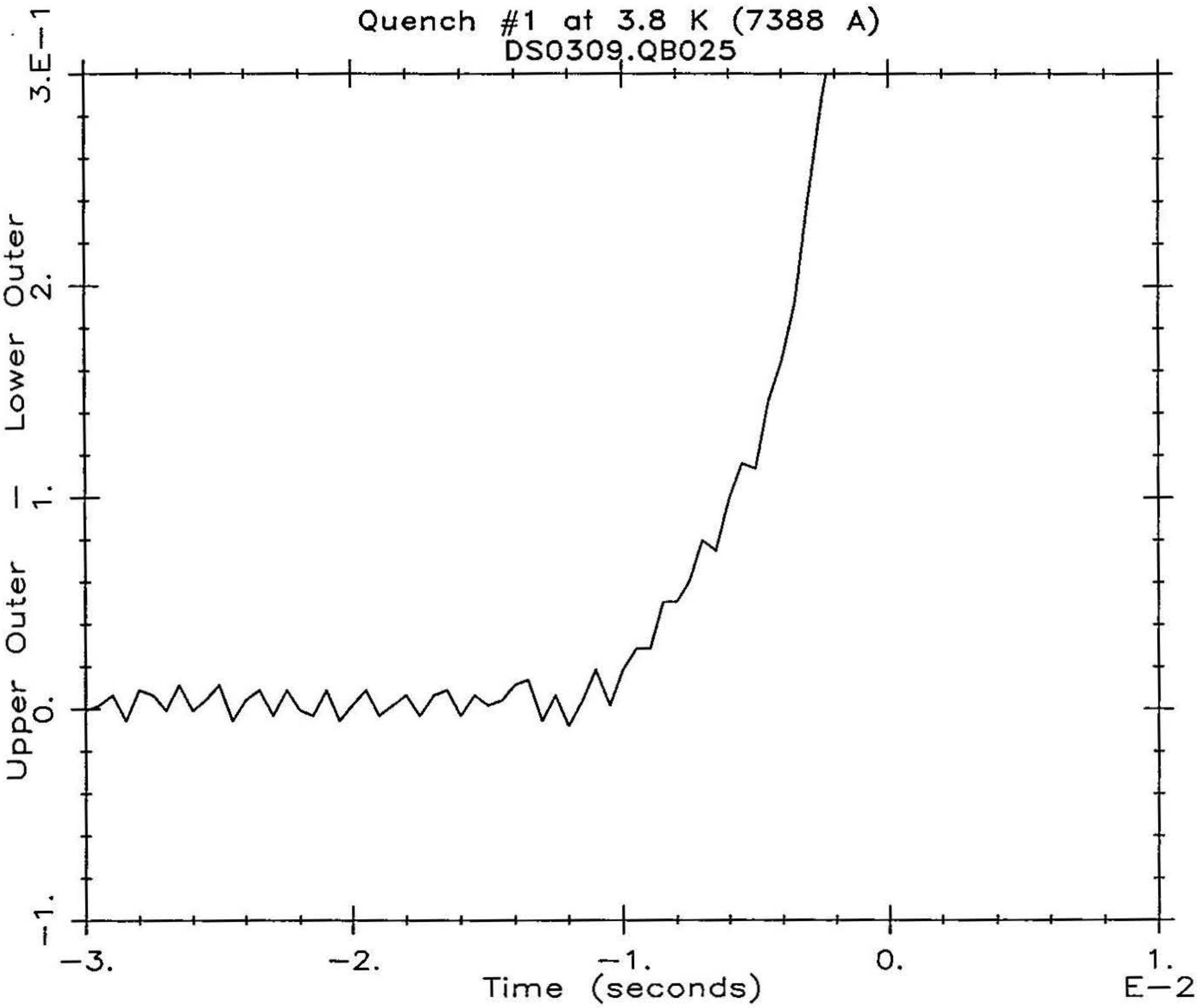

305: V Tap Str. Sec. L U Inner 16D−15B (Volts)
−0.2 0.8 1.8 2.8 3.8E−1
−1.5
−1.0
−0.5
0.0
0.5 E−2
Time (seconds)
Quench #4 (6830 A, 4.3 K)
DS0309.QB008
−0.2 0.8 1.8 2.8 3.8E−1
304: V Tap Return End R−L U Inner 16C−16D (Volts)
−0.2 0.8 1.8 2.8 3.8E−1
306: V Tap Lead End L−R U Inner 15B−15A (Volts)

Figure 3



(+212)−209

Figure 4

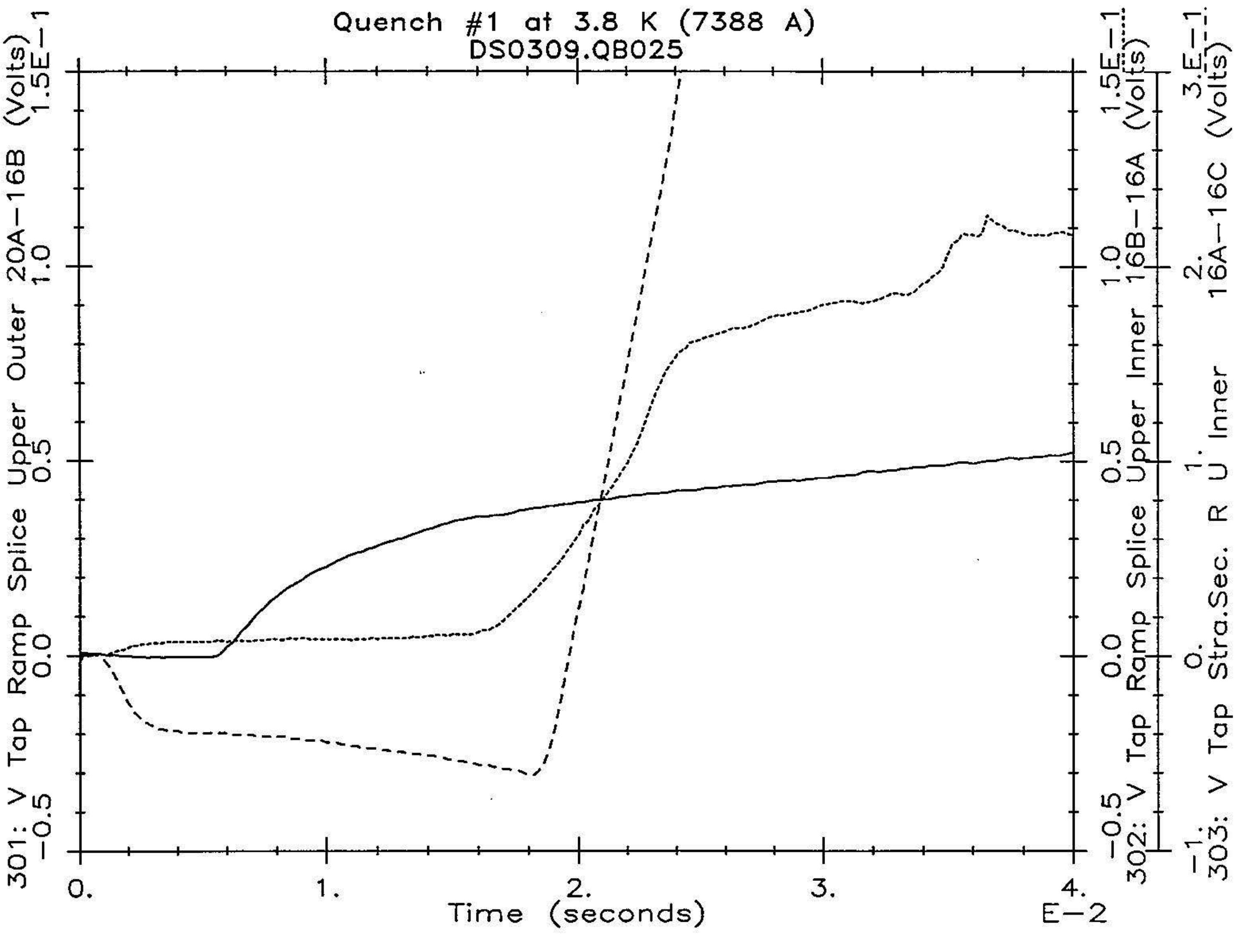
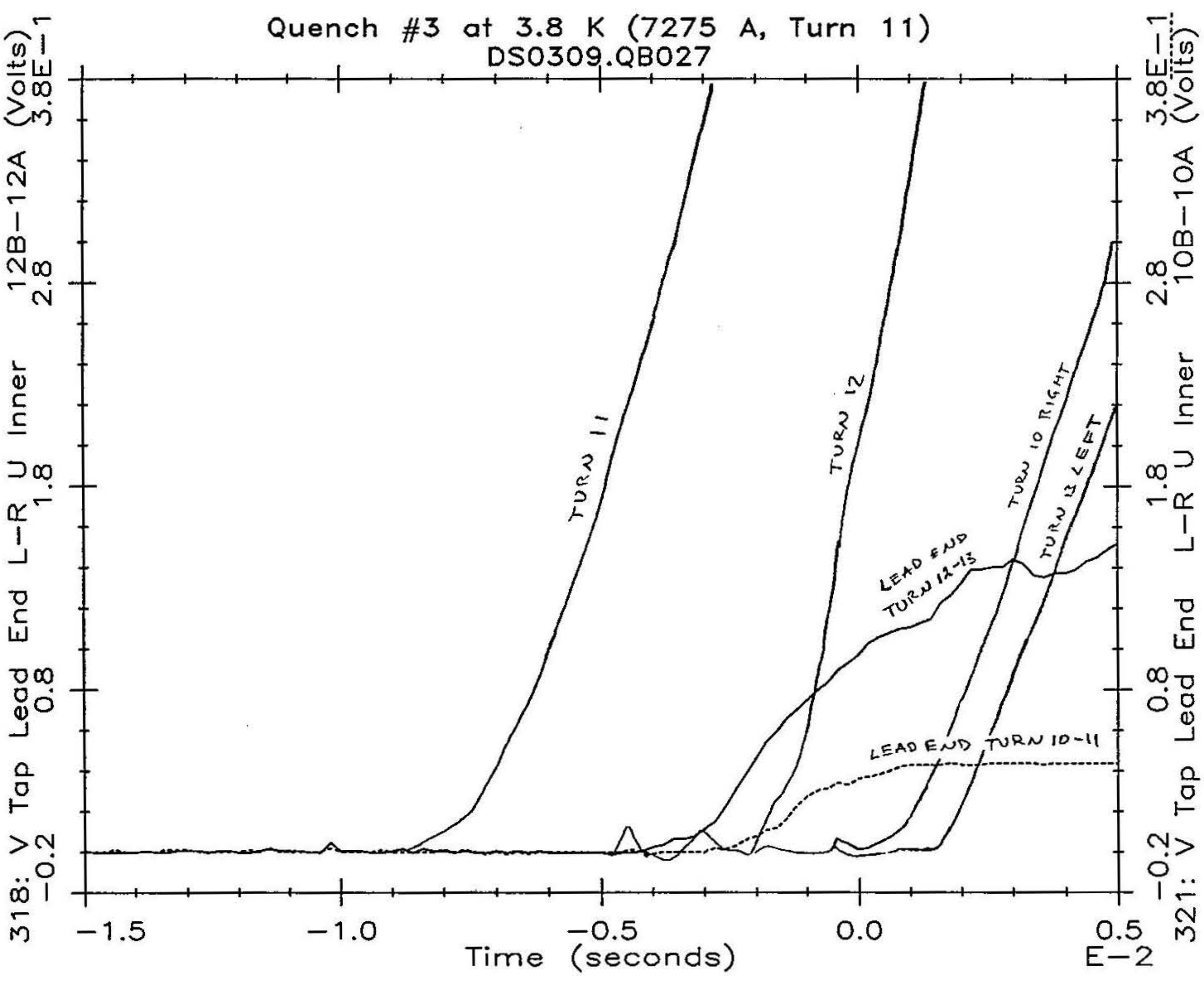
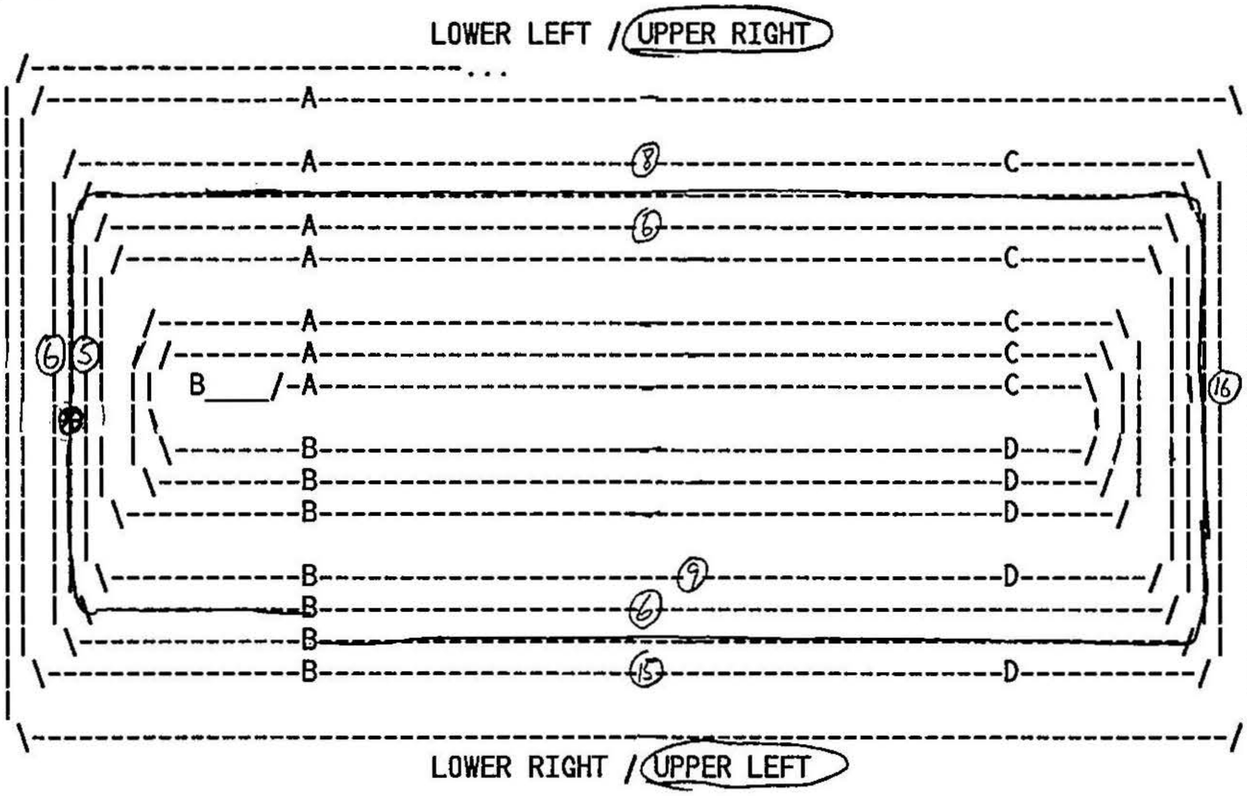

Quench #1 at 3.8 K (7388 A)
DS0309.QB025
301: V Tap Ramp Splice Upper Outer 20A−16B (Volts)
−0.5
0.0
0.5
1.0
1.5E−1
302: V Tap Ramp Splice Upper Inner 16B−16A (Volts)
−0.5
0.0
0.5
1.0
1.5E−1
303: V Tap Stra.Sec. R U Inner 16A−16C (Volts)
−1.
0.
1.
2.
3.E−1
0.
1.
2.
3.
4.
E−2
Time (seconds)

Figure 5



Quench #3 at 3.8 K (7275 A, Turn 11)
DS0309.QB027
318: V Tap Lead End L-R U Inner 12B-12A (Volts)
321: V Tap Lead End L-R U Inner 10B-10A (Volts)
3.8E-1
2.8
1.8
0.8
-0.2
-1.5
-1.0
-0.5
0.0
0.5
E-2
Time (seconds)
TURN 11
TURN 12
TURN 10 RIGHT
TURN 13 LEFT
LEAD END TURN 12-13
LEAD END TURN 10-11

Figure 6



DS0309.QB027

Figure 7

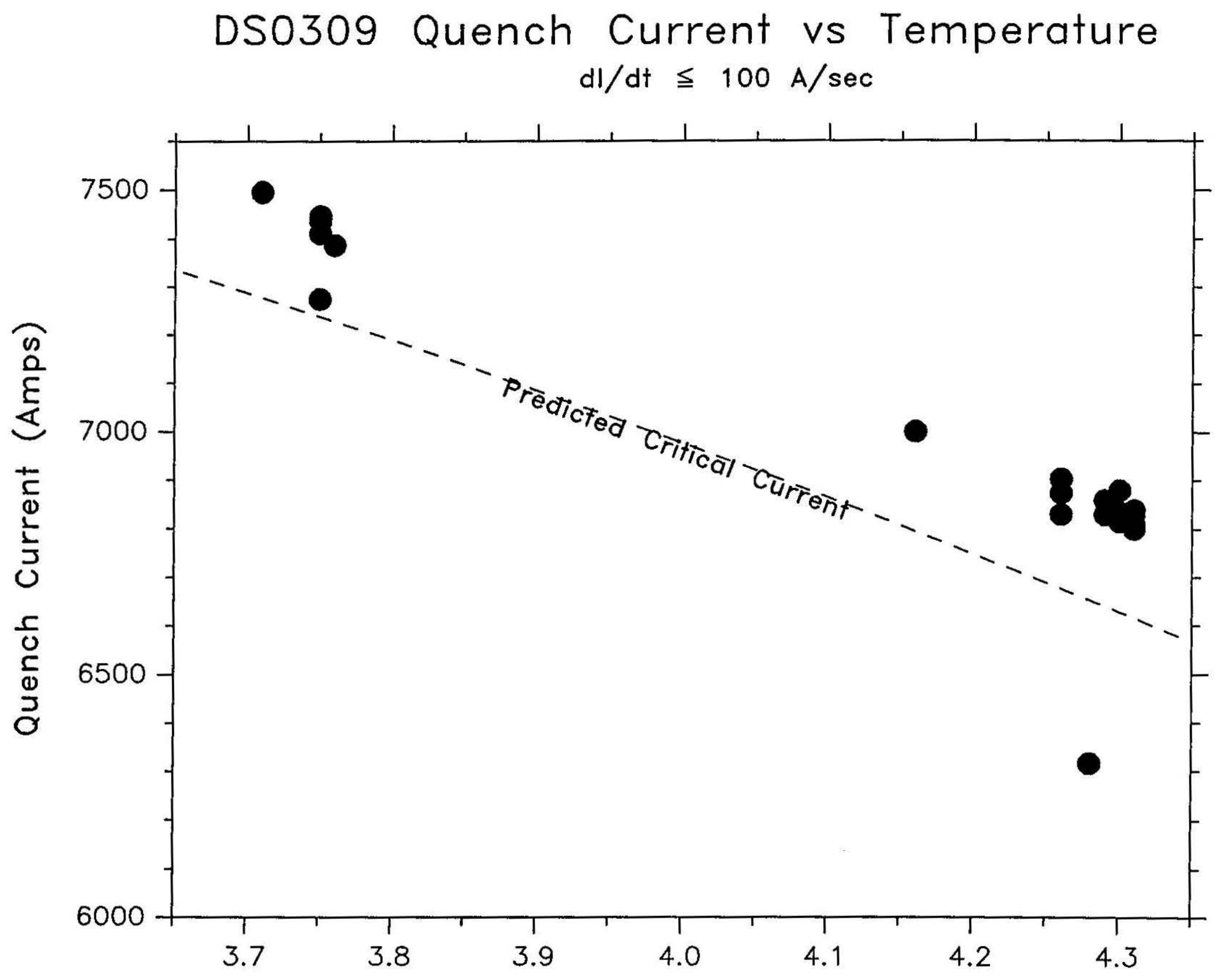

DS0309 Quench Current vs Temperature
dI/dt ≦ 100 A/sec
Quench Current (Amps)
7500
7000
6500
6000
Predicted Critical Current
3.7
3.8
3.9
4.0
4.1
4.2
4.3
Temperature (K)

Figure 8