TS-SSC 91-175
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September 1991

Summary of DSA324 Quenches

DSA324 is the third Fermilab 50 mm short SSC dipole that was tested in Lab2. This magnet experienced four thermal cycles. Tests during the first and second cooldown included quench training at 4.3 K and 4.2 K, ramp rate dependence study of quench current at 4.3 K , ramping down from 6500 A at high rates (up to 400 A/S) , strain gage runs to 7350 A at 4.3 K and harmonics measurements as a function of current at the center of the magnet and as a function of position at 5000 A. Some additional tests performed during the second cooldown included quench training at 3.8 K , ramp rate dependence study of quench current at 4.2 K , AC loss measurements at different ramp rates , transfer function and periodic remnant field study using Rawson Lush Fieldmeter. The bore tube was evacuated except during magnetic measurement tests. The voltage tap in the upper outer coil was broken. All the strain gages were in working order when the cooldown to helium temperature started, later a shell gage was lost. The rest of the instrumentation was functional during the remainder of the test. For third cooldown the magnet ends were not preloaded and during the fourth thermal cycle the ends were preloaded to ~500 lb/bullet at ambient temperature.

Quench History (First Cooldown)

A summary of all quench files with quench locations is attached at the end of this report and the quench history is plotted in Figure 1. Figure 2 is a map of voltage tap locations used to determine the quench origins. The quench propagation velocity in straight sections of the coil was typically ≥ 80 m/s and ~33 m/s in ramp splices during a standard plateau quench. The first spontaneous quench occurred during a strain gage run (Iq=7382 A) at 4.3 K , located in non-ramp splice side straight section of the lower inner turn 19 about 3.3 ms (~29.6 cm ± 5 cm) from the lead tap.

The magnet achieved an average plateau current of ~7435 A on the second quench. The magnet was quenched five times at plateau current before going on to a strain gage run and then to ramp rate study. All standard plateau quenches (SPQ) were at a ramp rate of 16 A/s and 4.3 K. All SPQ's originated in the straight section of the lower inner pole turn. Four plateau quenches were on ramp-splice side and one was on the non ramp-splice side. However, the quench origin moved around in the straight section of the pole turn. The quench location was about 40 to 60 cm ±5 cm from the lead tap (i.e. ramp splice tap). The quench velocity of these quenches was ~83 m/s. Figure 3 shows the voltages in three earliest segments for a typical plateau quench. Figure 4 shows the location of a typical plateau quench on the ramp splice and non-ramp splice side of the coil. Figure 5 shows the voltage growth in three earliest segments due to a typical quench on the side opposite the ramp-splice. The location of such quenches is ~25 cm ±5 cm from the lead tap .

4.2 K Quenches

The magnet did not show any training at 4.2 K and reached a current of 7690 A in first quench. All 4.2 K plateau quenches were in the same location (pole turn) as 4.3 K plateau quenches. Plateau quench was established by quenching the magnet twice with warm bore still evacuated and for the remaining 4.2 K quenches (in first thermal cycle) warm bore tube was at room temperature. There was no difference between evacuated and non-evacuated (bore tube) quenches. The magnet was ramped at a nominal ramp rate of 16 A/s and an average of ~7681 A quench current was achieved. All plateau quenches in turn 19 were about 4 -6 ms from the ramp splice and achieved a Vq≈ 83 m/s. One 4.2 K quench in turn 18 was also on the ramp-splice side of the inner lower coil , ~ 4 ms (37 ± 5 cm) from the return end tap. The magnet temperature was not lowered any further during the first thermal cycle .

Quench History

During the second cooldown period the magnet did not show any training at 4.3 K. The plateau current was ~7485 A , ~50 A higher than plateau current for the first thermal cycle. The magnet was quenched several times at 4.2 K before and after the low temperature (3.8 K) studies. Plateau quench current at 4.2 K before and after 3.8 K quenches were ~7740 A (~70 A higher than it was in the first thermal cycle ~7676 A) and ~7695 A respectively. The quench location was still the same (straight section of lower inner pole turn on the ramp splice side) at both temperatures. During 4.2 K quenching the only voltage tap in the lower outer coil was lost and a quench in the lower outer coil was detected. This quench originated approximately 13 ms from the ramp splice (nearest tap to the point of quench) in the lower outer coil. A strain gage run to I_q - 50 A =7700 A was also taken at 4.2 K .

During third cooldown the plateau quench currents (Iq) , at all temperatures, were lower than Iq during the other three test cycles. The full range of quench currents is much higher for the third thermal cycle.

Low Temperature Studies

DSA324 temperature was lowered to 3.8 K during the second thermal cycle. It was quenched eight times at low temperature. First two quenches were in the upper and lower outer coils , then there were two quenches in the lower inner pole turn on the ramp-splice side (this is also the location for plateau quenches) before the magnet reached a plateau current of ~8175 A. These quenches were roughly 6 ms (~49 +/- 5 cm) from the ramp-splice with a quench velocity $V_q \approx$ 87 m/s. A strain gage run was also taken during low temperature studies.

During the third cooldown , the magnet did not have any end preload. It showed some training and plateaued at 8078 A , almost ~100 A below the previous thermal cycle plateau current. Whereas , during the fourth cooldown the end preload was ~500 pound / bullet. The plateau quench current in this test cycle was ~8118 A. The difference in quench currents can not be explained by fluctuations in temperatures. Table 2 shows the average temperature during each test cycle.

Ramp Rate Study

The ramp rate dependence of DSA324 was studied during the first two cooldowns. The magnet was quenched at a series of ramp rates ranging from the nominal rate of 16 A/s to 300 A/s. During the first cooldown high ramp rate quench study was done at 4.3 K. All high ramp rate quenches in first test cycle , from 25 - 300 A/s , were in the upper inner multiple turn rather than in one of the ramp splices. All of these quenches originated near the lead end tap of the upper inner coil in turn 13 (on the ramp splice side). Since the multiple turns are not very well instrumented so its rather difficult to pin point the exact location of the quenches. Figure 6 compares the ramp rate dependence of DSA324 with other 50 mm aperture magnets.

During the second cooldown the magnet was tested for ramp rate dependence at 4.3 K and 4.2 K. All high ramp rate quenches were still in upper inner coil multiple turn with the exception of 25 A/s quenches which now were ~3.2 ms from the lead tap on non ramp-splice side of the lower inner coil.

All the quenches during third test cycle were at 16 A/s except one at 100 A/s. The only 6 A/s quench in the fourth cooldown was at 7387 A and two quenches were at 25 A/s, and the rest were at 16 A/s. There was one 100 A/s quench in third thermal cycle.

As discussed in TS-SSC 90-26, the SSC dipole magnets should be able to ramp down at the initial ramp rate of -325 A/s. To show magnet's stability DSA324 was ramped down from 6500 A to 4000 A at high ramp rates of -100, -200 , -300 and -400 A/s without quenching. At the end of this cycle the magnet was ramped at 16 A/s to quench. This, quench, during the first test cycle, was in the non ramp-splice side of the inner lower coil, ~3.2 ms (28.5 ± 5 cm , in first thermal cycle) from the lead tap .

Temperature Dependence

The quench performance of a magnet depends on temperature of helium bath in which the magnet is immersed. The relation between quench current for $dI/dt \leq 16$ A/s and the average of the three thermometers placed at top , middle and bottom of the magnet is shown in Figure 7. The solid dashed line in the figure is the critical current as predicted by Chris Quigg's program using Mike Green's parametrization of the critical surface. Table 2 shows the averages of plateau quench currents at 16 A/s at different temperatures (the average of three thermometers placed on the magnet skin). A plateau quench for this magnet is the one which originates in the pole turn of lower inner coil (turn 19) and is near the maximum current for a given temperature.

The cable used to wind the inner coils of DSA324 are from reel SSC 3S-00021. The short sample critical current (Ic) at 7 Tesla, 4.22 K for this cable is 10,079 A. A comparison of magnet performance and predicted quench current based on the short sample data is given in Table 1 and Table 2 shows the measured quench current at different temperatures during four cooldowns.

Table 1: Predicted critical current at different temperatures

Temp (K)	Predicted Iquench
4.35	7310 A
4.22	7470 A
3.80 K	7960 A

Table 2: Measured quench current at different temperatures during four test cycles.

Thermal Cycle	Temperature	Measured Iquench
1	4.35 K	7425 ± 9 A
2	4.36 K	7486 ± 5 A
3	4.29 K	7385 ± 7 A
4	4.35 K	7425 ± 3 A
1	4.17 K	7681 ± 9 A
2	4.17 K	7695 ±11 A
3	4.19 K	7554 ±52 A
4	4.18 K	7651 ± 8 A
2	3.81 K	7486 ±8 A
3	3.82 K	7385 ±16 A
4	3.82 K	7425 ±10 A

The error bars on the measured data are the standard deviation (of plateau currents) divided by the square root of the number of quenches for each temperature for each thermal cycle.

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DSA324 was cooled down four times and it experienced a total of 112 spontaneous quenches at 4.3 K, 4.2 K and 3.8 K. It is equipped with four SSC2 (12 inch long) type heater strip, one in each quadrant.

Quench File Summary
DSA324

First Thermal Cycle

4.35K Plateau Quenches:

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	1002.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.36	4.31	4.30	831.	71.	manual trip to check safety
	1	997.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.38	4.32	4.31	878.	71.	ckts and system
1	2	7382.	16.	0.0	0.0	U-L	0.0	-.012	-27.	LI	0.000	0.	4.40	4.34	4.33	880.	82.	First spontaneous quench IL19SL 3.3 ms from lead tap
2	3	7436.	16.	0.0	0.0	U-L	0.0	-.012	-30.	LI	0.000	0.	4.40	4.34	4.33	861.	69.	IL19SR 6.0 ms from ramp splice
3	4	7421.	16.	0.0	0.0	U-L	0.0	-.011	-26.	LI	0.000	0.	4.36	4.30	4.29	867.	71.	IL19SR 6.2 ms from lead tap
4	5	7455.	16.	0.0	0.0	U-L	0.0	-.009	-30.	LI	0.000	0.	4.40	4.34	4.32	879.	70.	IL19SR 4.7 ms from ramp splice
5	6	7436.	16.	0.0	0.0	U-L	0.0	-.013	-29.	LI	0.000	0.	4.39	4.34	4.33	851.	65.	IL19SR 7.2 ms from return tap
6	7	7421.	16.	0.0	0.0	U-L	0.0	-.012	-29.	LI	0.000	0.	4.39	4.33	4.32	847.	68.	IL19SR 6.5 ms from return tap

4.35 K Ramp Rate Study:

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
7	8	7421.	25.	0.0	0.0	U-L	0.0	-.006	-23.	UI	0.000	0.	4.33	4.28	4.28	809.	59.	IU Multi Turn
8	9	7240.	50.	0.0	0.0	U-L	0.0	-.006	-24.	UI	0.000	0.	4.40	4.33	4.31	856.	75.	IU Multi Turn
9	10	7122.	75.	0.0	0.0	U-L	0.0	-.007	-25.	UI	0.000	0.	4.39	4.33	4.32	851.	63.	IU Multi Turn
10	11	6897.	100.	0.0	0.0	U-L	0.0	-.015	-27.	UI	0.000	0.	4.39	4.34	4.33	853.	58.	IU Multi Turn
11	12	6790.	125.	0.0	0.0	U-L	0.0	-.012	-24.	UI	0.000	0.	4.39	4.34	4.33	853.	58.	IU Multi Turn
12	13	6476.	200.	0.0	0.0	U-L	0.0	-.020	-31.	UI	0.000	0.	4.40	4.34	4.34	857.	55.	IU Multi Turn
13	14	6662.	150.	0.0	0.0	U-L	0.0	-.018	-32.	UI	0.000	0.	4.39	4.34	4.33	859.	90.	IU Multi Turn
14	15	6344.	250.	0.0	0.0	U-L	0.0	-.019	-31.	UI	0.000	0.	4.36	4.31	4.30	826.	78.	IU Multi Turn
15	16	6217.	300.	0.0	0.0	U-L	0.0	-.016	-30.	UI	0.000	0.	4.40	4.33	4.32	864.	75.	IU Multi Turn
16	17	7426.	16.	0.0	0.0	U-L	0.0	-.012	-28.	LI	0.000	0.	4.39	4.33	4.32	853.	81.	IL19SL 3.75 ms from lead tap

4.2 K Plateau Quenches:

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
17	18	7690.	16.	0.0	0.0	U-L	0.0	-.007	-28.	LI	0.000	0.	4.21	4.16	4.16	721.	73.	IL19SR 5.6 ms from ramp splice
18	19	7681.	16.	0.0	0.0	U-L	0.0	-.007	-29.	LI	0.000	0.	4.21	4.16	4.16	721.	58.	IL19SR 4.0 ms from ramp splice
19	20	7666.	16.	0.0	0.0	U-L	0.0	-.007	-28.	LI	0.000	0.	4.21	4.16	4.15	718.	78.	IL18SR 4.0 ms from return tap
20	21	7676.	16.	0.0	0.0	U-L	0.0	-.007	-30.	LI	0.000	0.	4.21	4.16	4.15	718.	83.	IL19SR 4.3 ms from ramp splice
	22	72.	0.	0.0	0.0	U-L	0.0	0.000	1.	LO	0.000	0.	4.20	4.16	4.15	715.	84.	Trip
21	23	7656.	16.	0.0	0.0	U-L	0.0	-.006	-28.	LI	0.000	0.	4.20	4.16	4.15	715.	81.	IL19SR 5.5 ms from ramp splice
22	24	7705.	16.	0.0	0.0	U-L	0.0	-.013	-31.	LI	0.000	0.	4.20	4.16	4.15	715.	82.	IL19SR 4.1 ms from ramp splice

Second Thermal Cycle

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
	25	1002.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.44	4.38	4.37	881.	78.	manual trip to check system s.ckts
	26	1438.	0.	0.0	0.0	Cu L	0.0	0.000	0.	UI	0.000	0.	4.41	4.35	4.34	859.	69.	trip
	27	797.	0.	0.0	0.0	Cu L	0.0	0.000	0.	UI	0.000	0.	4.40	4.34	4.34	851.	71.	trip
23	28	7504.	16.	0.0	0.0	U-L	0.0	-.015	-32.	LI	0.000	0.	4.42	4.35	4.34	871.	81.	IL19SR 2.3 ms from ramp splice
24	29	7490.	16.	0.0	0.0	U-L	0.0	-.009	-31.	LI	0.000	0.	4.41	4.35	4.33	859.	67.	IL19SR 4.7 ms from ramp splice
25	30	7470.	16.	0.0	0.0	U-L	0.0	-.011	-29.	LI	0.000	0.	4.40	4.33	4.31	862.	82.	IL19SL 2.75 ms from lead tap
26	31	7480.	16.	0.0	0.0	U-L	0.0	-.013	-31.	LI	0.000	0.	4.40	4.34	4.33	852.	74.	IL19SR 4.8 ms from ramp splice
27	32	7480.	16.	0.0	0.0	U-L	0.0	-.013	-31.	LI	0.000	0.	4.41	4.34	4.33	858.	64.	IL19SR 4.5 ms from ramp splice

4.35K Ramp Rate Study:

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
28	33	7480.	25.	0.0	0.0	U-L	0.0	-.011	-28.	LI	0.000	0.	4.38	4.31	4.30	852.	68.	IL19SL 2.5 ms from lead tap
29	34	7245.	50.	0.0	0.0	U-L	0.0	-.007	-24.	UI	0.000	0.	4.40	4.34	4.32	855.	68.	IU Multi Turn
30	35	7157.	75.	0.0	0.0	U-L	0.0	-.008	-25.	UI	0.000	0.	4.39	4.34	4.33	847.	69.	IU Multi Turn
31	36	6985.	100.	0.0	0.0	U-L	0.0	-.014	-30.	UI	0.000	0.	4.41	4.35	4.34	867.	71.	IU Multi Turn
32	37	6775.	150.	0.0	0.0	U-L	0.0	-.017	-32.	UI	0.000	0.	4.40	4.34	4.33	850.	73.	IU Multi Turn
33	38	6525.	200.	0.0	0.0	U-L	0.0	-.017	-31.	UI	0.000	0.	4.41	4.35	4.33	853.	76.	IU Multi Turn
34	39	6295.	300.	0.0	0.0	U-L	0.0	-.016	-31.	UI	0.000	0.	4.39	4.34	4.33	845.	78.	IU Multi Turn

4.2 K Plateau Quenches:

35	40	7490.	16.	0.0	0.0	U-L	0.0	-.012	-30.	LI	0.000	0.	4.40	4.34	4.33	850.	78.	IL19SL 2.5 ms from lead tap
36	41	7749.	16.	0.0	0.0	U-L	0.0	-.007	-28.	LI	0.000	0.	4.22	4.16	4.15	719.	82.	IL19SR 5.7 ms from ramp splice
37	42	7671.	16.	0.0	0.0	U-L	0.0	-.009	-28.	LI	0.000	0.	4.21	4.16	4.15	714.	82.	IL19SR 4.5 ms from ramp splice
38	43	7705.	16.	0.0	0.0	U-L	0.0	-.007	-27.	LI	0.000	0.	4.21	4.16	4.15	712.	83.	IL19SR 2.7 ms from ramp splice
39	44	7739.	16.	0.0	0.0	U-L	0.0	-.007	-24.	LI	0.000	0.	4.21	4.15	4.14	712.	81.	IL19SR 3.0 ms from ramp splice
40	45	7558.	16.	0.0	0.0	U-L	0.0	-.014	-38.	LI	0.000	0.	4.21	4.16	4.15	713.	67.	OL (broke a voltage tap during ramp)
41	46	7749.	16.	0.0	0.0	U-L	0.0	-.007	-27.	LI	0.000	0.	4.21	4.15	4.15	712.	83.	IL19SR 5.8 ms from ramp splice
42	47	7739.	16.	0.0	0.0	U-L	0.0	-.009	-28.	LI	0.000	0.	4.21	4.15	4.14	711.	79.	IL19SR 7.0 ms from ramp splice
43	48	7749.	16.	0.0	0.0	U-L	0.0	-.008	-27.	LI	0.000	0.	4.21	4.16	4.15	712.	85.	IL19SR 3.3 ms from ramp splice
	49	189.	0.	0.0	0.0	V-dI	0.0	0.000	1.	LO	0.000	0.	4.21	4.16	4.15	713.	84.	trip during ACloss study
44	50	7705.	16.	0.0	0.0	U-L	0.0	-.012	-29.	LI	0.000	0.	4.21	4.16	4.15	712.	78.	IL19SR 3.3 ms from ramp splice
45	51	7651.	25.	0.0	0.0	U-L	0.0	-.009	-27.	LI	0.000	0.	4.21	4.15	4.15	713.	66.	IL19SL 3.2 ms from lead tap
	52	2412.	0.	0.0	0.0	V-dI	0.0	0.000	-14.	UI	0.000	0.	4.21	4.15	4.15	715.	77.	trip during upramp
46	53	7715.	25.	0.0	0.0	U-L	0.0	-.007	-27.	LI	0.000	0.	4.21	4.15	4.14	711.	81.	IL19SL 2.0 ms from lead tap
	54	6442.	0.	0.0	0.0	V-dI	0.0	0.000	-37.	UI	0.000	0.	4.21	4.15	4.15	711.	83.	Trip during upramp for harmonics
47	55	7690.	25.	0.0	0.0	U-L	0.0	-.005	-22.	UI	0.000	0.	4.21	4.15	4.15	711.	83.	IU Multi Turn

3.8 K Plateau Quenches:

48	56	7921.	16.	0.0	0.0	U-L	0.0	-.015	-39.	UI	0.000	0.	3.85	3.80	3.80	501.	79.	OU
49	57	7935.	16.	0.0	0.0	U-L	0.0	-.015	-39.	LI	0.000	0.	3.86	3.81	3.80	501.	76.	OL
50	58	8161.	16.	0.0	0.0	U-L	0.0	-.006	-26.	LI	0.000	0.	3.86	3.81	3.80	504.	80.	IL19SR 7.2 ms from taps
51	59	8151.	16.	0.0	0.0	U-L	0.0	-.005	-26.	LI	0.000	0.	3.84	3.80	3.79	490.	84.	IL19SR 7.0 ms from taps
	60	992.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.22	4.16	4.15	717.	77.	manual trip to check safety ckts
52	61	7735.	16.	0.0	0.0	U-L	0.0	-.007	-28.	LI	0.000	0.	4.21	4.16	4.15	716.	78.	IL19SR 5.6 ms from ramp splice

3.8 K Plateau Quenches:

53	62	8180.	16.	0.0	0.0	U-L	0.0	-.006	-26.	LI	0.000	0.	3.83	3.79	3.79	486.	81.	IL19SR 6.0 ms from ramp splice
54	63	7935.	16.	0.0	0.0	U-L	0.0	-.022	-42.	LI	0.000	0.	3.86	3.81	3.80	502.	76.	OL
55	64	8195.	16.	0.0	0.0	U-L	0.0	-.006	-26.	LI	0.000	0.	3.85	3.79	3.78	500.	76.	IL19SR 6.0 ms from ramp splice
56	65	8190.	16.	0.0	0.0	U-L	0.0	-.006	-24.	LI	0.000	0.	3.85	3.79	3.78	499.	77.	IL19SL 6.0 ms from lead tap

4.2K Ramp Rate Study:

57	66	7661.	50.	0.0	0.0	U-L	0.0	-.006	-24.	UI	0.000	0.	4.22	4.16	4.15	717.	78.	IU Multi Turn
58	67	7196.	100.	0.0	0.0	U-L	0.0	-.011	-32.	UI	0.000	0.	4.22	4.16	4.16	718.	70.	IU Multi Turn
59	68	6770.	200.	0.0	0.0	U-L	0.0	-.015	-32.	UI	0.000	0.	4.22	4.16	4.16	718.	75.	IU Multi Turn
60	69	6530.	300.	0.0	0.0	U-L	0.0	-.020	-31.	UI	0.000	0.	4.22	4.16	4.15	717.	81.	IU Multi Turn
61	70	7661.	16.	0.0	0.0	U-L	0.0	-.013	-29.	LI	0.000	0.	4.22	4.17	4.16	722.	78.	IL19SR 3.0 ms from ramp splice
62	71	7627.	16.	0.0	0.0	U-L	0.0	-.009	-30.	LI	0.000	0.	4.22	4.17	4.16	722.	79.	IL19SR 2.5 ms from ramp splice
63	72	7642.	16.	0.0	0.0	U-L	0.0	-.013	-30.	LI	0.000	0.	4.22	4.17	4.16	721.	97.	IL19SR 2.5 ms from ramp splice
64	73	7656.	16.	0.0	0.0	U-L	0.0	-.008	-29.	LI	0.000	0.	4.22	4.16	4.16	718.	81.	IL19SR 5.0 ms from ramp splice
	74	7274.	16.	0.0	0.0	Vtot	0.0	0.000	-41.	UI	0.000	0.	4.21	4.16	4.15	715.	91.	Trip
65	75	7666.	16.	0.0	0.0	U-L	0.0	-.008	-29.	LI	0.000	0.	4.21	4.16	4.15	714.	69.	IL19SR 5 ms from ramp splice
66	76	7661.	16.	0.0	0.0	U-L	0.0	-.012	-30.	LI	0.000	0.	4.21	4.16	4.15	715.	77.	IL19SR 2.5 ms from ramp splice
67	77	7671.	16.	0.0	0.0	U-L	0.0	-.008	-29.	LI	0.000	0.	4.21	4.16	4.15	715.	70.	IL19SR 5 ms from ramp splice
	78	6990.	0.	0.0	0.0	Cu L	0.0	0.000	-1.	UI	0.000	0.	4.22	4.16	4.16	720.	71.	TRIP
	79	7054.	0.	0.0	0.0	Cu L	0.0	0.000	-1.	UI	0.000	0.	4.21	4.16	4.15	714.	75.	TRIP

Third Cooldown

4.3 K quenches:

	80	91.	100.	0.0	0.0	Cu L	0.0	0.000	0.	UI	0.000	0.	4.21	4.16	4.15	716.	74.	TRIP
	81	1002.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.21	4.16	4.15	716.	82.	MANUAL TRIP TO CHECK SAFETY CKTS.
	82	997.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.21	4.16	4.15	716.	80.	DUMP, SYSTEM CHECK
	83	4131.	16.	0.0	0.0	Vtot	0.0	-.001	-25.	UI	0.000	0.	4.40	4.34	4.33	865.	90.	TRIP
68	84	7372.	16.	0.0	0.0	U-L	0.0	-.014	-32.	LI	0.000	0.	4.39	4.33	4.32	881.	76.	IL19SR 2 ms from ramp splice
69	85	7392.	16.	0.0	0.0	U-L	0.0	-.011	-26.	LI	0.000	0.	4.34	4.27	4.26	845.	99.	IL19SL 4 ms from lead tap
70	86	7392.	16.	0.0	0.0	U-L	0.0	-.009	-28.	LI	0.000	0.	4.29	4.23	4.22	861.	98.	IL19SL 4.7 ms from lead tap
71	87	7627.	16.	0.0	0.0	U-L	0.0	-.014	-31.	LI	0.000	0.	4.21	4.17	4.16	722.	81.	IL19SR 3.5 ms from ramp splice
	88	7000.	0.	0.0	0.0	Cu L	0.0	0.000	-1.	LI	0.000	0.	4.22	4.17	4.16	724.	76.	Trip
	89	7039.	0.	0.0	0.0	Cu L	0.0	0.000	-1.	UI	0.000	0.	4.21	4.17	4.16	722.	74.	Trip
72	90	7529.	16.	0.0	0.0	U-L	0.0	-.025	-37.	UI	0.000	0.	4.20	4.16	4.15	719.	68.	OU
73	91	6902.	100.	0.0	0.0	U-L	0.0	-.008	-28.	UI	0.000	0.	4.20	4.16	4.15	719.	57.	IU MULTI TURN
74	92	7622.	16.	0.0	0.0	U-L	0.0	-.005	-23.	UI	0.000	0.	4.21	4.16	4.15	723.	74.	UI MULTI TURN

	93	7010.	0.	0.0	0.0	Cu L	0.0	0.000	0.	UI	0.000	0.	4.21	4.16	4.15	721.	73.	Trip
	94	6932.	0.	0.0	0.0	Cu L	0.0	0.000	0.	LI	0.000	0.	4.21	4.16	4.16	722.	76.	Trip

3.8 K quench studies:

75	95	7754.	16.	0.0	0.0	U-L	0.0	-.015	-24.	UI	0.000	0.	3.84	3.80	3.80	496.	95.	UI MULTI TURN
76	96	7725.	16.	0.0	0.0	U-L	0.0	-.016	-36.	LI	0.000	0.	3.84	3.79	3.79	495.	92.	OL
77	97	7867.	16.	0.0	0.0	U-L	0.0	-.021	-38.	UI	0.000	0.	3.84	3.80	3.80	495.	96.	OU
78	98	7637.	16.	0.0	0.0	U-L	0.0	-.015	-24.	UI	0.000	0.	3.86	3.82	3.80	505.	92.	IU MULTI TURN
79	99	7984.	16.	0.0	0.0	U-L	0.0	-.014	-39.	UI	0.000	0.	3.84	3.80	3.80	496.	70.	OU
80	100	8063.	16.	0.0	0.0	U-L	0.0	-.008	-28.	LI	0.000	0.	3.85	3.81	3.80	503.	81.	IL19SR 7 ms from Lead tap
81	101	8102.	16.	0.0	0.0	U-L	0.0	-.005	-27.	LI	0.000	0.	3.84	3.79	3.79	494.	95.	IL19SR 7 ms from Lead tap
82	102	8023.	16.	0.0	0.0	U-L	0.0	-.010	-24.	LI	0.000	0.	3.85	3.81	3.80	500.	89.	IL16SL 4 ms from lead tap 415 (non pole turn quench)
83	103	8107.	16.	0.0	0.0	U-L	0.0	-.005	-26.	LI	0.000	0.	3.84	3.80	3.80	498.	86.	IL19SR 6 ms form Lead tap
84	104	8097.	16.	0.0	0.0	U-L	0.0	-.006	-26.	LI	0.000	0.	3.85	3.81	3.80	504.	92.	IL19SR 6 ms form Lead tap

Heater Studies:

	105	1991.	0.	0.0	0.0	U-L	0.0	-.200	-12.	UI	0.000	0.	4.26	4.22	4.21	761.	79.	
	106	1991.	0.	0.0	0.0	U-L	0.0	-.170	-12.	UI	0.000	0.	4.25	4.20	4.20	753.	79.	
	107	1991.	0.	0.0	0.0	U-L	0.0	-.150	-12.	UI	0.000	0.	4.26	4.21	4.21	761.	79.	
	108	1991.	0.	0.0	0.0	U-L	0.0	-.145	-12.	UI	0.000	0.	4.27	4.22	4.21	765.	78.	
	109	4993.	0.	0.0	0.0	U-L	0.0	-.025	-30.	UI	0.000	0.	4.27	4.22	4.22	761.	79.	
	110	4993.	0.	0.0	0.0	U-L	0.0	-.020	-30.	UI	0.000	0.	4.26	4.21	4.20	757.	80.	
	111	4993.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.27	4.22	4.22	768.	79.	
	112	4993.	0.	0.0	0.0	U-L	0.0	-.010	-30.	UI	0.000	0.	4.30	4.23	4.22	780.	78.	
	113	4993.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.29	4.23	4.22	842.	81.	
	114	-2.	0.	0.0	0.0	V-dI	0.0	0.000	1.	LO	0.000	0.	4.26	4.21	4.20	755.	78.	
	115	-2.	0.	0.0	0.0	V-dI	0.0	0.000	0.	LI	0.000	0.	4.26	4.21	4.20	758.	78.	
	116	1991.	0.	0.0	0.0	U-L	0.0	-.185	-12.	UI	0.000	0.	4.27	4.21	4.20	772.	79.	
	117	1991.	0.	0.0	0.0	U-L	0.0	-.170	-12.	UI	0.000	0.	4.28	4.22	4.21	799.	78.	
	118	1991.	0.	0.0	0.0	U-L	0.0	-.155	-12.	UI	0.000	0.	4.27	4.22	4.21	783.	81.	
	119	1991.	0.	0.0	0.0	U-L	0.0	-.155	-12.	UI	0.000	0.	4.24	4.20	4.19	740.	81.	
	120	4993.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.26	4.20	4.19	769.	78.	
	121	5002.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.33	4.22	4.20	808.	78.	
	122	4993.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.20	4.15	4.15	716.	83.	
	123	4993.	0.	0.0	0.0	U-L	0.0	-.095	-30.	UI	0.000	0.	4.20	4.15	4.15	717.	79.	
	124	4993.	0.	0.0	0.0	U-L	0.0	-.075	-30.	UI	0.000	0.	4.20	4.15	4.15	717.	79.	
85	125	7480.	16.	0.0	0.0	U-L	0.0	-.010	-27.	LI	0.000	0.	4.22	4.18	4.17	730.	80.	IL19SL 9 ms from Lead tap

Fourth Cooldown

	126	992.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.39	4.27	4.25	857.	6.	
	127	987.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	UI	0.000	0.	4.38	4.29	4.28	855.	12.	
86	128	7431.	16.	0.0	0.0	U-L	0.0	-.015	-32.	LI	0.000	0.	4.38	4.31	4.31	848.	78.	IL19SR 2.5 ms from Lead tap

(first spontaneous quench this cooldown ,during a strain gage run)

87	129	7421.	16.	0.0	0.0	U-L	0.0	-.013	-30.	LI	0.000	0.	4.41	4.36	4.35	878.	78.	IL19SR 5 ms from Lead tap
88	130	7421.	16.	0.0	0.0	U-L	0.0	-.012	-30.	LI	0.000	0.	4.39	4.34	4.33	856.	78.	IL19SR 4.5 ms from Lead tap
89	131	7426.	16.	0.0	0.0	U-L	0.0	-.013	-30.	LI	0.000	0.	4.39	4.33	4.32	854.	68.	IL19SR 5.5 ms from Lead tap
90	132	7690.	16.	0.0	0.0	U-L	0.0	-.008	-28.	LI	0.000	0.	4.21	4.16	4.16	720.	83.	IL19SR 6 ms from Lead tap
91	133	7676.	16.	0.0	0.0	U-L	0.0	-.008	-28.	LI	0.000	0.	4.21	4.16	4.16	720.	83.	IL19SR 4 ms from Lead tap
92	134	7661.	16.	0.0	0.0	U-L	0.0	-.011	-28.	LI	0.000	0.	4.21	4.16	4.16	720.	83.	IL19SR 7 ms(7ms) from Lead(RE) tap
93	135	7387.	6.	0.0	0.0	U-L	0.0	-.009	-30.	LI	0.000	0.	4.21	4.16	4.16	720.	83.	IL19SL 3 ms from Lead tap
94	136	7627.	16.	0.0	0.0	U-L	0.0	-.018	-28.	LI	0.000	0.	4.18	4.17	*****	734.	75.	IL19S 8 ms from Lead tap
95	137	7637.	16.	0.0	0.0	U-L	0.0	-.007	-27.	LI	0.000	0.	4.18	4.16	-4.41	720.	73.	IL19SR 4 ms from Lead tap
96	138	7612.	16.	0.0	0.0	U-L	0.0	-.013	-28.	LI	0.000	0.	4.21	4.19	-4.71	750.	79.	IL19SR 5 ms from Lead tap
97	139	7602.	16.	0.0	0.0	U-L	0.0	-.010	-26.	LI	0.000	0.	4.16	4.15	-5.68	717.	77.	IL19SL 5 ms from Lead tap
98	140	7642.	16.	0.0	0.0	U-L	0.0	-.008	-28.	LI	0.000	0.	4.23	4.22	*****	768.	77.	IL19SR 4 ms from Lead tap
99	141	7661.	16.	0.0	0.0	U-L	0.0	-.008	-28.	LI	0.000	0.	4.17	4.17	-1.34	724.	76.	IL19SR 5.5 ms from Lead tap

3.8 K quench studies:

100	142	8102.	16.	0.0	0.0	U-L	0.0	-.007	-26.	LI	0.000	0.	3.81	3.80	*****	497.	75.	IL19SR 6.5 ms from Lead tap
101	143	8116.	16.	0.0	0.0	U-L	0.0	-.007	-25.	LI	0.000	0.	3.82	3.81	*****	503.	76.	IL19SR 6.5 ms from Lead tap
102	144	8121.	16.	0.0	0.0	U-L	0.0	-.006	-26.	LI	0.000	0.	3.83	3.82	-2.81	507.	75.	IL19SR 5 ms from Lead tap
103	145	8116.	16.	0.0	0.0	U-L	0.0	-.007	-26.	LI	0.000	0.	3.82	3.81	*****	503.	77.	IL19SR 2.5 ms from Lead tap

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
104	146	8136.	16.	0.0	0.0	U-L	0.0	-.008	-26.	LI	0.000	0.	3.81	3.80	*****	498.	70.	IL19SR 5 ms from Lead tap
	147	4136.	16.	0.0	0.0	Cu L	0.0	0.000	0.	UI	0.000	0.	*****	*****	*****	726.	86.	Trip-lost thermometers (*)
4.2 K quenches:																		
105	148	7627.	25.	0.0	0.0	U-L	0.0	-.006	-22.	UI	0.000	0.	*****	*****	*****	713.	86.	IU Multiturn (lost thermometrs)
106	149	7671.	16.	0.0	0.0	U-L	0.0	-.014	-29.	LI	0.000	0.	4.21	4.16	4.16	719.	85.	IL19SR 3.5 ms from Lead tap

Heater Studies

	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
	150	1977.	0.	0.0	0.0	U-L	0.0	-.150	-12.	UI	0.000	0.	4.21	4.16	4.15	717.	85.
	151	4983.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.21	4.16	4.16	720.	81.
	152	1977.	0.	0.0	0.0	U-L	0.0	-.180	-12.	UI	0.000	0.	4.21	4.16	4.16	717.	82.
	153	1962.	0.	0.0	0.0	U-L	0.0	-.160	-12.	UI	0.000	0.	4.22	4.17	4.16	727.	77.
	154	4988.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.22	4.17	4.16	727.	77.
	155	1986.	0.	0.0	0.0	U-L	0.0	-.165	-12.	UI	0.000	0.	4.21	4.16	4.16	719.	83.
	156	4978.	0.	0.0	0.0	U-L	0.0	-.020	-30.	UI	0.000	0.	4.21	4.16	4.16	718.	83.
	157	1967.	0.	0.0	0.0	U-L	0.0	-.170	-12.	UI	0.000	0.	4.21	4.16	4.16	717.	77.
	158	4973.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.21	4.16	4.16	718.	78.
	159	1981.	0.	0.0	0.0	U-L	0.0	-.165	-12.	UI	0.000	0.	4.21	4.16	4.16	718.	79.
	160	4978.	0.	0.0	0.0	U-L	0.0	-.015	-30.	UI	0.000	0.	4.21	4.16	4.16	718.	79.
	161	1981.	0.	0.0	0.0	U-L	0.0	-.160	-12.	UI	0.000	0.	4.21	4.16	4.16	718.	79.
	162	4978.	0.	0.0	0.0	U-L	0.0	-.020	-30.	UI	0.000	0.	4.21	4.16	4.16	718.	79.
	163	1981.	0.	0.0	0.0	U-L	0.0	-.160	-12.	UI	0.000	0.	4.21	4.16	4.16	718.	79.
	164	4988.	0.	0.0	0.0	U-L	0.0	-.020	-30.	UI	0.000	0.	4.21	4.16	4.16	718.	79.

4.2 K quenches:

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
107	165	7676.	16.	0.0	0.0	U-L	0.0	-.010	-27.	LI	0.000	0.	4.21	4.16	4.16	720.	73.	IL19SR 10 ms(10 ms) from Lead tap
108	166	7646.	25.	0.0	0.0	U-L	0.0	-.005	-26.	LI	0.000	0.	4.20	4.15	4.15	717.	74.	IL19SR 2 ms from Lead tap
109	167	7318.	16.	0.0	0.0	U-L	0.0	-.155	28.	UO	0.000	0.	4.34	4.23	4.21	897.	79.	OU
110	168	7646.	16.	0.0	0.0	U-L	0.0	-.008	26.	UI	0.000	0.	4.21	4.17	4.16	718.	90.	IU Multiturn
111	169	7637.	16.	0.0	0.0	U-L	0.0	-.013	19.	LI	0.000	0.	4.22	4.17	4.17	728.	73.	IL19SR 4 ms from Lead tap
112	170	7666.	16.	0.0	0.0	U-L	0.0	-.008	18.	LI	0.000	0.	4.21	4.16	4.15	720.	76.	IL19SR 4 ms from Lead tap
	170	7666.	16.	0.0	0.0	U-L	0.0	-.008	18.	LI	0.000	0.	4.21	4.16	4.15	720.	76.	

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

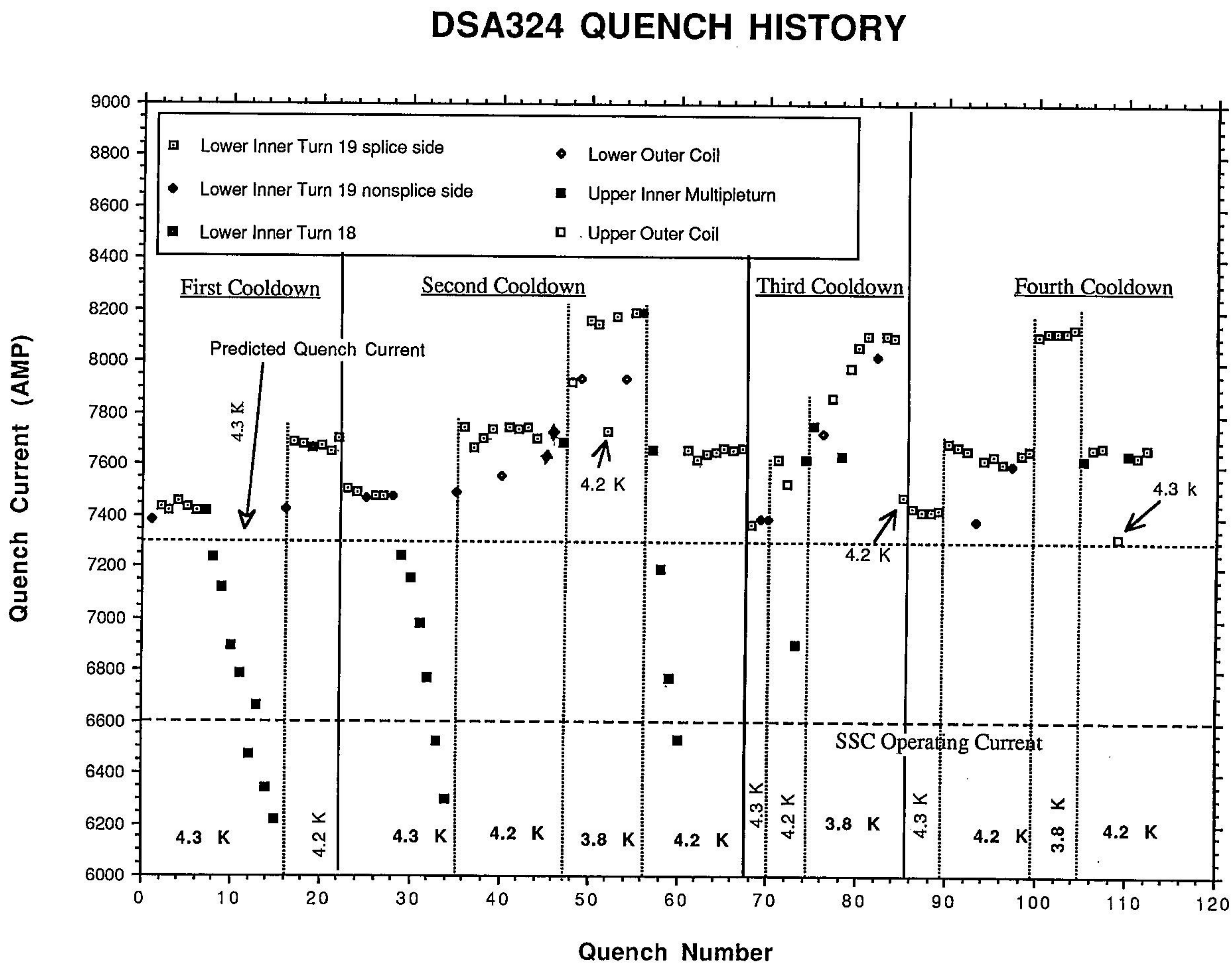
FORMAT:

```
  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



DSA324 QUENCH HISTORY
Lower Inner Turn 19 splice side
Lower Inner Turn 19 nonsplice side
Lower Inner Turn 18
Lower Outer Coil
Upper Inner Multipleturn
Upper Outer Coil
First Cooldown
Second Cooldown
Third Cooldown
Fourth Cooldown
Predicted Quench Current
SSC Operating Current
4.3 K
4.2 K
3.8 K
4.3 k
Quench Current (AMP)
Quench Number
9000
8800
8600
8400
8200
8000
7800
7600
7400
7200
7000
6800
6600
6400
6200
6000
0
10
20
30
40
50
60
70
80
90
100
110
120

Figure 1

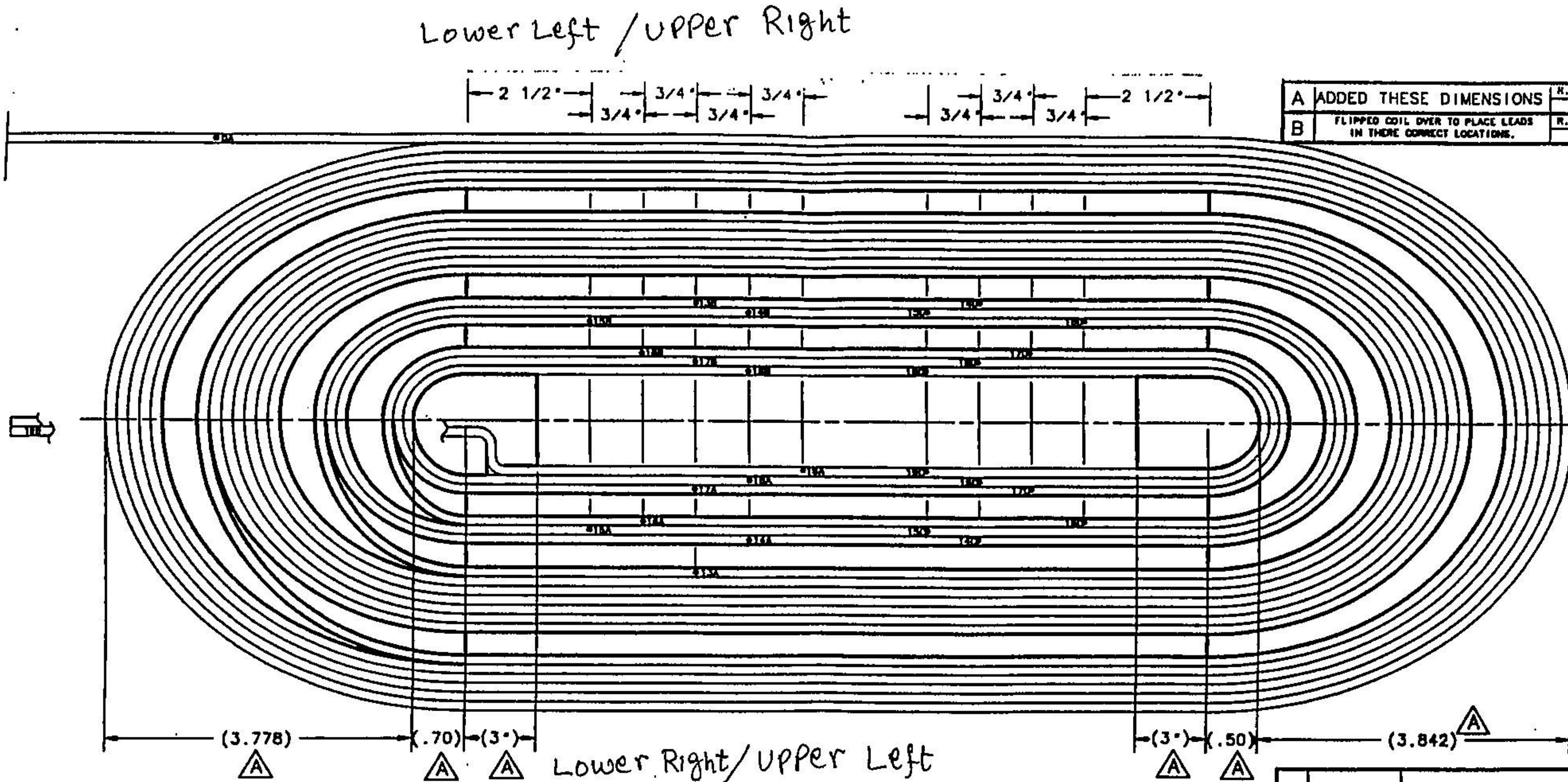


Figure 2

A	ADDED THESE DIMENSIONS	R.DIXON	11/19/90
B	FLIPPED COIL OVER TO PLACE LEADS IN THERE CORRECT LOCATIONS.	R.DIXON	12/06/90

NOTE:

1. VOLTAGE TAP WIRES FOR TAPS 0A, 19B, 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	

ORIGINATOR	STRAIT/KOSKA
DRAWN	R.DIXON 10/16/90
CHECKED	
APPROVED	
USED ON	
MATERIAL	

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DSA3XX
VOLTAGE TAPS
INNER COIL

SCALE	FILMED	DRAWING NUMBER	REV.
NONE		0102-MB-263907	B

CREATED WITH I-DEAS 4.1 USER NAME: SPUD

INCHES METRIC

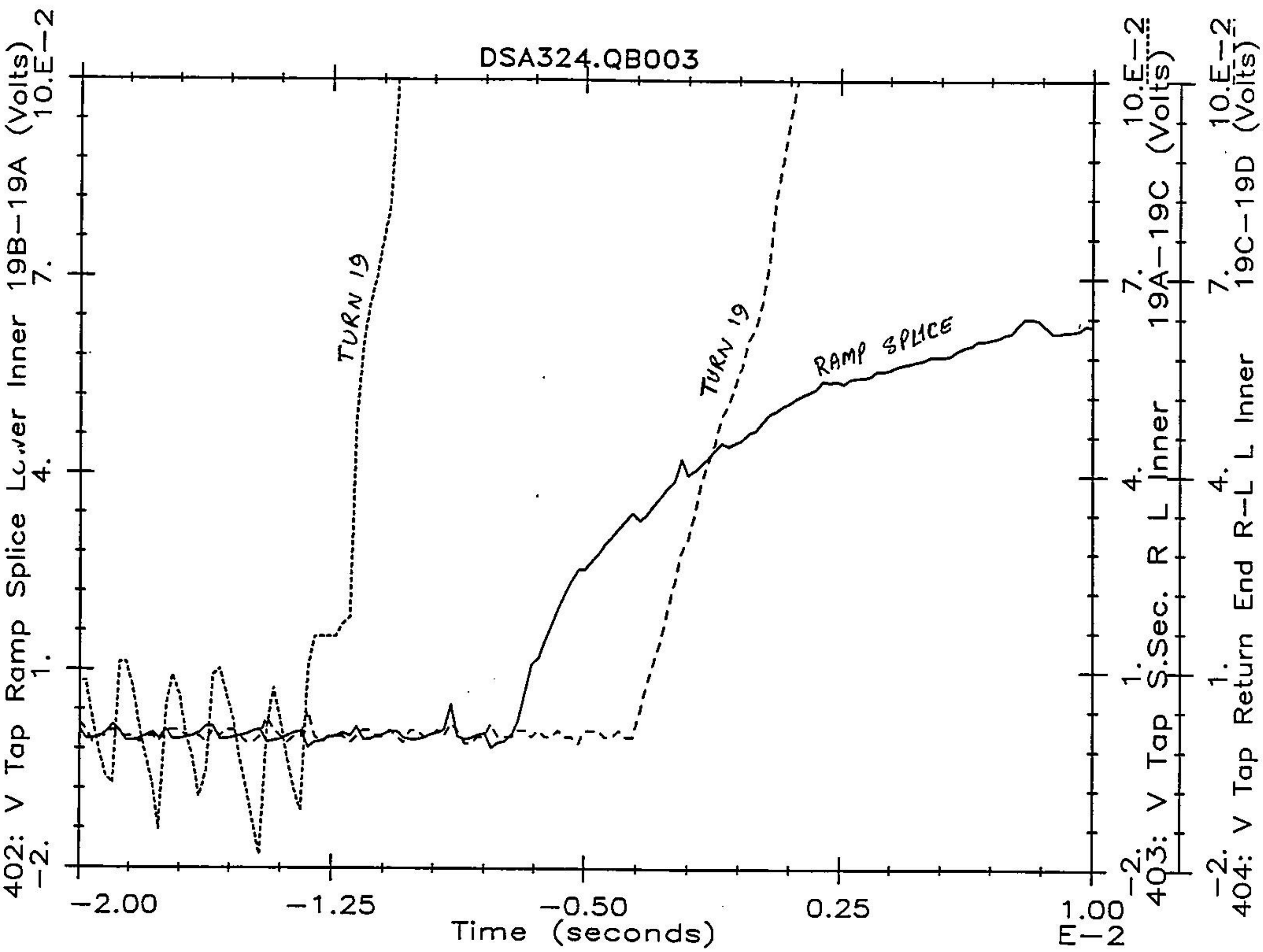

DSA324.QB003
402: V Tap Ramp Splice Lower Inner 19B−19A (Volts)
10.E−2
403: V Tap S.Sec. R L Inner 19A−19C (Volts)
404: V Tap Return End R−L L Inner 19C−19D (Volts)
−2.
1.
4.
7.
−2.00
−1.25
−0.50
0.25
1.00
E−2
Time (seconds)
TURN 19
TURN 19
RAMP SPLICE

Figure 3

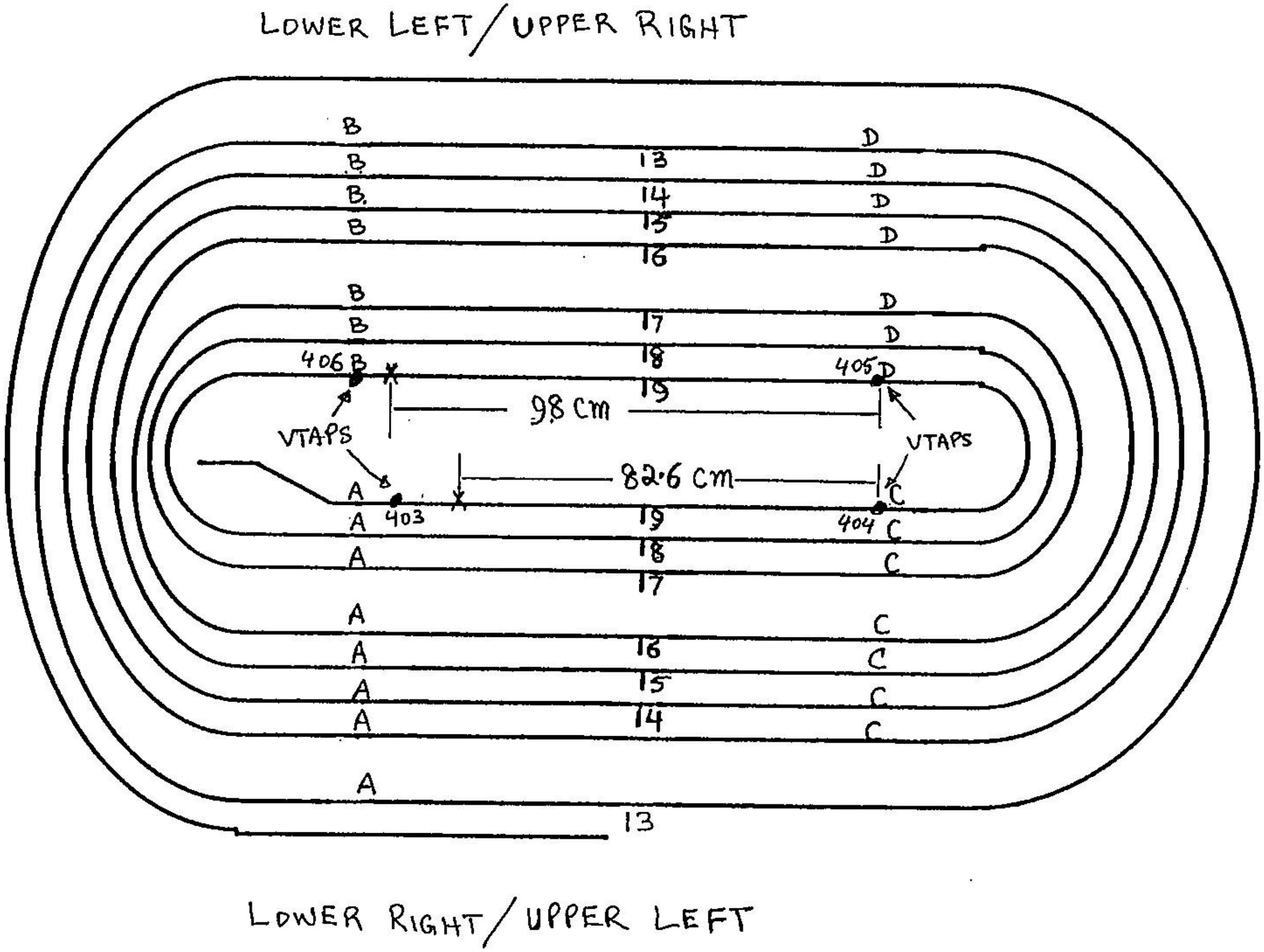
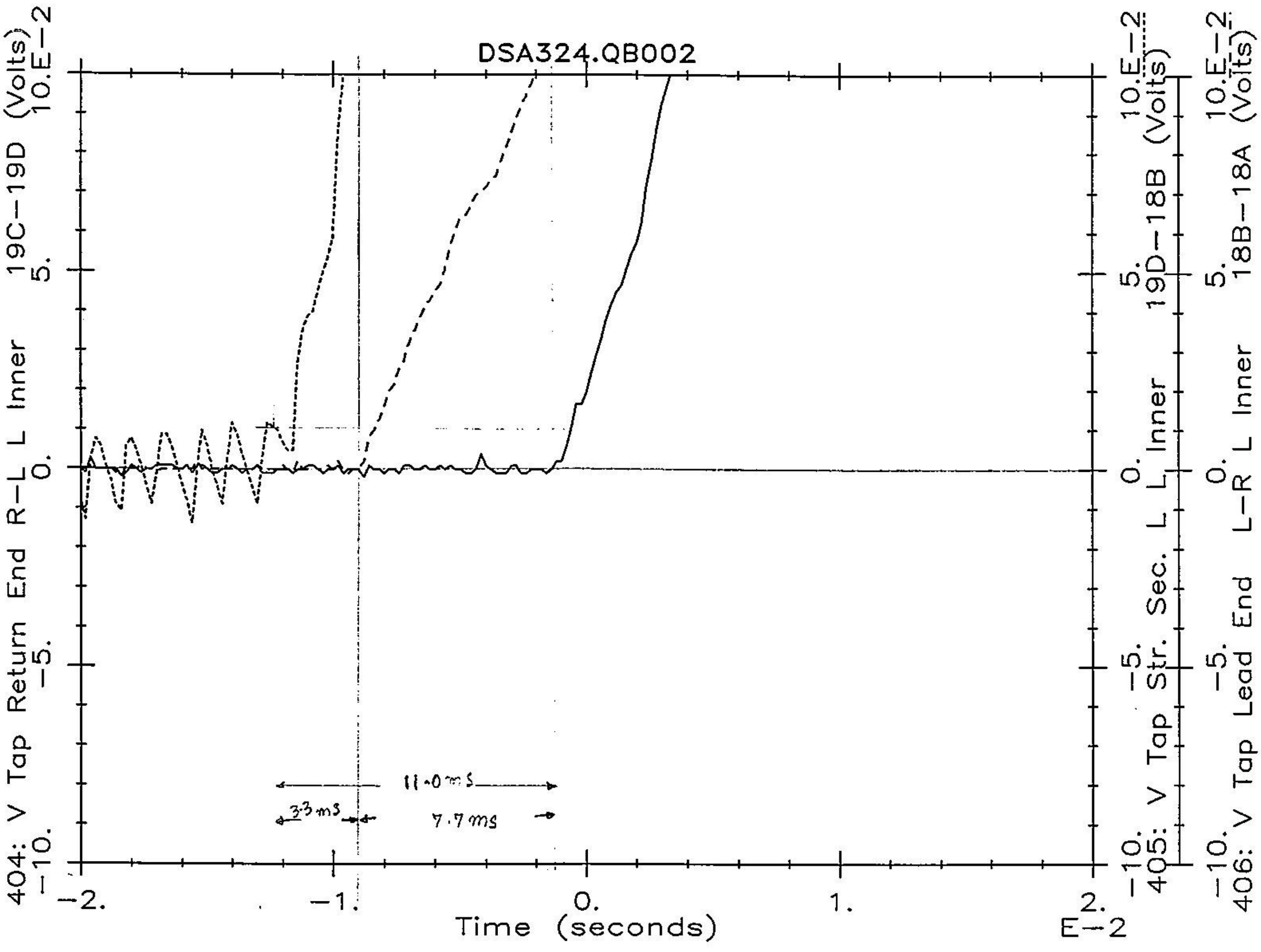

LOWER LEFT/UPPER RIGHT
B
B
B
B
B
B
406 B
13
14
15
16
17
18
19
D
D
D
D
D
D
405 D
VTAPS
98 cm
82.6 cm
VTAPS
A
403
A
A
A
A
A
A
A
19
18
17
16
15
14
13
C
404 C
C
C
C
C
C
LOWER RIGHT/UPPER LEFT

Figure 4



DSA324.QB002
404: V Tap Return End R-L L Inner 19C-19D (Volts)
405: V Tap Str. Sec. L L Inner 19D-18B (Volts)
406: V Tap Lead End L-R L Inner 18B-18A (Volts)
10.E-2
5.
0.
-5.
-10.
-2.
-1.
0.
1.
2.
E-2
Time (seconds)
11.0 ms
3.3 ms
7.7 ms

Figure 5

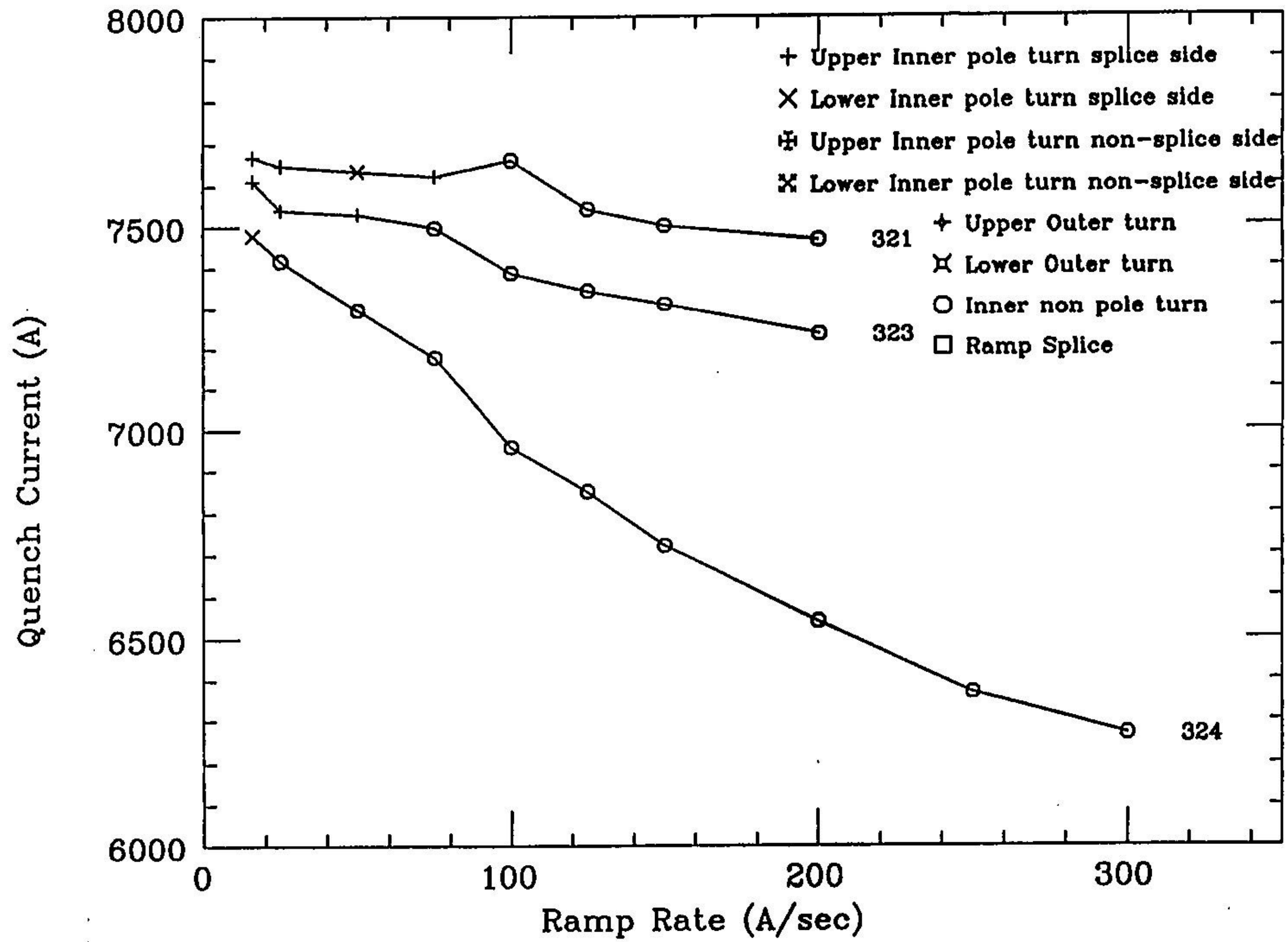

8000
7500
7000
6500
6000
Quench Current (A)
0
100
200
300
Ramp Rate (A/sec)
Upper Inner pole turn splice side
Lower Inner pole turn splice side
Upper Inner pole turn non-splice side
Lower Inner pole turn non-splice side
Upper Outer turn
Lower Outer turn
Inner non pole turn
Ramp Splice
321
323
324

Figure 6

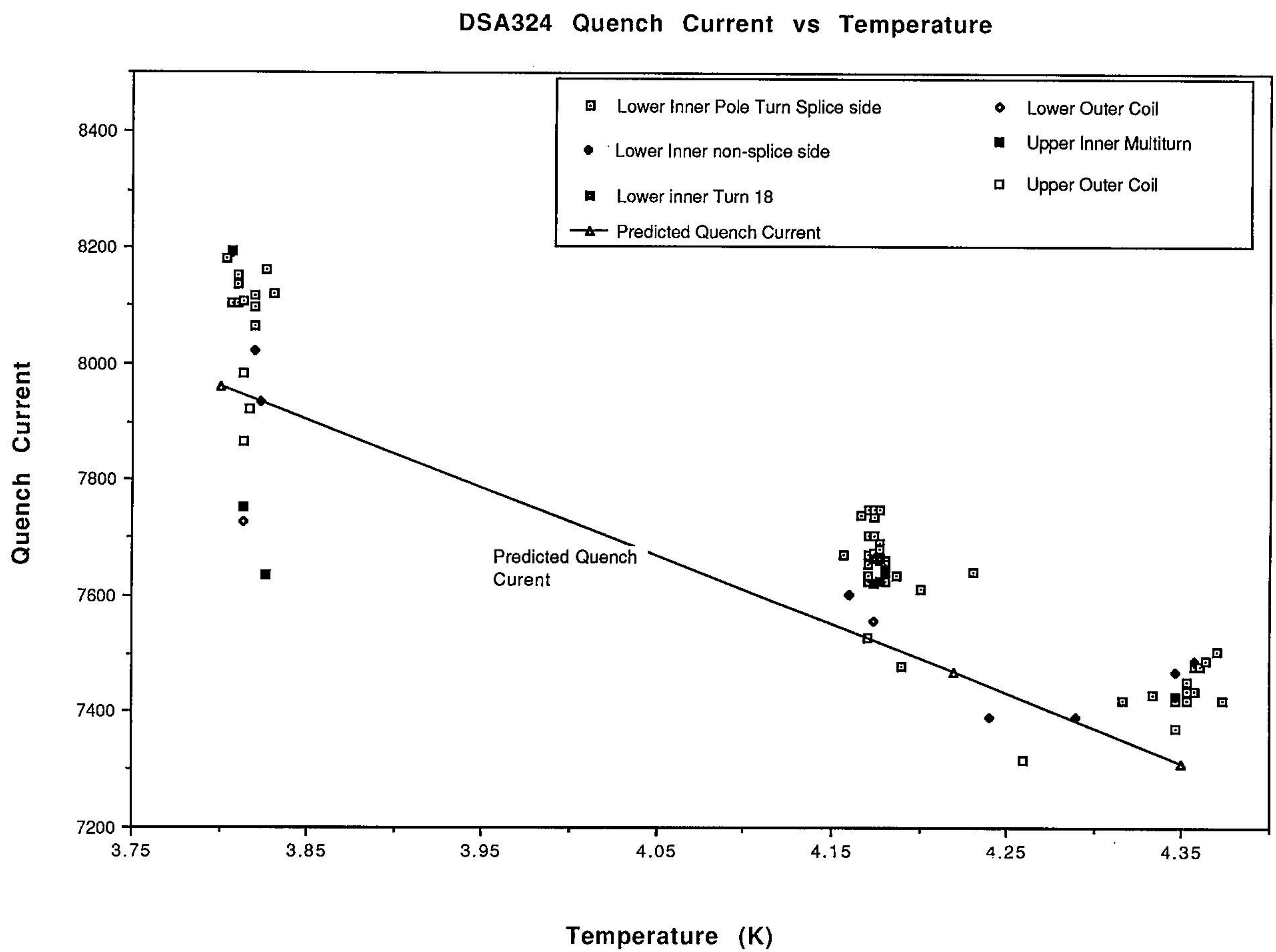

DSA324 Quench Current vs Temperature
Lower Inner Pole Turn Splice side
Lower Inner non-splice side
Lower inner Turn 18
Predicted Quench Current
Lower Outer Coil
Upper Inner Multiturn
Upper Outer Coil
Quench Current
8400
8200
8000
7800
7600
7400
7200
Predicted Quench
Curent
3.75
3.85
3.95
4.05
4.15
4.25
4.35
Temperature (K)

Figure 7