TS-SSC 91-002
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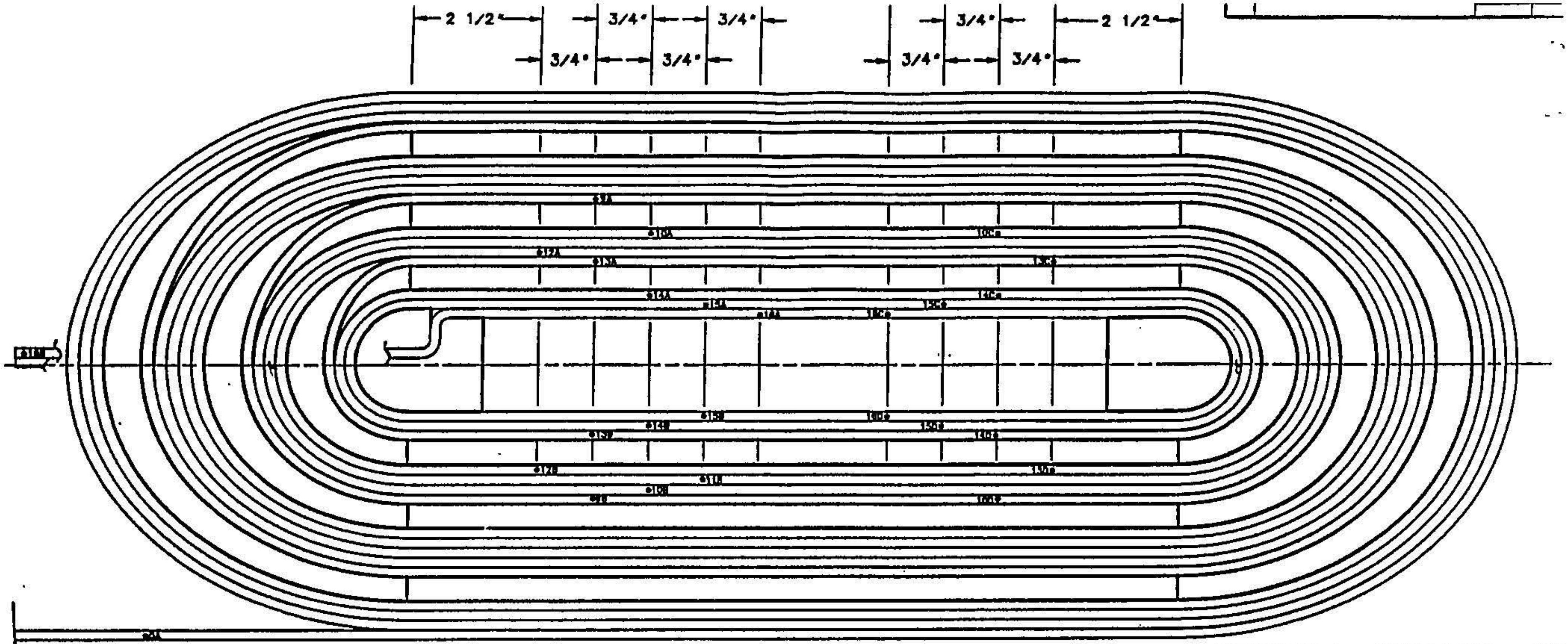
January 9, 1991

Summary of DS0313 Quench Performance

DS0313 is a 1m Fermilab SSC model magnet with a 40mm aperture. It is the first 1m magnet featuring a vertically split yoke. During the course of testing it was quenched a total of 44 times which included one thermal cycle, at temperatures of 4.3, 4.2 and 3.8K. Fewer spontaneous quenches were recorded in comparison with previous tests because of the extensive heater studies which were performed. This report is a chronological summary of test results including quench history, quench locations and ramp rate studies, followed by a comparsion of magnet performance with cable short sample.

Quench History (First testing cycle)

A summary of the quench data which includes quench currents, ramp rates, temperatures and quench locations is attached to the report. The quench summary sheet gives the quench times (locations) preceeded by a + (-) sign referring to the lead (non-lead) end side of the tap respectively. The quench propagation velocity was approximately 70 m/s at short sample in the straight sections. A map of the tap locations is given in Figure 1 for reference.



NOTE:

1. VOLTAGE TAP WIRES FOR TAPS 0A, 18B, 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.

PARTS LIST

ORIGINATOR STRAIT/KOSKA
DRAWN R. DIXON 1/5/90

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DS0308
VOLTAGE TAPS
INNER COIL

SCALE NONE

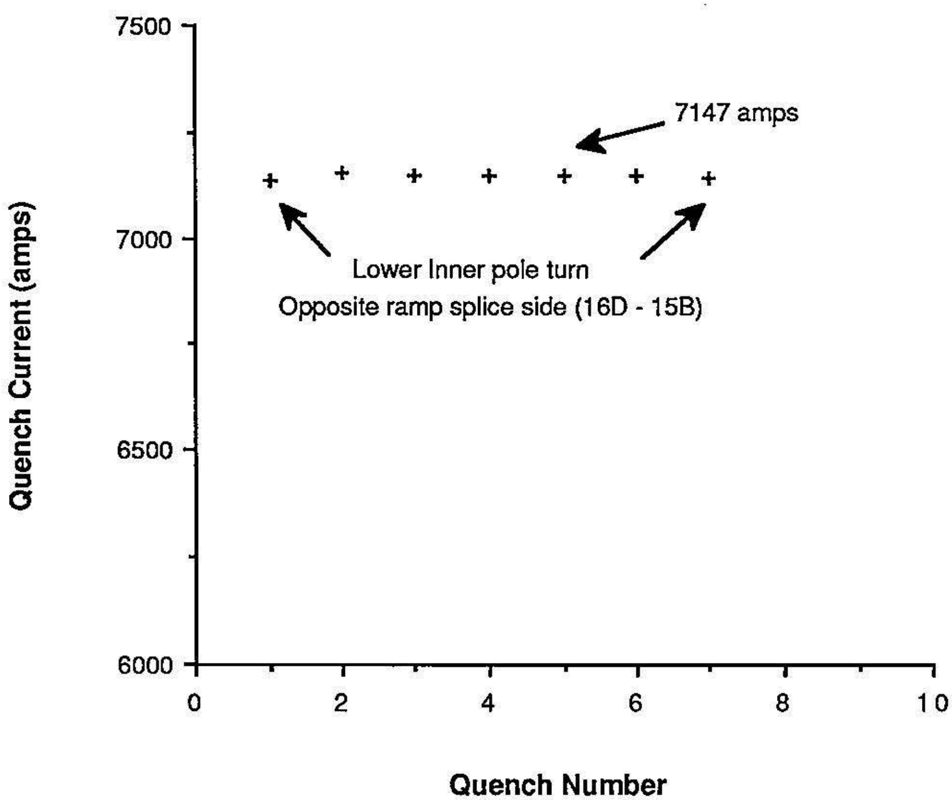
CREATED WITH I-DEAS 4.1 USER NAME:SPUD

Figure 1

Training Quenches

All quenchs prior to the ramp rate studies occured in the lower inner pole turn, opposite the ramp splice side in approximately the center of the magnet. These quenches will henceforward be refered to as standard plateau quenches or SPQ's. The magnet exhibited exceptional behavior with the first quench at 7137 amps being only 10 amps below a final plateau of 7147 amps (see Fig. 2).

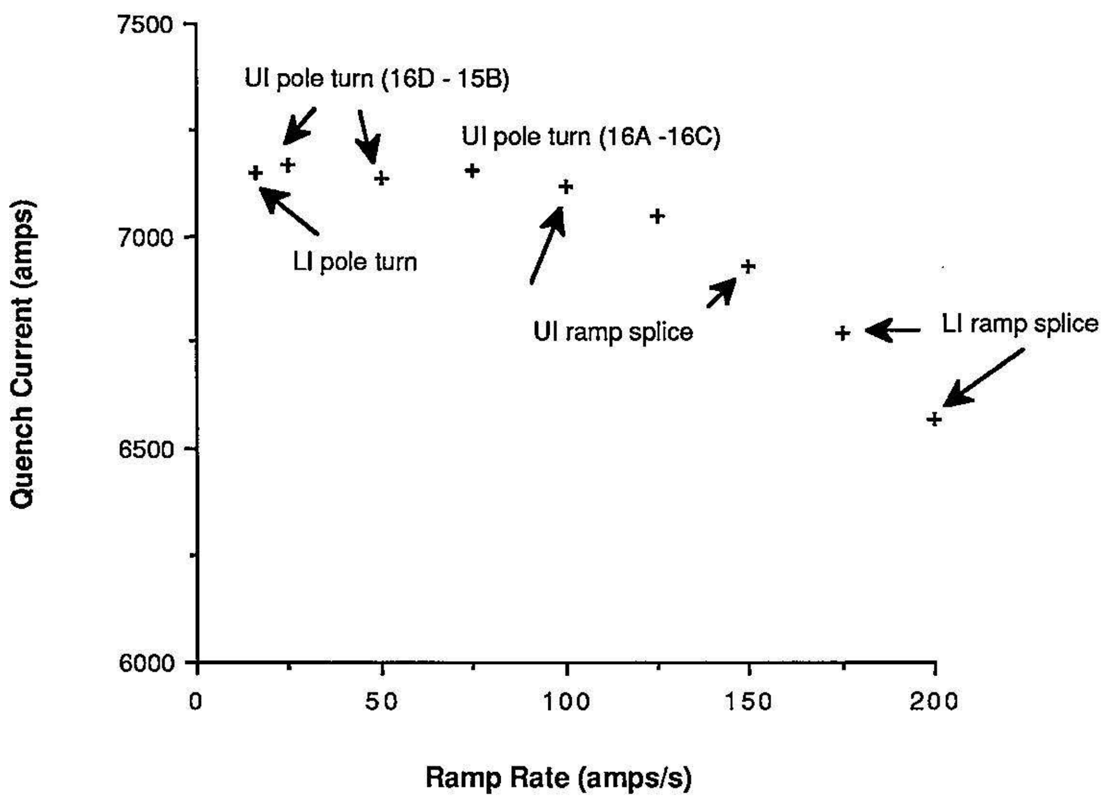
Fig. 2 DS0313 Training Behavior



Ramp Rate Studies

The magnet was then quenched at a series of ramp rates ranging from the nominal 16 amps/s to 200 amps/s. A plot of quench current as a function of ramp rate is given in Figure 3. Measurements made at the same ramp rate were averaged. None of the quenches in the ramp rate study occured in the standard plateau quench location for ramp rates above the nominal 16 amps/s. The quenches between 25 and 75 amps/s occured in the upper inner pole turns. As is typically the case, the higher ramp rate quenches were located in the ramp splices. The quenches at 100 - 150 amps/s were in the upper inner ramp splice while the two highest ramp rate quenches were (curiously) in the lower inner ramp splice.

Fig. 3 DS0313 Ramp Rate Dependence



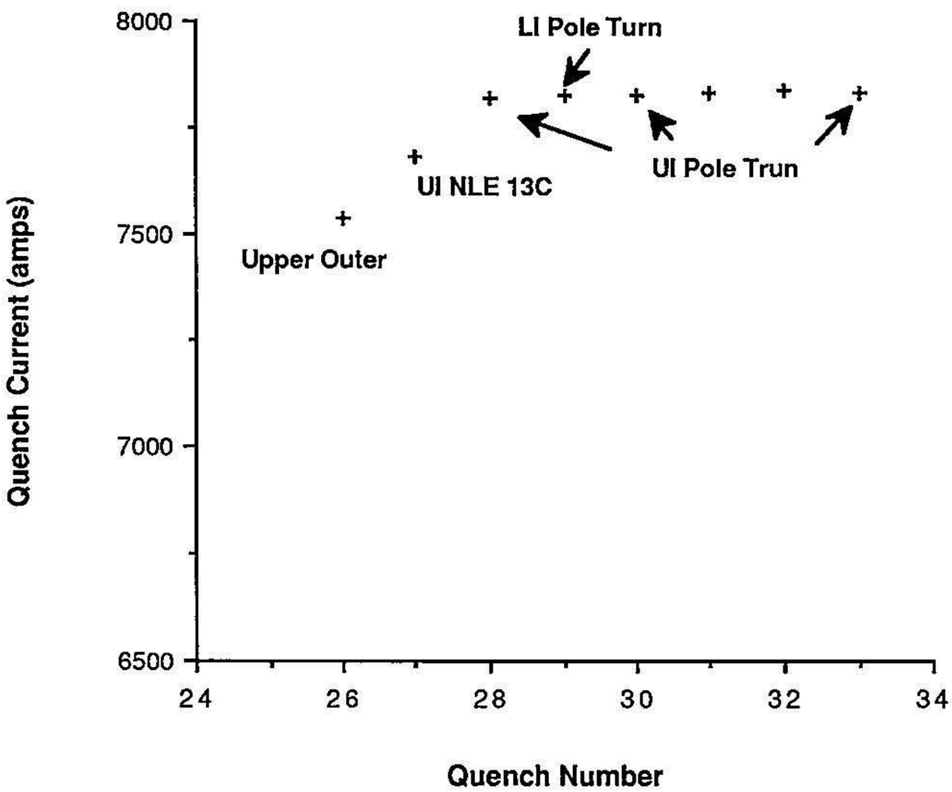
4.2K Studies

The magnet temperature was lowered to approximately 4.2K and quenched at a ramp rate of 16 amps/s. All quenches were at the standard plateau quench location with an average of 7335 amps.

3.8K Studies

The magnet temperature was then lowered further to 3.8K. The magnet exhibited 2 training quenches before reaching a plateau of 7827 amps where it quenched at the SPQ location. The second plateau quench occured in the upper inner pole turn on the ramp splice side, +5 ms from tap 16C. It is the second location in the magnet which seems to be associated with the conductor short sample limit. The quench data are plotted in Figure 4.

Fig. 4. DS0313 Quench Current and Location at 3.8K



The first test cycle was concluded by an extensive set of heater studies before being warmed to room temperature.

Quench History (After thermal cycle)

The magnet was recooled and the plateau currents at 4.3 and 4.2 K were reestablished.

4.3K Studies

It was quenched 7 times at 4.3K with an average quench current of 7134 amps. It exhibited no retraining. All quenches were standard plateau quenches located in the lower inner pole turn.

4.2K Studies

The quench studies were concluded by quenching the magnet 5 times at 4.2K. All quenches occured in the lower inner pole turn with an average current of 7364 amps. The magnet tests were concluded by another set of heater studies.

Quench Performance

The cable used to wind the inner coils was from reel SSC-I-S-00008. The short sample data, taken at Brookhaven, is given in Table 1. A comparison of magnet performance and predicted performance based on the short sample data is shown in Table 2. Two programs, written by M. Kuchnir were used to make the predictions; one using the empirical Morgan-Sampson parameterization based on fits to measurements taken in the region around 4.2K and the other based on the parameterization of M. Green which is based on extrapolation along the J-B-T surface. The normalization point for the Green extrapolation to low temperature is the measured quench current at 4.3K. The measured quench currents are taken from averages of SPQ's at 16 amps/s. The actual temperatures, taken from an average of the three thermometers placed at the top, middle and bottom of the magnet, are within 0.04K of the nominal values given in the table.

Table 1. Short sample data for cable SSC-I-S-00008.

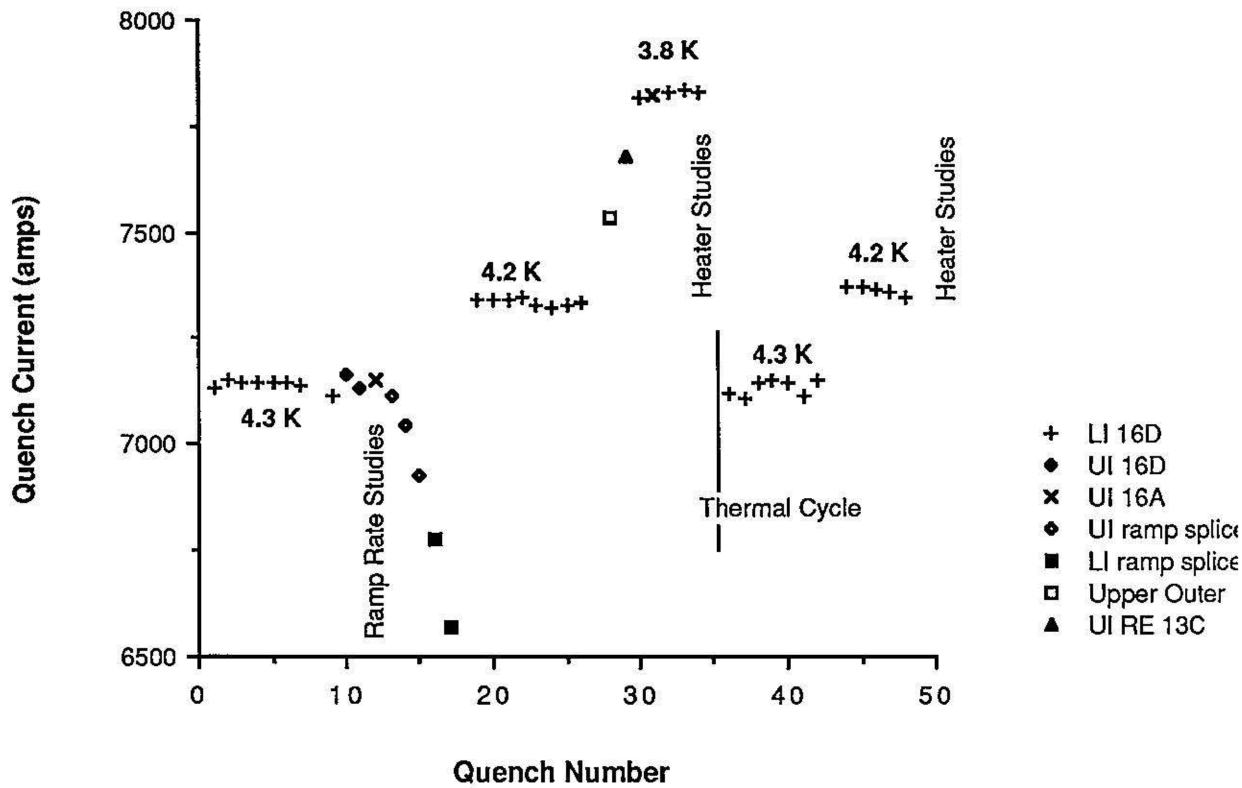
B (Tesla)	Ic (amps)	Jc (A/mm2)
7.0	8,099	1,590

Table 2. Comparison of magnet quench current with predicted performance.

			Predicted Iq	
Temperature	Measured Iq	Measured Iq thermal cycle	Morgan-Sampson	Green
4.3 K	7147 amps	7134 amps	6940 amps	
4.2 K	7335	7364	7030	7251 amps
3.8 K	7827		7380	7708

The quench history of DS0313 is summarized in Figure 5.

Fig. 5 DS0313 Quench Summary



Quench File Summary
DS0313

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/Comments
	0	1027.	0.	0.0	0.0	U-L	0.0	0.000	-6.	LI	0.000	0.	4.35	4.31	4.30	863.	86.	1000 amp dump
1	1	7137.	16.	0.0	0.0	U-L	0.0	-.008	20.	LI	0.000	0.	4.34	4.30	4.29	858.	83.	LI Inner pole turn, opposite ramp splice side, -5.6 ms from 15B
2	2	7152.	16.	0.0	0.0	U-L	0.0	-.008	-24.	UI	0.000	0.	4.34	4.30	4.29	858.	83.	Same as 1
3	3	7147.	16.	0.0	0.0	U-L	0.0	-.008	-21.	LI	0.000	0.	4.36	4.31	4.30	890.	86.	Same as 1
4	4	7147.	16.	0.0	0.0	U-L	0.0	-.008	-21.	LI	0.000	0.	4.34	4.29	4.28	859.	84.	Same as 1
5	5	7147.	16.	0.0	0.0	U-L	0.0	-.007	-20.	LI	0.000	0.	4.34	4.30	4.29	855.	74.	Same as 1
6	6	7147.	16.	0.0	0.0	U-L	0.0	-.008	-20.	LI	0.000	0.	4.34	4.30	4.29	857.	75.	Same as 1
7	7	7142.	16.	0.0	0.0	U-L	0.0	-.008	-20.	LI	0.000	0.	4.34	4.30	4.30	858.	88.	Same as 1

------------------------------------Ramp Rate Studies 4.3 K------------------------------------

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/Comments
8	8	7167.	25.	0.0	0.0	U-L	0.0	-.008	-23.	UI	0.000	0.	4.34	4.30	4.30	858.	88.	UI inner pole turn, opposite ramp splice side, 16d -15B
9	9	7137.	50.	0.0	0.0	U-L	0.0	-.008	-23.	UI	0.000	0.	4.34	4.30	4.30	858.	88.	Same as 8
10	10	7152.	75.	0.0	0.0	U-L	0.0	-.008	-23.	UI	0.000	0.	4.33	4.29	4.29	847.	77.	UI inner pole turn, ramp splice side, +5 ms from 16C
11	11	7118.	100.	0.0	0.0	U-L	0.0	-.011	-23.	UI	0.000	0.	4.34	4.30	4.29	858.	79.	Upper Inner ramp splice
12	12	7049.	125.	0.0	0.0	U-L	0.0	-.011	-23.	UI	0.000	0.	4.37	4.31	4.30	1311.	44.	Upper Inner ramp splice
13	13	6927.	150.	0.0	0.0	U-L	0.0	-.012	-24.	UI	0.000	0.	4.34	4.30	4.25	853.	78.	Upper Inner ramp splice
14	14	6569.	200.	0.0	0.0	U-L	0.0	-.014	-26.	LI	0.000	0.	4.34	4.31	4.28	855.	80.	Lower Inner ramp splice
	15	5135.	-400.	0.0	0.0	Cu L	0.0	0.000	0.	LI	0.000	0.	4.34	4.30	4.29	860.	88.	
15	16	7113.	16.	0.0	0.0	U-L	0.0	-.008	19.	LI	0.000	0.	4.36	4.32	4.31	870.	81.	Same as 1
16	17	6775.	175.	0.0	0.0	U-L	0.0	-.012	-25.	LI	0.000	0.	4.34	4.30	4.29	858.	72.	Lower Inner ramp splice

------------------------------------4.2 K------------------------------------

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/Comments
17	18	7343.	16.	0.0	0.0	U-L	0.0	-.007	-20.	LI	0.000	0.	4.21	4.17	4.16	753.	87.	Same as 1
18	19	7343.	16.	0.0	0.0	U-L	0.0	-.008	-21.	LI	0.000	0.	4.21	4.16	4.16	753.	83.	Same as 1
19	20	7338.	16.	0.0	0.0	U-L	0.0	-.008	-20.	LI	0.000	0.	4.20	4.17	4.16	753.	87.	Same as 1
20	21	7348.	16.	0.0	0.0	U-L	0.0	-.008	-20.	LI	0.000	0.	4.20	4.17	4.16	753.	77.	Same as 1
21	22	7328.	16.	0.0	0.0	U-L	0.0	-.008	-19.	LI	0.000	0.	4.21	4.17	4.16	753.	87.	Same as 1
22	23	7323.	16.	0.0	0.0	U-L	0.0	-.008	20.	LI	0.000	0.	4.20	4.16	4.15	747.	87.	Same as 1
23	24	7328.	16.	0.0	0.0	U-L	0.0	-.007	20.	LI	0.000	0.	4.20	4.16	4.16	748.	82.	Same as 1
24	25	7333.	16.	0.0	0.0	U-L	0.0	-.007	21.	LI	0.000	0.	4.19	4.15	4.15	745.	84.	Same as 1

------------------------------------3.8 K------------------------------------

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/Comments
25	26	7534.	16.	0.0	0.0	U-L	0.0	-.012	-32.	UI	0.000	0.	3.79	3.76	3.76	497.	79.	Upper Outer
26	27	7681.	16.	0.0	0.0	U-L	0.0	-.007	22.	UI	0.000	0.	3.80	3.78	3.79	498.	84.	UI non-lead end 13C - 13D
27	28	7818.	16.	0.0	0.0	U-L	0.0	-.004	23.	LI	0.000	0.	3.79	3.76	3.76	494.	82.	Same as 1
28	29	7823.	16.	0.0	0.0	U-L	0.0	-.004	22.	LI	0.000	0.	3.80	3.77	3.76	498.	81.	Same as 10
29	30	7823.	16.	0.0	0.0	U-L	0.0	-.004	23.	LI	0.000	0.	3.79	3.76	3.76	494.	80.	Same as 1
30	31	7828.	16.	0.0	0.0	U-L	0.0	-.004	23.	LI	0.000	0.	3.80	3.77	3.76	497.	79.	Same as 1
31	32	7837.	16.	0.0	0.0	U-L	0.0	-.004	23.	LI	0.000	0.	3.80	3.77	3.76	499.	83.	Same as 1
32	33	7832.	16.	0.0	0.0	U-L	0.0	-.004	25.	LI	0.000	0.	3.81	3.78	3.77	503.	85.	Same as 1
	34	6383.	16.	0.0	0.0	Cu L	0.0	0.000	0.	LI	0.000	0.	3.81	3.78	3.78	504.	91.	Lead Quench

------------------------------------Heater Studies 4.2 K------------------------------------

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/Comments
	35	1996.	0.	0.0	0.0	U-L	0.0	0.000	-8.	LI	0.000	0.	4.20	4.17	4.16	754.	80.	Heater Studies
	36	1007.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	LI	0.000	0.	4.21	4.17	4.16	755.	73.	Heater Studies
	37	1996.	0.	0.0	0.0	U-L	0.0	-.130	-11.	LI	0.000	0.	4.21	4.17	4.16	755.	70.	Heater Studies
	38	1996.	0.	0.0	0.0	U-L	0.0	-.100	-11.	LI	0.000	0.	4.21	4.17	4.16	756.	71.	Heater Studies
	39	1996.	0.	0.0	0.0	U-L	0.0	-.070	-11.	LI	0.000	0.	4.21	4.17	4.16	757.	80.	Heater Studies
	40	1996.	0.	0.0	0.0	U-L	0.0	-.055	-12.	LI	0.000	0.	4.21	4.17	4.16	756.	77.	Heater Studies
	41	4013.	0.	0.0	0.0	U-L	0.0	-.030	-23.	UI	0.000	0.	4.21	4.17	4.16	757.	73.	Heater Studies
	42	6491.	0.	0.0	0.0	U-L	0.0	-.010	-32.	UI	0.000	0.	4.21	4.17	4.16	757.	73.	Heater Studies
	43	4013.	0.	0.0	0.0	U-L	0.0	-.015	-23.	LI	0.000	0.	4.21	4.17	4.16	758.	72.	Heater Studies
	44	6476.	0.	0.0	0.0	U-L	0.0	-.005	-32.	UI	0.000	0.	4.21	4.17	4.16	757.	80.	Heater Studies
	45	1996.	0.	0.0	0.0	U-L	0.0	-.105	-12.	LI	0.000	0.	4.21	4.17	4.16	757.	74.	Heater Studies
	46	4008.	0.	0.0	0.0	U-L	0.0	-.035	-23.	LI	0.000	0.	4.21	4.17	4.16	757.	80.	Heater Studies

	47	6471.	0.	0.0	0.0	U-L	0.0	-.010	-32.	UI	0.000	0.	4.21	4.17	4.16	757.	78.	Heater Studies
	48	1007.	0.	0.0	0.0	U-L	0.0	0.000	-6.	LI	0.000	0.	4.35	4.31	4.30	861.	78.	1000 amp dump
	49	1007.	0.	0.0	0.0	U-L	0.0	0.000	-6.	LI	0.000	0.	4.36	4.31	4.30	860.	78.	1000 amp dump

--------------------------Thermal Cycle 4.3 K--------------------------

33	50	7122.	16.	0.0	0.0	U-L	0.0	-.008	20.	LI	0.000	0.	4.36	4.31	4.30	867.	90.	Same as 1
34	51	7108.	16.	0.0	0.0	U-L	0.0	-.008	-19.	LI	0.000	0.	4.35	4.31	4.29	863.	85.	Same as 1
35	52	7147.	16.	0.0	0.0	U-L	0.0	-.008	-19.	LI	0.000	0.	4.34	4.30	4.28	861.	85.	Same as 1
36	53	7152.	16.	0.0	0.0	U-L	0.0	-.008	-18.	LI	0.000	0.	4.36	4.32	4.30	861.	90.	Same as 1
37	54	7147.	16.	0.0	0.0	U-L	0.0	-.008	-19.	LI	0.000	0.	4.35	4.31	4.29	857.	86.	Same as 1
38	55	7113.	16.	0.0	0.0	U-L	0.0	-.008	-19.	LI	0.000	0.	4.35	4.30	4.29	875.	82.	Same as 1
39	56	7152.	16.	0.0	0.0	U-L	0.0	-.009	-18.	LI	0.000	0.	4.35	4.30	4.29	870.	80.	Same as 1

-----------------------------4.2 K-----------------------------

40	57	7372.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.20	4.16	4.15	742.	84.	Same as 1
41	58	7372.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.19	4.15	4.14	737.	83.	Same as 1
42	59	7367.	16.	0.0	0.0	U-L	0.0	-.008	19.	LI	0.000	0.	4.19	4.15	4.15	737.	85.	Same as 1
43	60	7362.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.20	4.16	4.15	741.	75.	Same as 1
44	61	7348.	16.	0.0	0.0	U-L	0.0	-.008	23.	LI	0.000	0.	4.19	4.15	4.14	745.	77.	Same as 1

------------------------------------Heater Studies 4.2 K------------------------------------

	62	1996.	0.	0.0	0.0	U-L	0.0	-.110	-12.	UI	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	63	1991.	0.	0.0	0.0	U-L	0.0	-.105	-10.	LI	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	64	1991.	0.	0.0	0.0	U-L	0.0	-.110	-1.	UI	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	65	1996.	0.	0.0	0.0	U-L	0.0	-.050	-1.	UI	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	66	4004.	0.	0.0	0.0	U-L	0.0	-.010	13.	UO	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	67	4004.	0.	0.0	0.0	U-L	0.0	-.030	13.	UO	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	68	6466.	0.	0.0	0.0	U-L	0.0	-.005	34.	UO	0.000	0.	4.23	4.19	4.19	763.	79.	Heater Studies
	69	6466.	0.	0.0	0.0	U-L	0.0	-.010	34.	UO	0.000	0.	4.22	4.18	4.17	762.	70.	Heater Studies
	70	6462.	0.	0.0	0.0	U-L	0.0	-.005	34.	UO	0.000	0.	4.22	4.18	4.17	762.	70.	Heater Studies
	71	1991.	0.	0.0	0.0	U-L	0.0	-.065	-1.	UI	0.000	0.	4.21	4.17	4.16	753.	60.	Heater Studies
	72	4004.	0.	0.0	0.0	U-L	0.0	-.020	13.	UO	0.000	0.	4.21	4.17	4.16	756.	64.	Heater Studies
	73	1991.	0.	0.0	0.0	U-L	0.0	-.060	-1.	UO	0.000	0.	4.21	4.17	4.16	749.	79.	Heater Studies
	74	1996.	0.	0.0	0.0	U-L	0.0	-.035	-1.	UI	0.000	0.	4.21	4.17	4.16	750.	81.	Heater Studies
	75	1996.	0.	0.0	0.0	U-L	0.0	-.020	-1.	UI	0.000	0.	4.21	4.17	4.16	749.	85.	Heater Studies
	76	1996.	0.	0.0	0.0	U-L	0.0	-.040	-1.	UI	0.000	0.	4.21	4.16	4.16	749.	83.	Heater Studies

----- 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

Distribution

R. Bossert
S. Delchamps
A. Devred
W. Koska
M. Lamm
P. Mantsch
G. Pewitt
J. Strait
J. Tompkins
M. Wake