TS-SSC 91-053
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March 21, 1991

Summary of DS0315 Quench Performance

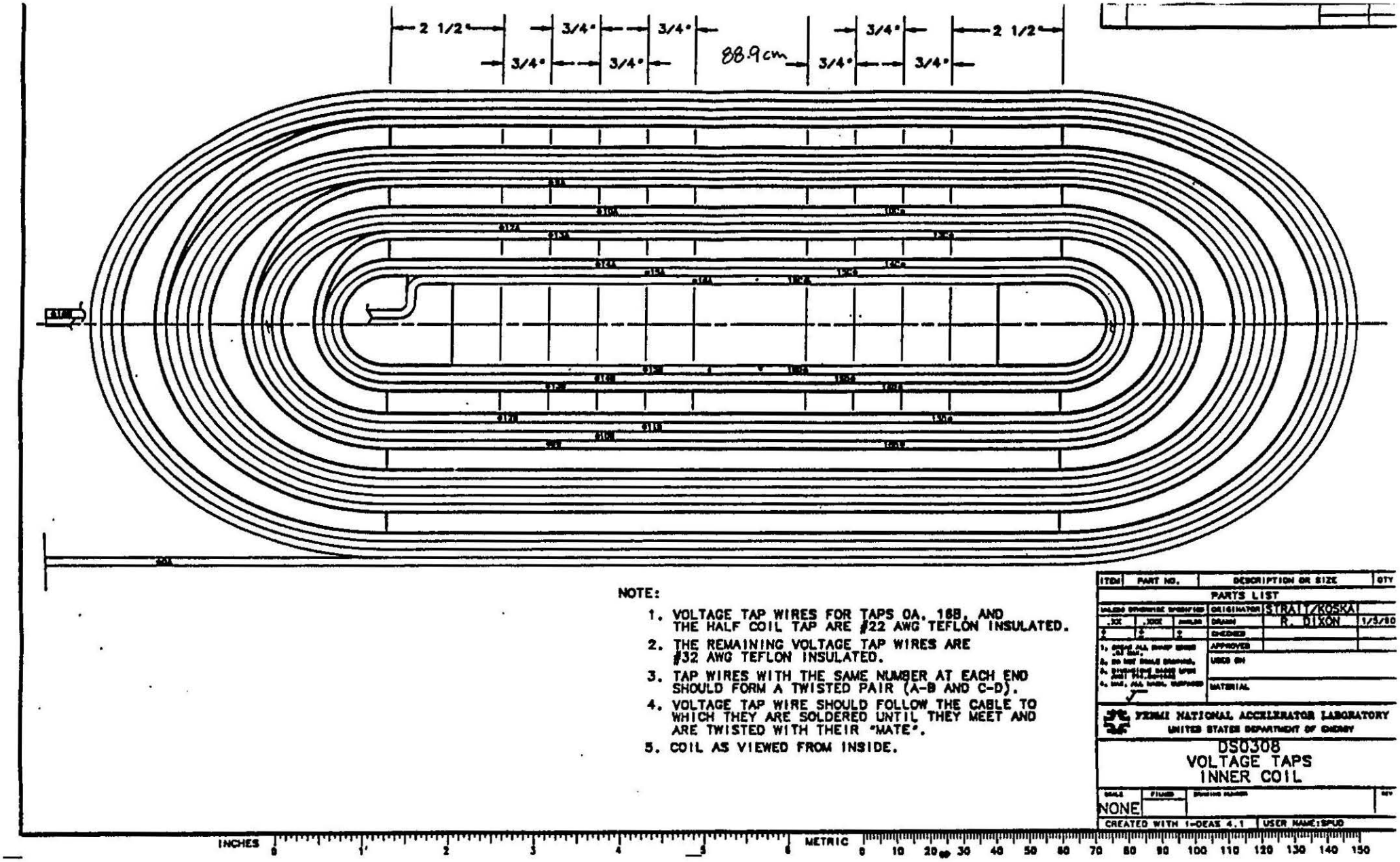
DS0315 is a 1m Fermilab SSC model magnet with a 40mm aperture. It has the following features:

- Aluminum End Cans
- Molded Stycast End Insulators
- Vertical Yoke

During the course of testing it was quenched a total of 42 times which included one thermal cycle, at temperatures of 4.3, 4.2 and 3.8K. An extensive set of heater studies was also 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 73 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.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY

PARTS LIST

ORIGINATOR	STRAIT/KOSKA	
DRAWN	R. DIXON	1/5/80
CHECKED		
APPROVED		
USED ON		
MATERIAL		

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

INCHES 0 1 2 3 4 5 6

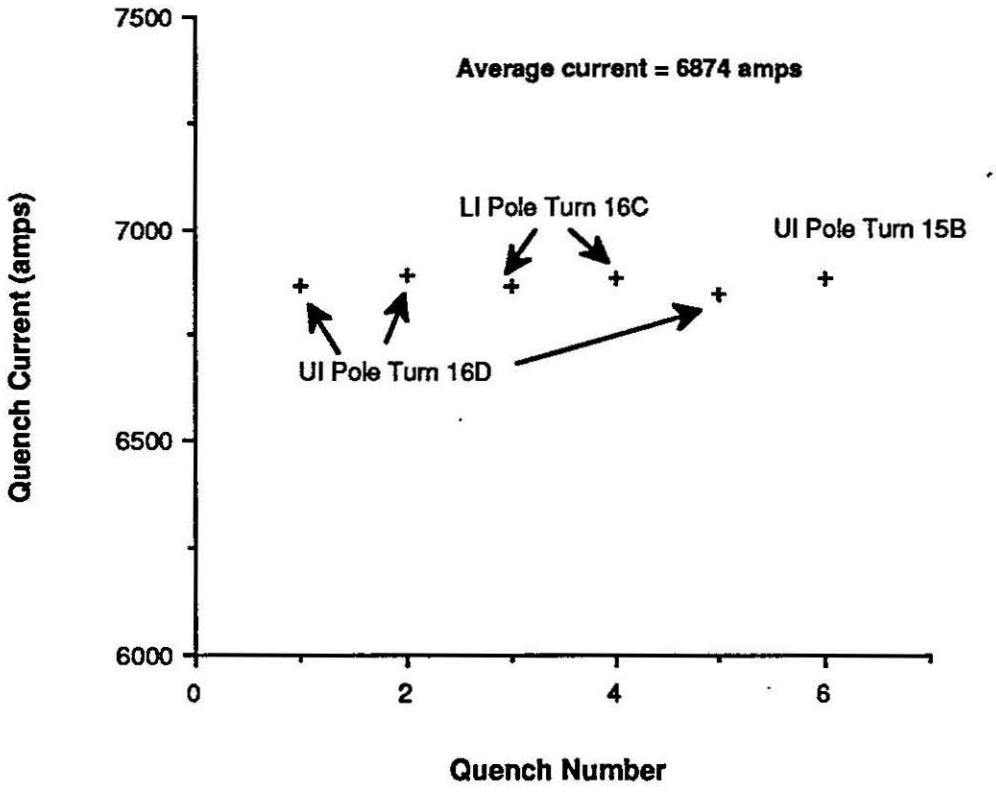
METRIC 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

Figure 1

Training Quenches

This magnet had no apparent training quenches. The first quench and several subsequent plateau quenches occured in the upper inner pole turn about +5.5ms from tap 16D. The quench behavior was unusual because of the variety of quench locations within both the upper and inner pole turns. An interesting feature of the quench locations is that a predominant number of quenches occured toward the center of the magnet within approximately 5ms of the pole turn taps. These positions coincide within errors with the ends of the gage collar pack. Evidence for this effect can also be seen in DS0311 and 313. The quench currents and locations are shown in Fig. 2 for the initial 4.3K studies at 16 amps/s.

Fig. 2 DS0315 Training Behavior



Ramp Rate Studies

The magnet was then quenched at a series of ramp rates ranging from the nominal 16 amps/s to 300 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. This magnet shows much less ramp rate dependence than previous magnets with a plateau that extends out to 175 amps/s. Another unusual feature of this magnet is that the ramp rate dependent quenches occured in the upper outer coil well away from the ramp splice. Fig. 4 compares the ramp rate dependence of DS0311 and DS0315. Each of these magnets used the same conductor but have significantly different ramp rate behavior.

Fig.3 DS0315 Ramp Rate Dependence

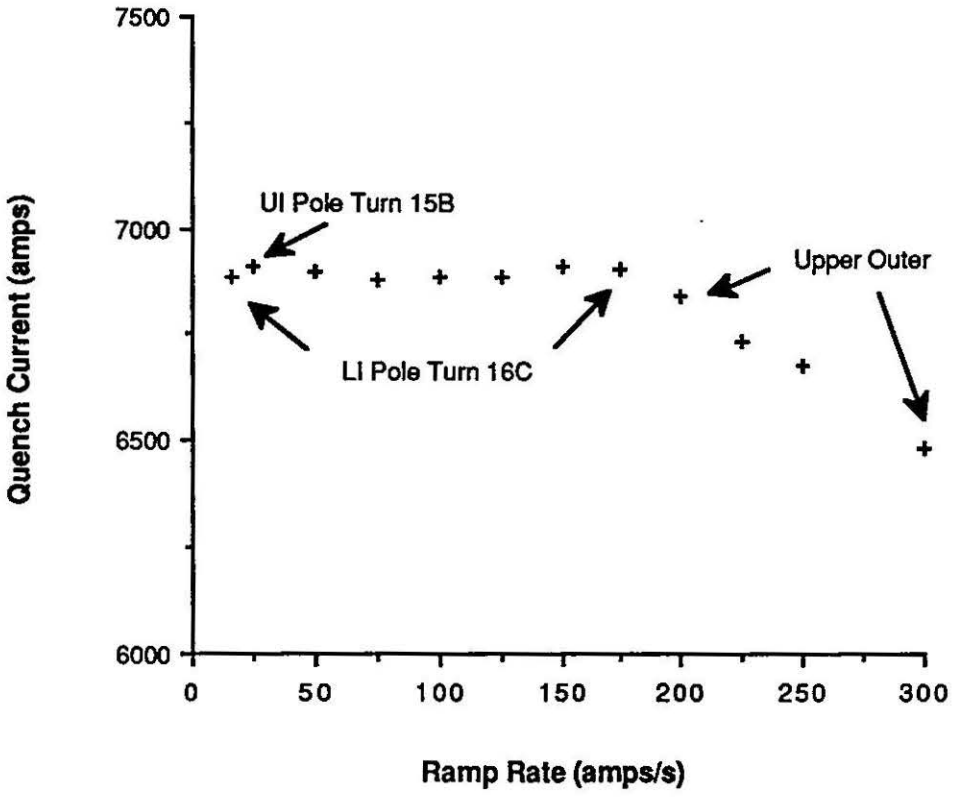
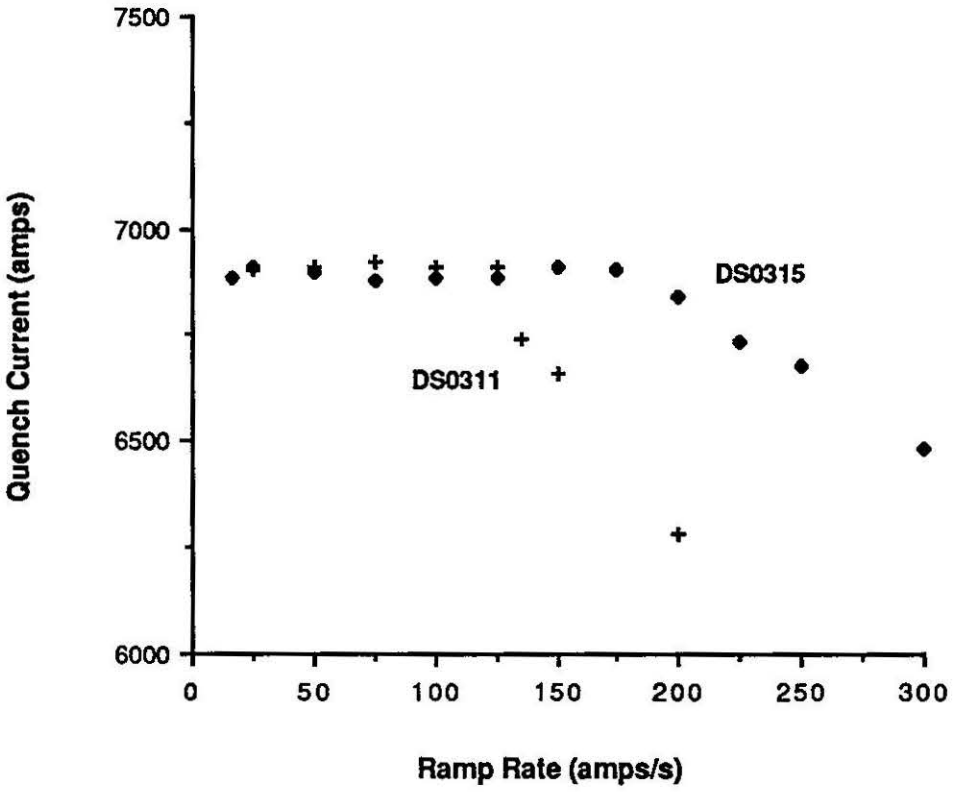


Fig. 4 DS0315 and DS0311 Ramp Rate Comparison



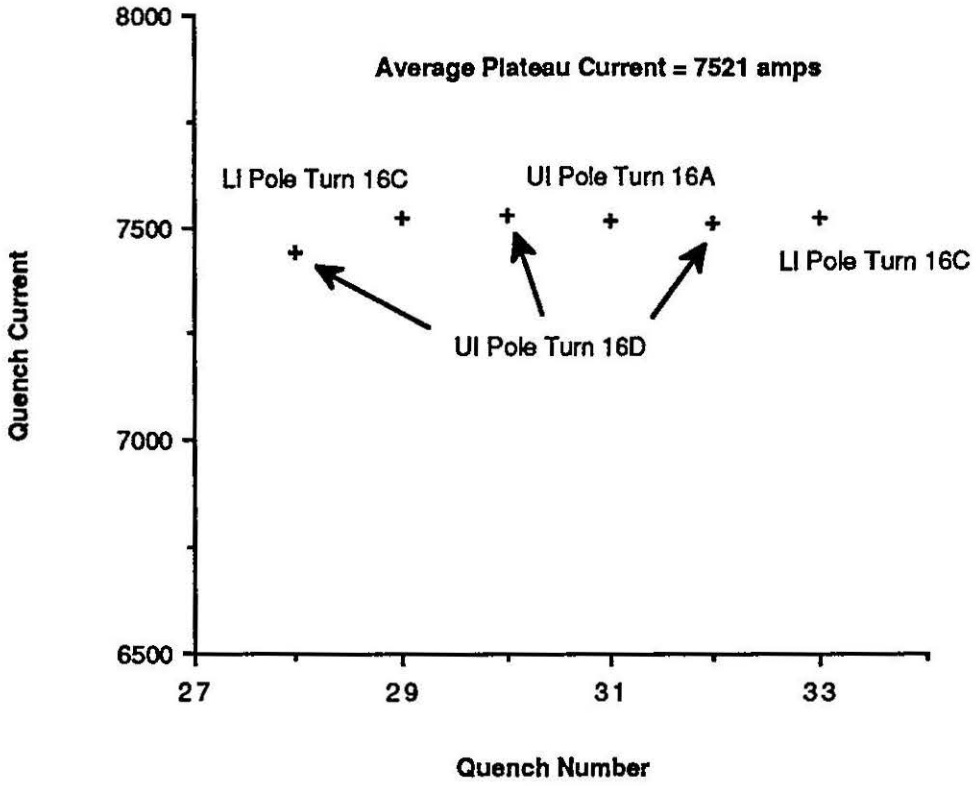
4.2K Studies

The magnet temperature was lowered to approximately 4.2K and quenched at a ramp rate of 16 amps/s. The first quench was at 7054 amps in the same location as the first 4.3K quench. The subsequent 4 quenches at 4.2K and 16 amps/s averaged 7067 amps at various pole turn locations.

3.8K Studies

The magnet temperature was then lowered further to 3.8K. The magnet exhibited 1 training quench at 7441 amps in the same location as the first 4.3K and 4.2K quenches before reaching a plateau of 7521 amps. The succeeding quenches again occured in various pole turn locations. The quench data are plotted in Figure 5.

Fig.5 3.8 K Training Behavior



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 4 times at 4.3K with an average quench current of 6884 amps. It exhibited no retraining. All quenches were located in the upper inner pole turn +5.5ms from tap 16D.

4.2K Studies

The quench studies were concluded by quenching the magnet 5 times at 4.2K. The quenches occured in three different locations in the upper inner pole turn with an average current of 7079 amps. The magnet tests were concluded by a set of heater studies and a final spontaneous quench at 4.2K and 16 amps/s was at 7059 amps.

Quench Performance

The cable used to wind the inner coils was from reel SC12-00004 which, as already mentioned, was the same reel as used for DS0311. The ultimate quench performance of the two magnets agrees very well (to within a few tenths of a percent). 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 plateau quenches 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 SC12-00004.

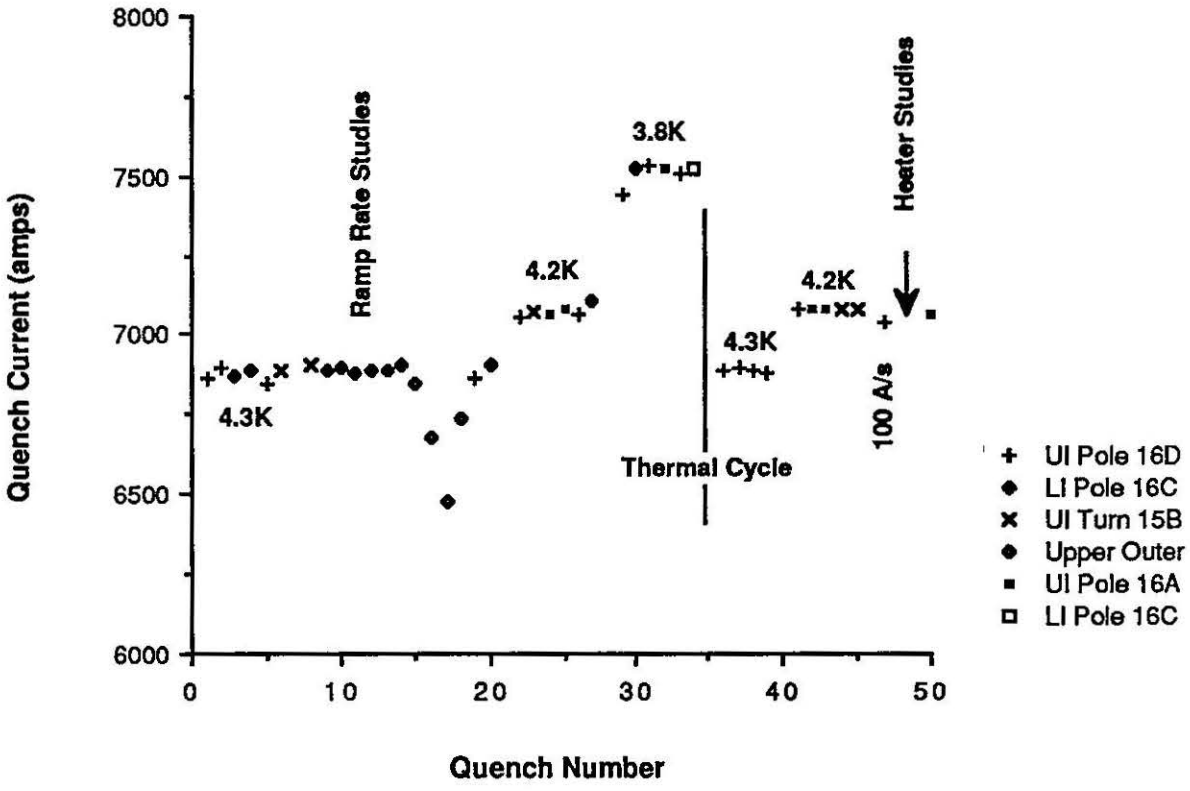
B (Tesla)	Ic (amps)	Jc (A/mm^2)
5.0	11,628	2,458
5.6	10,269	2,170
6.0	9,362	1,979
7.0	7,097	1,500

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

Temperature	Measured Iq	Measured Iq thermal cycle	Predicted Iq Morgan-Sampson	Predicted Iq Green
4.3 K	6874 amps	6884 amps	6685 amps	7004 amps
4.2 K	7065	7079	6782	7120
3.8 K	7521		7137	7571

The quench history of DS0315 is summarized in Figure 6.

Fig. 6 DS0315 Quench Summary



Quench File Summary
DS0315

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	1012.	0.	0.0	0.0	SC L	0.0	0.000	-6.	LI	0.000	0.	4.37	4.33	4.32	865.	92.	
	1	1017.	0.	0.0	0.0	U-L	0.0	0.000	-6.	LI	0.000	0.	4.35	4.29	4.28	878.	62.	
	2	5428.	0.	0.0	0.0	U-L	0.0	-.025	-22.	UI	0.000	0.	4.38	4.33	4.32	876.	96.	
----------4.3 K Studies----------																		
1	3	6863.	16.	0.0	0.0	U-L	0.0	-.007	21.	UI	0.000	0.	4.38	4.33	4.32	873.	88.	UI Pole Turn, Opposite Ramp Splice Side +5.5ms from 16D
2	4	6892.	16.	0.0	0.0	U-L	0.0	-.007	19.	UI	0.000	0.	4.36	4.31	4.30	856.	81.	Same as 1
3	5	6868.	16.	0.0	0.0	U-L	0.0	-.007	17.	LI	0.000	0.	4.36	4.31	4.31	855.	81.	LI Pole Turn, Ramp Splice Side +5.5ms from 16C
4	6	6887.	16.	0.0	0.0	U-L	0.0	-.007	18.	LI	0.000	0.	4.36	4.31	4.31	856.	82.	Same as 3
5	7	6848.	16.	0.0	0.0	U-L	0.0	-.007	19.	UI	0.000	0.	4.37	4.31	4.30	872.	84.	Same as 1
6	8	6887.	16.	0.0	0.0	U-L	0.0	-.008	19.	UI	0.000	0.	4.37	4.32	4.31	871.	86.	UI Pole Turn, Opposite Ramp Splice Side -4.8ms from 15B
7	9	6907.	25.	0.0	0.0	U-L	0.0	-.008	19.	UI	0.000	0.	4.37	4.32	4.32	865.	82.	Same as 6
8	10	6883.	16.	0.0	0.0	U-L	0.0	-.007	17.	LI	0.000	0.	4.39	4.33	4.32	889.	97.	Same as 3
9	11	6897.	50.	0.0	0.0	U-L	0.0	-.007	21.	LI	0.000	0.	4.36	4.32	4.31	860.	95.	Same as 3
10	12	6878.	75.	0.0	0.0	U-L	0.0	-.007	22.	LI	0.000	0.	4.38	4.32	4.31	876.	100.	Same as 3
11	13	6887.	100.	0.0	0.0	U-L	0.0	-.007	21.	LI	0.000	0.	4.38	4.33	4.31	873.	97.	Same as 3
12	14	6883.	125.	0.0	0.0	U-L	0.0	-.007	21.	LI	0.000	0.	4.36	4.32	4.31	856.	94.	Same as 3
13	15	6907.	150.	0.0	0.0	U-L	0.0	-.007	20.	LI	0.000	0.	4.36	4.32	4.31	858.	90.	Same as 3
14	16	6843.	200.	0.0	0.0	U-L	0.0	-.013	-25.	UI	0.000	0.	4.37	4.33	4.31	860.	87.	UO -10ms from Ramp Splice
15	17	6877.	250.	0.0	0.0	U-L	0.0	-.014	-25.	UI	0.000	0.	4.36	4.30	4.29	871.	92.	UO -10 ms from Ramp Splice
16	18	6481.	300.	0.0	0.0	U-L	0.0	-.013	-25.	UI	0.000	0.	4.36	4.32	4.30	862.	86.	UO -15ms from Ramp Splice
17	19	6736.	225.	0.0	0.0	U-L	0.0	-.013	-25.	UI	0.000	0.	4.36	4.32	4.31	856.	81.	UO -14ms from Ramp Splice
18	20	6858.	16.	0.0	0.0	U-L	0.0	-.008	21.	UI	0.000	0.	4.36	4.32	4.31	860.	73.	Same as 1, Down Ramp Test
19	21	6902.	175.	0.0	0.0	U-L	0.0	-.007	20.	LI	0.000	0.	4.36	4.32	4.31	856.	68.	Same as 3
----------4.2 K Studies----------																		
20	22	7054.	16.	0.0	0.0	U-L	0.0	-.007	20.	UI	0.000	0.	4.21	4.16	4.15	763.	100.	Same as 1
21	23	7069.	16.	0.0	0.0	U-L	0.0	-.007	21.	UI	0.000	0.	4.21	4.17	4.16	748.	96.	Same as 6
22	24	7059.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.20	4.17	4.16	741.	86.	UI Pole Turn, Ramp Splice Side, -5ms from 16A
23	25	7078.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.20	4.17	4.16	743.	71.	Same as 22
24	26	7064.	16.	0.0	0.0	U-L	0.0	-.007	24.	UI	0.000	0.	4.22	4.17	4.16	750.	92.	Same as 1
25	27	7103.	100.	0.0	0.0	U-L	0.0	-.005	25.	LI	0.000	0.	4.21	4.17	4.16	744.	82.	Same as 3
----------3.8 K Studies----------																		
26	28	7441.	16.	0.0	0.0	U-L	0.0	-.005	25.	UI	0.000	0.	3.80	3.75	3.74	491.	98.	Same as 1
27	29	7524.	16.	0.0	0.0	U-L	0.0	-.004	26.	LI	0.000	0.	3.82	3.78	3.77	501.	100.	Same as 3
28	30	7529.	16.	0.0	0.0	U-L	0.0	-.007	23.	UI	0.000	0.	3.81	3.77	3.76	495.	98.	Same as 1
29	31	7519.	16.	0.0	0.0	U-L	0.0	-.007	20.	UI	0.000	0.	3.80	3.77	3.76	491.	96.	UI Pole Turn, Ramp Splice Side, +8ms from 16A
30	32	7509.	16.	0.0	0.0	U-L	0.0	-.007	23.	UI	0.000	0.	3.81	3.77	3.76	501.	100.	Same as 1
31	33	7524.	16.	0.0	0.0	U-L	0.0	-.004	27.	LI	0.000	0.	3.81	3.77	3.76	495.	100.	LI Pole Turn, Ramp Splice side, +4.3ms from 16C
----------Thermal Cycle 4.3 K Studies----------																		
	34	1012.	0.	0.0	0.0	V-dI	0.0	0.000	-6.	LI	0.000	0.	4.37	4.32	4.32	859.	86.	
32	35	6883.	16.	0.0	0.0	U-L	0.0	-.007	22.	UI	0.000	0.	4.38	4.33	4.32	870.	85.	Same as 1
33	36	6892.	16.	0.0	0.0	U-L	0.0	-.007	20.	UI	0.000	0.	4.37	4.32	4.31	854.	95.	Same as 1
34	37	6883.	16.	0.0	0.0	U-L	0.0	-.007	19.	UI	0.000	0.	4.38	4.32	4.31	866.	84.	Same as 1
	38	111.	0.	0.0	0.0	Vtot	0.0	-.002	2.	UO	0.000	0.	4.38	4.32	4.31	868.	74.	
35	39	6878.	16.	0.0	0.0	U-L	0.0	-.007	19.	UI	0.000	0.	4.36	4.31	4.31	853.	72.	Same as 1
----------4.2 K Studies----------																		
36	40	7078.	16.	0.0	0.0	U-L	0.0	-.008	21.	UI	0.000	0.	4.22	4.18	4.17	746.	100.	Same as 1

37	41	7078.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.22	4.18	4.17	746.	100.	Same as 22
38	42	7078.	16.	0.0	0.0	U-L	0.0	-.007	19.	LI	0.000	0.	4.22	4.17	4.16	745.	71.	Same as 22
39	43	7078.	16.	0.0	0.0	U-L	0.0	-.007	22.	UI	0.000	0.	4.22	4.17	4.16	746.	67.	Same as 6
40	44	7083.	16.	0.0	0.0	U-L	0.0	-.007	22.	UI	0.000	0.	4.22	4.18	4.17	746.	72.	Same as 6
41	45	7034.	100.	0.0	0.0	U-L	0.0	-.005	23.	UI	0.000	0.	4.22	4.17	4.16	745.	93.	Upper Inner Pole Turn, Opposite Ramp Splice, +4.8ms from 16D

----------Heater Studies----------

	46	189.	-200.	0.0	0.0	V-dI	0.0	0.000	-1.	LI	0.000	0.	4.22	4.17	4.16	0.	85.	
	47	2001.	0.	0.0	0.0	U-L	0.0	-.104	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	80.	
	48	2001.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	77.	
	49	2001.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	84.	
	50	1996.	0.	0.0	0.0	V-dI	0.0	-.238	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	74.	
	51	1996.	0.	0.0	0.0	V-dI	0.0	-.234	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	83.	
	52	2001.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	75.	
	53	2001.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	85.	
	54	1991.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	83.	
	55	1996.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	76.	
	56	1991.	0.	0.0	0.0	V-dI	0.0	-.240	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	85.	
	57	1991.	0.	0.0	0.0	V-dI	0.0	0.000	-12.	LI	0.000	0.	4.22	4.17	4.16	0.	79.	
	58	1991.	0.	0.0	0.0	V-dI	0.0	-.025	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	77.	
	59	1991.	0.	0.0	0.0	V-dI	0.0	-.025	-12.	LI	0.000	0.	4.23	4.19	4.18	0.	86.	
	60	1996.	0.	0.0	0.0	V-dI	0.0	-.005	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	84.	
	61	1996.	0.	0.0	0.0	V-dI	0.0	-.030	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	85.	
	62	1996.	0.	0.0	0.0	V-dI	0.0	-.015	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	83.	
	63	1996.	0.	0.0	0.0	V-dI	0.0	-.020	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	78.	
	64	4513.	0.	0.0	0.0	V-dI	0.0	-.060	-28.	LI	0.000	0.	4.23	4.18	4.17	0.	78.	
	65	4513.	0.	0.0	0.0	V-dI	0.0	-.115	-27.	LI	0.000	0.	4.23	4.18	4.17	0.	77.	
	66	4513.	0.	0.0	0.0	V-dI	0.0	-.090	-27.	LI	0.000	0.	4.23	4.18	4.17	0.	77.	
	67	6491.	0.	0.0	0.0	U-L	0.0	-.020	-30.	LI	0.000	0.	4.27	4.19	4.18	0.	80.	
	68	6481.	0.	0.0	0.0	V-dI	0.0	-.070	-28.	LI	0.000	0.	4.28	4.25	4.18	0.	74.	
	69	6486.	0.	0.0	0.0	U-L	0.0	-.050	-29.	LI	0.000	0.	4.23	4.18	4.18	0.	74.	
	70	3.	0.	0.0	0.0	V-dI	0.0	0.000	1.	UO	0.000	0.	4.23	4.18	4.18	0.	74.	
	71	3.	0.	0.0	0.0	V-dI	0.0	0.000	0.	UO	0.000	0.	4.23	4.18	4.17	0.	85.	
	72	2001.	0.	0.0	0.0	V-dI	0.0	-.215	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	81.	
	73	2001.	0.	0.0	0.0	V-dI	0.0	-.195	-12.	LI	0.000	0.	4.23	4.18	4.17	0.	76.	
42	74	7059.	16.	0.0	0.0	U-L	0.0	-.010	21.	UI	0.000	0.	4.23	4.18	4.17	0.	77.	Same as 29

----- 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

Distribution:

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