"Unusual" Quench Behavior of DSA323

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As reported by Steve Delchamps at the MSIM on 5/14, DSA323 has displayed some unusual quench behavior -- quenching on the down ramp after exceeding 7000 A one or more times without quenching. We have done a number of tests varying the ramp rate, peak and minimum current, and dwell time at the peak current of sawtooth ramp cycles and compared the performance with the warm bore tube both cold and warm. There is no pattern in the results that are obvious to me. I give below a chronology of the behavior of the magnet in the hope that someone else may see a pattern or may suggest some further tests that might shed light on the cause of these quenches. (Tariq Jaffery and Dyrrell Lewis provided me with much of the information for the chronology below.)

DSA323 began to behave in an odd manner on 5/7 near the end of the tests on its second cooldown. It quenched at about 4100+-50 A on the down ramp after 1 to 3 cycles to >7300 A at 16 A/sec. Four such quenches occurred and all four originated at the return end of the lower inner coil pole turn. The ramp cycles were done to "scramble" the persistenc currents in advance of some remnant measurements. The warm bore was at room temperature and the Rawson probe was pulled out of the magnet but was partially inserted into the warm bore tube. Following this the Lab 2 folks "floated" the magnet until 5/10.

On 5/10, after the magnet had warmed to 40-50 K, the magnet was recooled and we did a 1000 A manual trip to check coil inductances to look for evidence of a turn-to-turn short. There was no evidence of short: the upper and lower inner coil inductances match each other to better than 0.1%; the upper and lower outer coils (where the quenches weren't) showed an apparent inductance difference of a few tenths of a percent, but the same (to better than 0.1%) apparent difference existed on the first 1000 A trip (file 0) and presumably reflects a small gain "error" in one of the amplifiers; the overall coil inductance matched that of the first 1000 A trip to about 0.15%, which I am confident is within the measurement accuracy.

We then tried tried to repeat the ramp cycles to 7400 A but with the warm bore evaucated. The magnet now quenched on the first up ramp three times at currents of 7123 A, 7294 A and 6559 A. The first was in the lower outer coil and the second two were in the uninstrumented portion of the lower inner coil, probably in turn 13.

Dyrrell Lewis suggested that we warm the magnet to room temperature and then re-cool it and try again. His argument was based on the fact that the first set of strange behavior occurred after the magnet had floated over the weekend and then things got worse after the magnet was floated for another three days. He reminded me that there was a low beta quad that showed degraded performance after a low temperature run followed by partial warming over the weekend. It was "fixed" by doing a full thermal cycle. It was conjectured at the time that there was a dewar leak which allowed air to be pulled into the dewar during the low temperature run and freeze somewhere in the baffles above the magnet. When the magnet was partially warmed the air thawed, dripped onto the magnet and re-froze. The thermal cycle dried the magnet and restored it to its initial condition.

A complete thermal cycle was done over the weekend of 5/10-13. After the magnet was recooled it was quenched twice at 4.35 K at currents of 7390 and 7430 A. The second is at the previously established plateau current and the

first is apparently about 40 A below plateau. A strain gauge run was done on the way to the first quench. Both quenches were in the straight section of the upper inner pole turn. The warm bore tube was let up to air and a series of four cycles between 2000 A and 6000 A at 25 A/sec was done without quenching.

On 5/15 an attempt was made to do the remnant field studies that were aborted on the previous cooldown. With the warm bore evaucated a series of four sawtooth ramps were attempted between 0 and 7200 A at 16 A/sec with a 60 sec dwell at 7200 A and no dwell at 0. The magnet quenched at 3600 A on fourth down ramp; the quench originated in the return end of the lower inner pole turn, as on the previous cooldown. The magnet was then ramped to quench at 25 A/sec and reached 7435 A, the plateau current. Two more sawtooth ramps between 0 and 7200 A at 16 A/sec with a 60 sec flattop were done without quenching.

On 5/16 four sawtooth ramps were attempted between 0 and 7000 A at 25 A/sec with a 180 sec flattop. The magnet quenched at 3405 A on the fourth downramp. The procedure was repeated and this time the quench occurred at 3235 A on the third down ramp.

On 5/17, with the warm bore tube at room temperature, six sawtooth ramps were done between 2000 and 6000 A at 16 A/sec without quenching. The magnet was then ramped up to 7200 A at 25 A/sec, held at the peak current for 45 minutes, and ramped down at 25 A/sec; it quenched at 3580 A on the down ramp. The warm bore was evauated and the same ramp cycle was repeated without quenching. This was repeated with the flattop reduced to 60 sec and the magnet quenched on the down ramp at 3365 A. Sawtooths 25-7025 A at 200 A/sec with a 60 sec flattop were done and the magnet quenced at 2855 A on the fourth down ramp. The down ramp rate was reduced to 6 A/sec (up at 200 A/sec) and 3 cycles were completed without quenching.

No further studies of this odd behavior have been done. In the course of doing a strain gauge run and magnetic field measurements the magnet has been quenched once at 4.35 K (7400 A) and three times at 4.2 K (7660+-20 A).

The quench summary table for the period of time discussed here is attached.

Quench File Summary
DSA323
Second Cooldown

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
34	108	7627.	16.	0.0	0.0	U-L	0.0	-.012	-29.	UI	0.000	0.	4.21	4.16	4.15	715.	66.	IU19SL
35	109	4150.	-16.	0.0	0.0	U-L	0.0	-.154	-23.	LI	0.000	0.	4.22	4.17	4.16	723.	80.	IL19 Return End
36	110	4082.	-16.	0.0	0.0	U-L	0.0	-.162	-23.	LI	0.000	0.	4.22	4.17	4.16	723.	76.	IL19 Return End
37	111	4062.	-16.	0.0	0.0	U-L	0.0	-.161	-23.	LI	0.000	0.	4.22	4.17	4.17	723.	81.	IL19 Return End
38	112	4077.	-16.	0.0	0.0	U-L	0.0	-.161	-23.	LI	0.000	0.	4.22	4.17	4.16	723.	80.	IL19 Return End
	113	1007.	0.	0.0	0.0	U-L	0.0	0.000	-6.	UI	0.000	0.	4.22	4.17	4.17	725.	72.	
39	114	7122.	16.	0.0	0.0	U-L	0.0	-.026	-34.	LI	0.000	0.	4.22	4.17	4.16	724.	82.	Lower Outer
40	115	7294.	16.	0.0	0.0	U-L	0.0	-.014	-26.	LI	0.000	0.	4.22	4.17	4.16	724.	80.	IL13, 17ms from 13A
41	116	6559.	16.	0.0	0.0	U-L	0.0	-.034	-29.	LI	0.000	0.	4.22	4.17	4.16	724.	79.	IL0-13

Third Cooldown

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
	117	1007.	0.	0.0	0.0	U-L	0.0	0.000	-6.	UI	0.000	0.	4.40	4.35	4.34	852.	73.	
42	118	7392.	16.	0.0	0.0	U-L	0.0	-.013	-31.	UI	0.000	0.	4.42	4.37	4.36	868.	70.	IU19SL
43	119	7426.	16.	0.0	0.0	U-L	0.0	-.014	-31.	UI	0.000	0.	4.42	4.36	4.35	862.	82.	IU19SL
44	120	3597.	-16.	0.0	0.0	U-L	0.0	-.067	-20.	LI	0.000	0.	4.45	4.38	4.37	887.	71.	IL19 Return End
45	121	7436.	25.	0.0	0.0	U-L	0.0	-.013	-31.	UI	0.000	0.	4.42	4.36	4.36	865.	81.	IU19SL
46	122	3406.	0.	0.0	0.0	U-L	0.0	-.086	-19.	LI	0.000	0.	4.42	4.36	4.35	867.	83.	IL19 Return End
47	123	3235.	-25.	0.0	0.0	U-L	0.0	-.109	-18.	LI	0.000	0.	4.41	4.35	4.35	860.	84.	IL19 Return End
48	124	3578.	-25.	0.0	0.0	U-L	0.0	-.067	-20.	LI	0.000	0.	4.41	4.35	4.34	854.	69.	IL19 Return End
49	125	3367.	-25.	0.0	0.0	U-L	0.0	-.093	-19.	LI	0.000	0.	4.40	4.34	4.33	853.	83.	IL19 Return End
50	126	2853.	-200.	0.0	0.0	U-L	0.0	-.094	-16.	LI	0.000	0.	4.41	4.35	4.34	859.	83.	
51	127	7402.	16.	0.0	0.0	U-L	0.0	-.014	-30.	UI	0.000	0.	4.41	4.35	4.34	863.	90.	
52	128	7661.	16.	0.0	0.0	U-L	0.0	-.012	-31.	UI	0.000	0.	4.22	4.17	4.17	720.	81.	
	129	6457.	16.	0.0	0.0	Vtot	0.0	0.000	-37.	UI	0.000	0.	4.23	4.18	4.17	720.	80.	
53	130	7676.	16.	0.0	0.0	U-L	0.0	-.013	-31.	UI	0.000	0.	4.22	4.17	4.17	720.	83.	
54	131	7642.	16.	0.0	0.0	U-L	0.0	-.014	-31.	UI	0.000	0.	4.22	4.17	4.16	720.	80.	

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 4) Vtot Magnet
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