TS-SSC-92-025
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DSA328 Quench Protection Heater Test Results _I

There are eight heaters in DSA328, two in each quadrant for quench protection. The purpose of heater tests is to study the effect of insulation thickness between the coil and the heater and its effect on the energy required to produce a heater induced quench. Heaters in diametrically opposite quadrants have the same insulation scheme. That is, heaters in quadrants 1 and 3 are separated from the coil by one 5 mil kapton wrap and heaters in quadrants 2 and 4 with two 5 mil kapton wrap.
Two heater strips diametrically opposite to each other in quadrants 1 and 3 and quadrants 2 and 4 were fired together, at different magnet currents, using the same time constant but different strip voltage. Heaters were fired in different combinations without changing the capacitance of heater firing unit (HFU). The heaters were powered by a capacitor bank (referred to here as heater firing unit or HFU), whose time constant can be adjusted. Figure 1 shows the schematic for the heater circuit in DSA328.The results from DSA328 heater tests are given below. The notations below are the same as in my previous memo.

Rh	= heater resistance (in ohms)
R_system	= system resistance including one heater strip, (in ohms)
R_add	= resistance added to the system to achieve required RC (in ohms)
R_tot	= R_sys + R_add to achieve the required Tau, (in ohms)
v_hfu	= heater firing unit voltage (in volts). The voltage is chosen in each case to give the same energy deposition in the heater strip as in the case R_add = 0.
T_fn	= total time between heater firing and appearence of coil becoming normal (in milli seconds)
Iq	= magnet current (2 kA, 5 kA)
Edep	= energy (J) depositied in the strip heater

The heater system, including two 0.7 ohm heater strips, has a total resistance of 5.1 ohms, and 4.5 ohms with one heater strip in the circuit. A system schematic is attached. The heaters were fired, in different combinations, at two different magnet currents i.e. 2000 A and 5000 A. Following four sets of data for different heater configurations show the heater response time T_fn and the energy deposited Edep to each heater strip at different voltages. All the heater tests were conducted while the magnet was at 4.2 K, 1 atmosphere.

Earlier heater studies on DS0313 and DS0315 have shown that for a certain magnet current, the response time Tfn for SSC heaters reduced as the strip voltages were increased while depositing the same amount of energy each time, while keeping the RC of the circuit constant. See Fermilab SSC heater memo TS-SSC_91-056. DSA328 heater studies show that for a constant RC the response time is reduced and the energy deposited in the strip heater increases as Vhfu is increased.

For data set 2 (2A and 4A in series,two 5-mil kapton wrap) the response time T_fn, for a given Vhfu, at 2 kA is ~20 percent higher than T_fn at 5 kA. Similarly for data sets 1 (1B and 3B in series) and 3 the response time T_fn, for a given Vhfu, at 2 kA is ~40 and ~35 percent higher than T_fn at 5 kA, this is expected since all "B" heaters are located near the poles. In Figure 3 the response time (T_fn in msec) is plotted against the voltage of heater firing unit, needed to deposit the required energy into the heater strip.

Fgiure 2 shows the energy required to induce a quench as a function of response time. Inorder to achieve the same T_fn, at a given current, it requires roughly

100 percent more energy to quench the magnet with double insulation heaters than it does with single layer insulation heaters. The minimum energy required to quench the magnet, at 5 kA, with the heater combination of data set 1 and 3 is about 17.5 and 21.9 joules with 85 and 95 Vhfu respectively. Further tests will be conducted during the second cooldown.

There is an estimated 10 msec uncertainty in finding quench start (Tq) and a ~5 percent variation in heater voltages which translates to roughly 10 percent variation in energy deposition, which is well within the range of errors for this test.The differences in heater response time T_fn are consistent with measurement uncertainties.

DATA SET 1:
DSA328 Heaters 1B and 3B in series, were fired together, with one 5-mil kapton between the heater and the coil

R_tot =5.1 ohm; C =35 mF; Rh =.71 ohm;

Tfn (msec)	Imag (A)	VHFU (v)	Edep (joule)
110	2003.	175.	74.4
160	2003.	150.	54.6
210	2003.	135.	44.2
215	2003.	115.	32.1
220	2003.	125.	37.9
380	2003.	100.	24.2
NOTE: Imag=5000 A, heater did not fire below 85 Vhfu			
87	5003.	160.	62.1
115	5005.	130.	41.0
130	5006.	115.	32.1
170	5002.	107.	27.8
232	5004.	100.	24.3
342	5002.	85.	17.5 minimum energy required to quench the magnet

DATA SET 2:
DSA328 Heaters 2A and 4A in series, were fired together, with two 5-mil kapton between the heater and the coil

R_tot =5.1 ohm; C =35 mF; Rh =.71 ohm;

Tfn (msec)	Imag (A)	VHFU (v)	Edep (joule)
255	2002.	150.	54.6
195	2002.	205.	102.0
145	2002.	250.	151.7
140	2002.	280.	190.3
120	2002.	300.	218.5
(Imag=5000 A			
125	5004.	220.	117.5
165	5000.	180.	78.6
202	5004.	140.	47.6
366	5003.	105	26.8

DATA SET 3:
DSA328 Heaters 2B and 4B in series, with two 5-mil kapton between

the heater and the coil

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R_tot =5.1 ohm; C =35 mF; Rh =.71 ohm;

Tfn (msec)	Imag (A)	VHFU (v)	Edep (joule)
120	2003.	300.	218.5
155	2003.	240.	139.8
175	2002.	200.	97.1
205	2003.	175.	74.3
275	2003.	141.	48.3
450	2002.	110.	29.4

NOTE: Imag=5000 A, heater did not fire below 95 Vhfu

(Imag=5000 A

90	5004.	260.	164
107	5004.	220.	117
125	5000.	180.	78.6
135	5004.	160.	62.1
180	5000.	140.	47.6
373	5000.	105.	29.4
530	5005.	95.	21.9 minimum energy required to quench the magnet

DATA SET 4:

Individual heater test results

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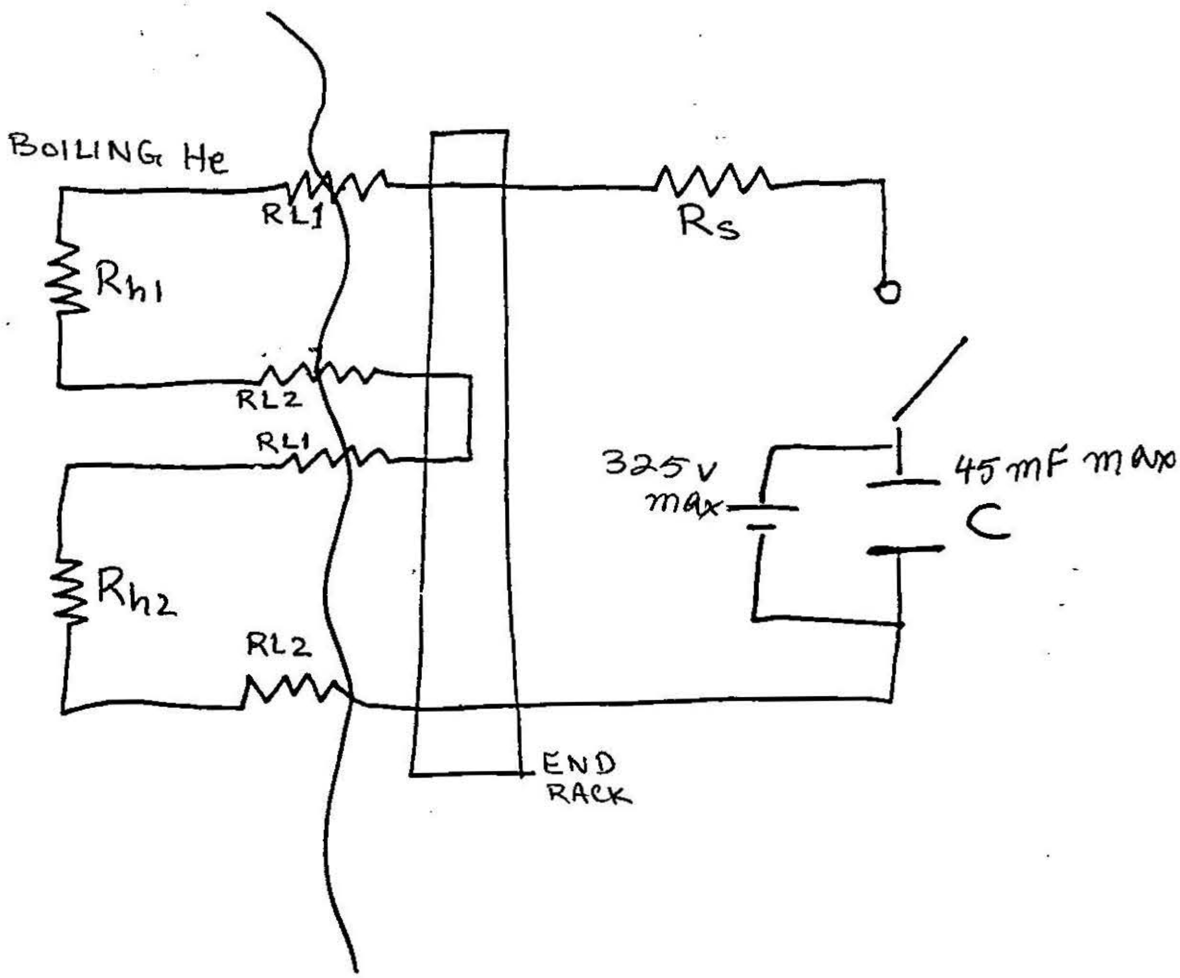
R_tot =4.5 ohm; C =35 mF; Rh =.71 ohm; Edep=110 joules

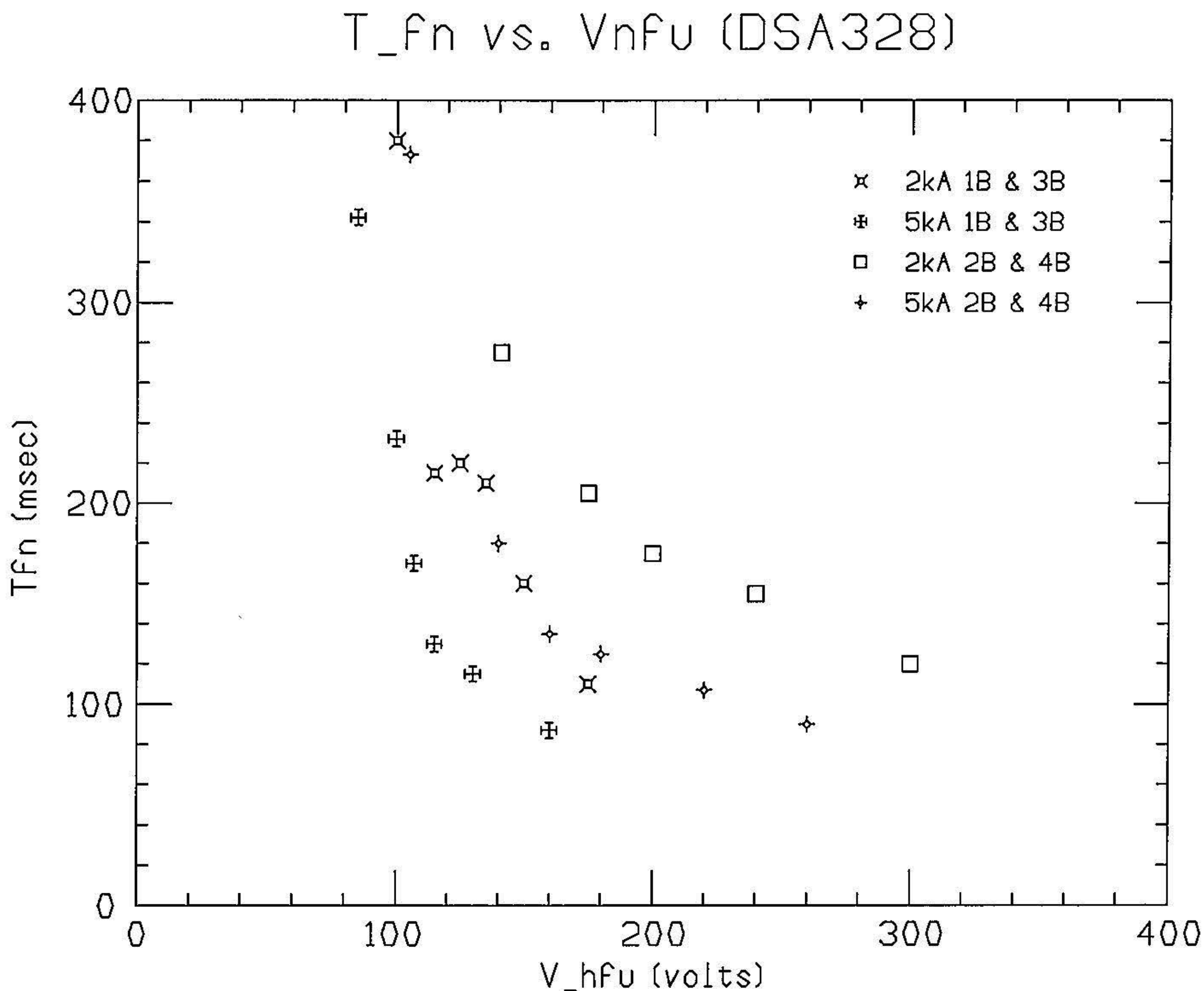
(Tfn (msec)	Imag (A)	VHFU (v)	T_hfu (joule)	Tq	Heater
150	2002	200	230	80	;2B
150	2002	200	240	90	;4B
145	2002	200	265	120	;2A
150	2002	200	270	120	;4A
90	2002	200	165	75	;1B
90	2002	200	175	85	;3B
90	2002	200	200	110	;1A

SYSTEM DIAGRAM FOR HEATER TESTS



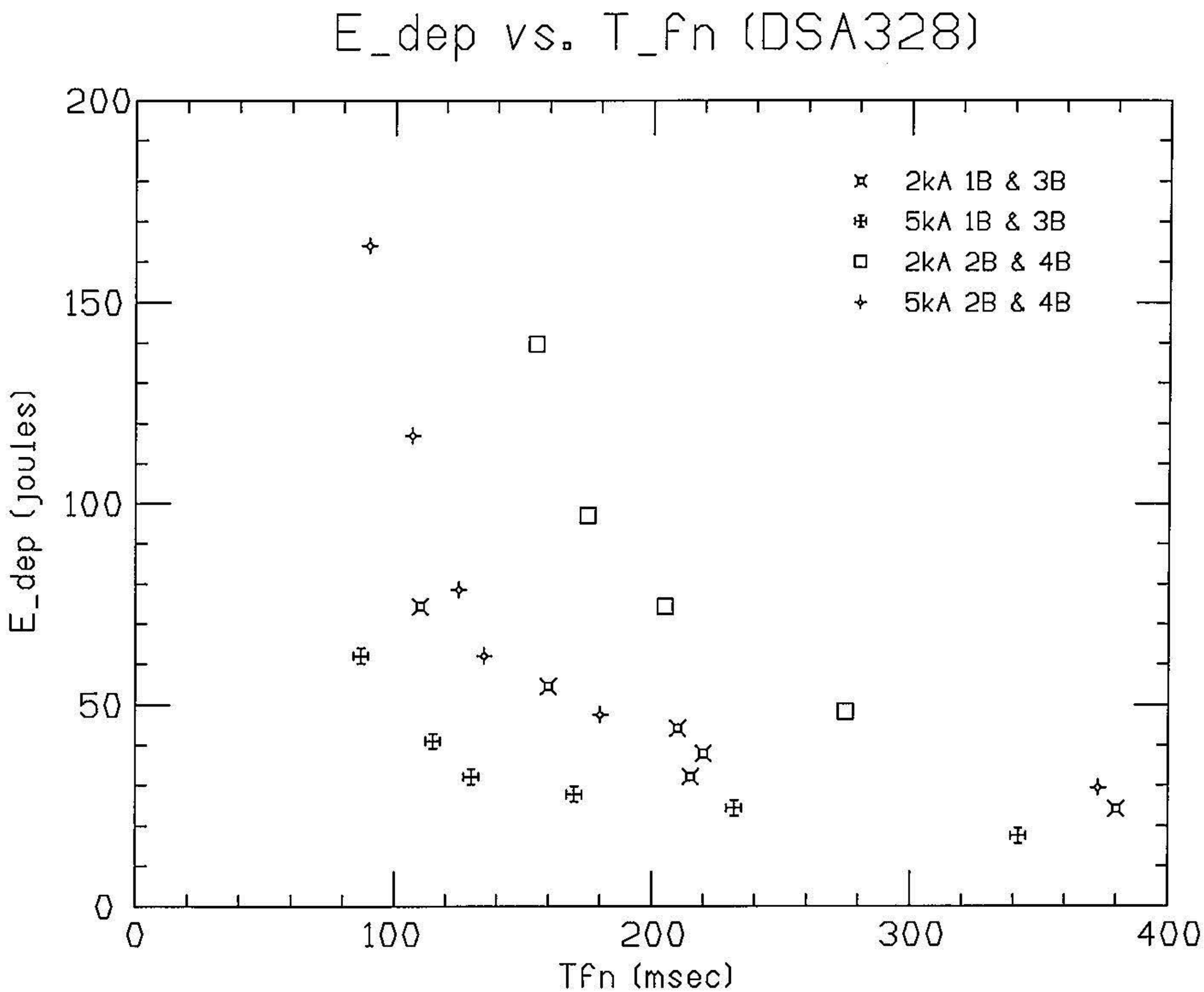
Rh = Heater resistance @ 4.2 K
C = Heater firing unit capacitance
Rl1 + Rl2 = Lead resistance
Rs = Shunt resistor

FIGURE 1



T_fn vs. Vnfu (DSA328)
2kA 1B & 3B
5kA 1B & 3B
2kA 2B & 4B
5kA 2B & 4B
Tfn (msec)
V_hfu (volts)
0
100
200
300
400

Figure 2



E_dep vs. T_fn (DSA328)
E_dep (joules)
Tfn (msec)
0
50
100
150
200
0
100
200
300
400
2kA 1B & 3B
5kA 1B & 3B
2kA 2B & 4B
5kA 2B & 4B

Figure 3

Distribution:

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