Fermilab

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MEMO TO: R. Bossert, S. Delchamps, J. Garvey, S. Gourlay, C. Haddock, W Koska, P. Mazur, D. Orris, J. Strait, M. Wake

FROM: Mike Lamm

SUBJECT: Test to Determine the Energy Deposition Limits on SSC Style Strip Heaters

As an adjunct to the heater test plan for DS0315, we have performed a test to determine if an SSC style heater could operate at several times the nominal energy deposition of 24 Joules in 235 mSec. A description of the heaters and their location, as well as the relevance of this energy deposition and time constant are explained elsewhere[1]. The tests were performed in boiling liquid helium at 1 atmosphere. During the heater firing there was no transport current supplied to the magnet. Successful heater operation was defined as no "open" power or voltage tap wires to the heater from the dewar header, and no hipot failures from the heater to the coil or collar.

We performed this heater destruction test on Heater #4, the heater in the third quardant. The system, as shown in figure 1 had the following parameters:

Rheater = .73 ohms
Rsystem = 1.73 ohms
Capacitance = 45.3 mF

This resistance and capacitance implies an RC time constant of 78 mSec which was consistent with measured heater voltage and current as a function of time (at low heater firing unit voltages only).

The maximum voltage supplied by the heater firing units was about 325 volts which corresponds to about 1 KJ deposited into the heater in 3 Tau = 234 mSec. We started at 24 Joules depostion and worked towards the maximum energy in 150 Joule steps. At each step the following procedure was performed:

1) Hi pot heater to ground at 600 Volts. Shell, coil as well as bore tube are grounded. Hi pot another heater in magnet as a consistency check. If O.K. ....

2) Fire heater through SSC program. Look at I(t) and V(t) heater for ananomalies. (Note this is also a monitor of how hot the heater is getting during energy deposition.) If O.K....

3) 8 manual heater trips. Stop if HFU fails to discharge.

4) 1 heater trip using SSC program. Observe I, V heater but do not save data. If O.K. go to "1".

The following is a summary of the results. With the exception of the 475 Joules HFU data, all of the first heater files were saved as quench files (DS0315.qb132 through DS0315.qb138 in mdtfl2::ssc$root:[data.quench]). For the 475 Joules data, plots were made of V,I and are saved in our test log book only.

file no.	Energy deposited in 3 Tau (Joules)	V(HFU)	Maximum Measured Heater Resistance V/I (ohms)	
132	24	50	.75	
133	175	135	.86	
134	325	185	.96	
N/A	475	223	1.00	
135	625	256	1.13	
136	775	285	1.20	
137	925	312	1.28	
138	1005	325	1.10	CIRCUIT FAILED

Figure 2-4 show the heater voltage, current, and measured resistance for 24 Joules, 925 Joules and 1005 Joules. At 24 Joules (figure 2), the resistance of the heater throughout the capacitor discharge is consistent with the 4 wire resistance measurement at 4.2 K. Thus this energy deposition does not meausurable change the heater temperature. In contrast. At 925 Joules (figure 3) the measured maximum resistance is 1.28 ohms which is to be compared to room temperature measurements of 1.5 ohms.

Note that the actual peak resistance is probably higher. This resistance is inferred by taking the ratio of two rapidly rising then exponentially falling distributions. Any slewing of these signals due to filtering plus the averaging of these signals by the data loggers per reading will tend to smooth out any peak signal.

The test stopped on the first heater firing at VHFU = 325 Volts (figure 4). The failure occurred in one of the high voltage connectors between the heater firing unit and the HV cables that go to the dewar. The connector pin and insulation was melted and covered with carbon, probably due to an arc from inside the cable connector.

The heater passed the 600 volt hi pot and none of the the sense or power leads to the heater from the dewar header were "open". Thus, the heater appears to have survived the tests.

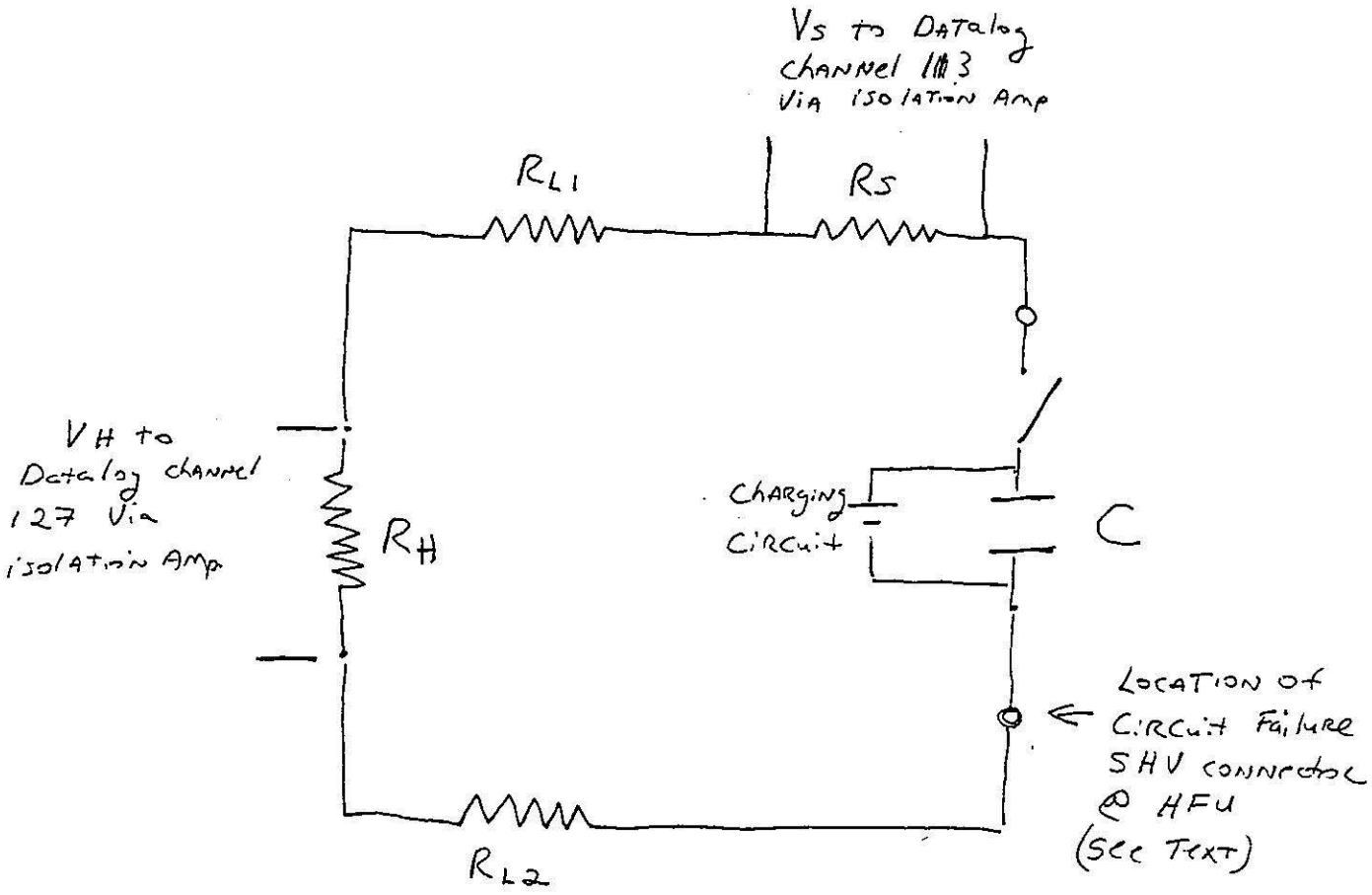
Conclusion:

One of the the SSC style heaters employed in DS0315 was tested repeatedly with energy depostion large compared to the nominal 24 Joules. We have shown that the heater can operate at 312 volts HFU or 925 Joules (the next-to-last voltage setting) and probably at higher energy depostions under these test conditions.

Reference:

[1] "SSC Quench Protection Heater Tests on Short 40 mm Dipole Magnets" C. Haddock et al. Test and Analysis Note MD-TA-171 SSC Laboratory

SYSTEM DIAGRAM FOR HEATER TESTS



Rh = Heater resistance @ 4.2 K = .73 ohms
C = Heater firing unit capacitance = 45.3 mF
Rl1 + Rl2 = Lead resistance = 1.0 ohms
Rs = Shunt resistor

Figure 1

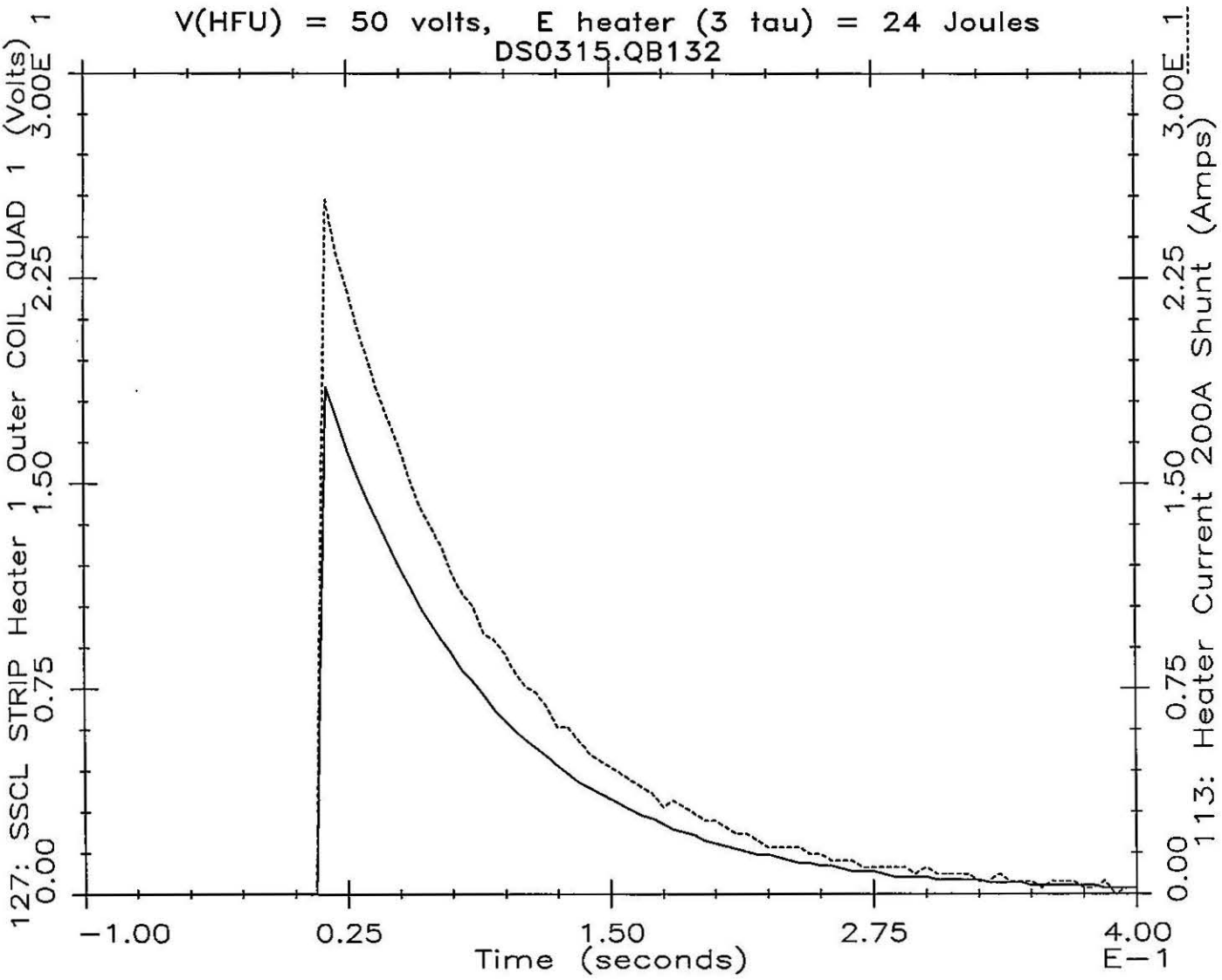
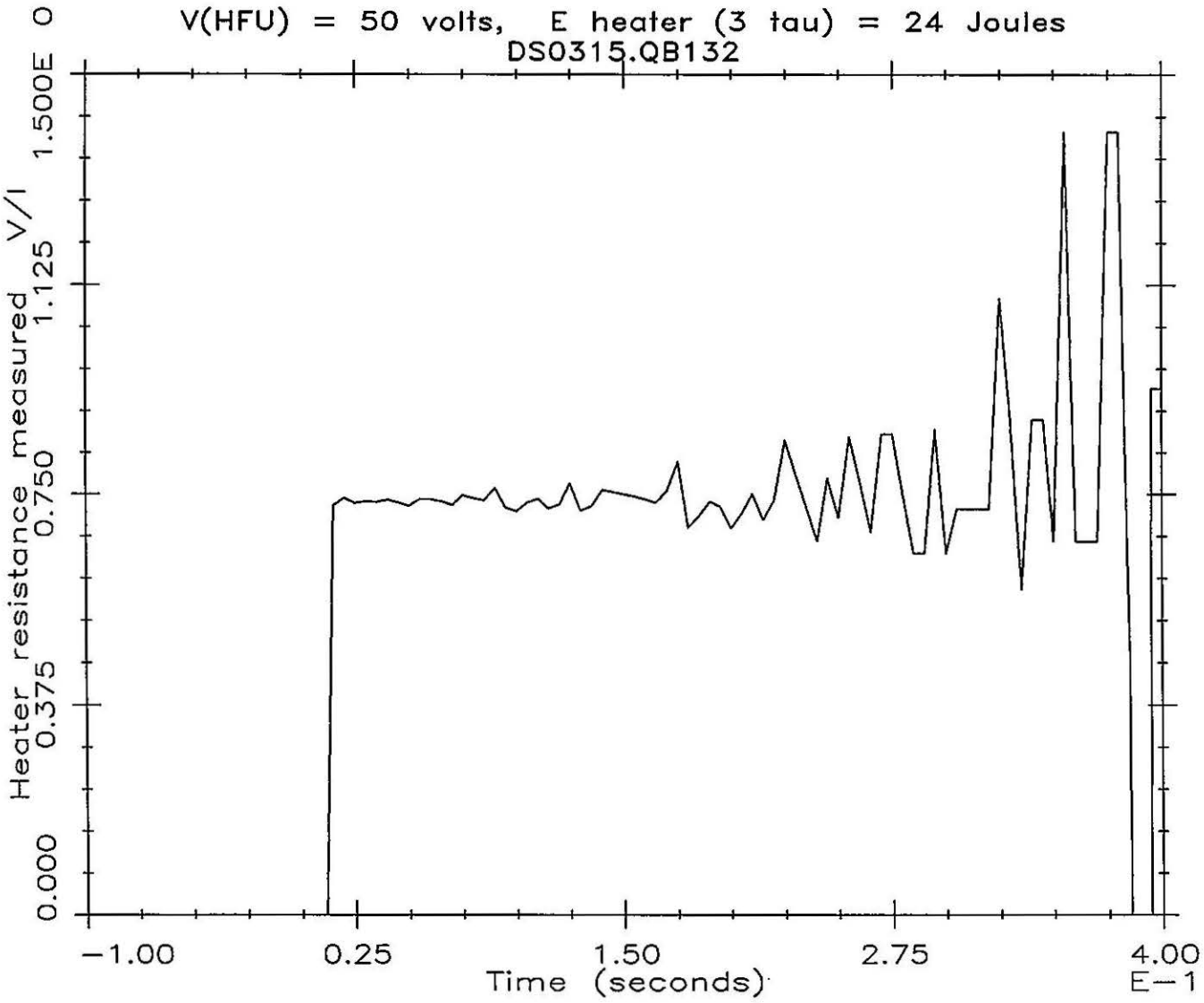

V(HFU) = 50 volts, E heater (3 tau) = 24 Joules
DS0315.QB132
127: SSCL STRIP Heater 1 Outer COIL QUAD 1 (Volts)
0.00
0.75
1.50
2.25
3.00E 1
113: Heater Current 200A Shunt (Amps)
0.00
0.75
1.50
2.25
3.00E 1
−1.00
0.25
1.50
2.75
4.00
E−1
Time (seconds)

Figure 2a



(+127)/(113)

Figure 26

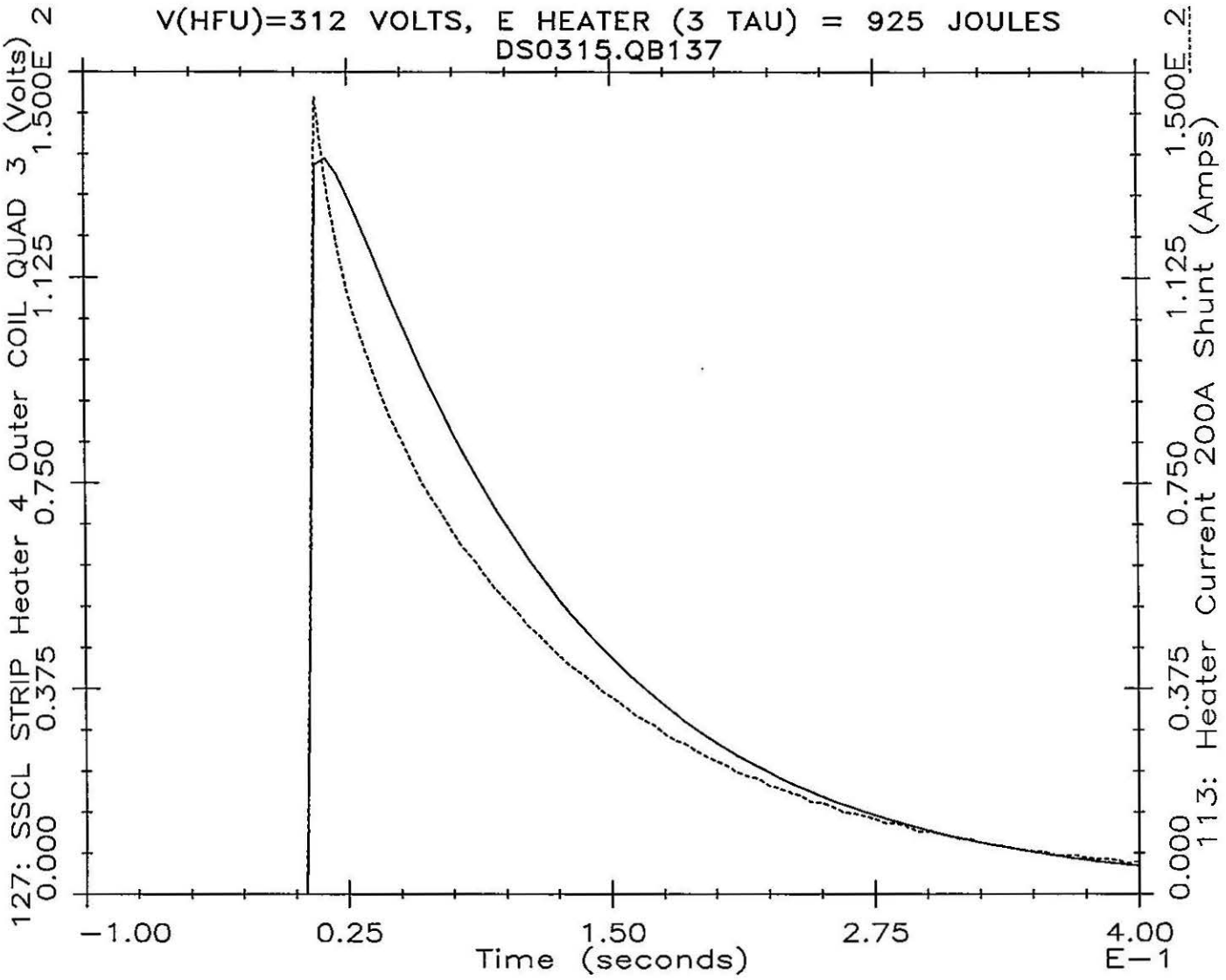
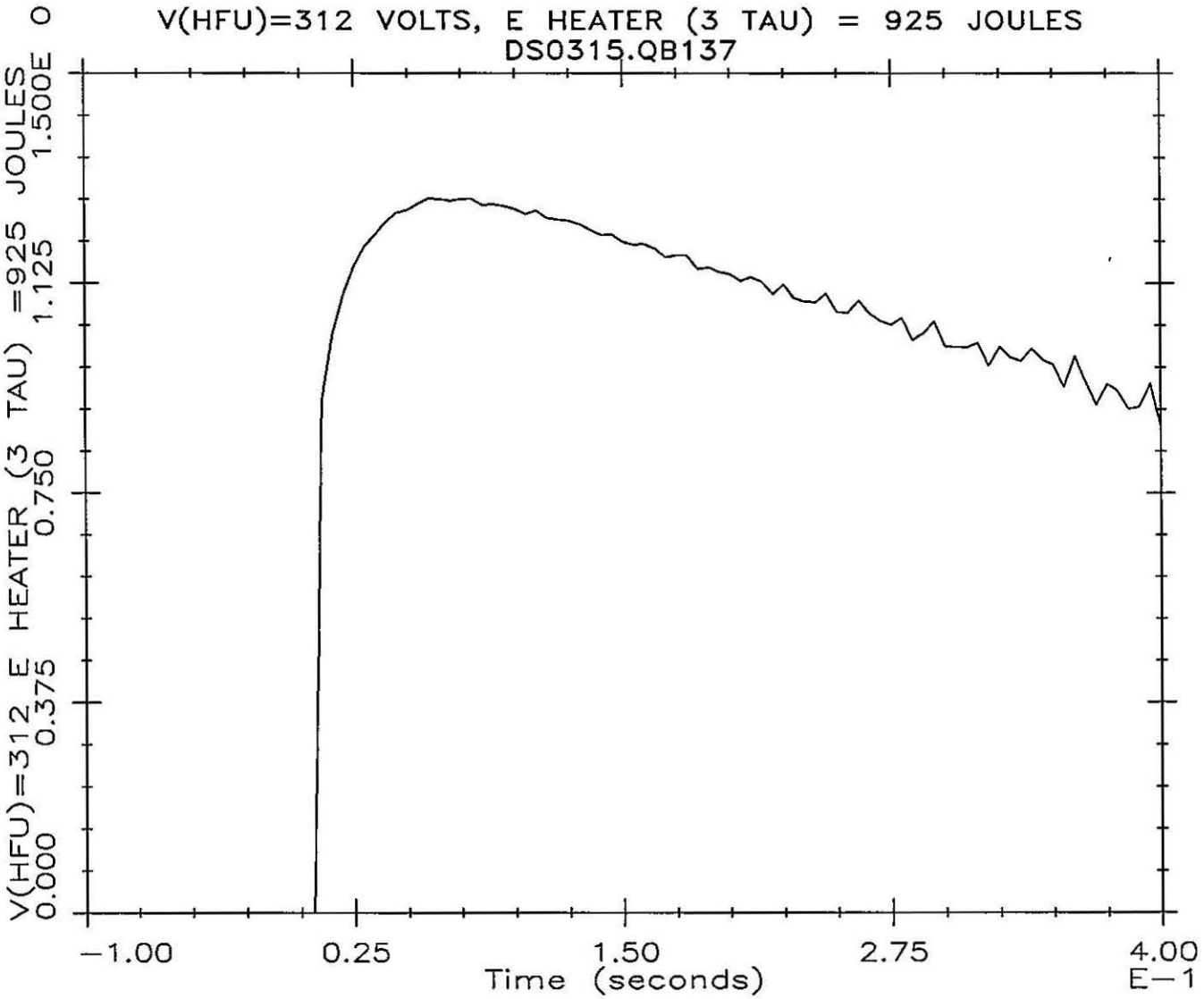

V(HFU)=312 VOLTS, E HEATER (3 TAU) = 925 JOULES
DS0315.QB137
127: SSCL STRIP Heater 4 Outer COIL QUAD 3 (Volts) 2
0.000
0.375
0.750
1.125
1.500E 2
113: Heater Current 200A Shunt (Amps) 2
0.000
0.375
0.750
1.125
1.500E 2
−1.00
0.25
1.50
2.75
4.00
E−1
Time (seconds)

Figure 3a



(+127)/(113)

Figure 36

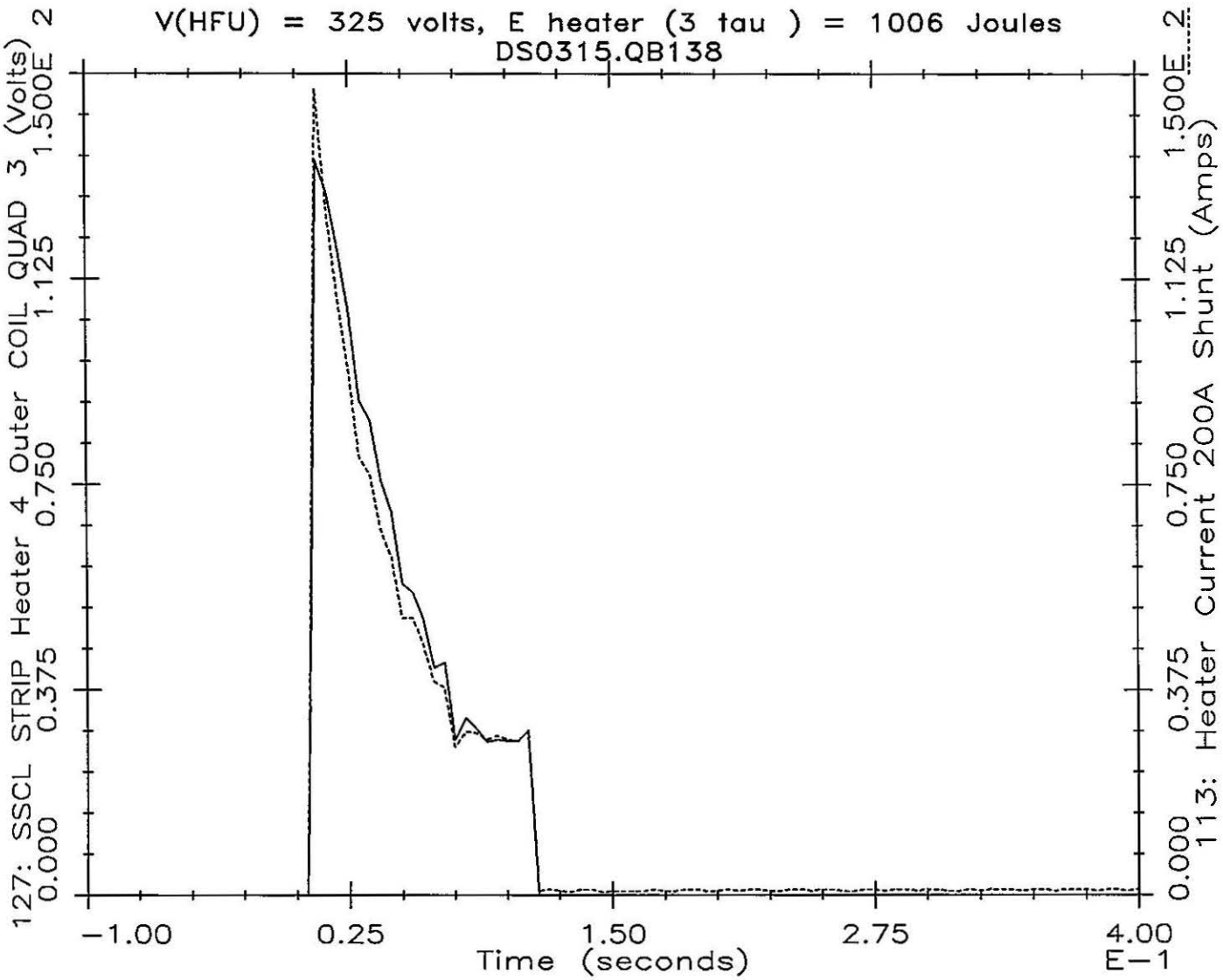
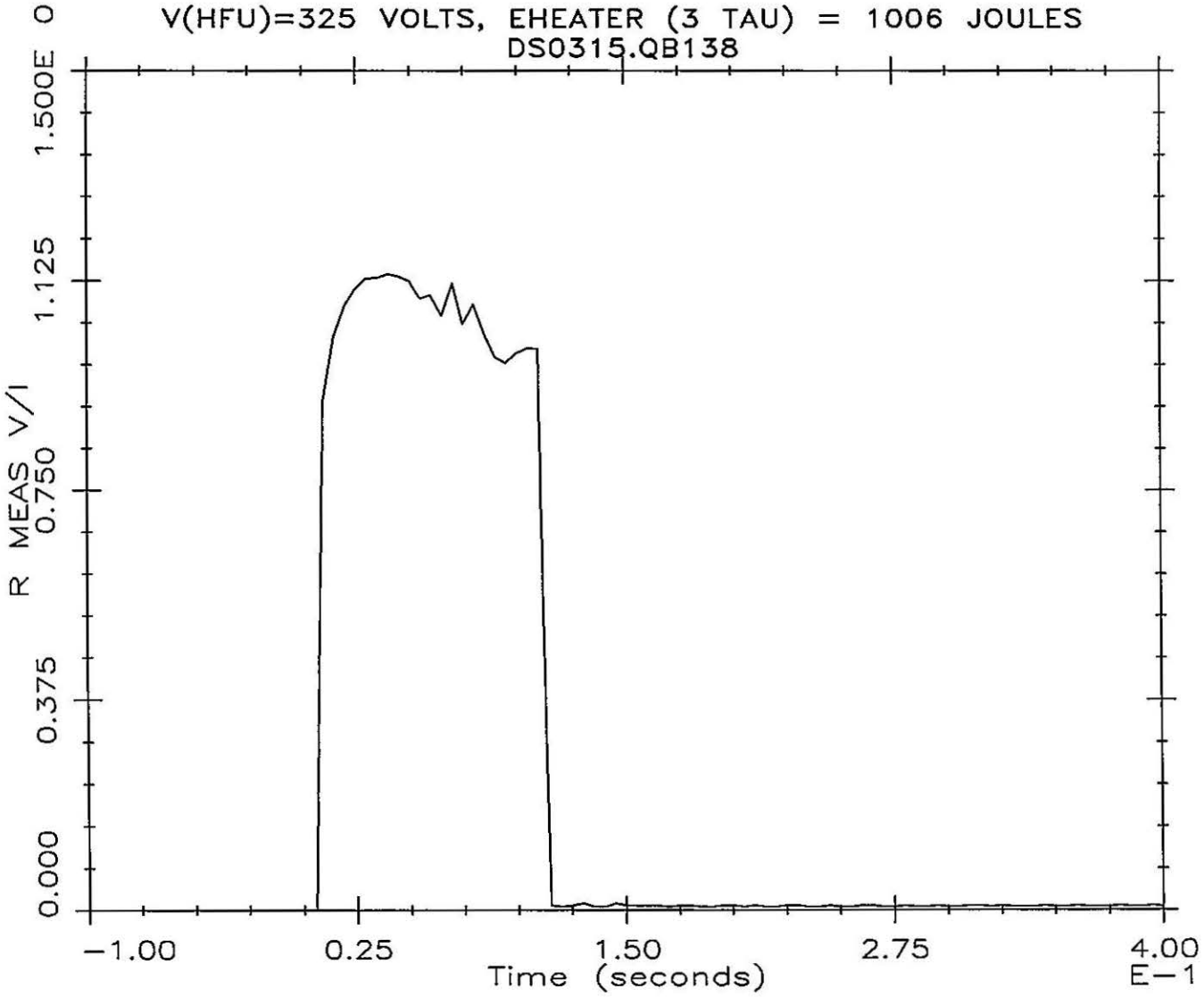

V(HFU) = 325 volts, E heater (3 tau) = 1006 Joules
DS0315.QB138
127: SSCL STRIP Heater 4 Outer COIL QUAD 3 (Volts)
0.000
0.375
0.750
1.125
1.500E 2
113: Heater Current 200A Shunt (Amps)
0.000
0.375
0.750
1.125
1.500E 2
−1.00
0.25
1.50
2.75
4.00
E−1
Time (seconds)

Figure 4a



(+127)/(113)

Figure 4b