SSC HEATER ENERGY RESULTS 12-APR-1990

Seven SSC quench files were analyzed spanning 3 magnets (dd17, dd19 , & dd26). Each file was that of a trip of either Q.D.C.#3 or Q.D.C.#6 which bypasses the heater delay. All but two trips were @ 2000 amps., the others @ 3000 amps.& 4500 amps.The temperatures spanned 3.5K to 4.5K.

The time required to quench both outer coils after the strip heaters were fired was determined from the resistive voltages of the quarter coils.

Plots were made of (strip heater voltage)**2/(cold heater resistance). The cold resistance of the strip heaters for dd0017 were not known so a nominal 1.25 ohms was chosen.

A first pass at determining the energy required to quench the outer coils was done by integrating (V**2)/r from t=0 to T, where T is the time at which both outer coils quenched. The integration was done by estimating the area under the curve so it is not an exact figure.

The following are my results:

File #	current	temp.	T(msec)	Energy/Htr.	Total Energy
DD0017.QB004	1992 amps	4.4K	205	236 Joules	472 Joules
DD0017.QB006	4491 amps	4.4K	98.5	**290 Joules	580 Joules
DD0017.QB014	1992 amps	3.9K	172	440 Joules	880 Joules
DD0019.QB161	1997 amps	3.9	160	480 Joules	960 Joules
DD0026.QB003	2928 amps	3.5K	125	577 Joules	1154 Joules
DD0026.QB013	1969 amps	4.5K	180	244 Joules	488 Joules
DD0026.QB033	2000 amps	4.0K	165	393 Joules	786 Joules

** There seems to be an inconsistancy beween dd0017.qb004 & 006 since it took more energy to quench the outer coils at a higher current. This may be explained in part due to increasing the supply voltage by 25 V after the 004 trip to make T<200 msec.

Strip Heater Voltages: These are the voltages measured accross each strip Htr.

File #	Voltage	Temp.
DD0017.QB004	86	4.4K
DD0017.QB006	95	4.4K
DD0017.QB014	112	3.9K
DD0019.QB161	111	3.9K
DD0026.QB003	125	3.5K
DD0026.QB013	86	4.5K
DD0026.QB033	105	4.0K

DARRYL ORRIS

SSC STRIP HEATER VOLTAGES 10-APRIL-1990

HEATER FIRING CIRCUIT:

The SSC strip heater firing circuit is made up "12" 2400uf 450V capacitors wired in parallel (28.8 mfd).

SETTING HEATER VOLTAGE:

When preparing to test an SSC magnet the heater voltage is set to a value that will quench the magnet in a time sufficient to maintain the conductor temperature below a specified value (dd0018 outer coils were limited to 800K) during worst case conditions, ie. a quench around 5000 amps.

The heater voltage is normally set by tripping the magnet at 2000 amps with a zero heater delay and checking that both outer coils quench <200 msec. The heater voltage would be incremented by 50 volts until this condition is reached with a maximum limit of 450 volts.

TYPICAL HEATER VOLTAGES.

Magnet	Temp.	Htr.V.	S.H. V.
dd0019	3.5K	350	?
dd0019	3.9K	325	110
dd0019	4.3K	310	100
dd0026	3.5K	360	125
dd0026	4.0K	310	105
dd0026	4.5K	310	100
dd0017	3.9K	325	110
dd0017	4.5K	285	95

NOTE: The strip heater voltages (S.H.) were measured using voltage taps at the ends of the strip heaters. The voltages were then read out by a LeCroy data logger.

DARRYL ORRIS

STRIP HEATER RESISTANCE 08-NOV-89

ROOM TEMPERATURE RESISTANCE:

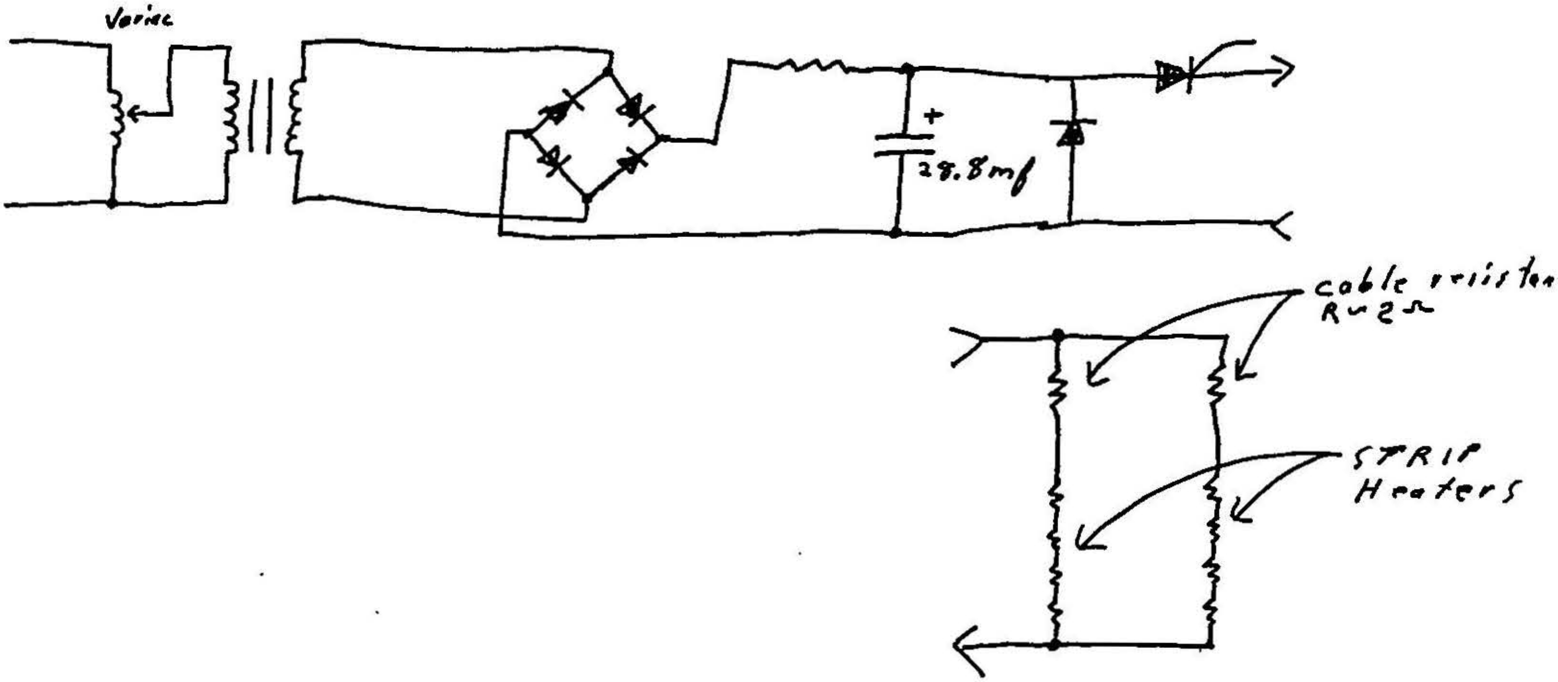
STAND #	MAGNET	S.H.#	2-WIRE	DATE	4-WIRE	DATE	DIFF.
5	DD0016	1	3.73	23-JAN-89	2.79	23-JAN-89	.94
5	DD0016	4	3.66	23-JAN-89	2.71	23-JAN-89	.95
4	DD0017	2	3.32	12-JAN-89	2.98	18-FEB-89	.34
4	DD0017	3	3.00	12-JAN-89	2.68	18-FEB-89	.32
4	DD0017	2			2.98	01-MAR-89	
4	DD0017	3			2.68	01-MAR-89	
5	DD0018	2	3.49	8-APR-89	2.62	8-APR-89	.87
5	DD0018	3	3.56	8-APR-89	2.66	8-APR-89	.90
5	DD0019	2	4.0	28-AUG-89	3.17	28-AUG-89	.8
5	DD0019	3	3.9	28-AUG-89	3.10	28-AUG-89	.8
5	DD0019	2	3.7 ?	30-AUG-89	3.17	30-AUG-89	.5
5	DD0019	3	3.9	30-AUG-89	3.09	30-AUG-89	.8
4	DD0026	1	3.31	09-SEPT-89			
4	DD0026	4	3.29	09-SEPT-89			
4	DD0026	2	3.31	09-SEPT-89	3.049	17-OCT-89	.26
4	DD0026	3	3.27	09-SEPT-89	3.030	17-OCT-89	.24

COLD (4.5K) RESISTANCE:

STAND #	MAGNET	S.H.#	2-WIRE	DATE	4-WIRE	DATE	DIFF.
5	DD0019	1	1.70	28-OCT-89			
5	DD0019	4	1.80	28-OCT-89			
5	DD0019	2	1.73	28-OCT-89	1.265	28-OCT-89	.46
5	DD0019	3	1.80	28-OCT-89	1.240	28-OCT-89	.56
4	DD0026	1	1.73	08-NOV-89			
4	DD0026	4	1.69	08-NOV-89			
4	DD0026	2	1.63	08-NOV-89	1.259	08-NOV-89	.37
4	DD0026	3	1.59	08-NOV-89	1.202	08-NOV-89	.39

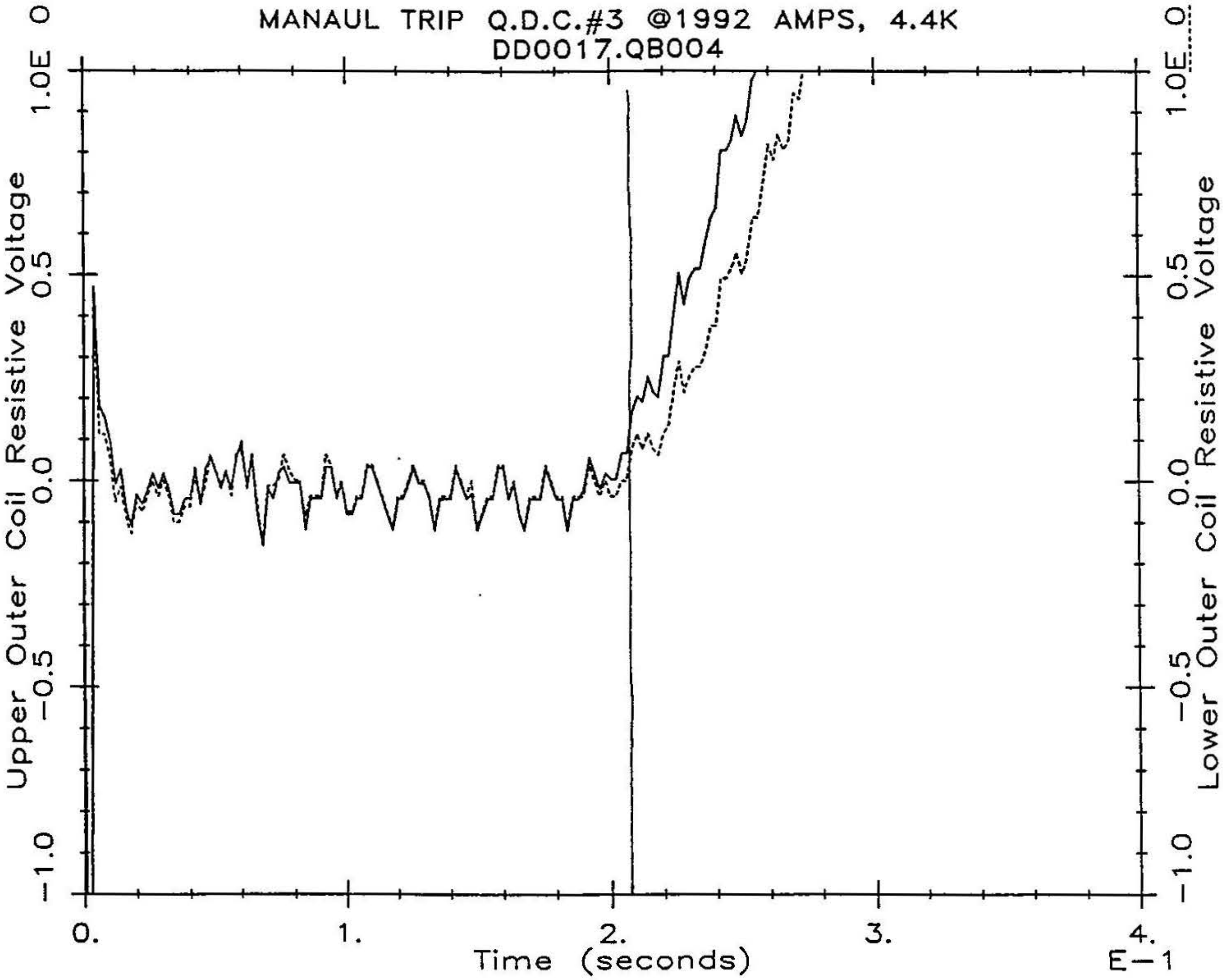
NOTE: All measurements are made at the test stand.
DARRYL ORRIS

Basic Heater Circuit



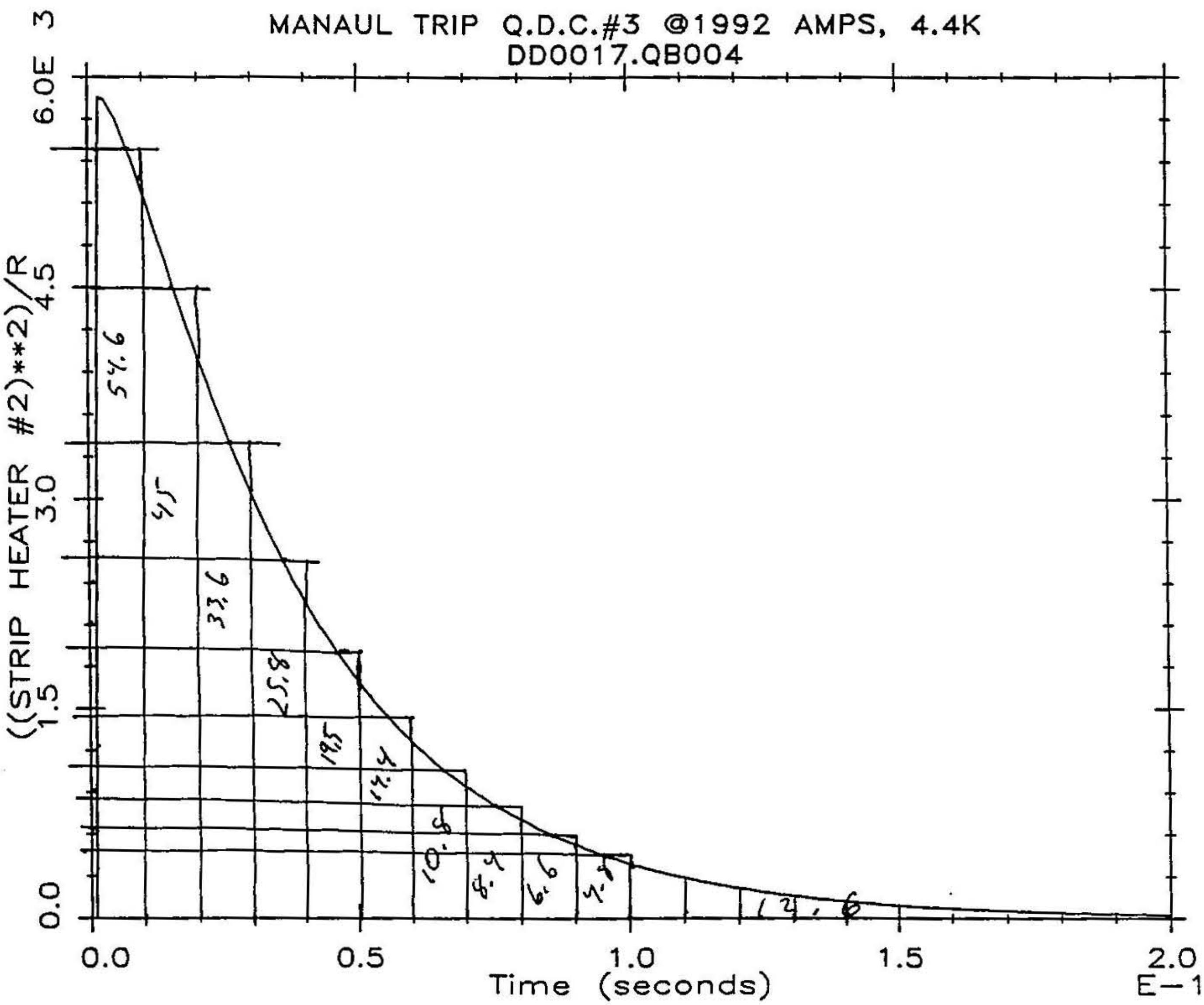
The capacitor bank is made up of 12 2400 μf capacitors (450v) wired in parallel.

The voltage is adjustable from 0-450 V.


MANAUL TRIP Q.D.C.#3 @1992 AMPS, 4.4K
DD0017.QB004
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
1.0E 0
1.0E 0
0.5
0.0
−0.5
−1.0
0.
1.
2.
3.
4.
E−1
Time (seconds)

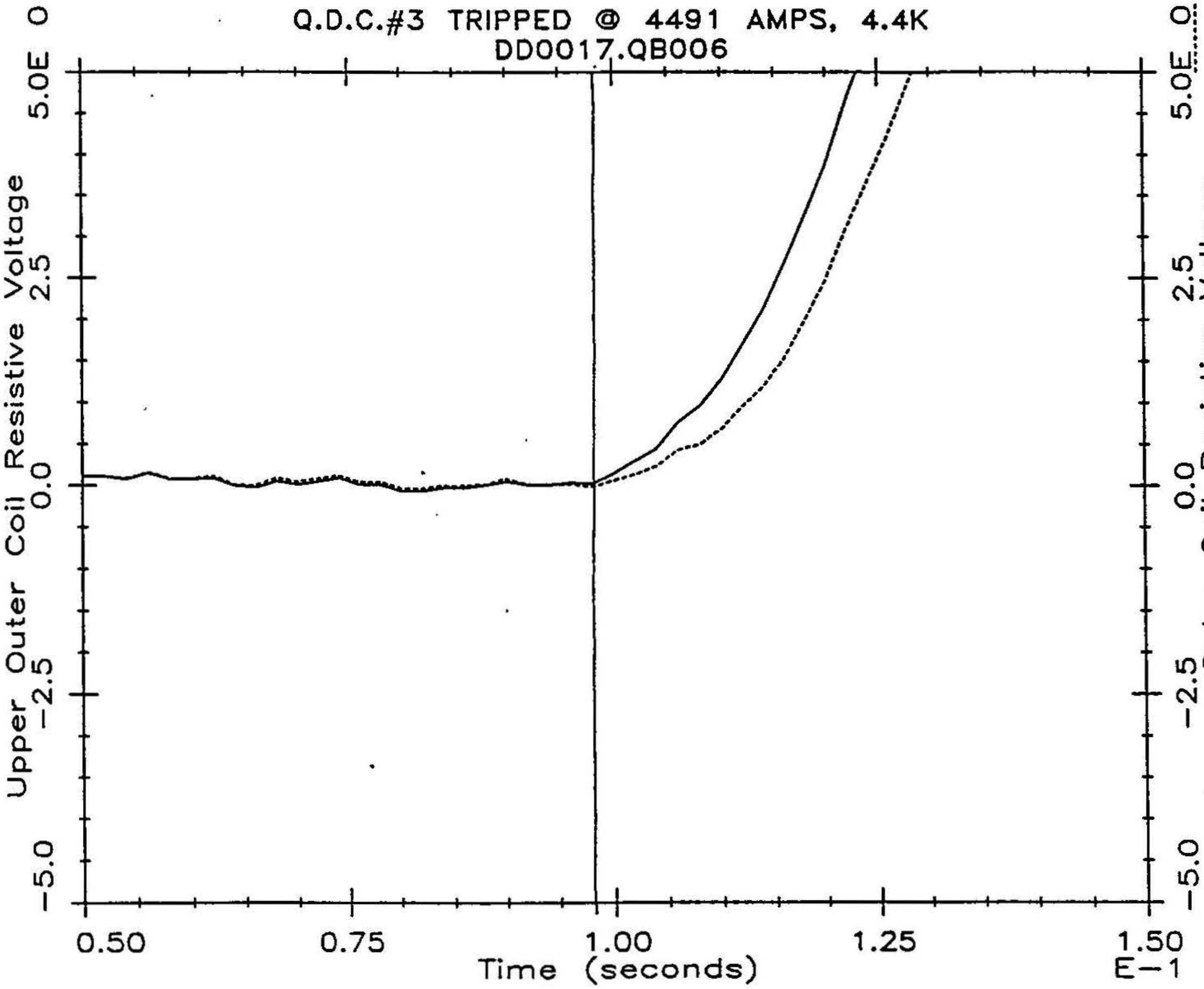
T = 205 msec

(240 joules)

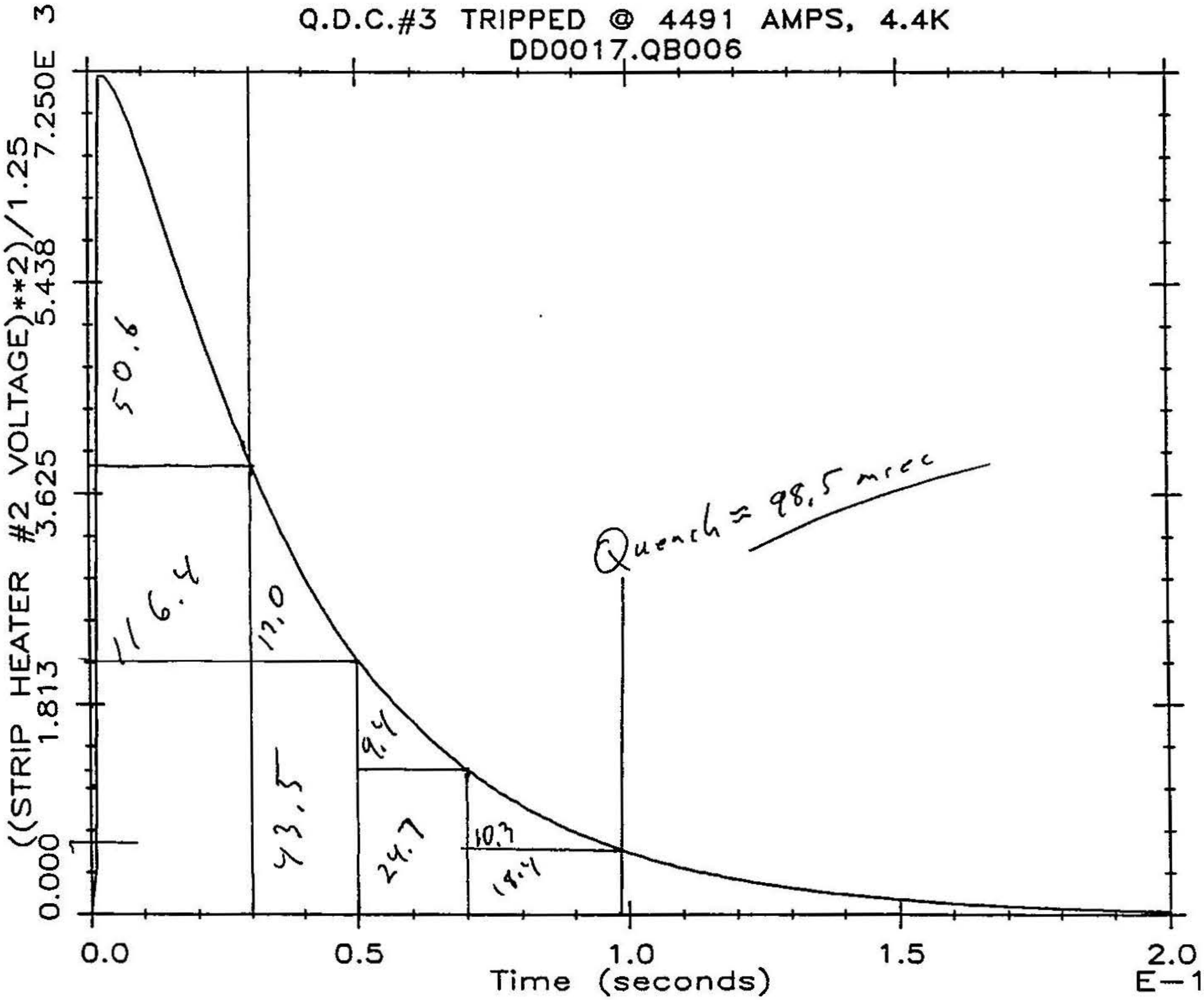


$\int_0^{.2} p\,dt \simeq 236$ joules

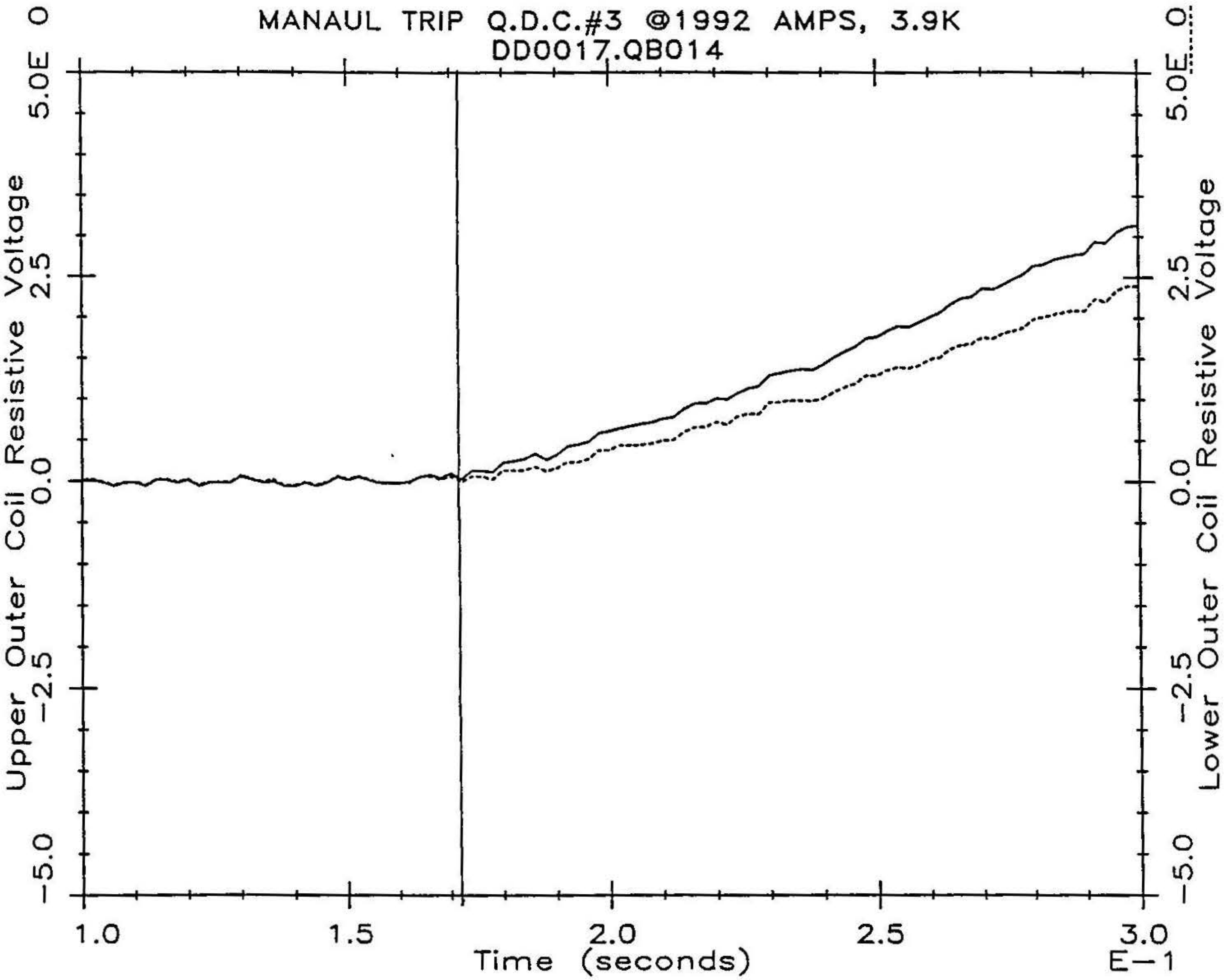
205 ms


Q.D.C.#3 TRIPPED @ 4491 AMPS, 4.4K
DD0017.QB006
5.0E 0
2.5
0.0
-2.5
-5.0
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
0.50
0.75
1.00
1.25
1.50
E-1
Time (seconds)

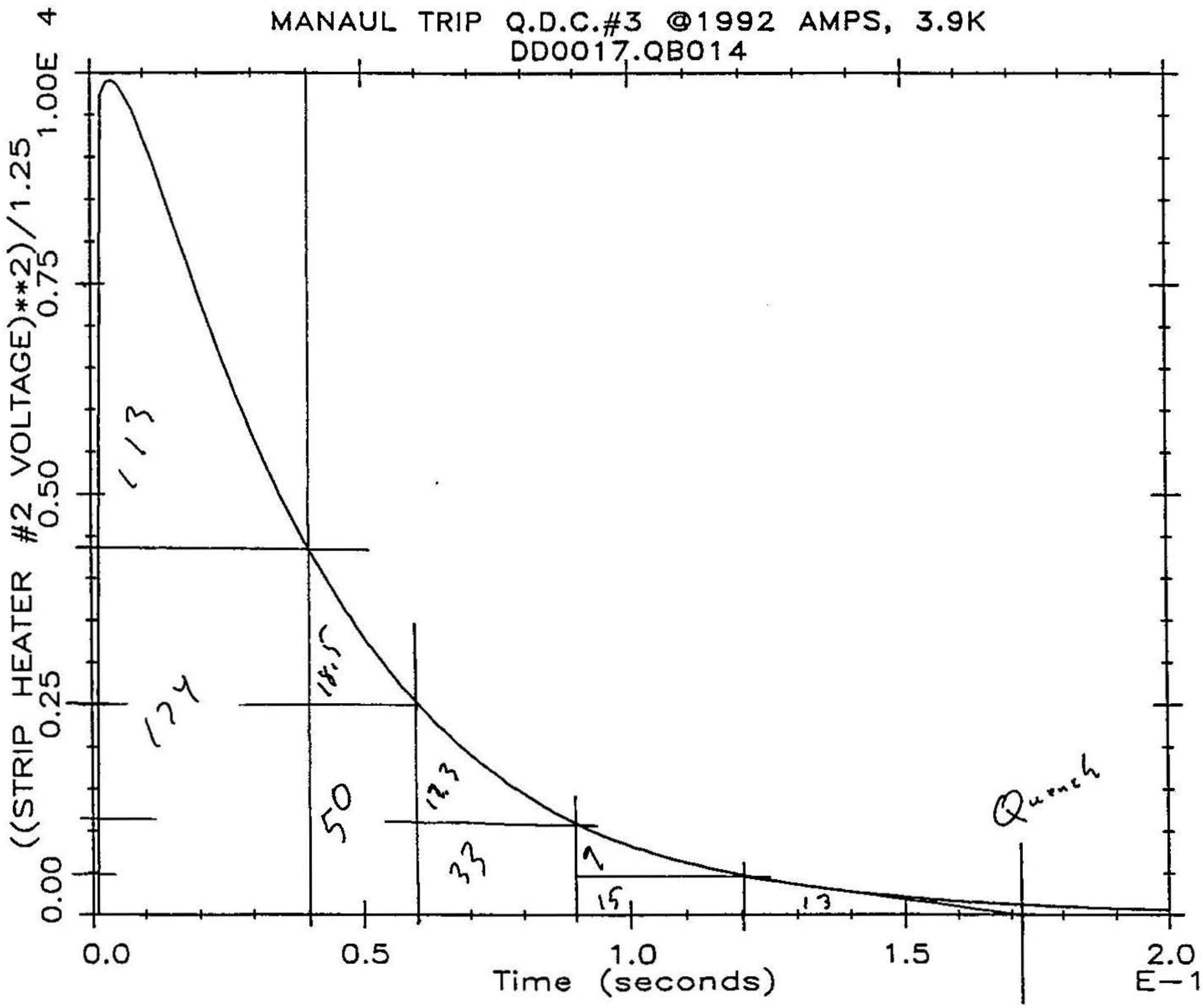
.0985 sec



$\int_{0}^{.0985} p\,dt \approx 290$ joules

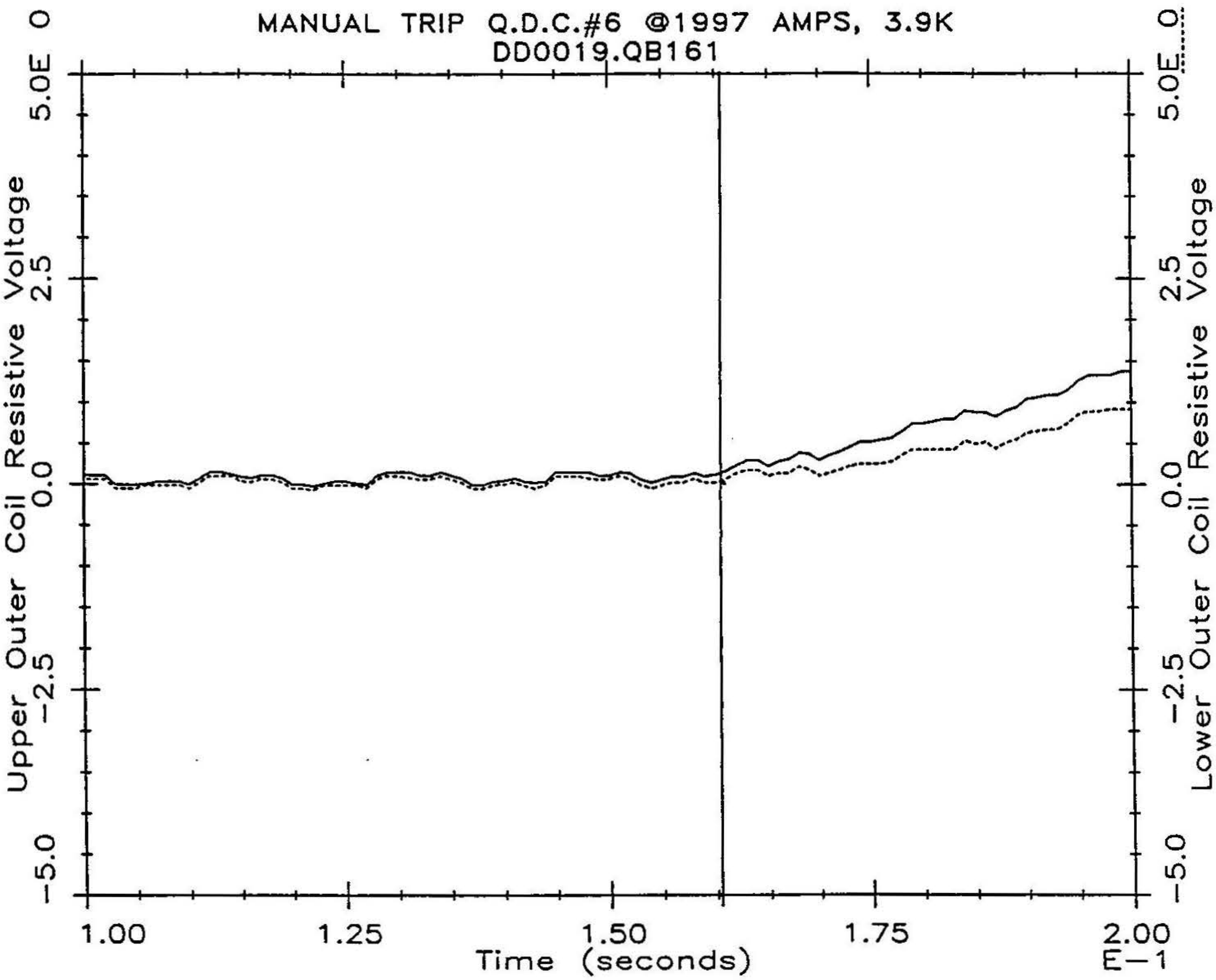

MANAUL TRIP Q.D.C.#3 @1992 AMPS, 3.9K
DD0017.QB014
5.0E 0
2.5
0.0
−2.5
−5.0
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
1.0
1.5
2.0
2.5
3.0
E−1
Time (seconds)

.172 sec

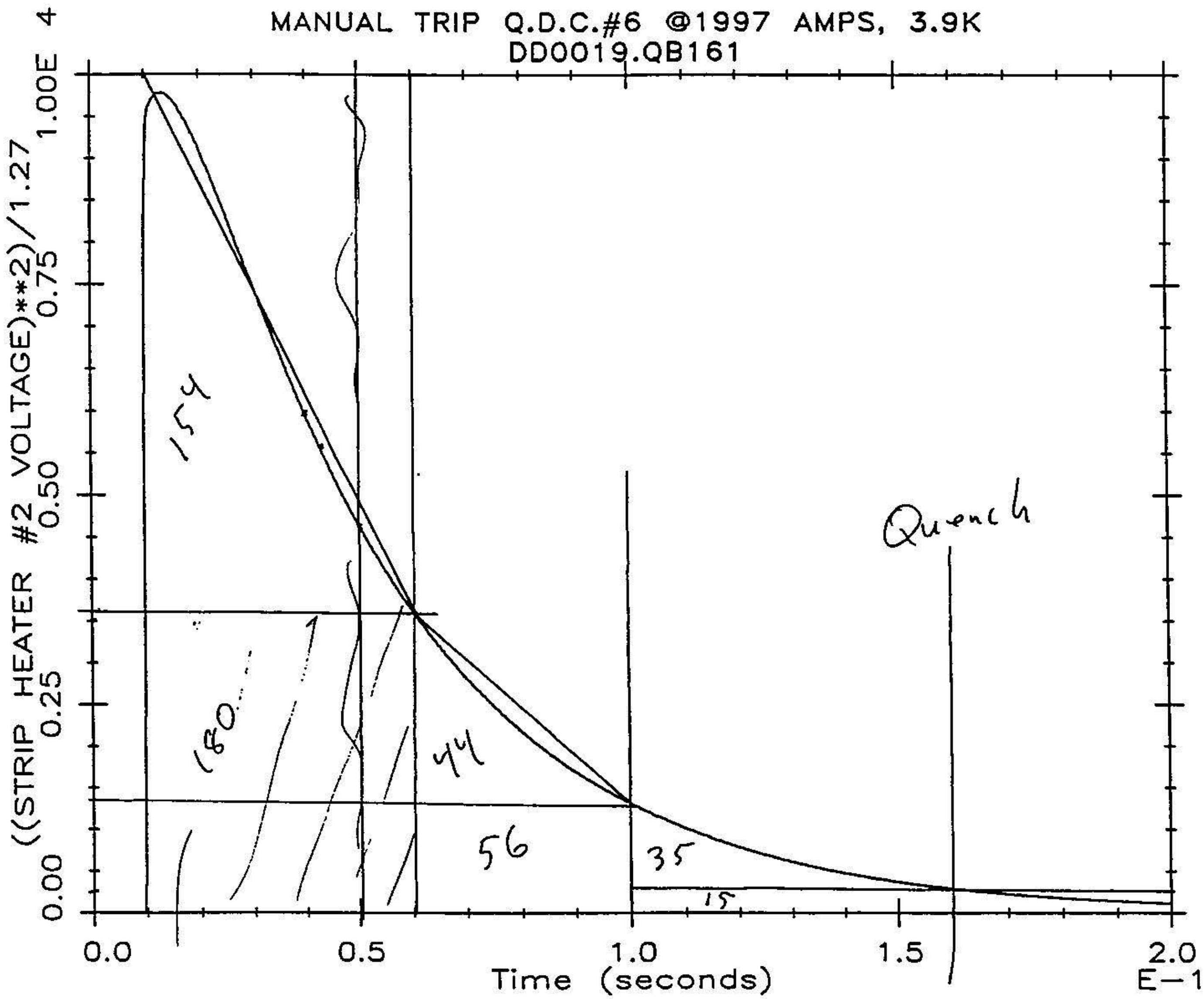


$\int_0^{.172\,sec} p\,dt \approx 440$ joules

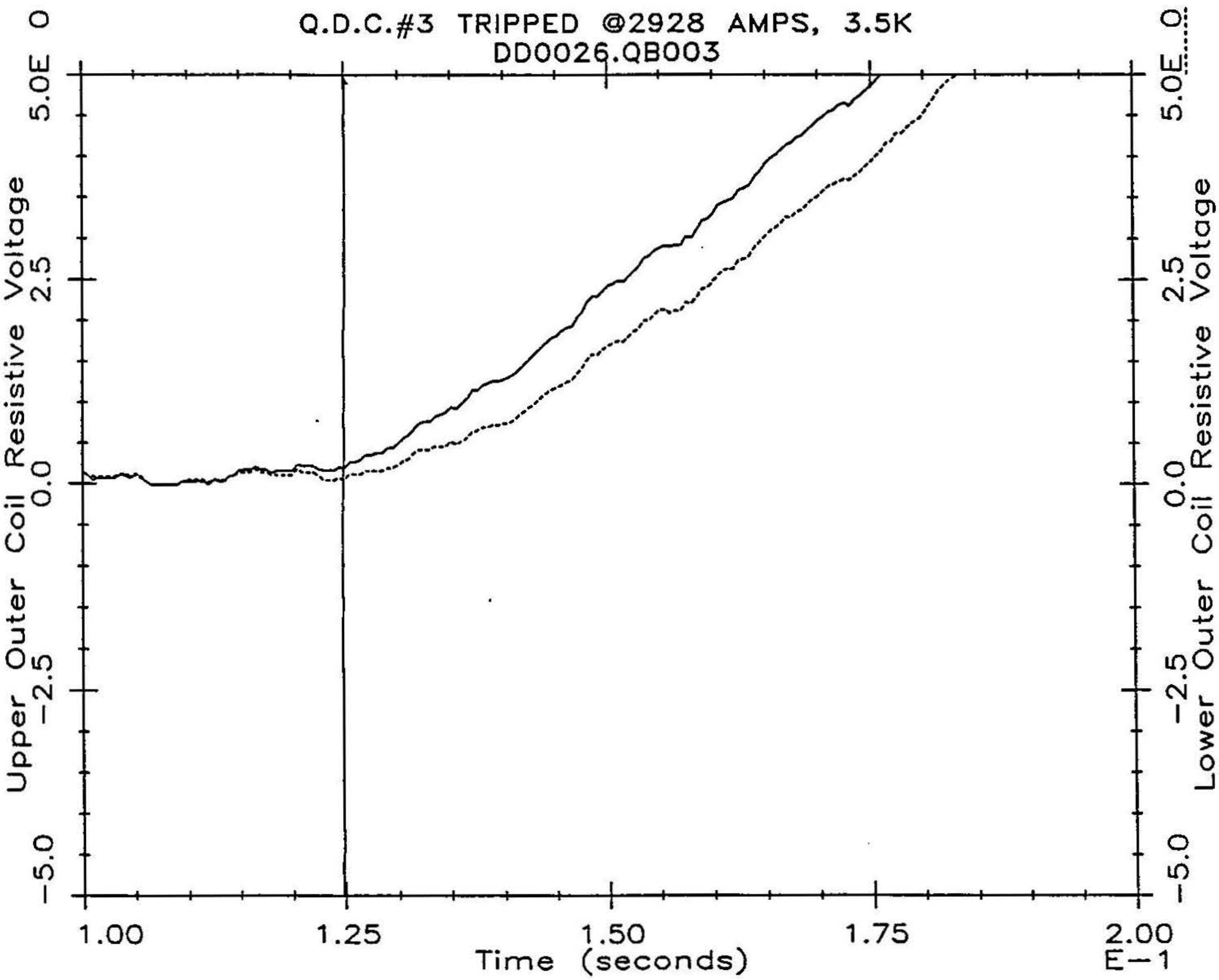
MANUAL TRIP Q.D.C.#6 @1997 AMPS, 3.9K
DD0019.QB161



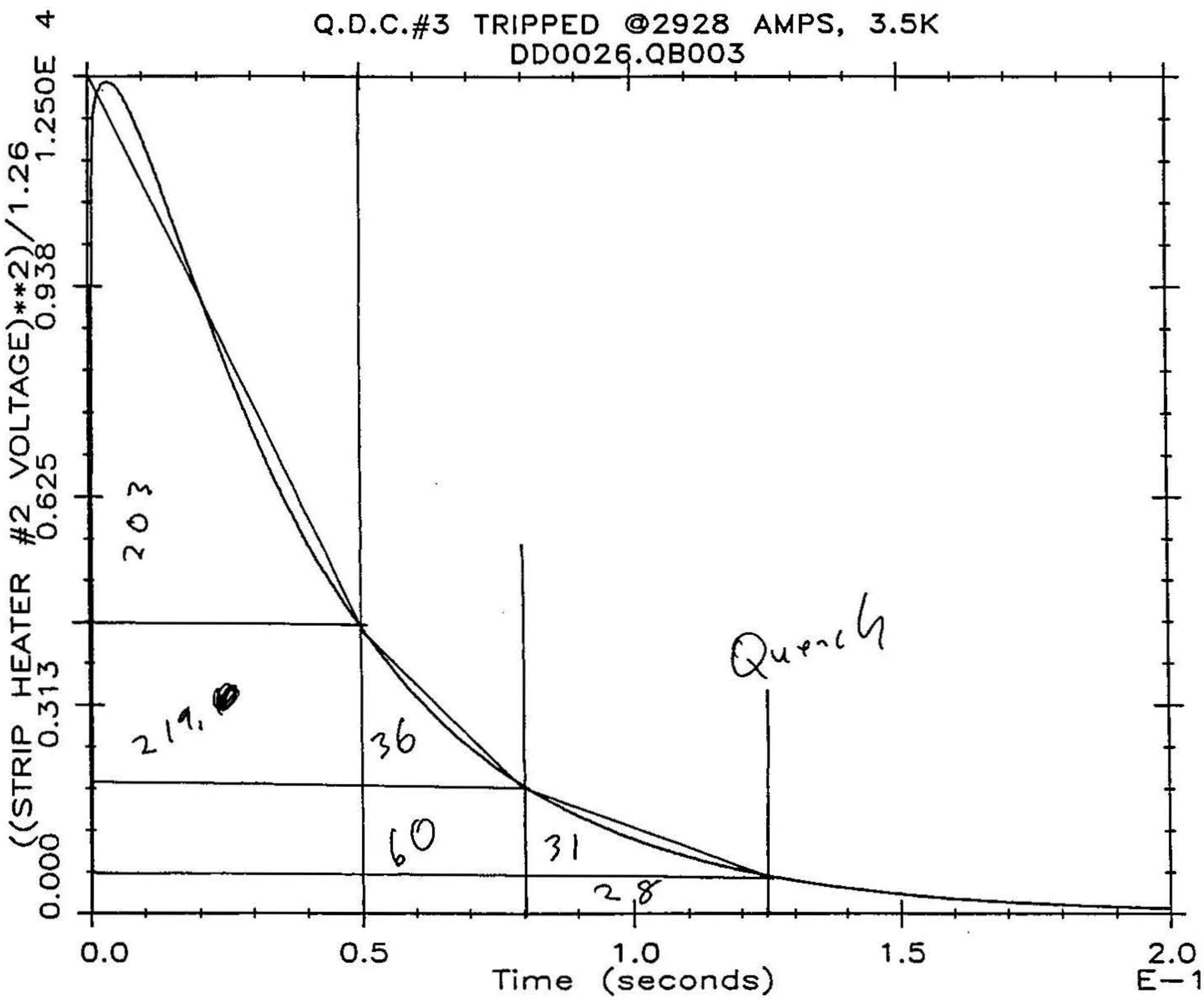
T ≃ .16 sec



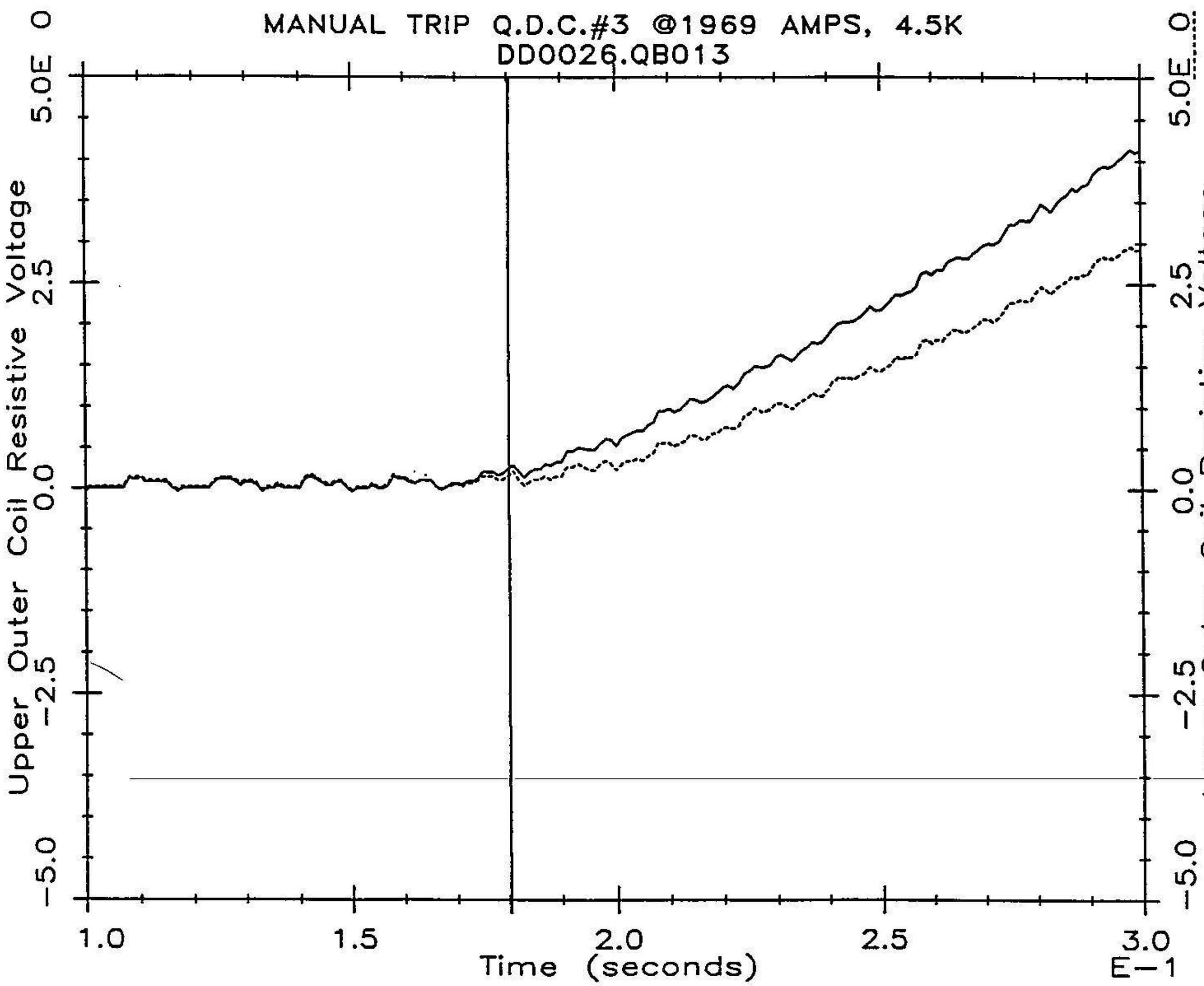
$\int_0^{.16\,sec} p\,dt \approx$ 480 joules


Q.D.C.#3 TRIPPED @2928 AMPS, 3.5K
DD0026.QB003
Upper Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
Lower Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
1.00
1.25
1.50
1.75
2.00
E−1
Time (seconds)

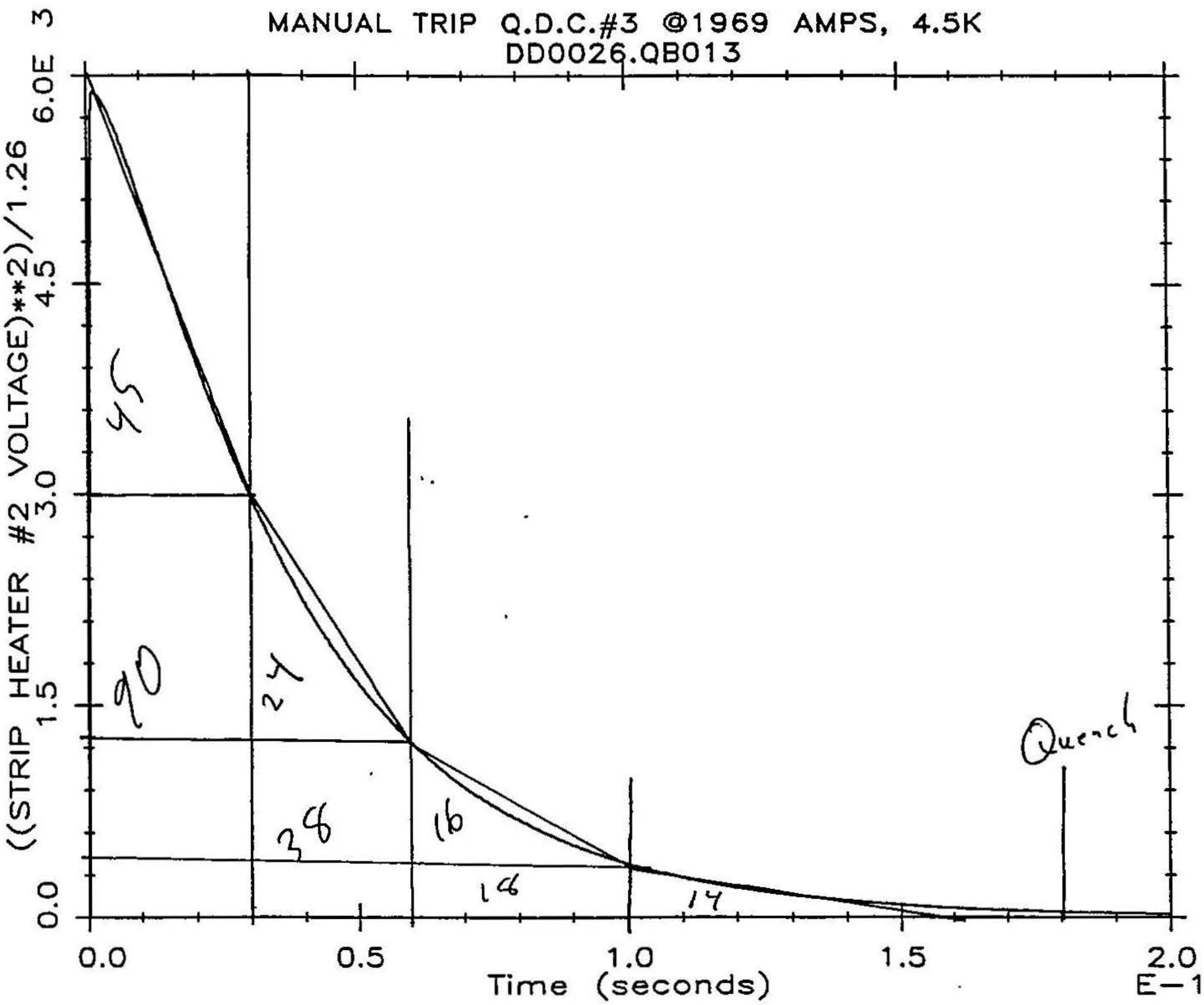
T = .125 sec



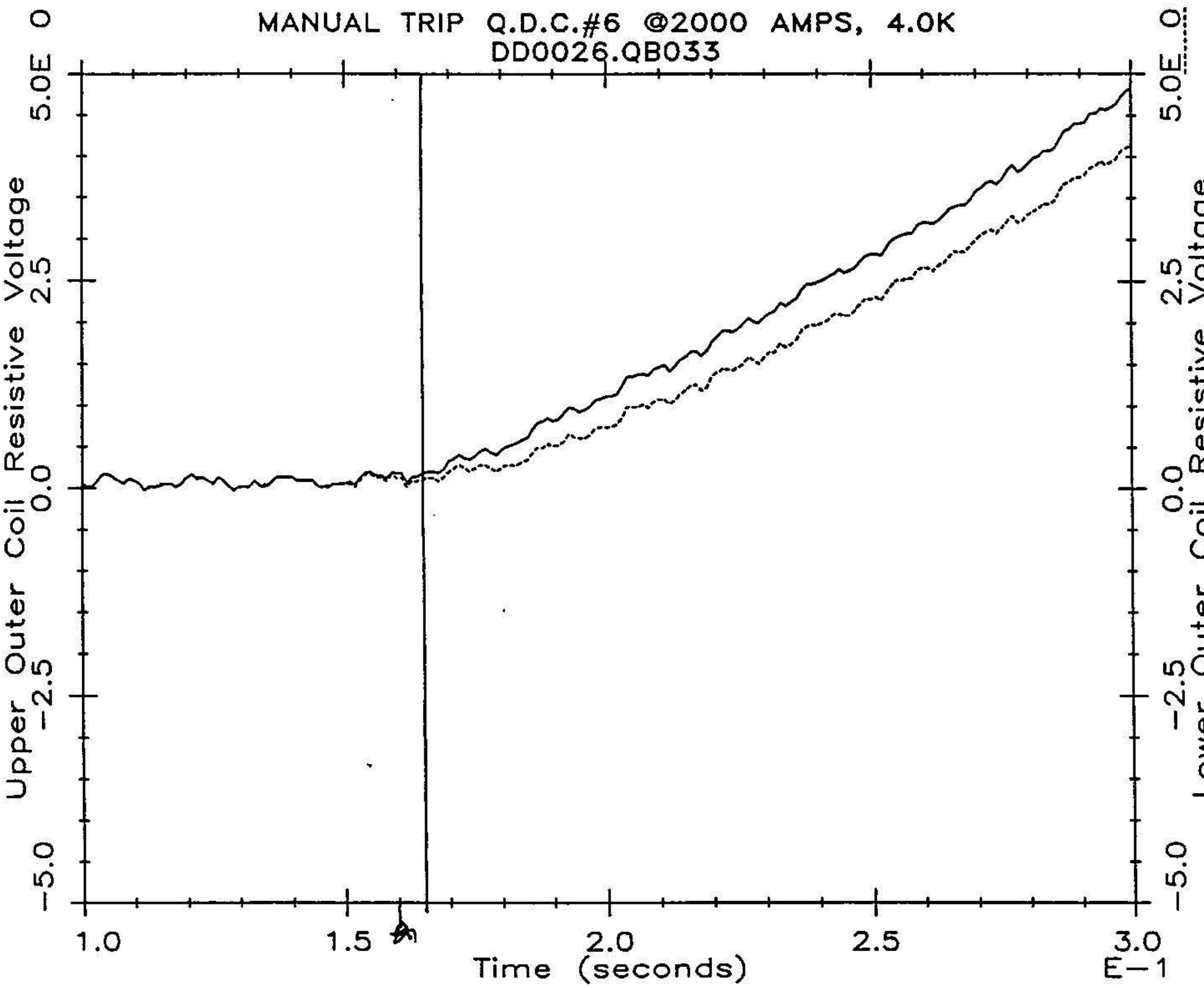
$$\int_0^{.125\,sec} p\,dt \approx 577$$


MANUAL TRIP Q.D.C.#3 @1969 AMPS, 4.5K
DD0026.QB013
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
1.0
1.5
2.0
2.5
3.0
E−1
Time (seconds)

T = .180 sec



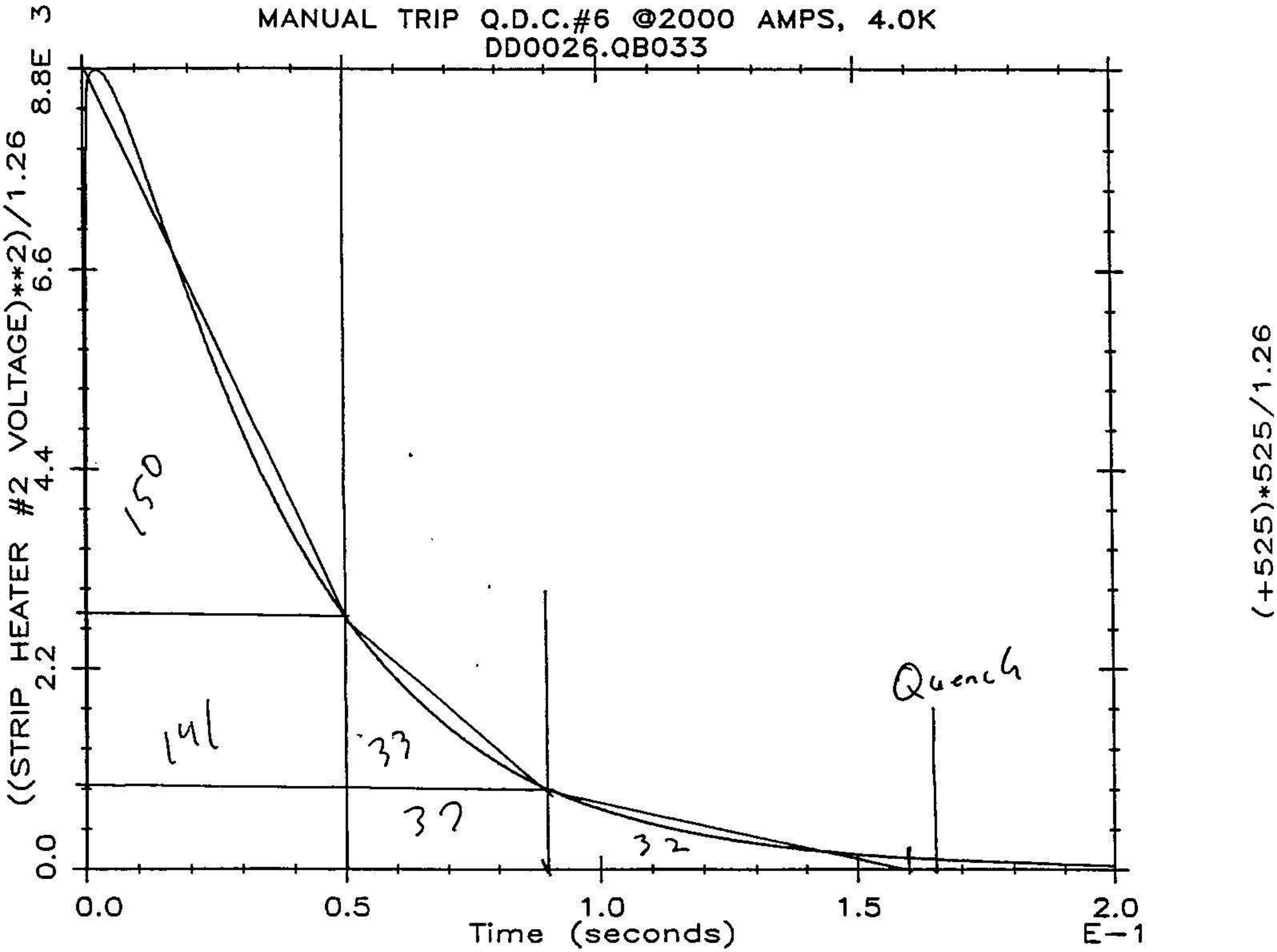
$\int_0^{.180\,sec} p\,dt \cong 244$ joules



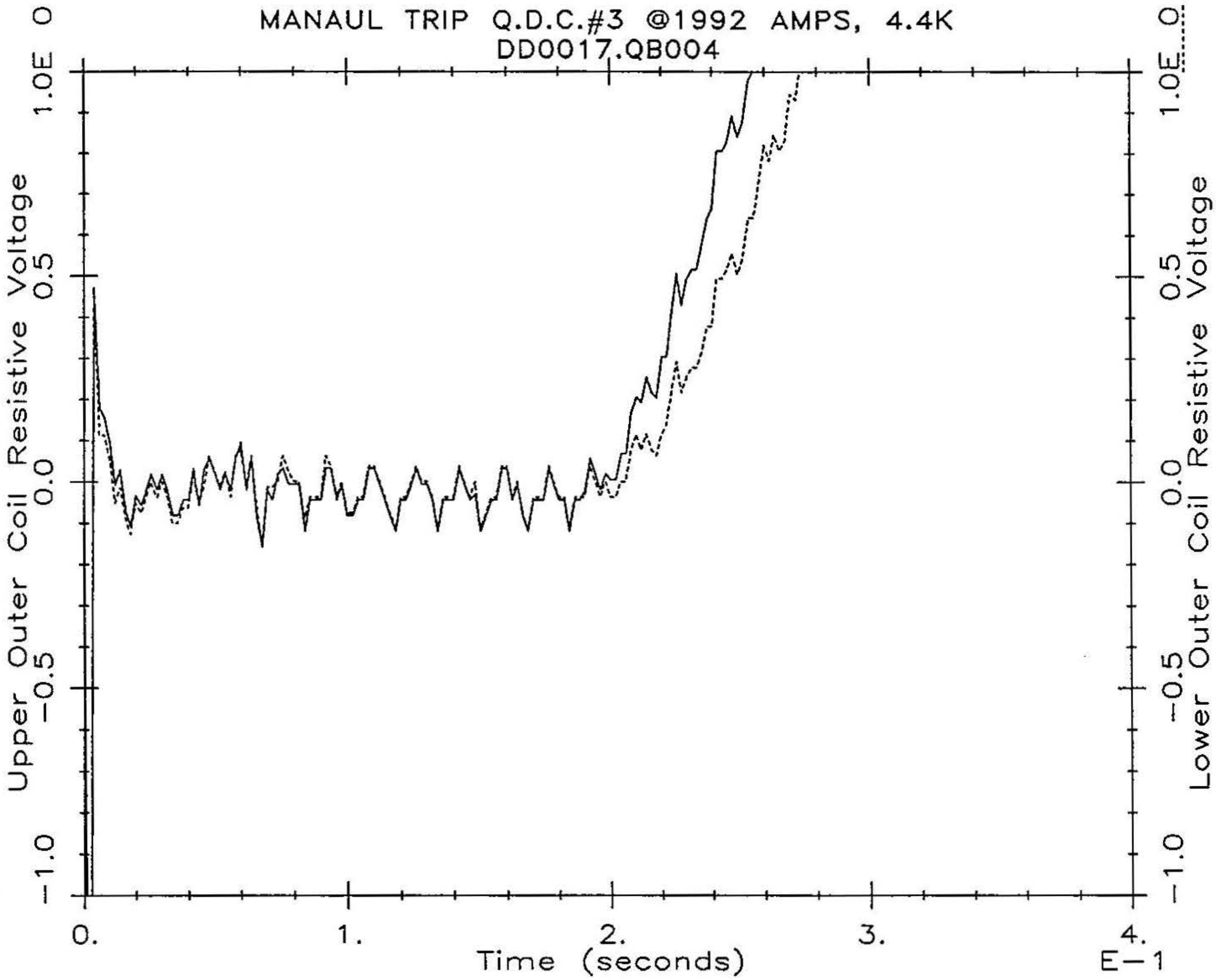
MANUAL TRIP Q.D.C.#6 @2000 AMPS, 4.0K
DD0026.QB033
5.0E 0
2.5
0.0
−2.5
−5.0
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
1.0
1.5
2.0
2.5
3.0
E−1
Time (seconds)

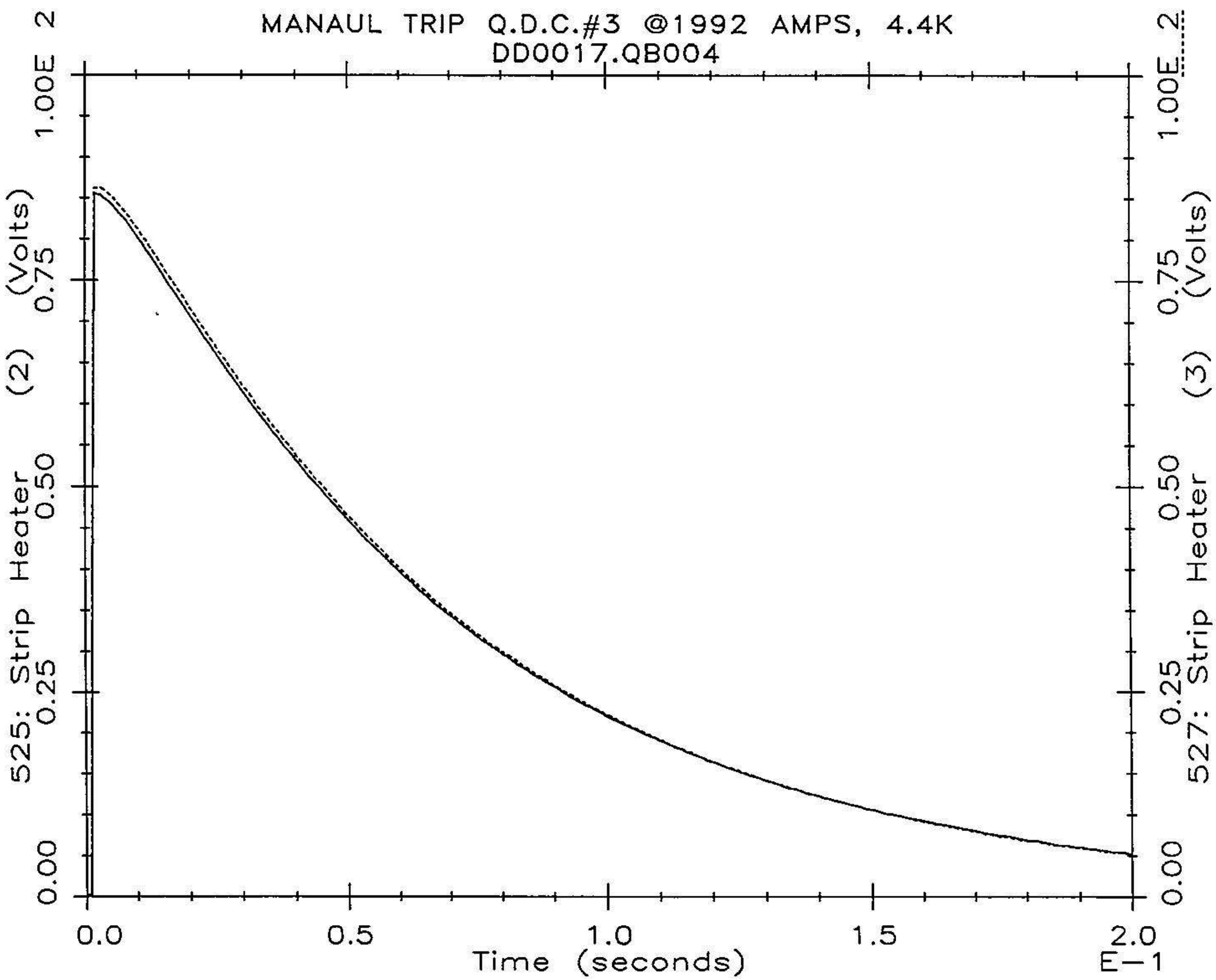
T = .165 sec

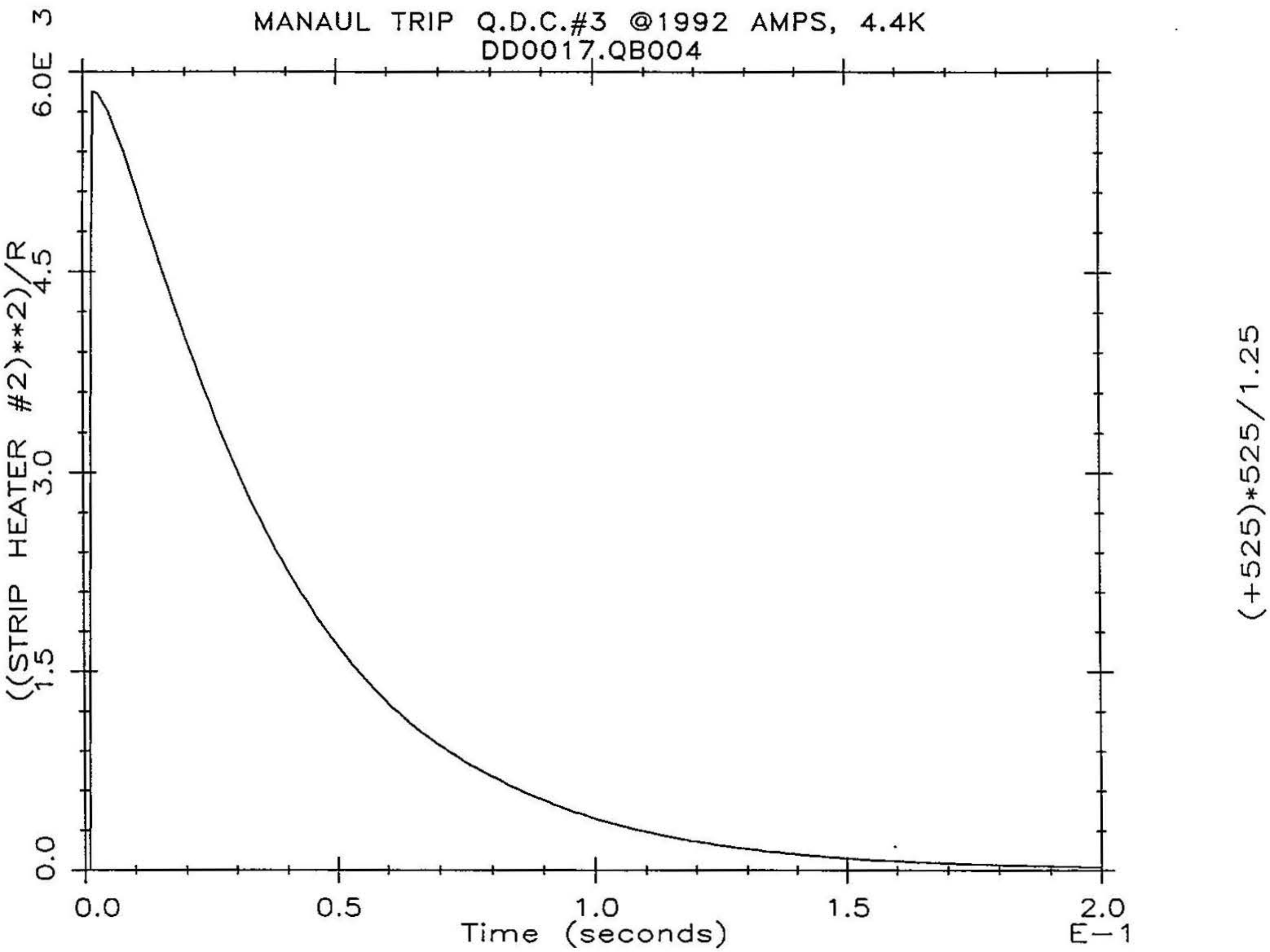
$E \simeq 396$ joules / Htr.

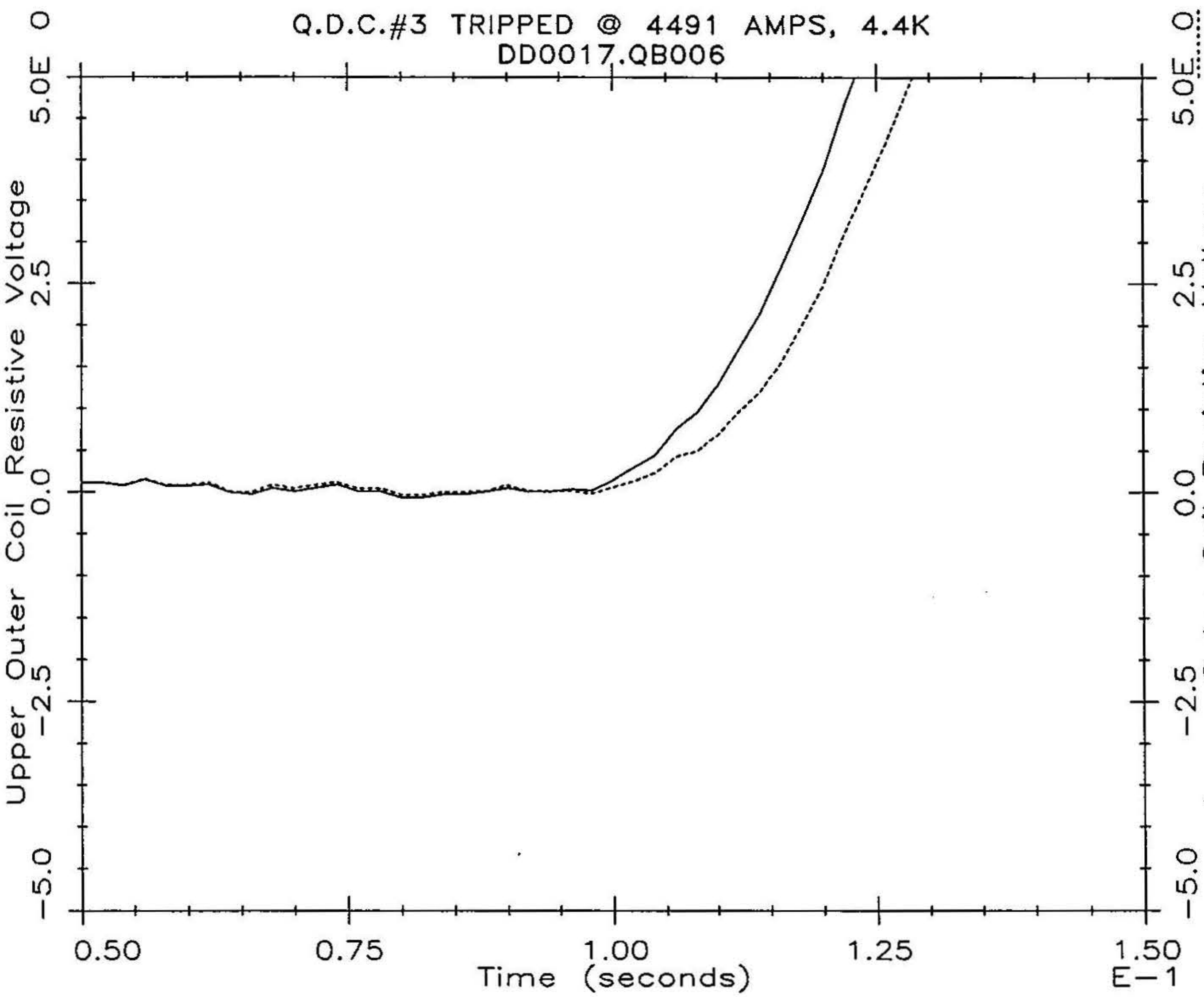


$\int_0^{.165} p\,dt \simeq 393$ joules

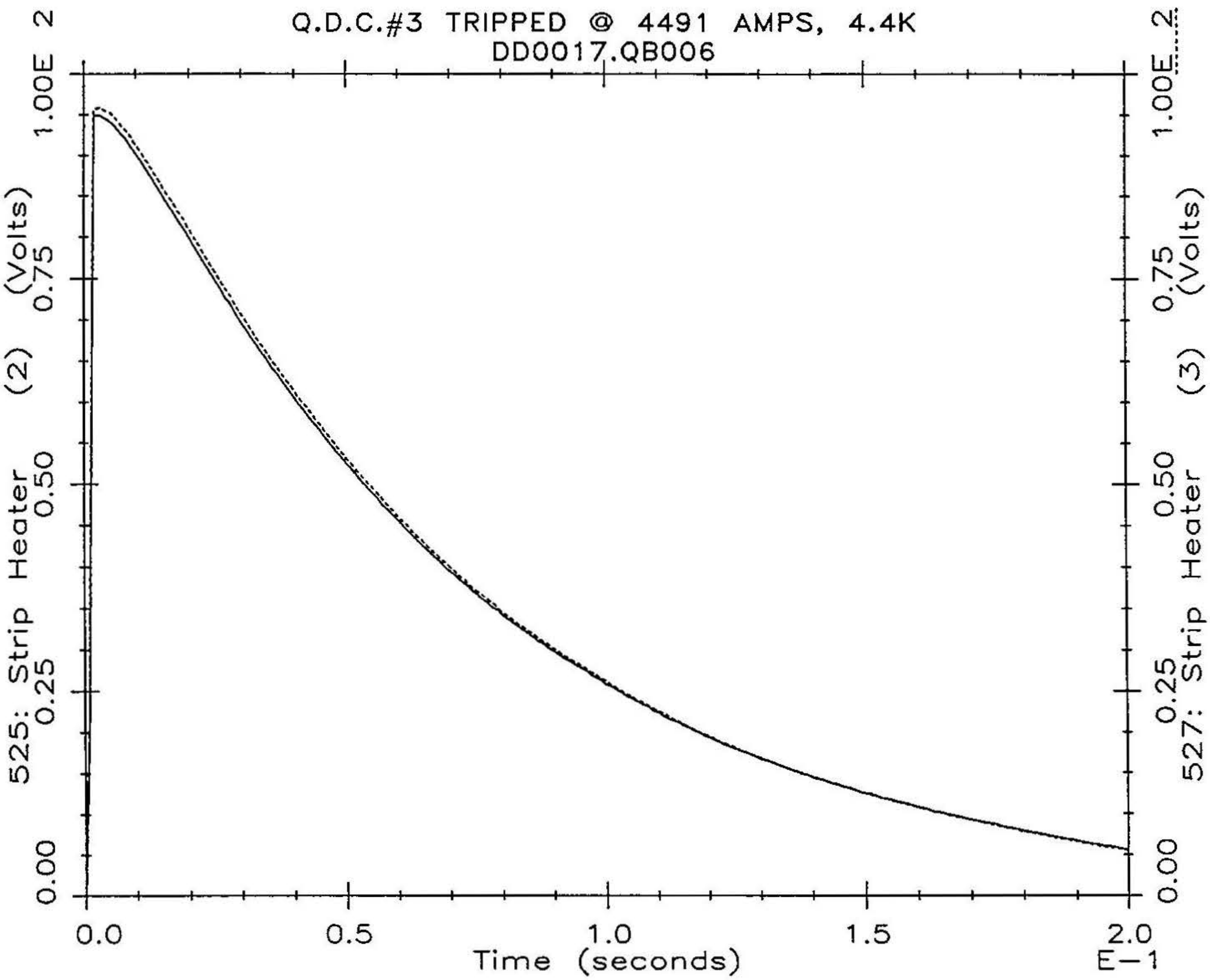

MANAUL TRIP Q.D.C.#3 @1992 AMPS, 4.4K
DD0017.QB004
1.0E 0
0.5
0.0
−0.5
−1.0
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
0.
1.
2.
3.
4.
E−1
Time (seconds)

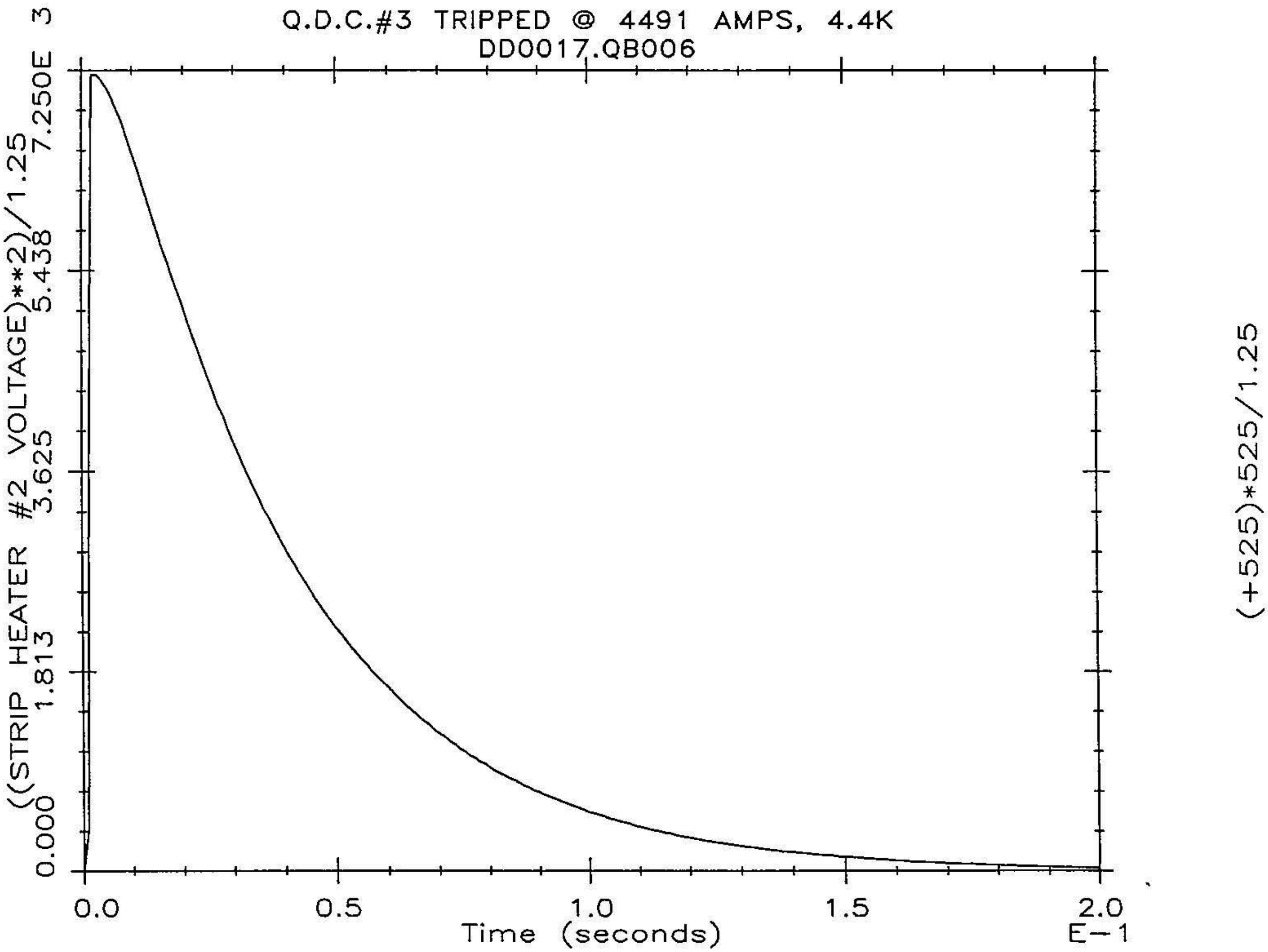

MANAUL TRIP Q.D.C.#3 @1992 AMPS, 4.4K
DD0017.QB004
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
1.00E 2
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
E−1
Time (seconds)


MANAUL TRIP Q.D.C.#3 @1992 AMPS, 4.4K
DD0017.QB004
((STRIP HEATER #2)**2)/R
6.0E 3
4.5
3.0
1.5
0.0
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)
(+525)*525/1.25

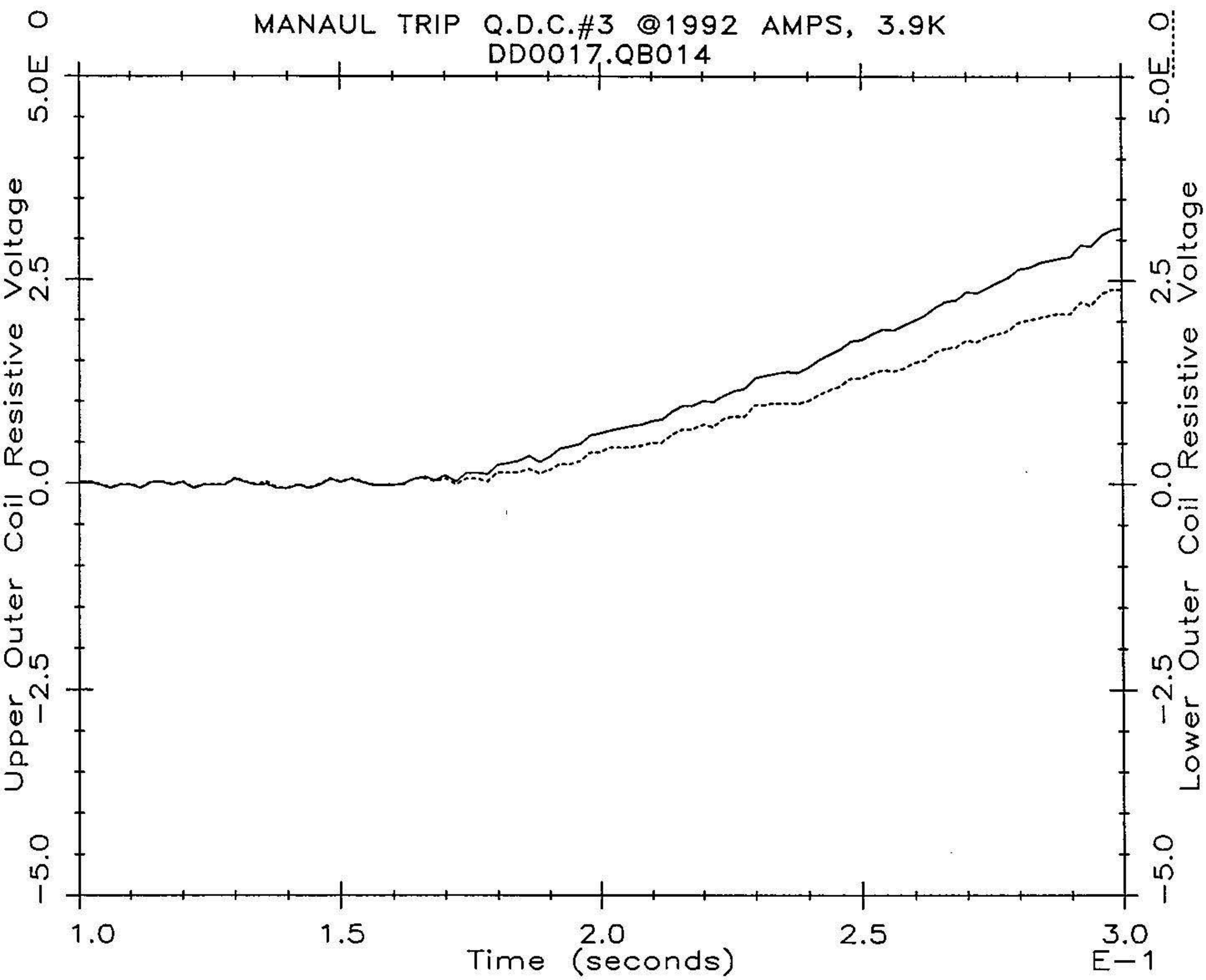


Q.D.C.#3 TRIPPED @ 4491 AMPS, 4.4K
DD0017.QB006
5.0E 0
2.5
0.0
−2.5
−5.0
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
0.50
0.75
1.00
1.25
1.50
E−1
Time (seconds)

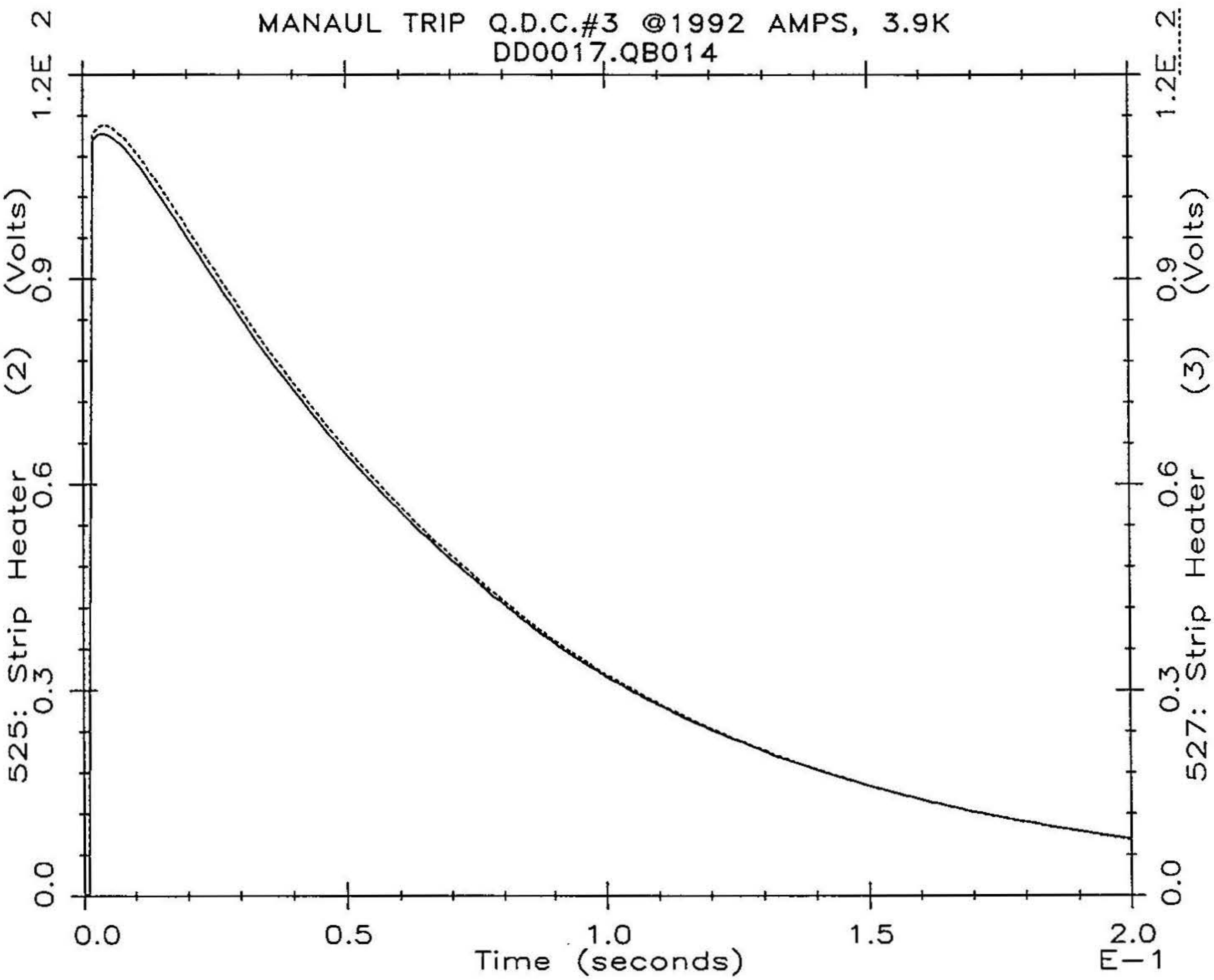

Q.D.C.#3 TRIPPED @ 4491 AMPS, 4.4K
DD0017.QB006
1.00E 2
0.75
0.50
0.25
0.00
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
0.0
0.5
1.0
1.5
2.0
E−1
Time (seconds)



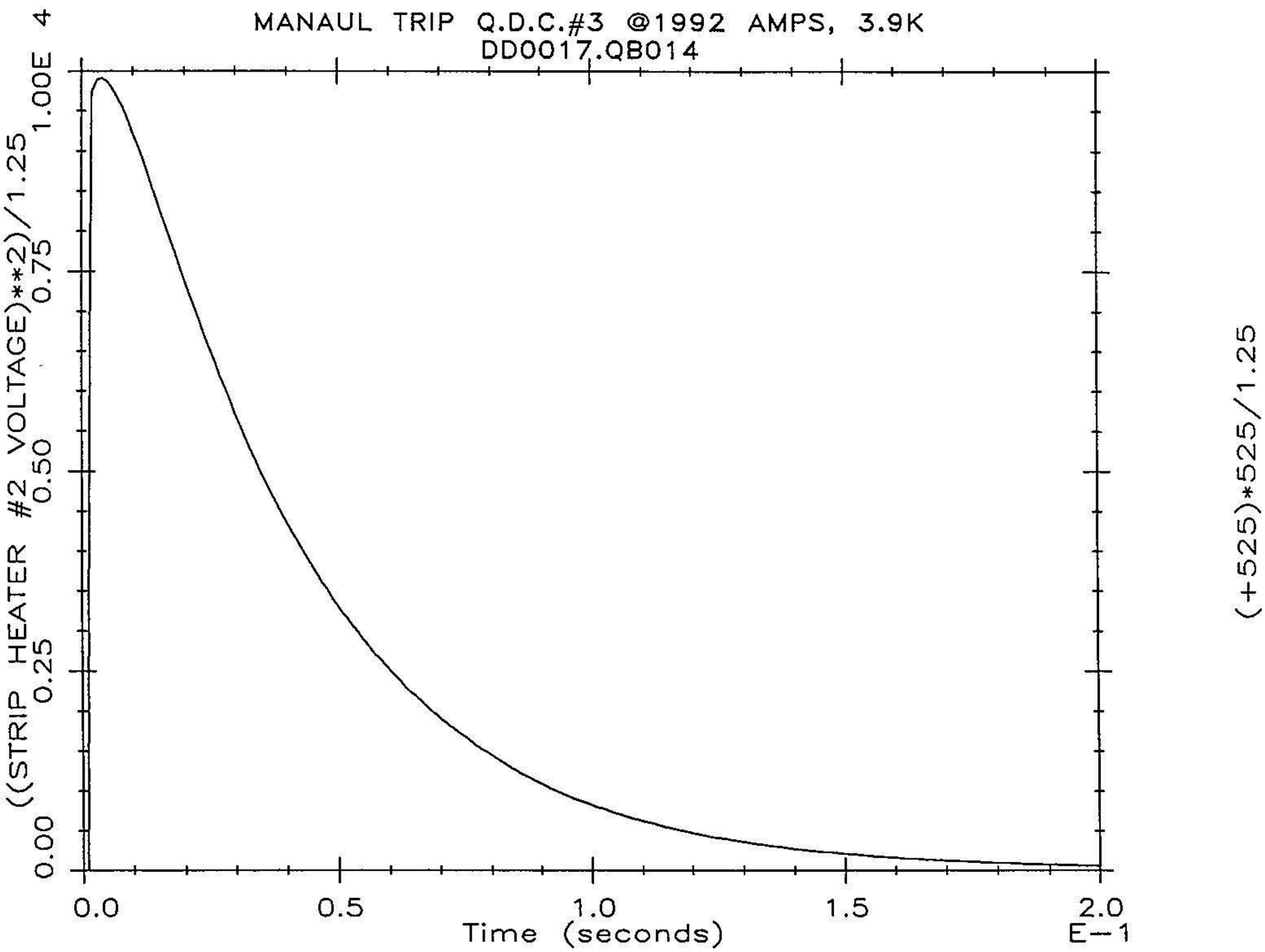
Q.D.C.#3 TRIPPED @ 4491 AMPS, 4.4K
DD0017.QB006
((STRIP HEATER #2 VOLTAGE)**2)/1.25
7.250E 3
5.438
3.625
1.813
0.000
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)
(+525)*525/1.25

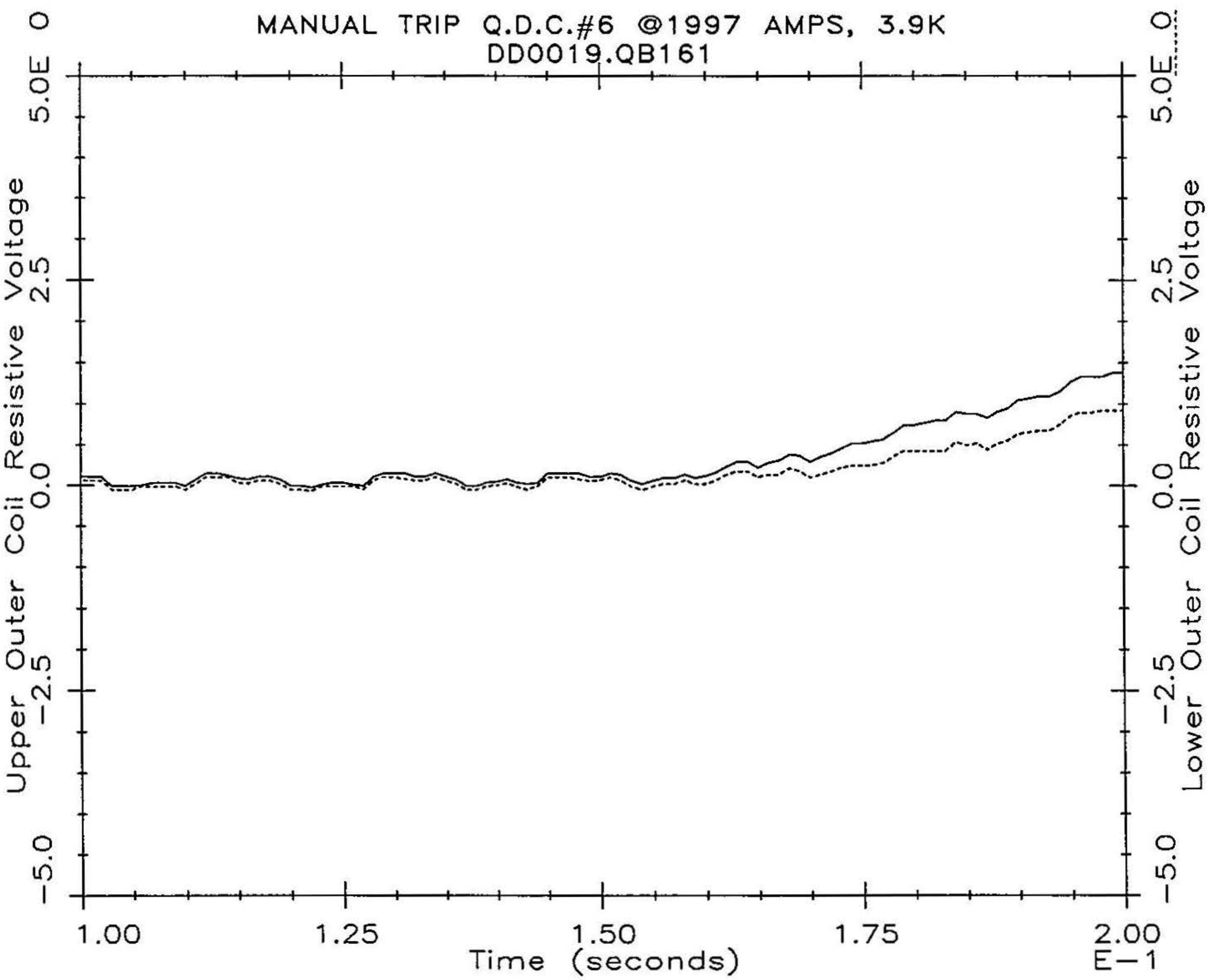


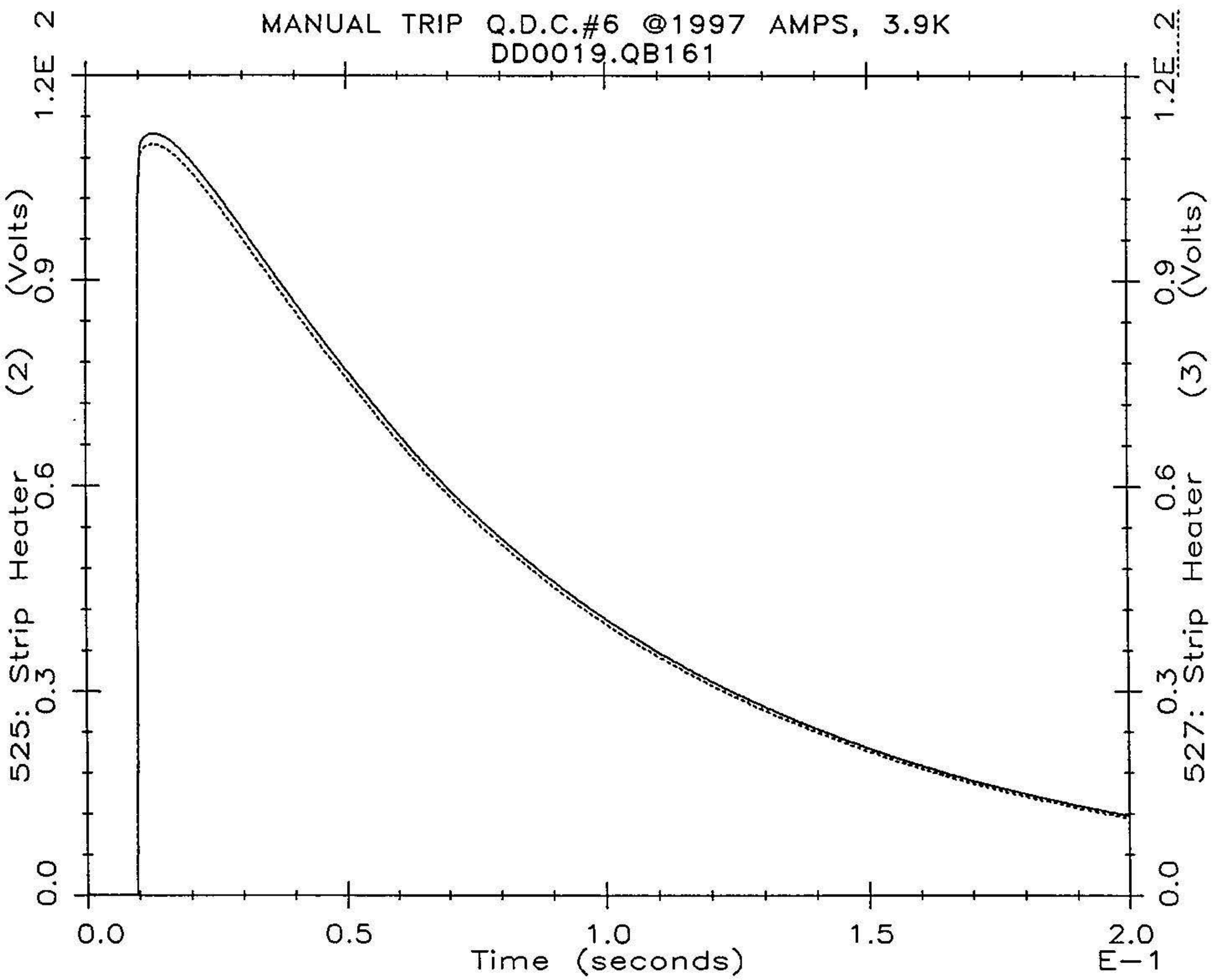
MANAUL TRIP Q.D.C.#3 @1992 AMPS, 3.9K
DD0017.QB014
Upper Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
Lower Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
1.0
1.5
2.0
2.5
3.0
E−1
Time (seconds)

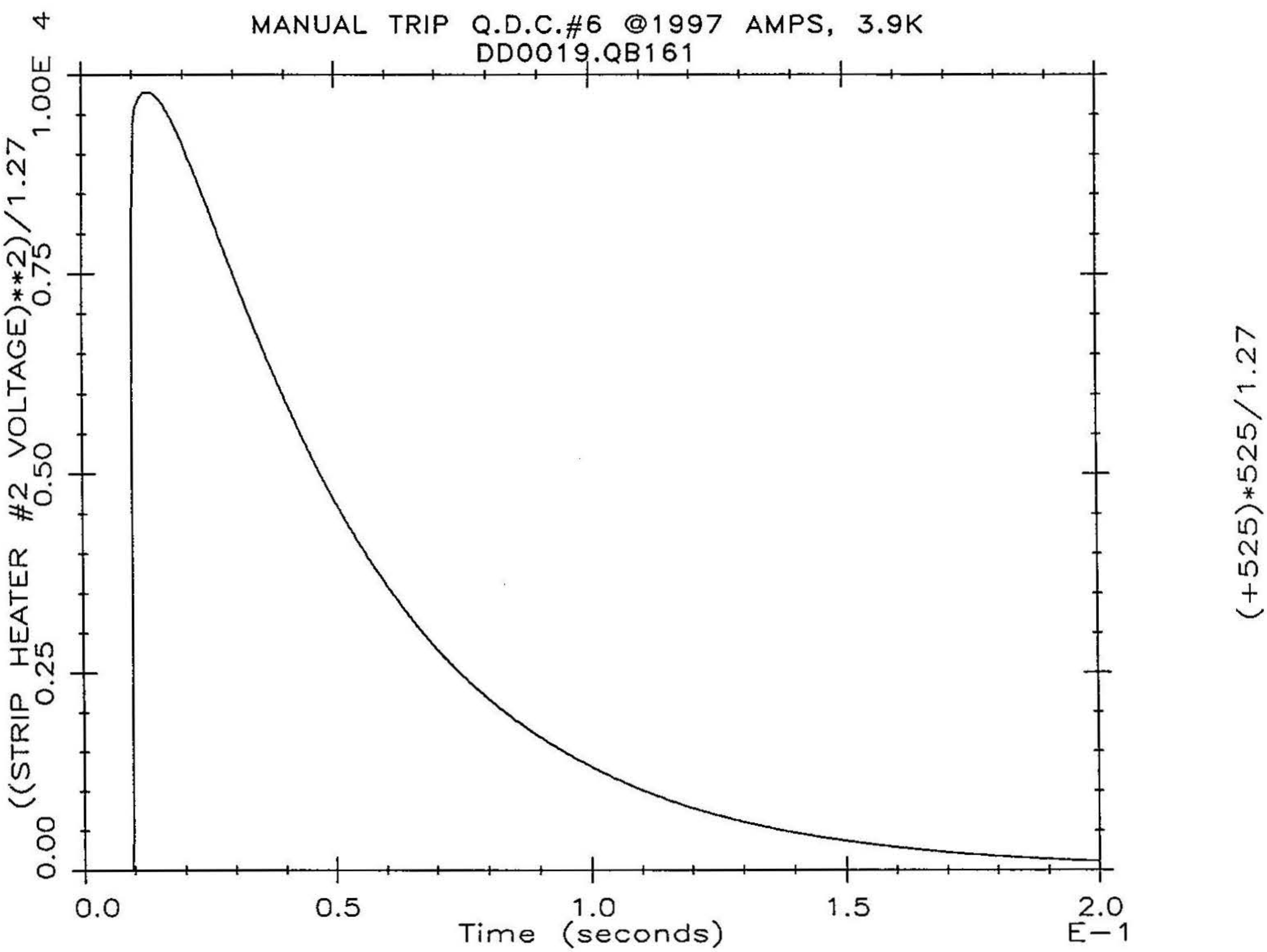


MANAUL TRIP Q.D.C.#3 @1992 AMPS, 3.9K
DD0017.QB014
1.2E 2
0.9
0.6
0.3
0.0
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)

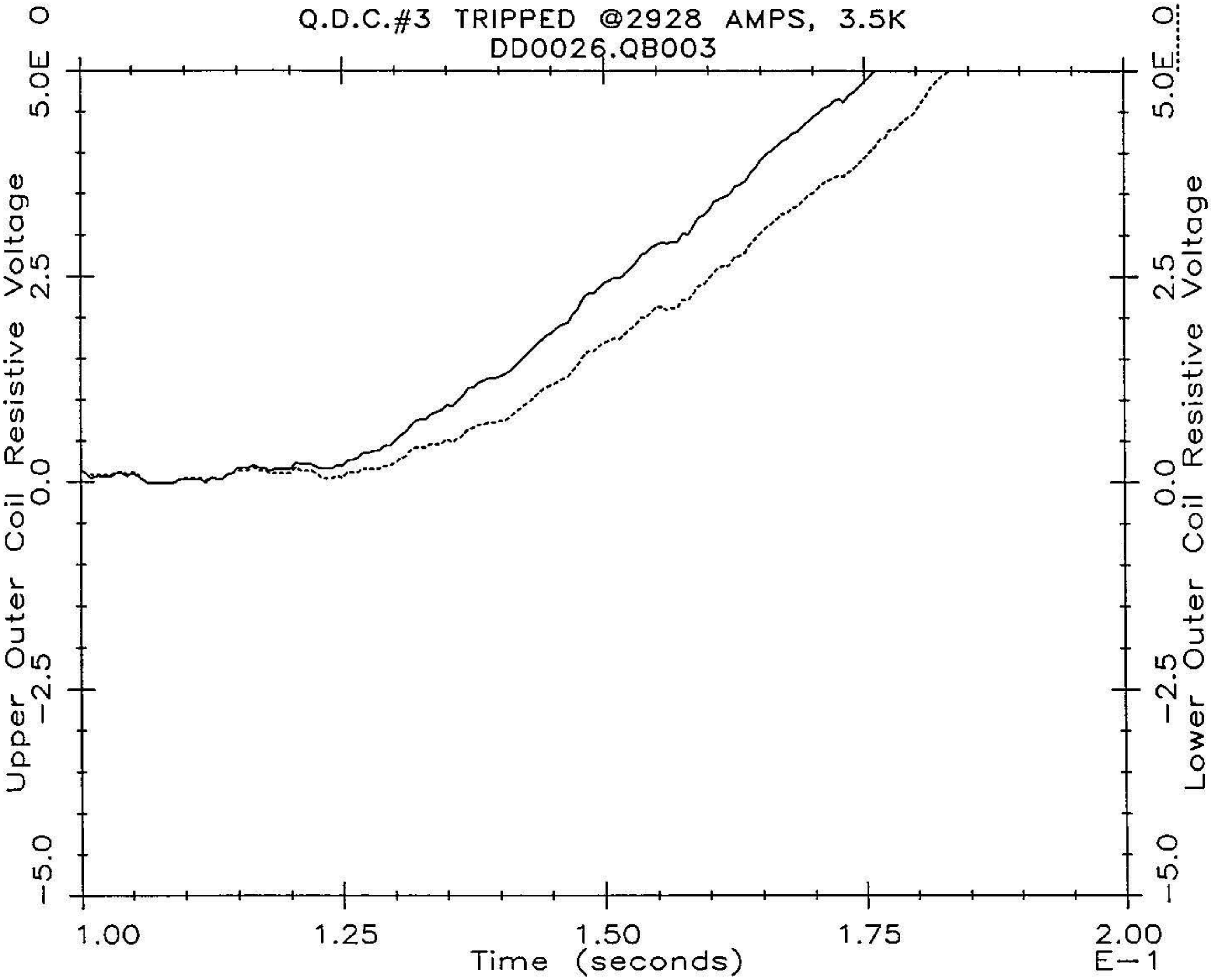

MANAUL TRIP Q.D.C.#3 @1992 AMPS, 3.9K
DD0017.QB014
((STRIP HEATER #2 VOLTAGE)**2)/1.25
1.00E 4
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)
(+525)*525/1.25


MANUAL TRIP Q.D.C.#6 @1997 AMPS, 3.9K
DD0019.QB161
5.0E 0
2.5
0.0
−2.5
−5.0
Upper Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
Lower Outer Coil Resistive Voltage
1.00
1.25
1.50
1.75
2.00
E−1
Time (seconds)

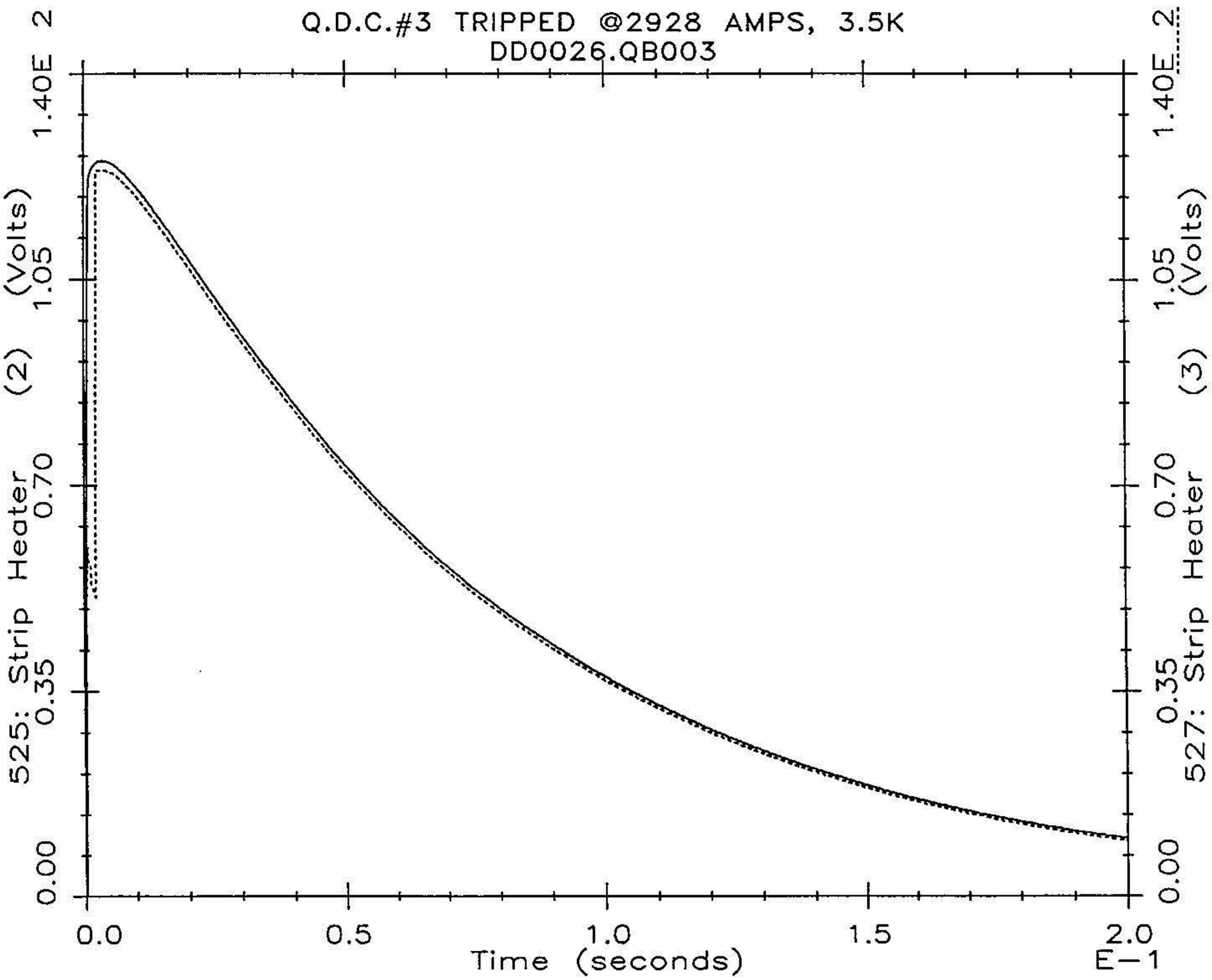

MANUAL TRIP Q.D.C.#6 @1997 AMPS, 3.9K
DD0019.QB161
1.2E 2
0.9
0.6
0.3
0.0
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)

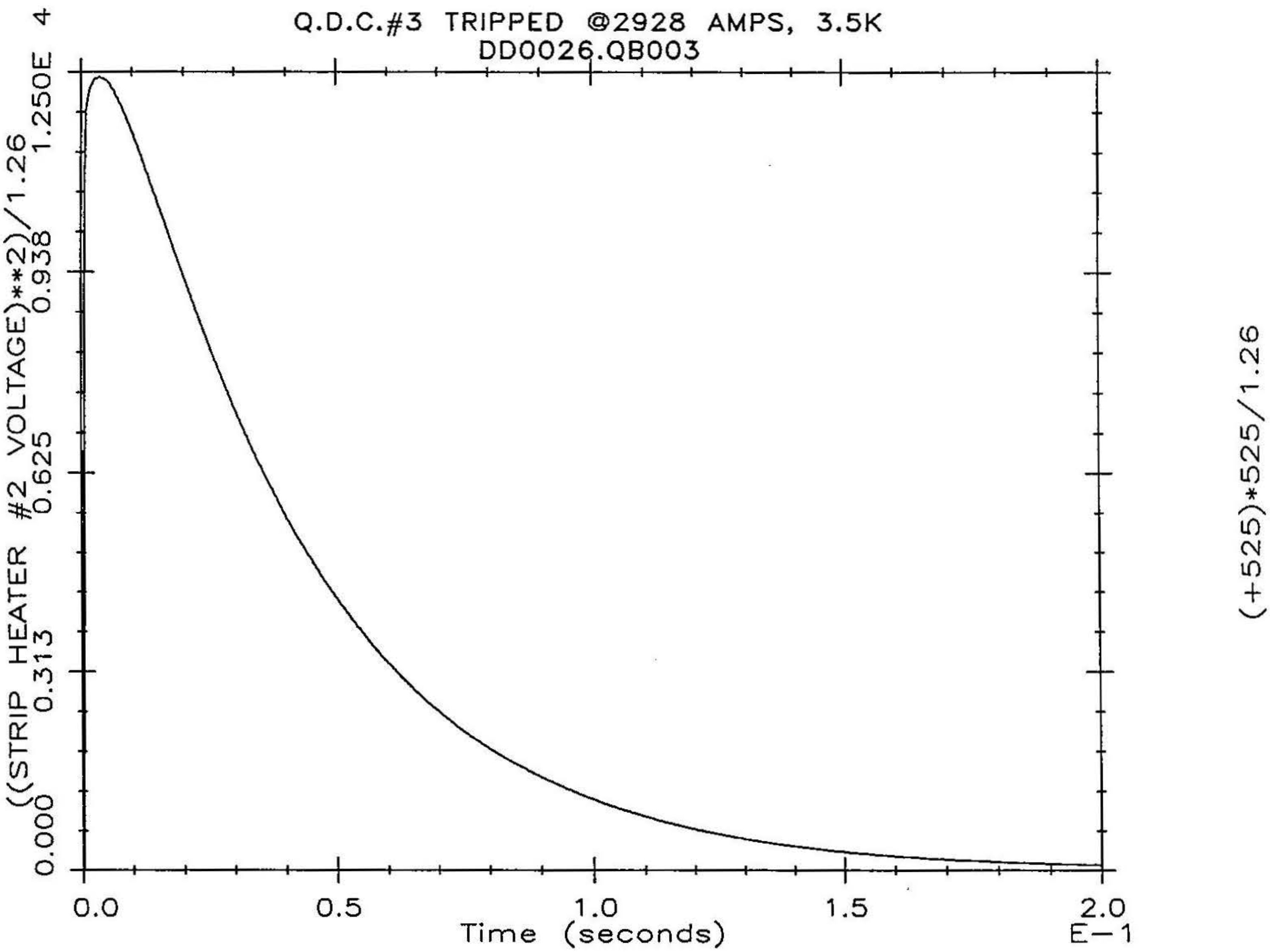


MANUAL TRIP Q.D.C.#6 @1997 AMPS, 3.9K
DD0019.QB161
((STRIP HEATER #2 VOLTAGE)**2)/1.27
1.00E 4
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
E−1
Time (seconds)
(+525)*525/1.27

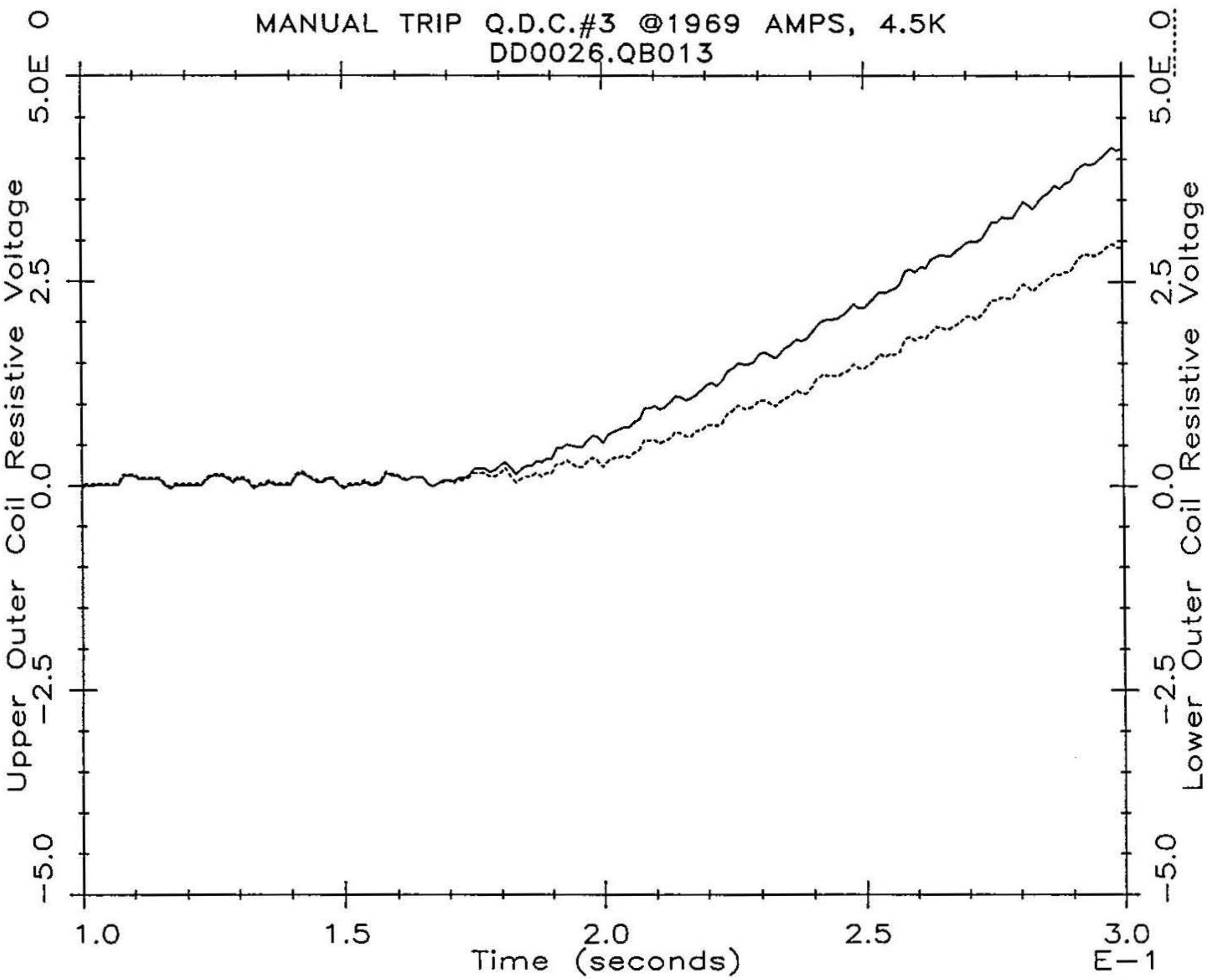


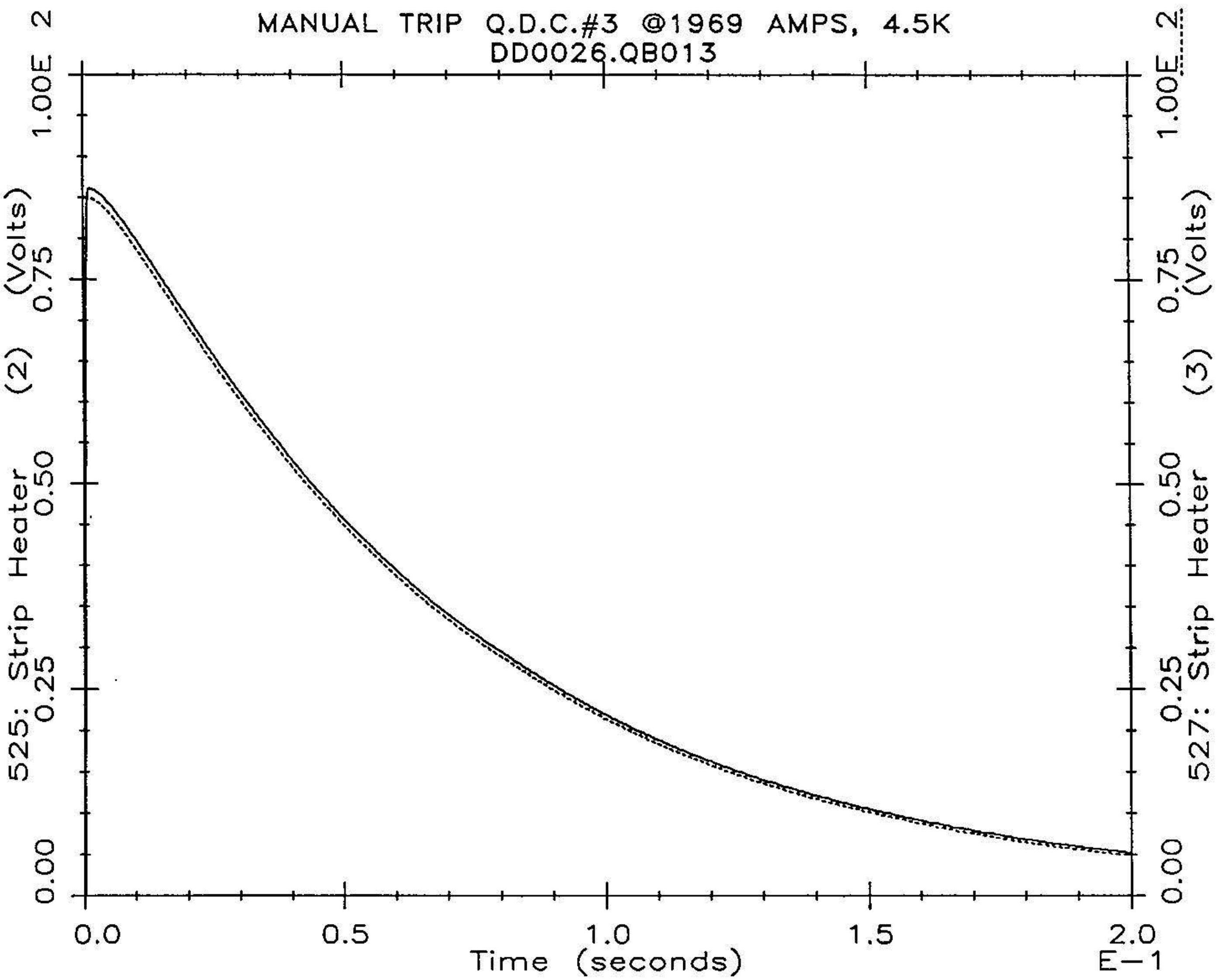
Q.D.C.#3 TRIPPED @2928 AMPS, 3.5K
DD0026.QB003
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
−2.5
−5.0
1.00
1.25
1.50
1.75
2.00
E−1
Time (seconds)

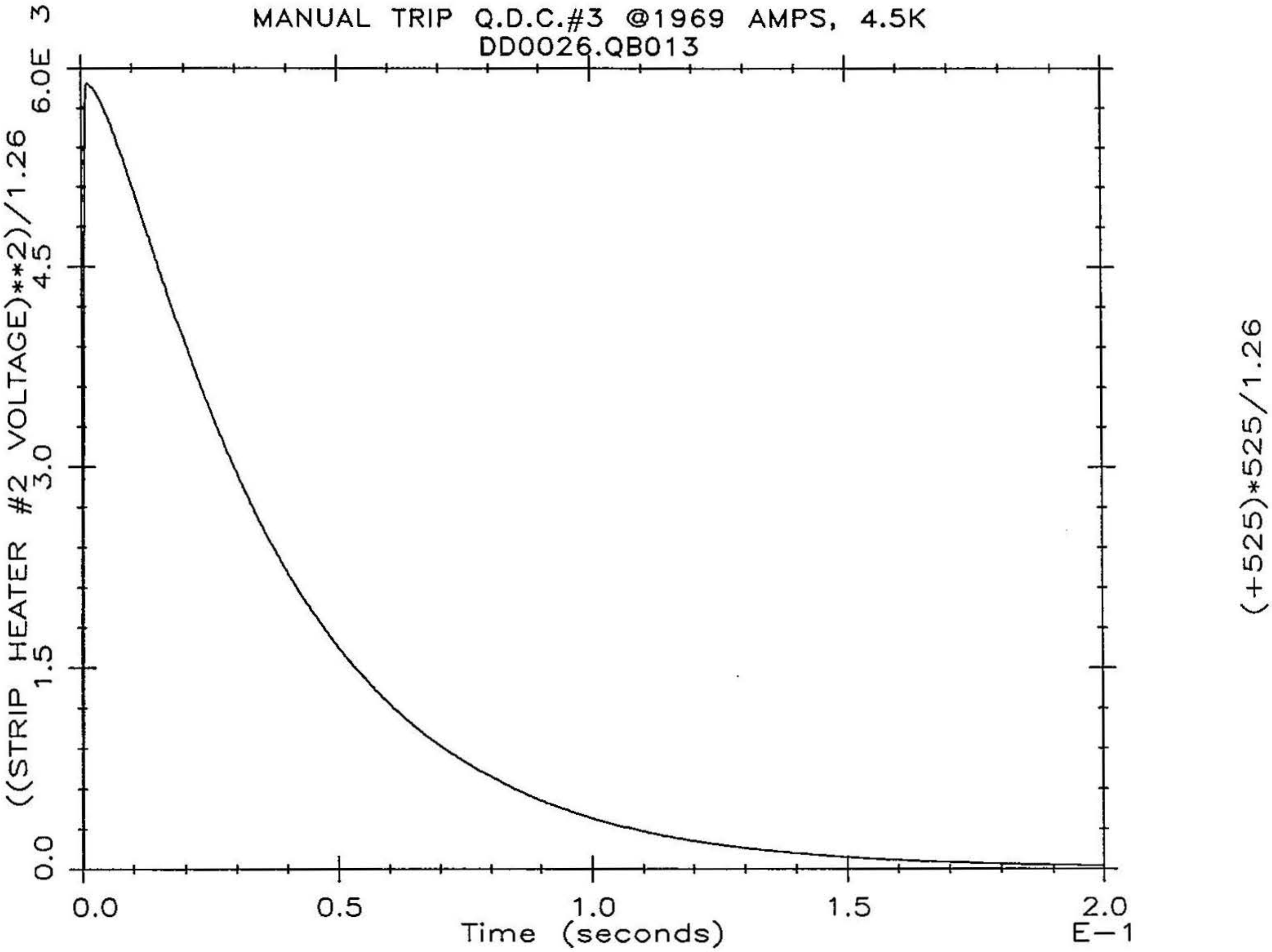

Q.D.C.#3 TRIPPED @2928 AMPS, 3.5K
DD0026.QB003
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
1.40E 2
1.05
0.70
0.35
0.00
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)



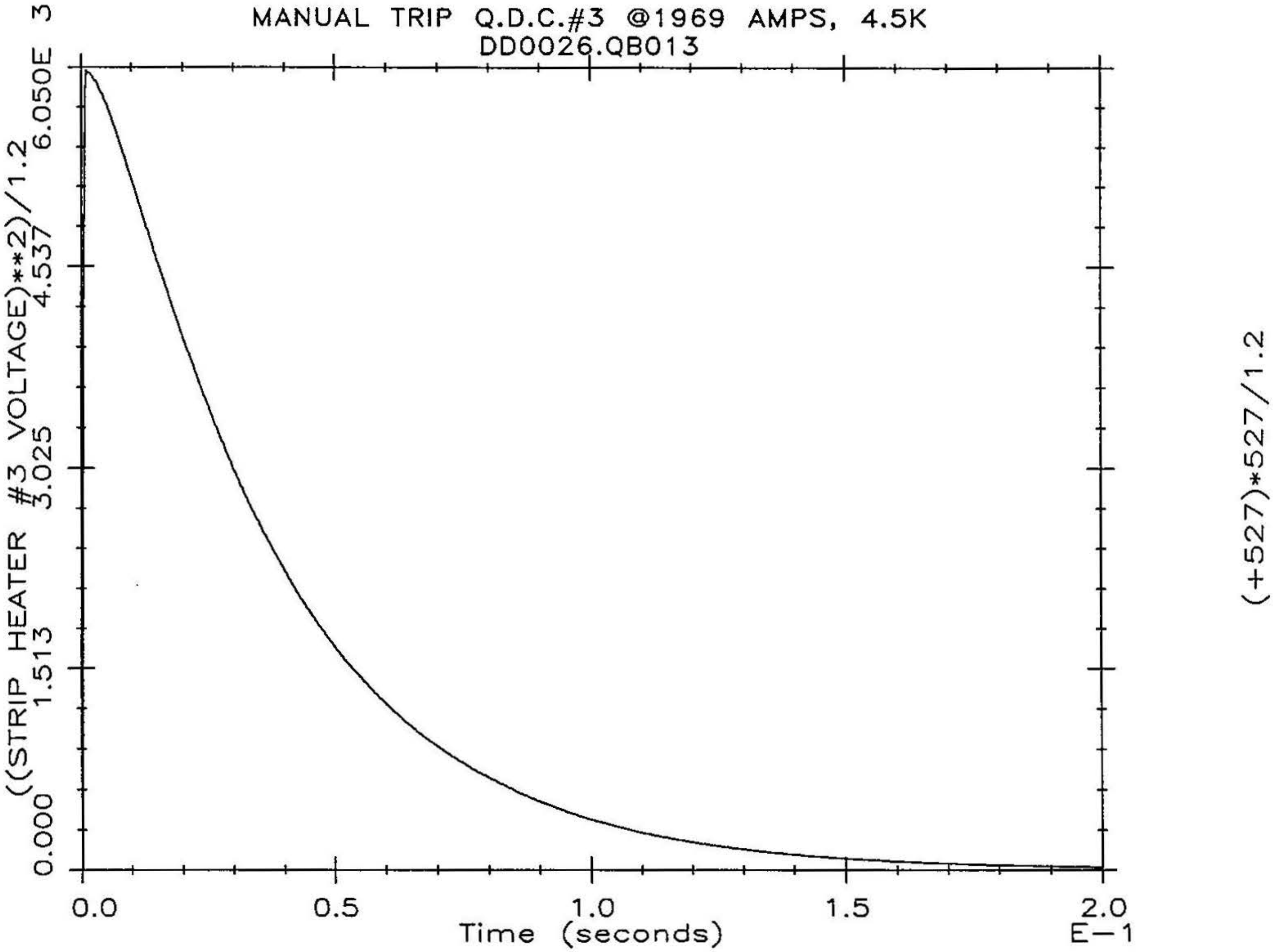
Q.D.C.#3 TRIPPED @2928 AMPS, 3.5K
DD0026.QB003
((STRIP HEATER #2 VOLTAGE)**2)/1.26
1.250E 4
0.938
0.625
0.313
0.000
(+525)*525/1.26
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)


MANUAL TRIP Q.D.C.#3 @1969 AMPS, 4.5K
DD0026.QB013
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
5.0E 0
2.5
0.0
-2.5
-5.0
1.0
1.5
2.0
2.5
3.0
E-1
Time (seconds)

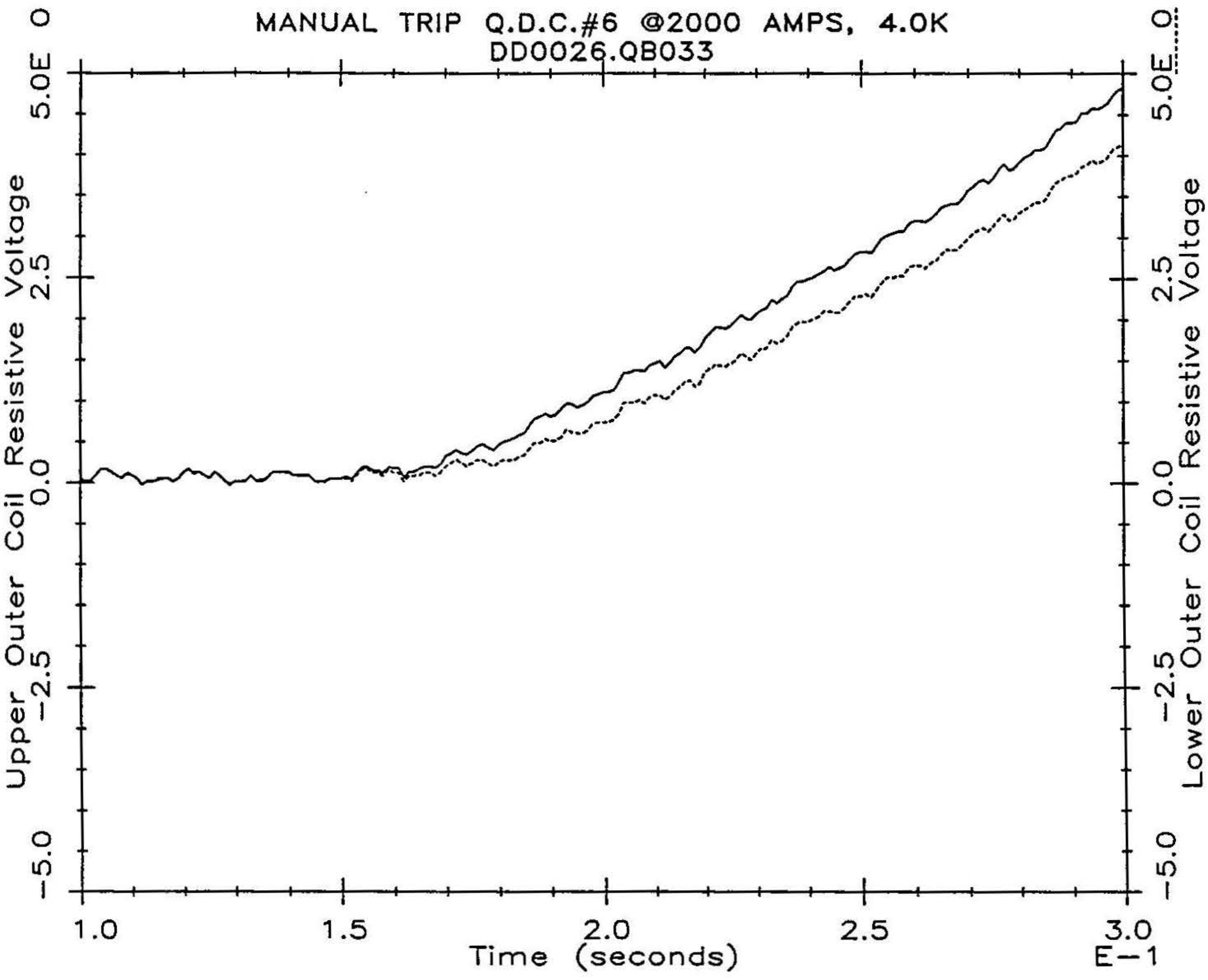

MANUAL TRIP Q.D.C.#3 @1969 AMPS, 4.5K
DD0026.QB013
1.00E 2
0.75
0.50
0.25
0.00
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)



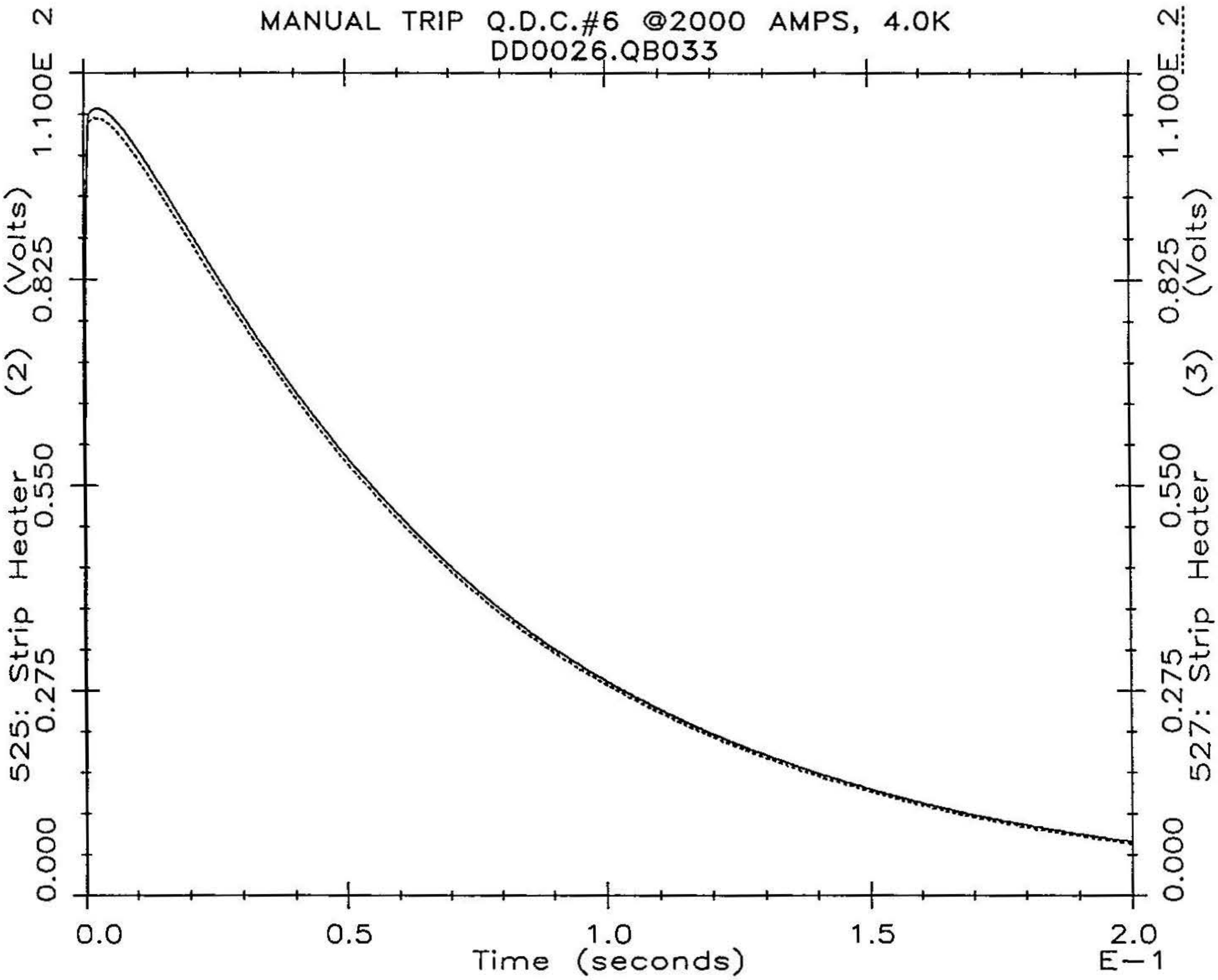
MANUAL TRIP Q.D.C.#3 @1969 AMPS, 4.5K
DD0026.QB013
((STRIP HEATER #2 VOLTAGE)**2)/1.26
6.0E 3
4.5
3.0
1.5
0.0
0.0
0.5
1.0
1.5
2.0
E−1
Time (seconds)
(+525)*525/1.26

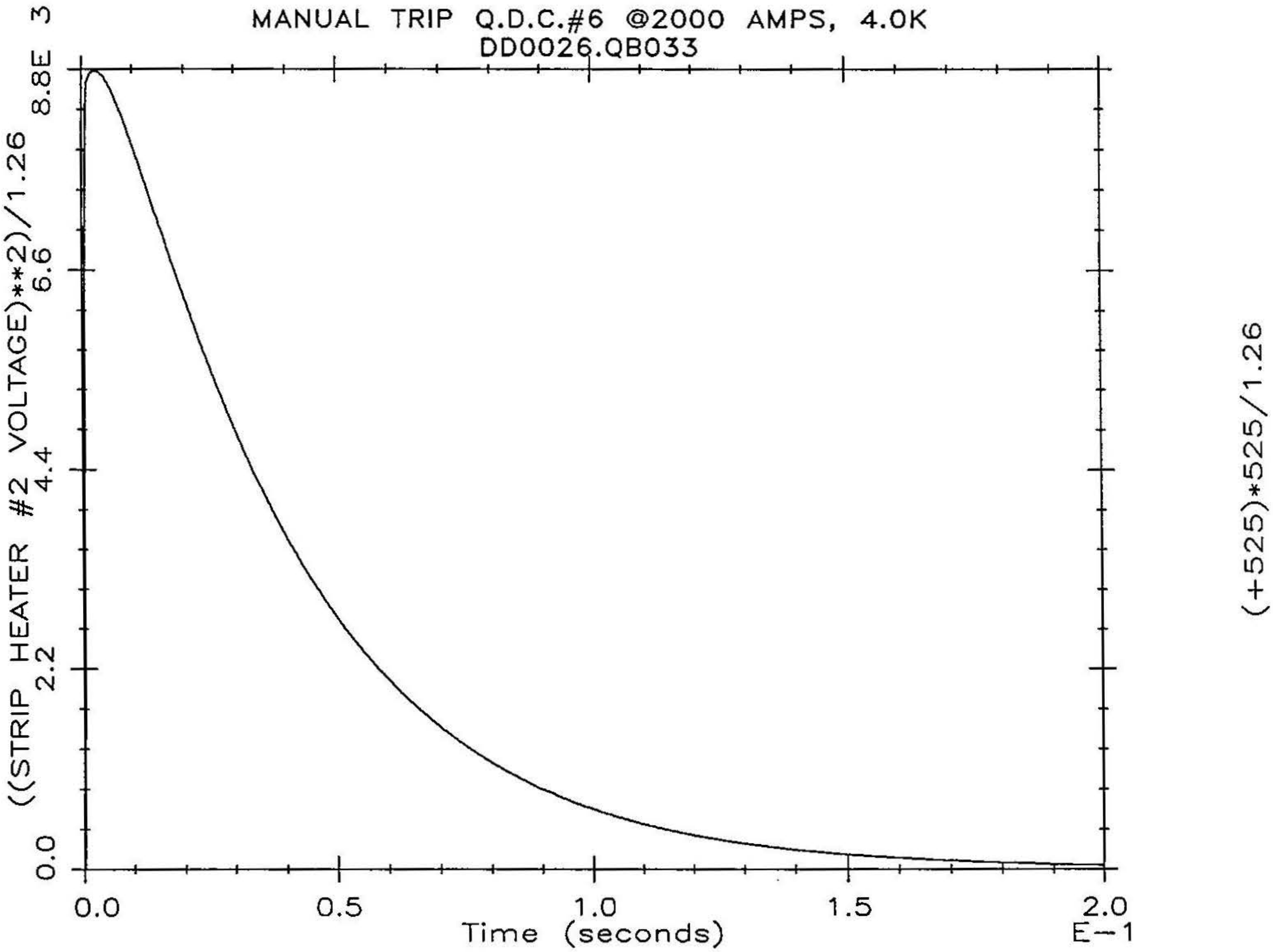


MANUAL TRIP Q.D.C.#3 @1969 AMPS, 4.5K
DD0026.QB013
((STRIP HEATER #3 VOLTAGE)**2)/1.2
6.050E 3
4.537
3.025
1.513
0.000
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)
(+527)*527/1.2



MANUAL TRIP Q.D.C.#6 @2000 AMPS, 4.0K
DD0026.QB033
5.0E 0
2.5
0.0
−2.5
−5.0
Upper Outer Coil Resistive Voltage
Lower Outer Coil Resistive Voltage
1.0
1.5
2.0
2.5
3.0
E−1
Time (seconds)


MANUAL TRIP Q.D.C.#6 @2000 AMPS, 4.0K
DD0026.QB033
525: Strip Heater (2) (Volts)
527: Strip Heater (3) (Volts)
1.100E 2
0.825
0.550
0.275
0.000
0.0
0.5
1.0
1.5
2.0
E−1
Time (seconds)



MANUAL TRIP Q.D.C.#6 @2000 AMPS, 4.0K
DD0026.QB033
((STRIP HEATER #2 VOLTAGE)**2)/1.26
8.8E 3
6.6
4.4
2.2
0.0
0.0
0.5
1.0
1.5
2.0
E-1
Time (seconds)
(+525)*525/1.26