TS-SSC 92-026

TEST RESULTS OF DSA328, 50 mm APERTURE MODEL DIPOLE

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TEST RESULTS OF DSA328
50 mm APERTURE, SHORT MODEL DIPOLES

I. INTRODUCTION

II. MECHANICAL BEHAVIOR

III. QUENCH BEHAVIOR

IV. HEATER TESTS

V. AC LOSSS

DSA328

-> VERTICALLY SPLIT YOKE

-> ALUMINUM END CAN/G-10 CR11 COLLETS

-> NO GLASS TAPE ON THE WEDGES (Inner coils)

-> ROOM TEMPERATURE COLLAR STRESS

INNER =70 MPa (10 kpsi) OUTER=45 MPa (6.5kpsi)

-> END PRELOAD =1 kN/per Bullet

-> VOLTAGE TAPS AND SHELL GAGES

2 Layers of 1 mil Kapton replaced glass-epoxy tape
⇒ All Kapton insulated wedges for inner coils.

Outer coils - left over from DSA325

ALL KAPTON INSULATED WEDGES FOR INNER COILS

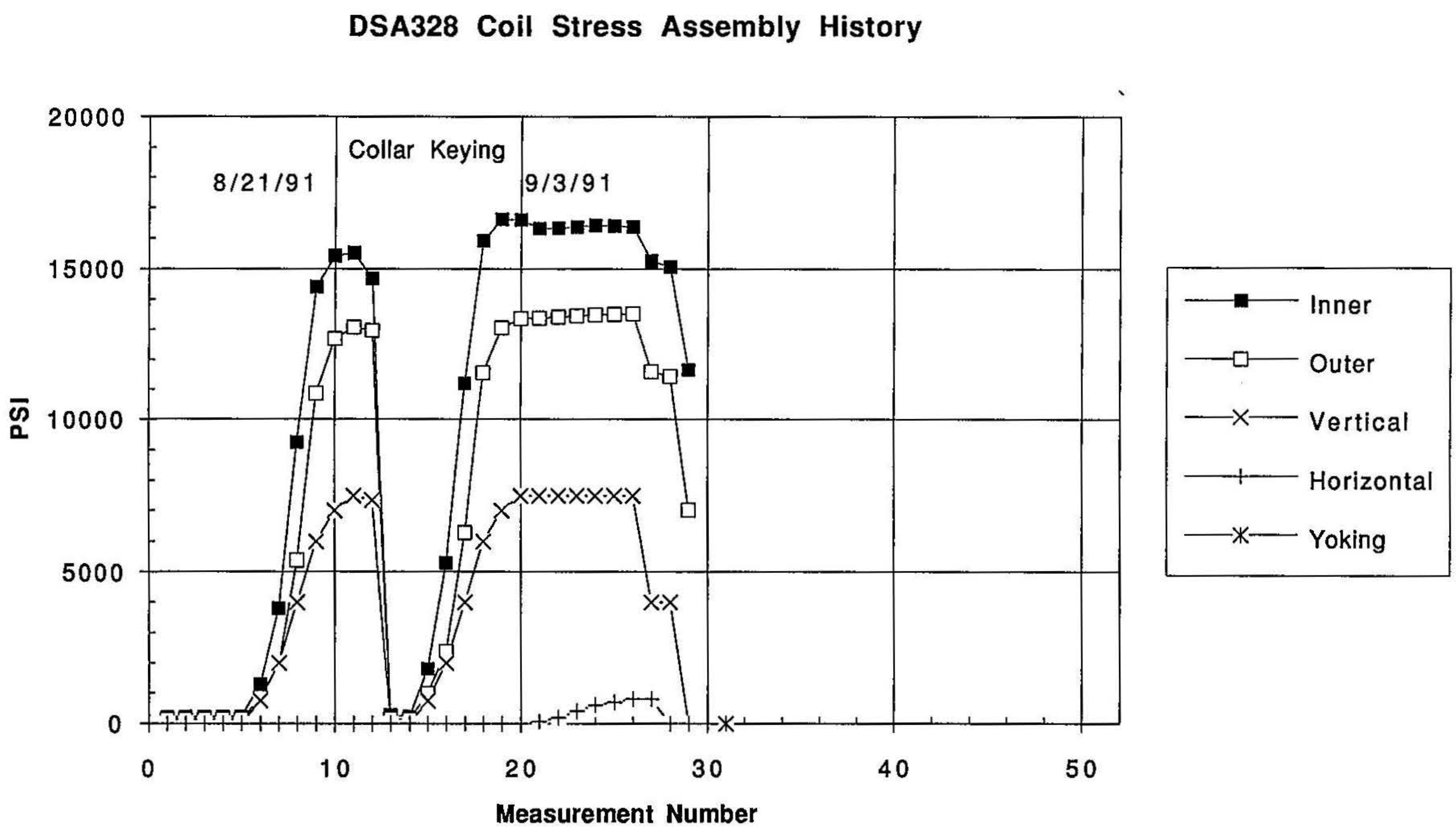
1 Layer of 5 mil Kapton removed from outer coil pole

ADDED 1 Layer of 3.8 mil Kapton to inner coil pole.

DSA329 - ALL KAPTON WEDGES IN BOTH INNER + OUTER COILS

SHIMMING

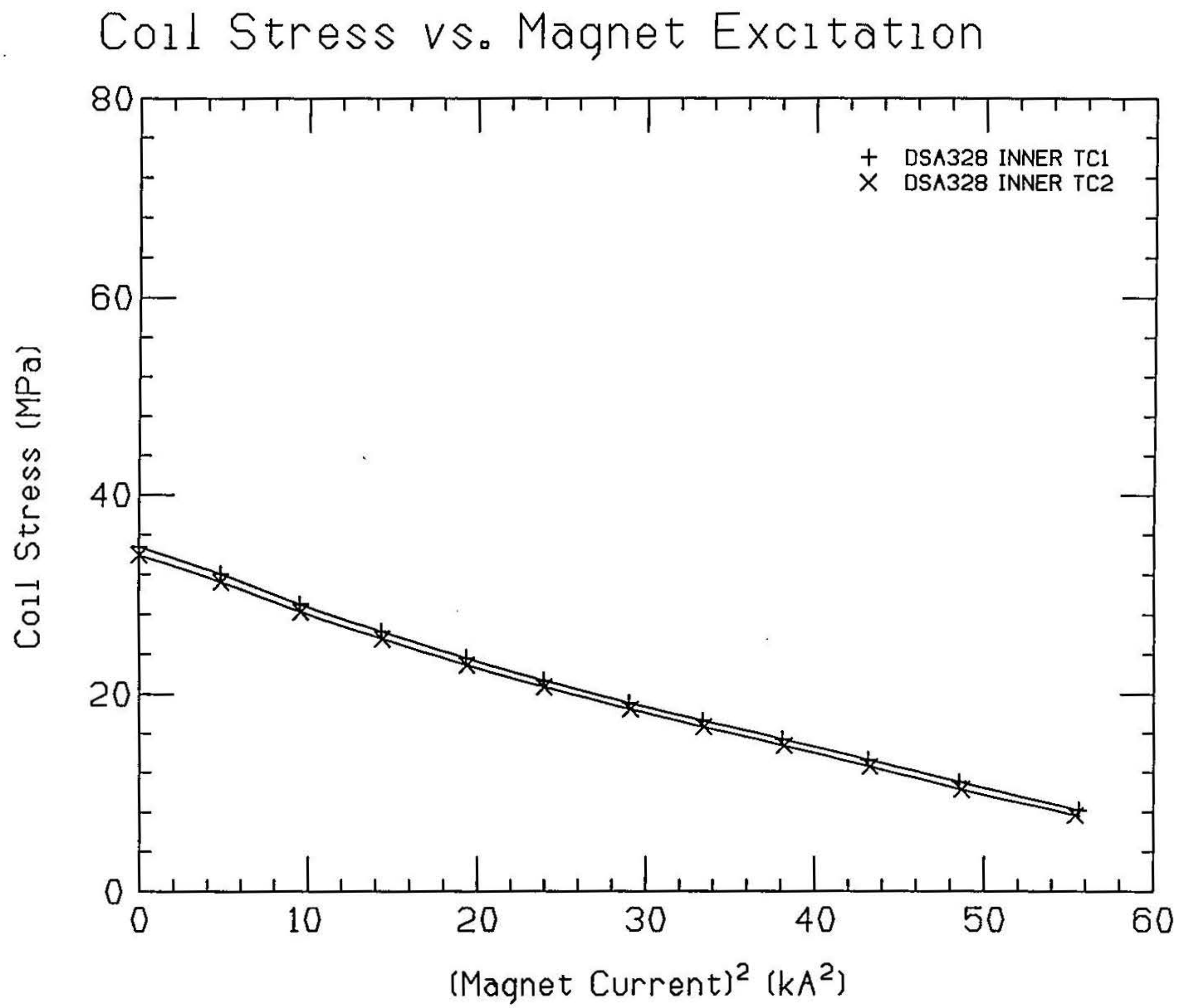
MAGNET	INNER COIL (mils of Kapton)	OUTER COIL
DSA321	0.	0.
DSA323	0.	0.
DSA324	+5.	+5.
DSA326	0.	0.
DSA101	0. (G-10)	-10. +2. (Kapton tape with adhesive)
DSA102	+8. (G-10)	-5. + +2. (Kapton tape with adhesive)
DSA328	+3.8	-5.

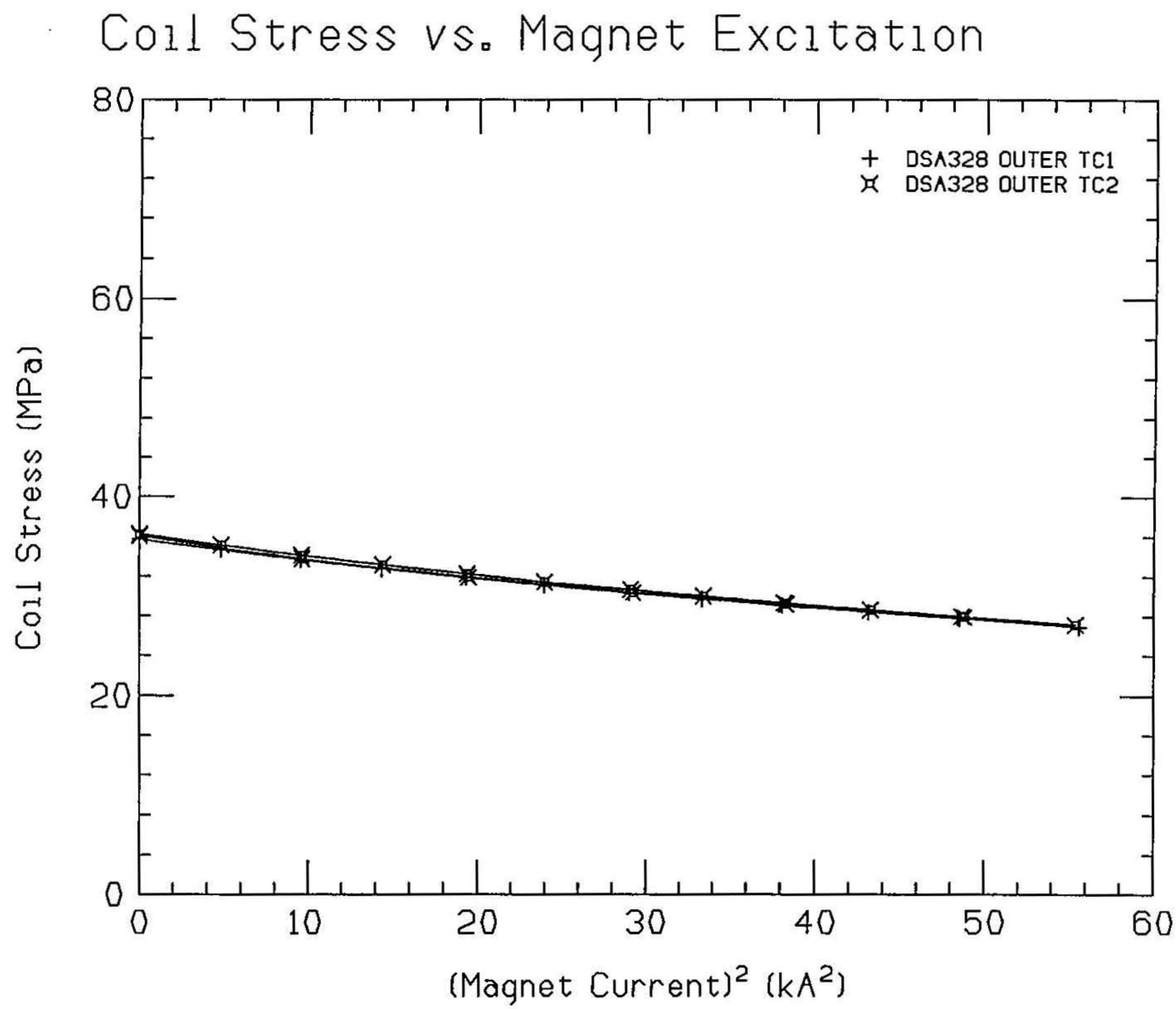


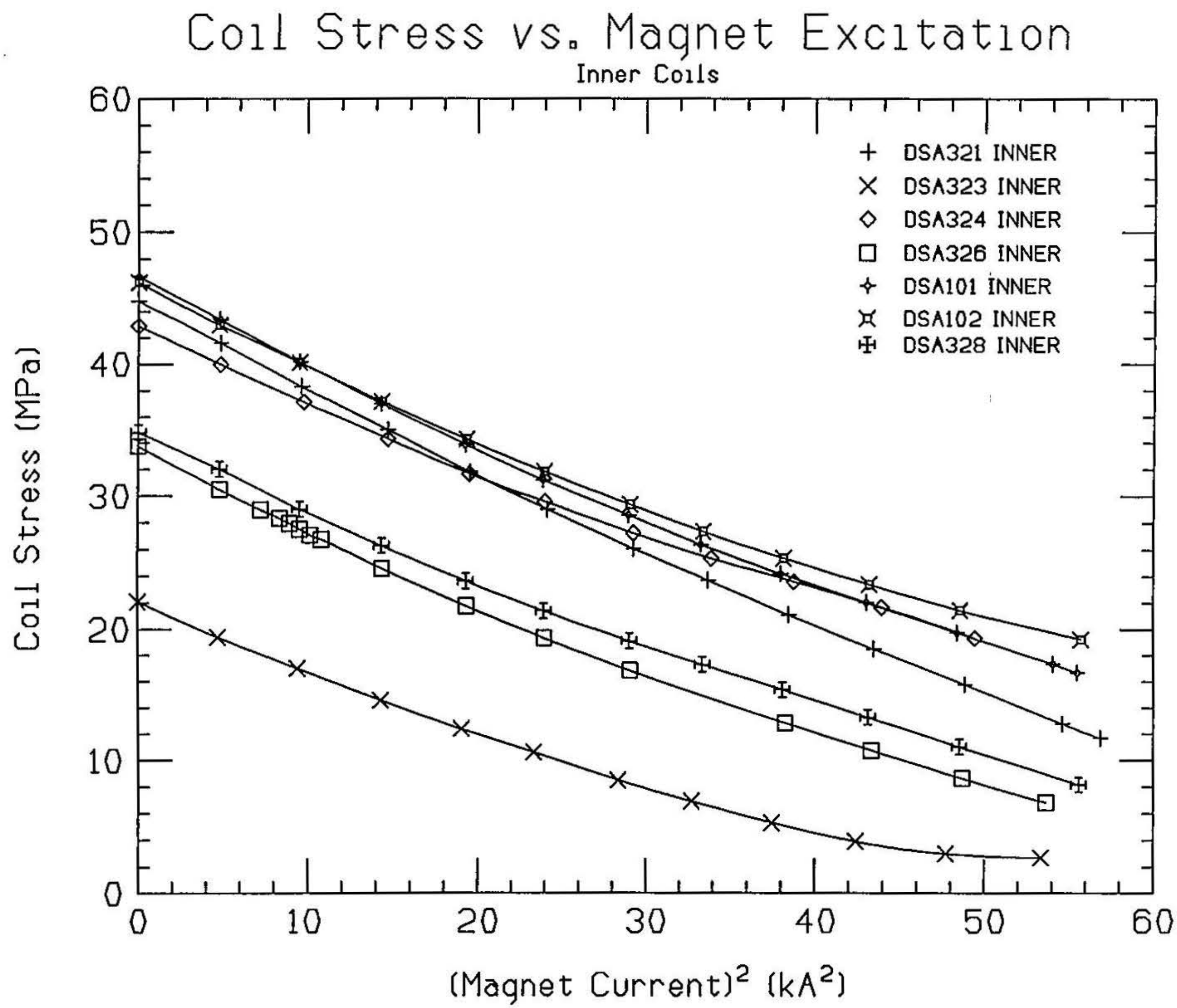
DSA328 Coil Stress Assembly History
20000
15000
10000
5000
0
PSI
0
10
20
30
40
50
Measurement Number
8/21/91
Collar Keying
9/3/91
Inner
Outer
Vertical
Horizontal
Yoking

PRESTRESS CHANGE WITH COOLDOWN
1.5 m Long , 50 mm Aperture
SSC Model Dipoles Tested at Fermilab

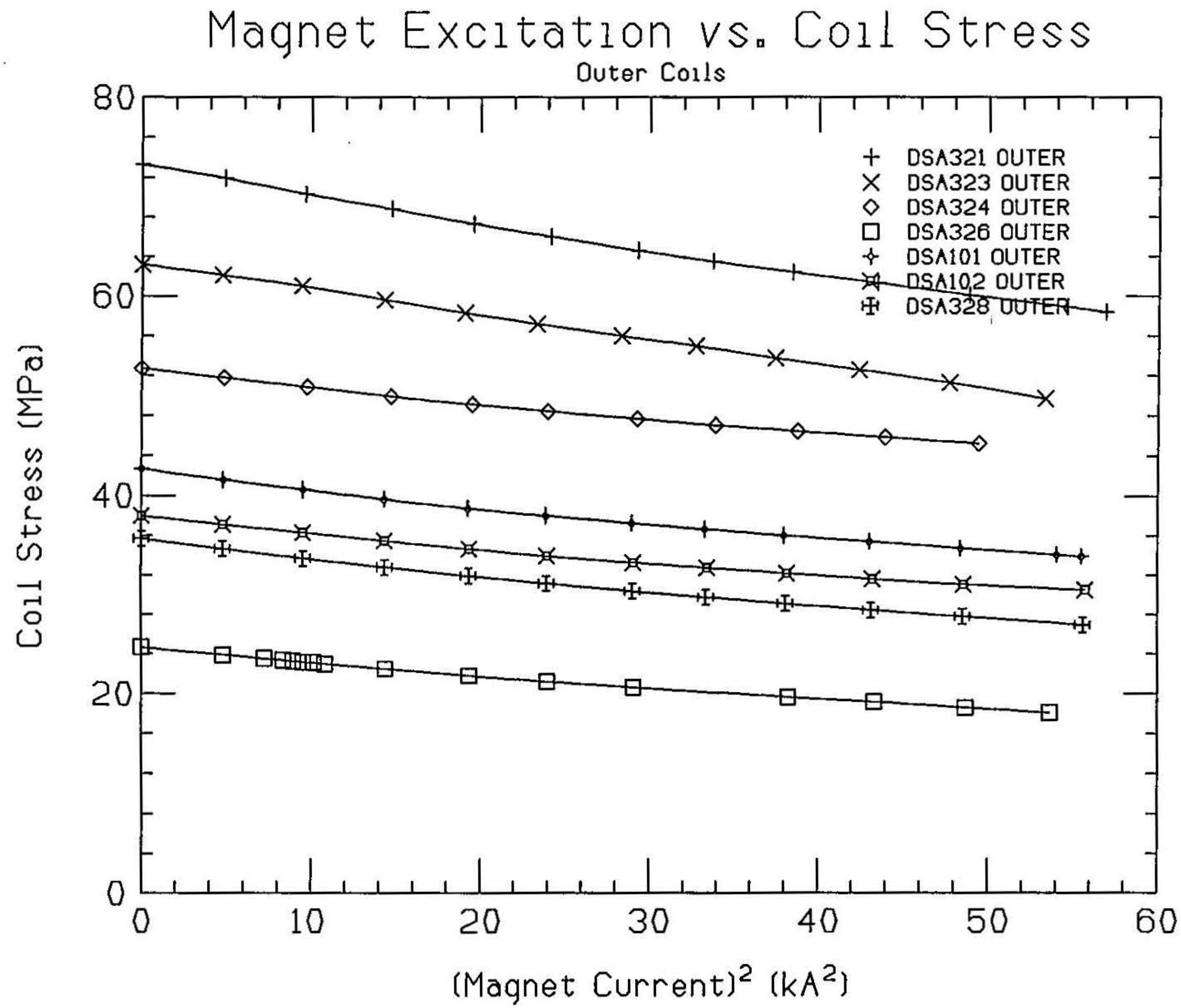
Magnet	Coil Stress Change (MPa) Inner Coil	Coil Stress Change (MPa) Outer Coil	End Force Change (kN)
DSA321	-19	-14	-1
DSA323	-30	-10	0
DSA324	-33	- 8	1
DSA326 (TC1)	-34	-25	4.8
DSA326 (TC2)	-37	-23	5
DSA326 (TC3)	-36	-22	-2.5
DSA101 (TC1)	-35	-22	---
DSA102 (TC1)	-49	-18	---
DSA328 (TC1)	-36	-8.5	+4.2


Coil Stress vs. Magnet Excitation
DSA328 INNER TC1
DSA328 INNER TC2
Coil Stress (MPa)
(Magnet Current)^2 (kA^2)
0
20
40
60
80
0
10
20
30
40
50
60

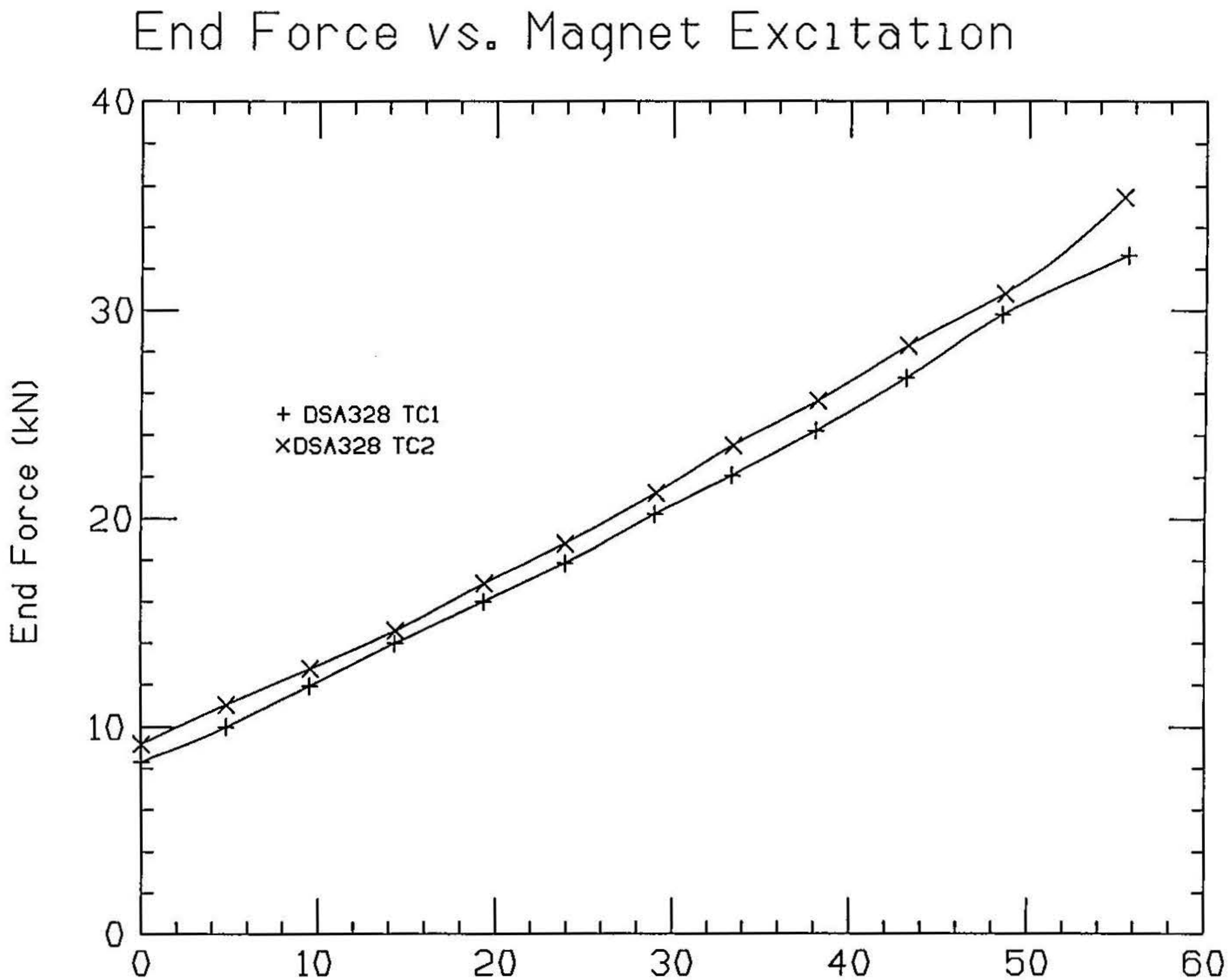

Coil Stress vs. Magnet Excitation
DSA328 OUTER TC1
DSA328 OUTER TC2
Coil Stress (MPa)
(Magnet Current)² (kA²)
0
20
40
60
80
0
10
20
30
40
50
60

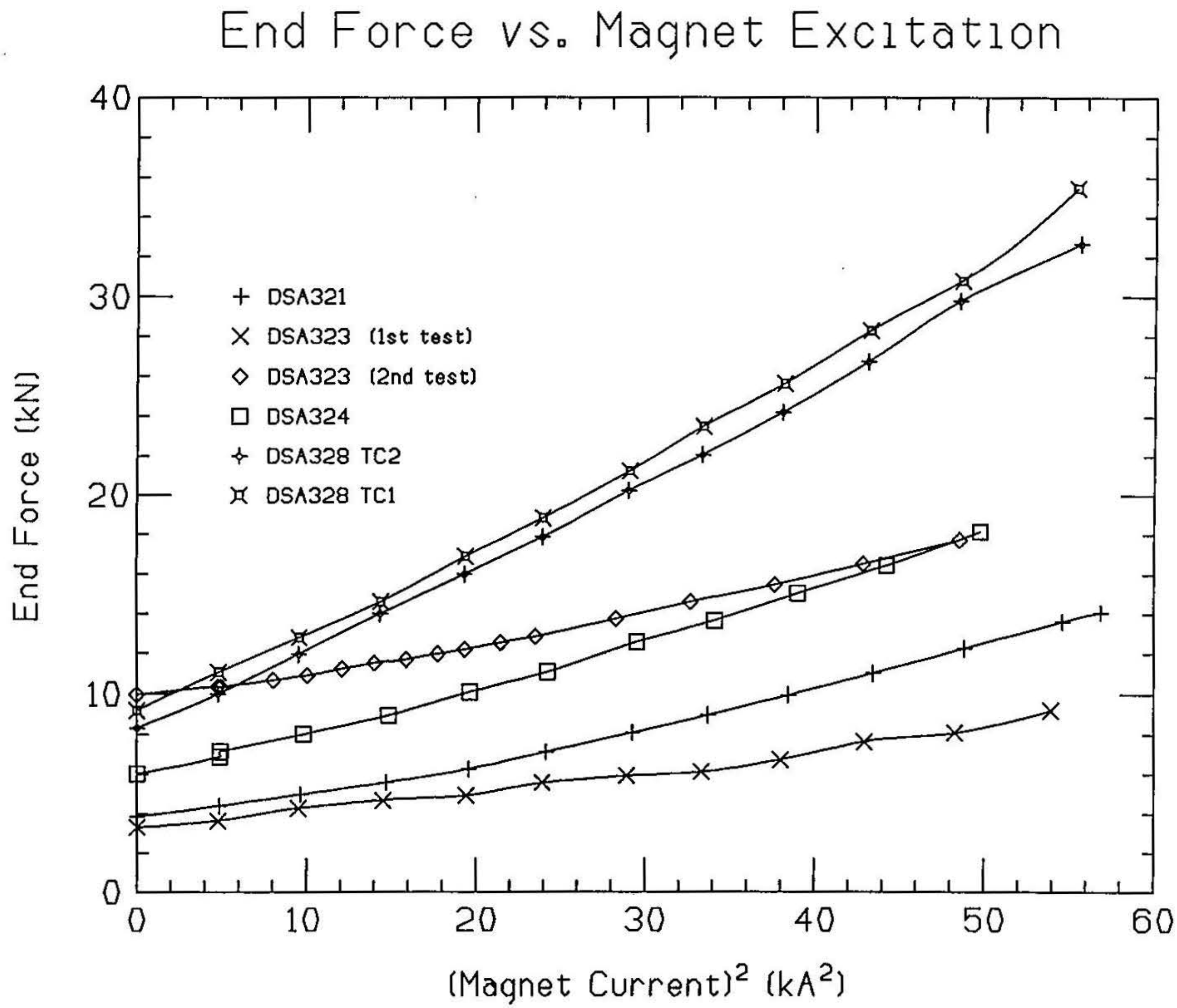


Coil Stress vs. Magnet Excitation
Inner Coils
DSA321 INNER
DSA323 INNER
DSA324 INNER
DSA326 INNER
DSA101 INNER
DSA102 INNER
DSA328 INNER
Coil Stress (MPa)
(Magnet Current)^2 (kA^2)
0
10
20
30
40
50
60



Magnet Excitation vs. Coil Stress
Outer Coils
DSA321 OUTER
DSA323 OUTER
DSA324 OUTER
DSA326 OUTER
DSA101 OUTER
DSA102 OUTER
DSA328 OUTER
Coil Stress (MPa)
(Magnet Current)^2 (kA^2)
0
20
40
60
80
0
10
20
30
40
50
60


End Force vs. Magnet Excitation
End Force (kN)
+ DSA328 TC1
×DSA328 TC2
0
10
20
30
40
50
60


End Force vs. Magnet Excitation
End Force (kN)
(Magnet Current)^2 (kA^2)
DSA321
DSA323 (1st test)
DSA323 (2nd test)
DSA324
DSA328 TC2
DSA328 TC1
0
10
20
30
40
50
60

TWO THERMAL CYCLES ON DSA328

-COOLDOWNS 1 &2-NO TRAINING- MAGNET PLATEAUED ABOVE THE PREDICTED CURRENT AT 4.2, 4.35 AND 3.8 K. PLATEAU QUENCHES IN THE UI COIL POLE TURN (TURN 19 STRAIGHT SECTION) .
ALL HIGH RAMP RATE QUENCHES IN MULTIPLE TURN.

-END PRELOAD ~250 LBS PER BULLET. THE LEAD END SCREWS WERE ALSO TORQUED THE SAME. LOST BULLET IN Q4 DURING COOLDOWN .

-ALL STANDARD PLATEAU QUENCHES WERE IN THE POLE TURN AND THE MAGNET PLATEAUED WELL ABOVE THE SSC OPERATING MARGIN .

DSA328

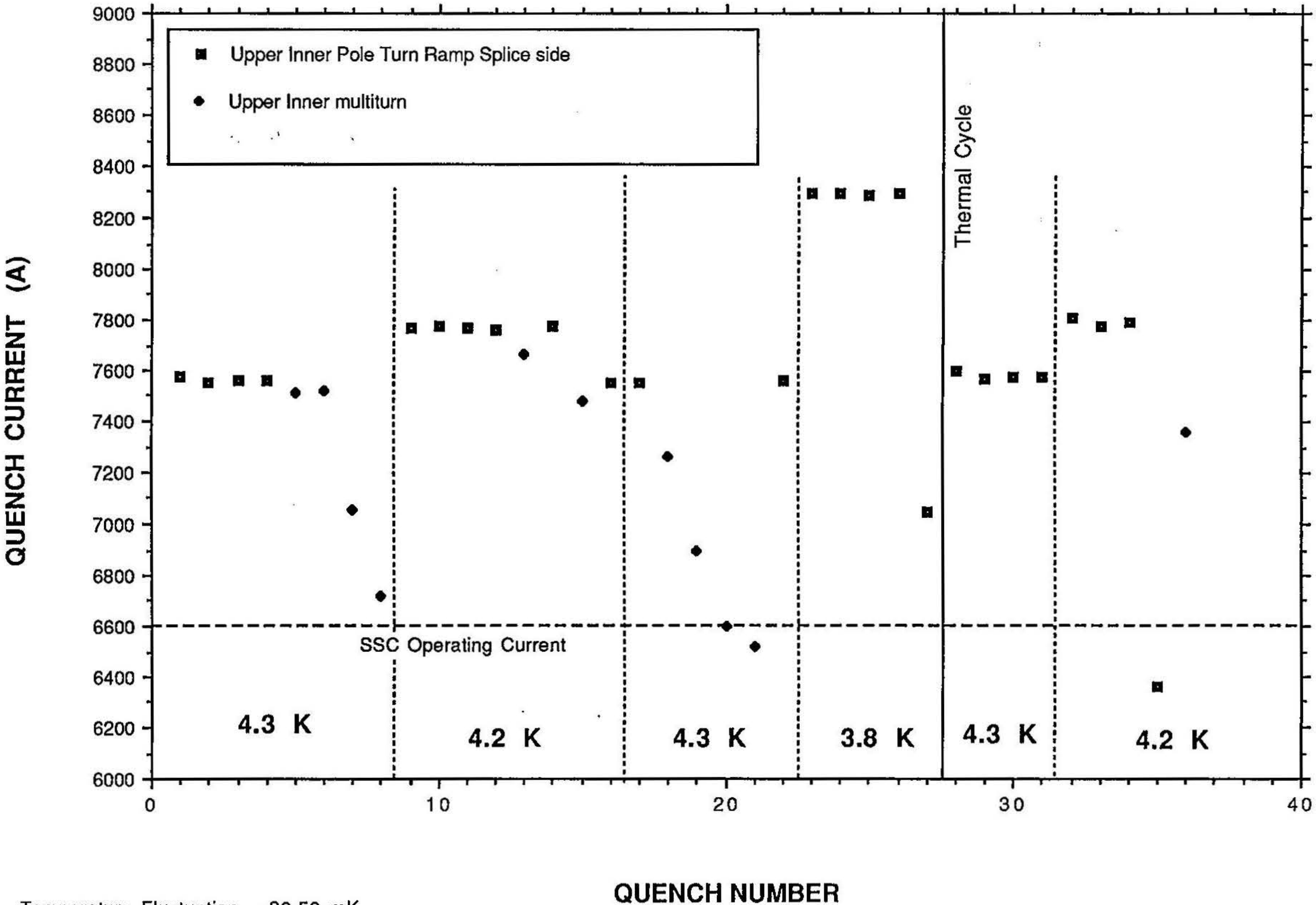
CABLES:	INNER	OUTER	
UP	SSC-3-I-00052	SSC-4-I-00025	FROM DSA325
LO	SSC-3-S-00025	SSC-4-I-00025	

	LO In	UP In
PREDICTED Iq at 4.35 K =	7480	7468
4.2 K =	7633	7622

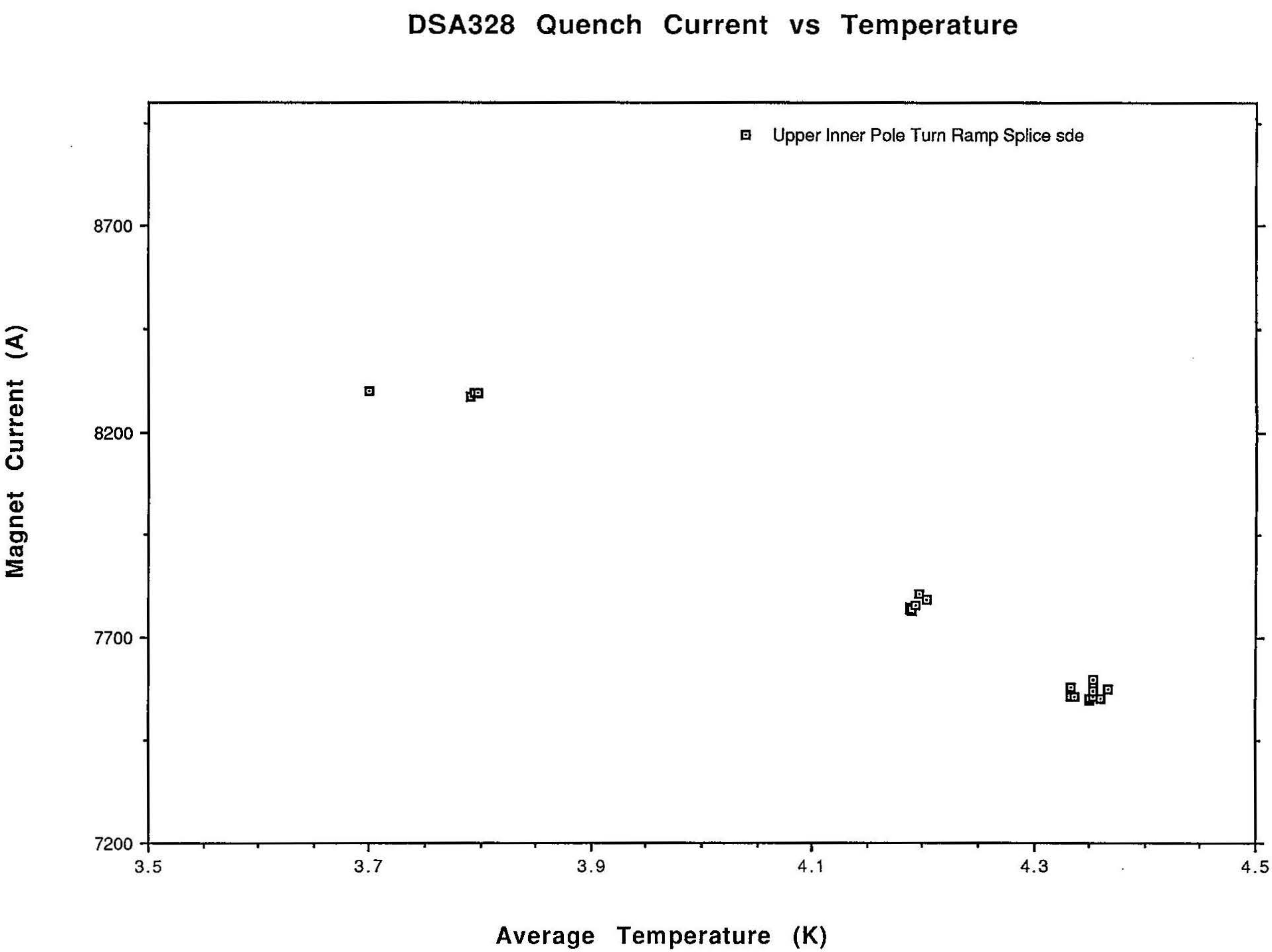
PLATEAU CURRENTS:

	TC1 (22 quenches)	TC2 (14 quenches)
4.35 K =	7560	7580
4.2 K =	7780	7790
3.8 K =	8293	----

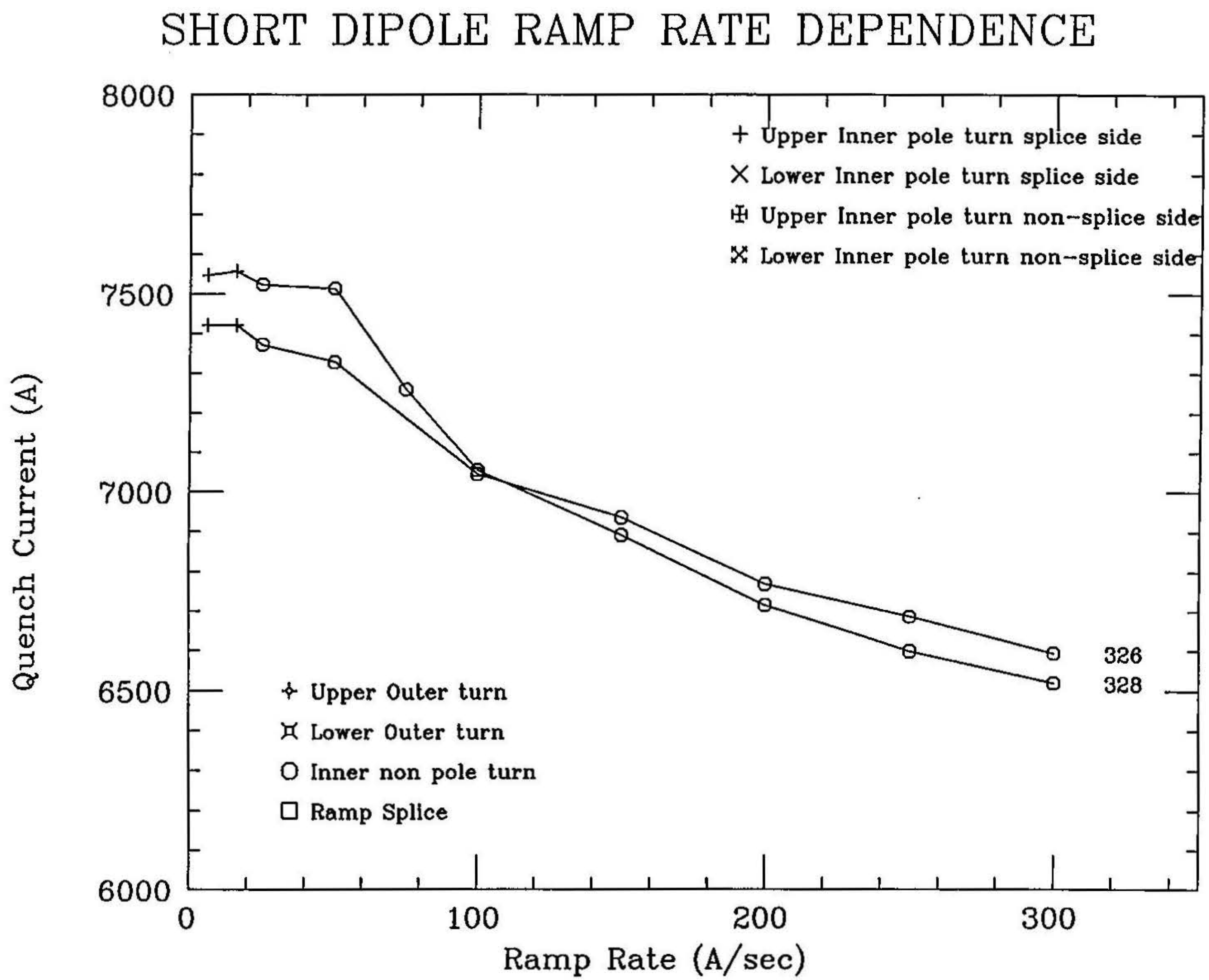
DSA328 QUENCH HISTORY
(Fermilab built 50 mm aperture, 1.5 m long SSC dipole)

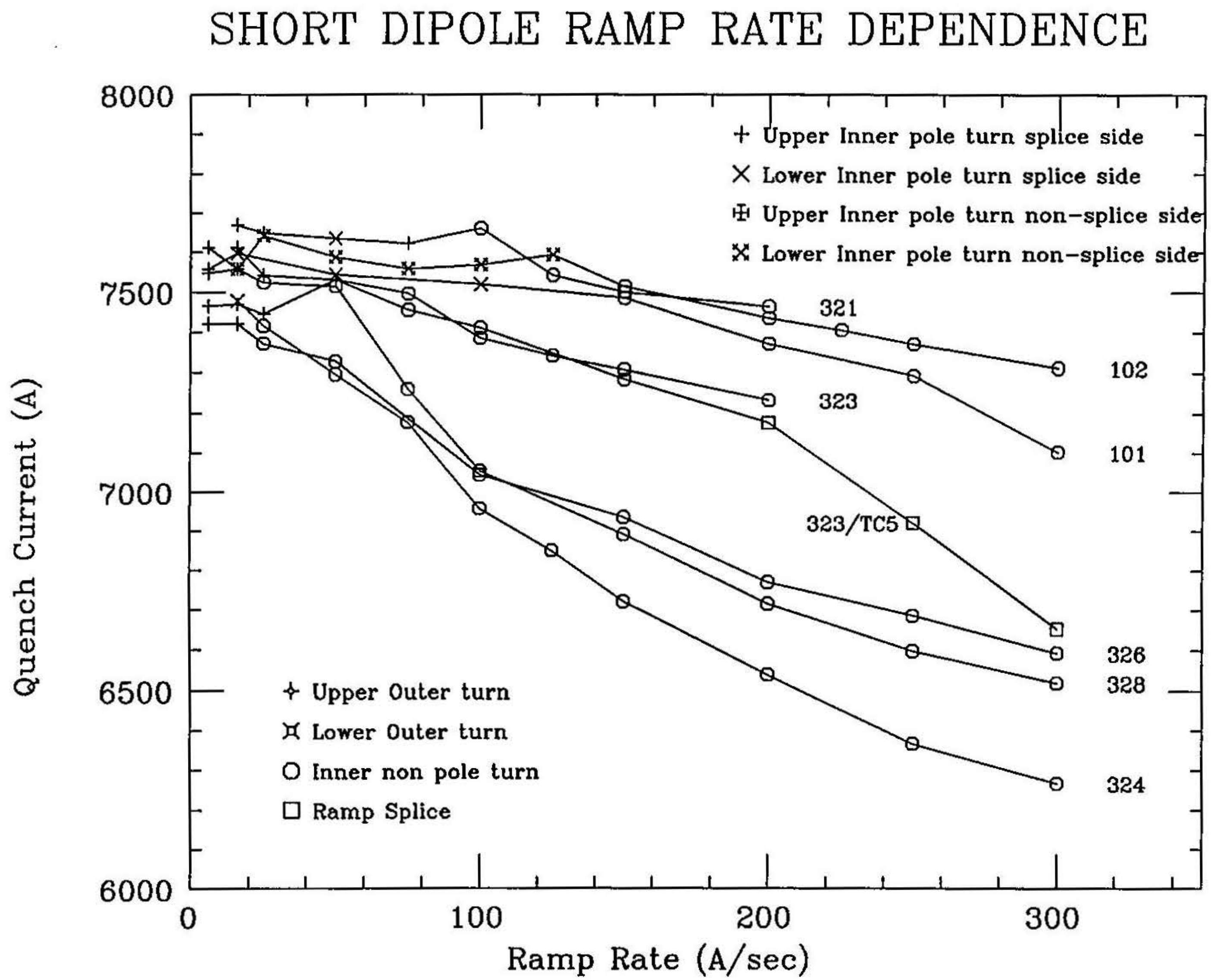


Temperature Fluctuation ~30-50 mK



Fluctuation in temp ~30-50 mK


SHORT DIPOLE RAMP RATE DEPENDENCE
Quench Current (A)
Ramp Rate (A/sec)
8000
7500
7000
6500
6000
0
100
200
300
Upper Inner pole turn splice side
Lower Inner pole turn splice side
Upper Inner pole turn non-splice side
Lower Inner pole turn non-splice side
Upper Outer turn
Lower Outer turn
Inner non pole turn
Ramp Splice
326
328



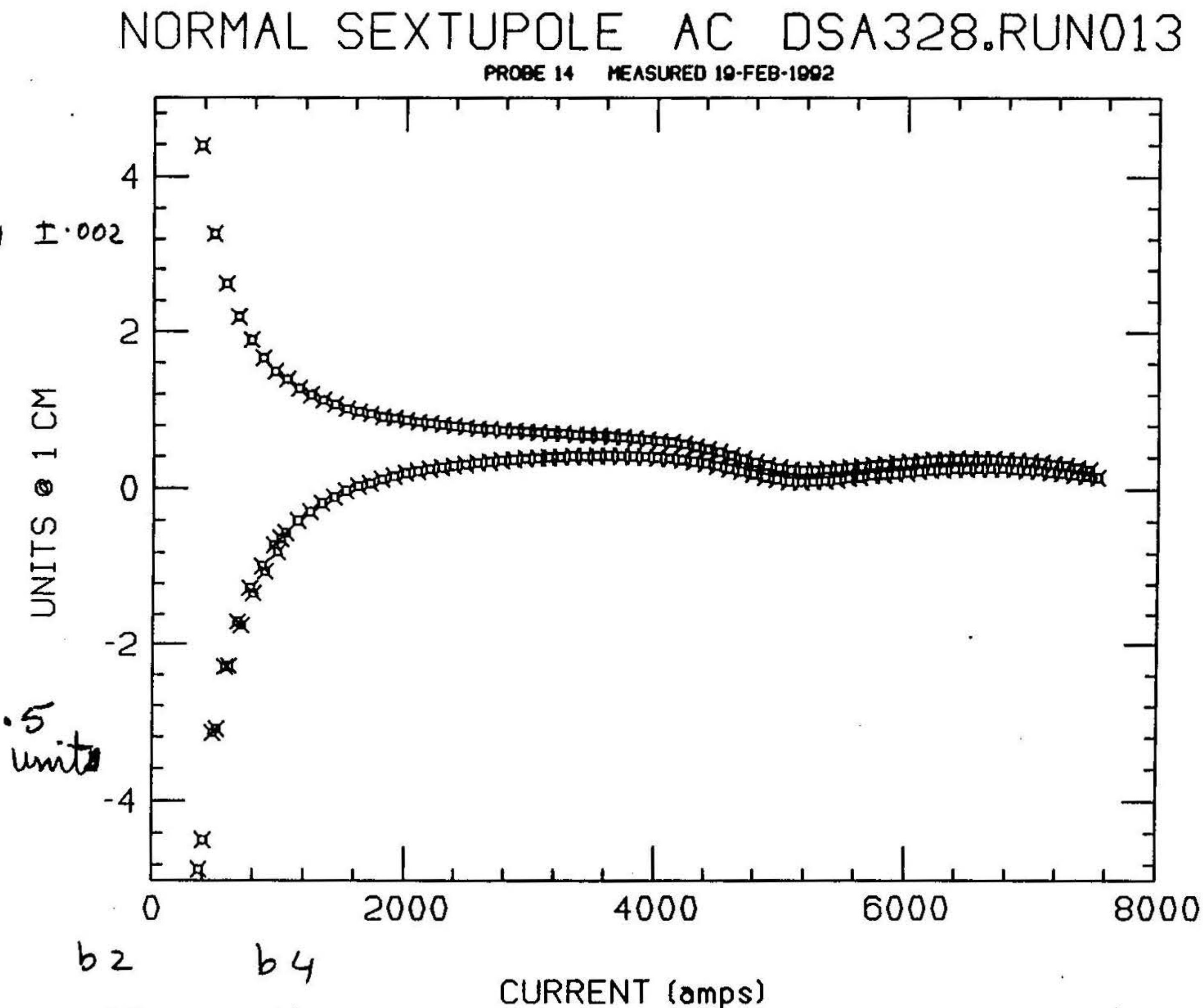
SHORT DIPOLE RAMP RATE DEPENDENCE
Quench Current (A)
Ramp Rate (A/sec)
8000
7500
7000
6500
6000
0
100
200
300
Upper Inner pole turn splice side
Lower Inner pole turn splice side
Upper Inner pole turn non-splice side
Lower Inner pole turn non-splice side
Upper Outer turn
Lower Outer turn
Inner non pole turn
Ramp Splice
321
102
323
101
323/TC5
326
328
324

courtesy of
M. Lamm

$T_{fcn}(T/kA)$
@ 2 kA, 3 kA } 1.044 ± .002

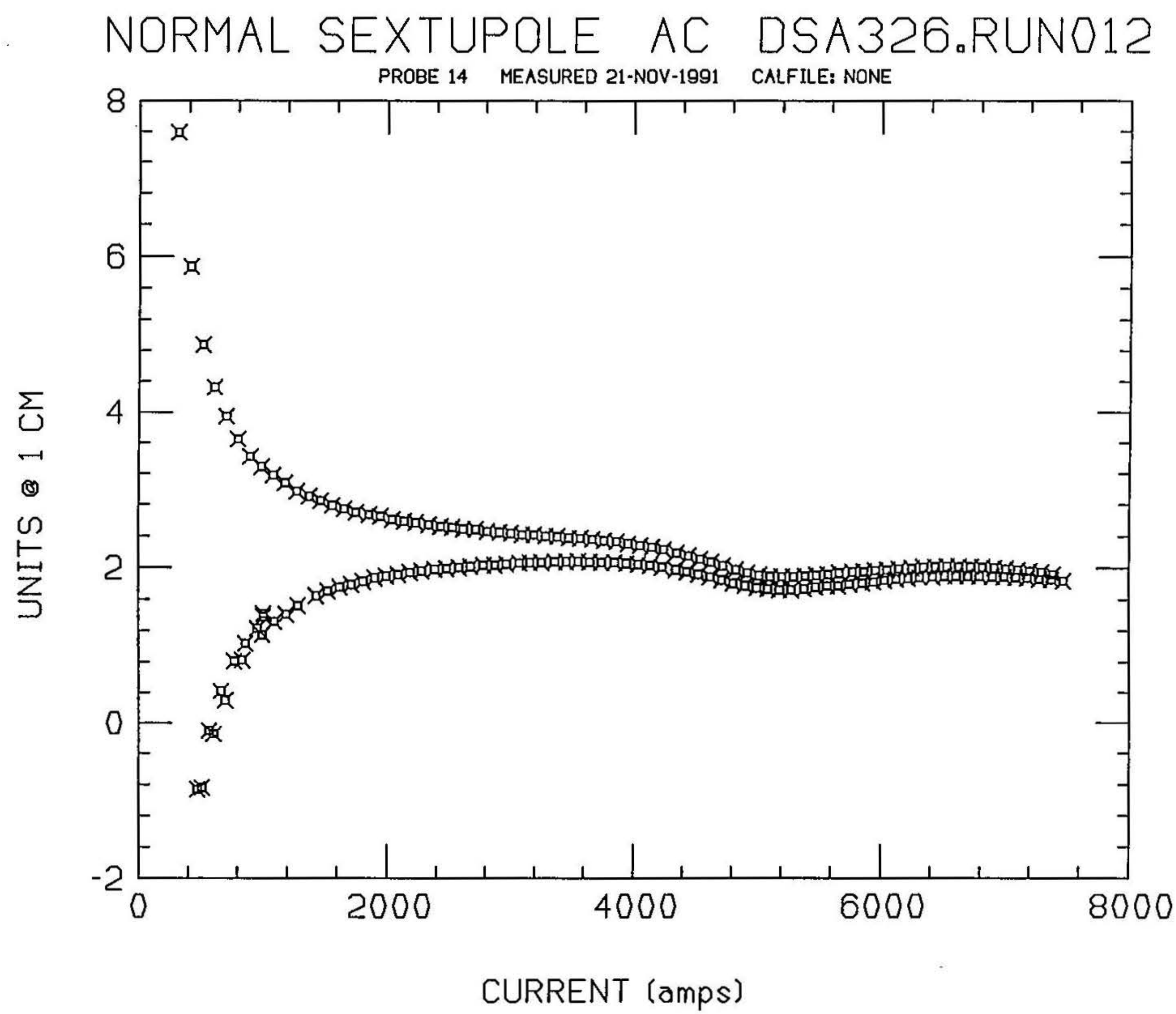
b.

cold $b_2 \approx .5$ units



warm	b2	b4
yoked	-.53	.14
collared	-5.9	←

Typical $b_2 = 1.5$, $b_4 = .24$



NORMAL SEXTUPOLE AC DSA326.RUN012
PROBE 14 MEASURED 21-NOV-1991 CALFILE: NONE
UNITS @ 1 CM
8
6
4
2
0
-2
0
2000
4000
6000
8000
CURRENT (amps)

AC LOSS MEASUREMENTS --- INTRODUCTION

The objectives of these studies were :

- To study the AC losses of SSC model dipole magnets, under unipolar and bipolar ramp conditions

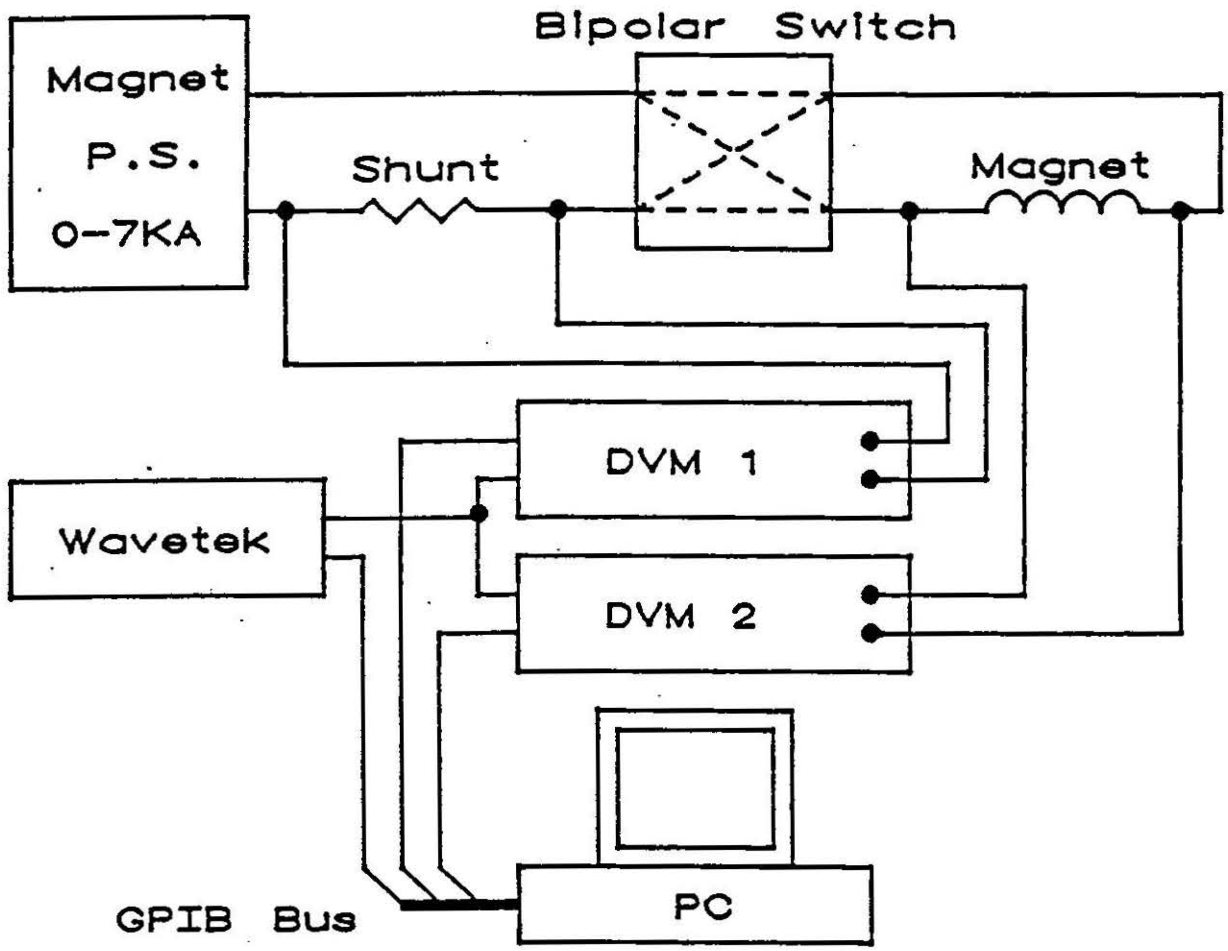
MEASUREMENT TECHNIQUE :

-IBM PC/AT BASED WITH "ASYST" DATA ACQUISITION SYSTEM WITH GPIB INTERFACE

-TWO HP3457A DVM'S SIMULTANEOUSLY READ SHUNT VOLTAGE AND MAGNET VOLTAGE (V_{MAG} AND I_{MAG})

- DVM'S ARE TRIGGERED SIMULTANEOUSLY USING TRIGGER PULSES FROM A DIGITAL WAVEFORM GENERATOR. NOMINAL TRIGGER RATE 4.5 HZ

-VOLTAGES ARE RECORDED AS A FUNCTION OF TIME, UPLOADED TO MICROVAX AND ANALYZED


Bipolar Switch
Magnet
P.S.
0-7KA
Shunt
Magnet
DVM 1
Wavetek
DVM 2
GPIB Bus
PC

DSA328

- S.C. HYSTERESIS LOSS = 110 J

COMPARES WELL WITH DSA323 + DSA324

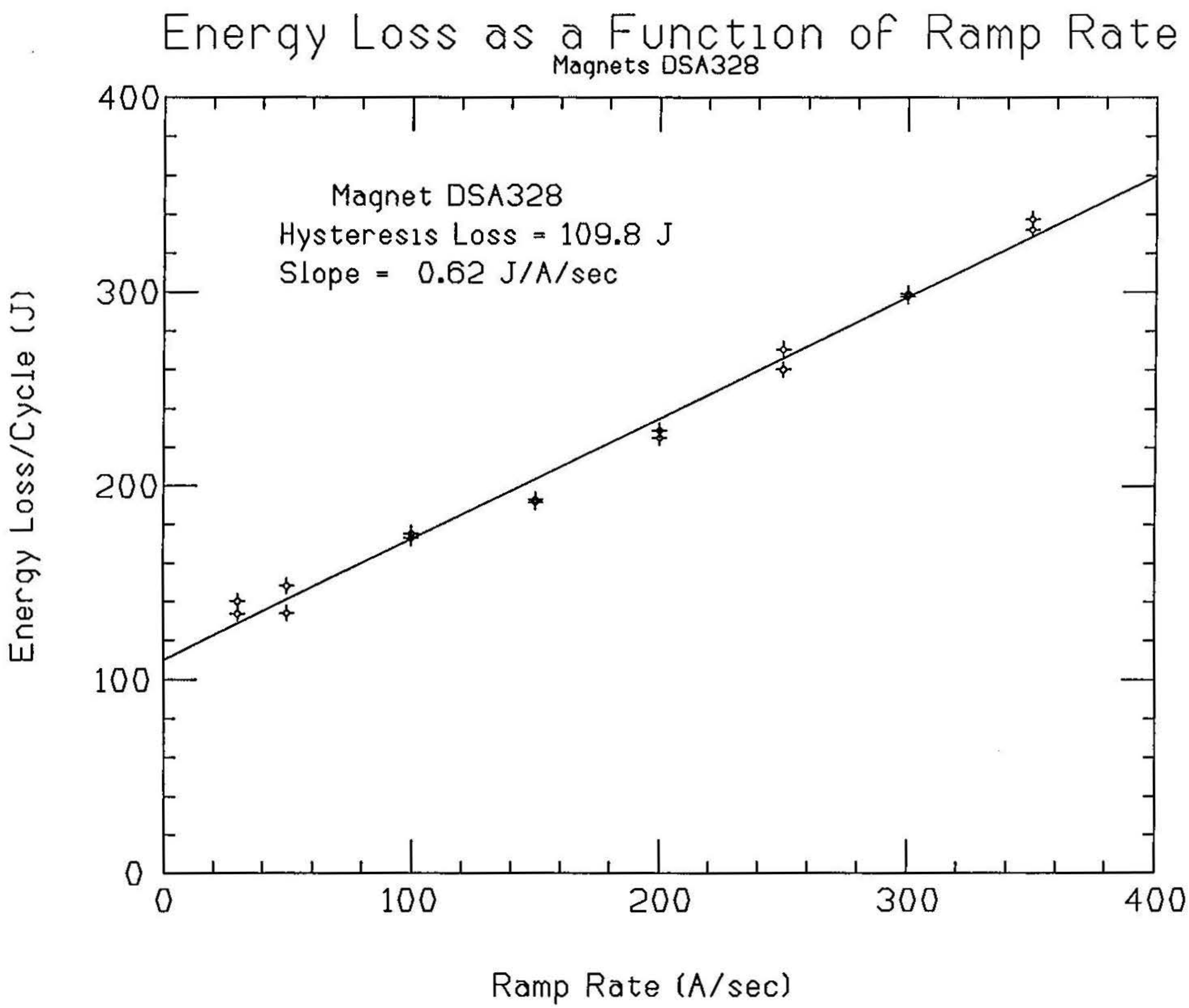
- RRATE DEPENDENCE = .62 J/A/s

DSA323 = .6 J/A/s
DSA324 = .7 J/A/s

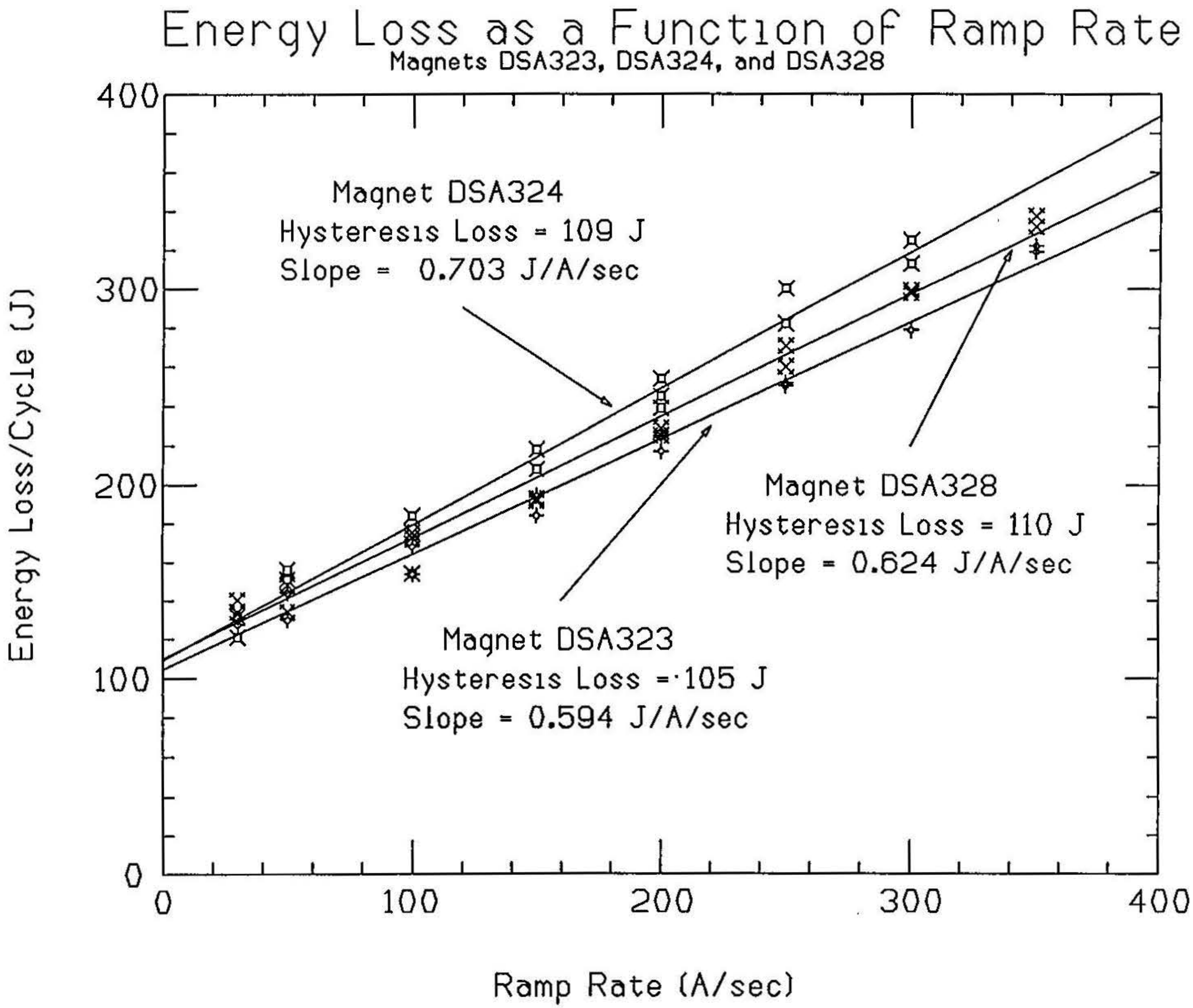
Measurement sensitivity better than 5%

→ 1 - Power supply
→ 10 line cycle integration - HP3457A
→ 4.5 HZ Data acquisition rate
→ 4.0 HZ Low Pass Filter on DVM inputs
→ 2 sets of Data at each RRate
→ Ramp cycle 500 — 5000 — 500 A at

$\frac{dI}{dt}$ = 30, 50, 100, 150, 200, 250
300, 350



Energy Loss as a Function of Ramp Rate
Magnets DSA328
Magnet DSA328
Hysteresis Loss = 109.8 J
Slope = 0.62 J/A/sec
Energy Loss/Cycle (J)
Ramp Rate (A/sec)
0
100
200
300
400

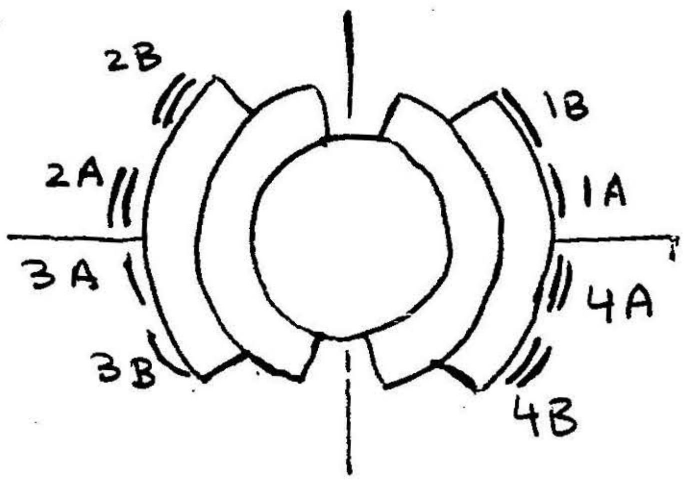

Energy Loss as a Function of Ramp Rate
Magnets DSA323, DSA324, and DSA328
Magnet DSA324
Hysteresis Loss = 109 J
Slope = 0.703 J/A/sec
Magnet DSA328
Hysteresis Loss = 110 J
Slope = 0.624 J/A/sec
Magnet DSA323
Hysteresis Loss = 105 J
Slope = 0.594 J/A/sec
Energy Loss/Cycle (J)
Ramp Rate (A/sec)
0
100
200
300
400

DSA328- HEATERS

Q1 AND Q3 – 1-5 mil Kapton wrap between heater And coil

Q2 AND Q4 – 2-5 mil Kapton between heater and coil

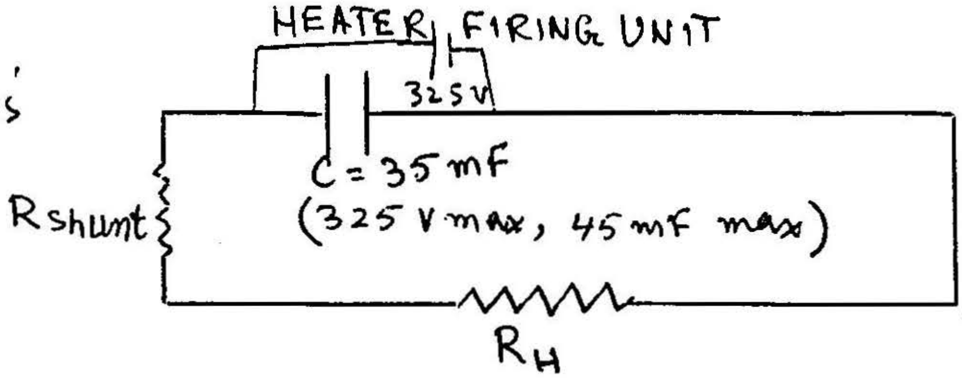
Heaters = .7Ω/pad ~ 17" unplated portion



8-HEATERS
2/QUADRANT

Max 12 caps, 45 mF
325 V Power supply ⇒ ~2.5 Joules
can be fired mannually or QDC (TTL logic)

1 heater, RC=155 ms



2 heaters in series
RC = 173 ms
R_H = .7 Ω/strip
R_{tot} = 5.1 Ω

Heater circuit for DSA328

- Time Precision ≈ 10 msec
- Estimate 10 msec uncertainty in finding Quench
- 5% variation in heater Voltages
⇒ 10% variation in energy deposition

Difference in response time I_{fn} is consistent with meas. uncertainity.

CONCLUSIONS

compare E_dep vs T_fn for different insulation schemes:

2-5 mil kapton layer scheme
E_dep ↑100% same T_fn

In order to get same T_fn Needs 100% more energy to induce quench

→ MID PLANE HEATERS: Requires ~20% more energy
E_dep ↑ T_fn ↑ and takes longer to quench

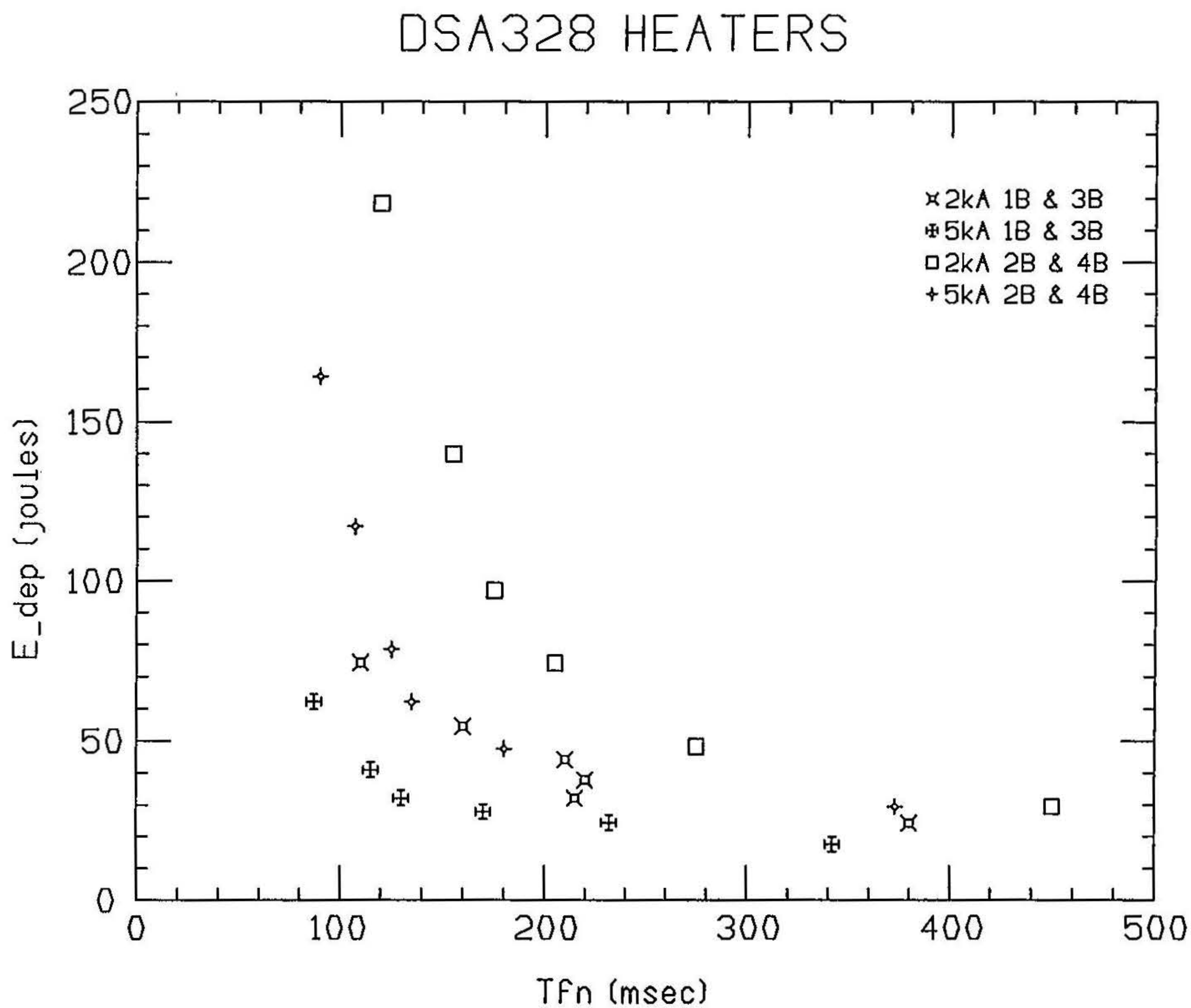
→

MIN. ENERGY REQD. TO INDUCE QUENCH AT 5KA. WITH HEATERS NEAR POLES

→ 1B + 3B – 1-5 mil kapton scheme = 17.5 J
@ Vhfu = 85 V;
T_fn = 342 ms

→ 2B + 4B – 2-5 mil kapton scheme = 21.9 J
@ Vhfu = 95 V
T_fn = 530 ms

* Difference in T_fn consistent with measurement uncertainties
* Heater that fires first sets the T_fn for 2 heaters series connection


DSA328 HEATERS
2kA 1B & 3B
5kA 1B & 3B
2kA 2B & 4B
5kA 2B & 4B
E_dep (joules)
Tfn (msec)
0
50
100
150
200
250
0
100
200
300
400
500

Distribution:

<u>FNAL</u>
S. Delchamps
W. Koska
M. Lamm
G. Pewitt
J. Strait
M. Wake

<u>SSCL</u>
J. Jayakumar
A. Labarge
G. Snitchler