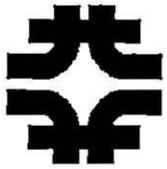


Fermilab

TS-SSC 90-036

Short Model Magnet Test Results at FNAL

J. Strait
Fermilab

SSC Site Specific Conceptual Design Review

SSC Laboratory
June 26, 1990

Fermilab Modifications to the 40 mm Baseline Design

Follow standard BNL (C358D) design with the following exceptions:

1) All Kapton coil insulation with no collaring shims or shoes.

   The 50 mm design calls for no collaring shims, but shoes will be used. The possible use of Teflon slip-planes is being evaluated.

2) Developable surface minimum stress constant perimeter ends with current blocks matching the 2-D current blocks. Spacers are made of machined G-10.

3) External inner-outer coil splice and collet end clamp.

4) Collar using tapered keys but square key techniques.

5) Horizontally split yoke with vertically elliptical collars
   or
   Vertically split yoke with horizontally elliptical collars.

   The long 50 mm magnets will be made with a vertically split yoke. The 40 mm models at FNAL will allow an early test of this design.

6) The yoke is aligned using full-length fiducials at the mid-plane. The upper and lower half skins are welded to the fiducial in a full-length press.

Fermilab/SSC 40 mm Short Model Program

Objectives

- Develop and demonstrate magnet design improvements to be incorporated into 50 mm models
- Develop assembly techniques using FNAL production oriented tooling
- Because of the similarities of the designs, experience with 40 mm models will apply directly to the 50 mm magnets

Priorities

- Those elements of the program that are most important to the 50 mm development are emphasized
- Where conflicts for resources (mostly manpower) occur between the 40 mm and 50 mm programs, priority is given to the 50 mm development
- When we are able to build the first 50 mm model, the 40 mm program will end

40 MM MODEL MAGNET DEVELOPMENT PROGRAM AT FERMILAB

May 30, 1990

	DS0307[7]	308	309	310	311[8]	312	313	314	315	316	317	318[9]
Design Features[1]												
Pro-oval collars, horizontally split yoke	X	X	X	X	X	X	X					
Horizontally oval collars, vertically split yoke								X	X	X	X	X
Individually determined coil ends	X	X	X	X	X							
Grouped outer coil ends						X	X	X	X	X	X	X
Teflon on coils	X			X	X							
Improved end clamp[2]										X	X	
Instrumentation[3]												
End clamp deflection gages		X				X				X	X	
End clamp strain gages				X		X				X	X	
Skin strain gages		X		X		X		X	X	X		
Test Plan[4]												
Mini-life test[5]			X	X					X			
Tests of collaring methods	X				X							
Disassemble after cold test			X					X	X			
Pot and section	X		X	X		X[10]		X	X			
Creep tests[6]				X		X						

NOTES

1 Unless otherwise noted all magnets have the standard Fermilab modifications to the base-line design: individually determined analytically designed coil ends, all Kapton coil insulation system with no collaring shims or shoes, collet end clamp with external inner-outer coil splice.

2 The improved end clamp has not been designed in detail but is currently planned to use G10 blocks with transverse fibers and a stainless steel can with increased radial thickness.

3 All magnets include, in addition to the instrumentation list in the table, 55 voltage taps, one strain gage collar pack (4 inner and 4 outer coil gages) and ''bullet'' gages at the return end.

4 The standard test plan includes room temperature harmonics measurements with the mole before and after the cold test, room temperature and 4.3 K harmonics measurements with the Lab 2 magnetometer, quench testing at 4.3 K and 3.8 K, strain gage measurements up to the highest fields attained at 4.3 K and 3.8 K and a thermal cycle with 4.3 K quench and strain gage tests repeated on the second cooldown.

5 A ''mini-life test'' consists of 500 excitation cycles between 2000 A and 6500 A at about 100 A/s.

6 Creep tests will be carried out at the SSCL and may include only a portion of a partially disassembled or sectioned magnet.

7 DS0307 was used only for assembly experiments and was not cold tested.

8 DS0311 is intended primarily as a test of assembly experiments and may not be cold tested.

9 Depending on the schedule for assembly of the first 50 mm model and the progress of the 40 mm development program, up to two more models beyond DS0318 may be built.

10 Ends only to be plotted.

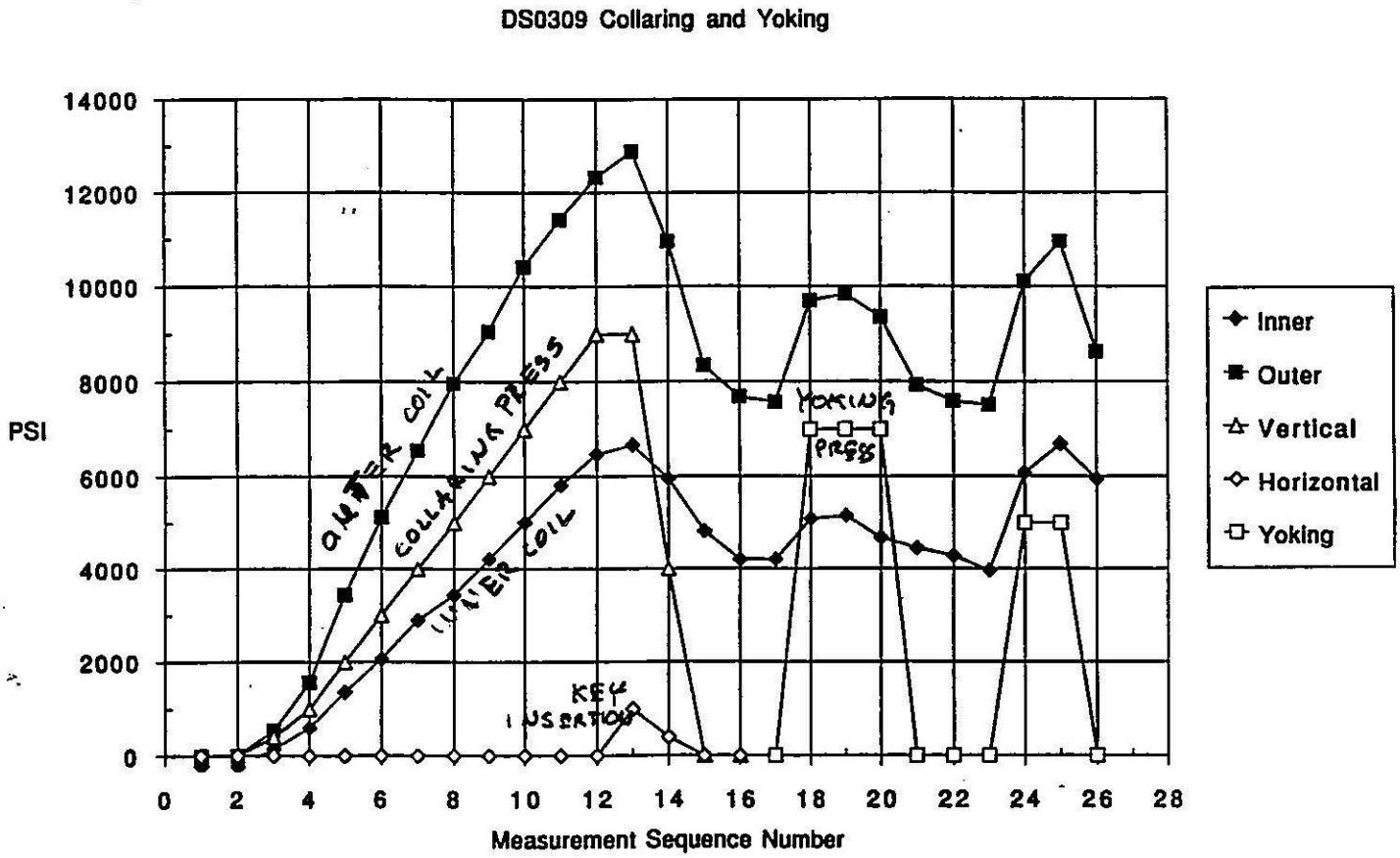
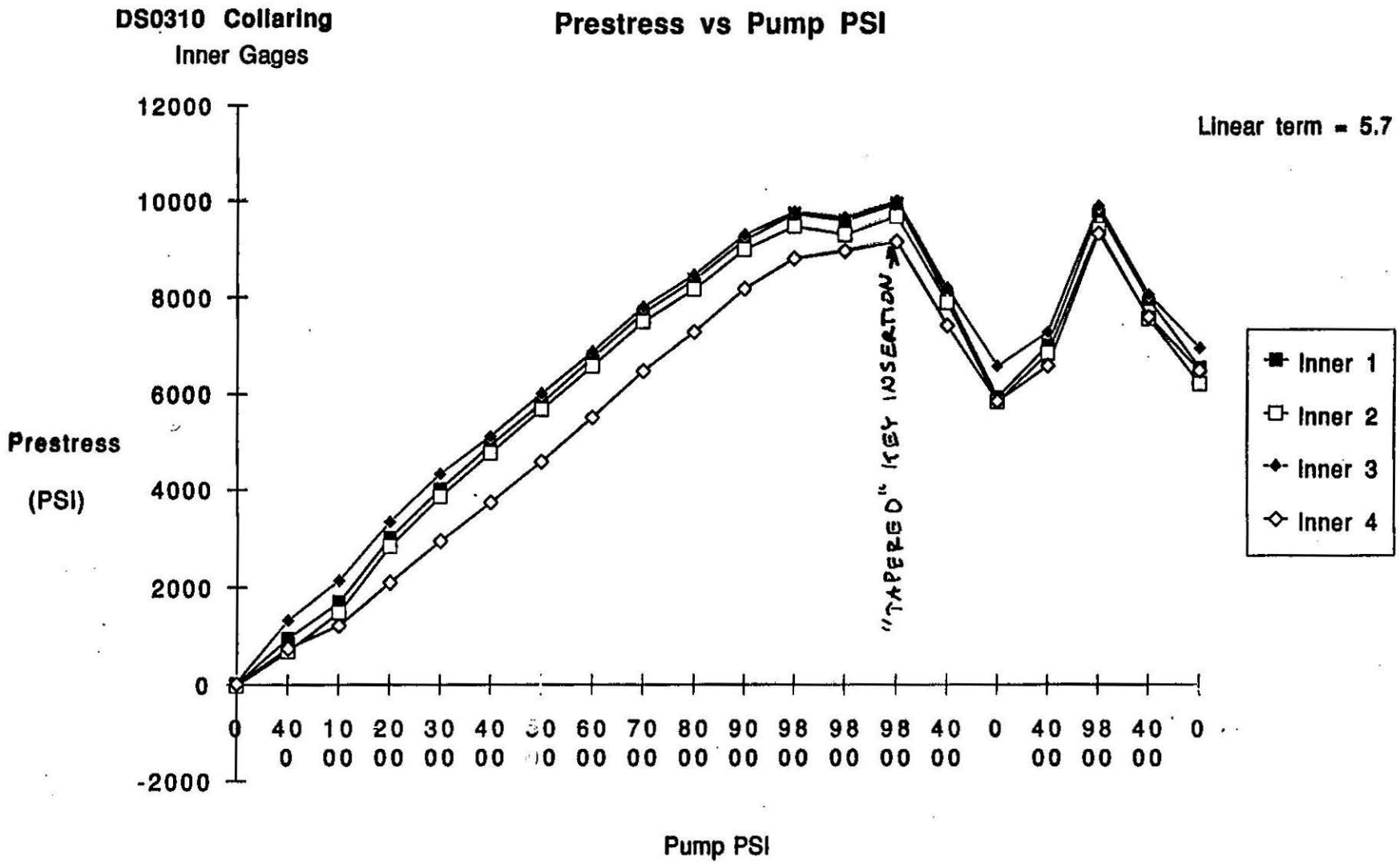
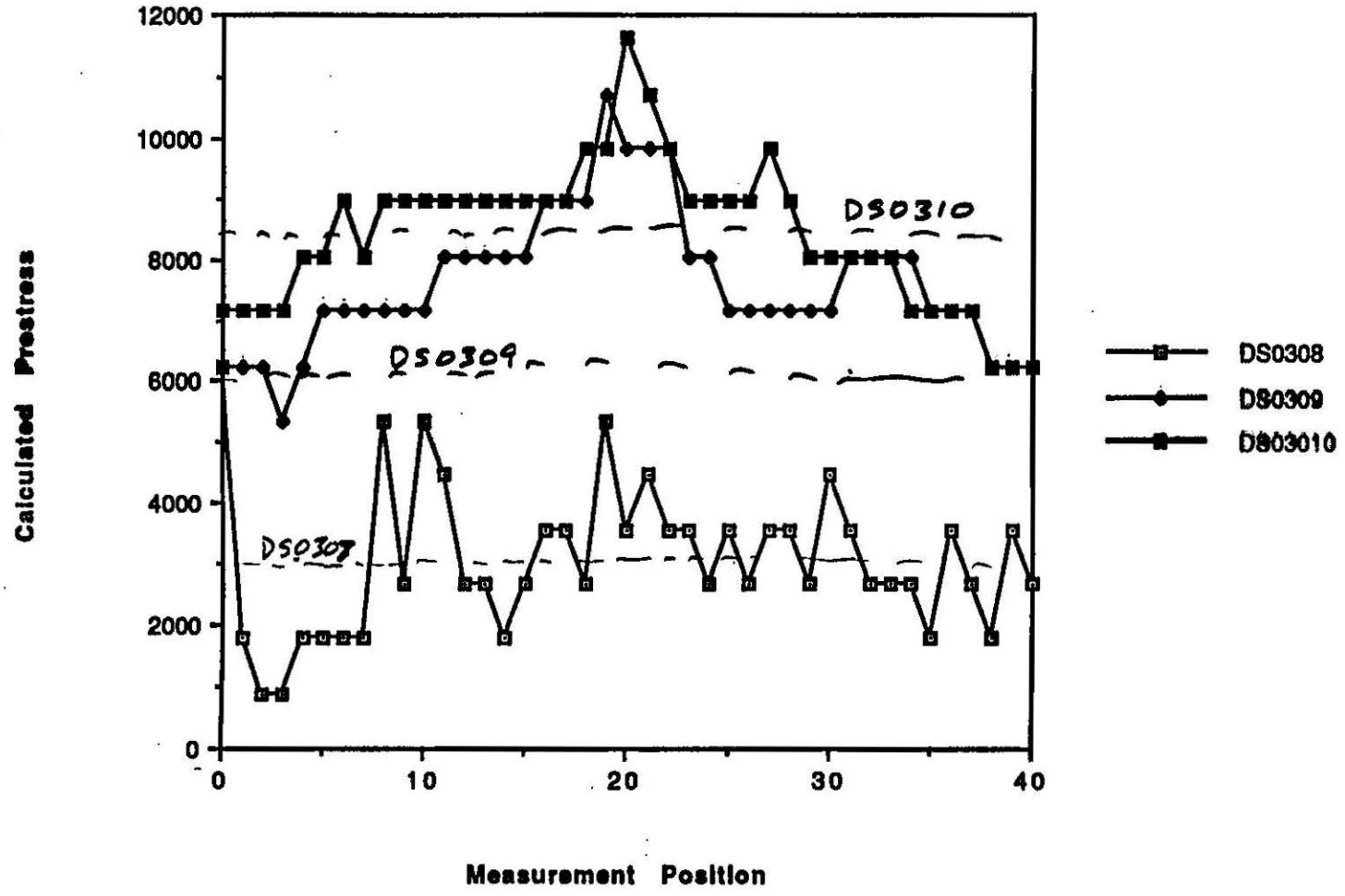

DS0309 Collaring and Yoking
PSI
14000
12000
10000
8000
6000
4000
2000
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Measurement Sequence Number
Inner
Outer
Vertical
Horizontal
Yoking
OUTER COIL
COLLARING PRESS
INNER COIL
KEY INSERTION
YOKING PRESS

Figure 1


DS0310 Collaring
Inner Gages
Prestress vs Pump PSI
Linear term = 5.7
12000
10000
8000
6000
4000
2000
0
-2000
Prestress
(PSI)
"TAPERED" KEY INSERTION
Inner 1
Inner 2
Inner 3
Inner 4
0 4000 1000 2000 3000 4000 5000 6000 7000 8000 9000 9800 9800 9800 4000 0 4000 9800 4000 0
Pump PSI

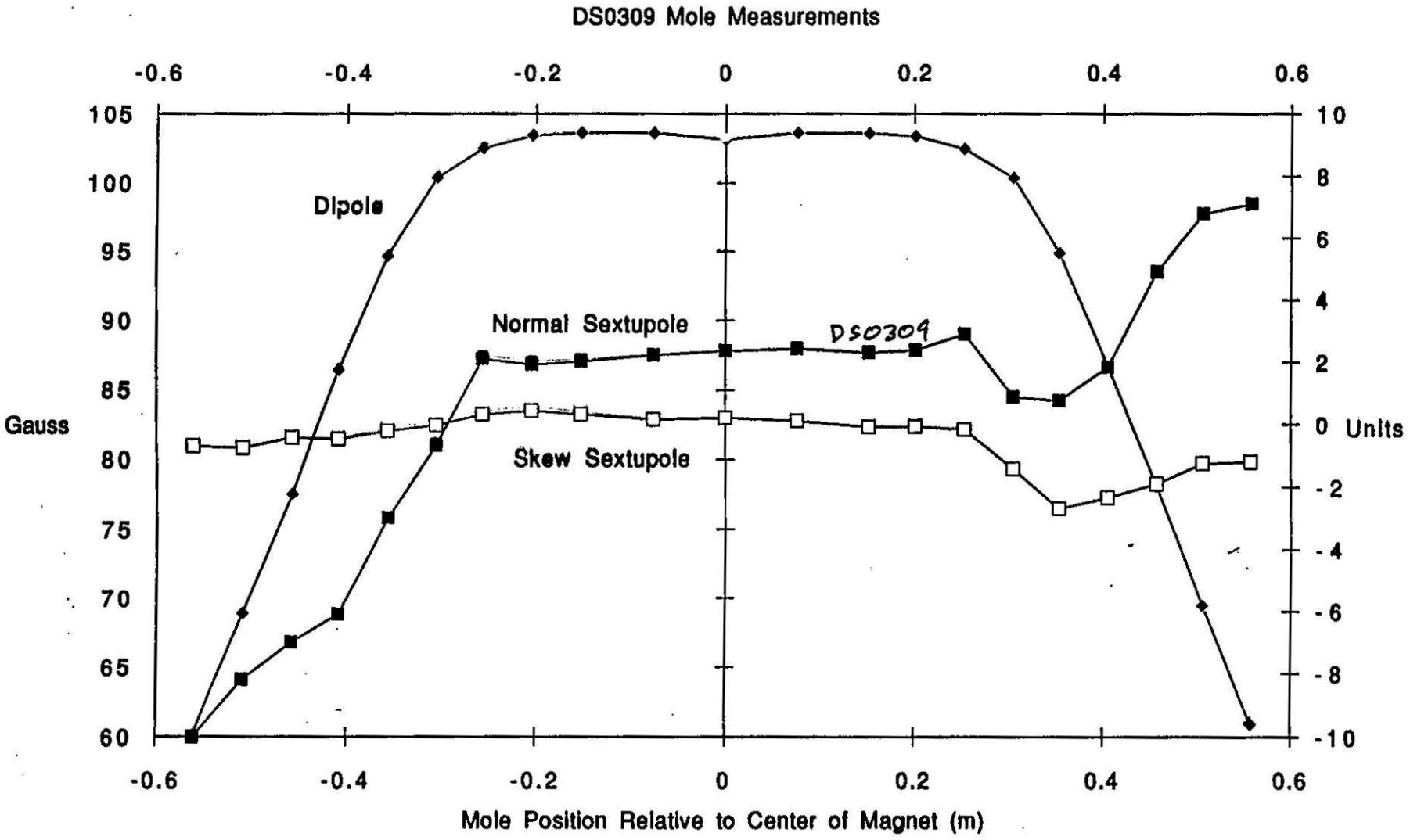
Comparison of Collared Coil Vertical Deflection
Magnets DS0308-DS0310



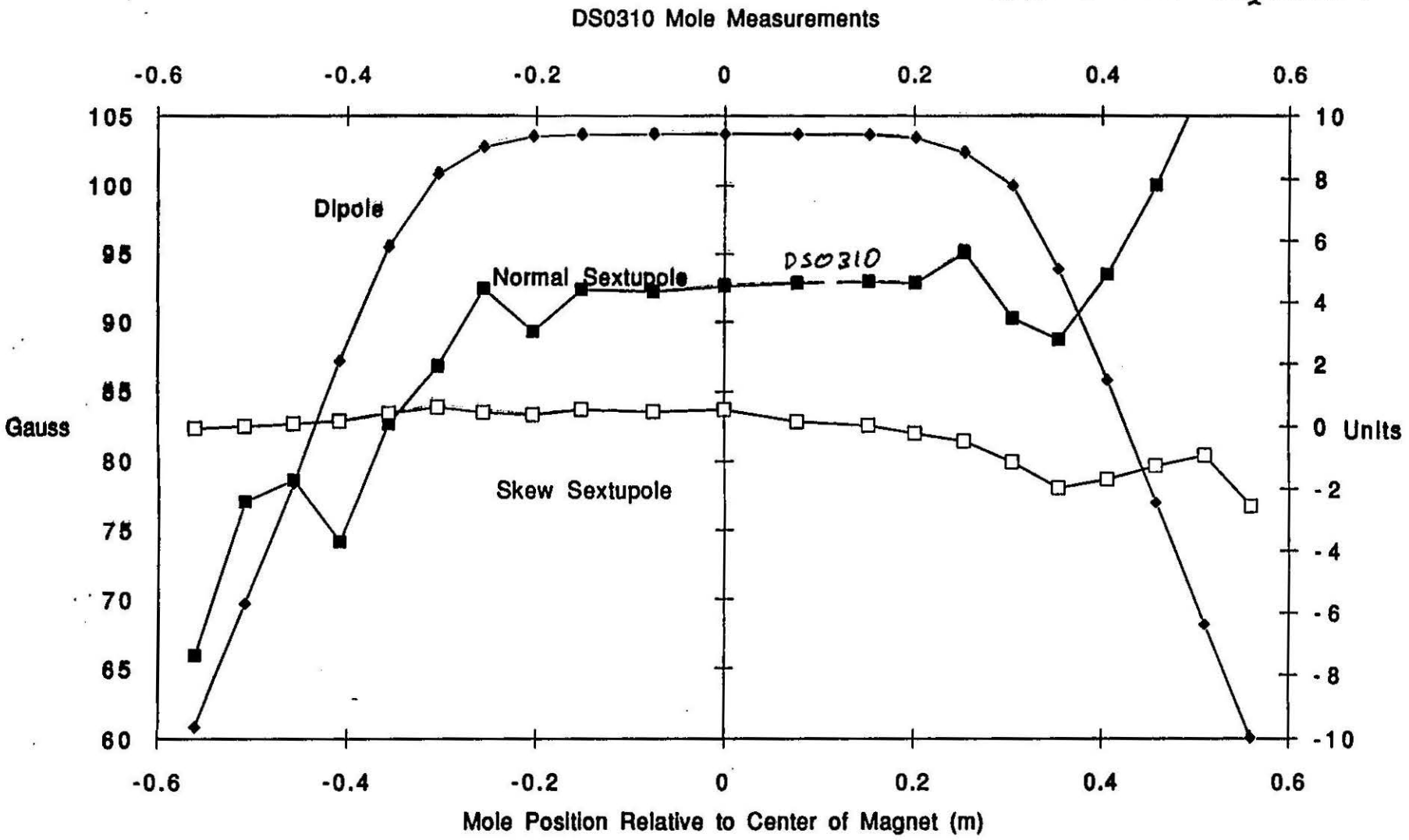
STRAIN GAGE READINGS:

	DS0308	DS0309	DS0310
INNER	2 kpsi	4 kpsi	7 kpsi
OUTER	3 kpsi	8 kpsi	10 kpsi

ROOM TEMPERATURE
HARMONICS MEASUREMENT



ADD 2/3 MILS SHIM TO OUTER/INNER COIL: EXPECT $\Delta b_2 = 2.3$ UNITS



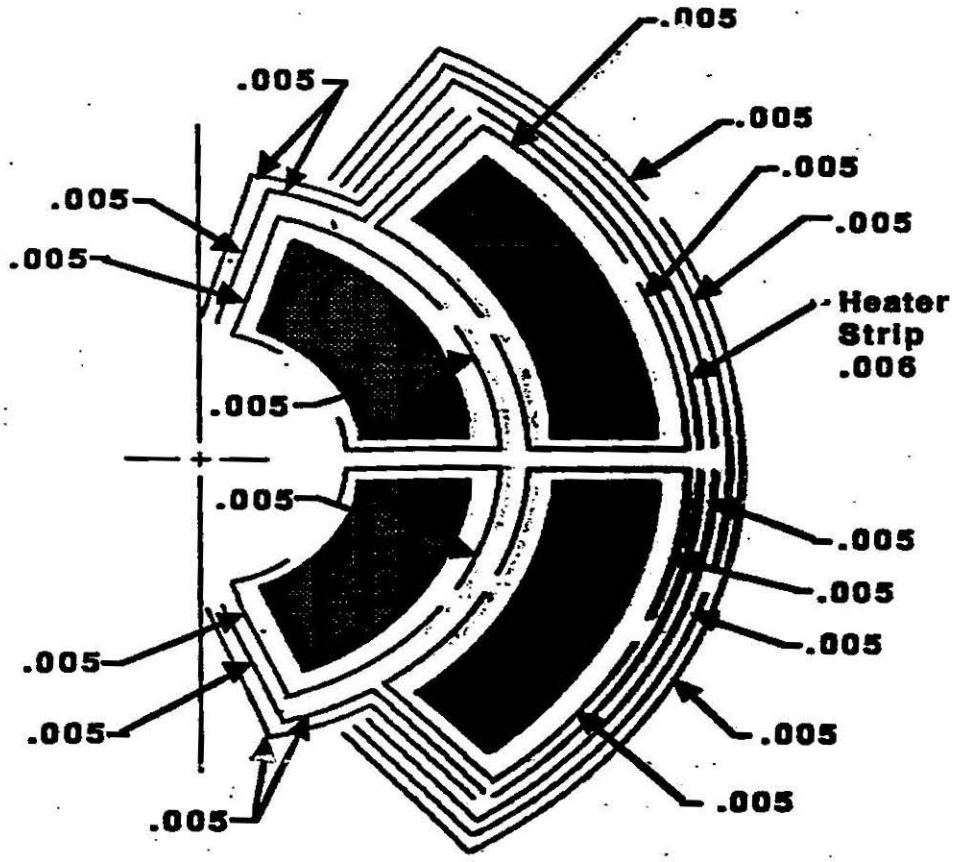
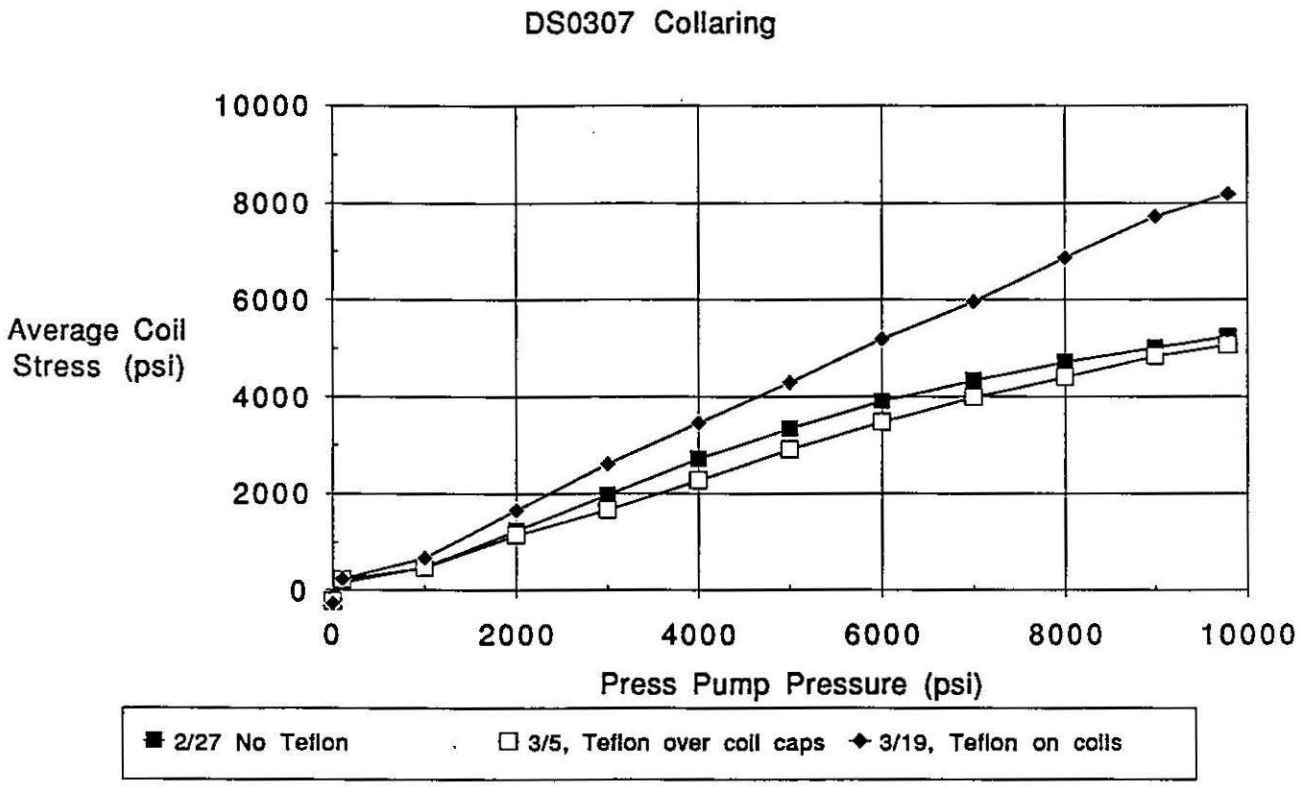
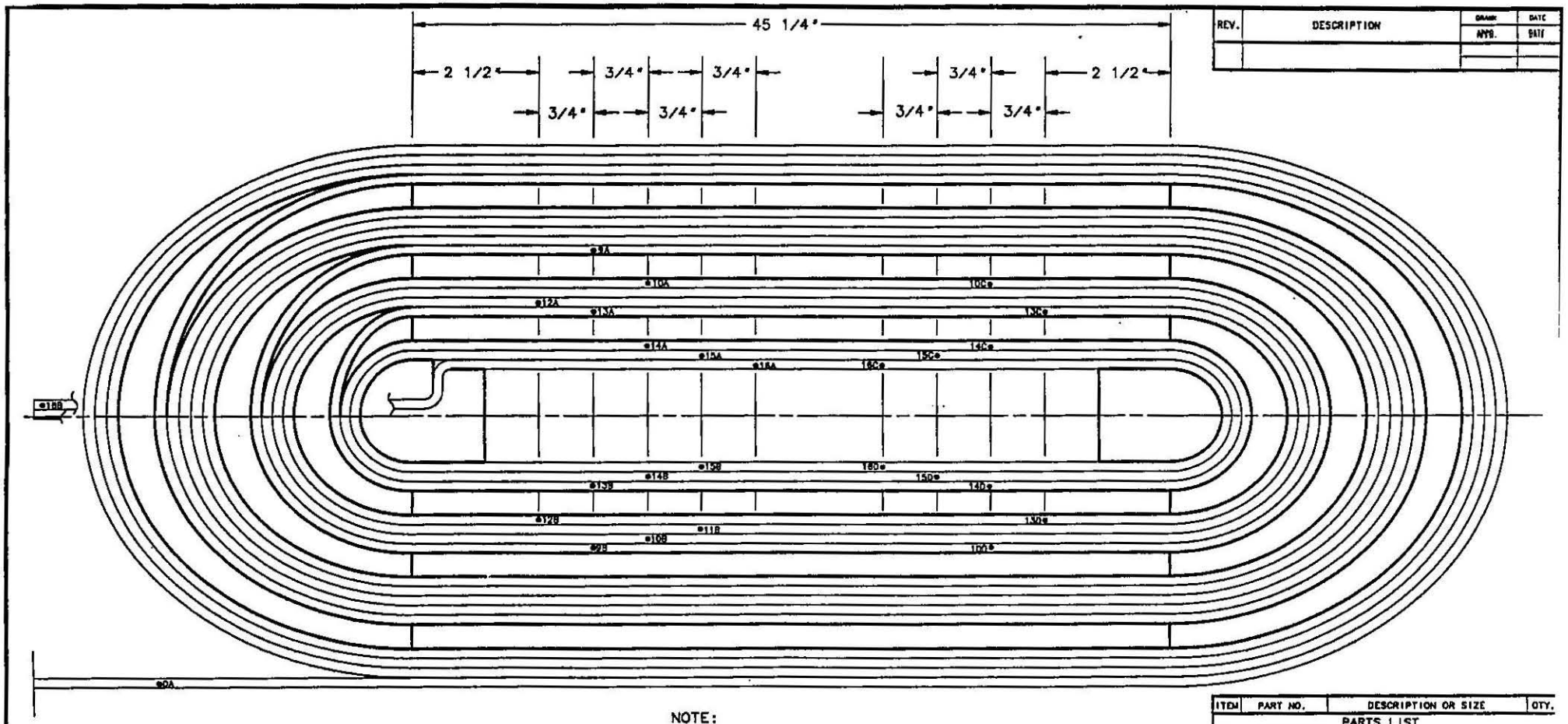


Figure 13. Fermilab Coil Insulation System


DS0307 Collaring
Average Coil Stress (psi)
10000
8000
6000
4000
2000
0
0
2000
4000
6000
8000
10000
Press Pump Pressure (psi)
2/27 No Teflon
3/5, Teflon over coil caps
3/19, Teflon on coils

Test Procedure for Magnets DS0308 and DS0309

DS0308	DS0309
Quench Testing at 4.2K	Quench Testing at 4.3 and 3.8K
Strain Gage Measurements	Strain Gage Measurements
Field Measurements	Field Measurements
Ramp Rate Study	Ramp Rate Study
	Thermal Cycle
	Mini-Life Test



REV.	DESCRIPTION	DRAWN	DATE
		ANYB.	DATE

NOTE:

1. VOLTAGE TAP WIRES FOR TAPS 0A, 16B, AND THE HALF COIL TAP ARE #22 AWG TEFLON INSULATED.
2. THE REMAINING VOLTAGE TAP WIRES ARE #32 AWG TEFLON INSULATED.
3. TAP WIRES WITH THE SAME NUMBER AT EACH END SHOULD FORM A TWISTED PAIR (A-B AND C-D).
4. VOLTAGE TAP WIRE SHOULD FOLLOW THE CABLE TO WHICH THEY ARE SOLDERED UNTIL THEY MEET AND ARE TWISTED WITH THEIR "MATE".
5. COIL AS VIEWED FROM INSIDE.

Figure 1a

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	STRAIT/KOSKA	
.XX	.XXX	ANGLES	DRAWN	R. DIXON	1/5/90
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES .02 MAX. 2. DO NOT SCALE DRAWING. 3. DIMENSIONS BASED UPON ANSI Y14.5M-1982 4. MAT. ALL MACH. SURFACES			APPROVED		
			USED ON		
			MATERIAL		

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

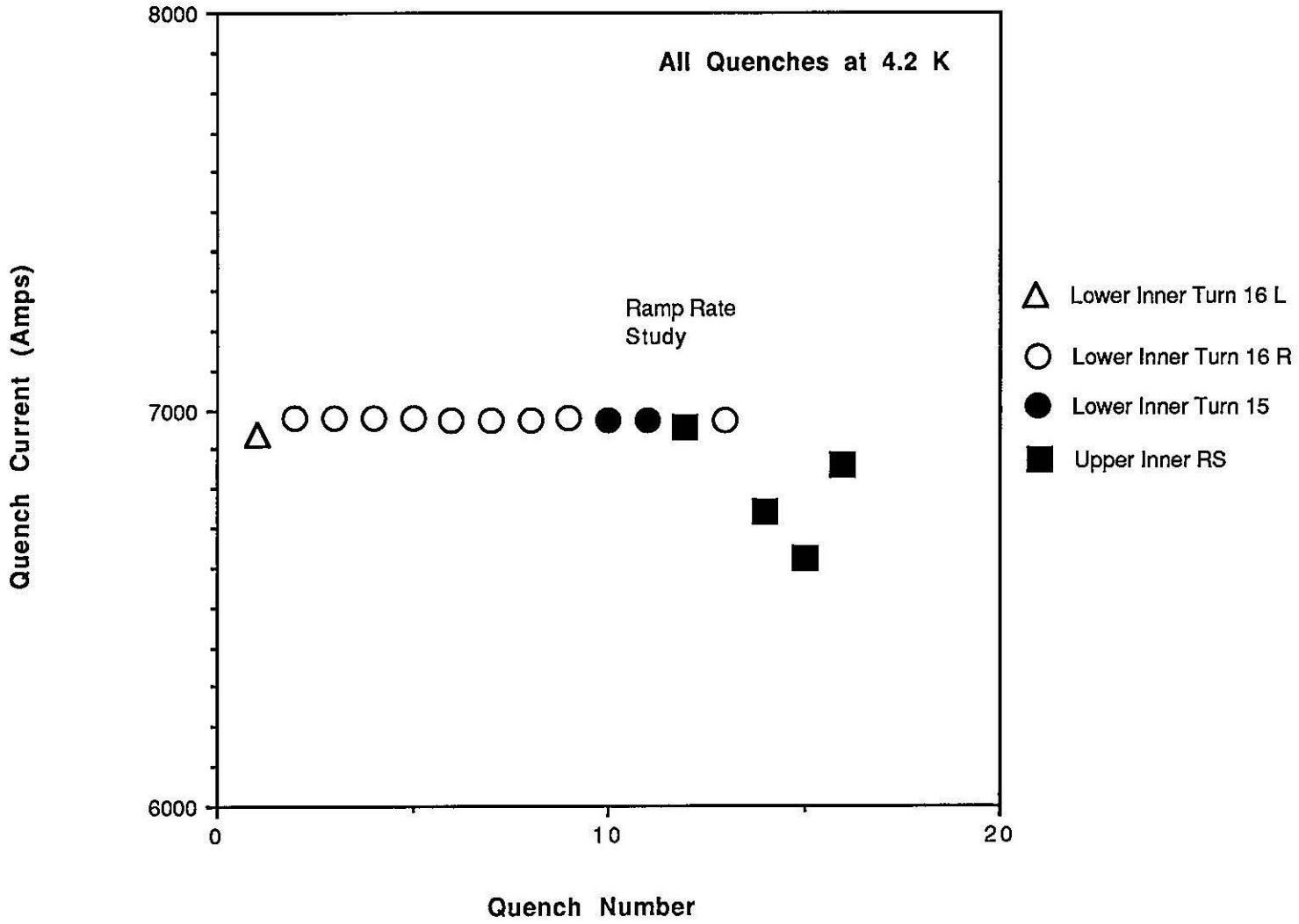
DS0308
VOLTAGE TAPS
INNER COIL

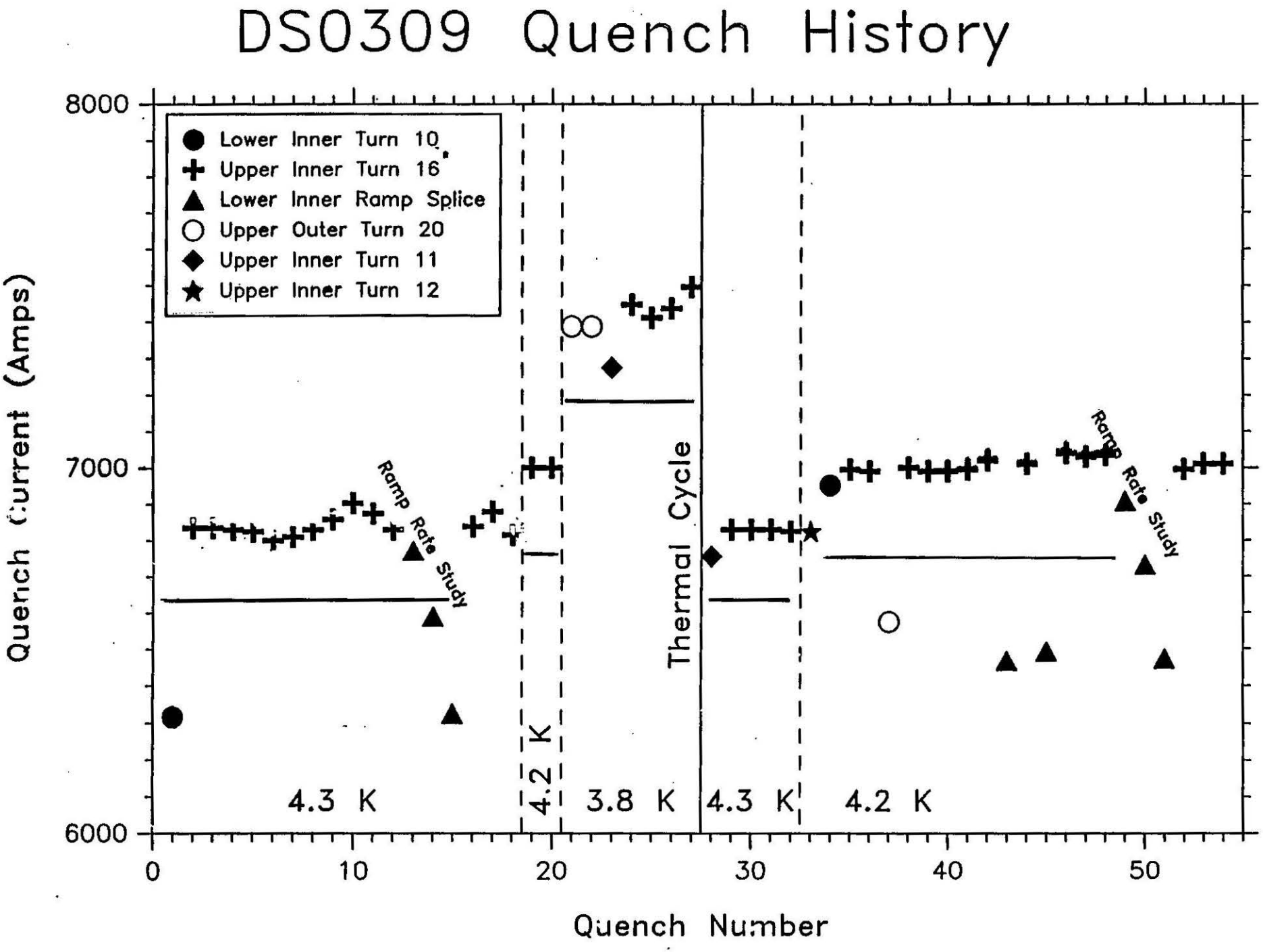
SCALE	FINISH	DRAWING NUMBER	REV.
NONE			

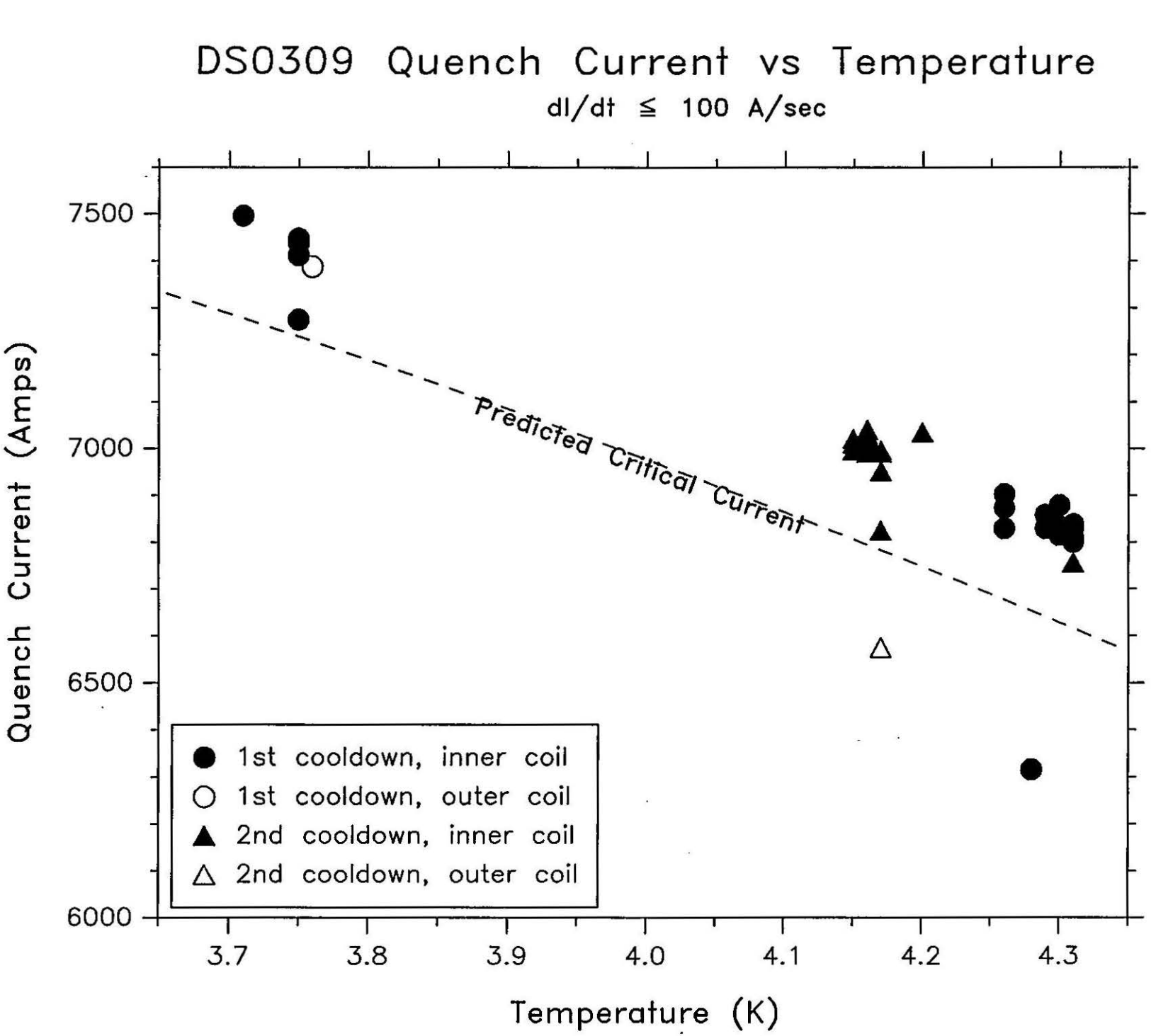
CREATED WITH I-DEAS 4.1 | USER NAME:SPUD

METRIC

DS0308 Quench History

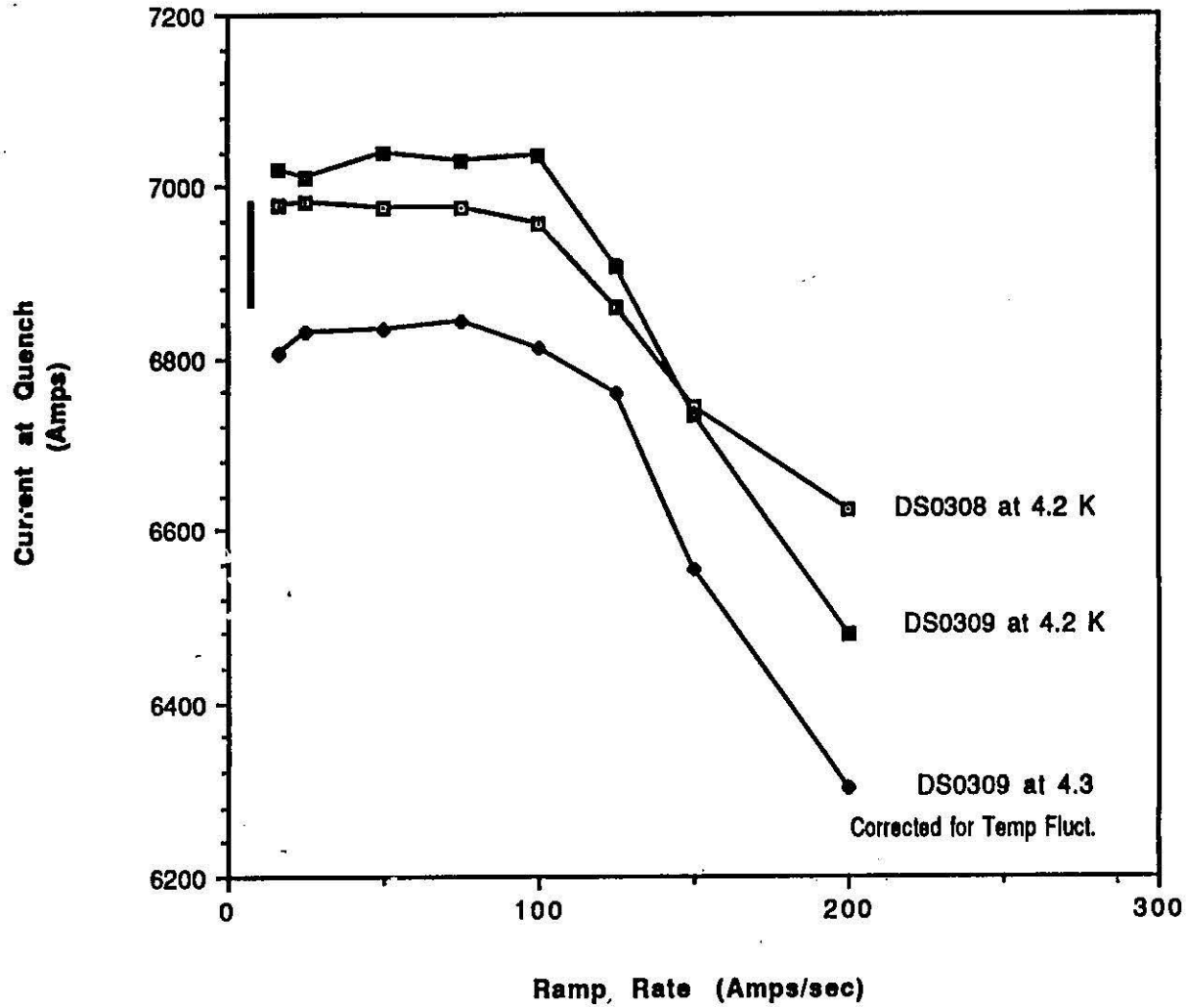


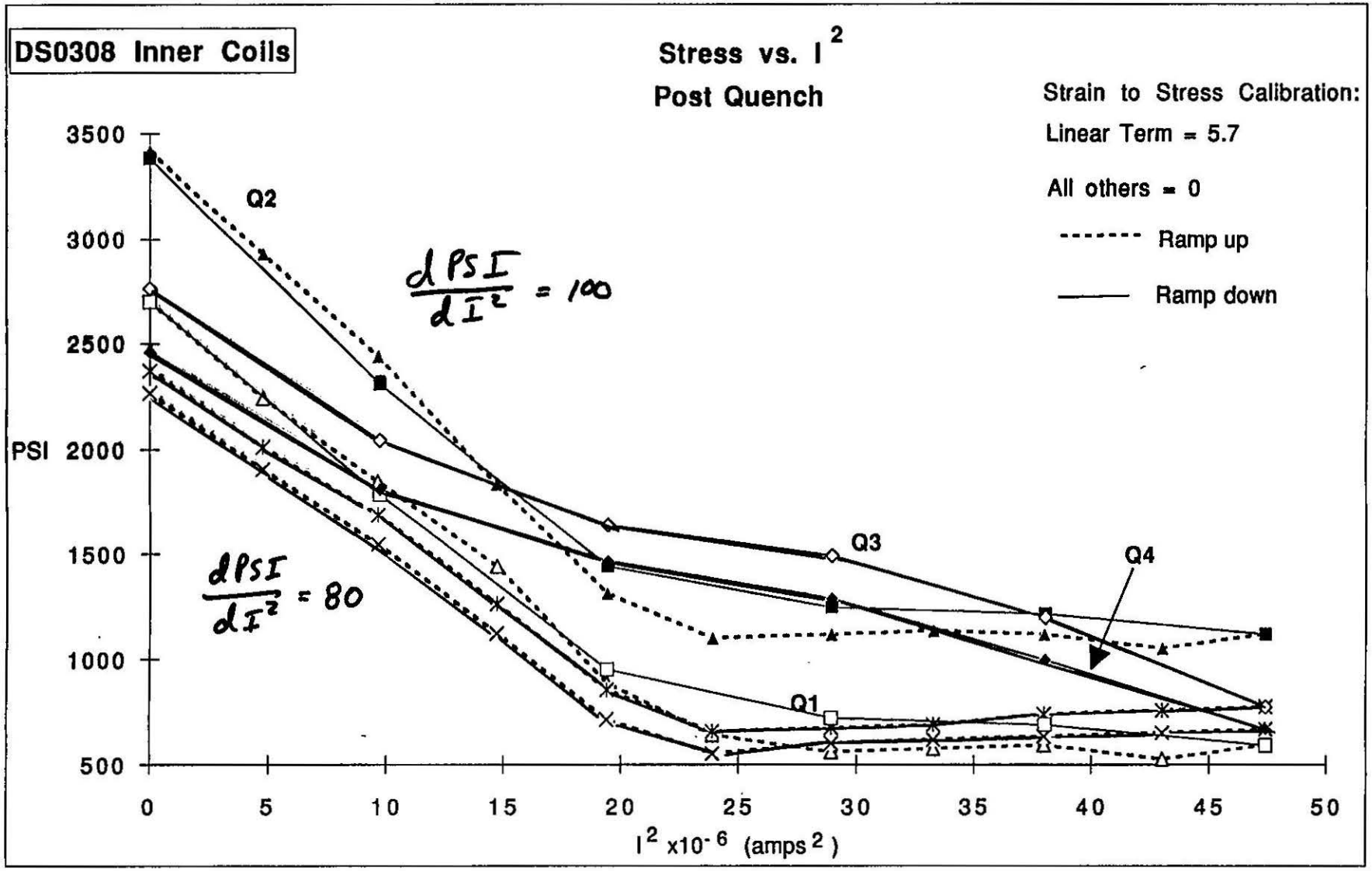

DS0309 Quench History
Lower Inner Turn 10
Upper Inner Turn 16
Lower Inner Ramp Splice
Upper Outer Turn 20
Upper Inner Turn 11
Upper Inner Turn 12
Quench Current (Amps)
8000
7000
6000
0
10
20
30
40
50
Quench Number
Ramp Rate Study
Thermal Cycle
4.3 K
4.2 K
3.8 K
4.3 K
4.2 K


DS0309 Quench Current vs Temperature
dI/dt ≤ 100 A/sec
Quench Current (Amps)
7500
7000
6500
6000
3.7
3.8
3.9
4.0
4.1
4.2
4.3
Temperature (K)
Predicted Critical Current
1st cooldown, inner coil
1st cooldown, outer coil
2nd cooldown, inner coil
2nd cooldown, outer coil

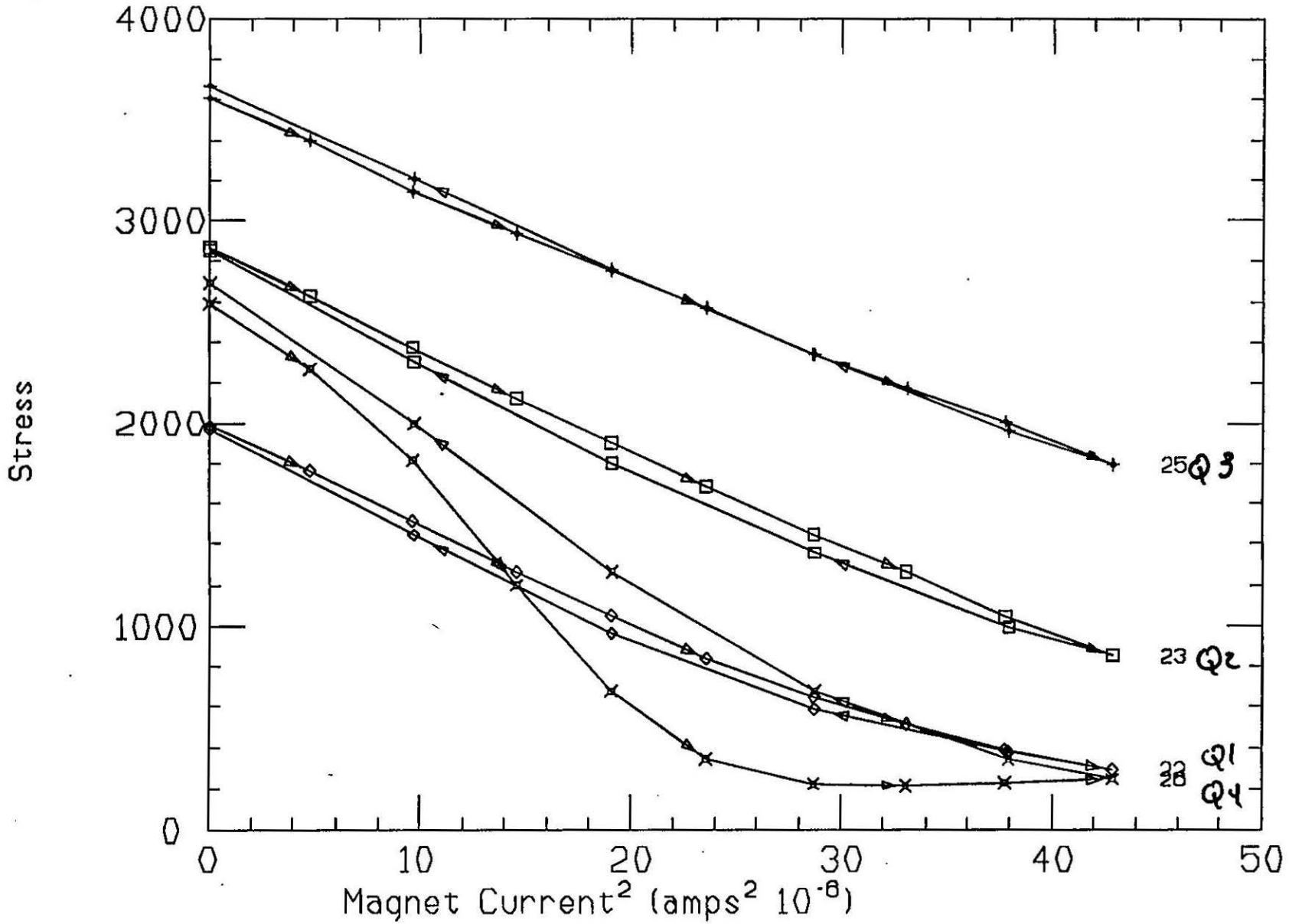
Down Ram
6500 - 4000
400 A/sec

Quench Current vs. Ramp Rate
DS0308 and DS0309



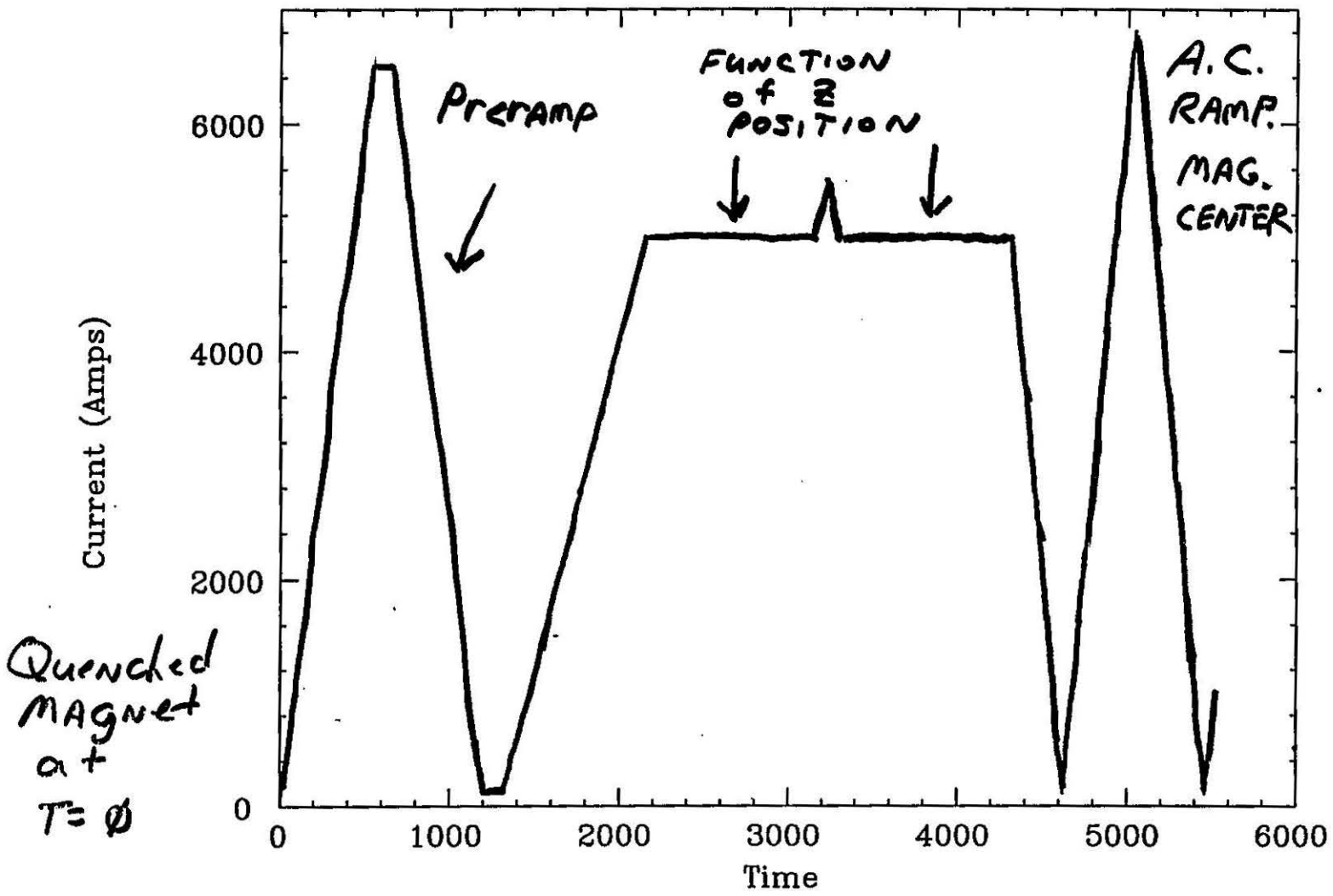

DS0308 Inner Coils
Stress vs. I 2
Post Quench
Strain to Stress Calibration:
Linear Term = 5.7
All others = 0
Ramp up
Ramp down
Q1
Q2
Q3
Q4
dPSI/dI² = 100
dPSI/dI² = 80
PSI
3500
3000
2500
2000
1500
1000
500
0
5
10
15
20
25
30
35
40
45
50
I 2 x10- 6 (amps 2)

DSØ3Ø9
Post - Quench



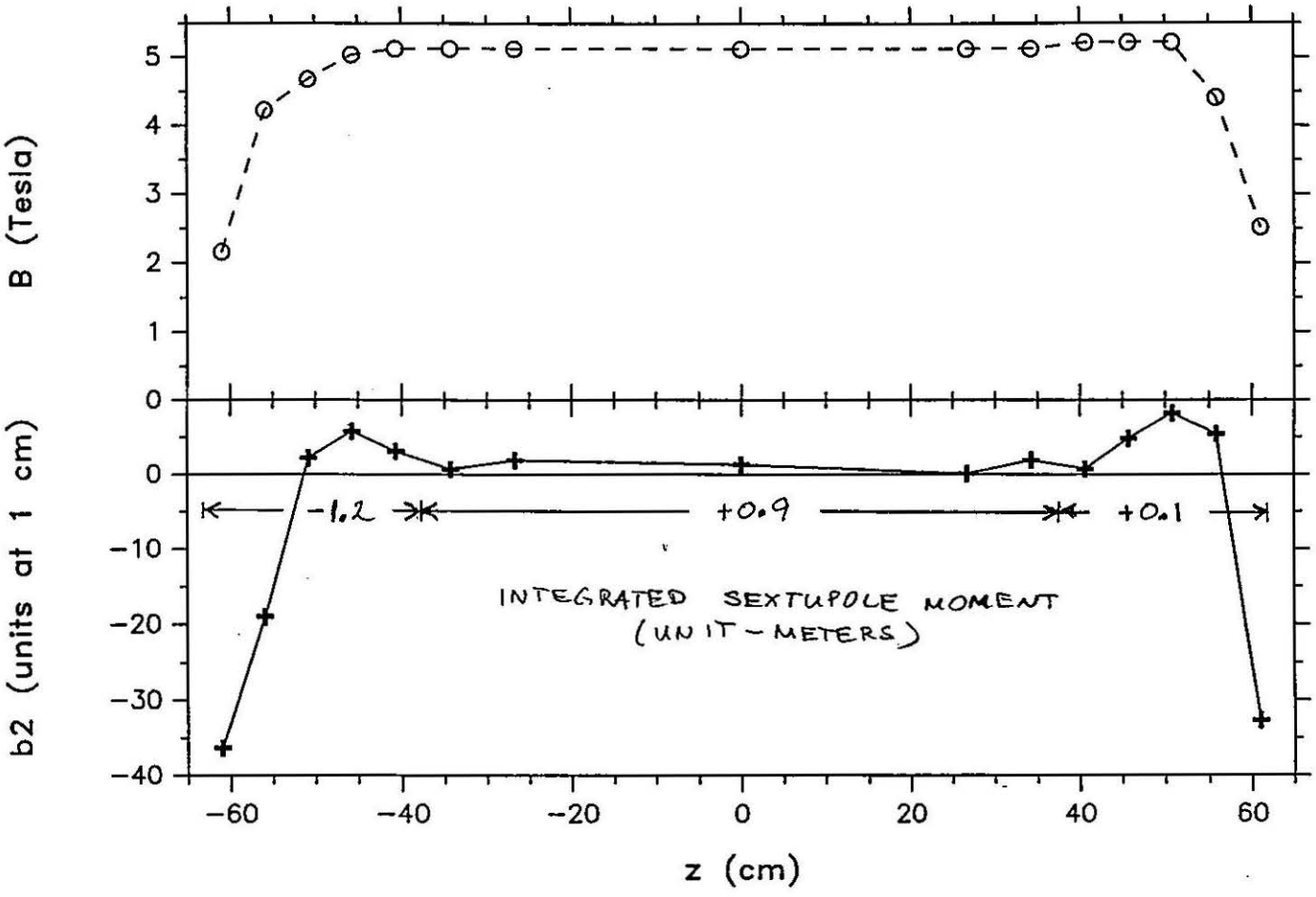
DS0309 File: DS0309.CA005 21-MAY-90 14:17:23 29-MAY-90 16:14:17

Waveform for Magnetic Measurements

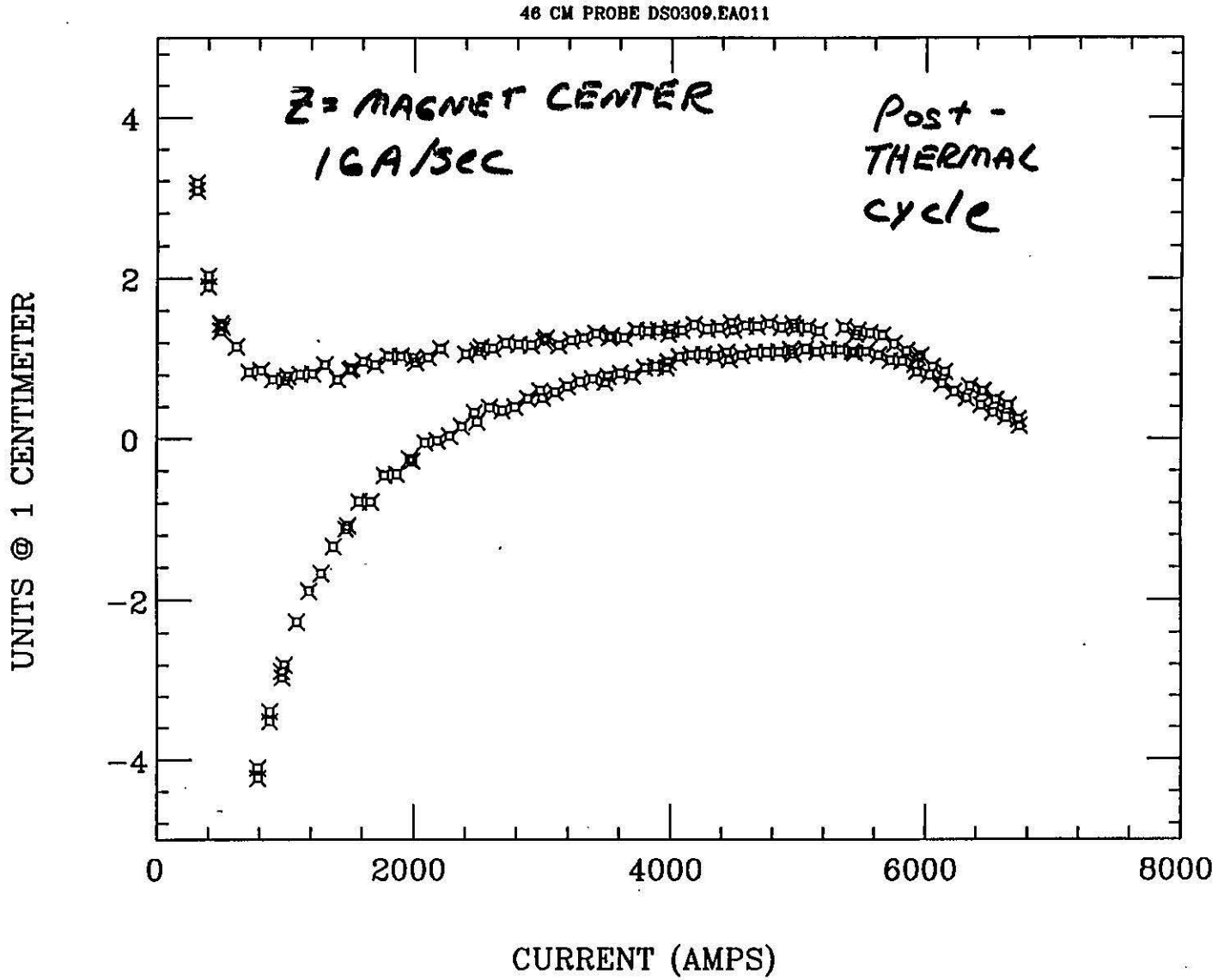


Quenched MAGnet at T = Ø

DS0309 Dipole Field and Sextupole Moment



NORMAL SEXTUPOLE DS0309



Summary

1) Valuable assembly experiences has been gained:

   - Coil molding, collaring and yoking techniques are being refined
   - Behavior of shimless insulation system as a function of prestress is being studied
   - Relation of prestress and harmonics is as expected

2) Two 1 m models have been successfully tested:

   - Operating field reached with 0 or 1 training quench
   - B (plateau) = 6.9 T for dI/dt $\leq$100 A/sec.
   - No quenching for down ramp at 400 A/sec
   - Shimless insulation OK after two cooldown cycles and >550 excitation cycles
   - Ends are magnetically "neutral"
   - Third magnet to be tested next week

3) Future tests include:

   - Further refinement of assembly techniques
   - Detailed measurements of yoke-skin interaction
   - Vertically split yoke