**Executive Summary of June 30, 1992 MSIM (GD San Diego)**

# TEST RESULTS OF FERMILAB 50 mm APERTURE, POST ASST DESIGN MODEL DIPOLE

**Tariq S. Jaffery**

DSA331 is the second "Post ASST" design Fermilab built 50 mm aperture short dipole that was cold tested in Lab2 (superconducting magnet test facility at Fermilab). This magnet has gone through two thermal cycles. This magnet showed training at 4.35K during both cooldowns and at 3.8 K in second test cycle, and all the plateau quenches were in the pole turns of inner lower/upper coils. During the second strain gage run (first cooldown) to high currents the magnet quenched in the lower inner coil pole turn at 6101 A. All quenches with low ramp rates (6,16,25 A/s), were in straight sections of the inner lower/upper coil pole turn.

**DSA331 AVERAGE PLATEAUE QUENCH CURRENTS**

| # quenches | | 22Qs | 22 Qs |
|---|---|---|---|
| | TEMP (K) | TC1 | TC2 |
| | 4.2 | 7851 A | 7850A |
| | 4.35 | 7633 A | 7649 A |
| | 3.8 | ---- | 8357A |

The ramp rate dependence of quench current on this magnet is somewhat similar to DSA329 and DSA330. All high ramp rate quenches were in the multipleturn (non pole turn) of the inner lower/upper coil which is not very well instrumented with voltage taps. There were couple of symmetric quenches in upper and lower inner coils at high ramp rates. The cold harmonics measurement data shows b2=3.3 and b4=0.61 units at 1 cm. radius. The magnet ends were preloaded to ~ 250 lb per bullet. The lead end screws were also torqued to achieve the same preload. AC loss measurements were also made on this magnet .

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# TEST RESULTS OF "POST ASST" DESIGN DSA331 MODEL DIPOLE

Tariq S. Jaffery
Fermi National Accelerator Laboratory
MSI Meeting at GD
June 30, 1992

# TEST RESULTS OF "POST ASST" DESIGN DSA331 MODEL DIPOLE

## I. INTRODUCTION

## II. MECHANICAL BEHAVIOR

## III. QUENCH BEHAVIOR

## IV. HARMONICS

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

| Magnet | Coil Stress Change (MPa) Inner Coil | | Outer Coil | | End Force Change (kN) | |
|---|---|---|---|---|---|---|
| | w | c | w | c | w | c |
| DSA329 (TC1) | -34 (67.4-33) | | (37.8-22) | -16 | (4.3;5.7) | +1.4 |
| DSA329 (TC2) | -35 (67.4-33) | | (37.8-22) | -17 | (5.6;6.5) | +1.1 |
| DSA330 (TC1) | -28 (56.4-28.2) | | (63.3-46.8) | -17 | (4.4;3.0) | -1.4 |
| DSA331 (TC1) | -36 (80.6-44.7) | | (34.9-22) | -13 | (5.1;6.4) | +1.4 |
| DSA331 (TC2) | -39 (82.2-33) | | (30.5-20.8) | -10 | (6;6.9) | +1.0 |

| Magnet | | coil | cable | insulation | shim | wedge |
|---|---|---|---|---|---|---|
| DSA330 | UP-out | 235 | 4-I-40 | 2H+2LT one side | +5 | |
| (Spalding) | LW-out | 236 | 4-I-58 | 2H+2LT one side | +5 | |
| | UP-in | 135 | 3-S-26 | 2H+butLT one side | +0 | (1) |
| | LW-in | 136 | 3-S-26 | 2H+butLT one side | +0 | (1) |
| DSA331 | UP-out | 240 | 4-I-58 | 2NP one side+2NP one side | +0 | |
| | LW-out | 239 | 4-I-56 | 2NP one side+2NP one side | +0 | |
| | UP-in | 140 | 3-S-26 | 3NP one side | +0 | |
| | LW-in | 139 | 3-S-26 | 3NP one side | (+5) | (2) |
| DSA332 | UP-out | 237 | 4-I-58 | 2H+2LT one side | +10 | |
| | LW-out | 238 | 4-I-58 | 2H+2LT one side | +10 | |
| | UP-in | 137 | 3-I-66 | 2H+butLT one side | +0 | |
| | LW-in | 138 | 3-S-26 | 2H+butLT one side | +0 | |
| DSA 333 | UP-out | 242 | 4-I-58 | 2H+2LT both side | +4 | |
| (torlon) | LW-out | 243 | 4-I-51 | 2H+2LT both side | +4 | |
| | UP-in | 143 | 3-I-66 | 2H+butLT both side | +2 | |
| | LW-in | 144 | 3-I-66 | 2NP+butLT both side | +2 | |
| DSA 334 | UP-out | | 4-O-25 | 2NP+2NP both side | | |
| (cryorad) | LW-out | | 4-O-25 | 2NP+2NP both side | | |
| | UP-in | | 3-I-66 | 2NP+butNP both side | | |
| | LW-in | | 3-I-66 | 2NP+butNP both side | | |
| DCA 320 | UP-out | 2022 | 4-S-29 | 2H+2LT one side | +5 | |
| | LW-out | 2023 | 4-S-29 | 2H+2LT one side | +5 | |
| | UP-in | 1021 | 3-I-66 | 2H+butLT one side | +0 | |
| | LW-in | 1022 | 3-I-68 | 2H+butLT one side | +0 | |
| DCA 321 | UP-out | 2024 | 4-S-30 | 2H+2LT one side | +5 | |
| | LW-out | 2025 | 4-S-30 | 2H+2LT one side | +5 | |
| | UP-in | 1023 | 3-S-25 | 2H+butLT one side | +0 | |
| | LW-in | 1024 | 3-S-25 | 2H+butLT one side | +0 | |
| DCA 322 | UP-out | 2026 | 4-S-31 | 2NP+2NP both side | +0 | |
| | LW-out | 2027 | 4-S-31 | 2NP+2NP both side | +0 | |
| | UP-in | 1025 | 3-S-35 | 2NP+butNP both side | +0 | |
| | LW-in | 1026 | 3-S-36 | 2NP+butNP both side | +0 | |
| DCA 323 | UP-out | 2028 | 4-S-32 | 2NP+2NP both side | +0 | |
| | LW-out | 2029 | 4-S-32 | 2NP+2NP both side | +0 | |
| | UP-in | 1027 | 3-S-40 | 2NP+butNP both side | +0 | |
| | LW-in | 1028 | 3-S-46 | 2NP+butNP both side | +0 | |

(1) Two 15 mil shims in large wedge. Had difficulty

(2) 15 mil shim in large wedge could have been used insted of 30 mil one. The pole shim of 5 mil was used only in the quadrant 4.

- Standard wedges have 15 mil brass shim in small inner wedges, 30 mil shim in large inner wedges and 10 mil shim in outer wedges to compensate the cable thickness change.

# KEYS AND SADDLES

**INNER COIL KEYS AND SADDLES ON RETURN END:**

**DSA330**

**MADE BY RESIN TRANSFER MOLDING PROCESS (G-10 like molded part).**

**DSA331**

**G-10CR, SO NOT CHANGED FROM ASST**

**END CANS: 6 LAYERS OF KAPTON BETWEEN COLLETS AND COIL ENDS**

**INSTALLED WITH ~67 MPa**

# COIL INSULATION

## DSA330

**Inner Coils: 1 layer of .001"x.375" bare kapton H film with 50% overlap surrounded by 1 layer of .001"x.375" kapton LT film with .0002" Scotch 2290 adhesive on one side butt lap.**

**Outer Coils:1 layer of .001"x.375" bare kapton H film with 50% overlap surrounded by 1 layer of .001"x.375" kapton LT film with .0002" Scotch 2290 adhesive on one side butt lap.**

## DSA331

**Inner Coils: 1 layer of .001"x.375" Apical NP with Cryorad adhesive on one side with 67% overlap.**

**Outer Coils:1 layer of .001"x.375" bare Apical NP with 50% overlap surrounded by 1 layer of .001"x.375" Apical NP with Cryorad adhesive on one side with 50% overlap.**

# WEDGE SHIMMING SCHEME

**DSA33X**

**STANDARD WEDGES TO COMPENSATE FOR CABLE THICKNESS CHANGE**

**INNER COILS:**

**#1 AND #2 (smaller wedges) HAVE .015" BRASS SHIM ON ONE POLE SIDE**

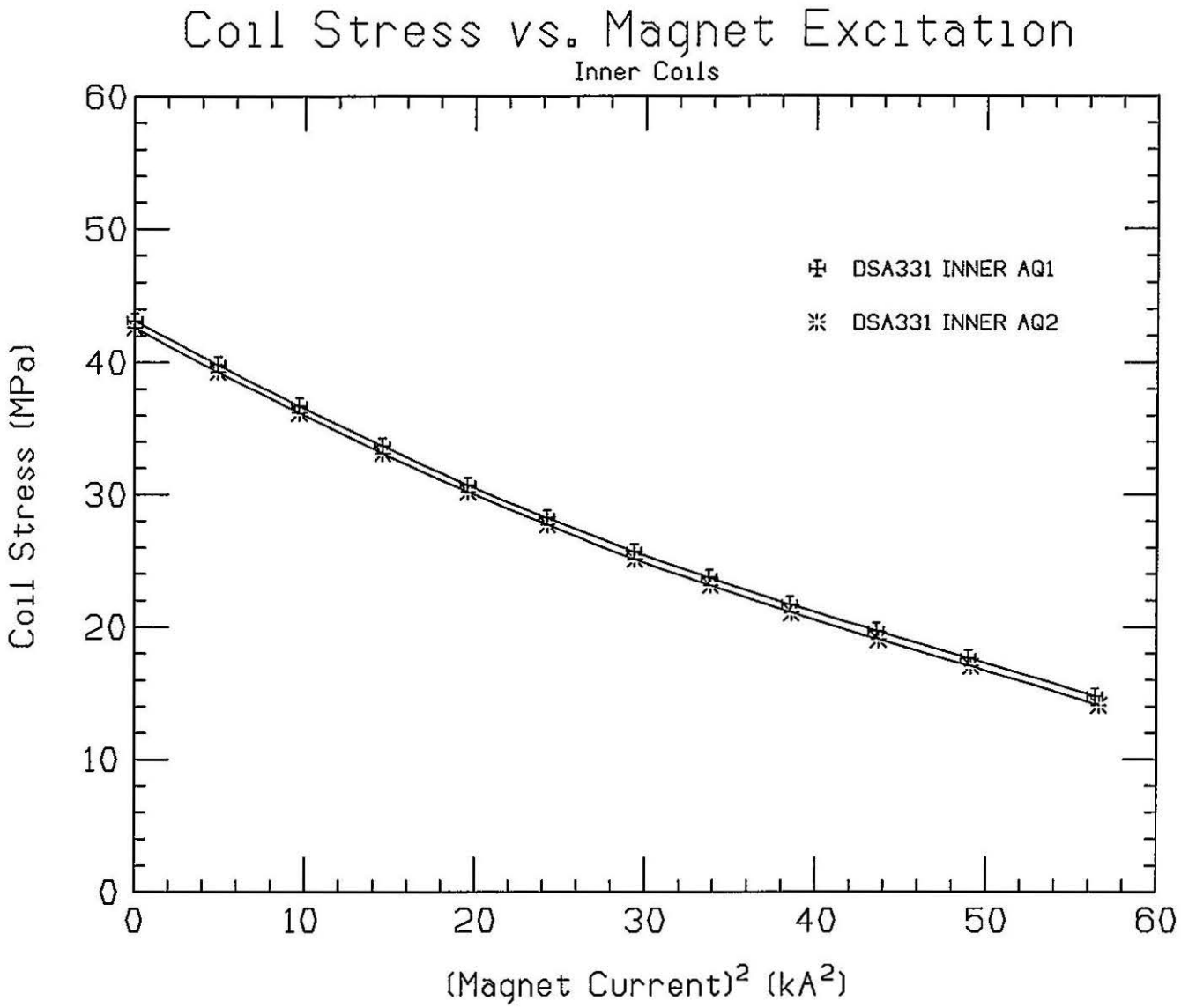
**#3 (thick wedge) HAS .015 BRASS SHIM ON EACH SIDE**

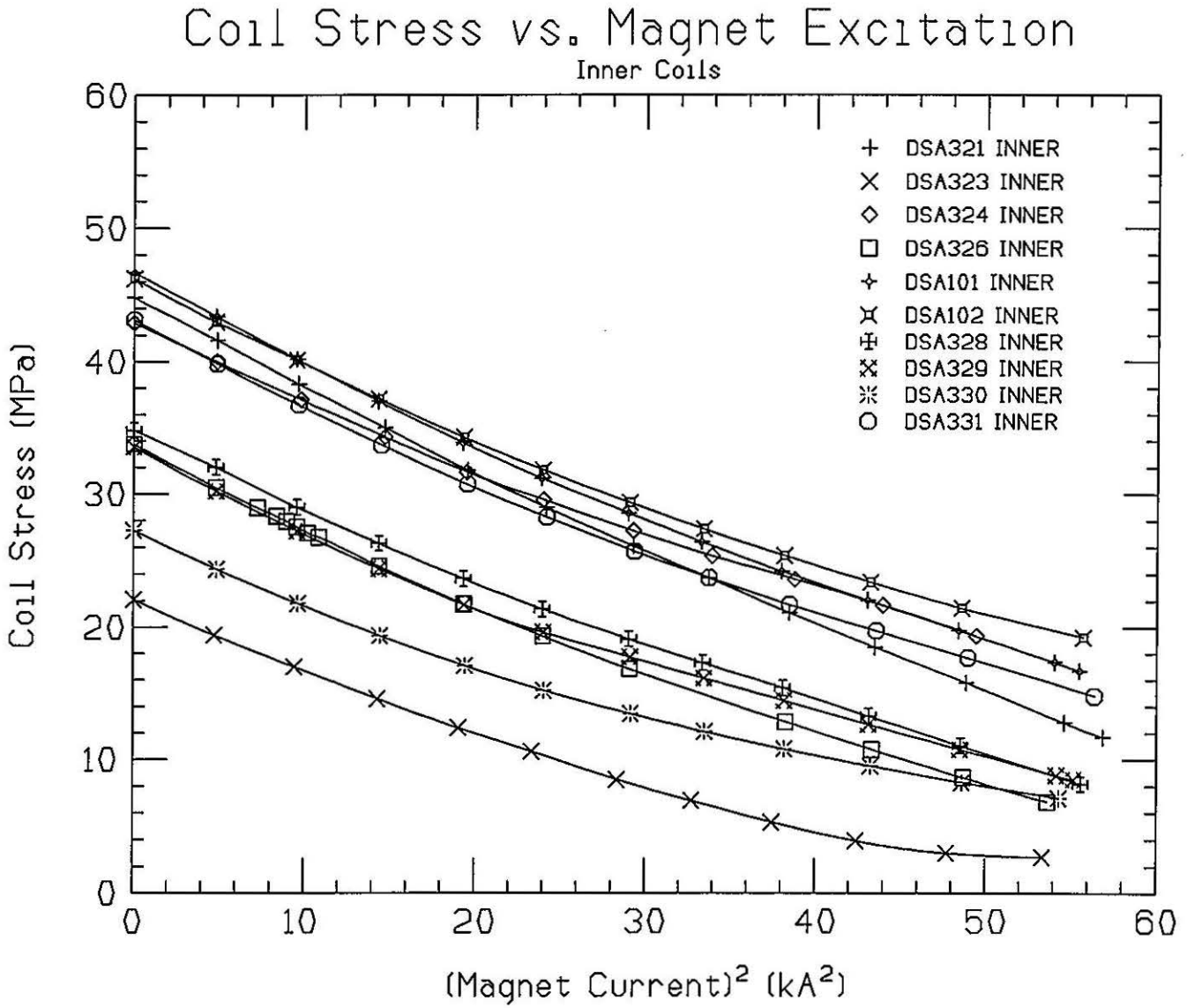
**OUTER COILS:**

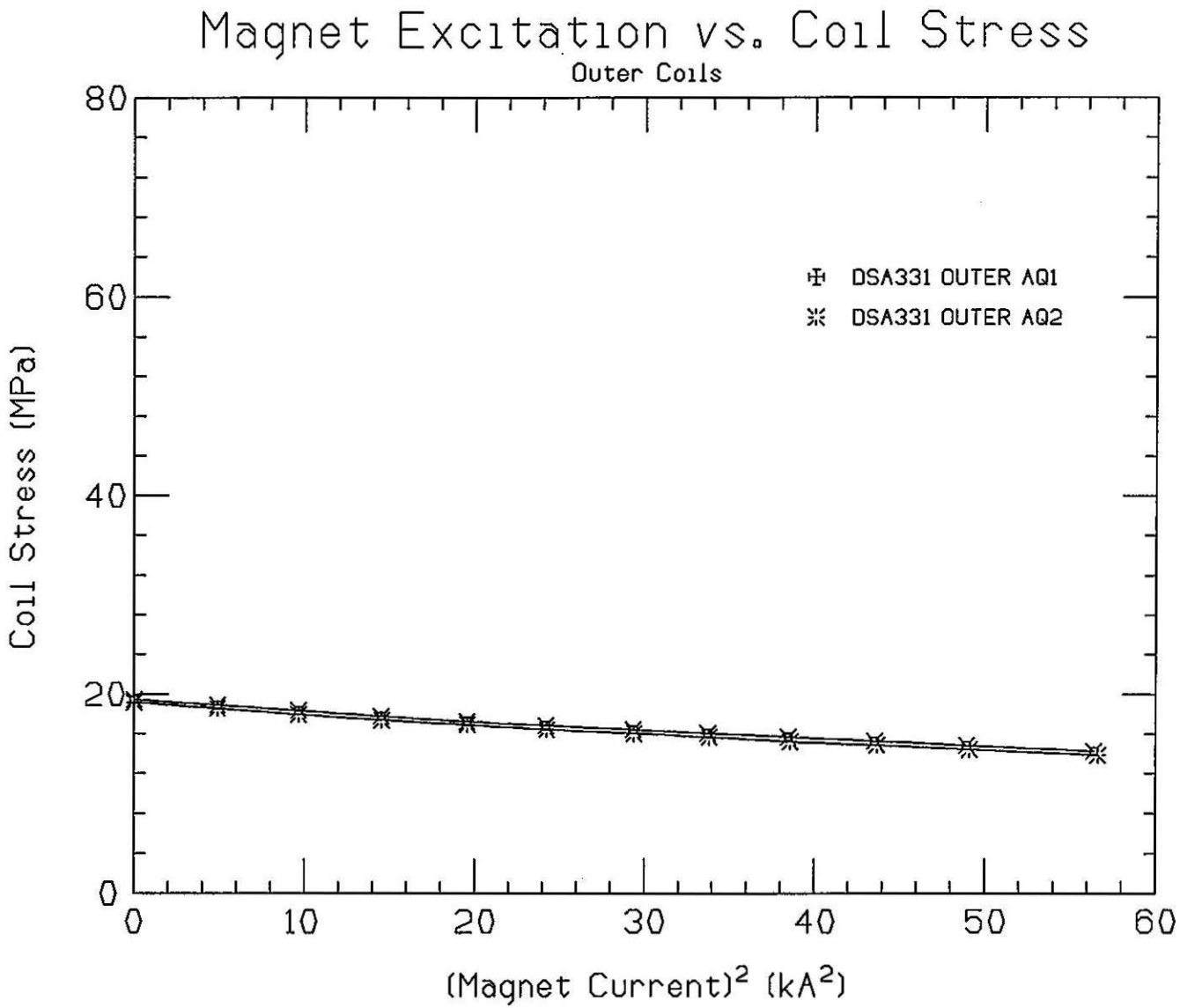
**0.010" BRASS SHIM ON POLE SIDE**

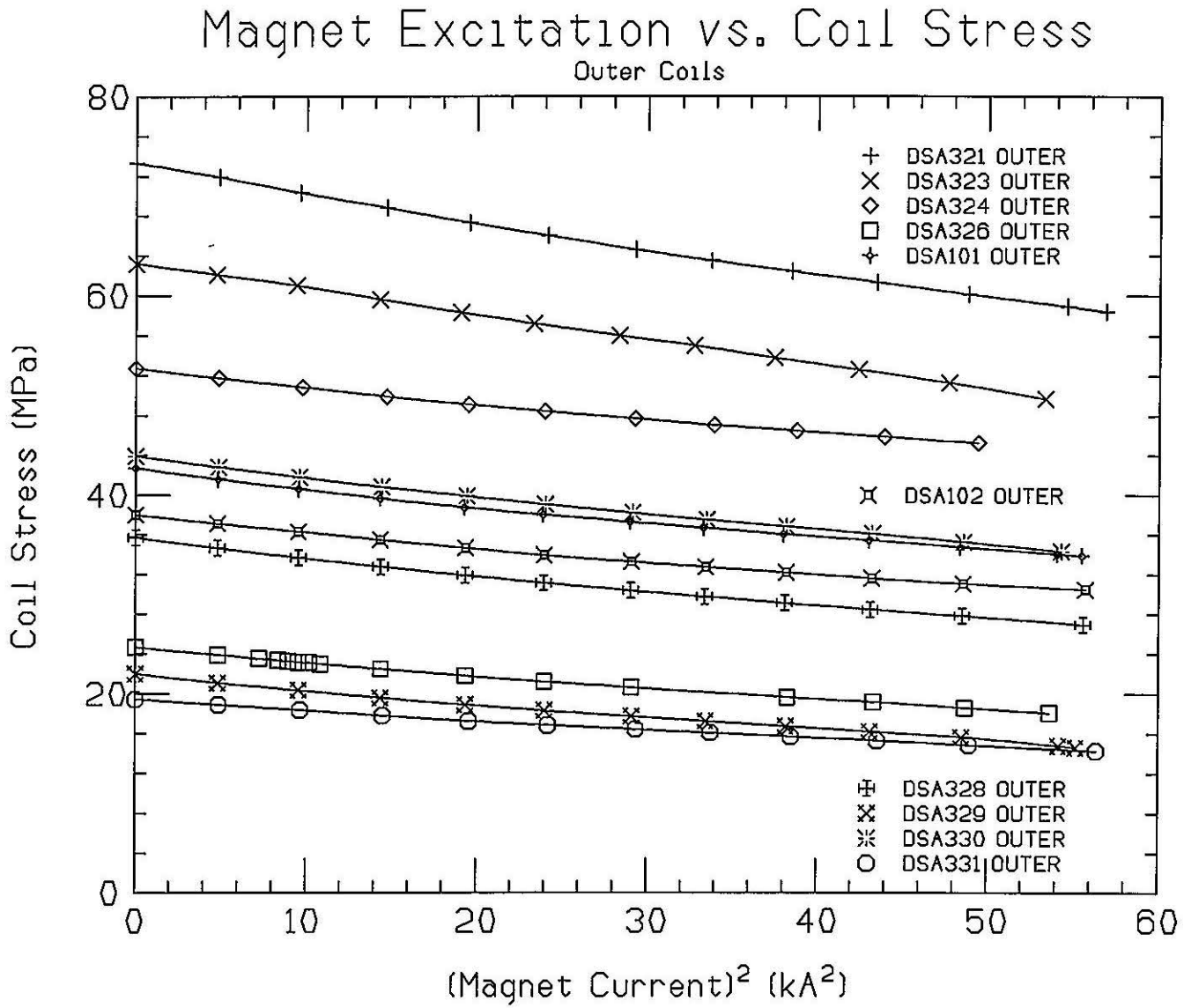
**END CANS: 6 LAYERS OF KAPTON BETWEEN COLLETS AND COIL ENDS**

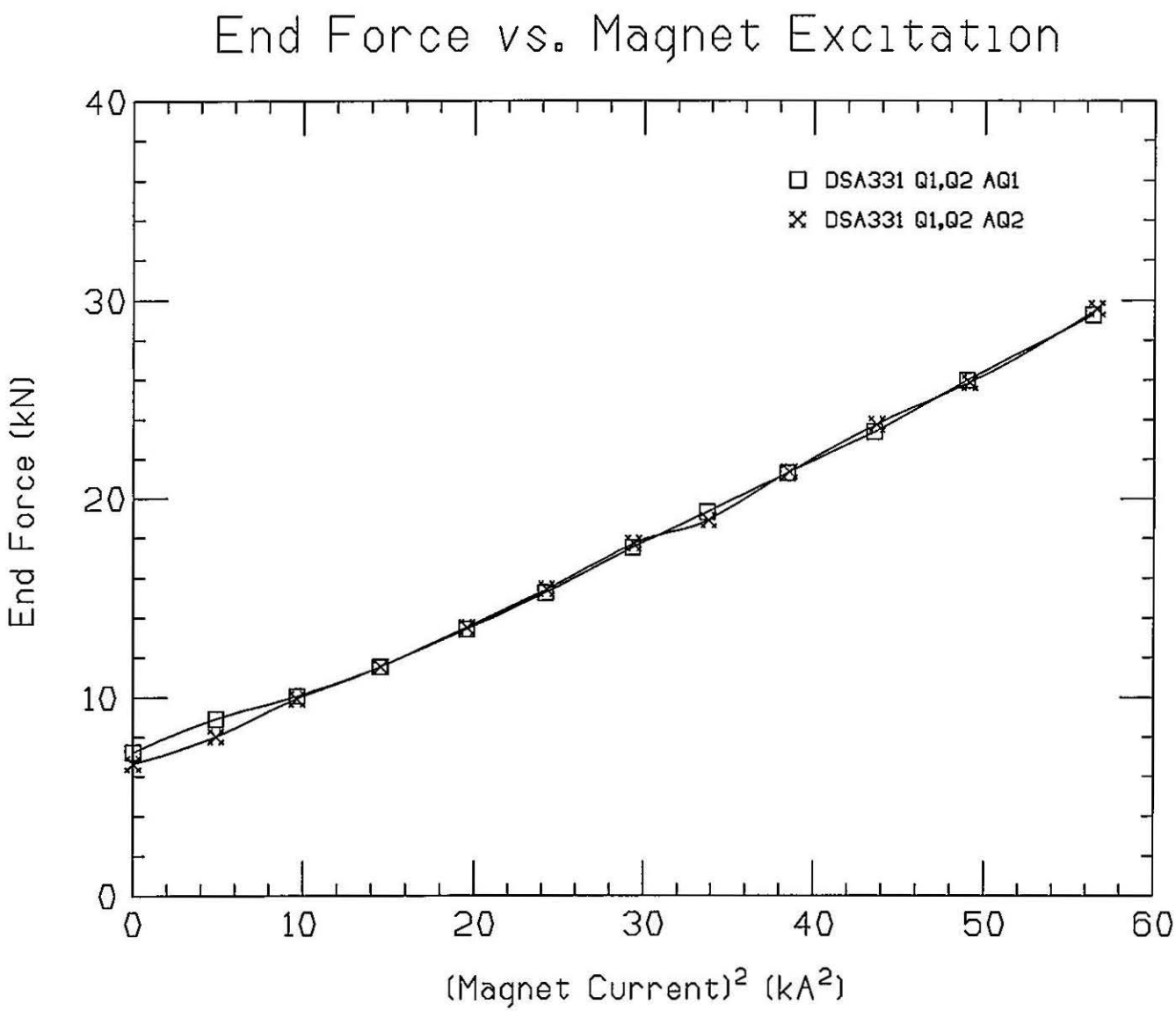
**INSTALLED WITH ~67 MPa**

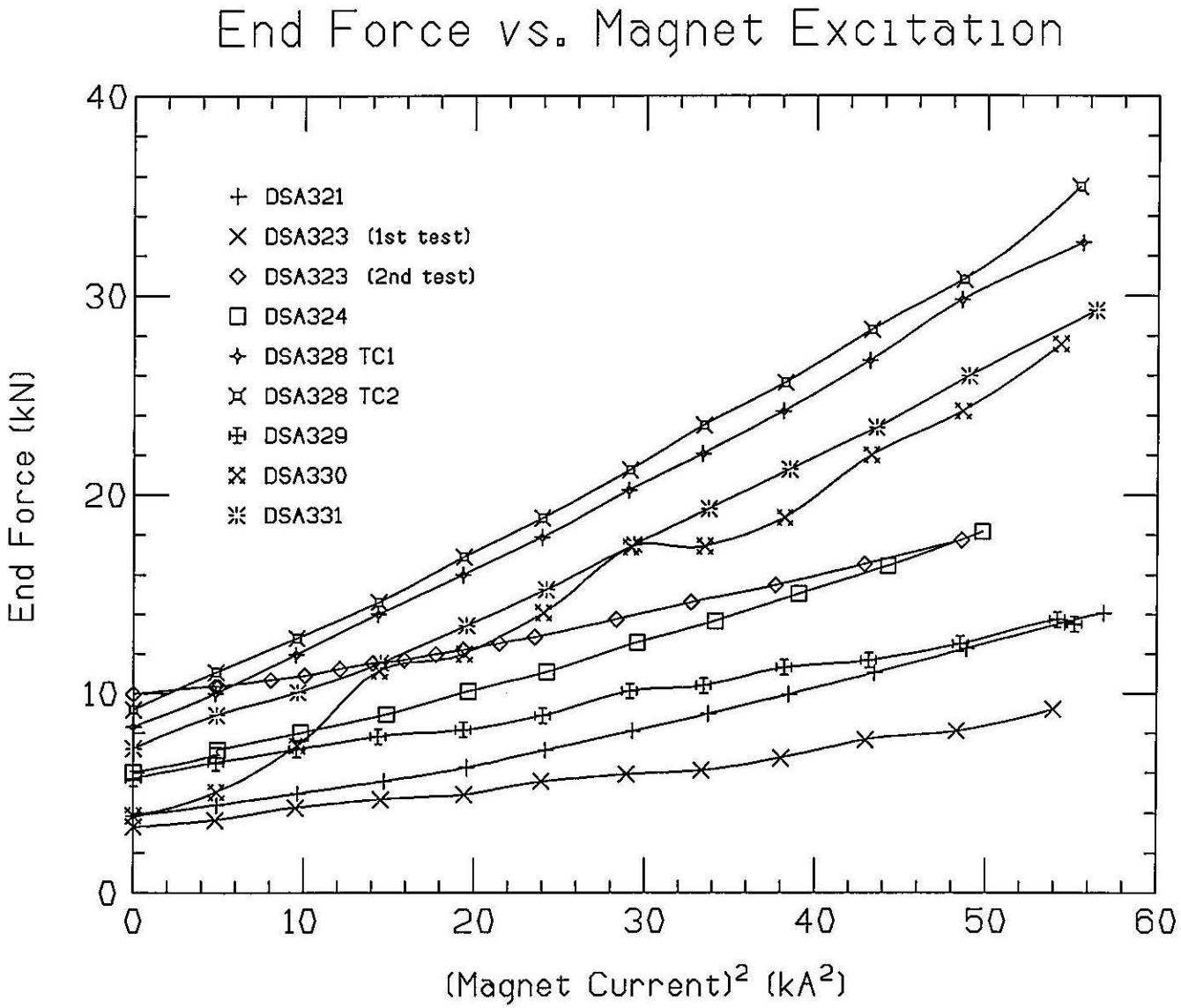

Coil Stress vs. Magnet Excitation
Inner Coils
DSA331 INNER AQ1
DSA331 INNER AQ2
Coil Stress (MPa)
(Magnet Current)$^2$ (kA$^2$)
0
10
20
30
40
50
60


Coil Stress vs. Magnet Excitation
Inner Coils
Coil Stress (MPa)
(Magnet Current)$^2$ (kA$^2$)
0
10
20
30
40
50
60
DSA321 INNER
DSA323 INNER
DSA324 INNER
DSA326 INNER
DSA101 INNER
DSA102 INNER
DSA328 INNER
DSA329 INNER
DSA330 INNER
DSA331 INNER


Magnet Excitation vs. Coil Stress
Outer Coils
DSA331 OUTER AQ1
DSA331 OUTER AQ2
Coil Stress (MPa)
0
20
40
60
80
0
10
20
30
40
50
60
(Magnet Current)$^2$ (kA$^2$)


Magnet Excitation vs. Coil Stress
Outer Coils
Coil Stress (MPa)
(Magnet Current)$^2$ (kA$^2$)
0
20
40
60
80
0
10
20
30
40
50
60
DSA321 OUTER
DSA323 OUTER
DSA324 OUTER
DSA326 OUTER
DSA101 OUTER
DSA102 OUTER
DSA328 OUTER
DSA329 OUTER
DSA330 OUTER
DSA331 OUTER


End Force vs. Magnet Excitation
DSA331 Q1,Q2 AQ1
DSA331 Q1,Q2 AQ2
End Force (kN)
(Magnet Current)² (kA²)
0
10
20
30
40
50
60


End Force vs. Magnet Excitation
DSA321
DSA323 (1st test)
DSA323 (2nd test)
DSA324
DSA328 TC1
DSA328 TC2
DSA329
DSA330
DSA331
End Force (kN)
(Magnet Current)$^2$ (kA$^2$)
0
10
20
30
40
50
60

# DSA331

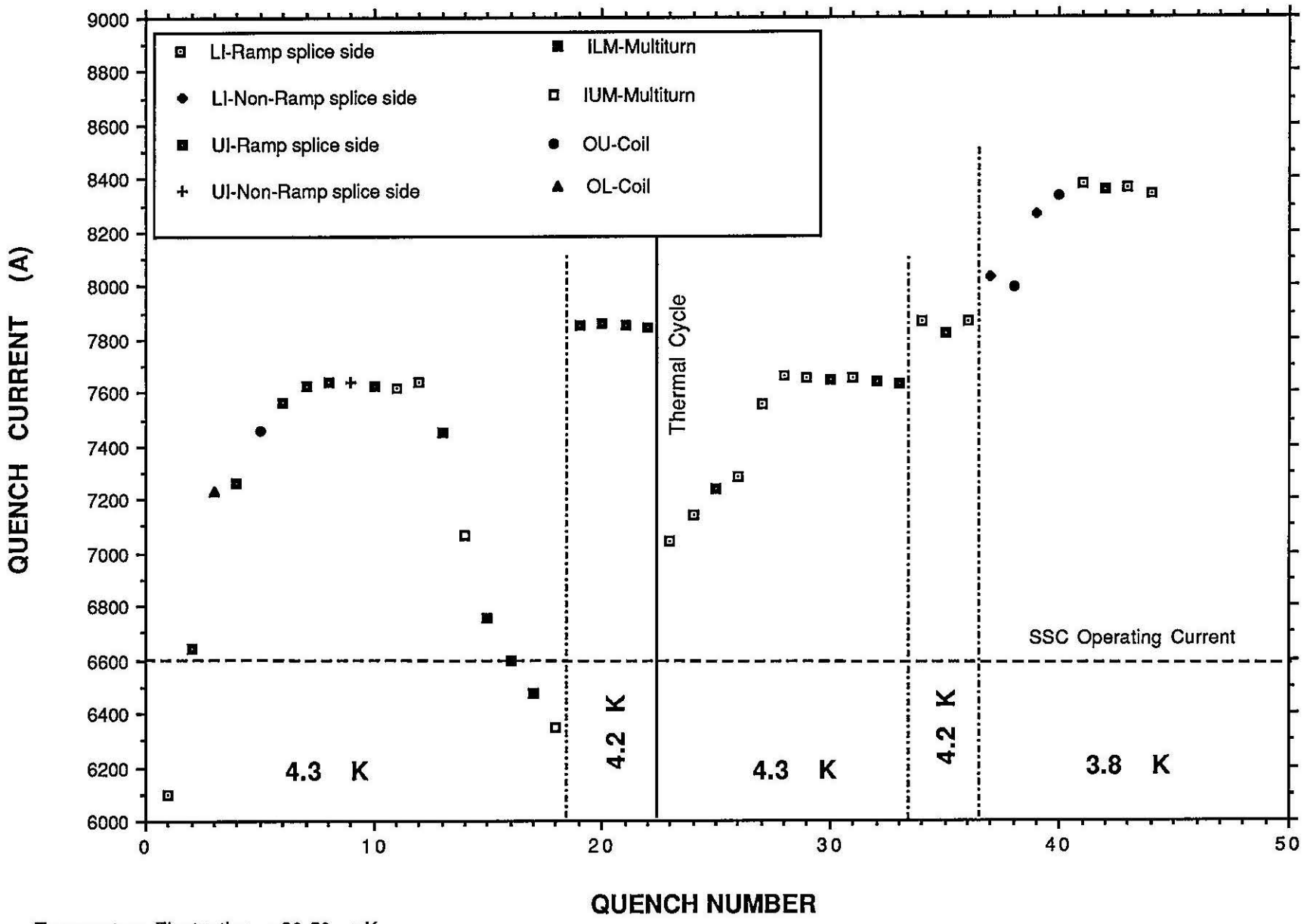
| CABLES: | INNER | OUTER |
|---|---|---|
| UP | SSC-3-S-00026 | SSC-4-I-00058 |
| LO | SSC-3-S-00026 | SSC-4-I-00056 |

**PREDICTED Iq at 4.35 K = 7480 A ; 3.8 K = 8161 A**

**PLATEAU CURRENTS (Avg):**

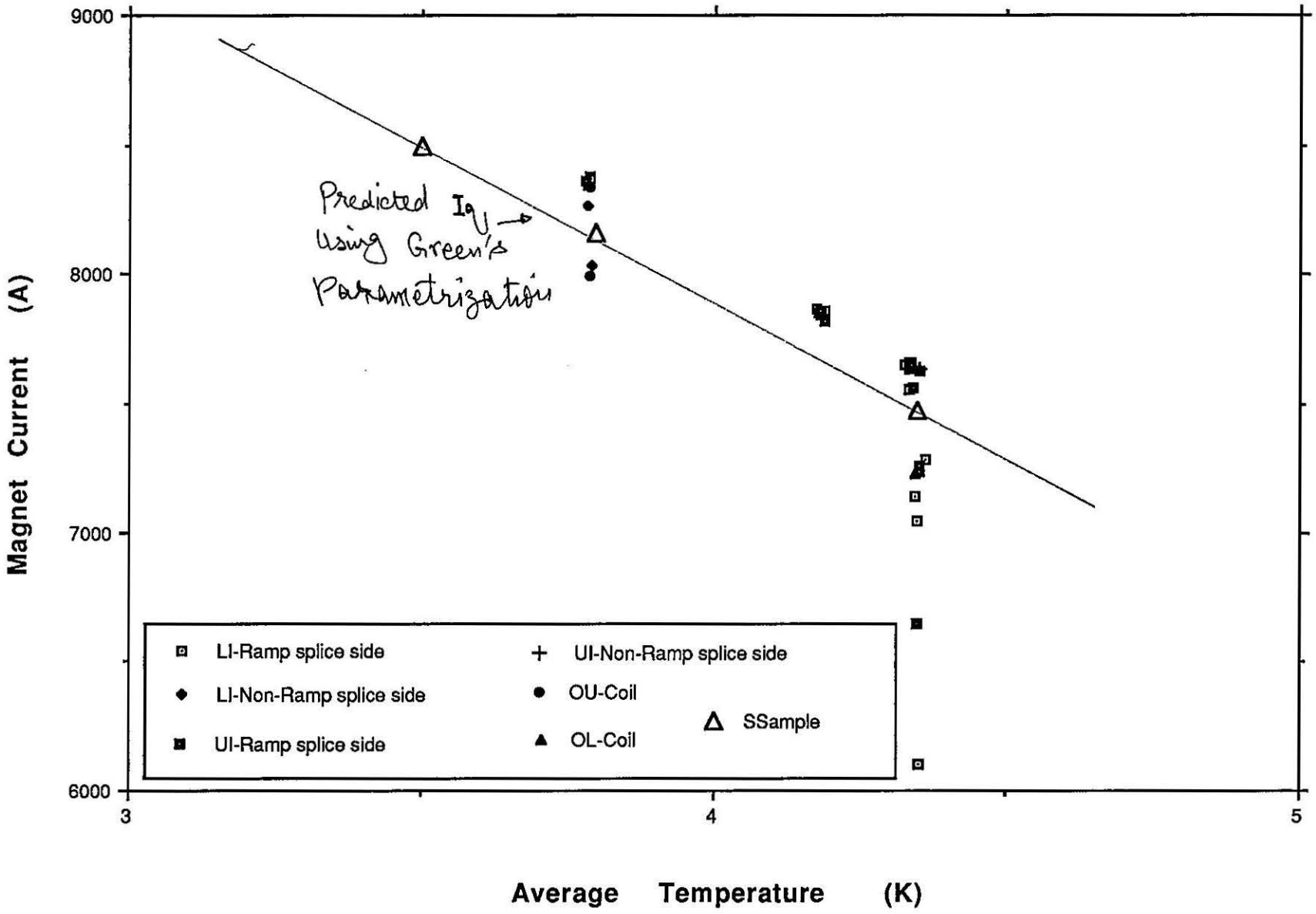
| | TC1 (22 quenches) | TC2 (22 quenches) |
|---|---|---|
| 4.3 K | = 7633 | 7649 |
| 4.2 K | = 7850 | 7851 |
| 3.8 K | = ---- | 8357 |

# DSA331 QUENCH HISTORY
## (Fermilab built 50 mm aperture, Post ASST Design Model Dipole)

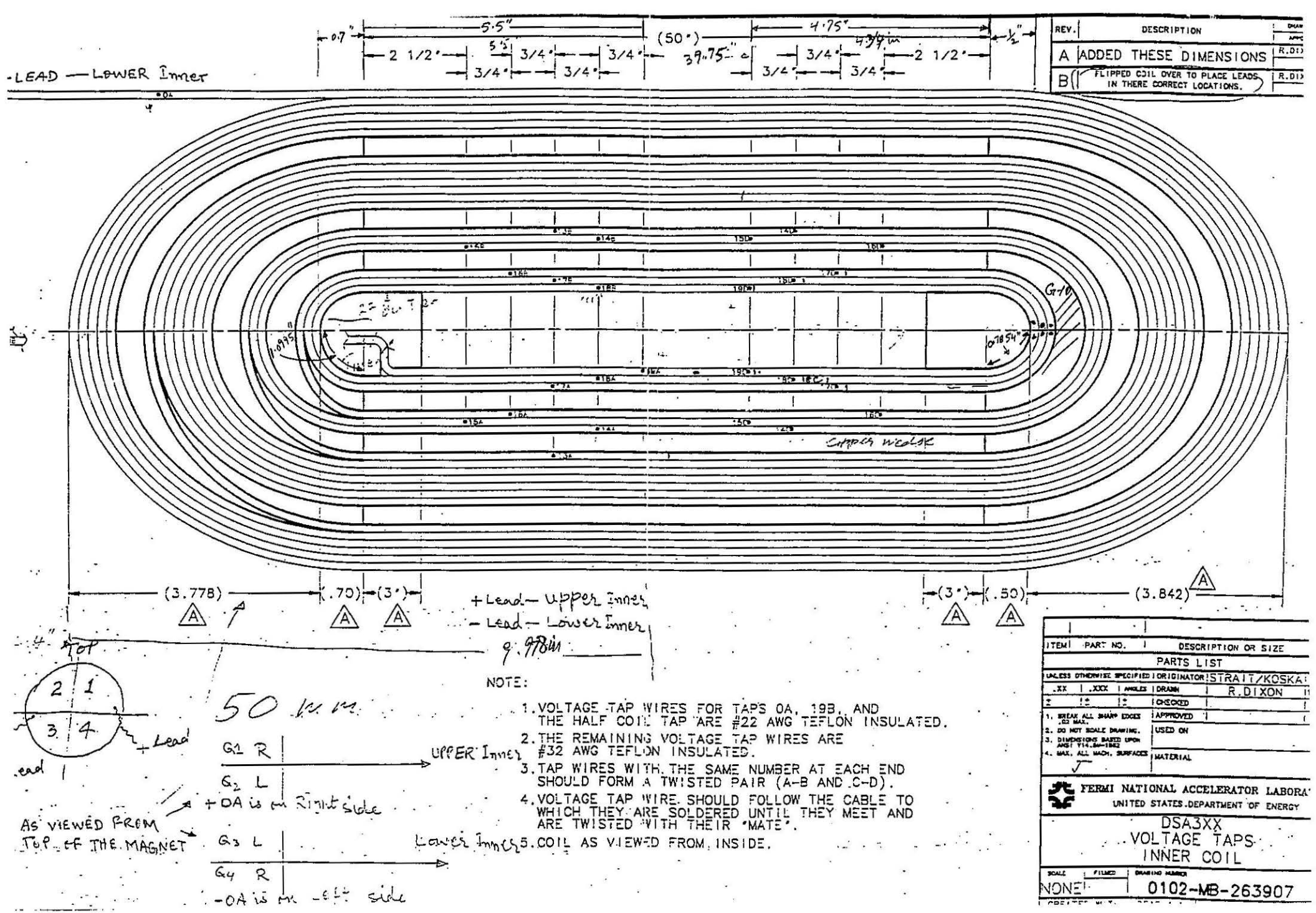



Temperature Fluctuation ~30-50 mK

# DSA331 Quench Current vs Temperature




Fluctuation in temp. ~30-50 mK




NOTE:

1. VOLTAGE TAP WIRES FOR TAPS 0A, 19B, 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.

| ITEM | PART NO. | DESCRIPTION OR SIZE |
|---|---|---|

PARTS LIST

UNLESS OTHERWISE SPECIFIED | ORIGINATOR: STRAIT/KOSKA
.XX | .XXX | ANGLES | DRAWN: R.DIXON
CHECKED
APPROVED
USED ON
MATERIAL

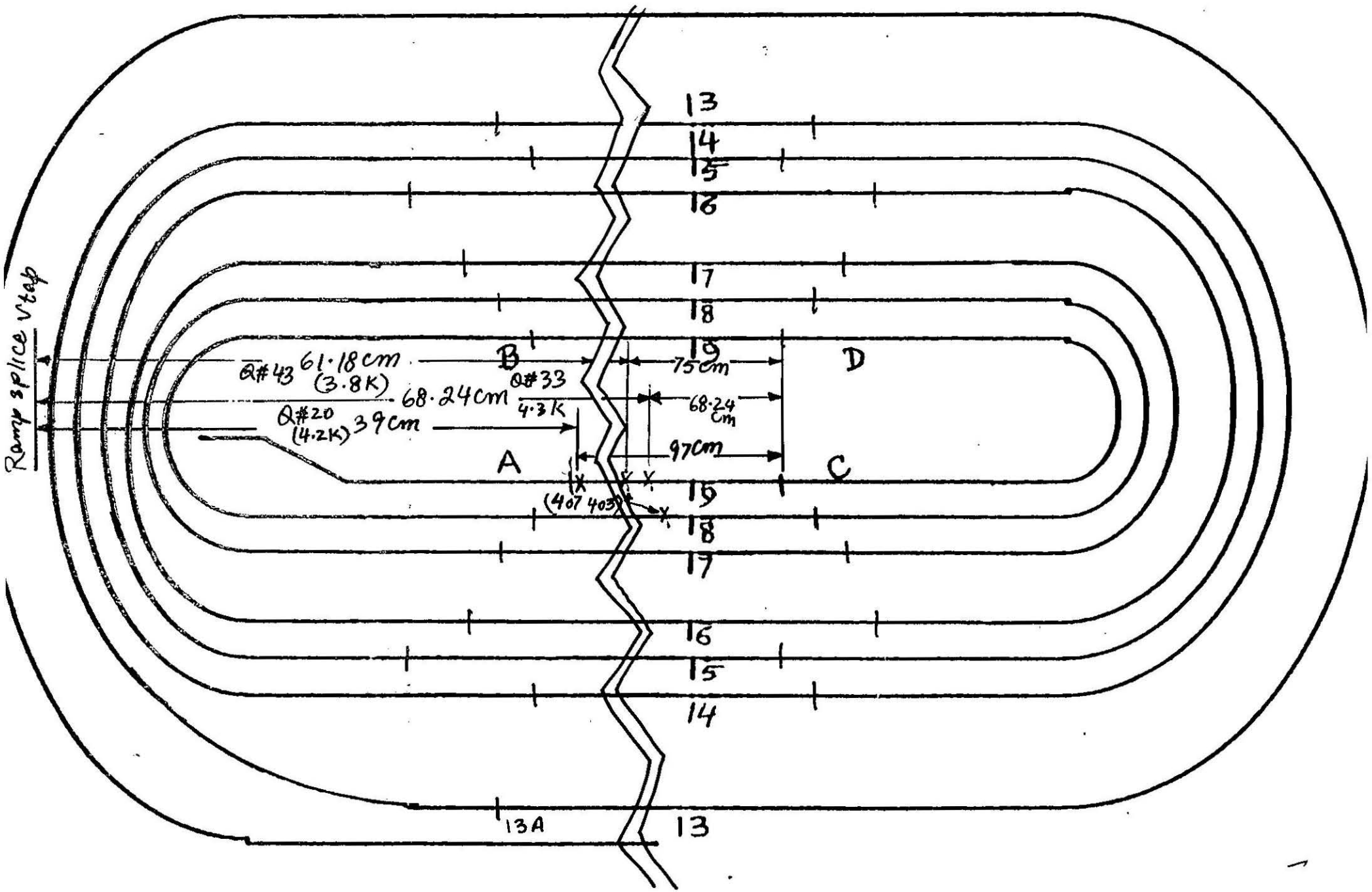
1. BREAK ALL SHARP EDGES .02 MAX.
2. DO NOT SCALE DRAWING.
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982
4. MAX. ALL MACH. SURFACES

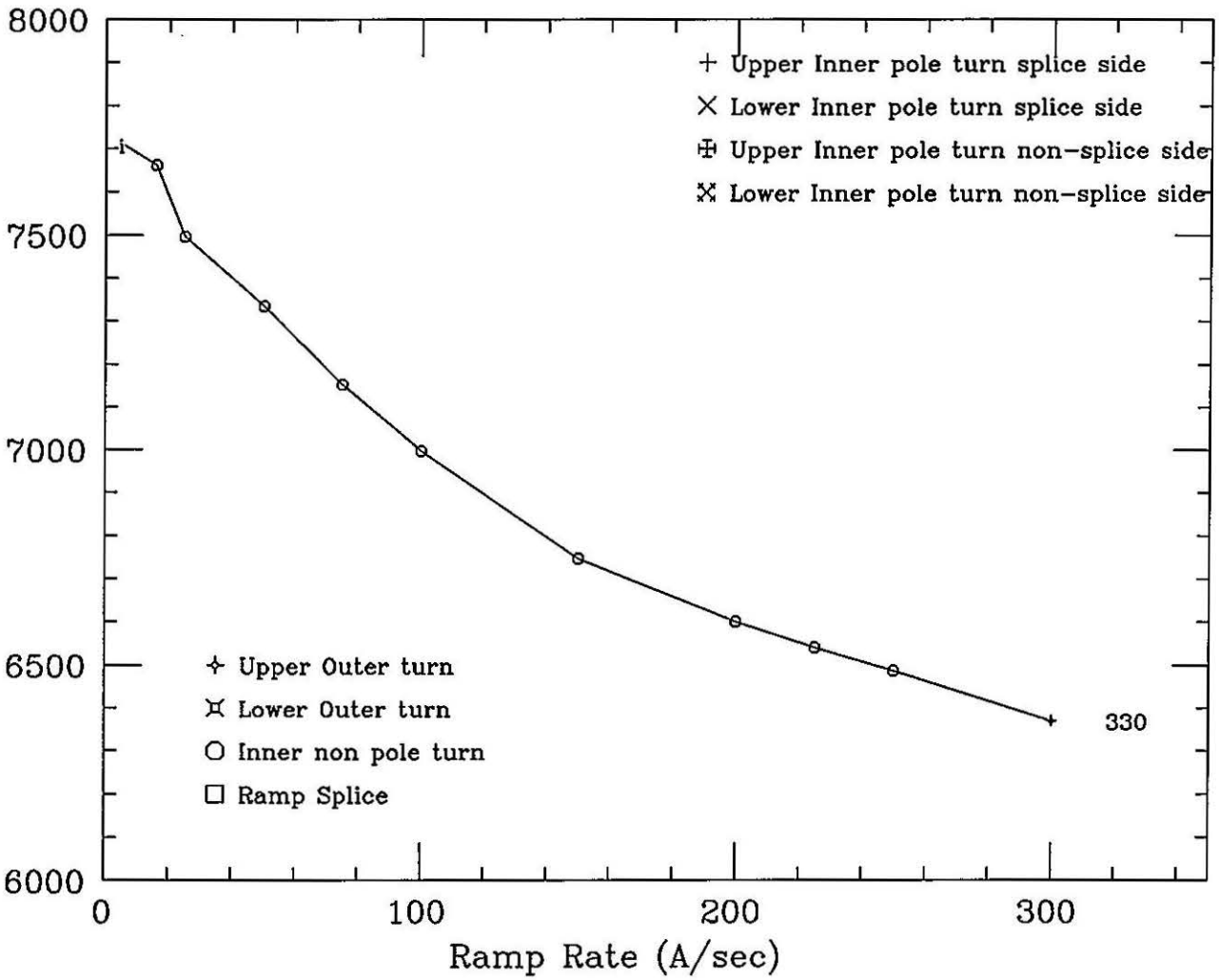
FERMI NATIONAL ACCELERATOR LABORA
UNITED STATES DEPARTMENT OF ENERGY

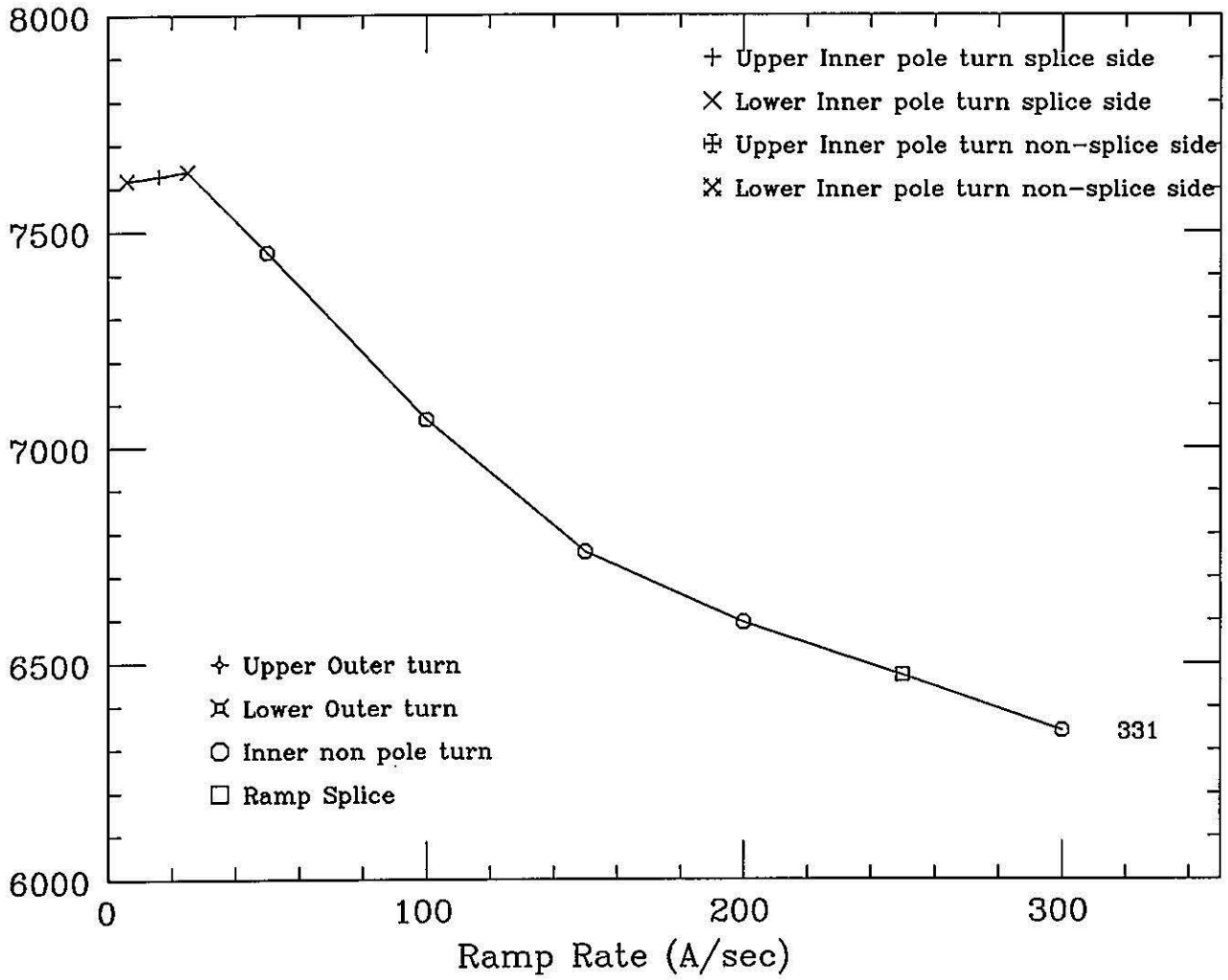
# DSA3XX VOLTAGE TAPS INNER COIL

SCALE: NONE | FILMED | DRAWING NUMBER: 0102-MB-263907

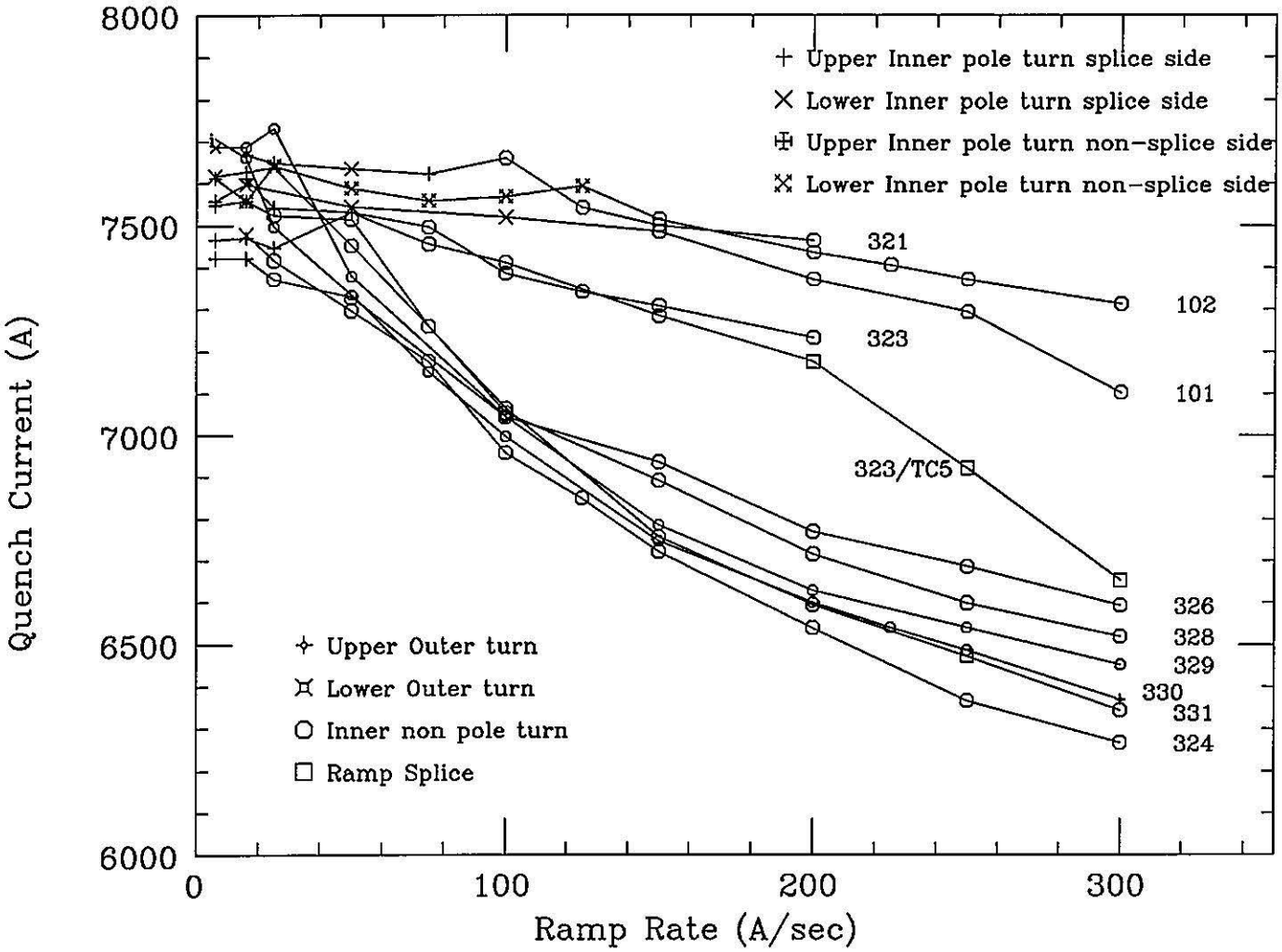
DSA331


Ramp splice Vtap
Q#43 61.18cm (3.8K)
68.24cm
Q#20 (4.2K) 39cm
Q#33 4.3K
75cm
68.24 cm
97cm
A
B
C
D
(407 403)
13
14
15
16
17
18
19
16
15
14
13A
13


8000
7500
7000
6500
6000
0
100
200
300
Ramp Rate (A/sec)
+ 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
330


8000
7500
7000
6500
6000
0
100
200
300
Ramp Rate (A/sec)
+ 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
331

# SHORT DIPOLE RAMP RATE DEPENDENCE



*Harmonic Components*

| Magnet | pole shim | $a_1$ | $b_2$ | $b_4$ | $b_6$ | $b_8$ | $b_{10}$ |
|---|---|---|---|---|---|---|---|
| DSA321 | +0 | | +3.20 | +0.22 | | | |
| | +0 | -2.15 | +2.95 | +0.33 | -0.08 | +0.05 | +0.02 |
| DSA323 | +0 | -0.33 | +1.50 | +0.13 | -0.05 | +0.05 | +0.02 |
| | +0 | +0.41 | +1.38 | +0.22 | -0.08 | +0.06 | +0.02 |
| DSA324 | -5 | | +1.94 | +0.04 | | | |
| | +5 | -0.00 | +1.76 | +0.19 | -0.04 | +0.05 | +0.02 |
| DSA326 | +0 | +0.96 | +2.24 | +0.28 | -0.03 | +0.05 | +0.01 |
| | +0 | +1.03 | +2.19 | +0.35 | -0.07 | +0.06 | +0.01 |
| DSA328 | +5 | +0.04 | +0.43 | +0.10 | -0.03 | +0.04 | +0.01 |
| | -5 | -0.10 | +0.07 | +0.26 | -0.03 | +0.06 | +0.01 |
| DSA329 | -5 | -0.05 | +1.28 | +0.10 | -0.03 | +0.04 | +0.01 |
| | +5 | -0.67 | +1.80 | +0.08 | -0.04 | +0.05 | +0.01 |
| long | +0 | +0.58 | +1.59 | +0.29 | -0.04 | +0.05 | +0.02 |
| ave. | +0 | +0.63 | +2.30 | +0.31 | -0.03 | +0.05 | +0.02 |
| Cal | -5,+5 | +0.00 | +0.34 | -0.08 | -0.02 | +0.04 | +0.02 |
| Cal | +0,+0 | +0.00 | +0.30 | +0.06 | -0.04 | +0.04 | +0.02 |
| Design | +0,+0 | +0.00 | -0.18 | -0.04 | +0.00 | +0.05 | +0.02 |
| Cal | +0,+0 | +0.00 | +1.58 | +0.40 | +0.03 | +0.07 | +0.02 |
| Cal | +0,+5 | +0.00 | +2.54 | +0.41 | +0.03 | +0.07 | +0.02 |
| Cal | +0,+10 | +0.00 | +3.51 | +0.41 | +0.02 | +0.07 | +0.02 |
| DSA330 | +0,1/2H+LTs | +1.41 | +3.09 | +0.63 | +0.01 | +0.06 | +0.02 |
| | +0,1/2H+1/2LTs | +1.27 | +3.94 | +0.71 | +0.04 | +0.07 | +0.02 |

Upper rows are cold measurements at 2000A and lower rows are warm measurements at ± 10A. Units are ratio to the dipole component in $10^{-4}$ at 1cm radius.

| | | $a_1$ | $b_2$ | $b_4$ | $b_6$ | $b_8$ | $b_{10}$ |
|---|---|---|---|---|---|---|---|
| cold DSA331 | | -1.51 | +3.31 | +0.61 | +0.03 | +0.7 | +0.2 |