TS-SSC-91-161

MSIM
BNL
AUGUST 6, 1991

CONTROL OF COIL SIZE VARIATIONS

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FACTORS CONTRIBUTING TO THE FINISHED COIL SIZE

I. CONSTRUCTION MATERIALS

A. Cable

1. Poor size correlation with thickness
2. Good correlation of size and M.O.E. with cable angle.

B. Kapton Film

C. Glass Tape

1. Compresses during cure from .0045" down to approx. .00175" (This can vary widely in local areas)
2. Percent epoxy content strongly determines amount of tape compression.

II. TOOLING

A. Winding Key (good correlation with tolerances)

B. Sizing Bars (good correlation with tolerances)

C. Mandrel (good correlation with EDM made tooling tolerances)

D. Liner

1. Sectional butt joints correlate
2. If slot in liner touches keys a sizing correlation occurs. (Keys must "float" for best coil accuracy)

E. Stop Bar Shims

1. Outer coil shims approx. 80% effective
2. Inner coil shims approx. 50% effective
3. These percentages are probably affected by:
   a. glass tape epoxy content
   b. keystone angle of cable
   c. process temperature

F. Mold Surface Finish

Early indications are that a "glass shot" finish of the base metal followed by the application of a thin chrome plate will provide a very slippery mold surface. This approach is presently under study for use on the interior of the liners.

III. CURING PROCESS PARAMETERS

A. Temperature of Cure

1. Temperature effects the amount of cable deflection by systematicly annealing the "as drawn" hard cable.

2. Temperature effects the final coil modulus of elasticity primarily by "packing" the annealed cable strands.

B. Length of Cure

1. Effects the final M.O.E. and size becauce of copper annealing and packing of the cable strands.

C. Cavity Pressure is effected by:

1. Construction material tolerances dominated by cable keystone angle and percent epoxy in the tape.

2. Stop bar shims

D. Curing Press Sequence

1. Pre-warming the coil before applying full pressure:
   a. Lowers Epoxy Viscosity
   b. Improves Kapton Elasticity

2. Cycling pressure between mandrel and sizing bars helps to center the coil and improve sizing statistics.

3. Cycling end clamp pressure improves closure of end parts in cable turn area.

E. Mold Release Compound

1. Pre-mold conditioning is necessary to prevent

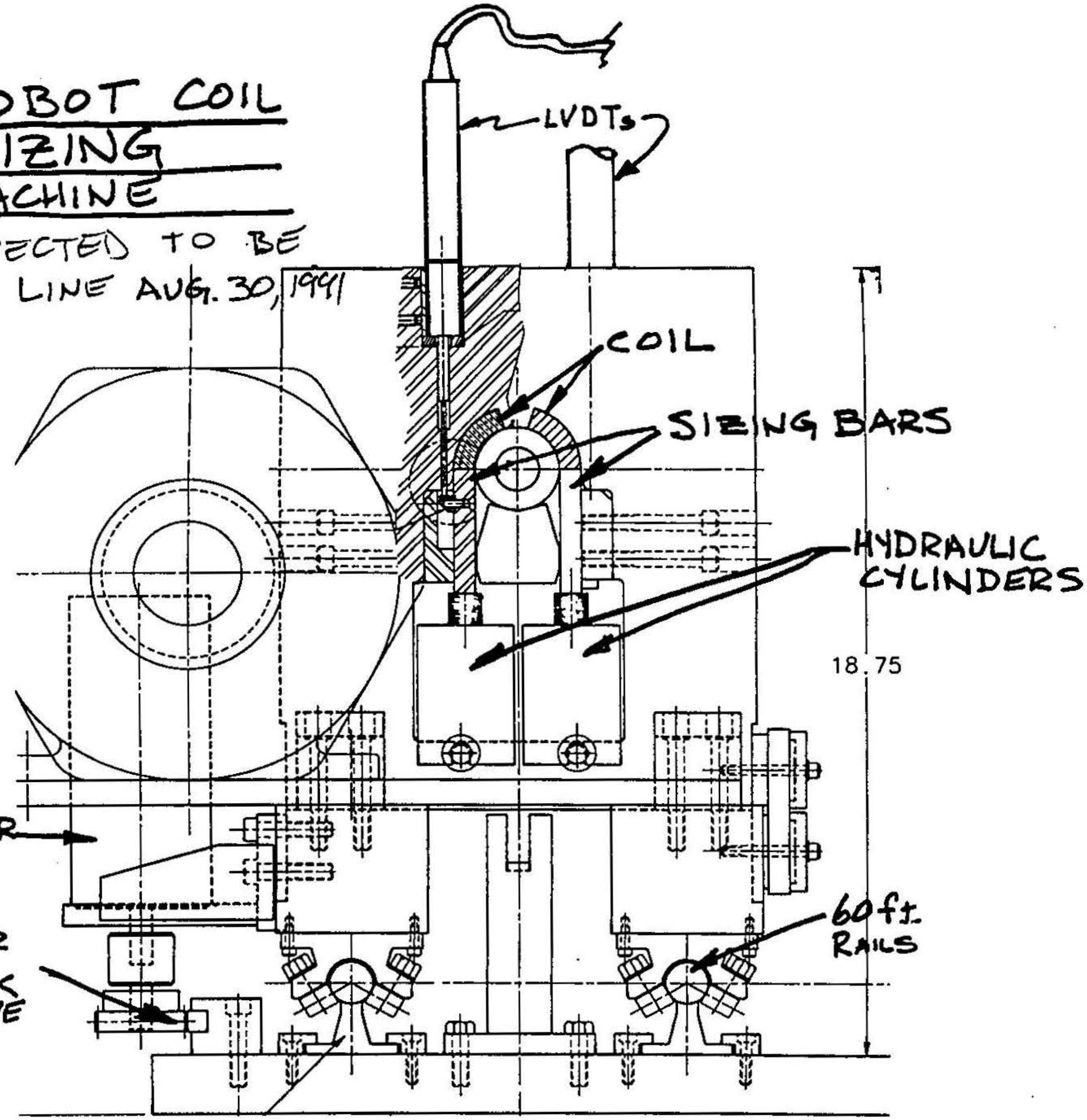
2. Need More development to find a mold release able to withstand very high "spot" forces.

F. Wedge Friction to Mold Walls

1. Glass tape on wedges is "digging-in" to liner walls causing very high friction and preventing reliable sliding of the coil in the mold.
2. A change to all kapton covered wedges (on the short coils only) appears to have greatly reduced friction and improved sizing statistics.

ROBOT COIL SIZING MACHINE

EXPECTED TO BE ON LINE AUG. 30, 1991



WHOLE COIL SUMMARY

Chart Version 1.0 5/7/91

LONG 50MM Inner Coil # 15M-50-1009

Master Used - Inner Master #1 Shim Size Used - .010

Press Fixture Serial Number Used - 87637

Machine Serial Number Used - SEMI-01 Mean Arc of Master - 1.5946"

	QUADRANT I/III POSITION 1-192		
	8 kpsi	12 kpsi	MOE
AVERAGE	0.0113	0.0081	2.09E+06
STD DEV	0.0008	0.0011	6.89E+04
RANGE	0.0026	0.0056	2.06E+05
MAX.	0.0123	0.0109	2.20E+06
MIN.	0.0097	0.0053	2.00E+06

	QUADRANT II/IV POSITION 1-192		
	8 kpsi	12 kpsi	MOE
AVERAGE	0.0108	0.0076	2.12E+06
STD DEV	0.0013	0.0010	7.61E+04
RANGE	0.0043	0.0055	2.06E+05
MAX.	0.0124	0.0103	2.20E+06
MIN.	0.0081	0.0048	2.00E+06

	WHOLE COIL		
	8 kpsi	12 kpsi	MOE
AVERAGE	0.0110	0.0079	2.11E+06
STD DEV	0.0011	0.0010	7.15E+04
RANGE	0.0043	0.0061	2.06E+05
MAX.	0.0124	0.0109	2.20E+06
MIN.	0.0081	0.0048	2.00E+06

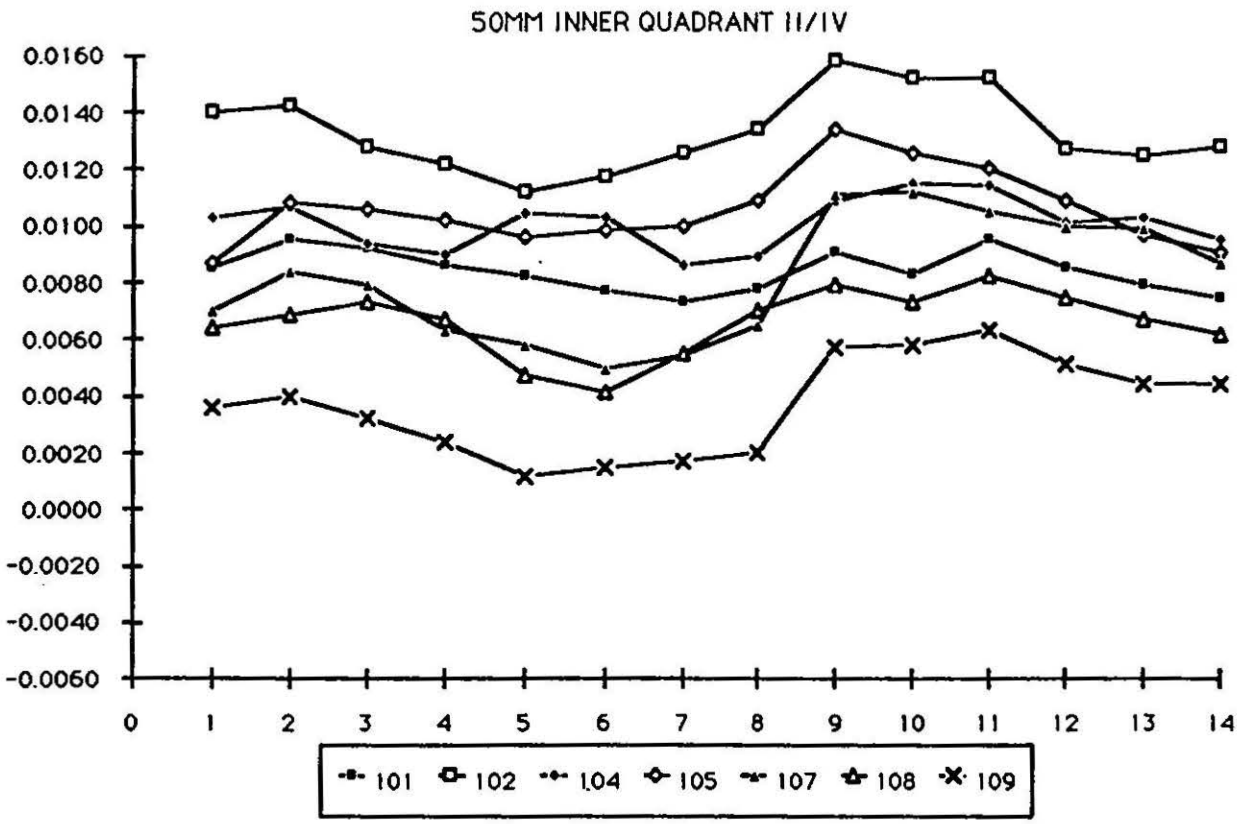
(AVERAGES, STD DEV, RANGE, MIN, MAX, FOR CALCULATIONS ABOVE ARE FROM THE ~~COIL WITH~~ RESPECT TO THE MASTER)

MEASUREMENT DATA

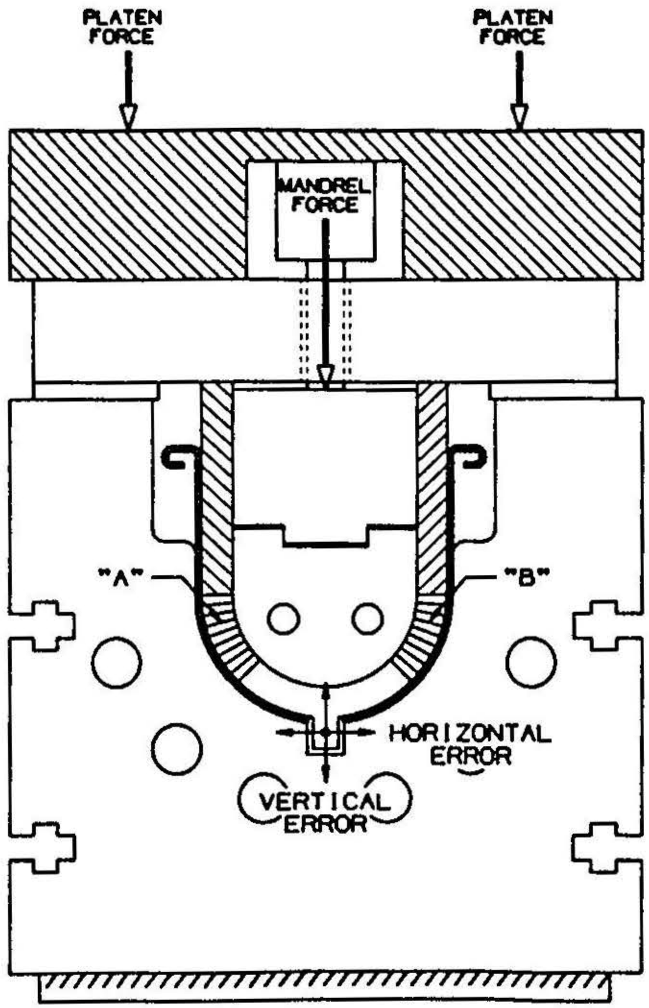
Coil # 15M-50-1009 Coil Type: Inner Date: 06/29/91 Measured By: JOYCE

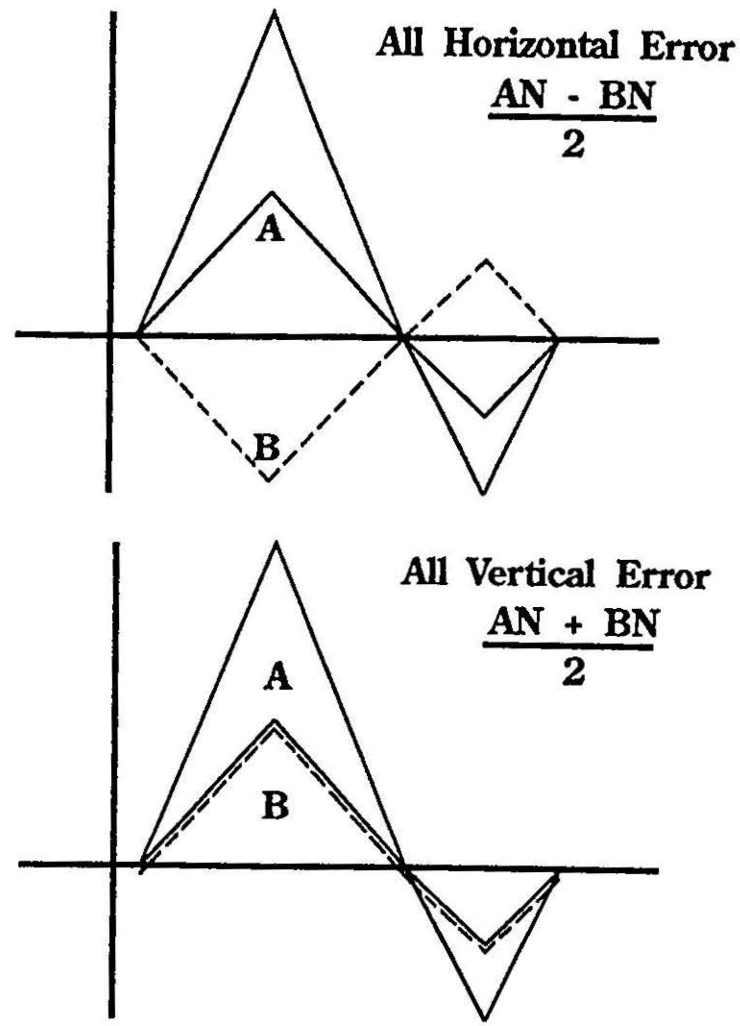
	Stress:	---- 6000 ----		---- 8000 ----		-- 10000 ----		-- 12000 --		COIL SIZE WITH RESPECT TO THE MASTER		DEVIATION FROM THE WHOLE COIL AVERAGE	MODULUS OF ELASTICITY
	Pos #	Coil	Master	Coil	Master	Coil	Master	Coil	Master	8000	12000	AT 12000	
Quad.	1							0.9995	0.9927		0.0068	-0.0011	
I/III	2							0.9992	0.9927		0.0065	-0.0014	
	3							1.0001	0.9927		0.0074	-0.0005	
	4							1.0003	0.9927		0.0076	-0.0003	
	5							1.0003	0.9927		0.0076	-0.0003	
	6							1.0003	0.9927		0.0076	-0.0003	
	7							1.0003	0.9927		0.0076	-0.0003	
	8							1.0003	0.9927		0.0076	-0.0003	
	9							1.0003	0.9927		0.0076	-0.0003	
	10							1.0004	0.9927		0.0077	-0.0002	
	11							1.0012	0.9927		0.0085	0.0006	
	12							1.0010	0.9927		0.0083	0.0004	
	13							1.0010	0.9927		0.0083	0.0004	
	14							1.0012	0.9927		0.0085	0.0006	
	15							1.0003	0.9927		0.0076	-0.0003	
	16							0.9990	0.9927		0.0063	-0.0016	
	17							0.9995	0.9927		0.0068	-0.0011	
	18							1.0005	0.9927		0.0078	-0.0001	
	19							1.0010	0.9927		0.0083	0.0004	
	20 UP	1.0127	1.0000	1.0086	0.9973	1.0047	0.9950	1.0008	0.9925	0.0113	0.0083	0.0004	2.13E+06
	20 DN	1.0085	0.9989	1.0055	0.9966	1.0029	0.9944	1.0008	0.9925				
	21							1.0010	0.9925		0.0085	0.0006	
	22							1.0015	0.9925		0.0090	0.0011	
	23							1.0018	0.9925		0.0093	0.0014	
	24							1.0013	0.9925		0.0088	0.0009	
	25							1.0016	0.9926		0.0091	0.0012	
	26							1.0018	0.9925		0.0093	0.0014	
	27							1.0017	0.9926		0.0092	0.0013	
	28							1.0014	0.9925		0.0089	0.0010	
	29							1.0016	0.9925		0.0091	0.0012	
	30							1.0013	0.9925		0.0088	0.0009	
	31							1.0019	0.9925		0.0094	0.0015	
	32							1.0019	0.9925		0.0094	0.0015	
	33							1.0008	0.9925		0.0083	0.0004	
	34							1.0011	0.9925		0.0086	0.0007	
	35							1.0019	0.9925		0.0094	0.0015	
	36							1.0008	0.9926		0.0083	0.0004	
	37							0.9988	0.9926		0.0063	-0.0016	
	38							0.9989	0.9925		0.0064	-0.0015	
	39							0.9992	0.9925		0.0067	-0.0012	
	40 UP	1.0110	1.0000	1.0070	0.9973	1.0032	0.9951	0.9993	0.9927	0.0097	0.0066	-0.0013	2.06E+06
	40 DN	1.0069	0.9989	1.0038	0.9966	1.0011	0.9945	0.9993	0.9927				
	41							0.9983	0.9927		0.0056	-0.0023	
	42							0.9980	0.9927		0.0053	-0.0026	
	43							1.0000	0.9927		0.0073	-0.0006	
	44							1.0020	0.9927		0.0093	0.0014	
	45							1.0023	0.9927		0.0096	0.0017	
	46							1.0024	0.9927		0.0097	0.0018	
	47							1.0021	0.9927		0.0094	0.0015	
	48							1.0017	0.9927		0.0090	0.0011	
	49							1.0014	0.9927		0.0087	0.0008	
	50							1.0009	0.9927		0.0082	0.0003	
	51							1.0009	0.9927		0.0082	0.0003	
	52							1.0003	0.9927		0.0076	-0.0003	

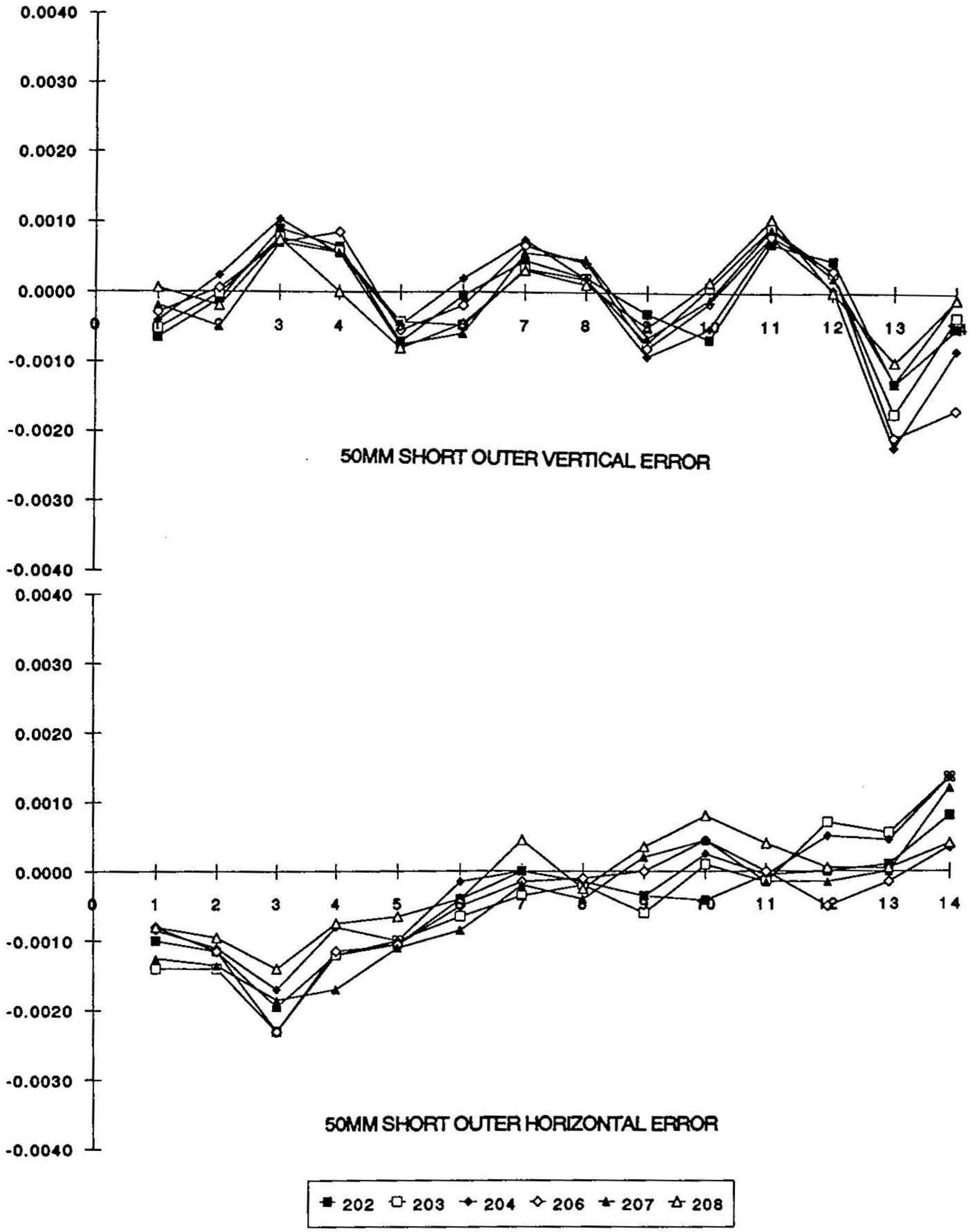
192 MEASURMENTS PER SIDE



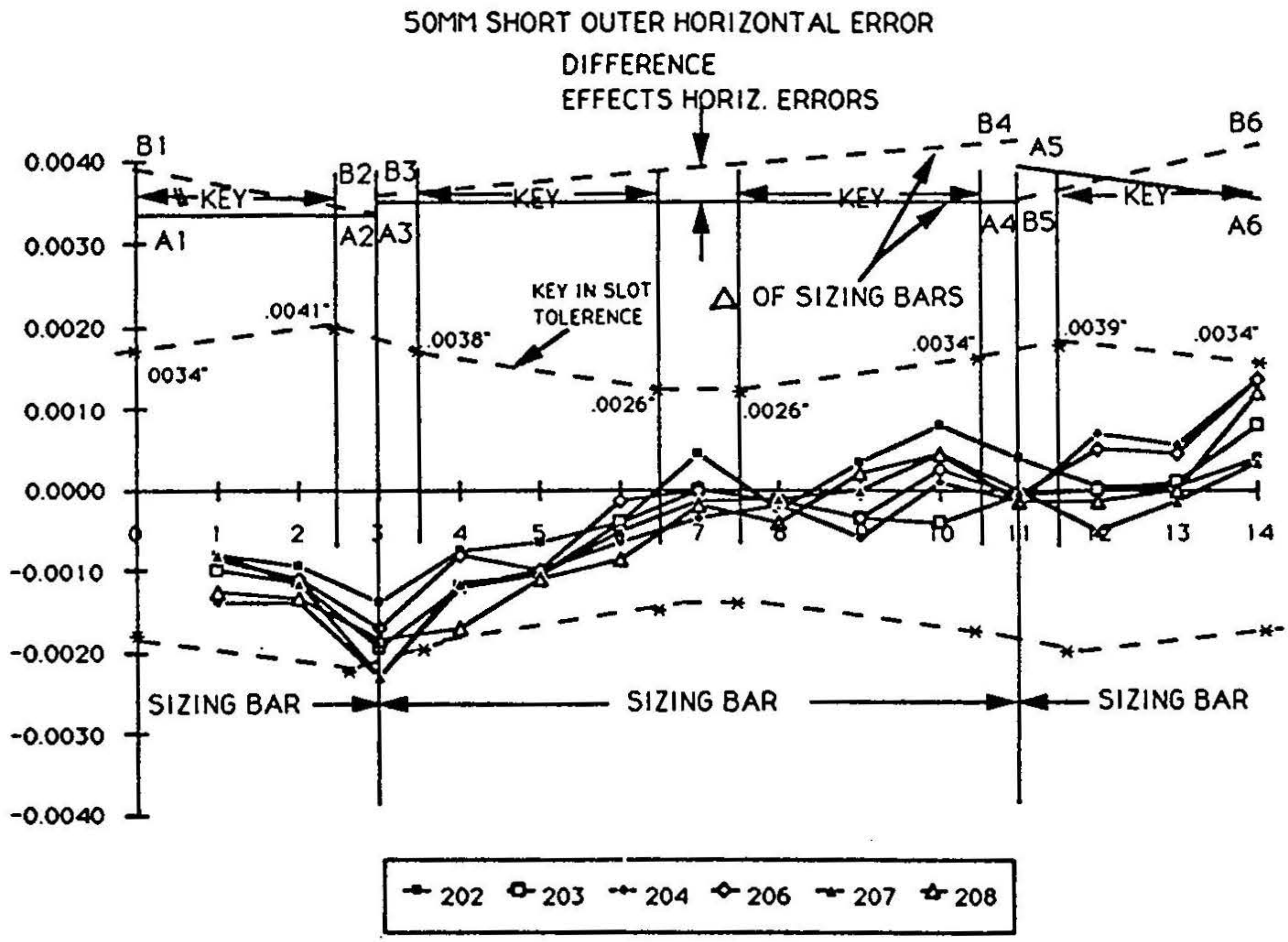
50MM INNER SHORT COILS
SIZE DEVIATION WITH RESPECT
TO THE MASTER


PLATEN FORCE
PLATEN FORCE
MANDREL FORCE
"A"
"B"
HORIZONTAL ERROR
VERTICAL ERROR

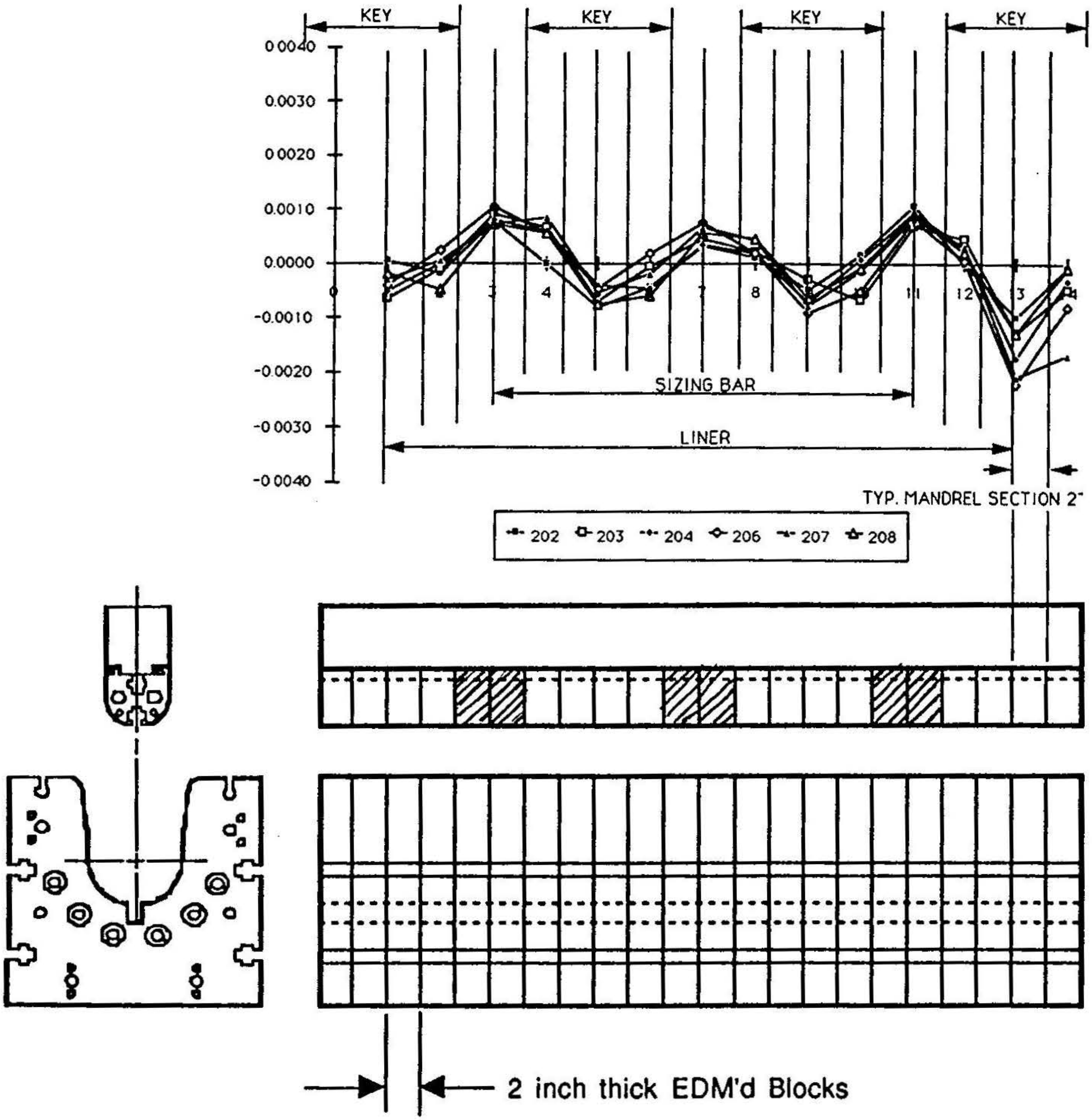

All Horizontal Error
$\frac{AN - BN}{2}$
A
B
All Vertical Error
$\frac{AN + BN}{2}$
A
B



OUTER COIL ERROR

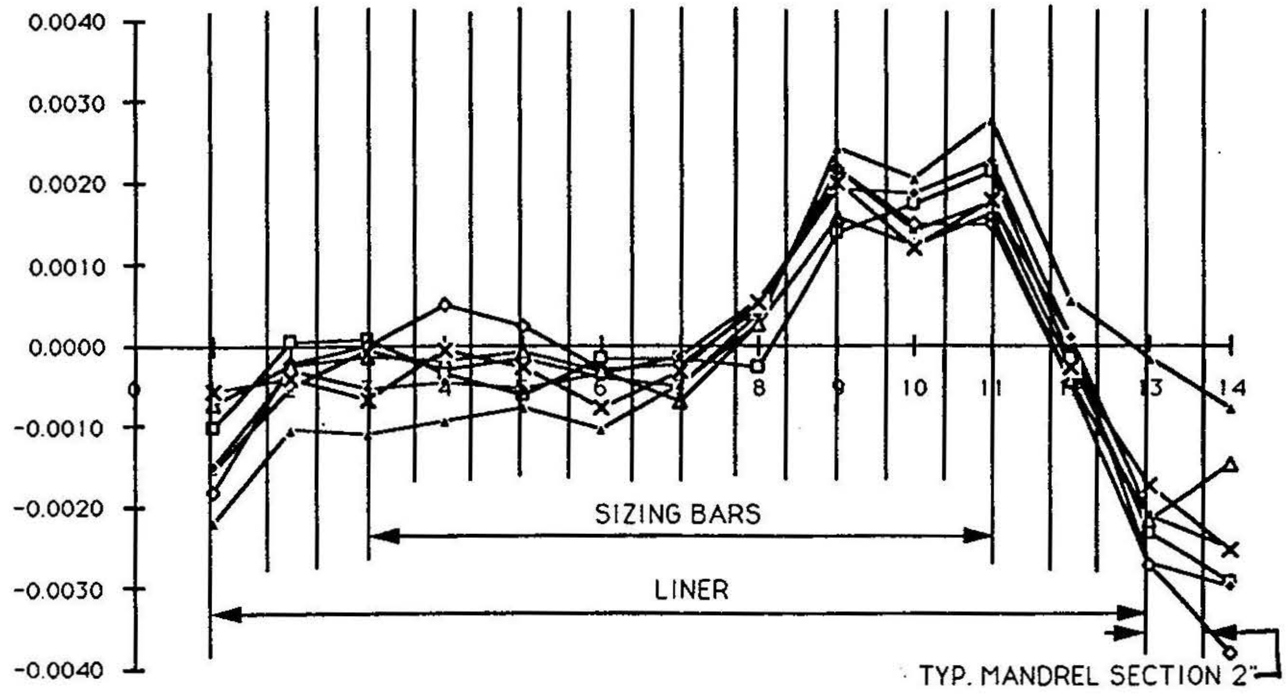


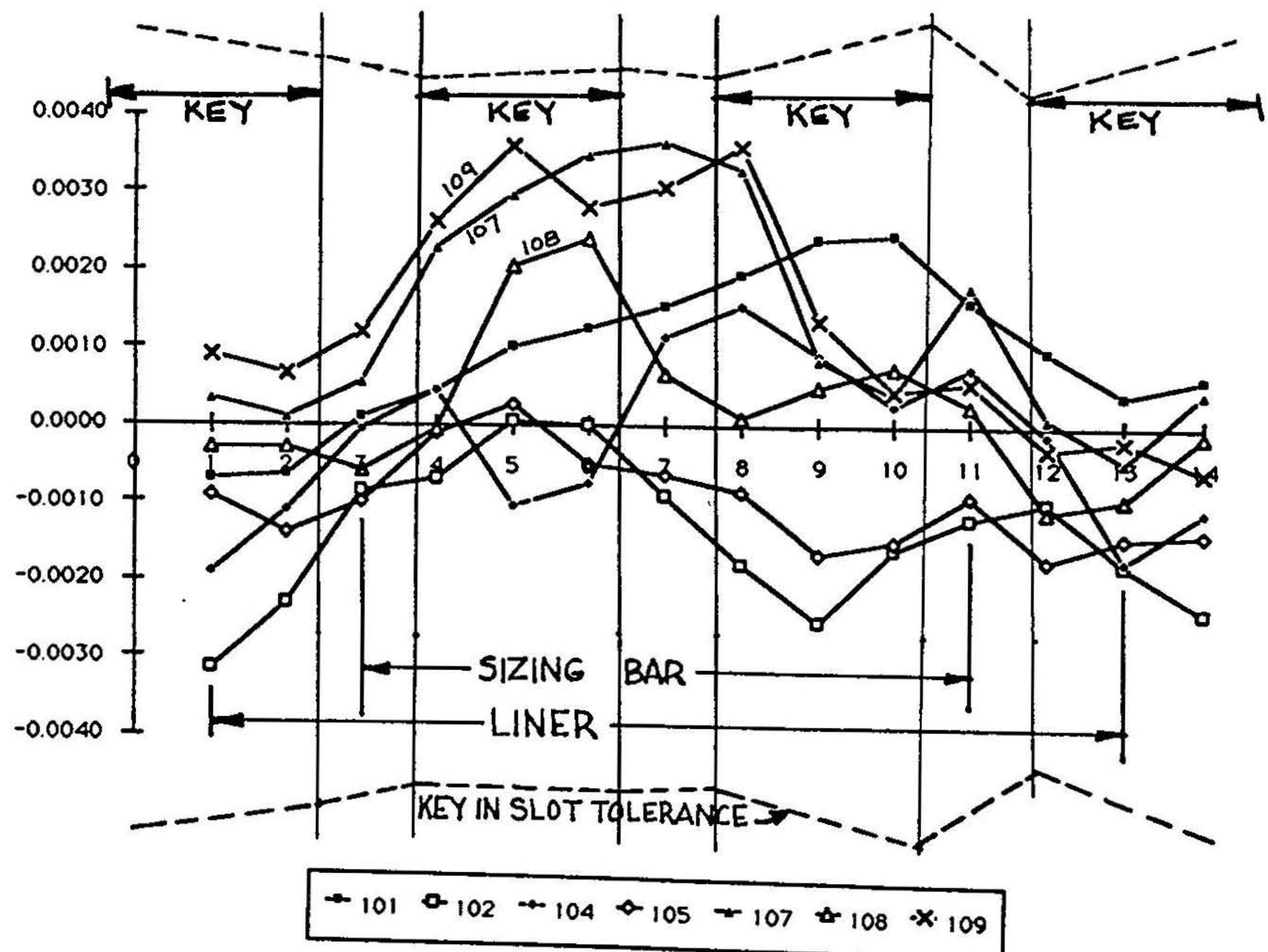
TYPICAL ANALYSIS OF
HORIZ. COIL SIZING ERROR
AND MOLD TOOL ELEMENTS
(SHORT 50mm OUTER COIL)



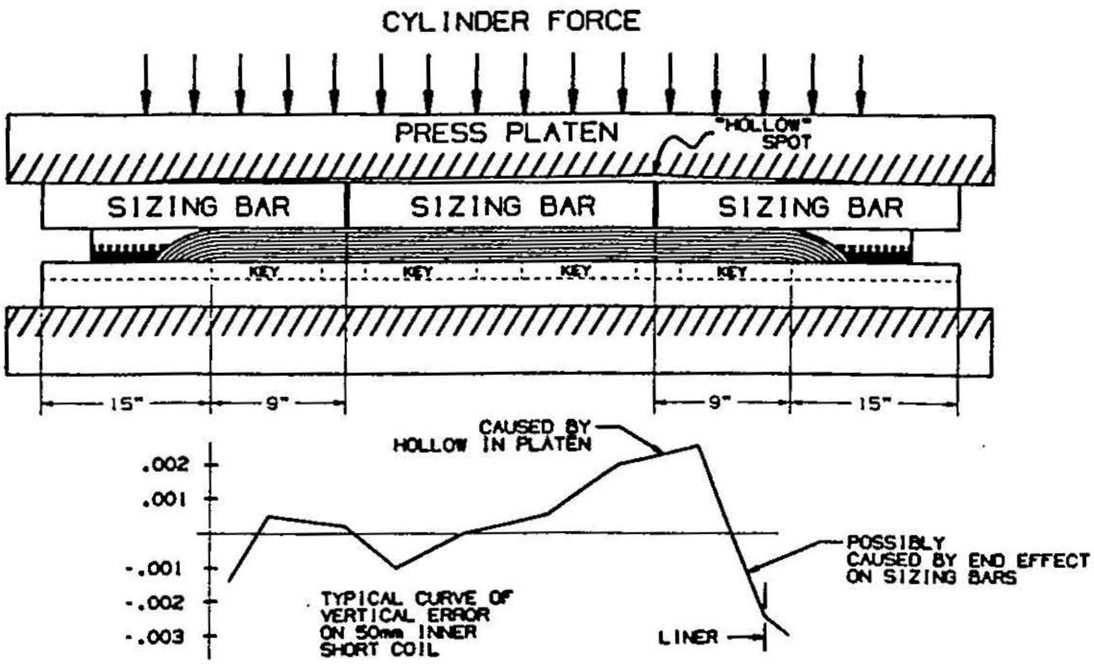
EDM'd Tooling

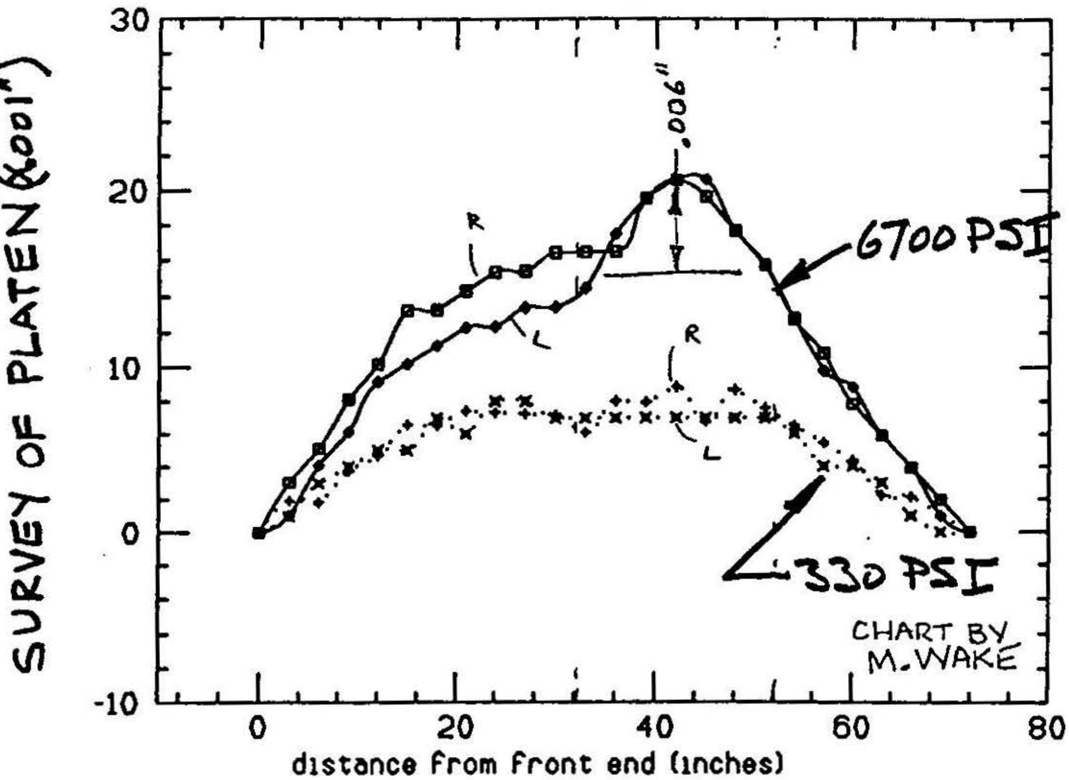
FLOATING KEY MANDREL SECTIONS WERE MADE BY A DIFFRENT SHOP THEN THE FIXED KEY SECTIONS



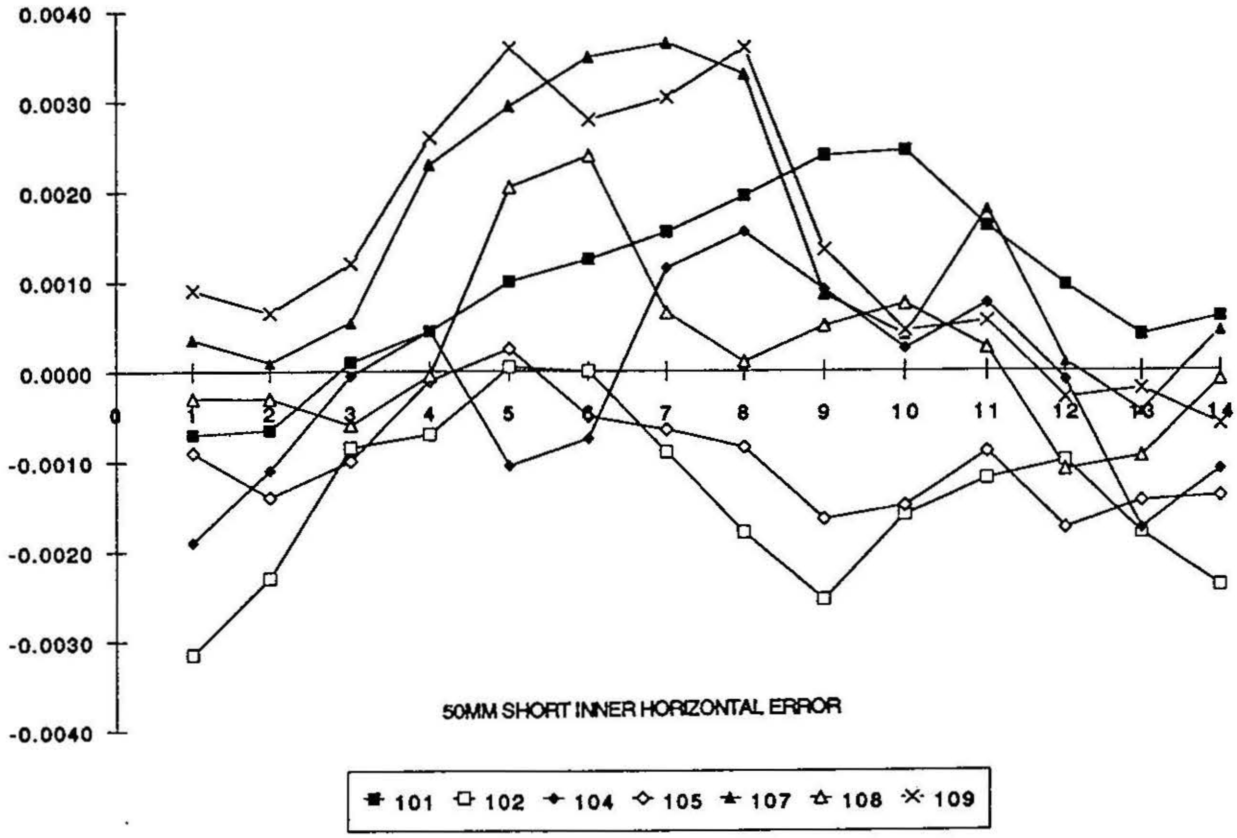


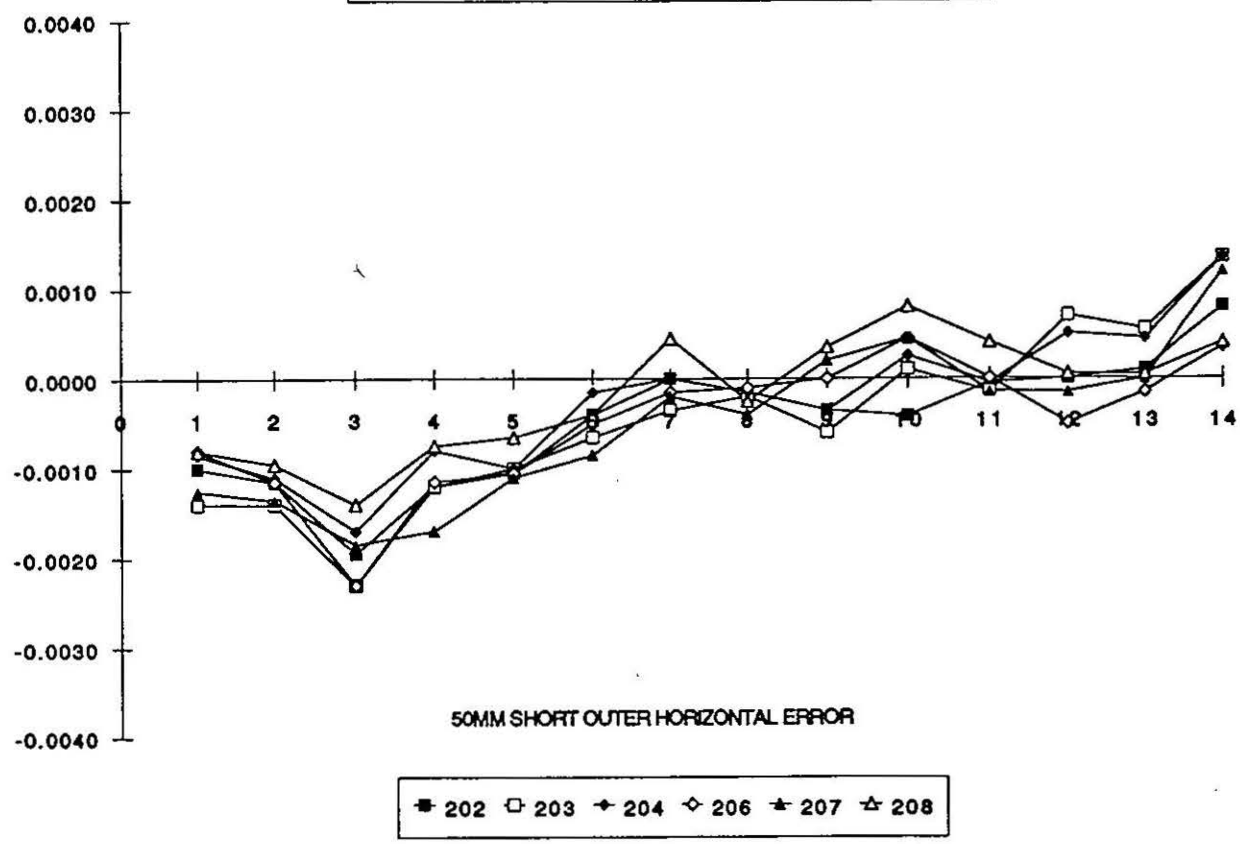
50MM SHORT INNER COIL ERRORS
AND MOLD TOOL ELEMENTS



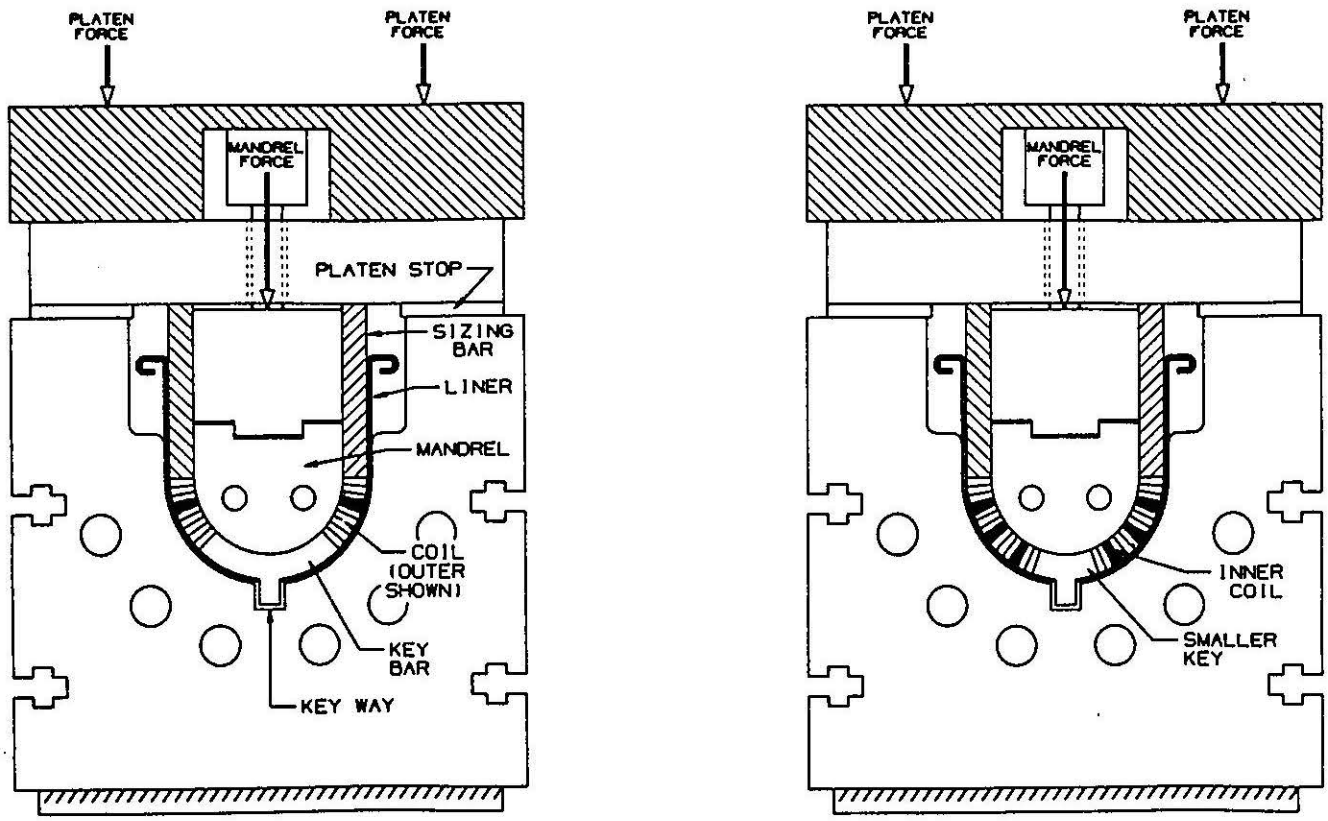


EFFECT OF HOLLOW SPOT
IN PRESS PLATEN





WHY WAS THE INNER COIL HORIZ. ERROR NON-SYSTEMATIC AND THE OUTER COIL SYSTEMATIC?

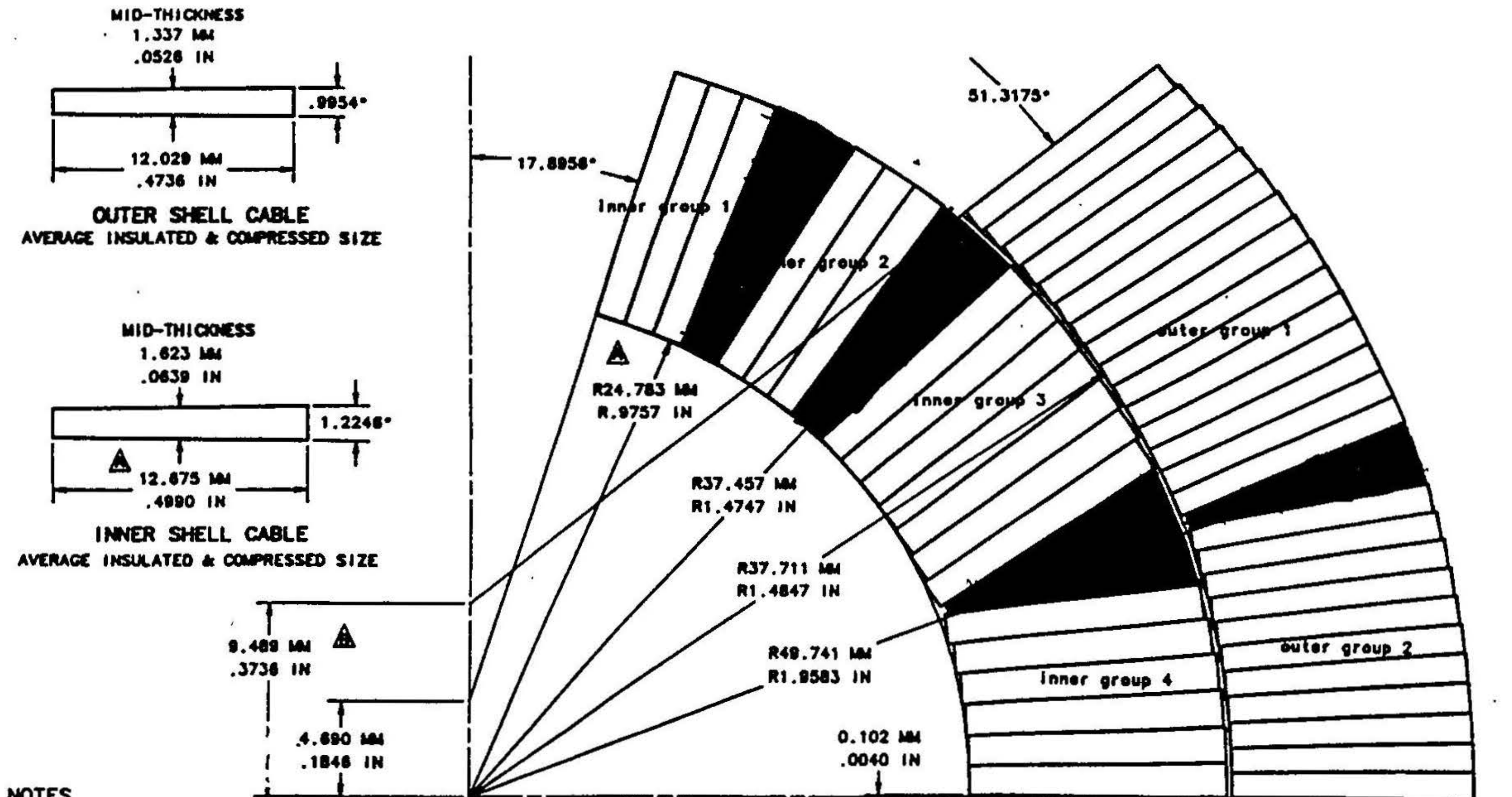


DIFFERENCES IN FRICTION BETWEEN INNER AND OUTER COILS AND THEIR MOLDS

INNER COIL WEDGES HAD 4.5 TIMES MORE AREA IN CONTACT WITH MOLD LINER

FIG.

$$\frac{\text{AREA OF INNER WEDGES}}{\text{AREA OF OUTER WEDGE}} \doteq \frac{4.5}{1}$$



NOTES

1. CABLE CORNER COORDINATES FOR DSX201 FROM BNLDAG::MORGAN 8 MAR 90.
2. THE COORDINATES WERE REFORMATED AND READ INTO THE IDEAS CAD PROGRAM WHICH AUTOMATICALLY CREATED GEOMETRY FOR ALL THE CABLES.
3. .0086 IN. WAS ADDED TO INSIDE END OF INNER CABLE. △
4. RECREATED CONDUCTOR POSITIONS USING AUTO-STACKING PROGRAM. △ POINT FILE NAME-dsx201b.pts. All WEDGE DIMENSIONS REMAIN THE SAME.

/sun2/home1/fulton/ssc/292000b.dwg SDRC IDEAS GEOMDRAW LEVEL 4.1

TOLERANCES UNLESS OTHERWISE SPECIFIED
± 2 PLACES ± 3 PLACES ± ANGLES
DIMENSIONS AND TOLERANCES PER ANSI Y14.5 STANDARDS. BREAK ALL SHARP EDGES .010.
SURFACE TEXTURE 125
USED ON

ENGINEER R.BOSSERT
DRAWN H.FULTON 18 APR 90
CHECKED N. BARTLETT 4-18-90
APPROVED R. BOSSERT 5-25-90
MATERIAL

FERMI NATIONAL ACCELERATOR LAB
U.S. DEPARTMENT OF ENERGY
TITLE SSC 50MM DIPOLE COLDMASS DSX201B(W6733B) CONDUCTOR PLACEMENT CROSS SECTION
SCALE 5X
DRAWING NUMBER 0102-MB-292000
SHEET
REV. B

Comparison of Short 50mm Inner Coil

With Glass-epoxy tape or Kapton as Outer

Wrap of Wedges

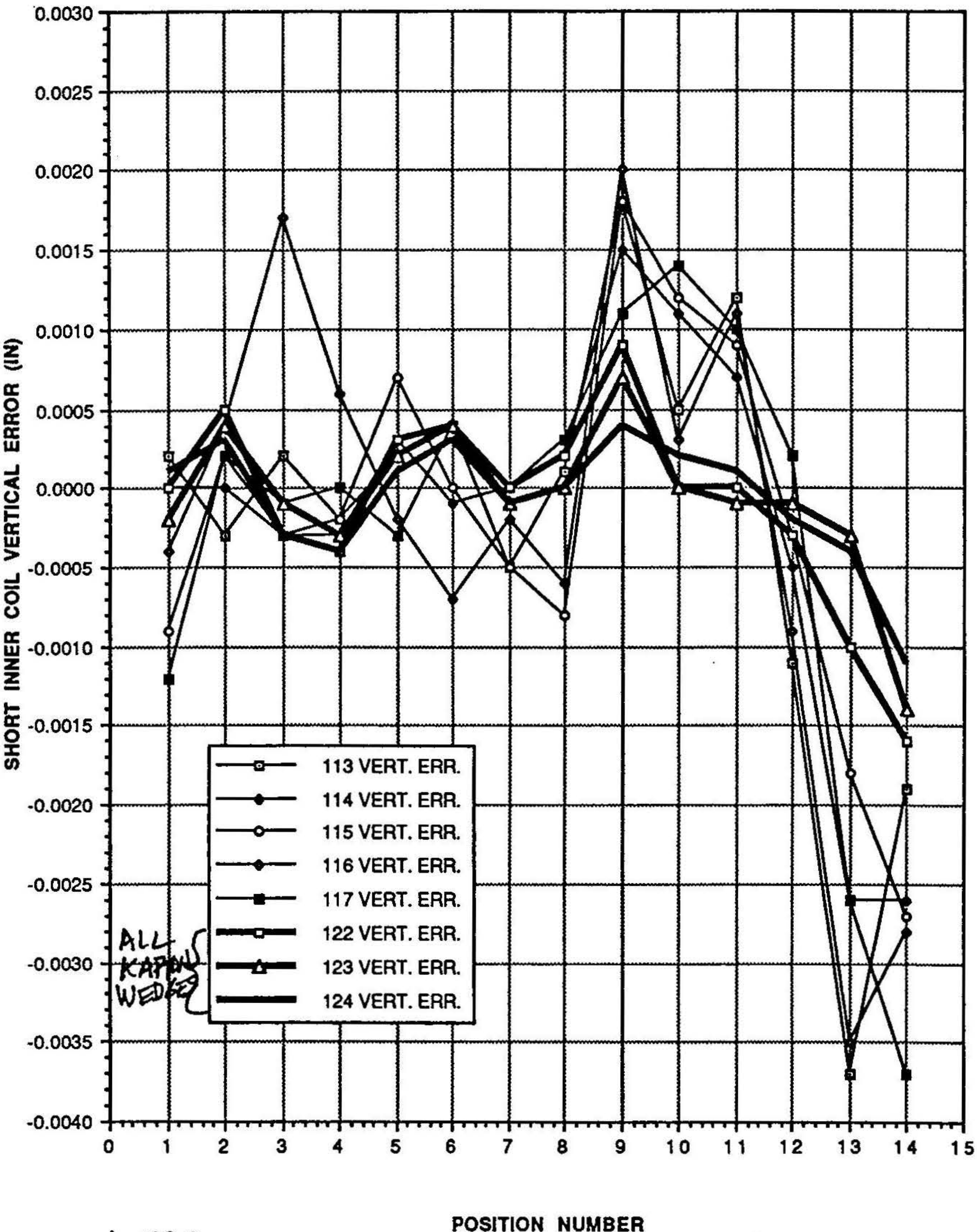
INNER COIL #	QUAD I/II AVG. W.R.T.M. (INCHES)	QUAD II/IV AVG. W.R.T.M. (INCHES)	WHOLE COIL AVG. W.R.T.M. (INCHES)	SIZE RANGE (INCHES)	WHOLE COIL STD.DEV . (INCHES)	MODULUS OF ELASTICITY COIL AVG. (X E+06)	CABLE REEL S/N
113	0.0055	0.0059	0.0057	0.0047	0.0013	2.34	3500021
114	0.007	0.0068	0.0069	0.0046	0.0012	2.3	3500021
115	0.007	0.0054	0.0062	0.0071	0.0017	2.42	3500021
116	0.0069	0.0068	0.0069	0.0072	0.0019	2.35	3500021
117	0.0057	0.0064	0.0061	0.0058	0.0014	2.38	3500021
AVG. OF 5	0.0064	0.0063	0.0064	0.0059	0.0015	2.36	
122	0.0058	0.0054	0.0056	0.0025	0.0007	2.05	PRACT."F"
123	0.0058	0.0047	0.0053	0.0027	0.0004	2.09	3500026
124	0.0054	0.0047	0.005	0.0021	0.0005	2.06	3500026
AVG. OF 2	0.0057	0.0049	0.0053	0.0024	0.0005	2.07	
W/O SHIM	(-.0025) .0032	(-.0025) .0024	(-.0025) .0028				
%CNG.	-50%	-62%	-56%	-59.3%	-66.6%	-12.3%	

GLASS TAPE WEDGES

ALL KAPTON WEDGES

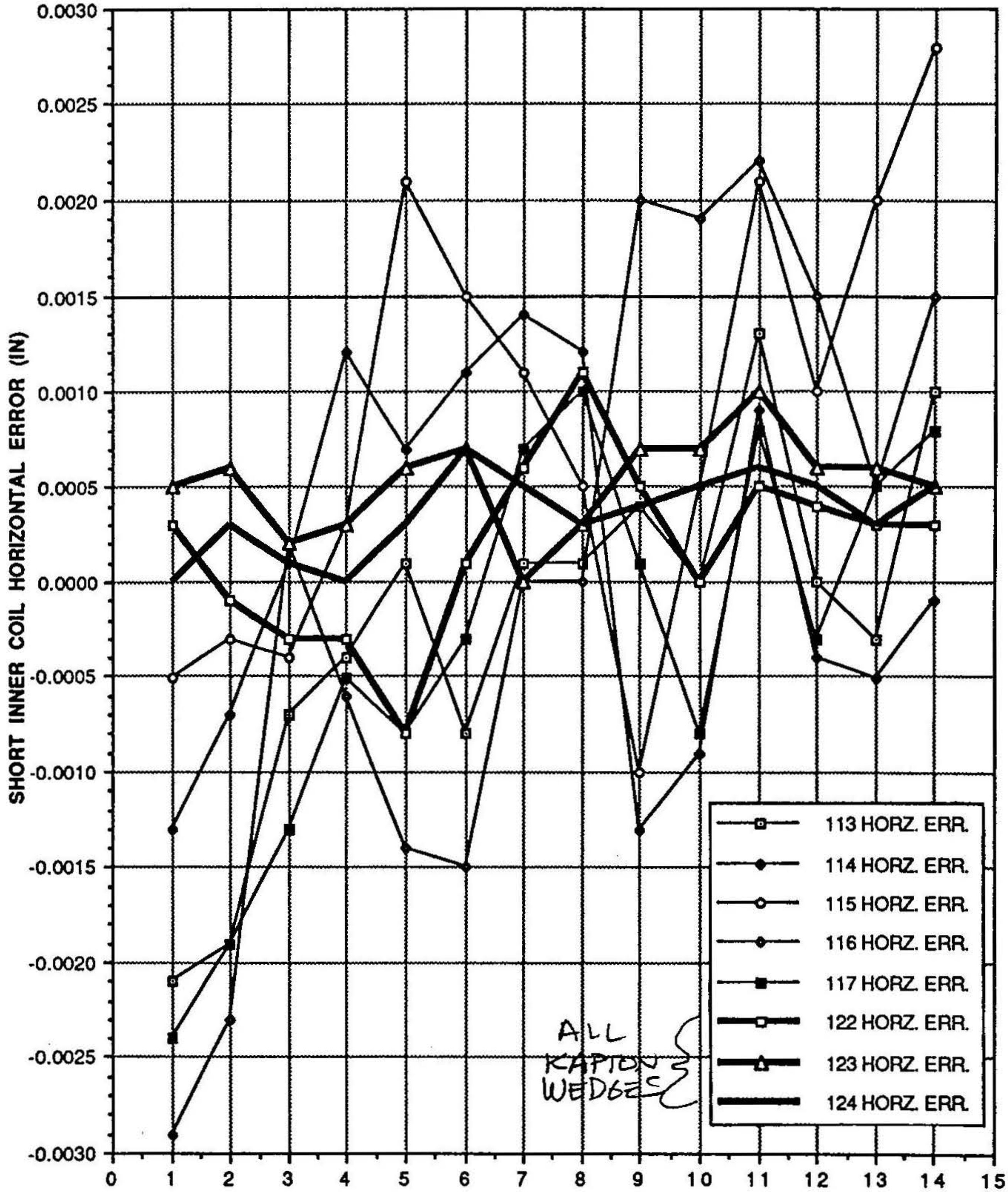
W.R.T.M. = With Respect To The Master

SHORT INNER COIL (113-117 & 122-124)
VERTICAL ERROR (IN) VS POSITION NUMBER



LESS VERTICAL ERROR INDICATES COIL "SLID DOWN" EASIER IN THE MOLD WITH ALL KAPTON WEDGES

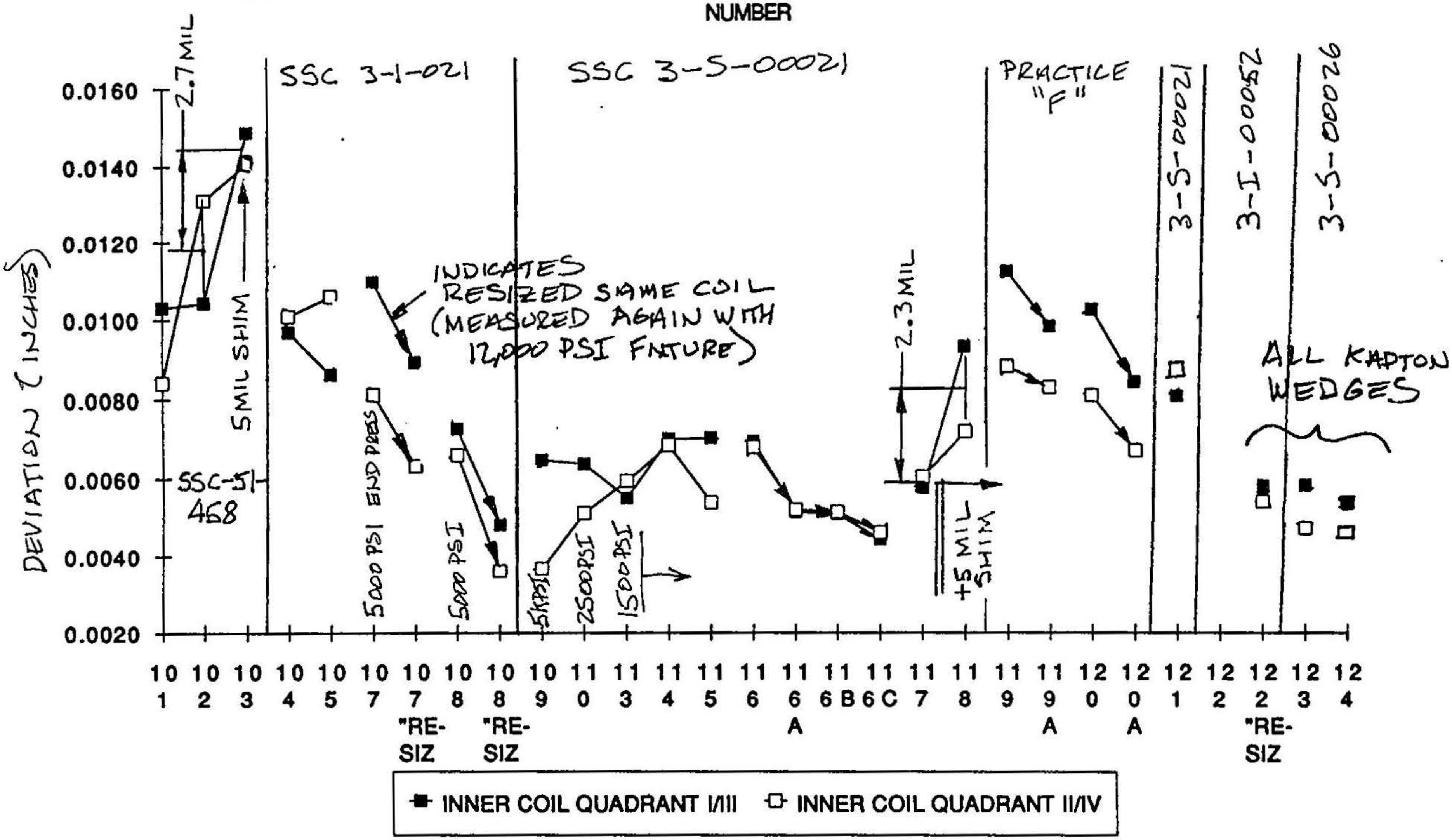
SHORT INNER COIL (113-117 & 122-124)
HORIZONTAL ERROR (IN) VS POSITION NUMBER



POSITION NUMBER

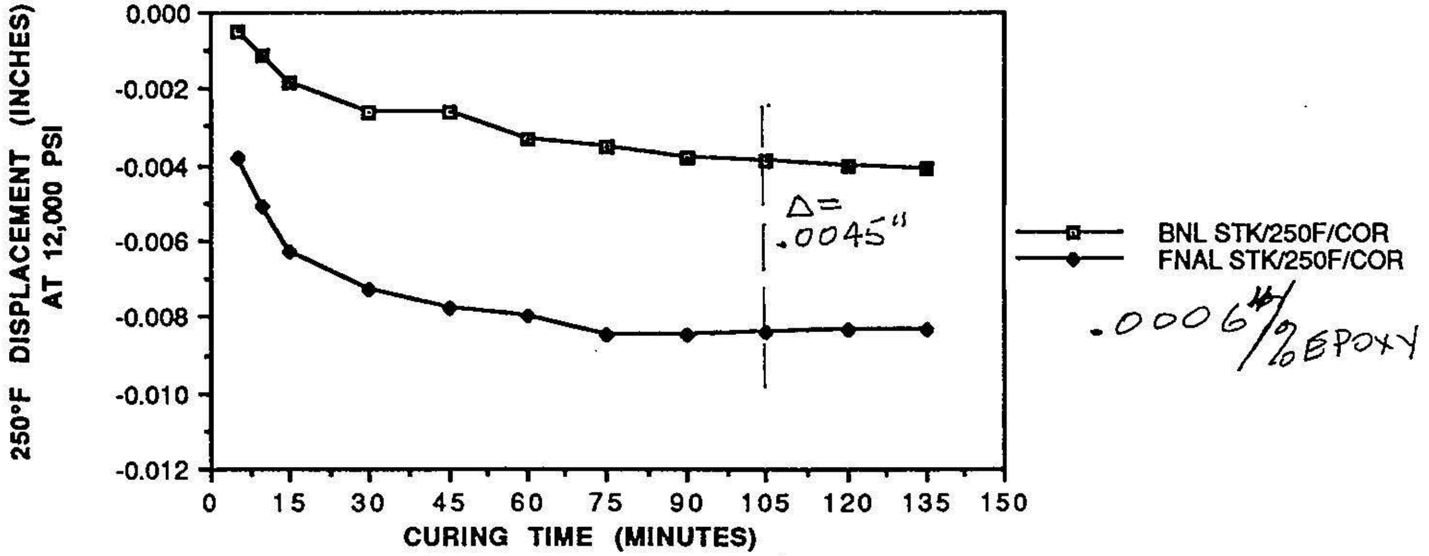
LESS HORIZ. ERROR INDICATE COIL WAS BETTER ABLE TO CENTER ITSELF IN MOLD

INNER COIL AVERAGES OF THE COIL DEVIATION FROM THE MASTER AT 12,000 COIL PSI BY COIL NUMBER

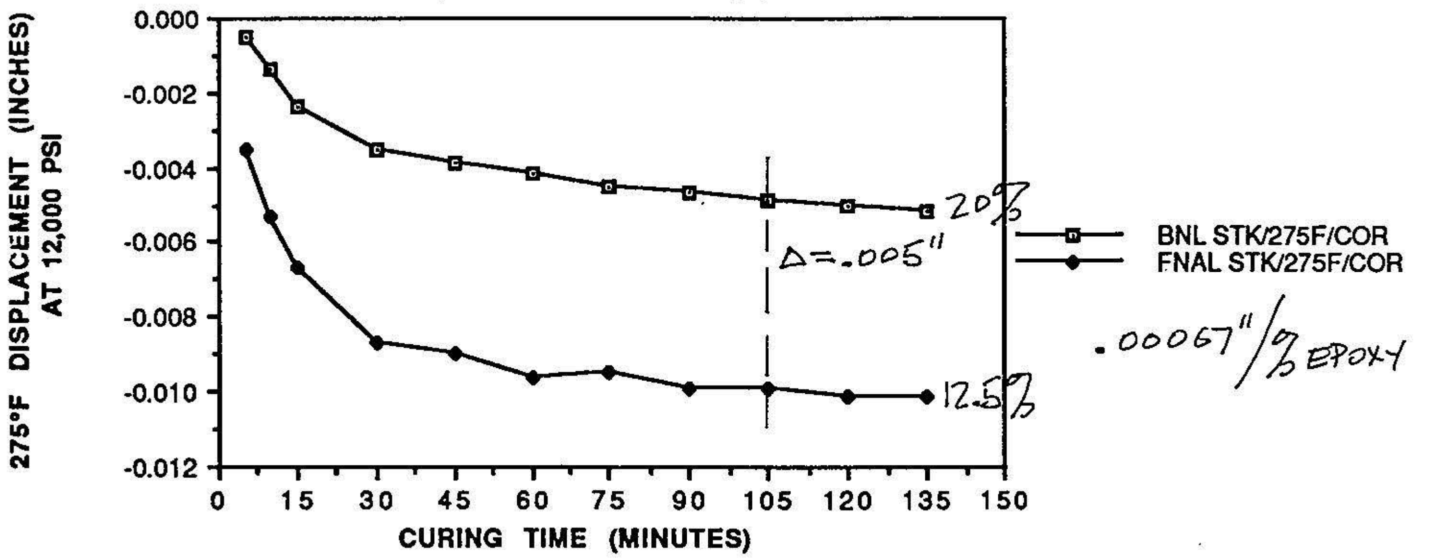


Updated 7/27/91

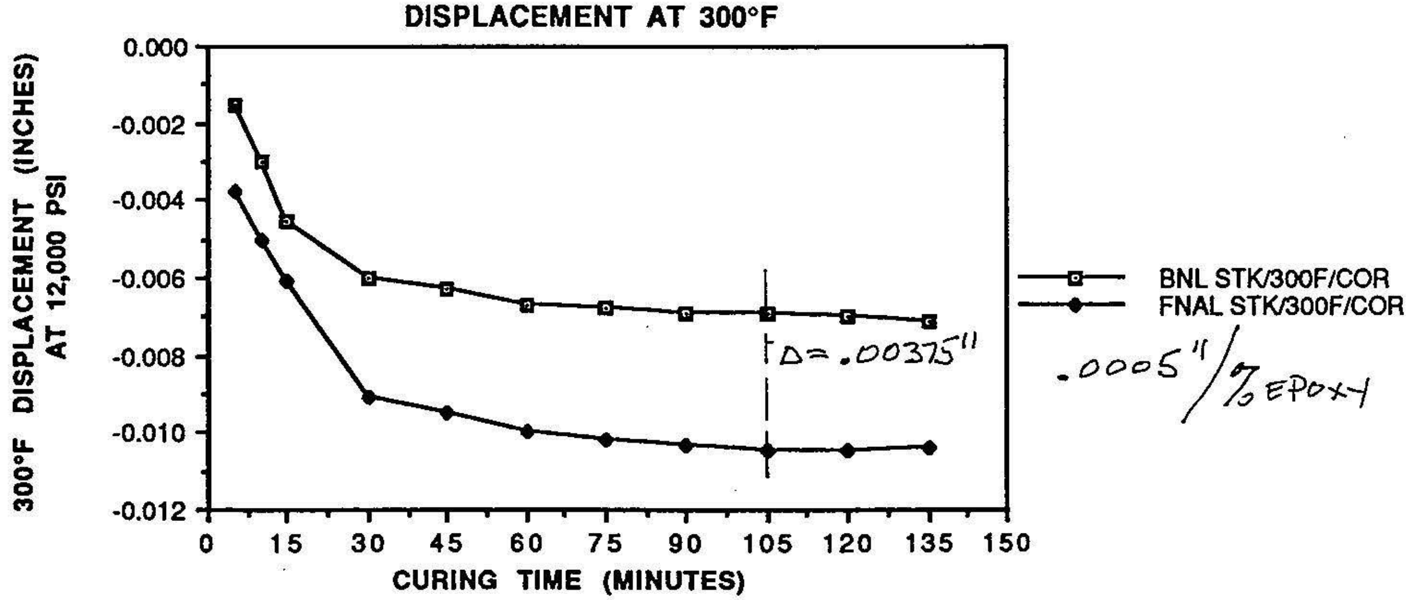
COMPARISON OF FNAL & BNL TEN STACK
DISPLACEMENT AT 250°F



COMPARISON OF FNAL & BNL TEN STACK
DISPLACEMENT AT 275°F



COMPARISON OF FNAL & BNL TEN STACK
DISPLACEMENT AT 300°F

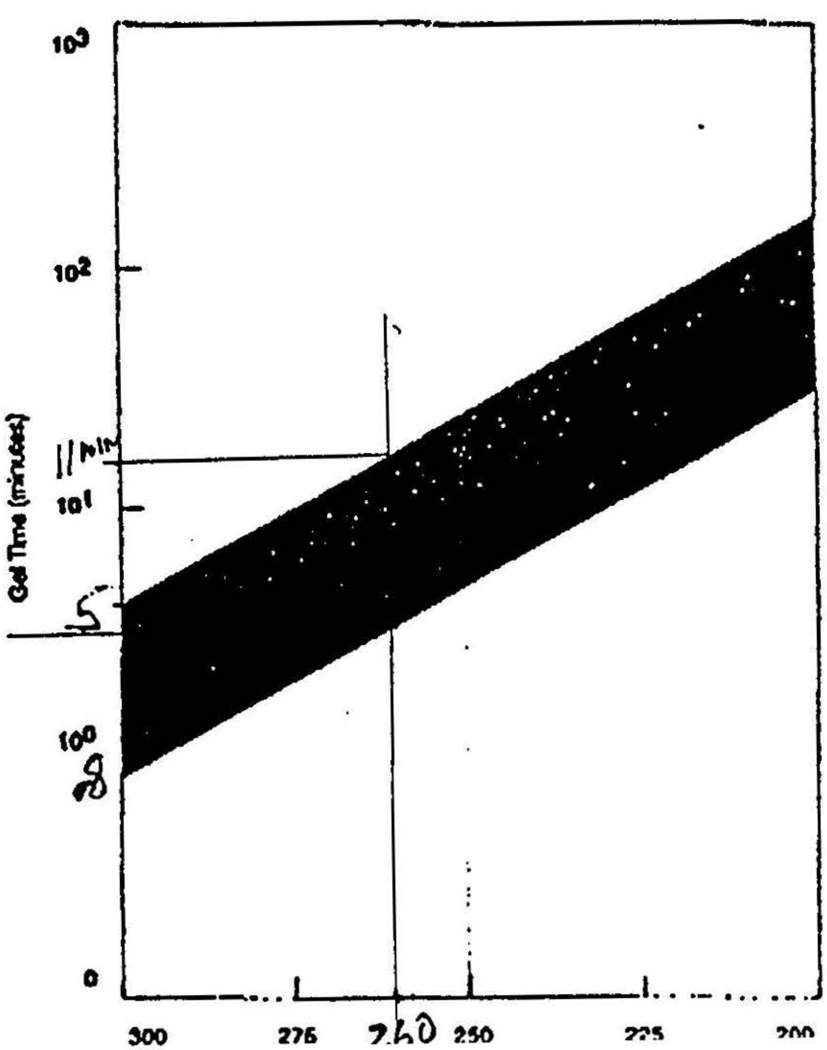


.J4 KJ/m^2

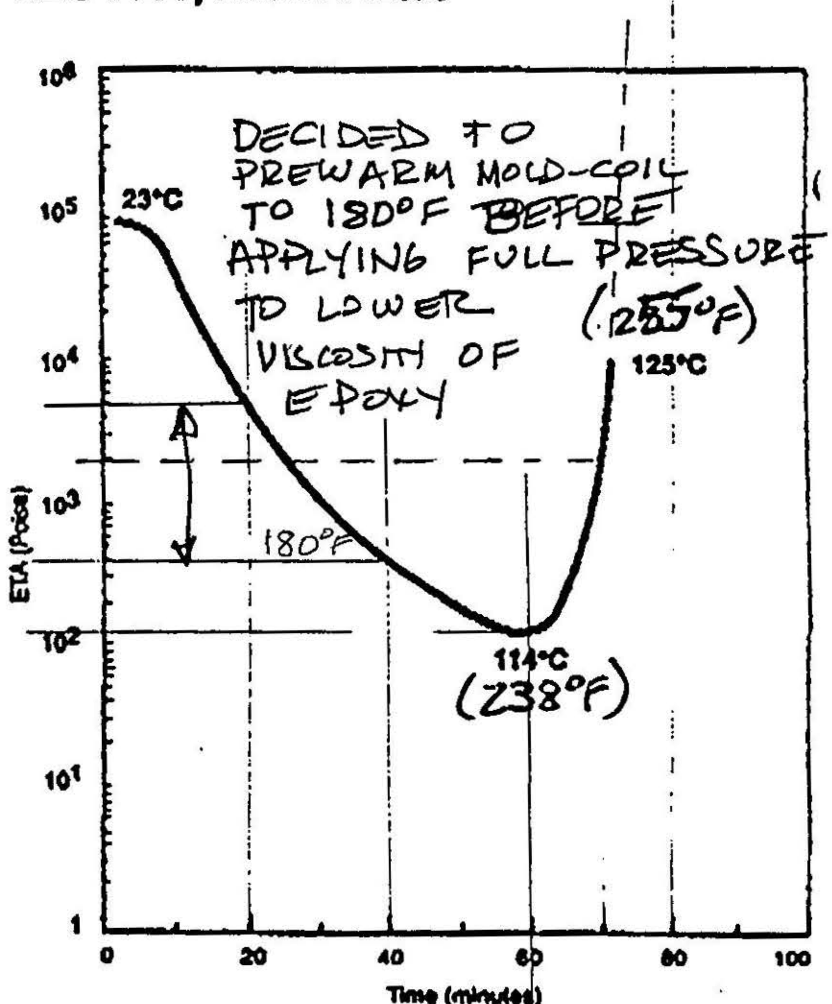
Gel Time @ 250°F .... 5-11 min.

HEXCEL EPOXY USED IN GLASS TAPE

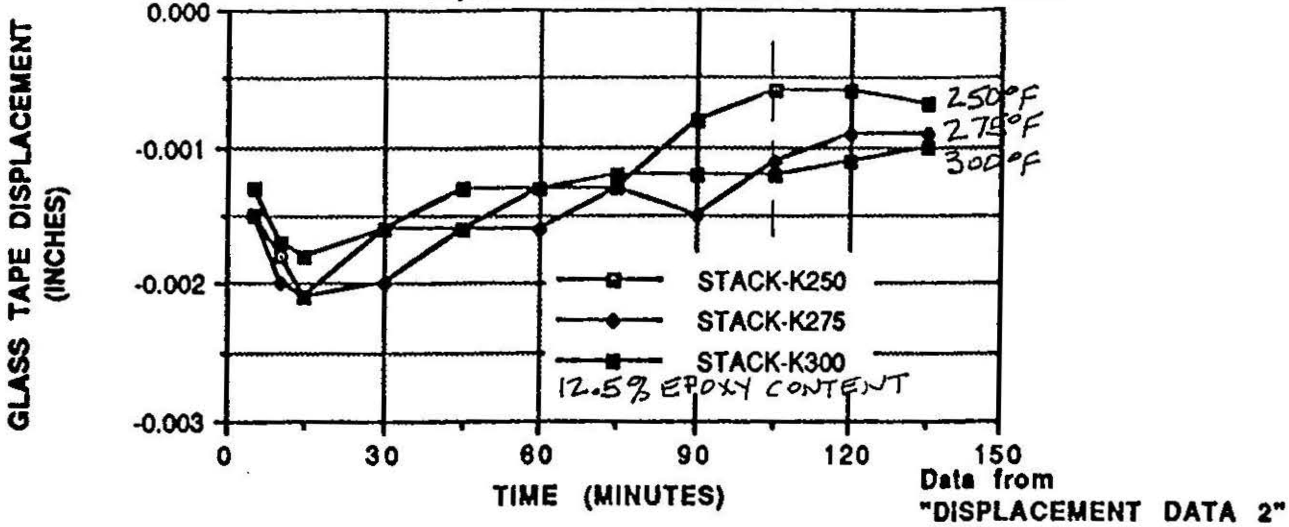
F185
Gel Time vs. Temperature



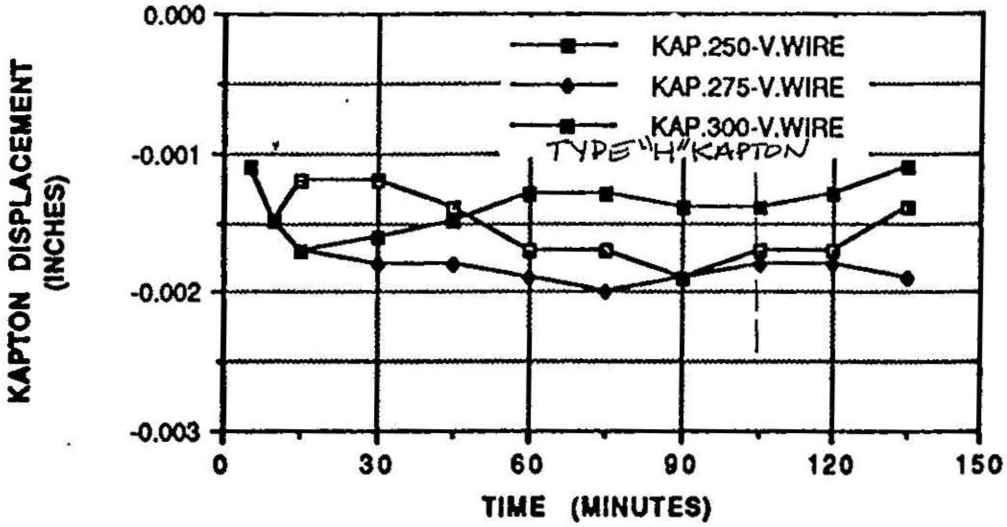
Rheometrics Curve of F185
2 Deg./Min., 10 Rad/Sec,
RDS-7700, 50mm Plates



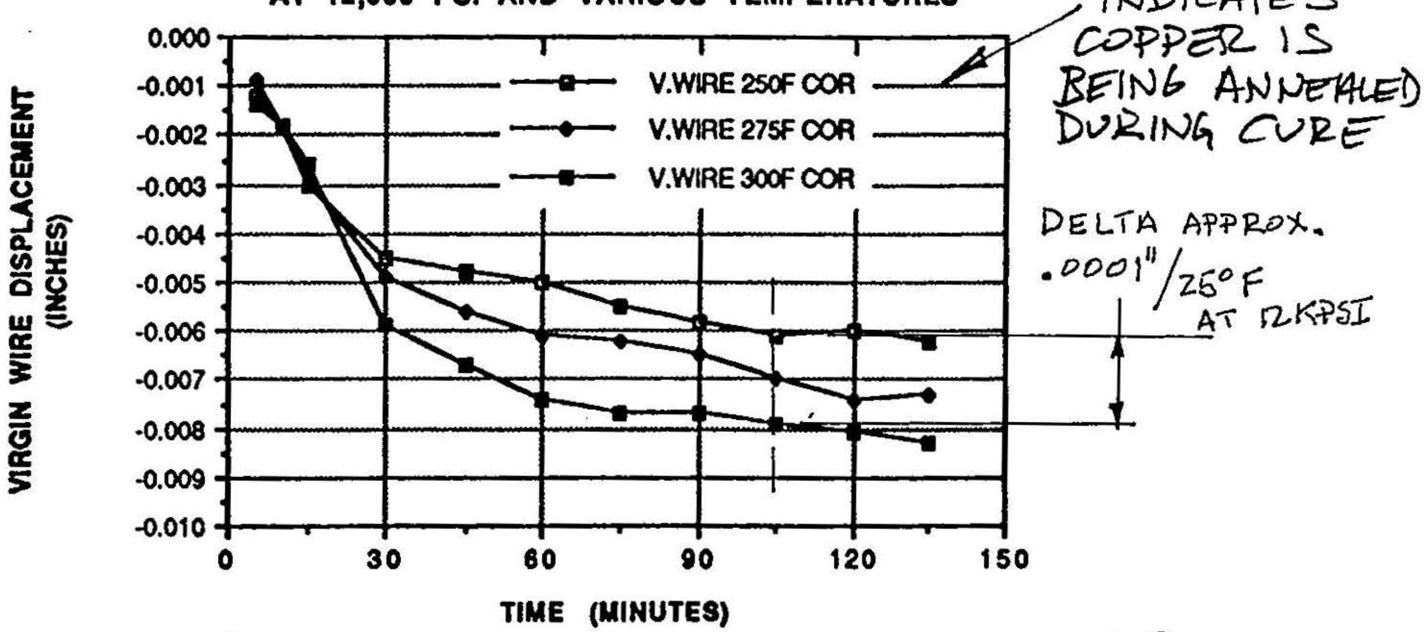
GLASS TAPE DISPLACEMENT IN A 10 STACK
AT 12,000 PSI AND VARIOUS TEMPERATURES



KAPTON DISPLACEMENT IN A 10 STACK
AT 12,000 PSI AND VARIOUS TEMPERATURES

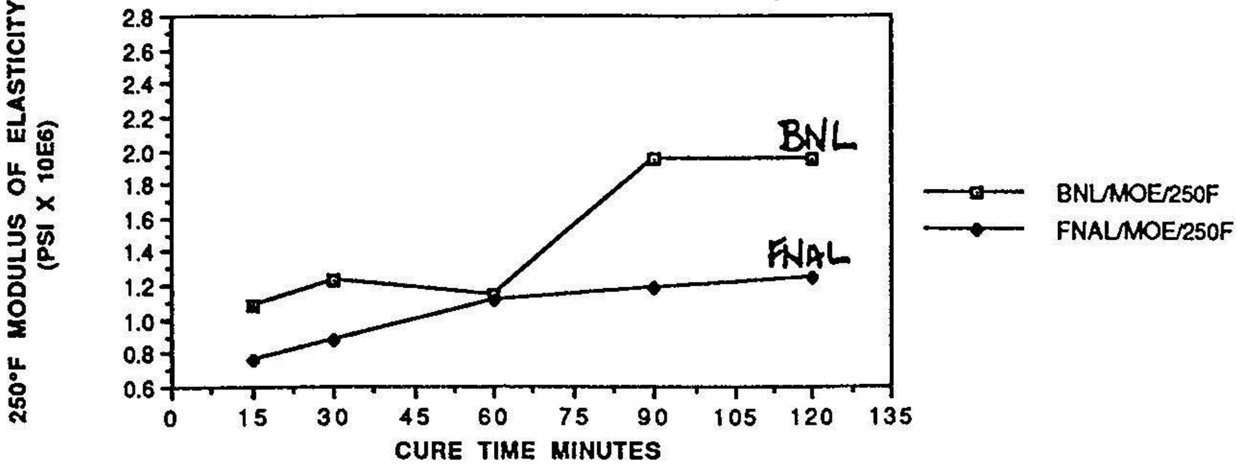


VIRGIN WIRE DISPLACEMENT IN A 10 STACK
AT 12,000 PSI AND VARIOUS TEMPERATURES

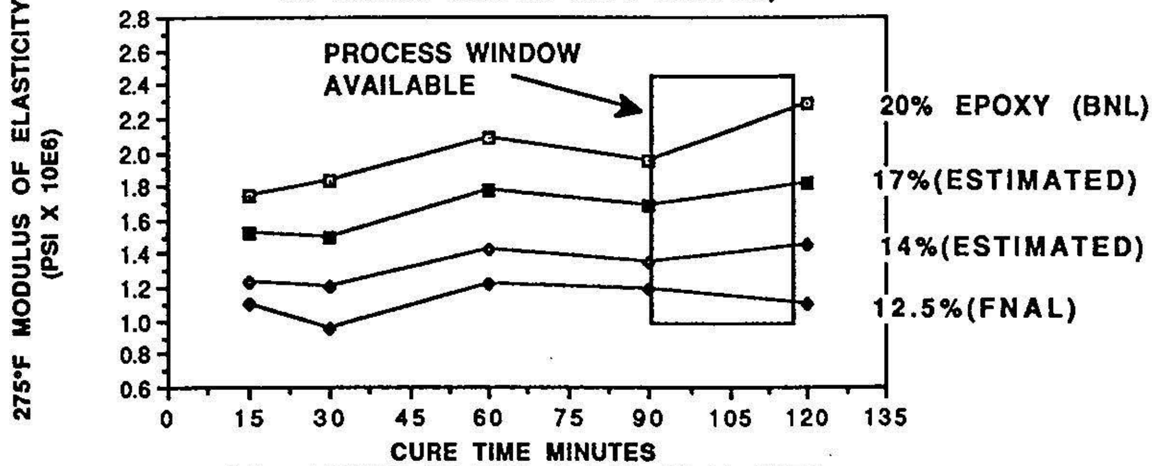


ALL DATA IS FROM 40MM INNER TEN STACKS

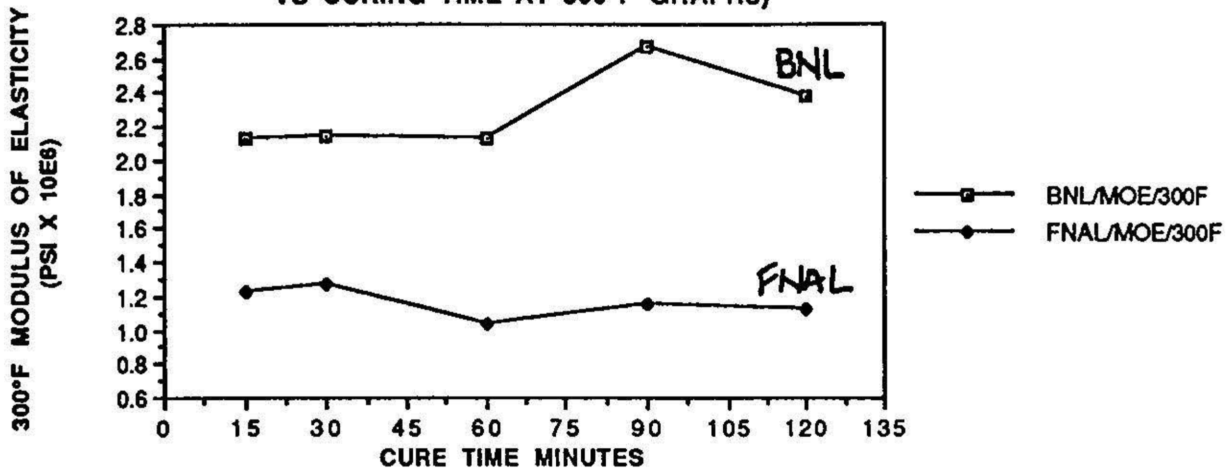
COMPARISON OF FNAL & BNL (ELASTICITY VS CURING TIME AT 250°F GRAPHS)

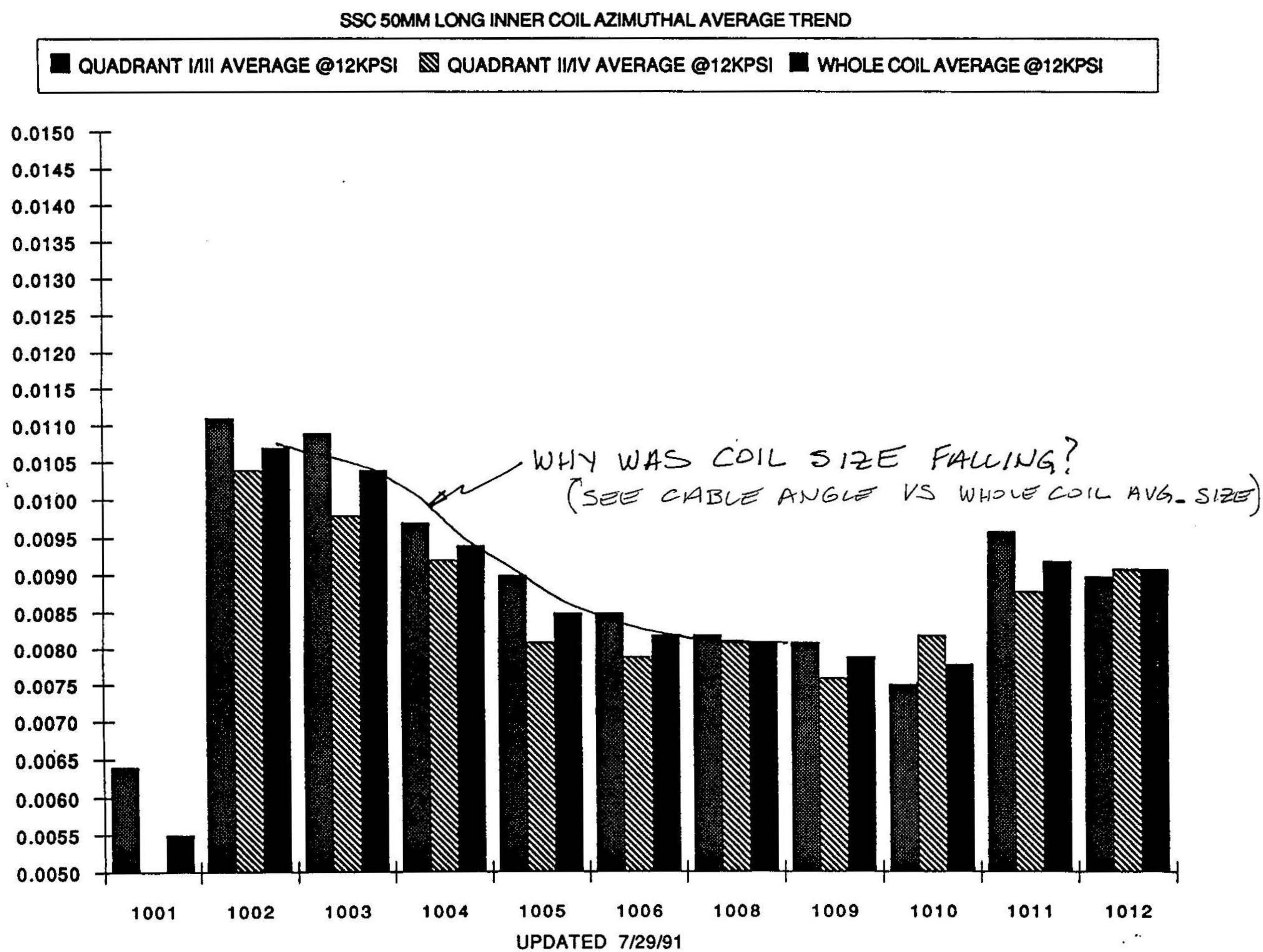


COMPARISON OF FNAL & BNL (ELASTICITY VS CURING TIME AT 275°F GRAPHS)

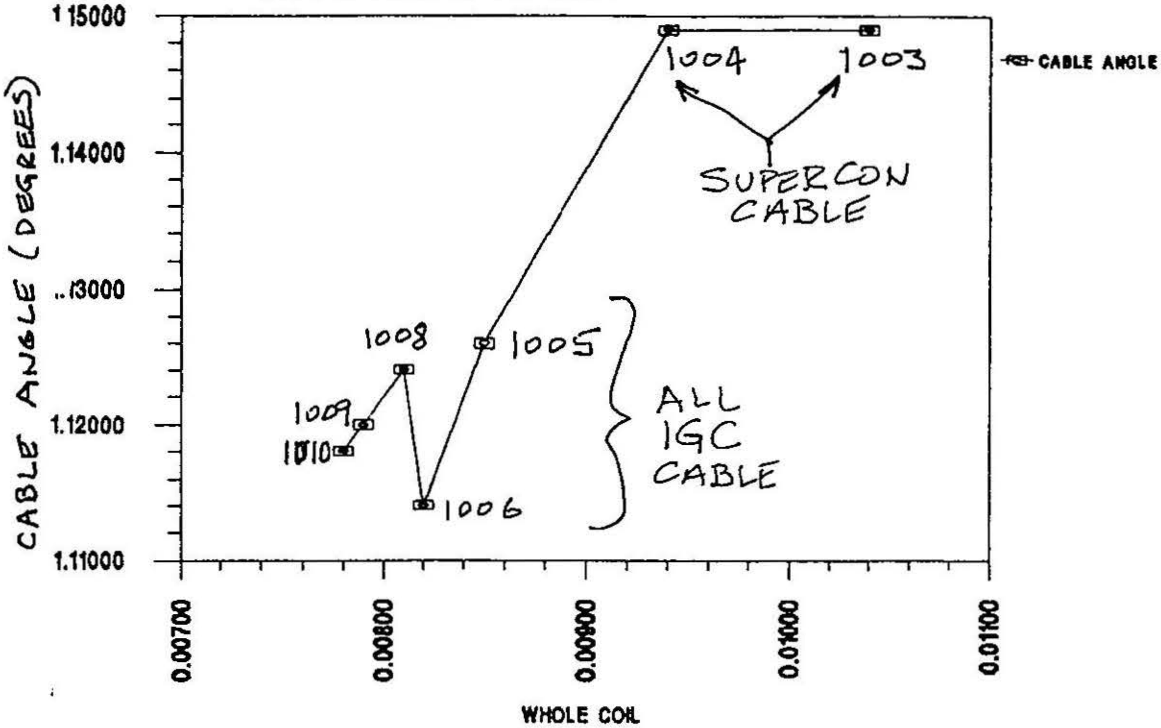


COMPARISON OF FNAL & BNL (ELASTICITY VS CURING TIME AT 300°F GRAPHS)

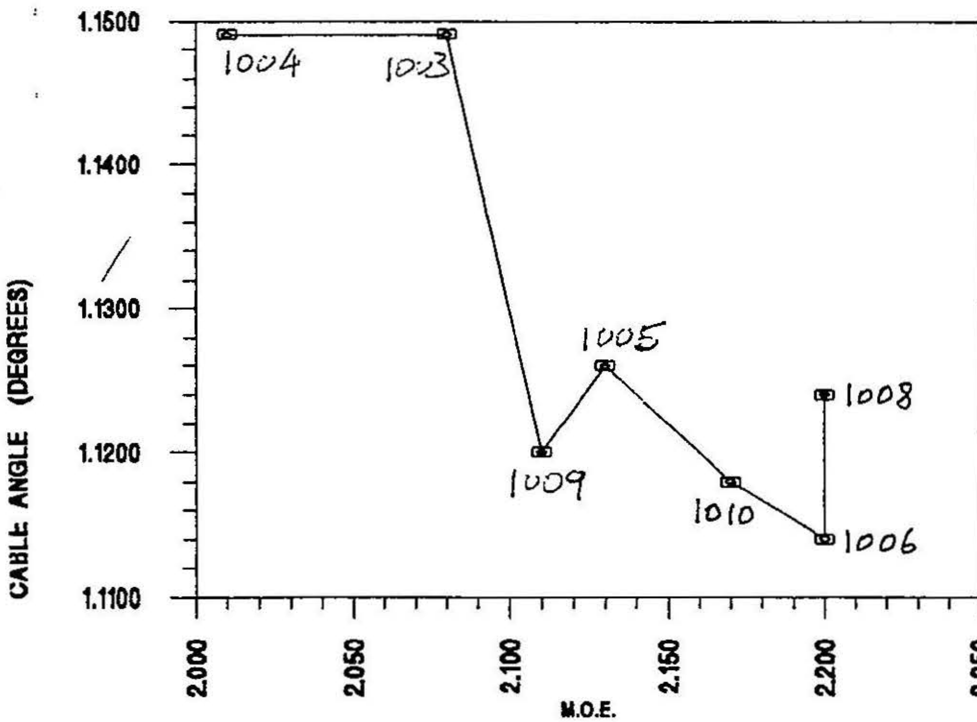



SSC 50MM LONG INNER COIL AZIMUTHAL AVERAGE TREND
QUADRANT I/III AVERAGE @12KPSI
QUADRANT II/IV AVERAGE @12KPSI
WHOLE COIL AVERAGE @12KPSI
0.0150
0.0145
0.0140
0.0135
0.0130
0.0125
0.0120
0.0115
0.0110
0.0105
0.0100
0.0095
0.0090
0.0085
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
WHY WAS COIL SIZE FALLING?
(SEE CABLE ANGLE VS WHOLE COIL AVG. SIZE)
1001
1002
1003
1004
1005
1006
1008
1009
1010
1011
1012
UPDATED 7/29/91

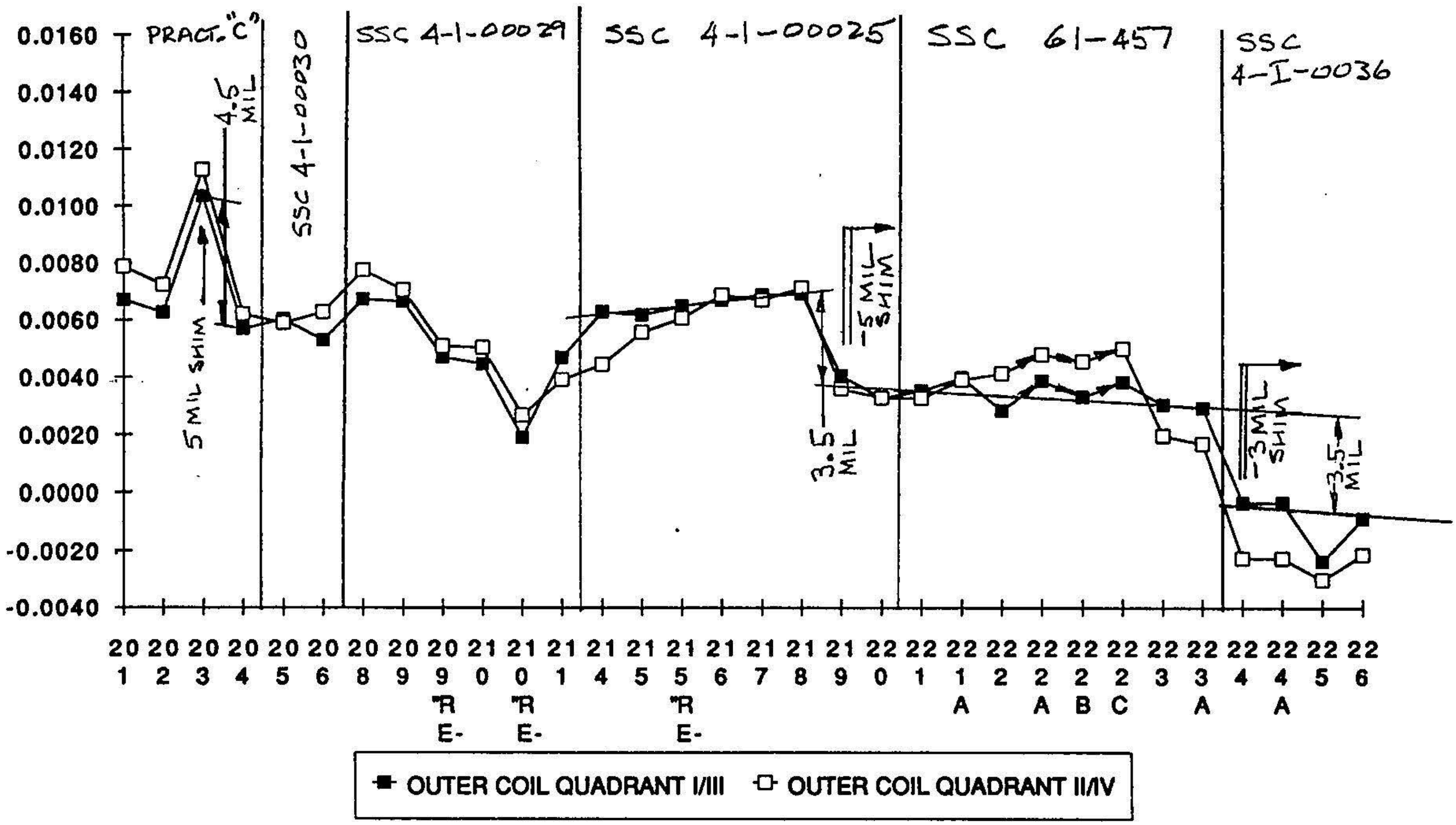
SSC 50mm LONG INNER COILS (FNAL)
CABLE ANGLE VS SIZE



SSC 50mm LONG INNER COILS (FNAL)
CABLE ANGLE VS MODULUS OF ELASTICITY

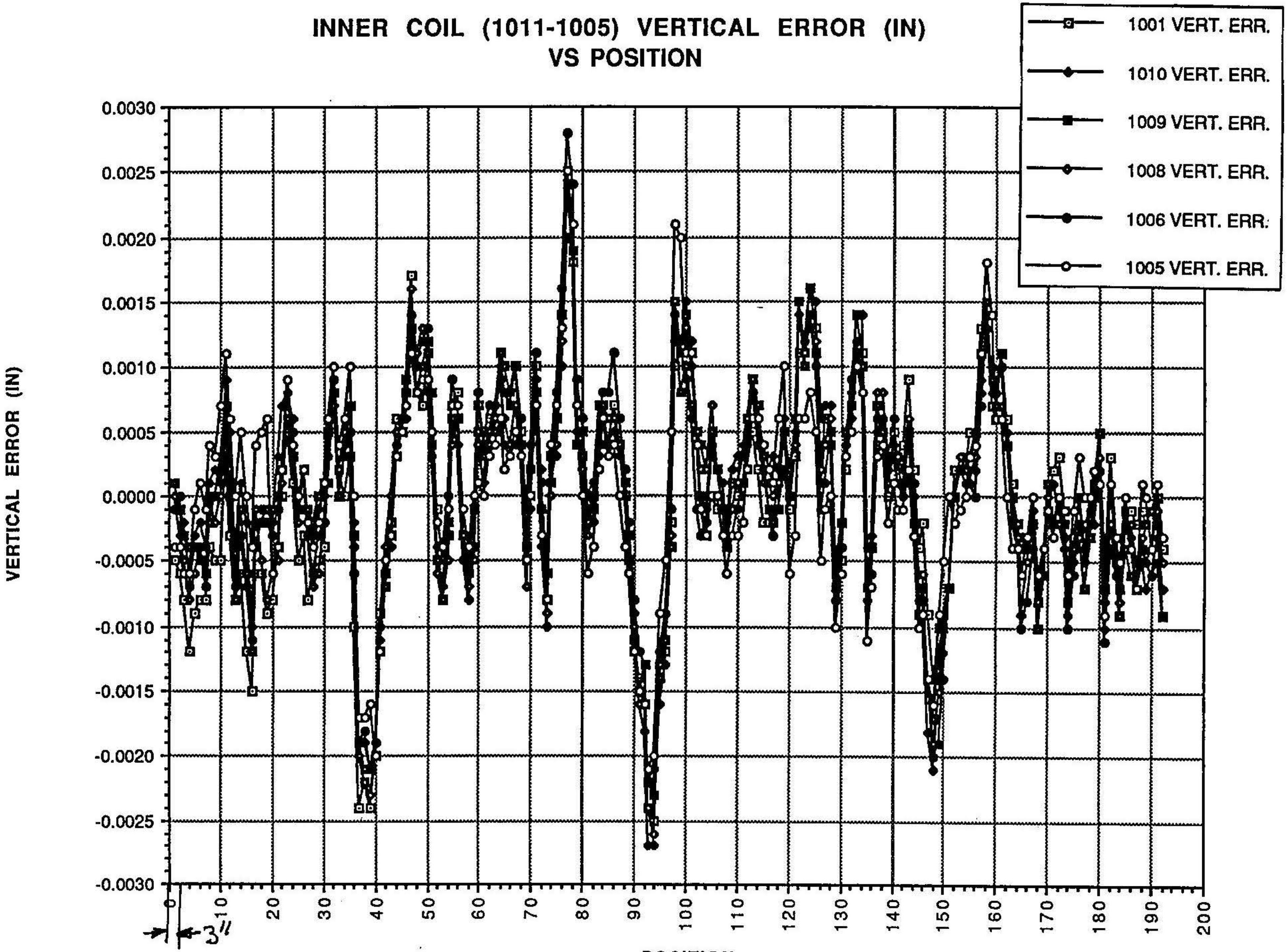


OUTER COIL AVERAGES OF THE COIL DEVIATION FROM THE MASTER AT 12,000 COIL PSI BY COIL NUMBER

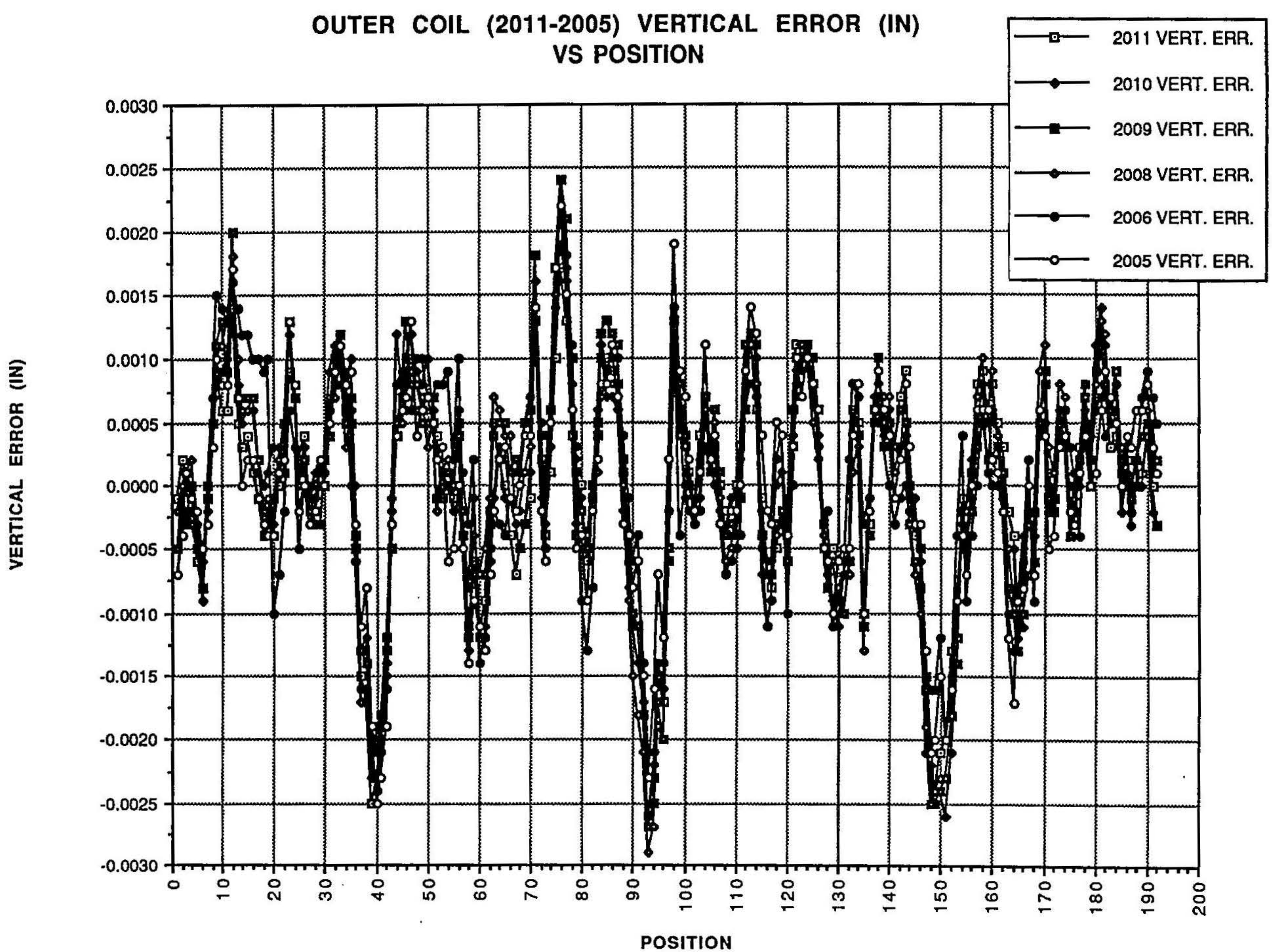


SHORT 50mm OUTER COILS

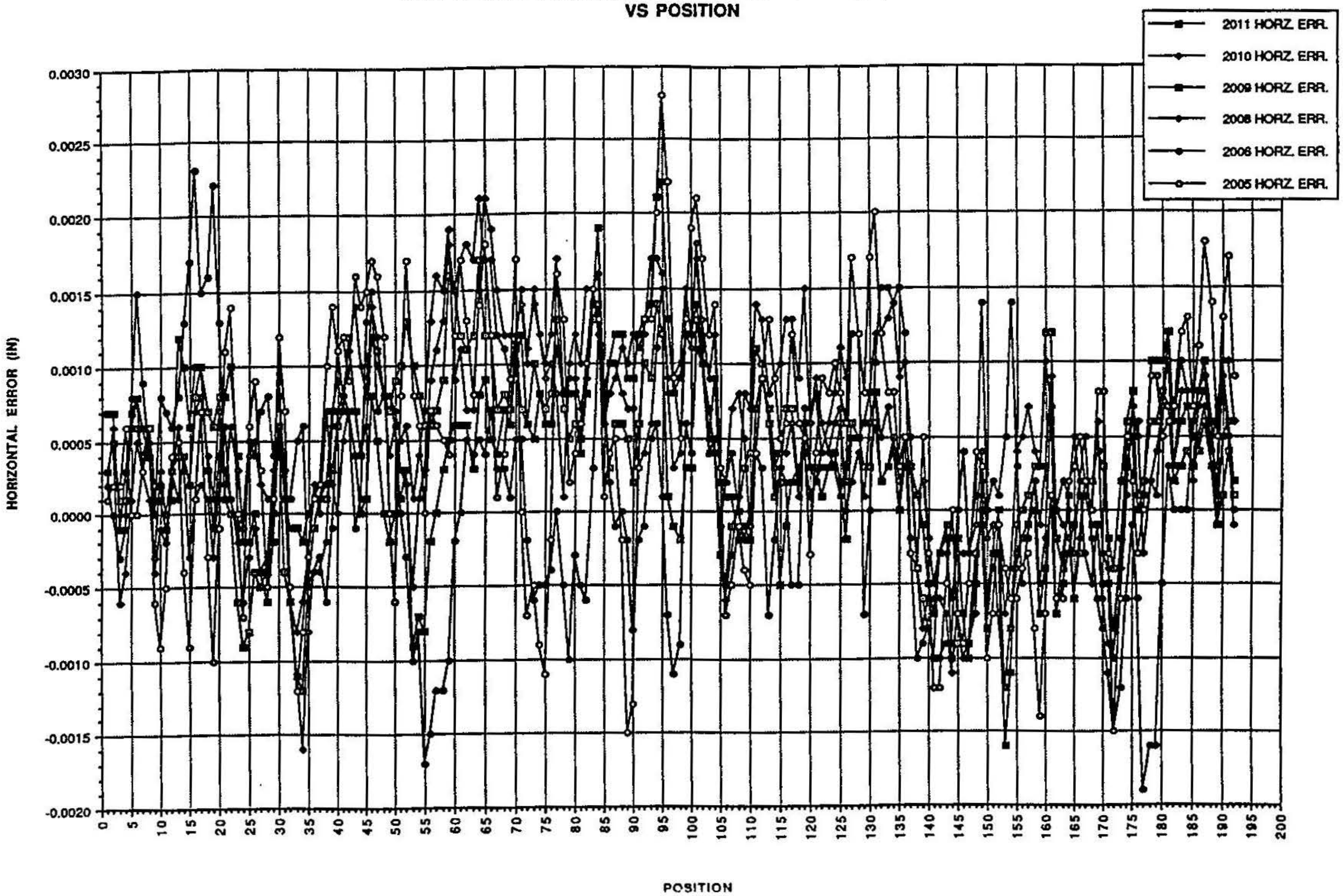
Updated 7/27/91



6 TYPICAL LONG COILS (FNAL)


OUTER COIL (2011-2005) VERTICAL ERROR (IN)
VS POSITION
2011 VERT. ERR.
2010 VERT. ERR.
2009 VERT. ERR.
2008 VERT. ERR.
2006 VERT. ERR.
2005 VERT. ERR.
VERTICAL ERROR (IN)
POSITION
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
-0.0020
-0.0025
-0.0030
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

OUTER COIL (2011-2005) HORIZONTAL ERROR (IN)
VS POSITION



INNER COIL (1011-1005) HORIZONTAL ERROR (IN)
VS POSITION