TS-SSC 91-065

# COIL SIZE MEASUREMENTS AND COIL CURING

R.E. Sims

Presented at the Fermilab
Production Readiness Review

4/4/91

Distribution:
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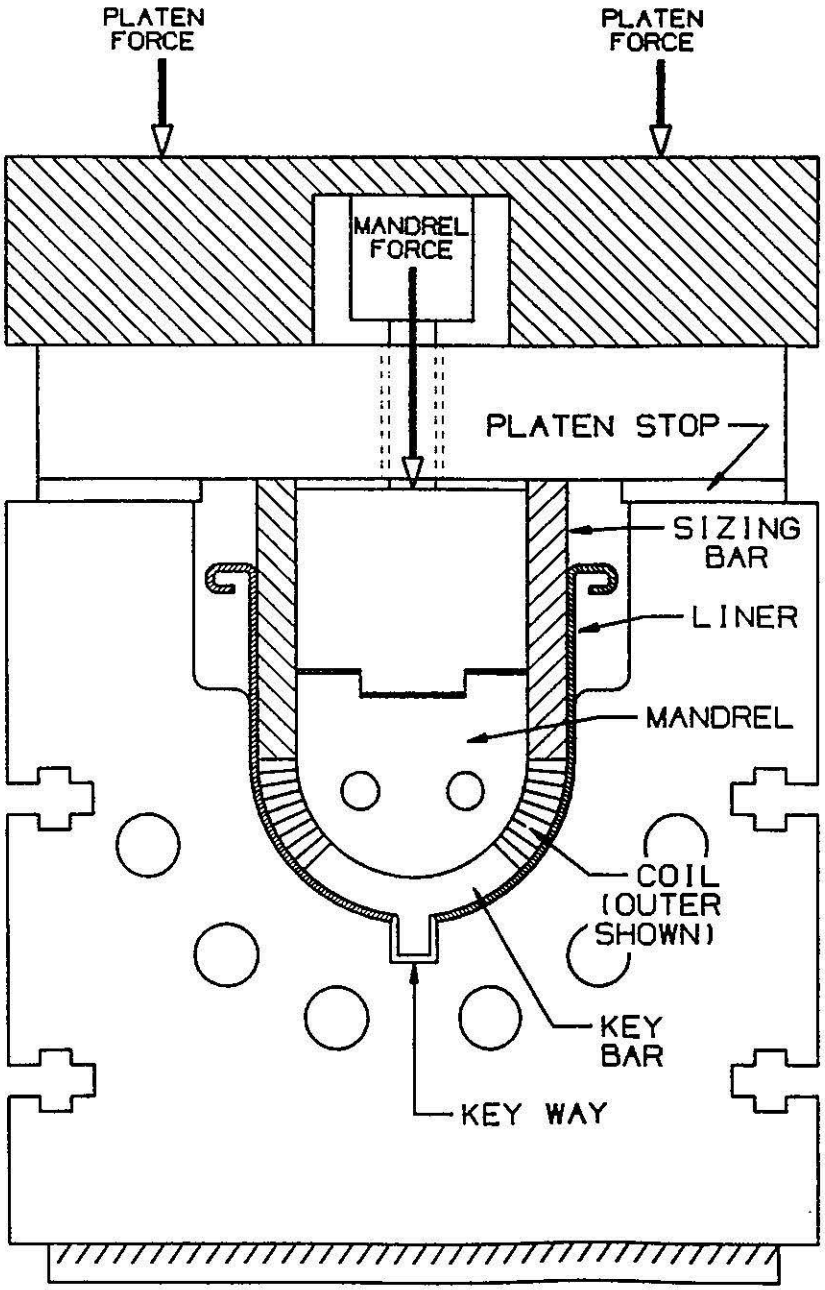
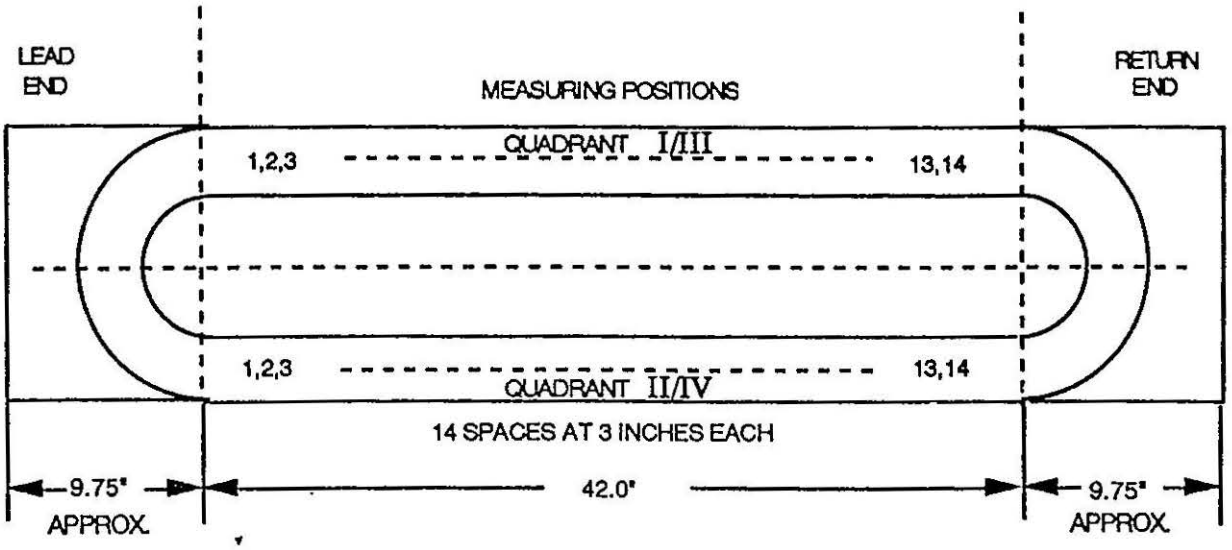
# Factors Contributing to the Finished Coil Size

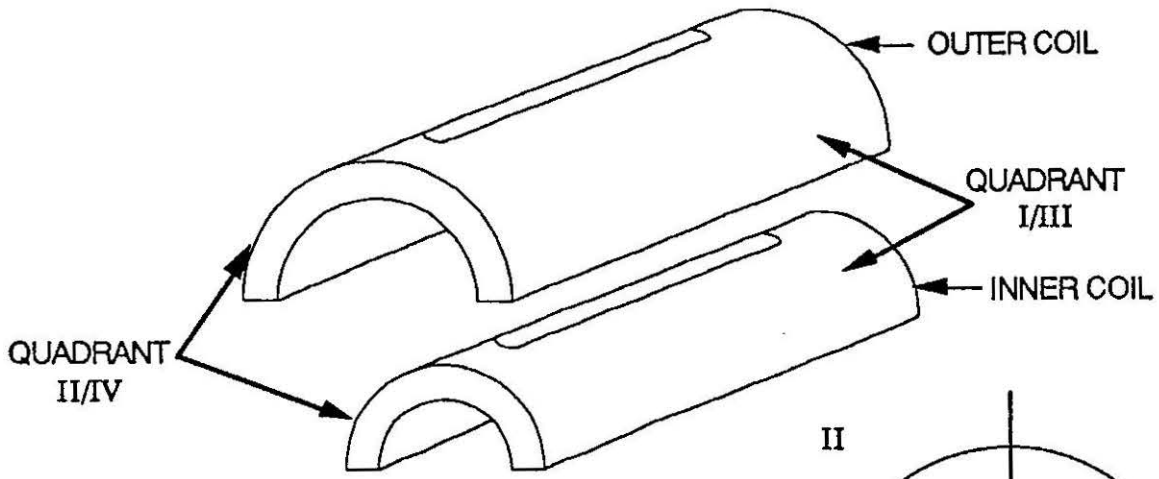
1. Construction Materials
   A. Cable
   B. Kapton Film
   C. Glass Tape

2. Tooling
   A. Winding Key
   B. Sizing Bars
   C. Mandrel
   D. Liner
   E. Optional Shims

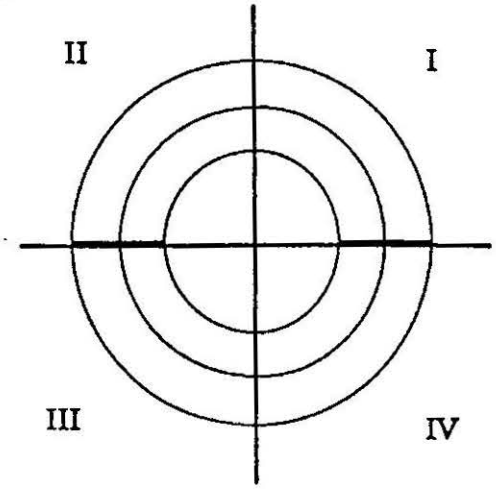
3. Curing Process Parameters
   A. Temperature of Cure
   B. Length of Cure
   C. Percent of Epoxy in Glass Tape
   D. Cavity Pressure
   E. Curing Press Sequence
   F. Mold Release Compound


PLATEN FORCE
PLATEN FORCE
MANDREL FORCE
PLATEN STOP
SIZING BAR
LINER
MANDREL
COIL (OUTER SHOWN)
KEY BAR
KEY WAY




LOOKING FROM THE LEAD END




SSC 50MM SHORT
OUTER COIL
SIZING POSITIONS

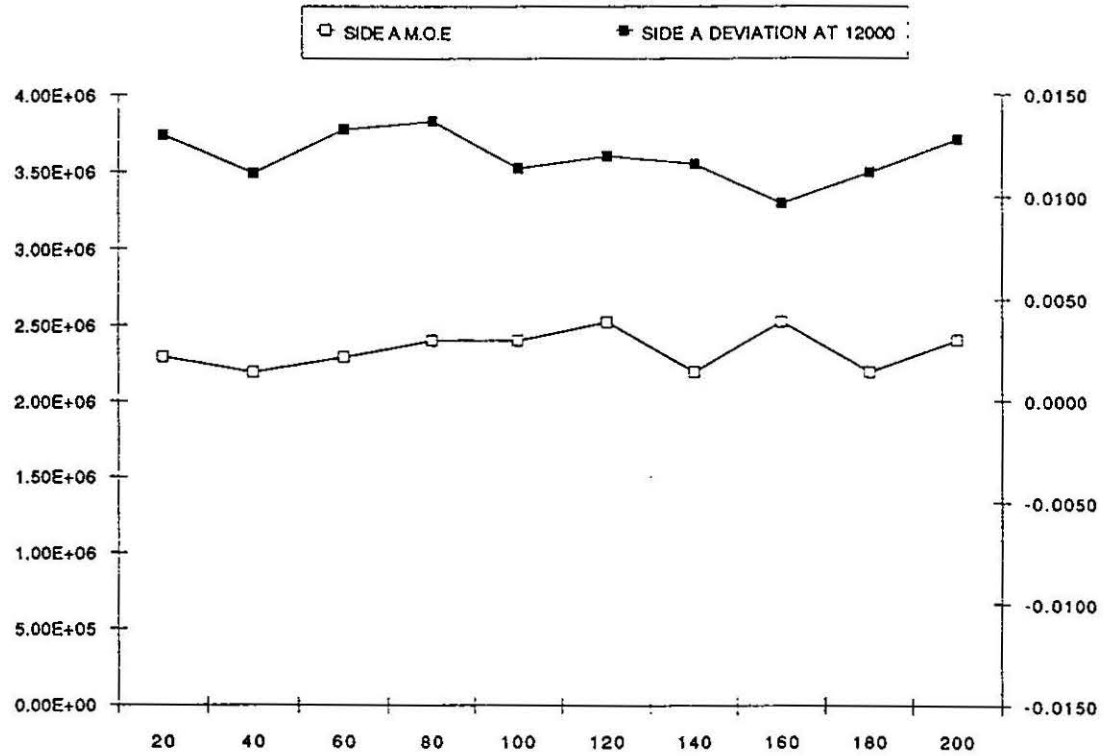
# Long SSC Inner Coil # 17M-1016

| | SIDE A (1-213) | | | | SIDE B (214-426) | | | | WHOLE COIL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8 kpsi | 12 kpsi | MOE | | 8 kpsi | 12 kpsi | MOE | | 8 kpsi | 12 kpsi | MOE |
| AVERAGE | 0.0120 | 0.0100 | 2338266 | AVERAGE | 0.0124 | 0.0108 | 2419820 | AVERAGE | 0.0122 | 0.0104 | 2379043 |
| STD DEV | 0.0012 | 0.0010 | 127403 | STD DEV | 0.0007 | 0.0012 | 166824 | STD DEV | 0.0010 | 0.0012 | 150405 |
| RANGE | 0.0040 | 0.0060 | 327950 | RANGE | 0.0023 | 0.0078 | 607315 | RANGE | 0.0040 | 0.0085 | 607315 |
| MAX | 0.0137 | 0.0127 | 2518284 | MAX | 0.0136 | 0.0152 | 2797649 | MAX | 0.0137 | 0.0152 | 2797649 |
| MIN | 0.0097 | 0.0067 | 2190334 | MIN | 0.0113 | 0.0074 | 2190334 | MIN | 0.0097 | 0.0067 | 2190334 |

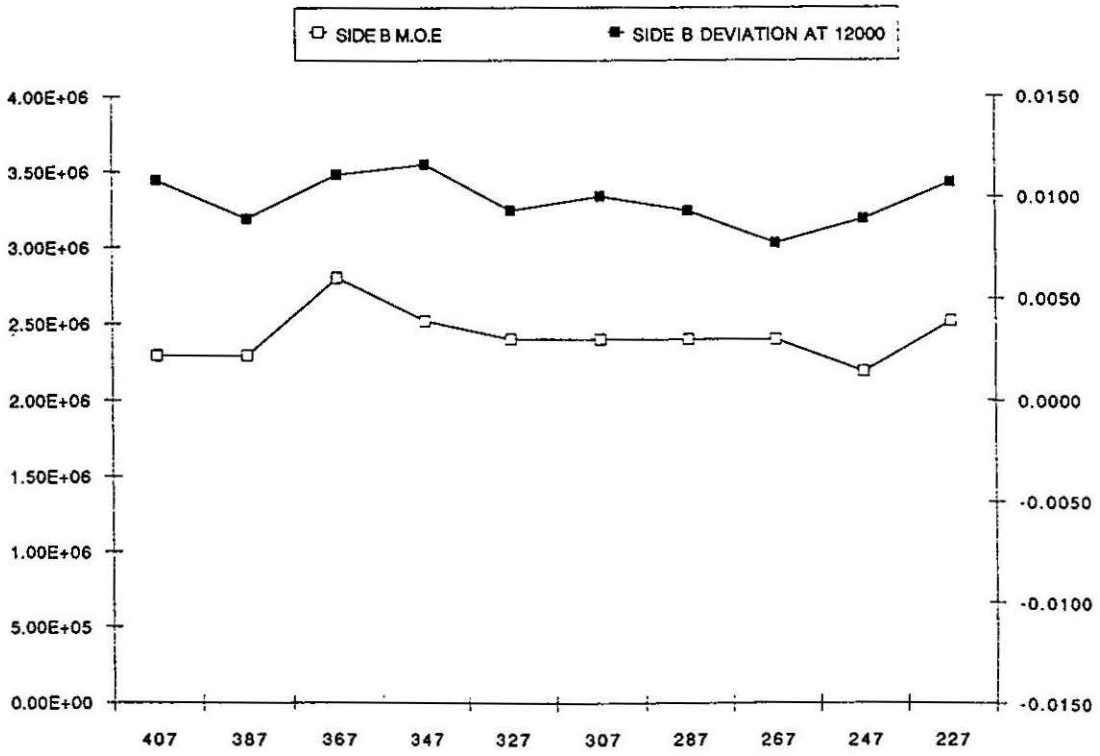
MEASUREMENT DATA

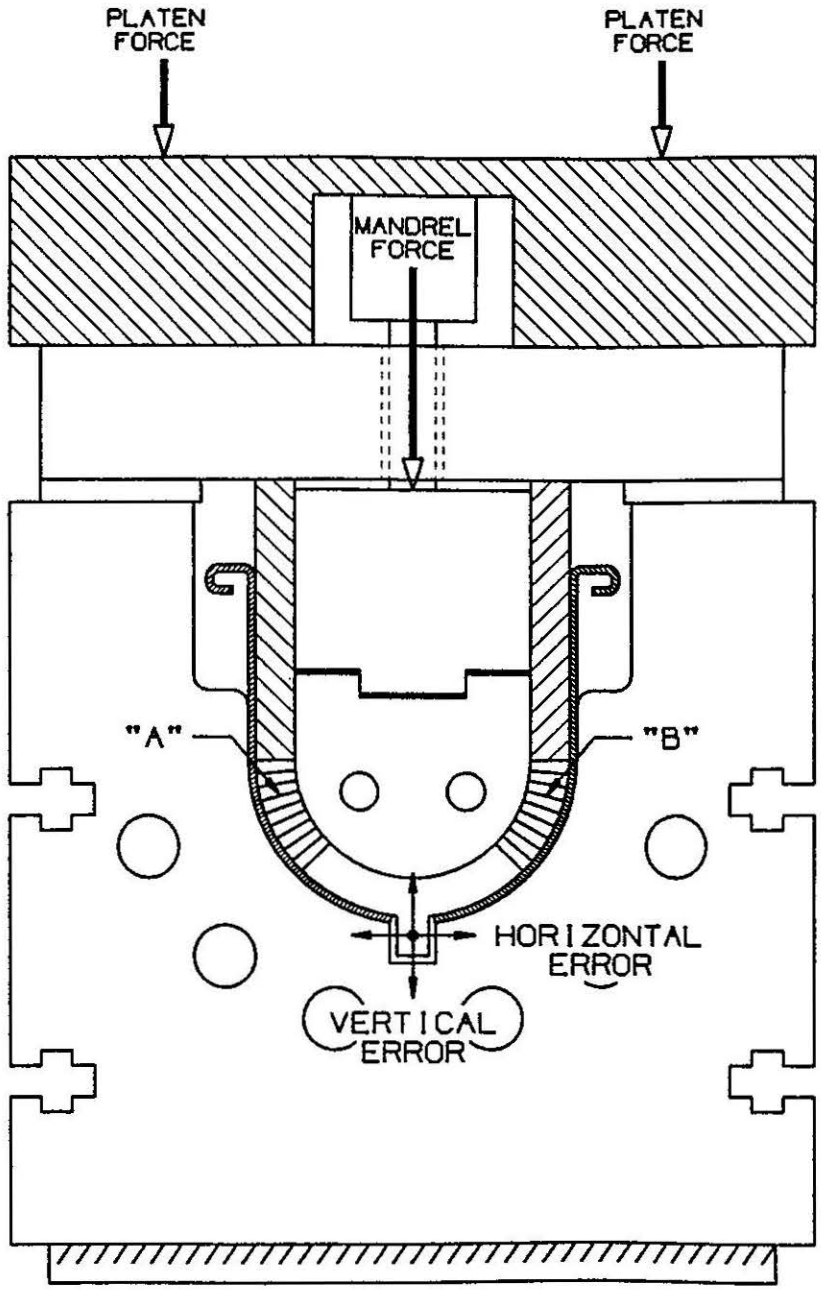
Coil #17M-1016 Coil Type: Inner Date: 1/19/91 MEAS. BY: SANDERS

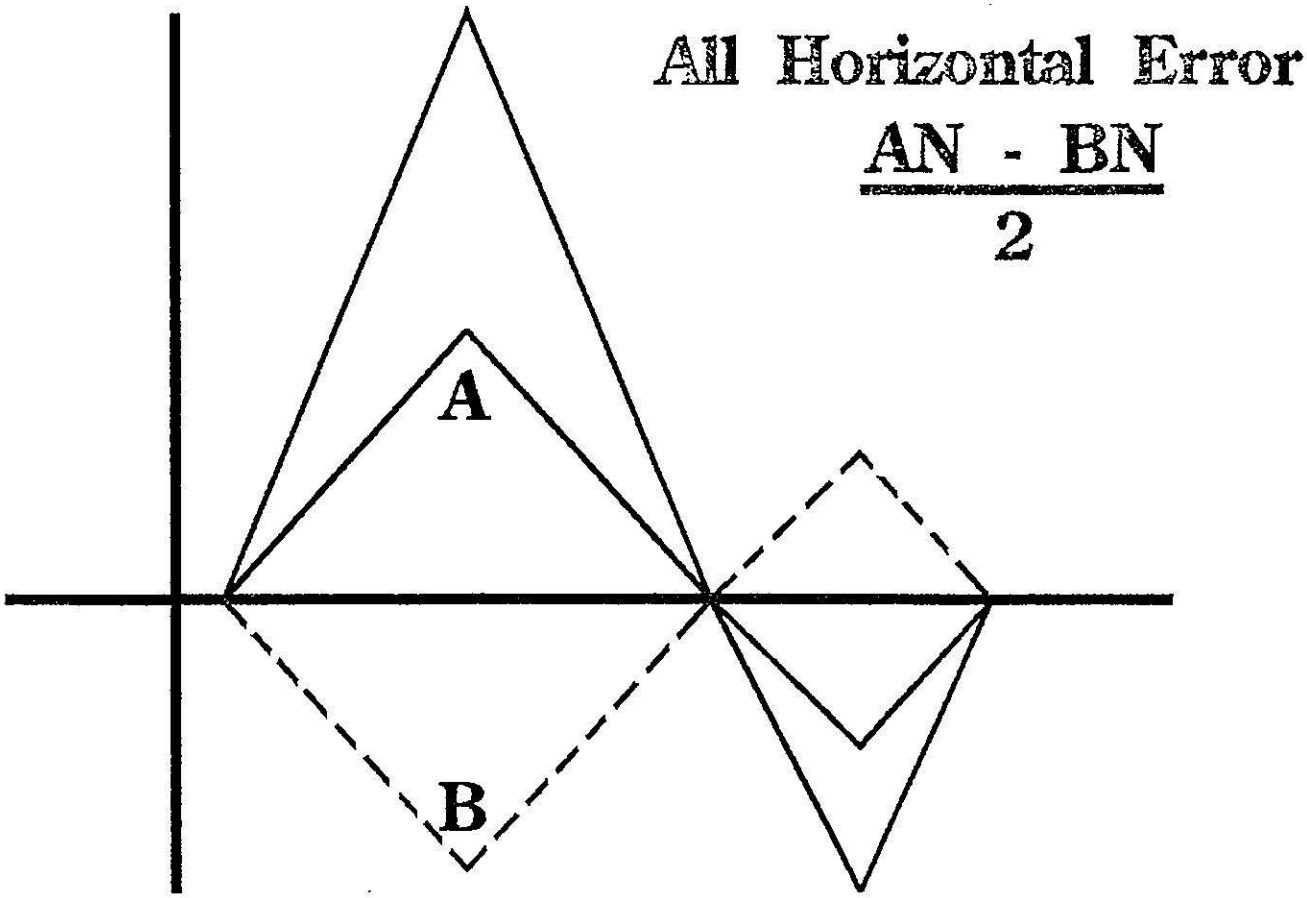
| Stress: | 6000 | | 8000 | | 10000 | | 12000 | | COIL SIZE WITH RESPECT TO THE MASTER | | DEVIATION FROM THE WHOLE COIL AVERAGE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pos # | Coil | Master | Coil | Master | Coil | Master | Coil | Master | 8000 | 12000 | AT 12000 | MOE |
| 1 | | | | | | | 1.0039 | 0.9950 | | .0089 | -.0015 | |
| 2 | | | | | | | 1.0050 | 0.9950 | | .0100 | -.0004 | |
| 3 | | | | | | | 1.0050 | 0.9951 | | .0099 | -.0005 | |
| 4 | | | | | | | 1.0055 | 0.9951 | | .0104 | .0000 | |
| 5 | | | | | | | 1.0055 | 0.9951 | | .0104 | .0000 | |
| 6 | | | | | | | 1.0050 | 0.9951 | | .0099 | -.0005 | |
| 7 | | | | | | | 1.0054 | 0.9950 | | .0104 | .0000 | |
| 8 | | | | | | | 1.0052 | 0.9950 | | .0102 | -.0002 | |
| 9 | | | | | | | 1.0054 | 0.9950 | | .0104 | .0000 | |
| 10 | | | | | | | 1.0055 | 0.9950 | | .0105 | .0001 | |
| 11 | | | | | | | 1.0060 | 0.9950 | | .0110 | .0006 | |
| 12 | | | | | | | 1.0057 | 0.9950 | | .0107 | .0003 | |
| 13 | | | | | | | 1.0059 | 0.9951 | | .0108 | .0004 | |
| 14 | | | | | | | 1.0058 | 0.9951 | | .0107 | .0003 | |
| 15 | | | | | | | 1.0051 | 0.9951 | | .0100 | -.0004 | |
| 16 | | | | | | | 1.0053 | 0.9950 | | .0103 | -.0001 | |
| 17 | | | | | | | 1.0062 | 0.9950 | | .0112 | .0008 | |
| 18 | | | | | | | 1.0055 | 0.9950 | | .0105 | .0001 | |
| 19 | | | | | | | 1.0058 | 0.9950 | | .0108 | .0004 | |
| 20 UP | 1.0139 | 1.0000 | 1.0115 | 0.9985 | 1.0085 | 0.9970 | 1.0063 | 0.9955 | .0130 | .0108 | .0004 | 2289713 |
| 21 | | | | | | | 1.0064 | 0.9958 | | .0106 | .0002 | |
| 22 | | | | | | | 1.0067 | 0.9955 | | .0112 | .0008 | |
| 23 | | | | | | | 1.0070 | 0.9958 | | .0112 | .0008 | |
| 24 | | | | | | | 1.0058 | 0.9954 | | .0104 | .0000 | |
| 25 | | | | | | | 1.0045 | 0.9955 | | .0090 | -.0014 | |
| 26 | | | | | | | 1.0046 | 0.9956 | | .0090 | -.0014 | |
| 27 | | | | | | | 1.0055 | 0.9956 | | .0099 | -.0005 | |
| 28 | | | | | | | 1.0042 | 0.9956 | | .0086 | -.0018 | |
| 29 | | | | | | | 1.0069 | 0.9956 | | .0113 | .0009 | |
| 30 | | | | | | | 1.0066 | 0.9956 | | .0110 | .0006 | |
| 31 | | | | | | | 1.0070 | 0.9956 | | .0114 | .0010 | |
| 32 | | | | | | | 1.0064 | 0.9956 | | .0108 | .0004 | |
| 33 | | | | | | | 1.0069 | 0.9956 | | .0113 | .0009 | |
| 34 | | | | | | | 1.0065 | 0.9956 | | .0109 | .0005 | |
| 35 | | | | | | | 1.0060 | 0.9956 | | .0104 | .0000 | |
| 36 | | | | | | | 1.0062 | 0.9956 | | .0106 | .0002 | |
| 37 | | | | | | | 1.0060 | 0.9956 | | .0104 | .0000 | |
| 38 | | | | | | | 1.0061 | 0.9956 | | .0105 | .0001 | |
| 39 | | | | | | | 1.0066 | 0.9956 | | .0110 | .0006 | |
| 40 UP | 1.0121 | 1.0000 | 1.0094 | 0.9982 | 1.0067 | 0.9969 | 1.0042 | 0.9953 | .0112 | .0089 | -.0015 | 2190334 |
| 41 | | | | | | | 1.0046 | 0.9952 | | .0094 | -.0010 | |
| 42 | | | | | | | 1.0039 | 0.9951 | | .0088 | -.0016 | |
| 43 | | | | | | | 1.0046 | 0.9951 | | .0095 | -.0009 | |
| 44 | | | | | | | 1.0056 | 0.9951 | | .0105 | .0001 | |
| 45 | | | | | | | 1.0063 | 0.9952 | | .0111 | .0007 | |
| 46 | | | | | | | 1.0060 | 0.9952 | | .0108 | .0004 | |
| 47 | | | | | | | 1.0064 | 0.9952 | | .0112 | .0008 | |
| 48 | | | | | | | 1.0079 | 0.9952 | | .0127 | .0023 | |
| 49 | | | | | | | 1.0078 | 0.9952 | | .0126 | .0022 | |
| 50 | | | | | | | 1.0060 | 0.9952 | | .0108 | .0004 | |
| 51 | | | | | | | 1.0054 | 0.9952 | | .0102 | -.0002 | |
| 52 | | | | | | | 1.0040 | 0.9952 | | .0088 | -.0016 | |
| 53 | | | | | | | 1.0038 | 0.9952 | | .0086 | -.0018 | |
| 54 | | | | | | | 1.0037 | 0.9952 | | .0085 | -.0019 | |

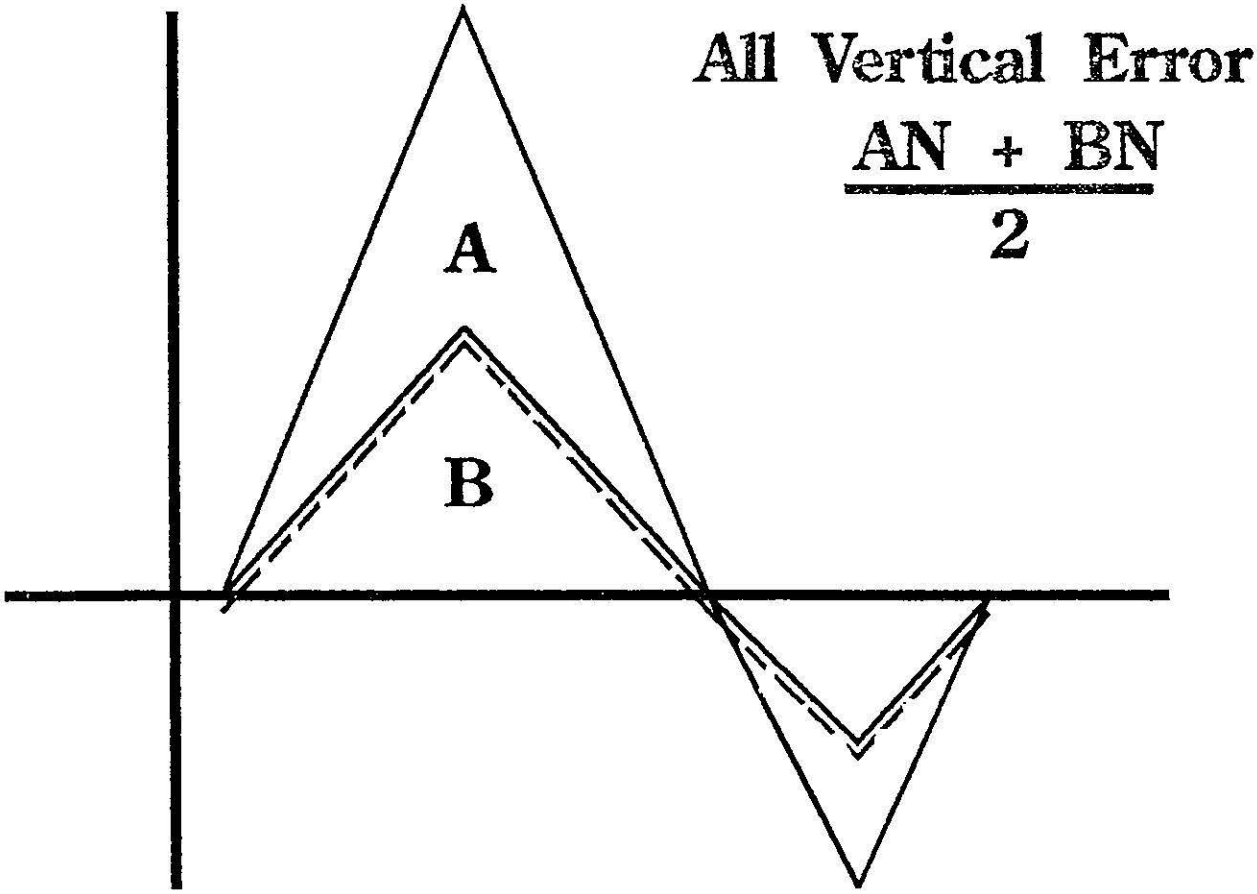


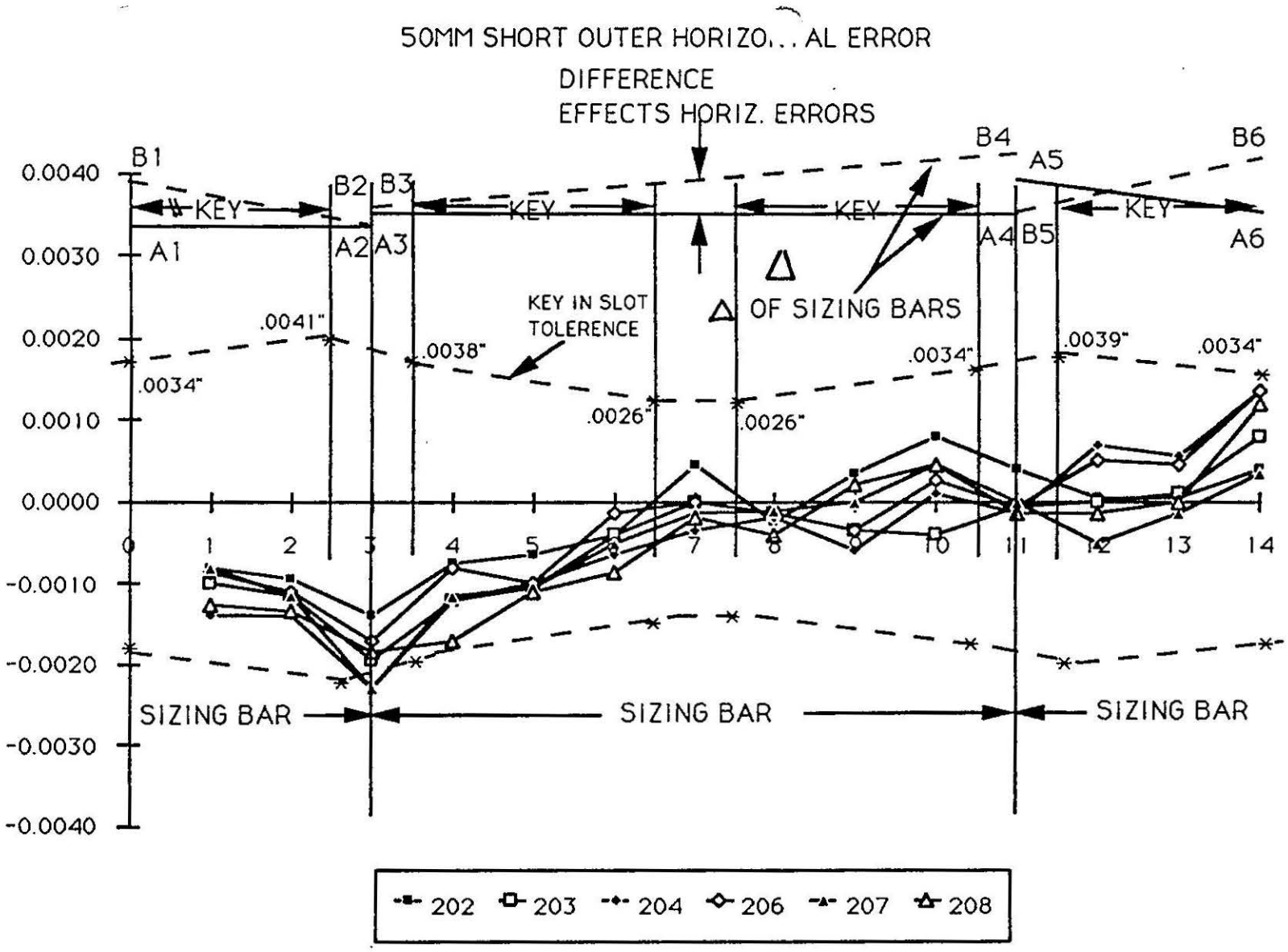

1016 SIDE B MOE TO SIDE B



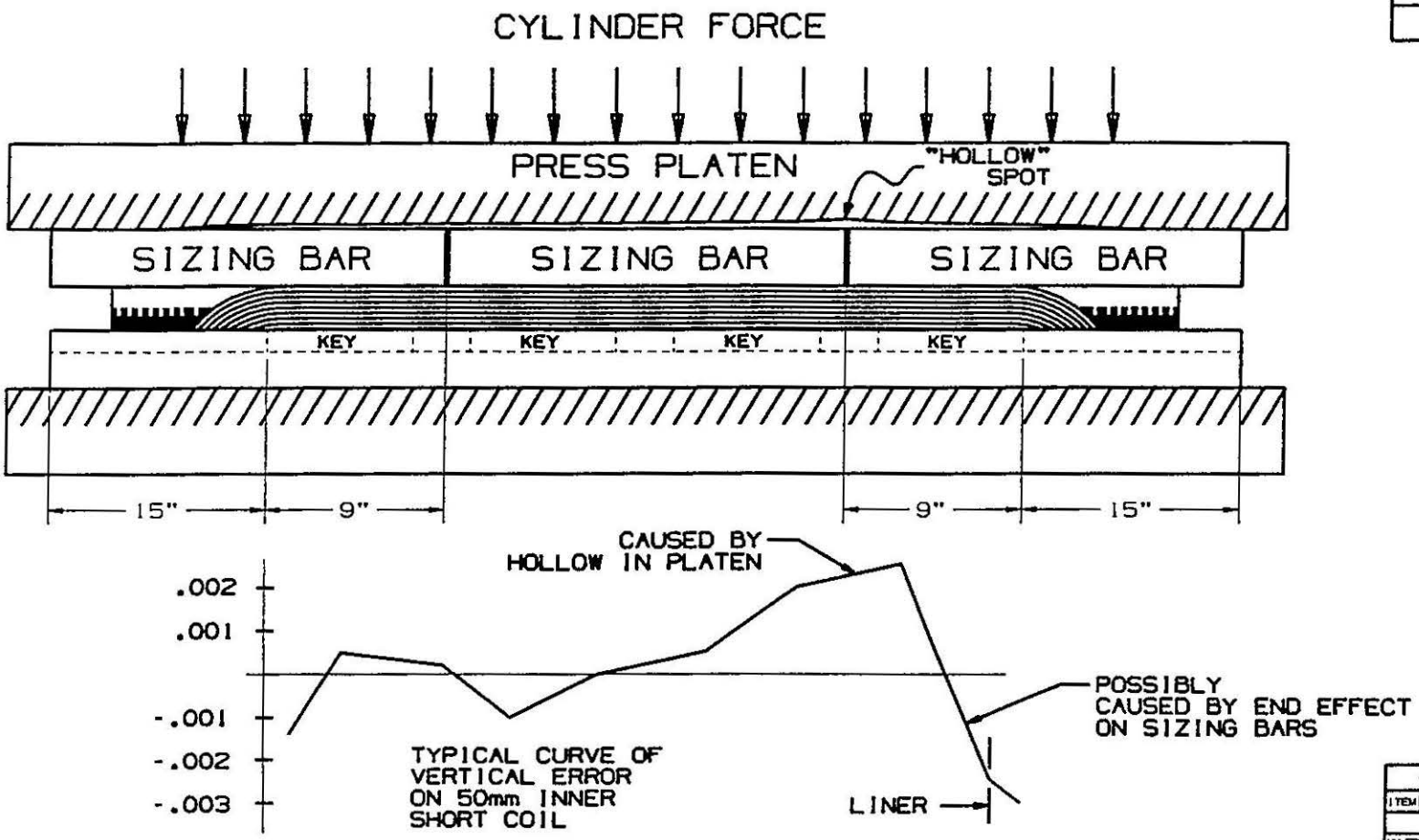

PLATEN FORCE
PLATEN FORCE
MANDREL FORCE
"A"
"B"
HORIZONTAL ERROR
VERTICAL ERROR


All Horizontal Error
AN - BN
2
A
B


All Vertical Error
AN + BN
2
A
B


50MM SHORT OUTER HORIZO... AL ERROR
DIFFERENCE
EFFECTS HORIZ. ERRORS
B1
B2
B3
B4
A5
B6
KEY
KEY
KEY
KEY
A1
A2
A3
A4
B5
A6
Δ
Δ OF SIZING BARS
KEY IN SLOT
TOLERENCE
.0041"
.0038"
.0034"
.0026"
.0026"
.0034"
.0039"
.0034"
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
0
1
2
3
4
5
7
8
10
11
12
13
14
SIZING BAR
SIZING BAR
SIZING BAR
202
203
204
206
207
208

| REV. | DESCRIPTION | DRWN / APPD. |
|---|---|---|
| | | |




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

PARTS LIST

UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. TOLERANCES: ± 1 mm.
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982.
4. INCH DIMENSIONS ARE FOR REFERENCE ONLY.
5. BREAK ALL SHARP EDGES.
6. DO NOT SCALE DRAWING.
7. MAX. ALL MACH. SURFACES ✓
8. DIMENSION IDENTIFICATION: MILLIMETER [100] | MILLIMETER/INCH

| | |
|---|---|
| ORIGINATOR | |
| DRAWN | |
| CHECKED | |
| APPROVED | |
| USED ON | |
| MATERIAL | |

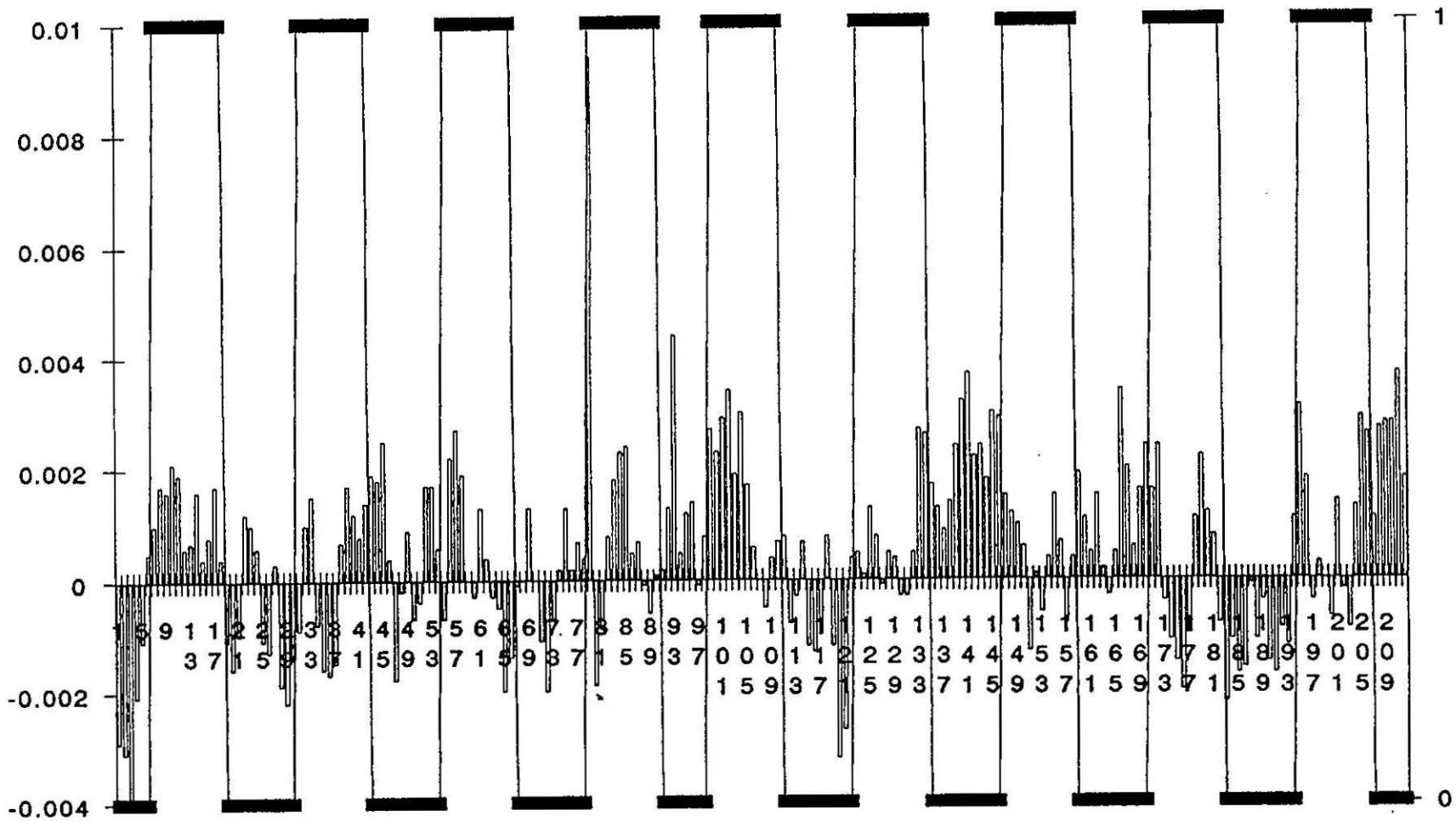
FERMI NATIONAL ACCELERATOR LABORAT
UNITED STATES DEPARTMENT OF ENERGY
SSC

# 50mm CURING PRESS SIDE VIEW

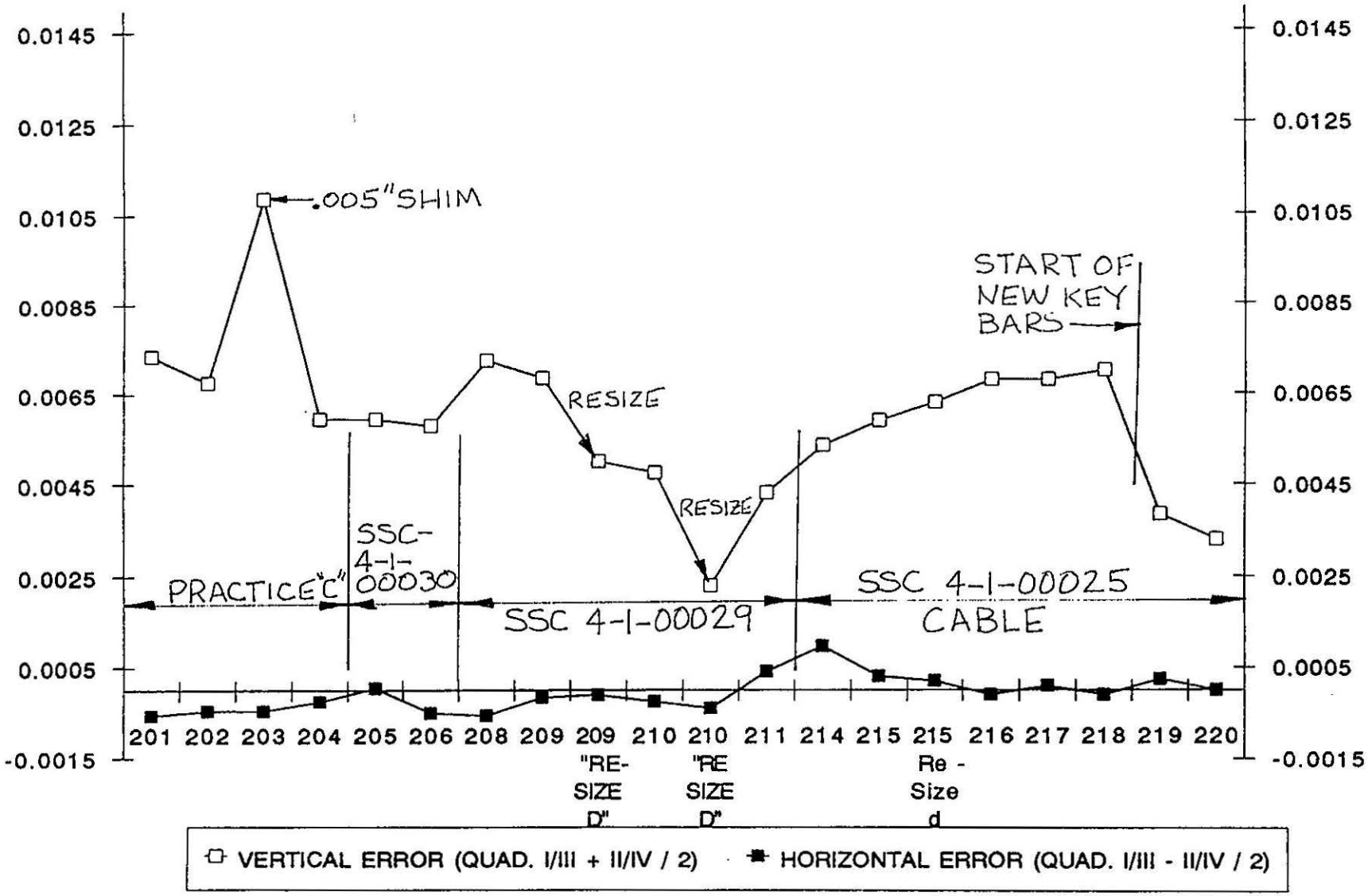
| SCALE | FINISH | DRAWING NUMBER |
|---|---|---|
| | | |

1011RLI ⌒ (LC

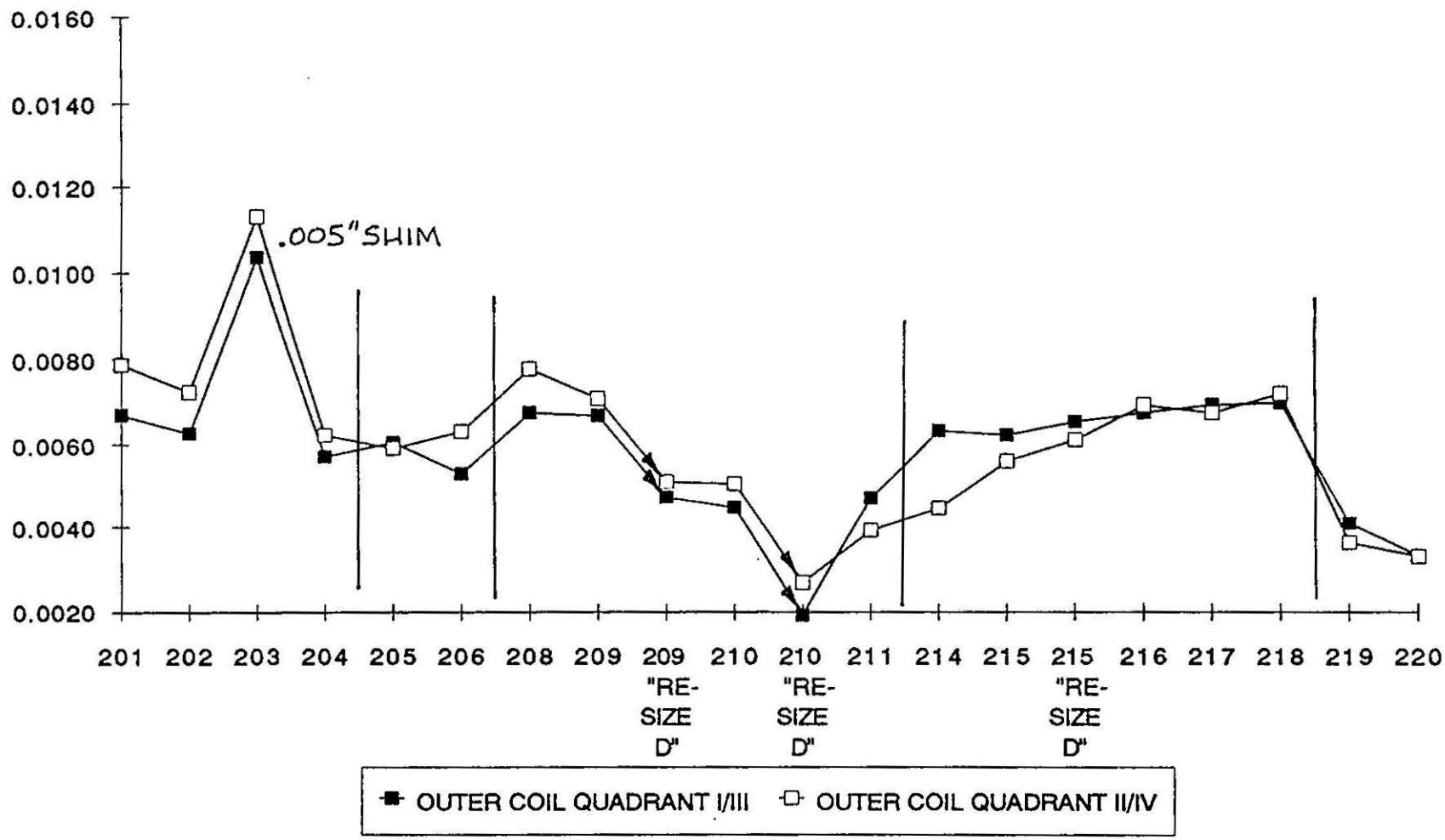
LINER AND A-B



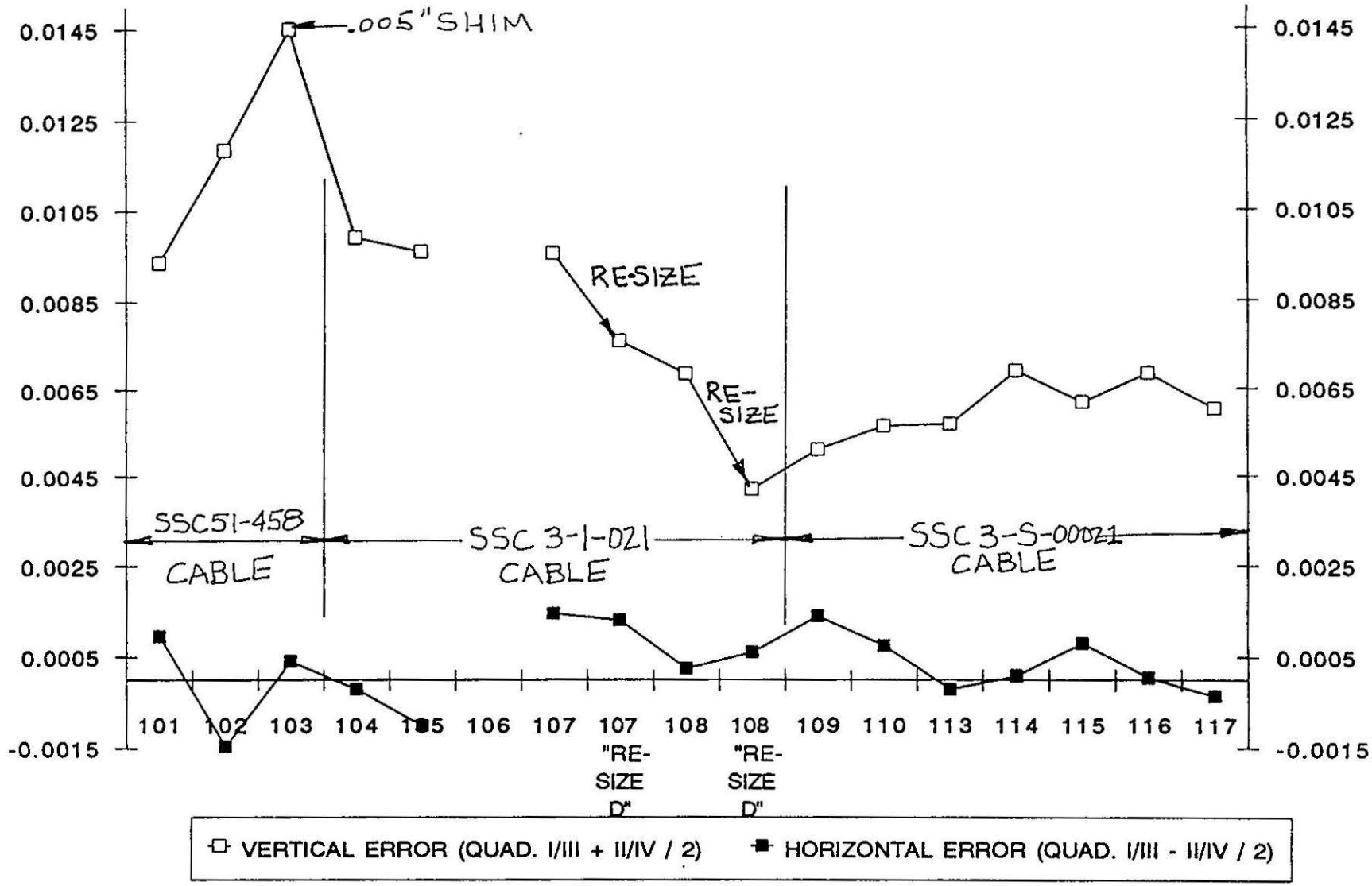
50MM SHORT OUTER COIL VE `CAL AND HORIZONTAL ERROR



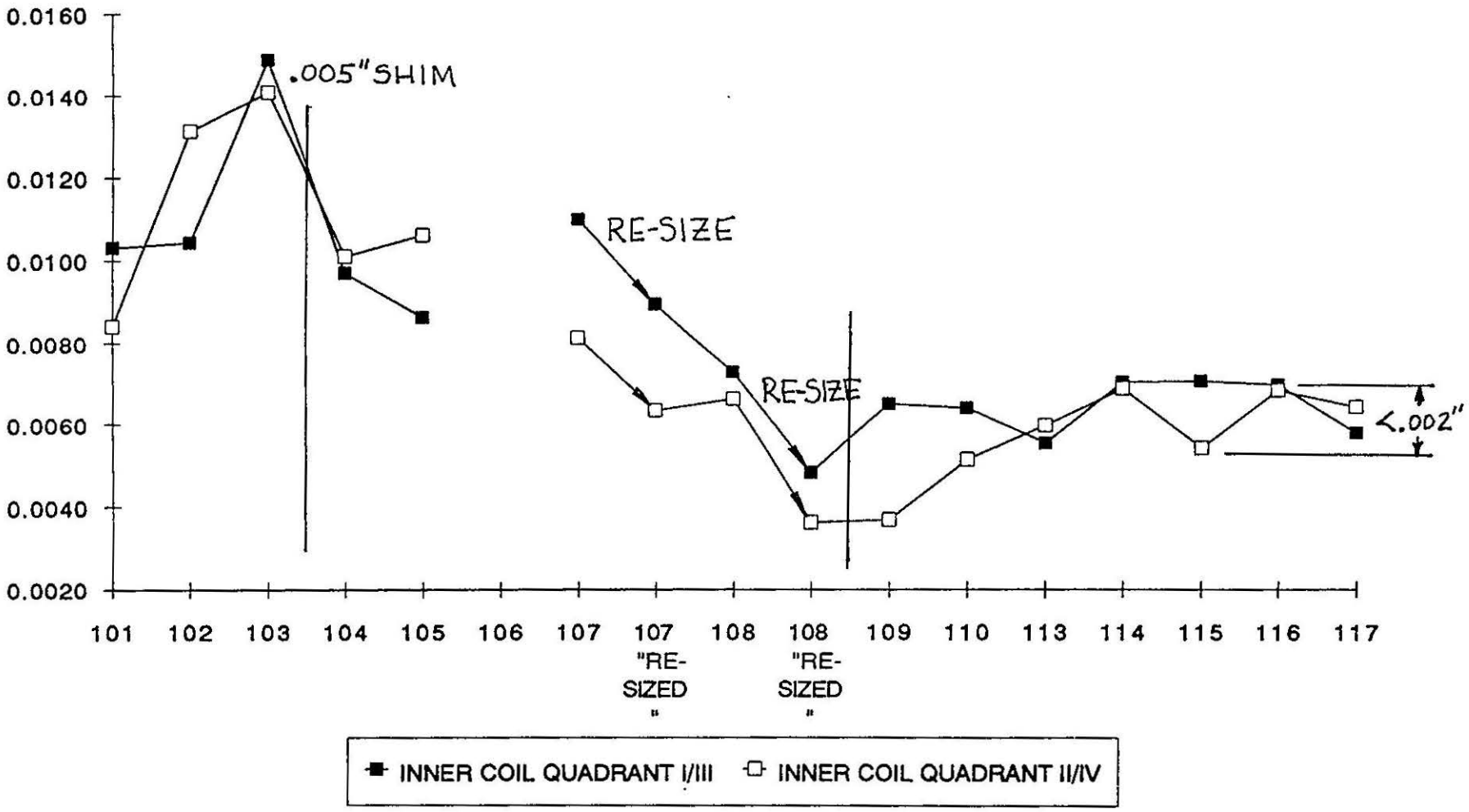
OUTER COIL AVERAGES OF THE COIL DEVIATION FROM THE MASTER AT 12,000 COIL PSI BY COIL NUMBER



50MM SHORT INNER COIL VE .CAL AND HORIZONTAL ERROR



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



TOTALS FOR A MM SHORT COILS

| | | SIZE AVERAGE QUAD. I/III | SIZE AVERAGE QUAD. II/IV | SIZE AVERAGE WHOLE COIL | SIZE RANGE | M.O.E. AVERAGE | WHOLE COIL STD. DEV. | VERTICAL ERROR | HORIZONTAL ERROR |
|---|---|---|---|---|---|---|---|---|---|
| OUTER COIL DATA | AVERAGE | 0.0067 | 0.0075 | 0.0071 | 0.0046 | 1.85E+06 | 0.0010 | 0.0071 | -0.0004 |
| | STD DEV | 0.0017 | 0.0018 | 0.0017 | 0.0002 | 9.77E+04 | 0.0001 | 0.0018 | 0.0002 |
| | RANGE | 0.0051 | 0.0054 | 0.0050 | 0.0007 | 2.40E+05 | 0.0003 | 0.0051 | 0.0006 |
| | MIN | 0.0053 | 0.0059 | 0.0058 | 0.0043 | 1.75E+06 | 0.0009 | 0.0058 | -0.0006 |
| | MAX | 0.0104 | 0.0113 | 0.0108 | 0.0050 | 1.99E+06 | 0.0012 | 0.0109 | 0.0001 |

| OUTER 50MM COIL # 1M-50- | SHIM USED | SIZE AVERAGE QUAD. I/III | SIZE AVERAGE QUAD. II/IV | SIZE AVERAGE WHOLE COIL | SIZE RANGE | M.O.E. AVERAGE | WHOLE COIL STD. DEV. | VERTICAL ERROR | HORIZONTAL ERROR | REEL SERIAL NUMBER |
|---|---|---|---|---|---|---|---|---|---|---|
| 201 | NONE | 0.0068 | 0.0079 | 0.0074 | 0.0045 | 1.75E+06 | 0.0009 | 0.0074 | -0.0006 | PRCT "C" |
| 202 | NONE | 0.0063 | 0.0072 | 0.0067 | 0.0046 | 1.94E+06 | 0.0010 | 0.0068 | -0.0005 | PRCT "C" |
| 203 | 5 MIL. | 0.0104 | 0.0113 | 0.0108 | 0.0050 | 1.79E+06 | 0.0012 | 0.0109 | -0.0005 | PRCT "C" |
| 204 | NONE | 0.0057 | 0.0062 | 0.0060 | 0.0045 | 1.99E+06 | 0.0010 | 0.0060 | -0.0003 | PRCT "C" |
| 205 | NONE | 0.0060 | 0.0059 | 0.0060 | 0.0043 | 1.77E+06 | 0.0010 | 0.0060 | 0.0001 | SSC 4-I-00030 |
| 206 | NONE | 0.0053 | 0.0063 | 0.0058 | 0.0046 | 1.85E+06 | 0.0011 | 0.0058 | -0.0005 | SSC 4-I-00030 |
| 208 | NONE | 0.0067 | 0.0078 | 0.0072 | 0.0044 | | 0.0011 | 0.0073 | -0.0006 | SSC 4-I-00029 |
| 209 | NONE | 0.0067 | 0.0070 | 0.0068 | 0.0036 | 1.76E+06 | 0.0008 | 0.0069 | -0.0002 | SSC 4-I-00029 |
| 209 "RE-SIZED" | NONE | 0.0049 | 0.0051 | 0.0050 | 0.0036 | 2.07E+06 | 0.0010 | 0.0050 | -0.0001 | SSC 4-I-00029 |
| 210 | NONE | 0.0045 | 0.0050 | 0.0048 | 0.0037 | 1.75E+06 | 0.0010 | 0.0048 | -0.0003 | SSC 4-I-00029 |
| 210 "RESIZED" | NONE | 0.0019 | 0.0027 | 0.0023 | 0.0031 | 2.04E+06 | 0.0007 | 0.0023 | -0.0004 | SSC 4-I-00029 |
| 211 | NONE | 0.0047 | 0.0039 | 0.0043 | 0.0039 | 1.72E+06 | 0.0010 | 0.0043 | 0.0004 | SSC 4-I-00029 |
| 214 | NONE | 0.0063 | 0.0044 | 0.0054 | 0.0048 | 1.83E+06 | 0.0013 | 0.0054 | 0.0010 | SSC 4-I-00025 |
| 215 | NONE | 0.0062 | 0.0056 | 0.0059 | 0.0051 | 1.81E+06 | 0.0011 | 0.0059 | 0.0003 | SSC 4-I-00025 |
| 215 "RE-SIZED" | NONE | 0.0065 | 0.0061 | 0.0063 | 0.0042 | 2.27E+06 | 0.0009 | 0.0063 | 0.0002 | SSC 4-I-00025 |
| 216 | NONE | 0.0067 | 0.0069 | 0.0068 | 0.0040 | 1.72E+06 | 0.0010 | 0.0068 | -0.0001 | SSC 4-I-00025 |
| 217 | NONE | 0.0069 | 0.0067 | 0.0068 | 0.0035 | 1.65E+06 | 0.0009 | 0.0068 | 0.0001 | SSC 4-I-00025 |
| 218 | NONE | 0.0069 | 0.0071 | 0.0070 | 0.0053 | 1.78E+06 | 0.0012 | 0.0070 | -0.0001 | SSC 4-I-00025 |
| 219 | NONE | 0.0041 | 0.0036 | 0.0038 | 0.0058 | 1.94E+06 | 0.0014 | 0.0039 | 0.0003 | SSC 4-I-00025 |
| 220 | NONE | 0.0033 | 0.0033 | 0.0033 | 0.0032 | 1.82E+06 | 0.0008 | 0.0033 | 0.0000 | SSC 4-I-00025 |

NOTE:

1M-50-201 MEASURING PRESSURE WAS 12,484 PSI

1M-50-204 WAS COOLED TO 210 DEG. F THEN LET TO COOL BY RADIATION OVERNIGHT

1M-50-208 WAS CURED 10 DEG. F LOWER BUT ALLOWED TO COOL NATURALLY OVERNIGHT

1M-50-208 WAS MEASURED AT 12,000 COIL PSI ONLY ie NO MODULUS OF ELASTICITY READING

VERTICAL ERROR (QUAD. I/III + II/IV)/2

HORIZONTAL ERROR (QUAD. I/III - II/IV)/2

UPDATED 3/27/91

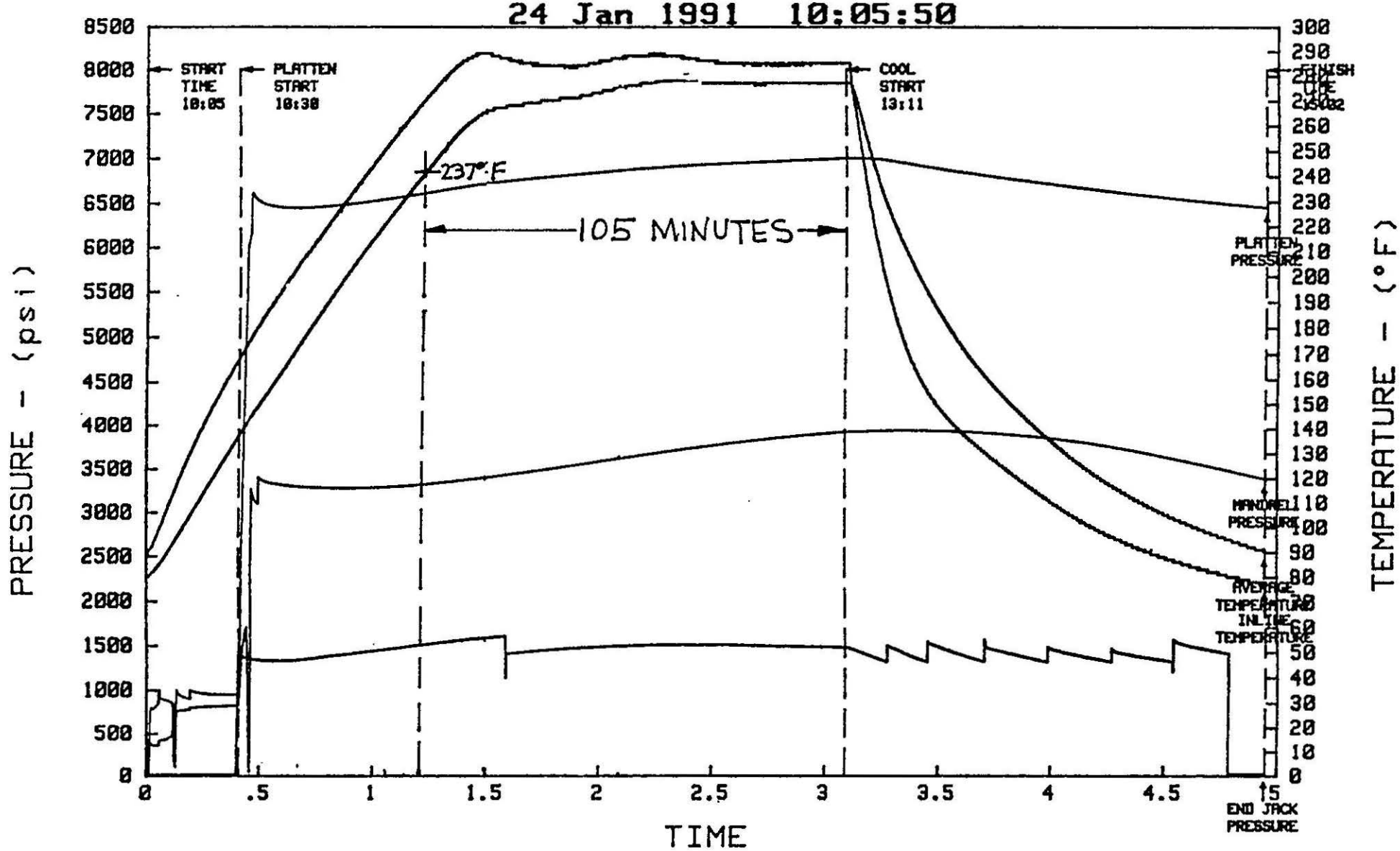
TOTALS FOR / MM SHORT COILS

| | | SIZE AVERAGE QUAD. I/III | SIZE AVERAGE QUAD. II/IV | SIZE AVERAGE WHOLE COIL | SIZE RANGE | M.Q.E. AVERAGE | WHOLE COIL STD. DEV. | VERTICAL ERROR | HORIZONTAL ERROR |
|---|---|---|---|---|---|---|---|---|---|
| INNER COIL DATA | AVERAGE | 0.0108 | 0.0108 | 0.0108 | 0.0072 | 2.39E+06 | 0.0018 | 0.0108 | 0.0000 |
| | STD DEV | 0.0022 | 0.0025 | 0.0020 | 0.0012 | 2.40E+05 | 0.0004 | 0.0020 | 0.0011 |
| | RANGE | 0.0063 | 0.0060 | 0.0051 | 0.0032 | 5.50E+05 | 0.0011 | 0.0052 | 0.0029 |
| | MIN | 0.0086 | 0.0081 | 0.0094 | 0.0059 | 2.15E+06 | 0.0014 | 0.0094 | -0.0015 |
| | MAX | 0.0149 | 0.0141 | 0.0145 | 0.0091 | 2.70E+06 | 0.0025 | 0.0145 | 0.0015 |

| INNER 50MM COIL # 1M-50- | SHIM USED | SIZE AVERAGE QUAD. I/III | SIZE AVERAGE QUAD. II/IV | SIZE AVERAGE WHOLE COIL | SIZE RANGE | M.Q.E. AVERAGE | WHOLE COIL STD. DEV. | VERTICAL ERROR | HORIZONTAL ERROR | REEL SERIAL NUMBER |
|---|---|---|---|---|---|---|---|---|---|---|
| 101 | NONE | 0.0103 | 0.0084 | 0.0094 | 0.0068 | 2.24E+06 | 0.0017 | 0.0094 | 0.0010 | SSC51-458 |
| 102 | NONE | 0.0104 | 0.0133 | 0.0119 | 0.0081 | 2.15E+06 | 0.0020 | 0.0119 | -0.0015 | SSC51-458 |
| 103 | 5 MIL | 0.0149 | 0.0141 | 0.0145 | 0.0059 | 2.21E+06 | 0.0014 | 0.0145 | 0.0004 | SSC51-458 |
| 104 | NONE | 0.0097 | 0.0101 | 0.0099 | 0.0064 | 2.67E+06 | 0.0016 | 0.0099 | -0.0002 | SSC 3-I-021 |
| 105 | NONE | 0.0086 | 0.0106 | 0.0096 | 0.0071 | 2.70E+06 | 0.0017 | 0.0096 | -0.0010 | SSC 3-I-021 |
| 106 | | | | | | | | | | |
| 107 | NONE | 0.0110 | 0.0081 | 0.0095 | 0.0091 | 2.35E+06 | 0.0025 | 0.0096 | 0.0015 | SSC 3-I-021 |
| 107 "RE-SIZED" | NONE | 0.0089 | 0.0063 | 0.0076 | 0.0066 | 2.58E+06 | 0.0022 | 0.0076 | 0.0013 | SSC 3-I-021 |
| 108 | NONE | 0.0071 | 0.0066 | 0.0068 | 0.0048 | 2.18E+06 | 0.0013 | 0.0069 | 0.0003 | SSC 3-I-021 |
| 108 "RE-SIZED" | NONE | 0.0048 | 0.0036 | 0.0042 | 0.0059 | 2.32E+06 | 0.0014 | 0.0042 | 0.0006 | SSC 3-I-021 |
| 109 | NONE | 0.0065 | 0.0037 | 0.0051 | 0.0080 | 2.21E+06 | 0.0022 | 0.0051 | 0.0014 | SSC 3-S-00021 |
| 110 | NONE | 0.0064 | 0.0049 | 0.0056 | 0.0061 | 2.10E+06 | 0.0016 | 0.0057 | 0.0008 | SSC 3-S-00021 |
| 113 | NONE | 0.0055 | 0.0059 | 0.0057 | 0.0047 | 2.34E+06 | 0.0013 | 0.0057 | -0.0002 | SSC 3-S-00021 |
| 114 | NONE | 0.0070 | 0.0068 | 0.0069 | 0.0046 | 2.30E+06 | 0.0012 | 0.0069 | 0.0001 | SSC 3-S-00021 |
| 115 | NONE | 0.0070 | 0.0054 | 0.0062 | 0.0071 | 2.42E+06 | 0.0017 | 0.0062 | 0.0008 | SSC 3-S-00021 |
| 116 | NONE | 0.0069 | 0.0068 | 0.0069 | 0.0072 | 2.35E+06 | 0.0019 | 0.0069 | 0.0001 | SSC 3-S-00021 |
| 117 | NONE | 0.0057 | 0.0064 | 0.0061 | 0.0058 | 2.38E+06 | 0.0014 | 0.0061 | -0.0004 | SSC 3-S-00021 |

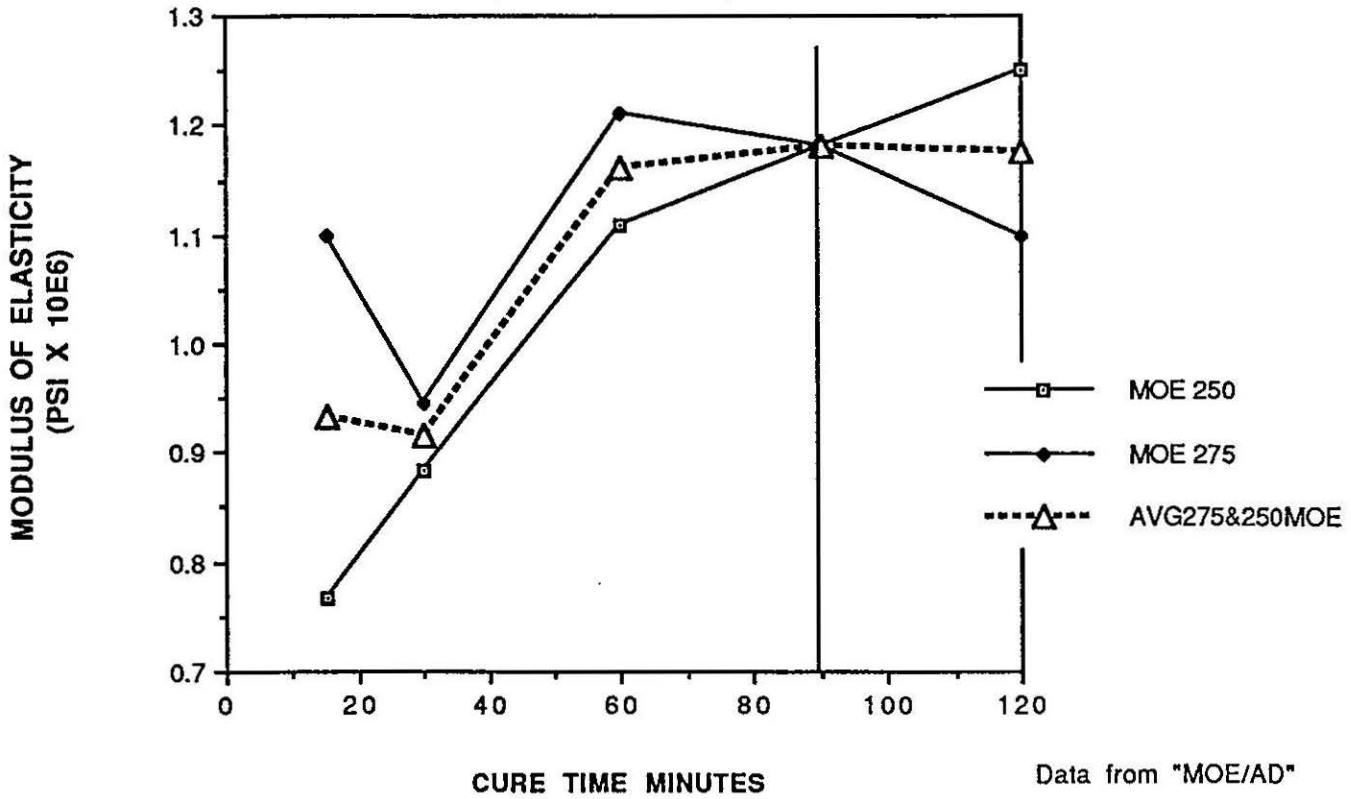
NOTES:

# SSC Curing Press Data
## Coil Serial# 17M-1008R
## 24 Jan 1991 10:05:50



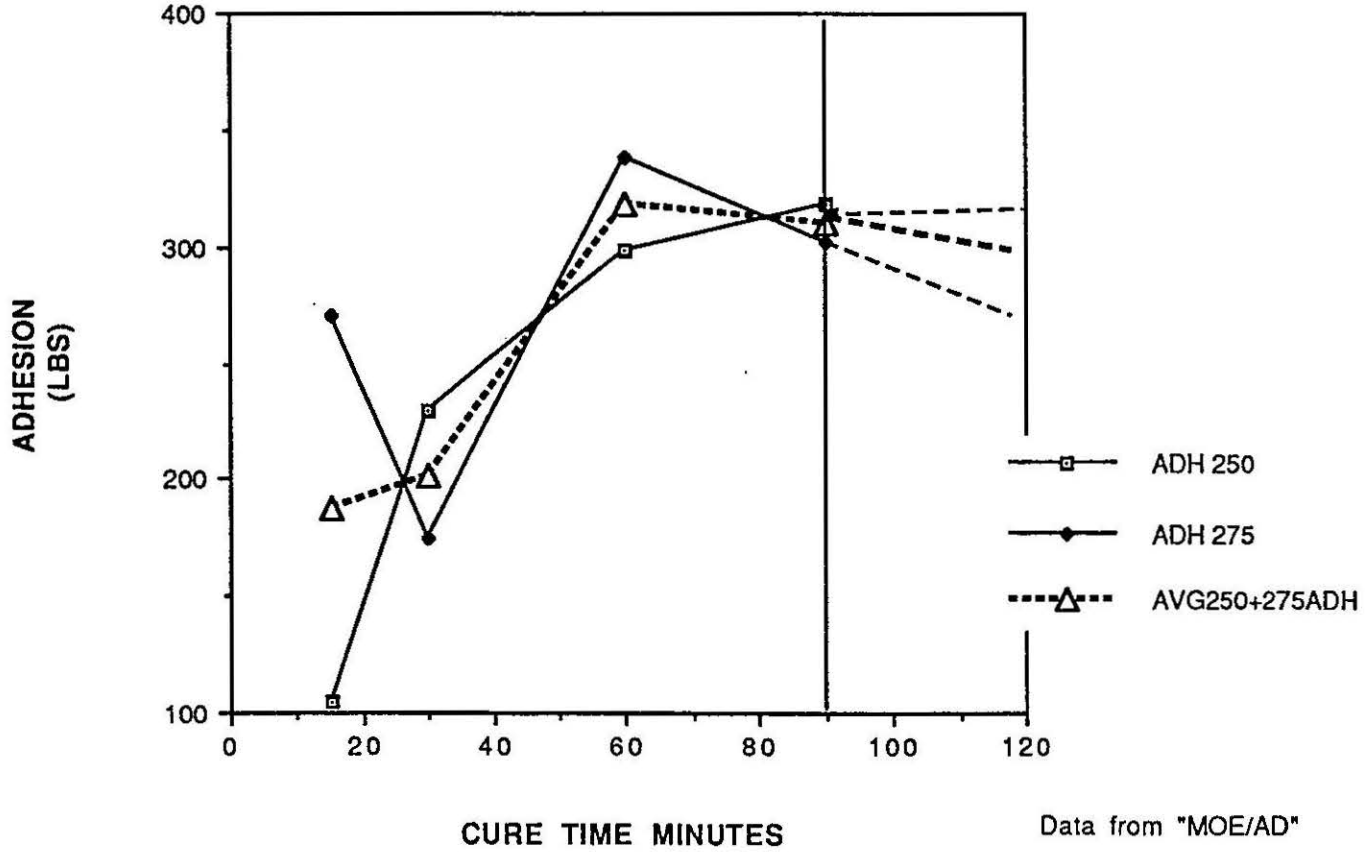

PLATTEN 1000 psi = 2222 #/in
MANDREL 1000 psi = 333 #/in
END JACK 1000 psi = 2000 #

## COMPARISON OF MODULUS OF ELASTICITY AT 250F, 265F(PROJECTED) &275F



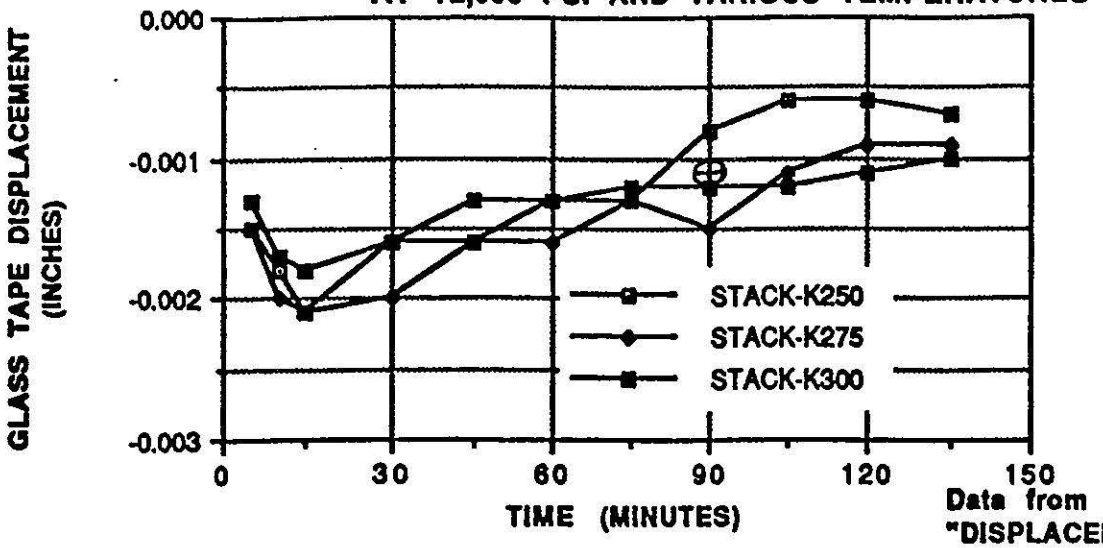

Data from "MOE/AD"

## COMPARISON / PROJECTION OF ADHESION 250F, 265F PROJECTED, 275F



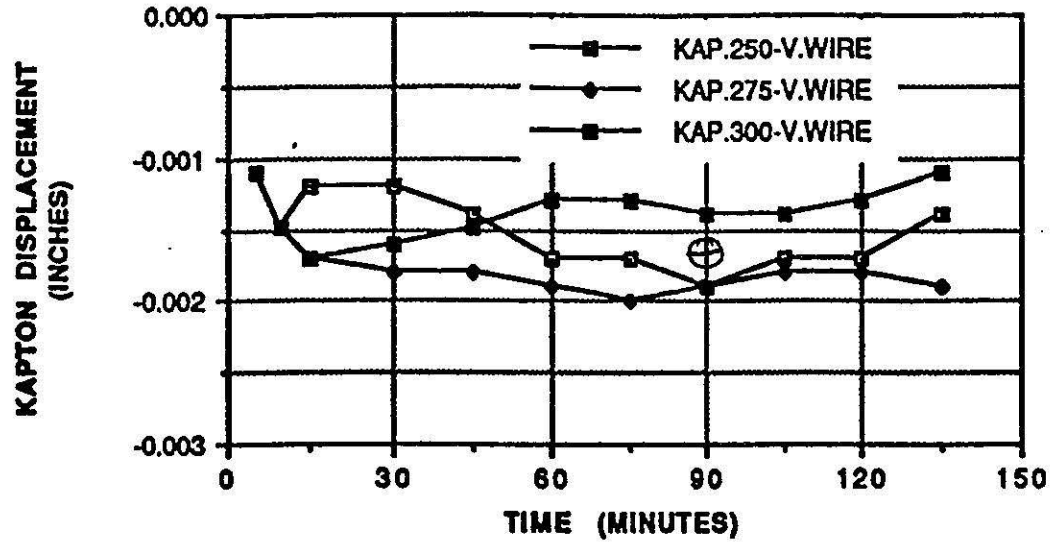

Data from "MOE/AD"

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

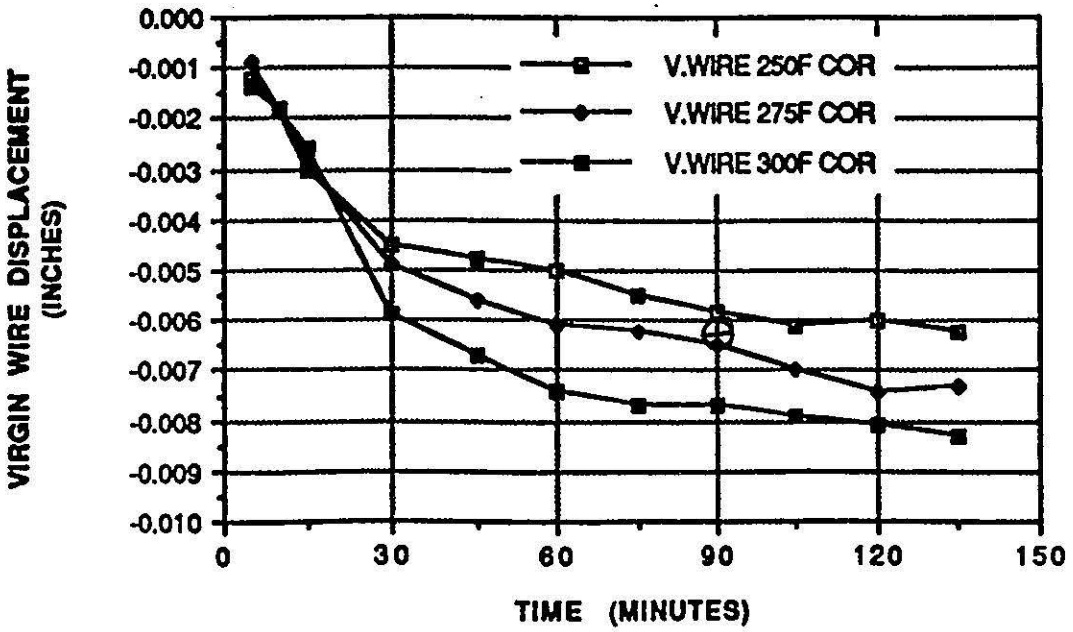



Data from "DISPLACEMENT DATA 2"

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



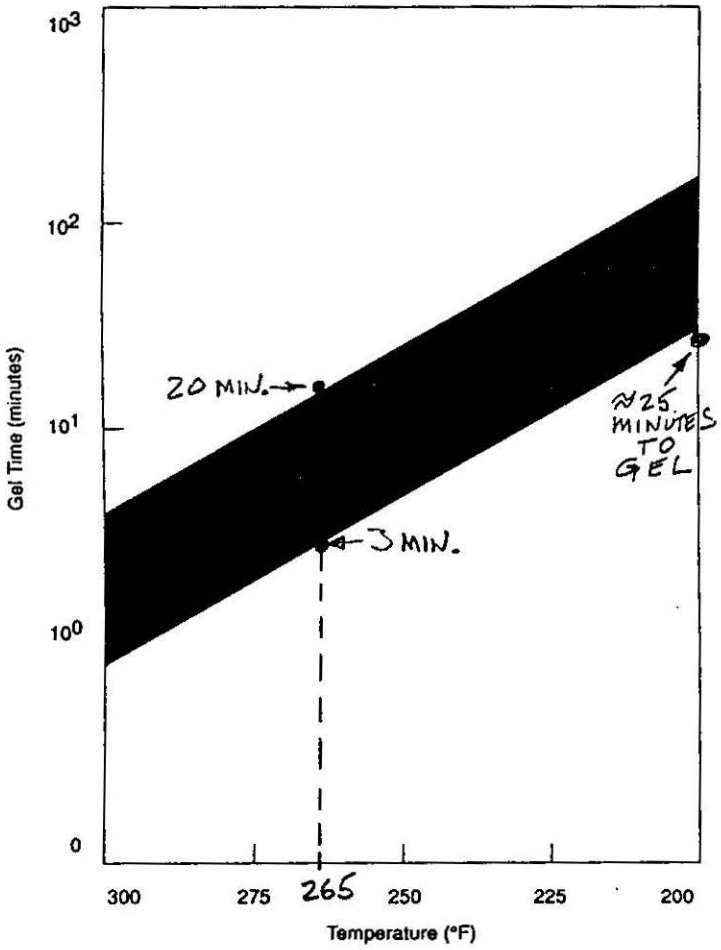

VIRGIN WIRE DISPLACEMENT IN A 10 STACK
AT 12,000 PSI AND VARIOUS TEMPERATURES



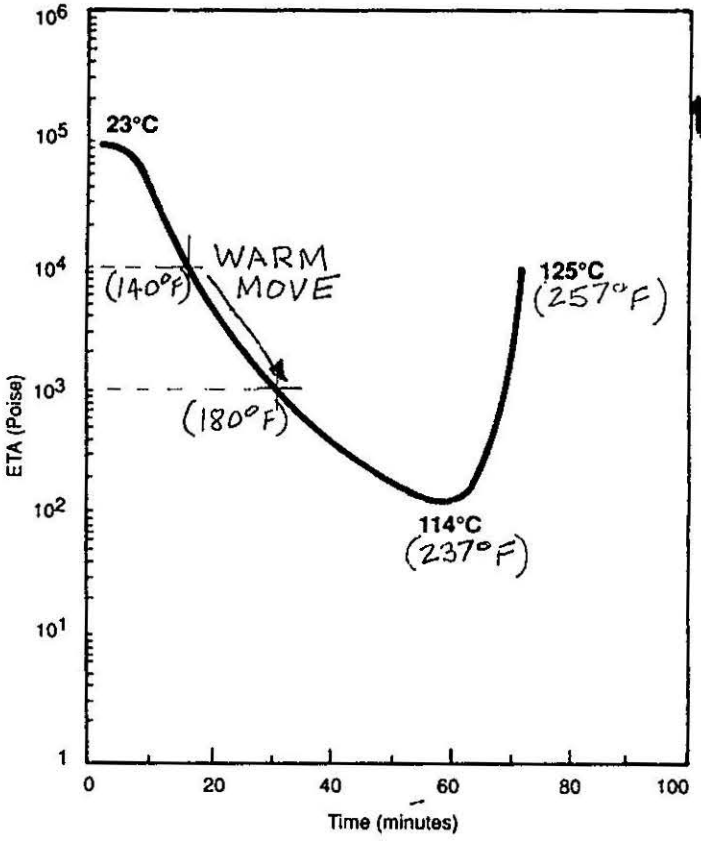
6.04 KJ/m²

Gel Time @ 250°F ..... 5-11 min.

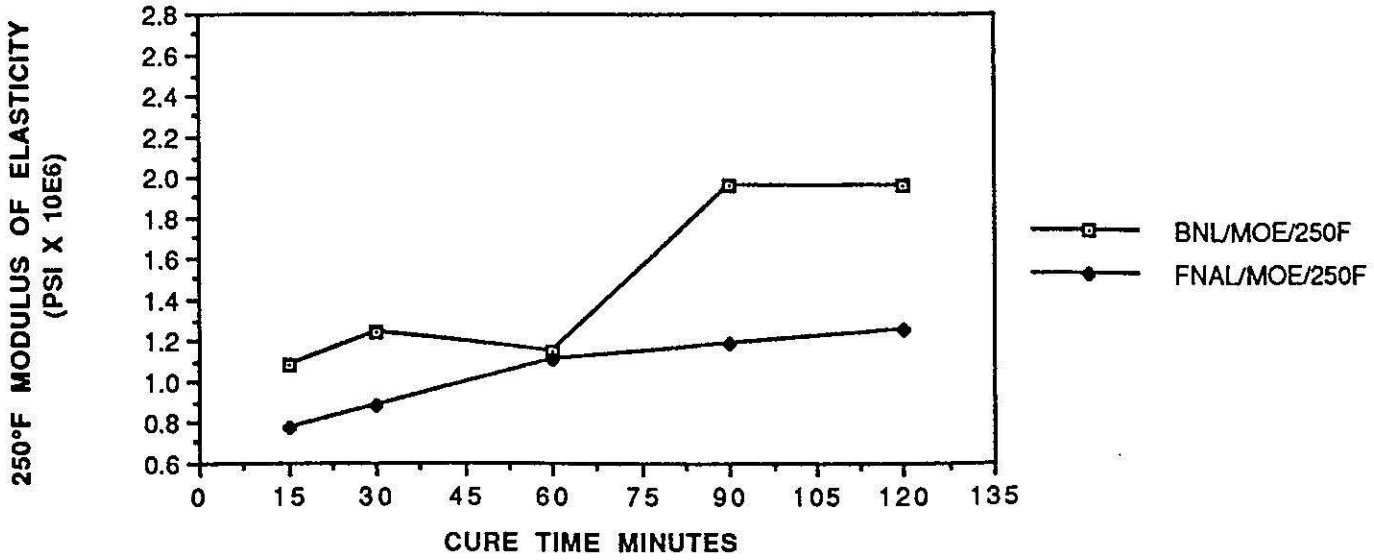
**F185**
**Gel Time vs. Temperature**



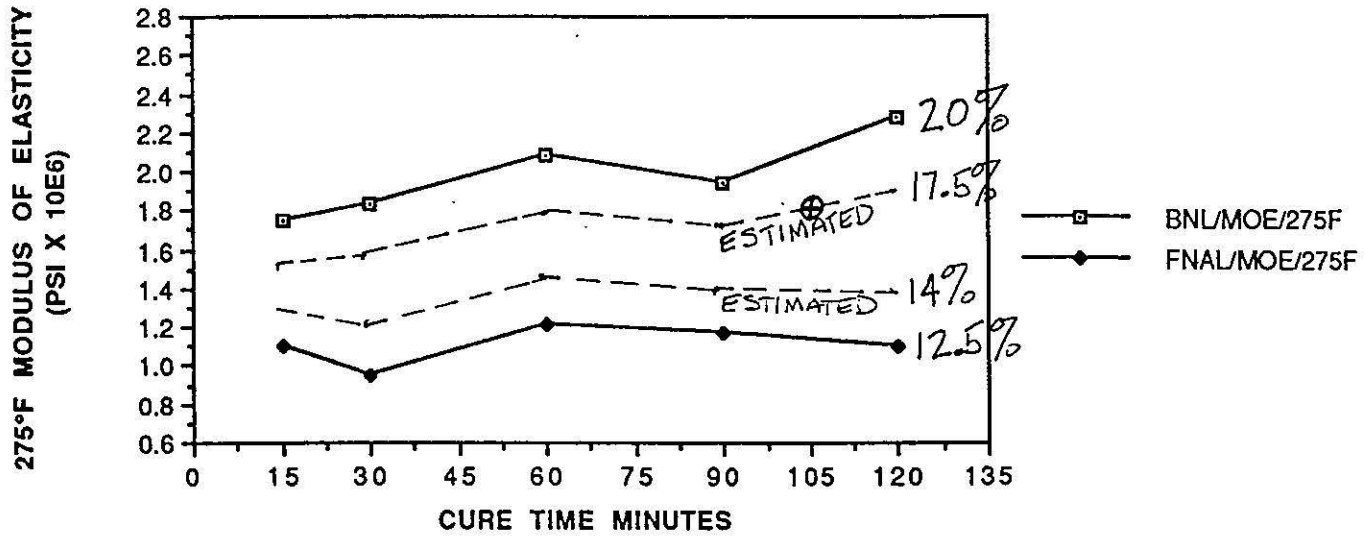

**Rheometrics Curve of F185**
**2 Deg./Min., 10 Rad/Sec,**
**RDS-7700, 50mm Plates**



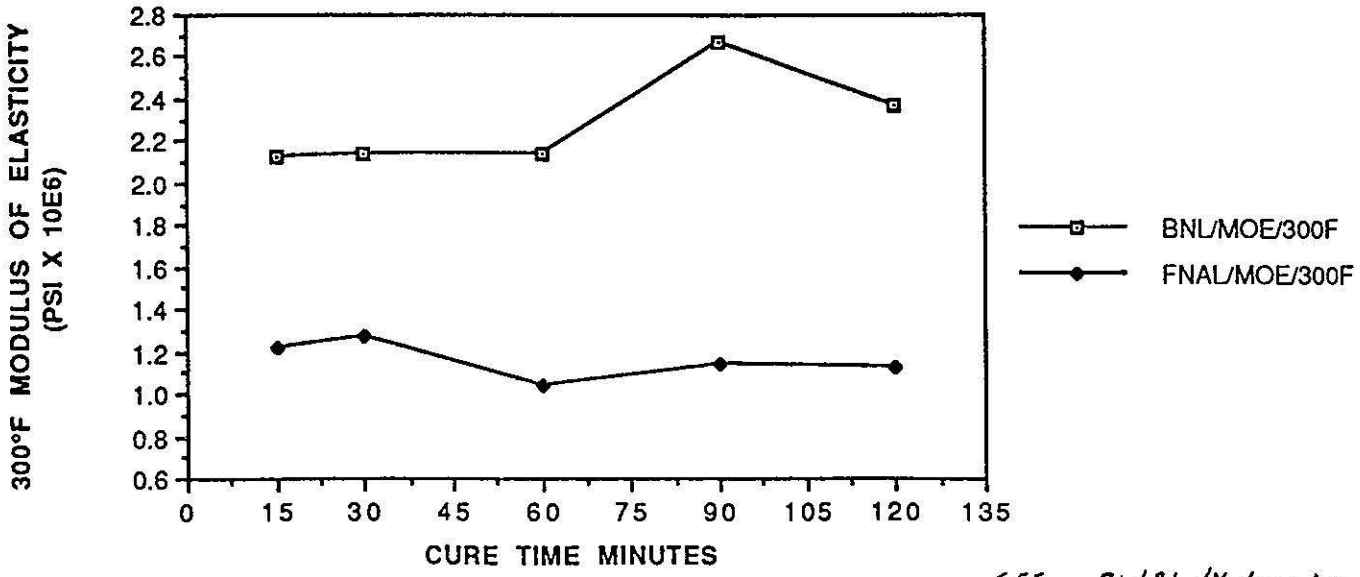
## COMPARISON OF FNAL & BNL (ELASTICITY VS CURING TIME AT 250°F GRAPHS)




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

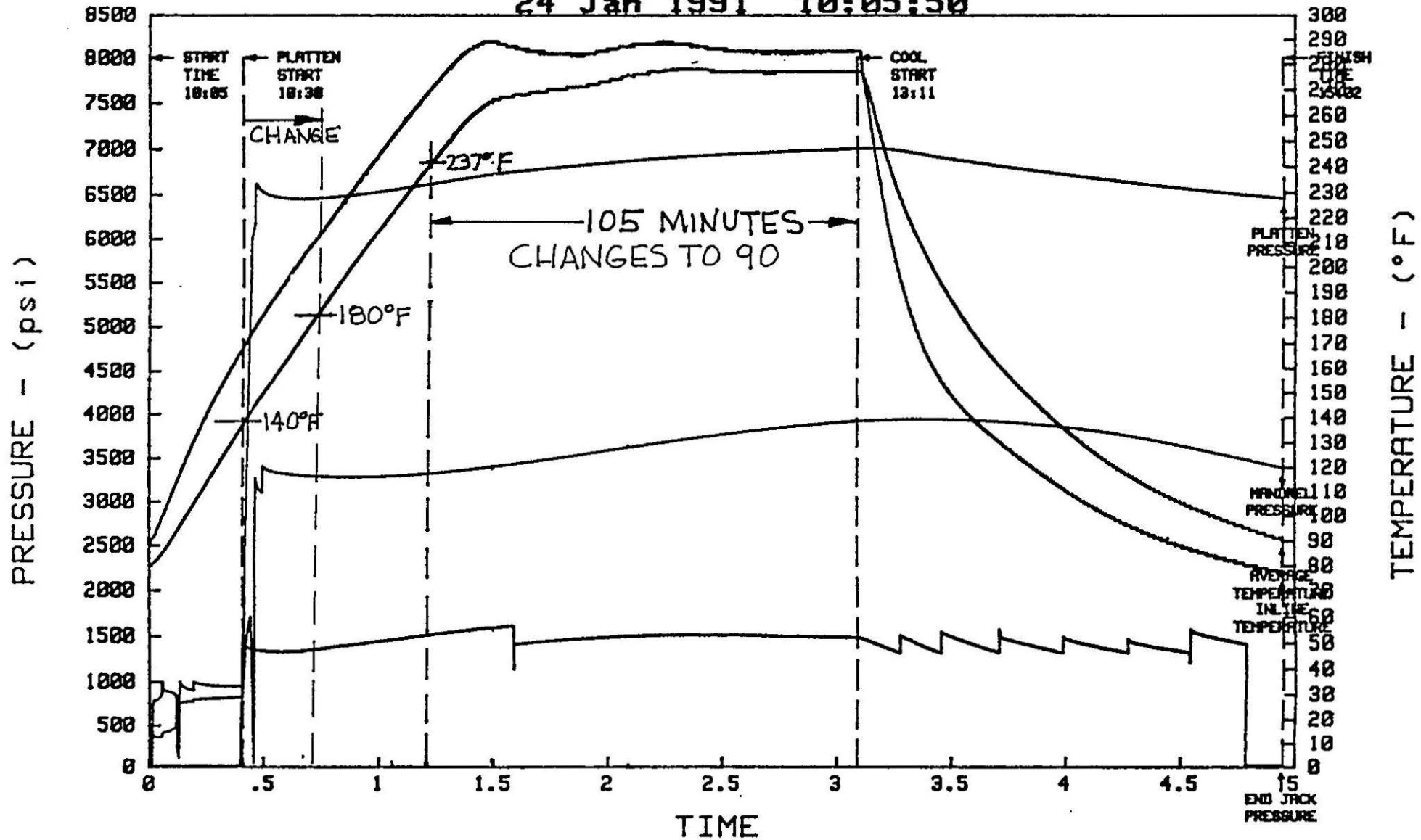



## COMPARISON OF FNAL & BNL (ELASTICITY VS CURING TIME AT 300°F GRAPHS)




SEE FL/BL/%/DSP/AD

# SSC Curing Press Data
## Coil Serial# 17M-1008R
## 24 Jan 1991 10:05:50




PLATTEN 1000 psi = 2222 #/in
MANDREL 1000 psi = 333 #/in
END JACK 1000 psi = 2000 #