

Fermilab

TS-SSC 91-096
5/23/91

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Subj: DCA310 Coil Molding and Coil Sizes

Based on an analysis[1] by Masayoshi of coil sizes and preloads in short 50 mm magnets (see Fig. 1) we find that the target size for the inner coils is 10 mils oversize and for the outer coil is 0 mils oversize relative to the master. The DSA327 inner coils[2] were molded to the target size using a 5 mil molding shim under the mold stop bars (sum of stop bar plus shim thickness = 0.255"). The DSA327 outer coils were molded about 3 mils oversize using stop bars that had been ground to a 0.247" thickness and no shims. The short coil molds are made of 2" EDMed blocks and the long molds are made of laminations. Therefore small differences in the required molding shims were expected, but the sign of the difference was unknown a priori.

The first long inner coil (15m-50-1001) was molded with the same molding shim as the short coils. It is, on the average, 5.5 mils larger than the master, or 4.5 mils smaller than the target size. (Fig. 2 is a plot of the left-right average size along the length of the two inner coils and Table I summarizes the average, standard deviation and range of coils sizes for the four coils in DCA310.) The molding shim was increased to 10 mils for the second coil (15m-50-1002) and it is 10.7 mils larger than the master. This is within the target range of 10+-2 mils. The 5 mils increase in the mold cavity resulted in a 5.2 mil increase in the coil size.

The nominal mold stop bar thickness is 0.250". Because it was anticipated from the short coils that the outer coils would need to be molded in a smaller cavity a set of bars ground to 0.240" were ordered. However, these were not available when the first long outer coil (15m-50-2001) was molded. With the 0.250" stop bar and no shim this coil was 2.5 mils oversize. (Figure 3 shows the left-right average coil size along the length of the two outer coils.) The second coil (15m-50-2002) was molded with the 0.240" bars installed and a 7 mil shim. It is -0.4 mils in size relative to the master, essentially the target value. The 3 mil decrease in cavity size resulted in a 2.9 mil decrease in coil size.

In summary, one inner coil (1002) is of the desired size and the other (1001) is about 5 mils undersize; one outer coil (2002) is of the desired size and the other (2001) is about 3 mils oversize. The second coil molded of each type is of the target size, suggesting that we have picked the correct mold shim.

As pointed out by Masayoshi[3] it is quite striking how well correlated are the coil size variations between the two inner and the two outer coils. For both coil types, most of the variations and essentially all of the variations greater than +-1 mil in the left-right average are identical between the two coils of each type. The two coil averages of the inner

and outer coils are plotted in Fig. 4. It is plain that size variations are also well correlated between the two coil types. It seems likely, therefore, that the size variations result either from the press or from some features common to the two mold system designs, e.g. the relative locations of the sizing bar and retainer boundaries. The most striking features are the large dips in coil size at -170μ , -10μ and $+155\mu$. Similar dips of approximately the same magnitude and almost identical spacing were observed in the long 40 mm coil sizes[4].

The left-right size differences, averaged over the two coils of each type, are plotted along the length of the coil in Fig. 5. The overall range of variation is similar to the "vertical error" in Fig. 4. There is less correlation between the inner and outer coils than for the left-right average, but clearly present. The most striking feature is the slow approximately ± 1 mil variation along the length of the coil.

References

- [1] M. Wake, Relationship Between Coil Size and Preloading in 50 mm Magnets, TS-SSC 91-070, 4/15/91.
- [2] J. Strait, Development of Collar Keying Procedures, presented at the MSIM, 5/14/91, TS-SSC 91-085.
- [3] M. Wake, Coil Size Deviations of Long Dipole DCA310, TS-SSC 91-086, 5/20/91.
- [4] W. Koska, Azimuthal 40 mm Long Coil Size Variations, TS-SSC 90-099, 12/4/90.

Table I

Chart Version 1.0 5/7/91
 LONG 50MM Inner Coil # 15M-50-1001

Master Used - Inner Master #1 Shim Size Used - .005"
 Press Fixture Serial Number Used - 72195
 Machine Serial Number Used - SEMI-01 Mean Arc of Master - 1.5946"

| | QUADRANT VIII POSITION 1-192 | | | QUADRANT II/IV POSITION 1-192 | | | WHOLE COIL | | |
|---------|------------------------------|---------|----------|-------------------------------|---------|----------|------------|---------|----------|
| | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE |
| AVERAGE | 0.0089 | 0.0064 | 2.41E+06 | 0.0074 | 0.0047 | 2.36E+06 | 0.0082 | 0.0055 | 2.38E+06 |
| STD DEV | 0.0013 | 0.0013 | 8.05E+04 | 0.0016 | 0.0012 | 2.38E+05 | 0.0016 | 0.0015 | 1.74E+05 |
| RANGE | 0.0033 | 0.0062 | 2.73E+05 | 0.0052 | 0.0055 | 6.00E+05 | 0.0058 | 0.0079 | 6.00E+05 |
| MAX | 0.0105 | 0.0097 | 2.56E+06 | 0.0099 | 0.0073 | 2.66E+06 | 0.0105 | 0.0097 | 2.66E+06 |
| MIN | 0.0072 | 0.0035 | 2.28E+06 | 0.0047 | 0.0018 | 2.06E+06 | 0.0047 | 0.0018 | 2.06E+06 |

Chart Version 1.0 5/7/91
 LONG 50MM Inner Coil # 15M-50-1002

Master Used - Inner Master #1 Shim Size Used - 0.01
 Press Fixture Serial Number Used - 72195
 Machine Serial Number Used - SEMI-01 Mean Arc of Master - 1.5946"

| | QUADRANT VIII POSITION 1-192 | | | QUADRANT II/IV POSITION 1-192 | | | WHOLE COIL | | |
|---------|------------------------------|---------|----------|-------------------------------|---------|----------|------------|---------|----------|
| | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE |
| AVERAGE | 0.0142 | 0.0111 | 2.15E+06 | 0.0128 | 0.0104 | 2.20E+06 | 0.0135 | 0.0107 | 2.18E+06 |
| STD DEV | 0.0011 | 0.0011 | 9.38E+04 | 0.0010 | 0.0011 | 5.37E+04 | 0.0013 | 0.0012 | 7.94E+04 |
| RANGE | 0.0040 | 0.0057 | 2.85E+05 | 0.0038 | 0.0057 | 1.52E+05 | 0.0054 | 0.0062 | 2.85E+05 |
| MAX | 0.0160 | 0.0138 | 2.28E+06 | 0.0144 | 0.0133 | 2.28E+06 | 0.0160 | 0.0138 | 2.28E+06 |
| MIN | 0.0120 | 0.0081 | 2.00E+06 | 0.0106 | 0.0076 | 2.13E+06 | 0.0106 | 0.0076 | 2.00E+06 |

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

Chart Version 1.0 5/7/91
 LONG 50MM Outer Coil # 15M-50-2001

Master Used - Outer Master #1 Shim Size Used - No Shim Used
 Press Fixture Serial Number Used - 72195
 Machine Serial Number Used - SEMI-01 Mean Arc of Master - 1.4513"

| | QUADRANT VIII POSITION 1-192 | | | QUADRANT II/IV POSITION 1-192 | | | WHOLE COIL | | |
|---------|------------------------------|---------|----------|-------------------------------|---------|----------|------------|---------|----------|
| | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE |
| AVERAGE | 0.0059 | 0.0028 | 1.92E+06 | 0.0048 | 0.0021 | 1.90E+06 | 0.0054 | 0.0025 | 1.91E+06 |
| STD DEV | 0.0012 | 0.0012 | 6.97E+04 | 0.0014 | 0.0012 | 3.29E+04 | 0.0014 | 0.0012 | 5.35E+04 |
| RANGE | 0.0040 | 0.0060 | 1.88E+05 | 0.0045 | 0.0059 | 6.25E+04 | 0.0053 | 0.0069 | 1.88E+05 |
| MAX | 0.0077 | 0.0055 | 2.01E+06 | 0.0069 | 0.0045 | 1.94E+06 | 0.0077 | 0.0055 | 2.01E+06 |
| MIN | 0.0037 | -0.0005 | 1.82E+06 | 0.0024 | -0.0014 | 1.88E+06 | 0.0024 | -0.0014 | 1.82E+06 |

Chart Version 1.0 5/7/91
 LONG 50MM Outer Coil # 15M-50-2002

Master Used - Outer Master #1 Shim Size Used - ~~No Shim Used~~ - 0.003"
 Press Fixture Serial Number Used - 277838
 Machine Serial Number Used - SEMI-01 Mean Arc of Master - 1.4513"

| | QUADRANT VIII POSITION 1-192 | | | QUADRANT II/IV POSITION 1-192 | | | WHOLE COIL | | |
|---------|------------------------------|---------|----------|-------------------------------|---------|----------|------------|---------|----------|
| | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE | 8 kpsi | 12 kpsi | MOE |
| AVERAGE | 0.0029 | 0.0000 | 2.10E+06 | 0.0016 | -0.0008 | 2.08E+06 | 0.0022 | -0.0004 | 2.09E+06 |
| STD DEV | 0.0012 | 0.0011 | 6.21E+04 | 0.0014 | 0.0010 | 5.24E+04 | 0.0014 | 0.0011 | 5.64E+04 |
| RANGE | 0.0039 | 0.0061 | 1.48E+05 | 0.0043 | 0.0056 | 1.48E+05 | 0.0049 | 0.0070 | 1.48E+05 |
| MAX | 0.0045 | 0.0030 | 2.15E+06 | 0.0039 | 0.0016 | 2.15E+06 | 0.0045 | 0.0030 | 2.15E+06 |
| MIN | 0.0006 | -0.0031 | 2.01E+06 | -0.0004 | -0.0040 | 2.01E+06 | -0.0004 | -0.0040 | 2.01E+06 |

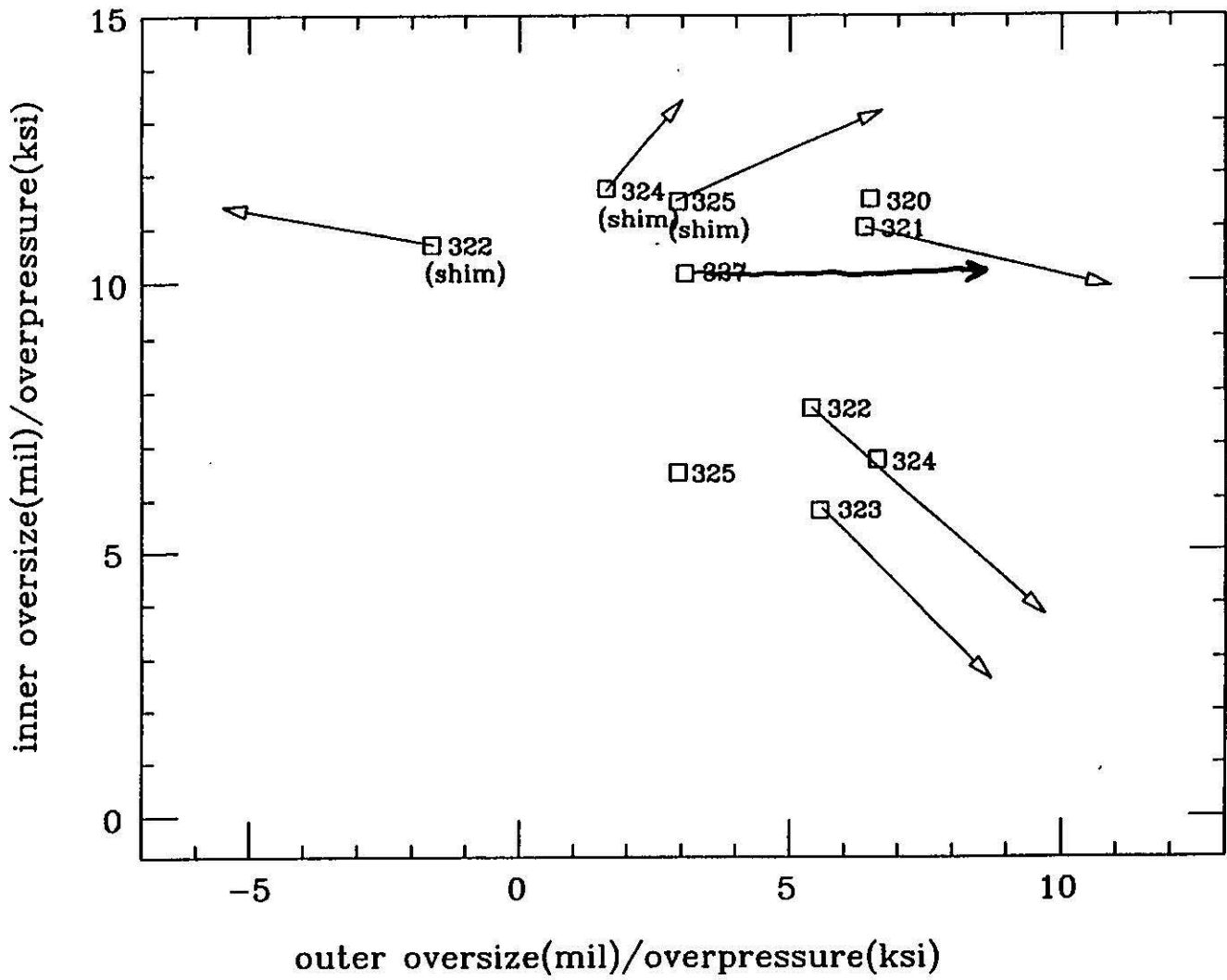


Figure 1

Inner Coils for DCA310

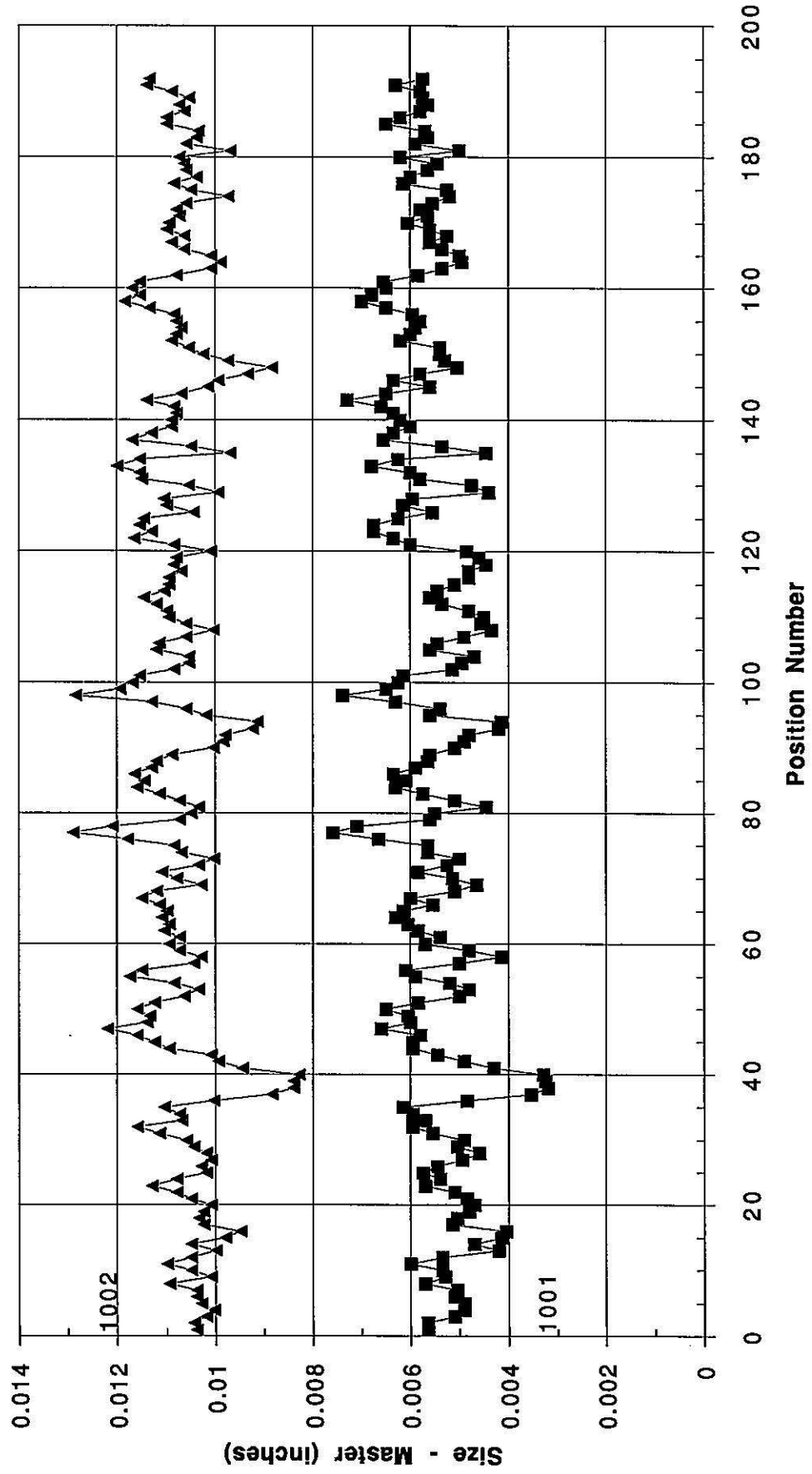


Figure 2

DCA310 Outer Coils

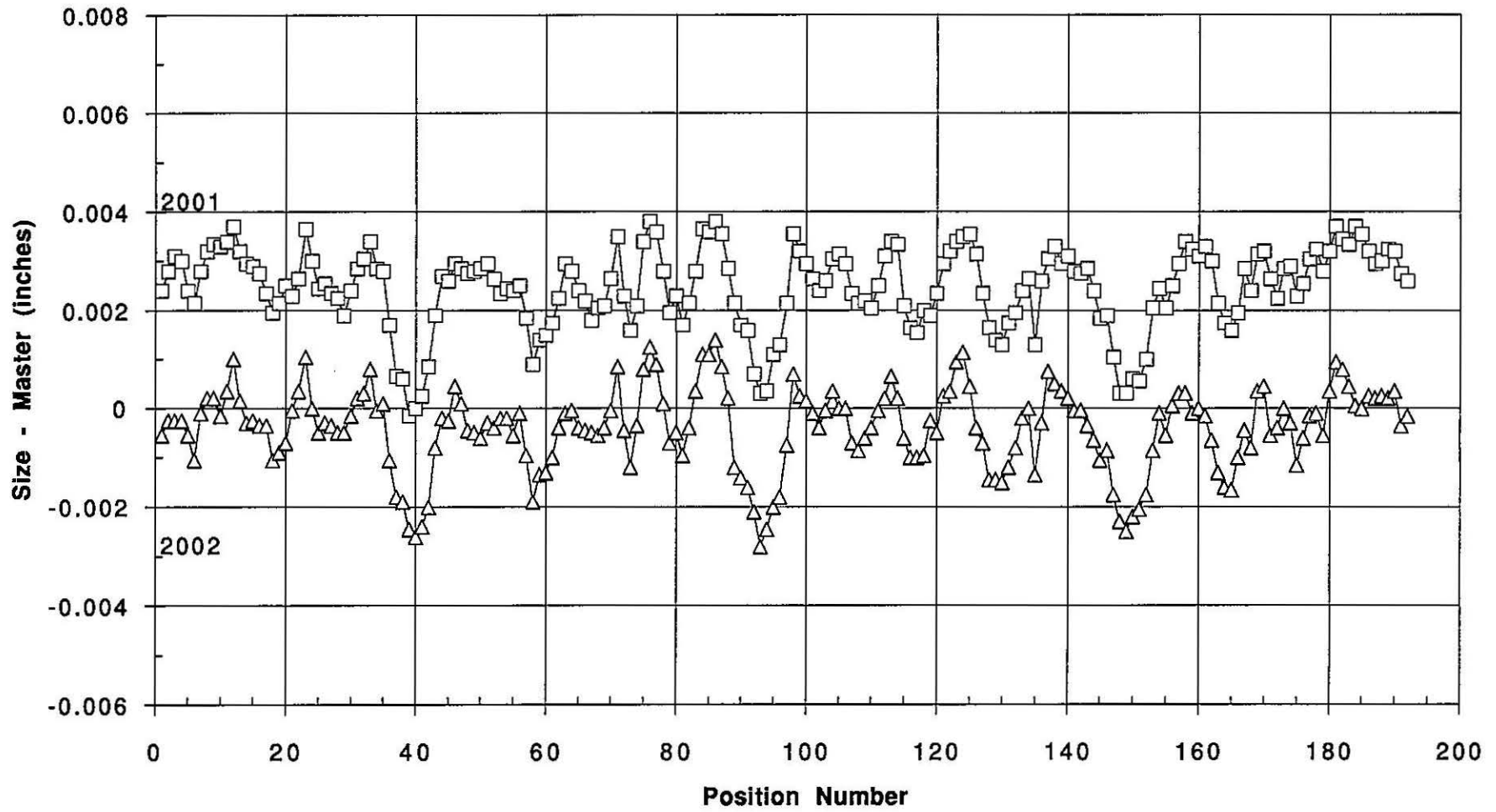


Figure 3

DCA310 Average Coil Sizes

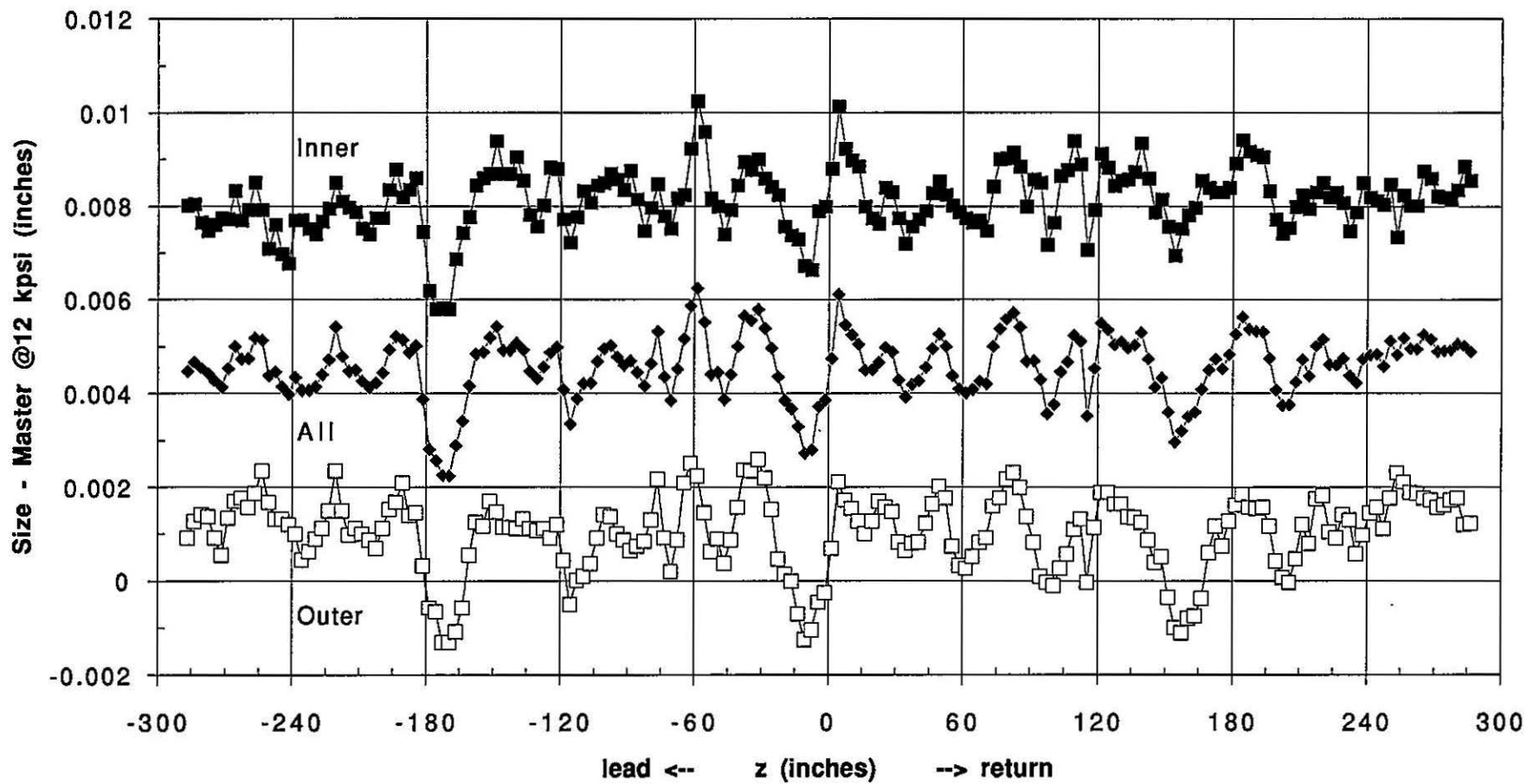


Figure 4

DCA310 Coil Sizes: (QI/III - QII/IV)/2

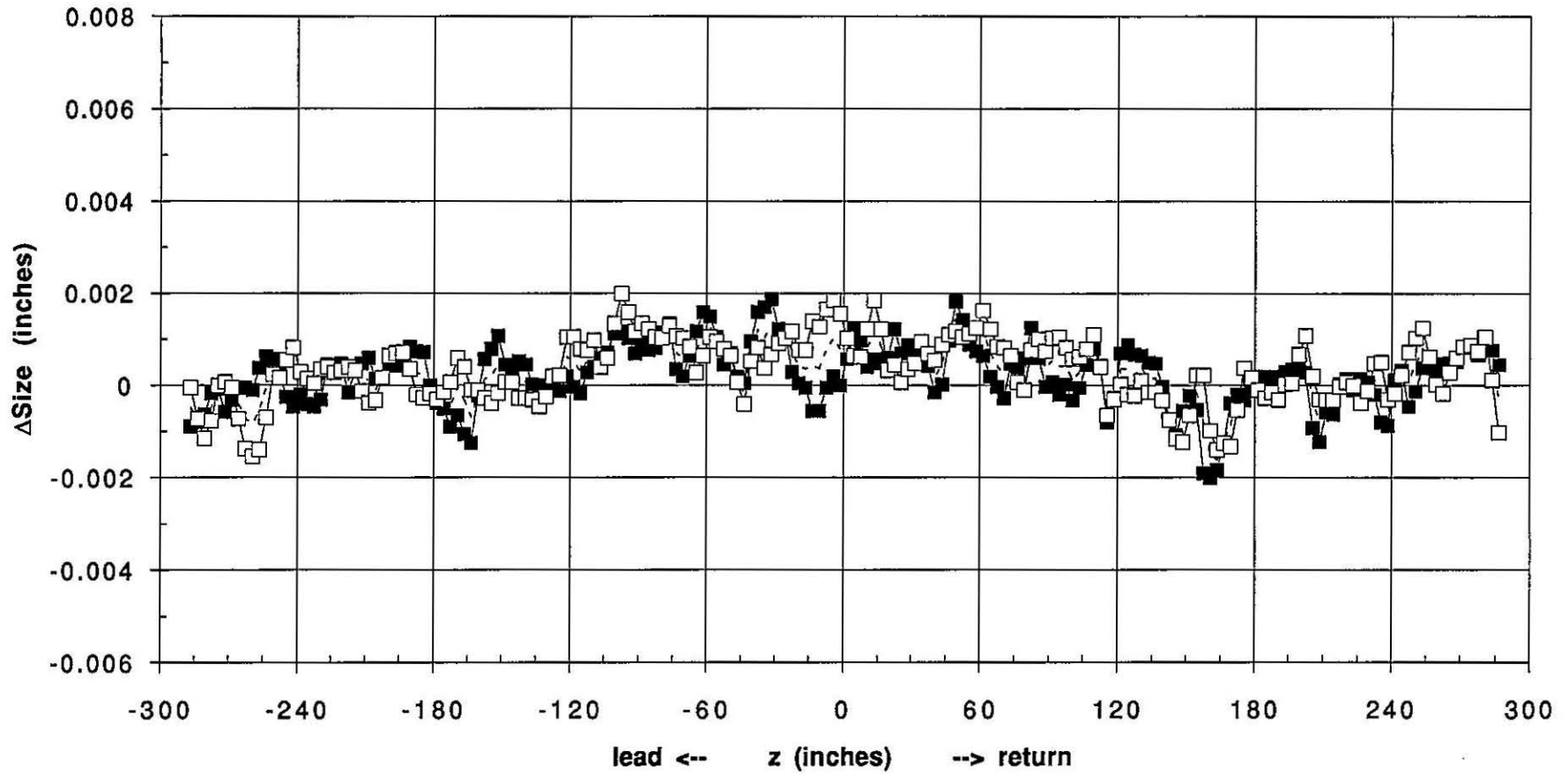
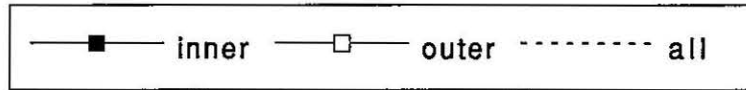


Figure 5