Comparison of Room Temperature End Can Deflection Data for 40 mm Aperture SSC 1m Dipole Magnets

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S. W. Delchamps
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For some time we have been studying the problem of how best to achieve a reasonable prestress at the magnet ends. We have considered various end can materials and end insulator materials. All but one of the 1 m 40 mm aperture magnets so far have been constructed using the standard G-10 insulator material ("azimuthal G10) and stainless steel end cans, and we have kept data on the deflection of the end cans during instalation at both the lead and non-lead ends.

One magnet, DS0311, was equipped at the non-lead end with insulators made from G10 so that the fiber planes were perpendicular to the magnet axis ("transverse G10".) The behavior of this end clamp was compared with the conventional clamp of DS0310 in the memo **TS-SSC 90-064.**

To supplement our experimental studies, finite element analyses have been made for various end can and insulator materials. The most comprehensive note on this so far has been **TS-SSC 90-085.**

In this report, I will compare experimental data and finite element analysis predictions for magnets DS0308 - DS0313. (DS0312 is not included in this series, as it has never had end clamps installed.)

We have recorded three types of data so far on room temperature end can deflections. These are: 1) caliper measurements of the can diameter before and after installation, 2) strain gage readings (only on DS0310, 311, and 313), and 3) "pi-tape" measurements of the can diameter before and after installation (only on 313.)

The caliper measurements are made at the horizontal midplane, the vertical midplane, and at 45 degrees to either side of the vertical midplane. **Table 1 and Table 2** summarize these measurements. The 0.5", 1.5", and 2.5" column headings give the axial position of the measurement, relative to the end of the collars. (0.5" is closest to the collars.) The four numbers correspond to the change in diameter (positive or negative) in mils when the can is installed on the magnet at the horizontal, vertical, 45 degrees and 135 degrees position.

With the exception of DS0308, a trend seems to develop, with both the lead and non-lead end cans deflecting inward at the horizontal midplane, and outward at the vertical midplane.

DS0311 looks anamalous at first, but there is strong reason to believe that the raw data sheet in the traveller was filled out wrong, so that the negative deflections will all be at the horizontal midplane. The numbers for DS0311 are therfore italicized and set in bold type. (Note however, that this does not explain the positive pairs of numbers at the 0.5" and 2.5" lead end positions.)

The places where numbers are missing for DS0310, 311, and 313 show where the strain gages mounted on the non-lead end can interfered with application of the calipers.

Finite element analysis predicts a -15 mil horizontal deflection, and a 22 mil vertical deflection. DS0309 and DS0310 seem to follow this prescription. The finite element prediction for "transverse" G10 (used on the non-lead end of DS0311) is -14 mils horizontal deflection and 23.5 mils vertical deflection. This compares fairly well with the DS0311 non-lead end data, if the horizontal and vertical measurements are transposed as mentioned above.

Magnets DS0310, 311, and 313 had strain gages installed on their non-lead end cans. The gages on DS0310 were positioned in such a way that the azimuthal strains at angles corresponding to the horizontal, vertical, and 45 degrees measurements may be obtained directly. This is done by averaging the strain gage readings for the two angular positions that correspond to the caliper ends of a given measurement. (For example, to get the strain gage reading for "horizontal," the readings at 0 degrees and 180 degrees are averaged.) These strains, in units of microstrain, are shown in Table 2.

DS0311 had its end can rotated azimuthally, so that a direct correspondence between its strain gage and caliper readings cannot be made. The number shown in Table 2 for this magnet is the average azimuthal strain (microstrain units) over all azimuthal angles.

For DS0313, strain gage readings are shown for horizontal, vertical, 45 degrees, and 135 degrees.

DS0313 had its end can diameters measured with a pi-tape before and after installation. At both the lead end and non-lead end, the change in diameter was 8 mils. This is to be compared with the average deflection of the DS0313 end cans over the four caliper measurements, which give 7.2 mils.

We encounter some apparent inconsistency if we compare the strain gage readings and the caliper measurements. For the caliper readings, we might assume that the diameter change can be directly linked with an azimuthal strain with 180 degree reflection symmetry, so that

microstrain = (diameter change in mils) * (10**3) / (6.250 inches)

So for example for DS0310, we obtain from the caliper readings microstrains of -3520, 3040, and 1280, which are to be compared with -602, 252, and 716 from the strain gages. For DS0313, we get -2080, 2400, 1760, 2560 from the calipers, and -203, 314, 1157, and 1170 from the strain gages.

It is not clear what the discrepancy is. It may not be correct to use the above equation to infer a strain from the change in diameter of the end can. Furthermore, the strain gages report the effects of both azimuthal and longitudinal strain added in quadrature. However, in general their readings are smaller than the microstrains derived from the calipers.

Table 1. Lead End Deflections (mils)
[Horizontal, Vertical, 45 degrees, 135 degrees]*

Magnet	0.5"	1.5"	2.5"
DS0308	0, 2, 8, 3	1, -2, 6, 3	2, -3, 6, 3
DS0309	-10, 10, 6, 12	-9, 7, 5, 9	-7, 6, 4, 6
DS0310	-14, 20, 19, 12	-16, 14, 10, 1	-13, 11, 7, 4
DS0311	***14, 12***, 11, 16	***8, -11***, 6, 10	***5, 7***, 3, 8
DS0313	-5, 6, 2, 1	-6, 6, 3, 1	-8, 7, 3, 1

Table 2. Non-lead End Deflections (mils)
[Horizontal, Vertical, 45 degrees, 135 degrees]
And Strain Gage Readings**

Magnet	0.5"	1.5"	2.5"	strain gage (microstrain)
DS0308	-11, 10, 10, 0	-10, 9, 8, -1	-8, 7, 7, 0	
DS0309	-13, 17, 12, 14	-12, 13, 8, 11	-10, 10, 6, 8	
DS0310	-22, 19, 8, 6	_, _, _, _	-7, 10, _, _	-602,252,716, _
DS0311	***39, -12***, 24, 16	_, ***-13***, _, 8	***17, -12***, 7, 4	***2142***
DS0313	-13, 15, 11, 16	-13, 11, _, 11	-9, 9, _, 7	-203,314,1157,1170

Table 3. Pi Tape Measurements of Can Diameter
Given as Increase of Diameter (mils)

DS0313	lead end: 8 mil increase
DS0313	non-lead end: 8 mil increase

*** Deflections in this table are given as change in diameter. Negative values indicate a decrease in diameter.**

**** The non-lead end cans of DS0310, 311, and 313 were equipped with strain gages. The gages on 311 were rotated azimuthally by mistake from their intended positions, so that not all angles are available.**

Distribution:

R. Bossert
J. Carson
S. Delchamps
W. Koska
M. Lamm
J. Strait
M. Wake