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TS-SSC 92-008

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January 8, 1992

To: Jim Strait, FNAL

From: Jim Kerby, FNAL

Subject: Write up of SSC 50mm Dipole Cold Mass Stiffness Measurements

Enclosed find a write up of the bending deflection tests conducted on the DCA310 cold mass. Please enter it in the TS-SSC report file.

cc: Bob Churchill, GD
Michael Hiller, B&W

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December 30, 1991
TS-SSC 92-008

TO: SSC 50mm File

FROM: Jim Kerby, TS/Engineering

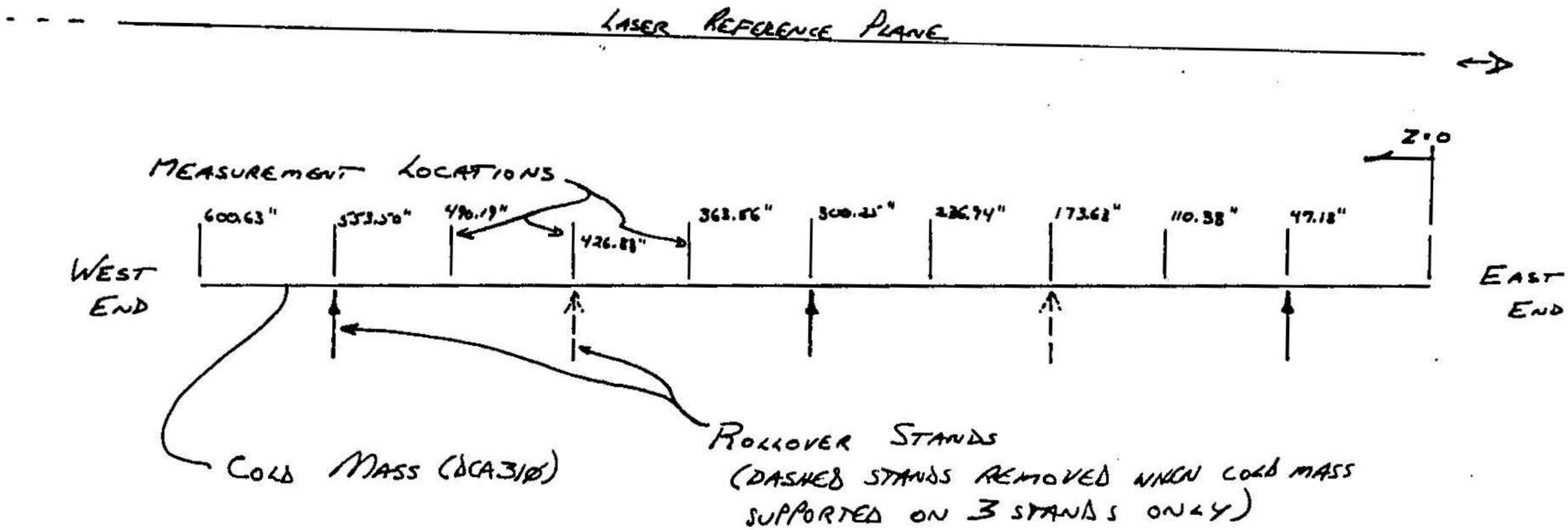
SUBJECT: Stiffness of Collider Dipole Cold Mass

The bending stiffness of an SSC 50mm Collider Dipole Cold Mass has been determined experimentally. The deflection of the DCA310 cold mass due to gravity while supported at 3 points has been measured, and compared with predictions from an ANSYS model in which the cold mass stiffness is equal to a multiple of the cold mass shell bending stiffness. Best agreement is reached when a cold mass stiffness equal to 1.5 times the shell stiffness is used. This is considerably higher than the factor of 1.25 commonly used for calculation of the 40mm cold mass stiffness.

MEASUREMENTS

The deflection of the cold mass DCA310, without the end domes or extension tubes, was measured. The cold mass was supported on the east rollover stand in the Industrial Center Building, so the cold mass could be easily rotated and measurements taken in four yoke split orientations, each 90 degrees apart. In all, 5 data sets were taken: one with the cold mass supported by all five stands and the yoke split in the vertical orientation, and four with the cold mass supported on three stands and the cold mass rotated 90 degrees between each measurement (resulting in 2 sets each of vertical and horizontal yoke split data). Each set consists of 11 data points, with one point above each of the stand locations, one point midway between each of the stand locations, and one point at each end. The location of the stands and the survey points are shown in figure 1. The data are presented in Tables 1 through 3.

A survey laser was used to establish a reference plane from which the position of the top (outer diameter) of the cold mass was measured. The location of the cold mass above the easternmost stand (Z = 47.13 inches) was arbitrarily defined as the zero point. Table 1 lists the data taken for the cold mass supported by the five stands, with the yoke split oriented vertically.



LASER REFERENCE PLANE
Z=0
MEASUREMENT LOCATIONS
600.63"
553.50"
490.19"
426.83"
363.56"
300.21"
236.74"
173.62"
110.38"
47.18"
WEST END
EAST END
COLD MASS (DCA310)
ROLLOVER STANDS
(DASHED STANDS REMOVED WHEN COLD MASS SUPPORTED ON 3 STANDS ONLY)

Table 1. Cold Mass Supported at Five Points

Z Position	5 Pt V	Lst Sqrs	5 Pt Corr
0.00 in	0.006 in	0.001 in	0.005 in
47.13	0.000	0.000	0.000
110.38	-0.010	-0.001	-0.009
173.63	-0.002	-0.003	0.001
236.94	-0.010	-0.004	-0.006
300.25	-0.007	-0.005	-0.002
363.56	-0.009	-0.007	-0.003
426.88	-0.006	-0.008	0.002
490.19	-0.021	-0.009	-0.012
553.50	-0.011	-0.010	-0.001
600.63	-0.001	-0.011	0.010

To account for differences between the laser reference plane and the vertical position of the five stands, a least squares fit of the data at the five stand locations was done. This curve (column 3 of table 1) was then applied as a correction to the data set, resulting in the corrected measurements shown in column 4. The correction adjusts the data for the difference between the position of the laser reference plane and a best fit plane through the positions of the rollover stands. This same correction is also applied to the remaining 4 data sets, where the cold mass is supported on three stands only.

Table 2 lists the measurements for the cold mass sag when the yoke split is in the vertical (designated with a 'V' in the data titles) position. The two raw data sets are listed in columns 2 (3Pt V1) and 4 (3Pt V2), with the corrected data (denoted by 'c' in the headings) in columns 3 (3Pt V1c) and 5 (3Pt V2c), respectively. Column 6 is the average (V Avg c) of columns 3 and 5. The data in columns 3 and 5 are also shown in figure 2.

Table 2. Vertical Yoke Split Orientation Deflections

Z Pos	3 Pt V1	3Pt V1c	3 Pt V2	3Pt V2c	V Avg c
0.00 in	0.049 in	0.048 in	0.063 in	0.062 in	0.055 in
47.13	-0.002	-0.002	-0.001	-0.001	-0.002
110.38	-0.082	-0.081	-0.091	-0.090	-0.085
173.63	-0.104	-0.101	-0.119	-0.116	-0.109
236.94	-0.061	-0.057	-0.067	-0.063	-0.060
300.25	-0.023	-0.018	-0.025	-0.020	-0.019
363.56	-0.073	-0.067	-0.072	-0.066	-0.066
426.88	-0.123	-0.115	-0.115	-0.107	-0.111
490.19	-0.104	-0.095	-0.086	-0.077	-0.086
553.50	-0.017	-0.007	-0.014	-0.004	-0.005
600.63	0.064	0.075	0.058	0.069	0.072

Corrected Deflection for Vertical Split Orientation

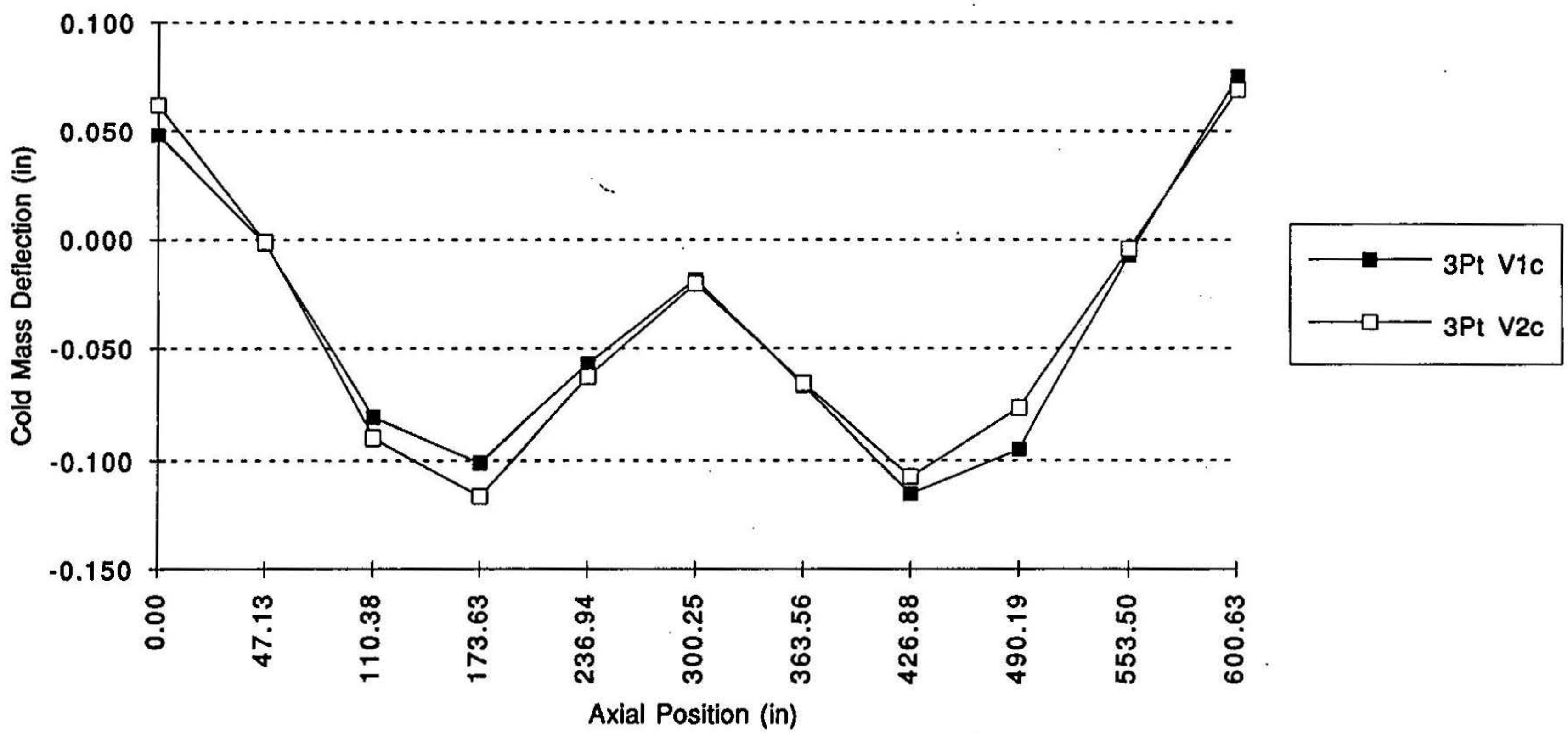


Table 3 and figure 3 show the data for the horizontal (designated with an 'H' in the headings) orientation of the yoke split in the same format as used in Table 2. The averages in both cases agree well, although the data from the horizontal orientation is much more scattered and unexpected, particularly at the east (0 inch) end of the magnet in the second trial. This data was repeatable, but remains unexplained.

Table 3. Horizontal Yoke Split Deflections

Z Pos	3 Pt H1	3Pt H1c	3 Pt H2	3Pt H2c	H Avg c
0.00 in	0.102 in	0.101 in	-0.019 in	-0.020 in	0.041 in
47.13	0.004	0.004	0.004	0.004	0.004
110.38	-0.121	-0.120	-0.045	-0.044	-0.082
173.63	-0.140	-0.137	-0.070	-0.067	-0.102
236.94	-0.078	-0.074	-0.044	-0.040	-0.057
300.25	-0.019	-0.014	-0.017	-0.012	-0.013
363.56	-0.061	-0.055	-0.084	-0.078	-0.066
426.88	-0.105	-0.097	-0.128	-0.120	-0.109
490.19	-0.080	-0.071	-0.098	-0.089	-0.080
553.50	-0.007	0.003	-0.008	0.002	0.003
600.63	0.028	0.039	0.080	0.091	0.065

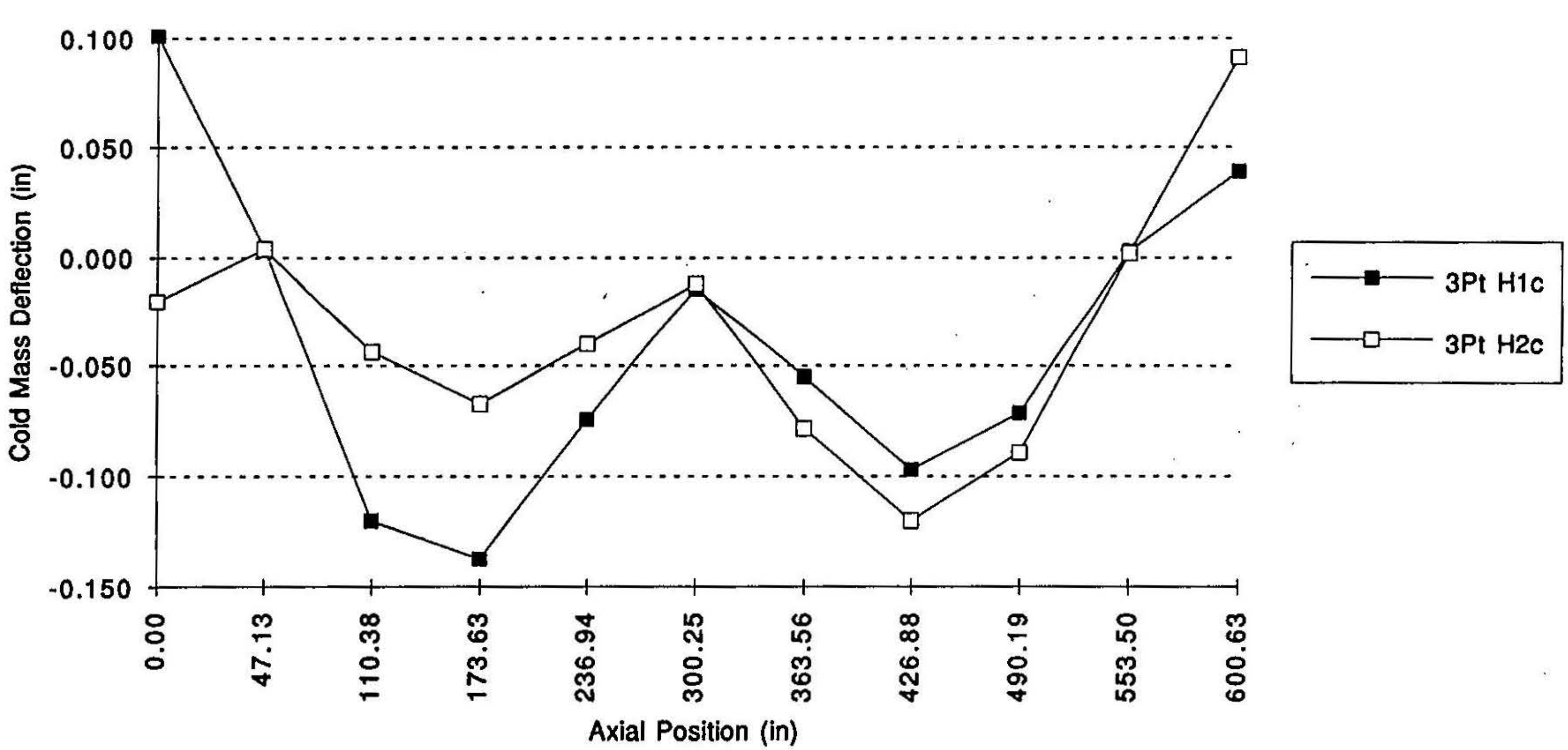
Since the data should be symmetrical about the center rollover stand, Table 4 (and figure 4) shows the half magnet averages for both the vertical (1/2 V Ac) and horizontal (1/2 H Ac) yoke splits positions, and the overall average deflection (1/2 Avg) of the cold mass, independent of the yoke split orientation. Also included are the ANSYS predictions for bending stiffnesses equal to the cold mass shell stiffness times 1.6 and 1.5. The 0.016 inch average deflection measured at the center stand is unexplained--simple compression of the stand under the increased load (due to the 2 stands being removed) accounts for only a maximum of 0.003 inches.

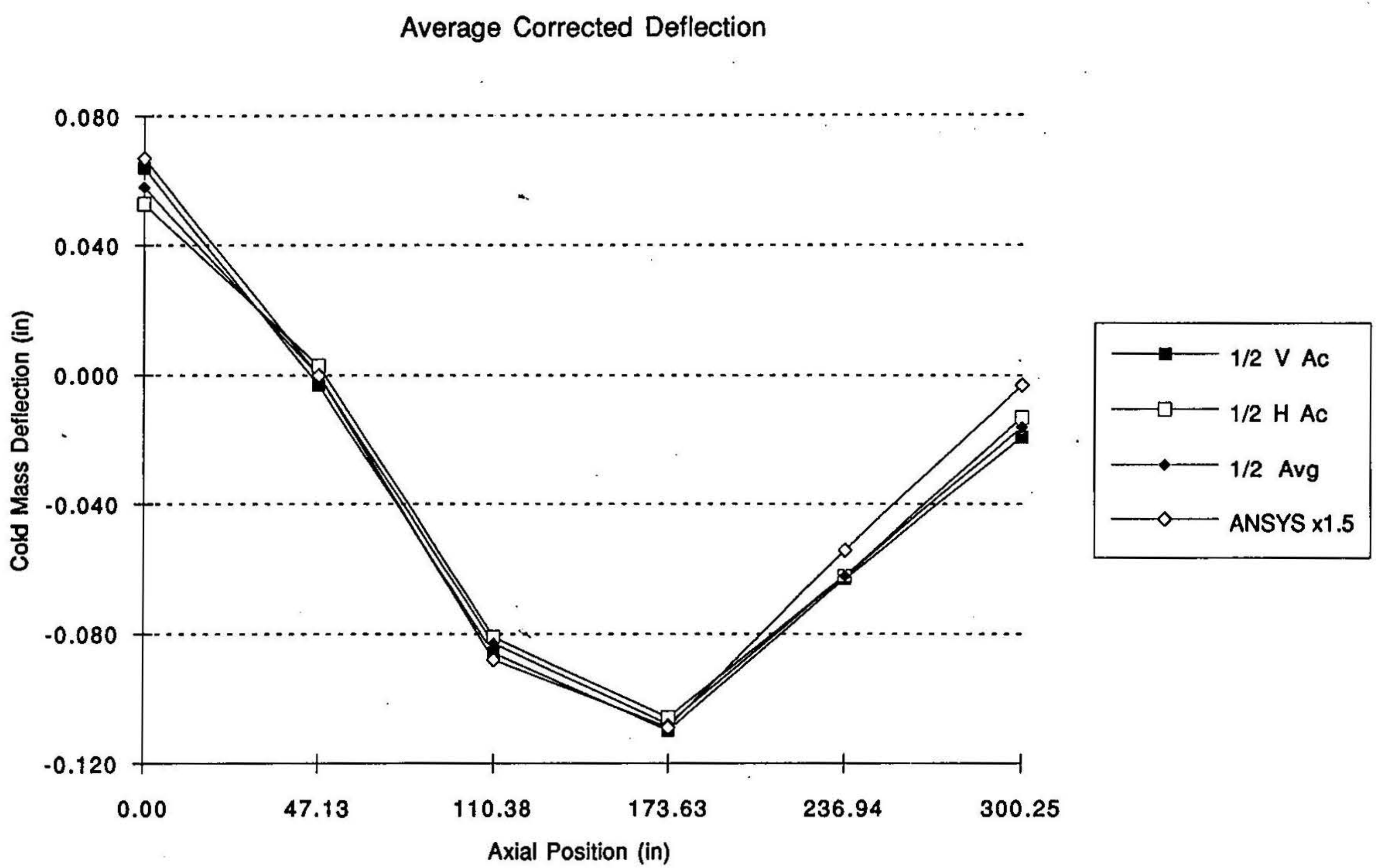
Table 4. Average Deflections and Model Predictions

Z Pos	1/2 V Ac	1/2 H Ac	1/2 Avg	ANSYS x1.6	ANSYS x1.5
0.00 in	0.064 in	0.053 in	0.058 in	0.063 in	0.067 in
47.13	-0.003	0.003	0.000	0.000	0.000
110.38	-0.086	-0.081	-0.083	-0.083	-0.088
173.63	-0.110	-0.106	-0.108	-0.102	-0.109
236.94	-0.063	-0.062	-0.062	-0.050	-0.054
300.25	-0.019	-0.013	-0.016	-0.003	-0.003

These results were used to derive an equivalent cold mass stiffness, based on a multiple of the skin bending stiffness. For this, a small ANSYS model was created using 3-D beam elements, which properly represent the mass and dimensions of the cold mass. Predicted deflections, as a function of the multiple of the skin thickness, are shown in table 4. Predictions for the

Corrected Deflection for Horizontal Split Orientation





Average Corrected Deflection
0.080
0.040
0.000
-0.040
-0.080
-0.120
Cold Mass Deflection (in)
0.00
47.13
110.38
173.63
236.94
300.25
Axial Position (in)
1/2 V Ac
1/2 H Ac
1/2 Avg
ANSYS x1.5

case where a multiple of 1.5 times the skin thickness is used are also plotted in figure 4.

Best agreement between the model and the measured deflections is seen when a multiplier of approximately 1.5 is used. This is considerably higher than the factor of 1.25 typically used with the SSC 40mm dipole cold mass, but in agreement with the stiffness multiple used for LHC dipole cold masses.

Unexplained is the large deflection seen at the center rollover stand when the cold mass was supported by just three stands. A very simple calculation of the compression of the box beam under increased loading suggests this should have increased by only 0.003 inches as compared with the case where all five stands are used. However, this does not account for any other pieces in the rollover stand structure.

TS-SSC 92-008 ADDENDUM

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January 29, 1992

TO: SSC 50mm File

FROM: Jim Kerby, TS/Engineering

SUBJECT: Stiffness of Collider Dipole Cold Mass - Addendum

Mike Robbins (GD) has correctly raised questions about the mass of the cold mass used in the stiffness calculations. I used a cold mass weight of 11360 kg (25000 lb) (as specified in the PIDS and referenced in various other publications), while a simple calculation gives a value of 10658 kg (23500 lb), and riggers in the Industrial Center Building have been using a value of between 9524 - 9977 kg (21000 - 22000 lb). Obviously, the uncertainty of this value is rather high (the measurement by the riggers was not precise).

Since the cold mass was modeled as a simple beam, the deflection scales linearly with the mass (or mass per unit length, depending on which form of the equation you happen to be working with). The area moment is in the denominator of this same equation. Thus, to keep the deflections constant, the ratio of the mass to area moment multiplier (1.5-1.6 in the report) should also be kept constant.

For example, if the cold mass actually weighs 22000 lb, the correct multiplier would be found by scaling by (22/25), giving a area moment multiplier of 1.3 - 1.4.

cc: Bob Churchill, GD
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