The only official copy of this file is the one on-line on the Superconducting Magnet Division website. Before using a printed copy, verify that it is the most current version by checking the document issue date on the website.

Large Hadron Collider
Magnet Division Procedure

Proc. No.: LHC-MAG-R-1038

Issue Date: Oct. 17, 2000

Rev. No.: B

Rev. Date: Nov. 29, 2001

Class: Dipole
Title: D1 /D2 /D3 /D4 Twist Check and Fiducial Survey

· Prepared by: Signature on File

· LHC Project Engineer: Signature on File

· Cognizant Engineer: Signature on File

· Production Section Head: Signature on File

· Q. A. Approval: Signature on File

· ES&H Review: Signature on File

REVISION RECORD

Rev. No.	Date	Page	Subject	Approval
A	10/17/00		Initial Release.	
B	11/29/01		Changes per ECN #MG2070	

1. SCOPE

1.1 Background

Proper alignment of the dipole field is crucial to the operation of the accelerator. Ten (10) fiducials located on the outside of the cold mass shell, in conjunction with four (4) fiducials located on each of two end volumes, are used to position the cold mass within the vacuum vessel. Additionally there are six (6) fiducials located on the vacuum vessel which are used to position the cryostatted magnet assembly within the tunnel at CERN. The positions of the cold mass fiducials are referenced to the cryostat fiducials, and the data are transferred to CERN. Following shipment of the magnet assembly, the position of the cold mass within the cryostat can be verified by comparing the relative positions of the cold mass fiducials on the end volumes to the cryostat fiducials. During installation of the magnet assembly in the CERN tunnel, only the fiducials located on the cryostat are visible.

1.2 Purpose

This specification describes the procedures used to locate the cold mass, and therefore the dipole field, relative to the fiducials on the outside of the vacuum vessel, using mechanical and optical means. Magnet alignment and fiducial location checks based on magnetic measurements are covered in a separate specification.

2. APPLICABLE DOCUMENTS

The following documents, of the issue in effect on the date of manufacture, shall be considered an integral part of this specification.

RHIC-MAG-R-8792 - Removal of Cold Mass Twist

3. REQUIREMENTS

3.1 Definitions

The center of the dipole field is defined by the position of the yoke laminations. Because the ten (10) cold mass fiducials are in intimate contact with the yoke, they represent indirectly the position of the dipole field.

An a,b,c coordinate system is employed for measuring fiducial locations; it is a standard right-handed coordinate system. Axis a is horizontal, b is vertical, c is longitudinal. The origin of the coordinate system is located on the plane which passes

through the center set of fiducials (cold mass longitudinal midpoint) perpendicular to the beam tube axis, with (0,0,0) positioned at the yoke center. Positive axes are defined as follows, as viewed from the lead end of the magnet: a is positive to the right, b is positive upward, c is positive toward the non-lead end. Refer to Figure 1.

3.2 Magnet Support

The three cold mass cradles, which eventually mount to the support posts, shall be supported on, and in contact with, a level coplanar surface when measurements are made of the cold mass twist and straightness. The coplanar surface may be locally interrupted (i.e., three pedestals are acceptable). In addition, a secondary surface(s) of precisely known offset from this plane must be present below and immediately behind each end volume in order to measure and correct cold mass sag. Refer to Figure 2.

The two extremity cast cradles on the underside of the vacuum vessel shall be used to support the magnet assembly when measurements are made of the cold mass position within the vacuum vessel. Two points of support shall be located at the lead end, and one point at the non-lead end, the three points coinciding with the spherical bearing locations on the underside of the cradles and port cover. Refer to Figure 3.

3.3 Environment

Measurements must be carried out in a stable atmosphere and at constant temperature. The equipment and the magnet must be in equilibrium before calibration of the equipment is made or any data are taken.

4. PROCEDURES

4.1 Measurement of Cold Mass Twist and Straightness

Locate the cold mass on the pre-established coplanar surface defined in section 3.2. The cold mass cradles will sit on the coplanar cradle supports. Verify that all three cradles are in contact.

CAUTION:

Notify cognizant engineer prior to proceeding if this condition cannot be obtained.

4.1.1 Calibrate the electronic inclinometer ("Cold mass Leveling Tool" or CLT) by establishing the “zero” reading for the CLT on a known level surface.

4.1.2 Measure and record the cold mass twist at each of the five (5) sets of fiducial holes located in the shell. The standard deviation of the five measurements must be less than or equal to 1.0 mrad.

4.1.3 To correct for an out of tolerance condition, a plan must be devised in consultation with the cognizant engineer and the welders experienced in repairing twist in RHIC CQS cold masses; refer to RHIC-MAG-R-8792 as a guide. The plan will describe how the pattern of weld on the outside of the shell should be laid down to remove enough twist to bring the readings within tolerance. Perform the correction welding according to the plan.

4.1.4 Record initial cold mass sag and straightness values in traveler. The cold mass sag at the end volumes must be within .02 inches as compared to the sag directly adjacent to the extremity cradles. Refer to Figure 4. Straightness must be within 0.04 inches between cold mass end plates. Measure straightness at eleven (11) equidistant points between the end plates. Refer to Figure 5. Correct sag and straightness to within these limits if required by devising a plan with the cognizant engineer and the welders that will consist of adding transverse weld stripes across the shell.

4.1.5 Record final sag and straightness values if corrections were required. Then measure and record the twist again at the 5 sets of fiducial holes. The standard deviation of the five measurements must be less than or equal to 1.0 mrad.

CAUTION:

Notify cognizant engineer prior to proceeding if this condition cannot be obtained.

4.2 Establishment of Cold Mass Fiducial Locations

4.2.1 Clean the lamination notches at the ten (10) fiducial hole locations to be measured, and install precision-ground temporary fiducial sockets in the notches using cyanoacrylate adhesive. The ten temporary fiducial sockets must be identical to each other and symmetric about their bore axes. The glue must be squeezed out to a minimum uniform thickness at all fiducials by applying continuous pressure during the entire cure time.

4.2.2 Set up the “MANCAT” optical computer measuring system around the cold mass. The theodolites must "see" all ten fiducials on the top of the cold mass as well as the four fiducials on each of the end volumes.

4.2.3 Zero the “MANCAT” system.

4.2.4 Install tooling balls in the fiducial sockets at the ten shell hole locations on top of the cold mass. Install tooling balls in the four fiducial locations at each end volume. The end volume fiducials are .2500 diameter holes in bosses welded to the end volumes. Install tooling balls in these also.

4.2.5 Take “a”, “b”, and “c” position readings of the center of the tooling balls located in each shell hole fiducial socket. There are ten (10) shell locations to measure. Record the "a", "b" and "c" readings in the traveler for each location.

4.2.6 Use the measurements above to establish a datum plane based on a “least squares” analysis of the ten shell hole tooling ball locations.

4.2.7 Take “a”, “b”, and “c” position readings of each of the end volume fiducials at the lead and non-lead ends. There are eight (8) locations to measure. Record the "a", "b" and "c" readings in the traveler for each location.

4.2.8 Reference the positions of the eight end volume fiducials to the theoretical plane calculated in step 4.2.6. Record the positions of the end volume fiducials, as offsets from the theoretical plane, in the traveler.

NOTE:

The roll, pitch, and yaw of the cold mass within the vacuum vessel will be determined with respect to the positions of the eight end volume fiducials as recorded in the traveler.

4.2.9 Remove the tooling balls and the temporary fiducial sockets. Carefully store the sockets for future use.

4.2.11 Using a dial indicator, measure the vertical height of the shell just behind each end volume relative to the table surface, and record the readings. Refer to Figure 4.

4.2.12 Weld on the ten cover discs over the shell holes. Weld the discs using a crisscross pattern, alternately welding one disc, then the opposite disc, etc., moving back and forth along the length of the cold mass. Use the same pattern from cold mass to cold mass.

4.2.13 Again compare the cold mass sag just behind each end volume to the measurement taken at its respective extremity cradle, verifying that each set of measurements is

within .02 inches. ONLY IF REQUIRED, DEVISE A PLAN WITH THE COGNIZANT ENGINEER and the welders that will consist of adding transverse weld stripes across the shell to correct sag and/or straightness. Record sag /straightness readings again in the traveler if a plan must be implemented.

CAUTION:

ANY PROPOSED CORRECTIONS IN COLD MASS TWIST OR SAG AT THIS POINT MUST BE APPROVED BY THE COGNIZANT ENGINEER BEFORE BEING ATTEMPTED.

4.3 Alignment of Cold Mass Within Vacuum Vessel

4.3.1 Set up the “MANCAT” laser computer measuring system around the cryostat. The theodolites must "see" all four (4) fiducials on each of the end volumes.

4.3.2 Zero the “MANCAT” system.

4.3.3 Install tooling balls in the four fiducial locations on each end volume.

4.3.4 Take “a”, “b”, and “c” position readings of the tooling balls in each of the end volume fiducials at the lead and non-lead ends. There are eight (8) locations to measure. Record the "a", "b" and "c" readings in the traveler for each location. Use the measurements above to establish a datum plane based on a “least squares” analysis of the eight fiducial locations. This plane will be a copy of the plane established by the temporary cold mass fiducials (step 4.2.6).

4.3.5 Install the Taylor-Hobson (T-H) fiducial cups and spheres onto the mounting plates on the vacuum vessel. There are six (6) locations. Refer to Figure 6.

4.3.6 Take “a”, “b”, and “c” position readings of the T-H fiducials. Record the "a", "b" and "c" readings in the traveler for each location.

4.3.7 Reference the positions of the T-H fiducials to the plane established by the eight end volume fiducials located in step 4.3.4. Record the positions of the vacuum vessel fiducials in the traveler.

NOTE:

The roll, pitch, and yaw of the cold mass within the vacuum vessel, and the alignment of the cold mass with respect to the beam lattice in the CERN tunnel,

will be set with respect to the positions of the T-H fiducials as recorded in the traveler.

5. QUALITY ASSURANCE PROVISIONS

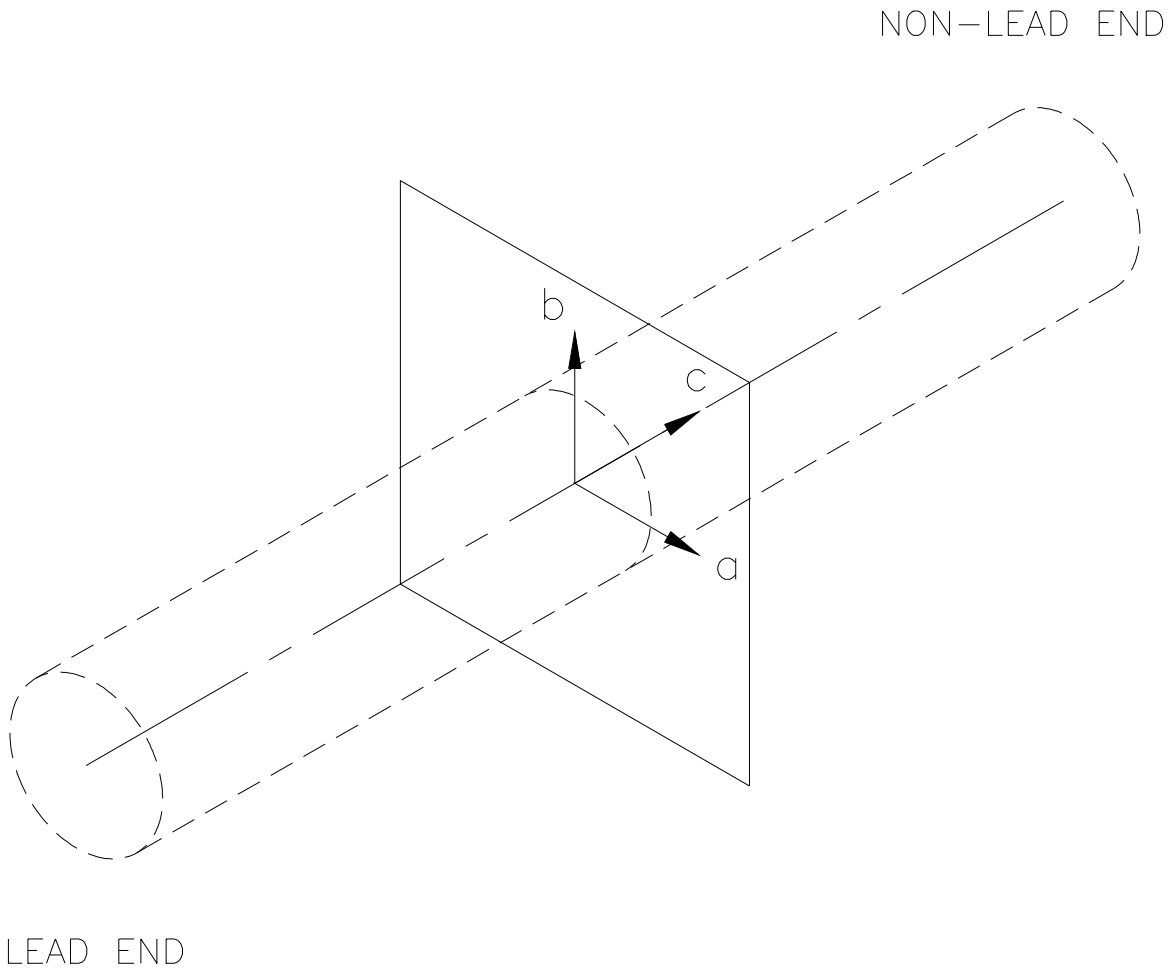
5.1 The Quality Assurance provisions of this procedure require that all assembly and test operations be performed in accordance with the procedural instructions contained herein.

5.2 Measuring and test equipment used for this procedure shall contain a valid calibration label in accordance with RHIC-MAG-Q-1000.

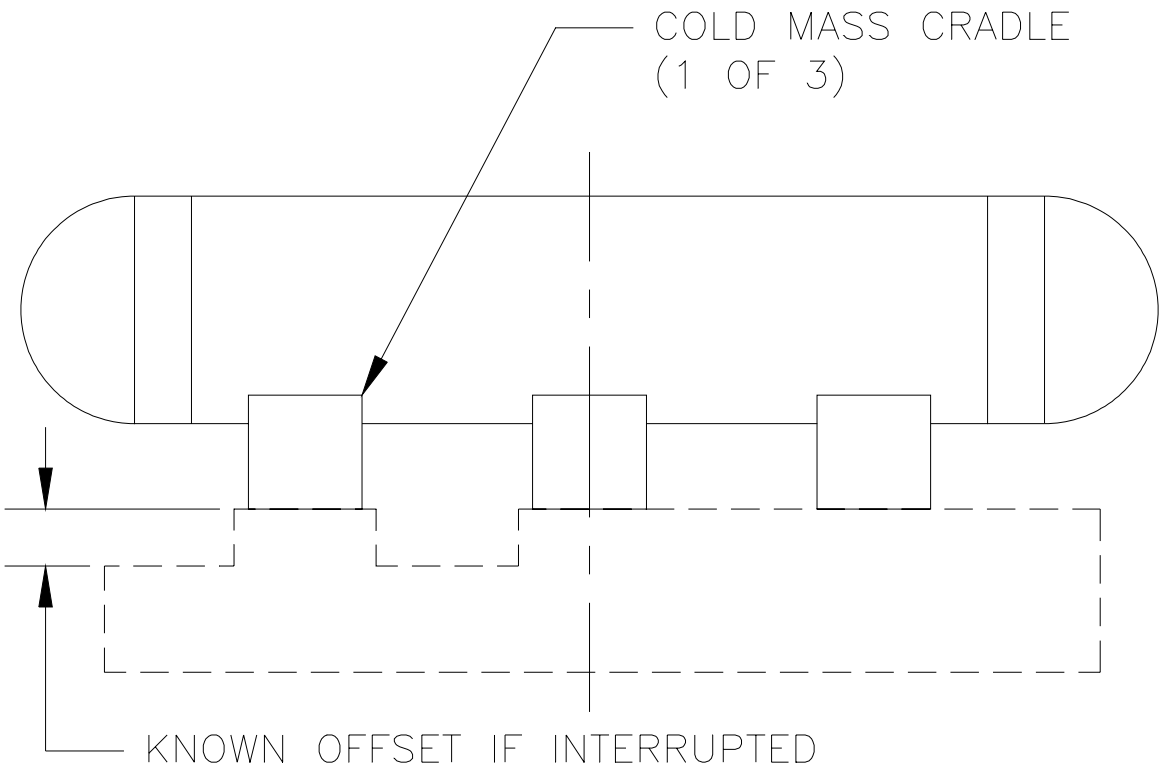
5.3 All discrepancies shall be identified and reported in accordance with RHIC-MAG-Q-1004.

6. PREPARATION FOR DELIVERY

N/A

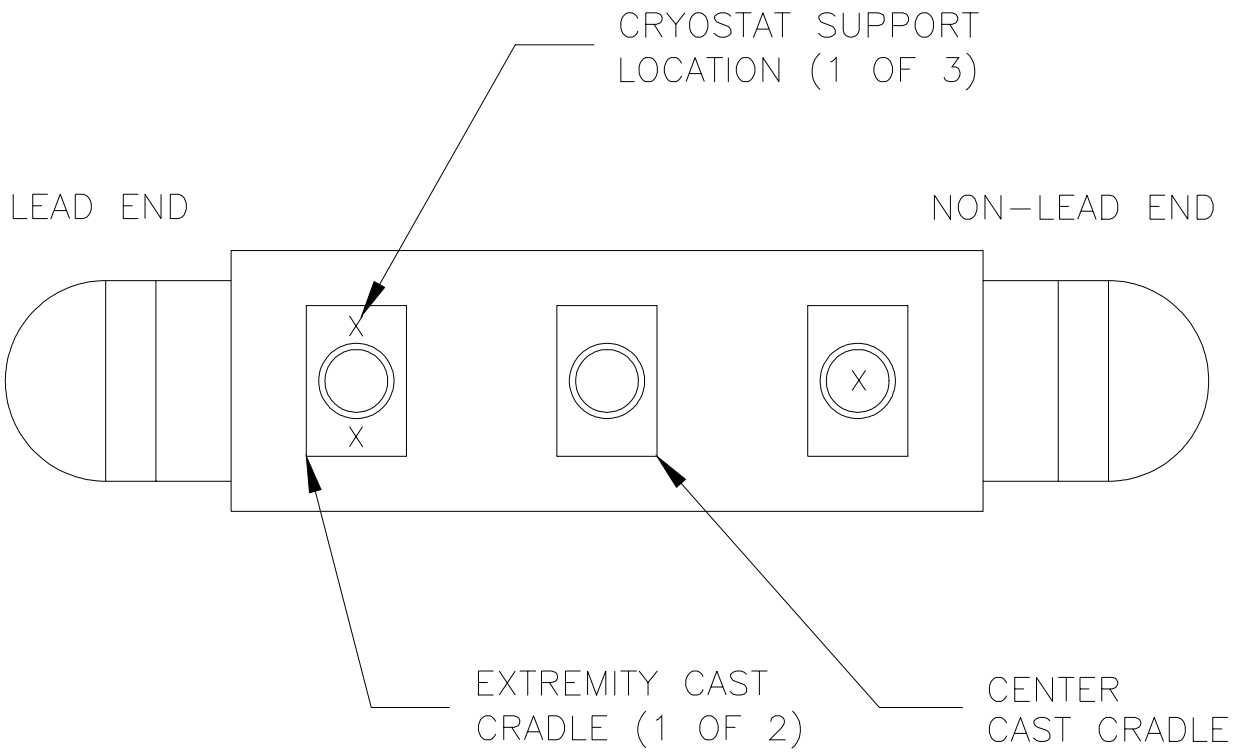


COORDINATE SYSTEM DEFINITION
FIGURE 1



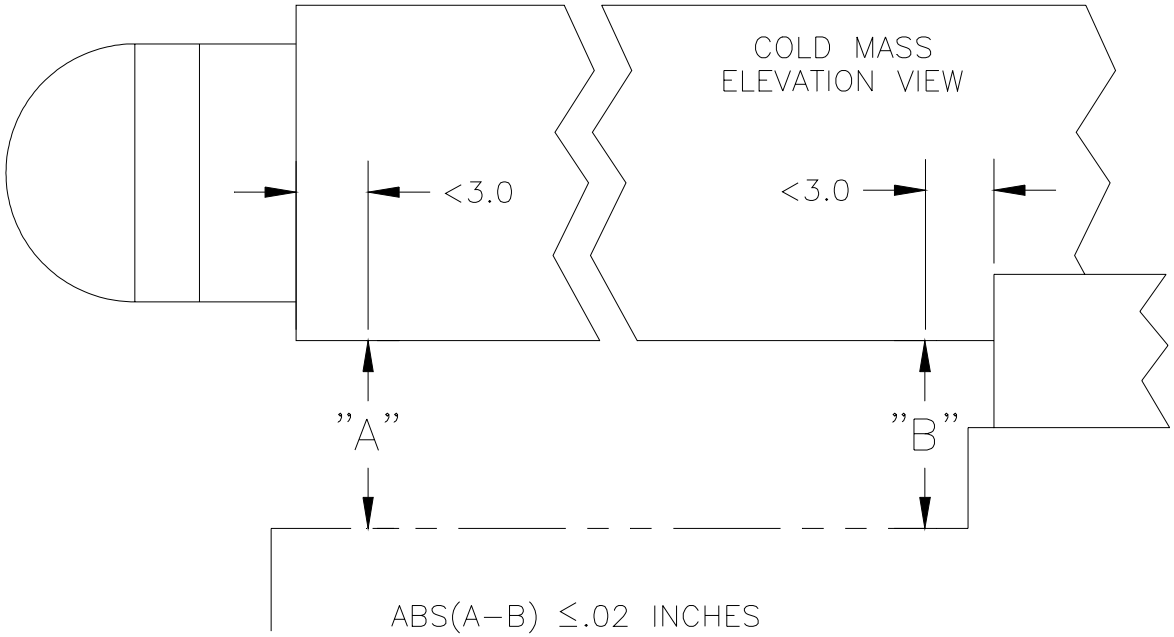
INTERRUPTED... OR...CONTINUOUS COPLANAR SUPPORT SURFACE(S) FOR COLD MASS DURING SURVEY

FIGURE 2



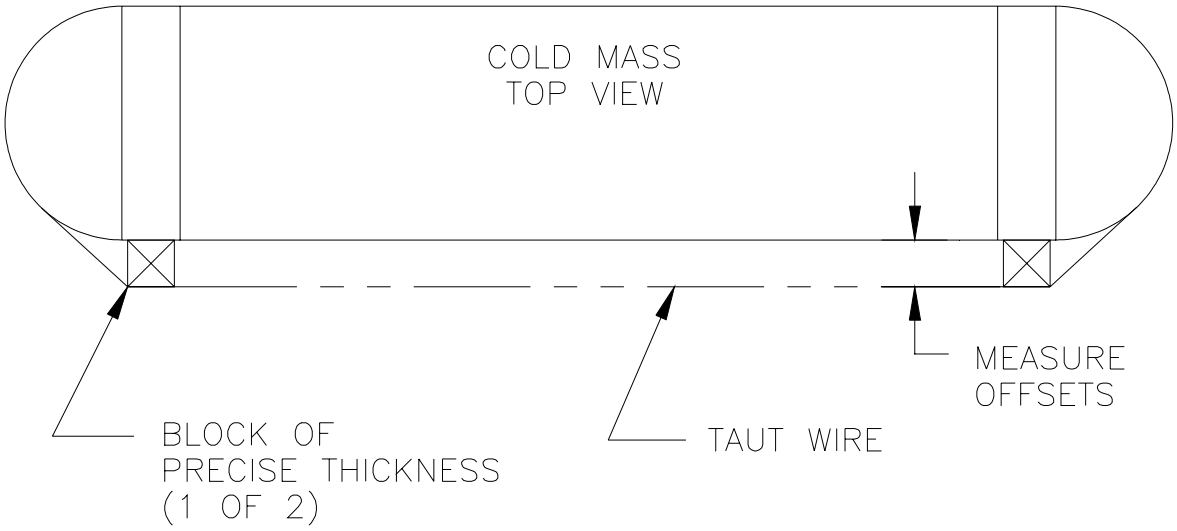
VIEW OF UNDERSIDE OF CRYOSTAT
"X" INDICATES SUPPORT LOCATION

FIGURE 3



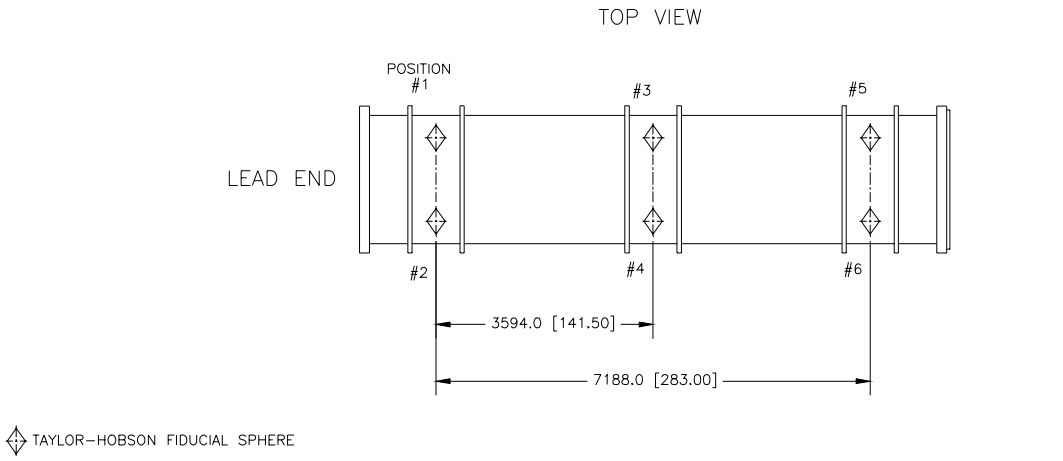
CHECKING & VERIFYING COLD MASS
SAG WITHIN TOLERANCE

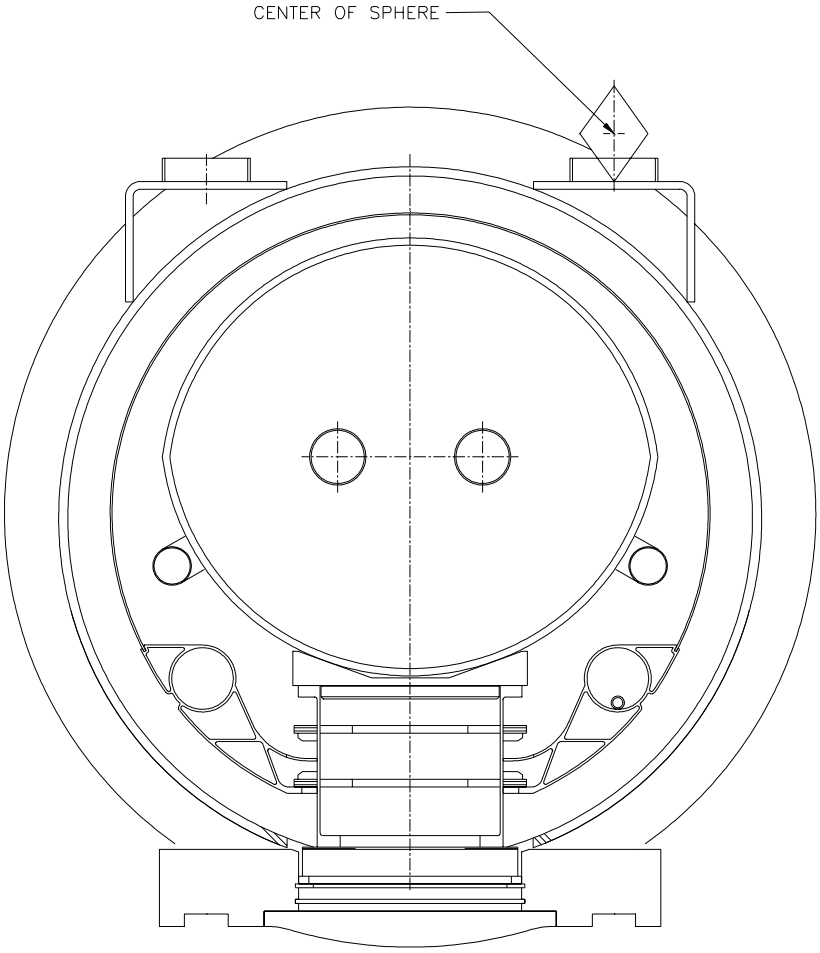
FIGURE 4



CHECKING & VERIFYING COLD MASS
STRAIGHTNESS WITHIN TOLERANCE

FIGURE 5





FIDUCIAL LOCATIONS

FIGURE 6