SSC LONG DIPOLE INTERNAL ALIGNMENT FROM BEAM TO FIDUCIALS

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The SSC long dipole cold mass is 56 feet long, 11 inches in diameter, weighs 16,000 lb. The center of the magnetic field can be assumed to be located at the center of the iron yoke. The 1 1/8 inch diameter beam tube is not accurately located at the center of the cold mass, but it can be assumed to remain in its installed location.

The cold mass is supported by 5 short stiff posts spaced 135 inches apart.

Prior to insertion into the vacuum vessel, the center post is welded to the cold mass. constraining it axially and rotationally. The other posts are fitted with saddles which permit rotation and which permit axial sliding to accommodate cooldown contraction of about 1 1/2 inches.

The vacuum vessel is a 55 foot long, 24 inch diameter, 1/4 inch wall steel pipe, with 5 stiffening rings. It is made up of short pieces which are welded on a special fixture which accounts for the 3/8 inch vertical deflection when the cold mass is installed. This welded structure, so far not annealed, has changed its shape in transportation tests. Further work to produce a stable structure is in process.

The cold mass/post assembly is pulled into the vacuum vessel. The 5 cold mass support posts are bolted to flat surfaces on the inside of each of the vacuum vessel stiffening rings.

Provision is made at the base of each post for vertical shimming and for lateral adjustment via oversized holes. Uniform thickness shims are planned.

The vacuum vessel is provided with 4 support feet. The rather low torsional rigidity of the vacuum vessel requires that, during the alignment and measurement process and when installed in the tunnel, one pair of feet be supported to allow axial and rotational freedom in a reasonably semi-kinematic fashion.

The alignment task consists of assuring that, with respect to accessible external fiducials, the center of the magnetic field is everywhere in its correct position within ±0.020 inches including a 3.2 mm sagitta and that the average V-plane is correct to within ±l milliradian.

The essential larger issue is that, once aligned, the dipole must stay in alignment throughout its 30 year life. This life includes cooldowns, handling, transportation, installation, and normal operation. After installation in the ring, no verification of correct internal alignment is possible.

Status of Dipole Alignment Activity as SSC/Fermilab

1. SSC dipoles for use in the accelerator must be aligned to be within ±0.020 inches of the shape of a "perfect" magnet. Eighteen development magnets have been built to date.
2. The assembly and alignment methods in use have produced magnets which are within about ±0.040 inches of expected alignment.
3. These methods are capable of improvement, to meet alignment requirements and have been more than adequate for the development program.
4. Alignment verification has been done using optical tooling which has an accuracy of about ±0.005 inches. It takes two men about 1½ shifts to measure a magnet.
5. An alignment bench using stretched wires is being built which will increase the attainable accuracy, reduce the measurement time, and provide for future automated data collection and analysis.
6. This bench will be used on DD0019 to shim and to adjust the support posts prior to final tightening.
7. DD0019 will be aligned on this bench with the correct sagitta, to be within about ±010 inches of the "perfect" shape.
8. The bench will also support vacuum vessel stability studies and is being planned so that measurements can be made during cooldown to liquid nitrogen temperature.

Appendix

Alignment Criteria From SSC Magnet Industrialization Program Technical Orientation - Roger Coombes; 4\89.

1. Alignment

   (Preliminary, for reference only)

   a. Alignment References

   i. External Fiducials

   During installation in the tunnel. the magnet will be accessible to survey equipment from one side only.

   The fiducials will therefore be mounted on one side of the magnet at the location of the exterior feet.

   At each location two survey references will be required.

   ii. Magnet Axis

   The physical center of the yoke can be taken to represent the magnetic axis.

   The vertical field direction will be confirmed during warm testing.

   b. The overall requirement for magnet field positioning accuracy for a series of magnets in the ring is stated in terms of the RMS deviation of the magnet axis with respect to the ideal orbit of the beam.

   We assume that systematic errors are eliminated, and that we are dealing only with random errors.

   To first order equal errors in opposite directions tend to cancel each other.

   The assembled collider ring will conform to requirements when the magnetic fields provided by the dipole magnets are positioned within the following tolerances:

   Collider Ring Accuracy

X rms	1 mm (horizontal)
Y rms	1 mm (vertical)
0 rms	0.6 mrad (roll about magnetic axis)

   c. As the beam passes through a dipole magnet, the horizontal curvature of its path is significant and will require the dipole to be “curved“ accordingly.

The sagitta is given by:

$$S = \frac{1^2}{8r} = 3.4\ mm$$

$$1 = 16.54\ m$$

$$r = 10.108\ km$$

[Ref. Prime Item Requirements Document (PIRD) sec. 3.2.2.1.2.]

The ends of some dipole magnets will interface with spool-pieces. quadrupoles. or other magnets. and this will require the ends of the magnet to be centered in the cryostat.

d. The overall requirement for the field positioning accuracy can be broken down into two main components which interface at the fiducial marks on the outside of the magnet cryostat.

i. Exterior survey and positioning system (SSC).

ii. Magnet accuracy (Vendor).

Our current, belief is that the total tolerance can be divided equally between these two components.

The tolerance assigned to the component relating to magnet accuracy then becomes:

Magnet Overall Accuracy

[Ref. PIRD sec. 3.2.2.5.2.]

X rms	0.7 mm
Y rms	0.7 mm
0 rms	0.6 mrad

e. Magnet overall accuracy

The magnet accuracy specified above is the required accuracy of the relationship of the exterior fiducials to the true axis of a magnet.

This relationship is again made up of two components:

i. Manufacturing precision

ii. Transfer of axis to fiducials

Again, we believe that the error budget can be divided equally between these two components and the error budget assigned to the manufacture and assembly of the magnet becomes:

Magnet Manufacturing Accuracy

X rms	0.5 mm
Y rms	0.5 mm
0 rms	0.4 mrad

An identical error budget is assigned to the transfer of the axis to the fiducials. including measurement errors.

f. Other requirements:

In addition to the average values that must be achieved over a series of magnets. we can also define acceptance limits for an individual magnet.

The manufacturing precision of an individual magnet must meet the following requirements:

i. Departure of the centerline of the cold-mass from the ideal curve shall be within ±1mm horizontally and vertically (with an RMS requirement to be added later).

ii. When the average field angle is vertical. the deviation of a sub-section of the field angle from vertical shall not exceed 10 mrad m.

iii. The overall accuracy of the magnet must enable the average roll axis to be located to ±l mrad.

g. Cooldown

It is predicted that the change in position of the cold mass relative to yoke during cooldown will be uniform for all magnets. This change will be measured during the R&D program at the labs.

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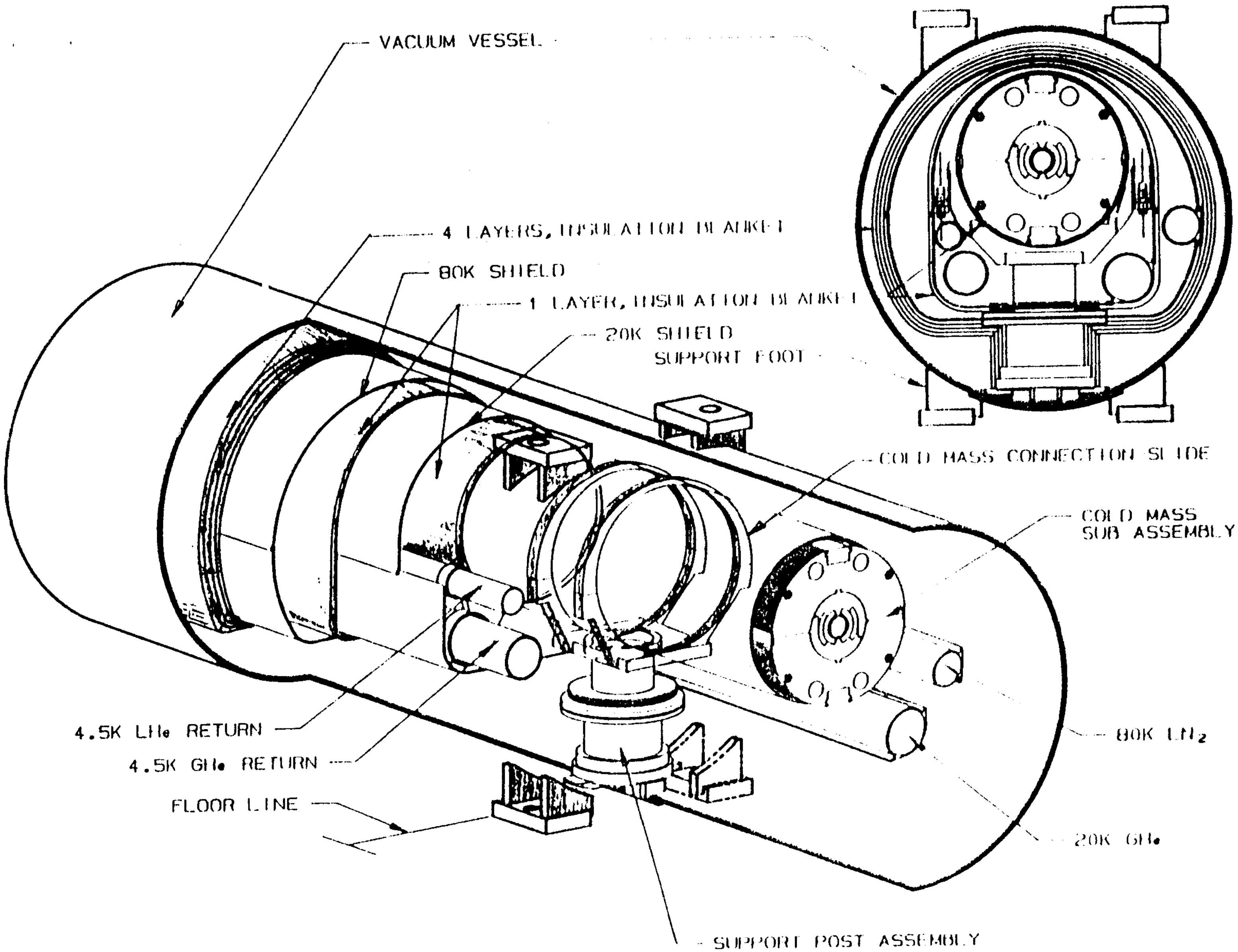

VACUUM VESSEL
4 LAYERS, INSULATION BLANKET
80K SHIELD
1 LAYER, INSULATION BLANKET
20K SHIELD
SUPPORT FOOT
COLD MASS CONNECTION SLIDE
COLD MASS
SUB ASSEMBLY
4.5K LHe RETURN
4.5K GHe RETURN
FLOOR LINE
80K LN2
20K GHe
SUPPORT POST ASSEMBLY

SSC Accelerator Rings
Superconducting Components

Element	Function	Length	Quantity
• Dipole magnet	• Beam steering	17.5m	7,600
• Quadrupole magne	• Beam focusing	4.5m	1,356
• Spool piece	• Magnet power	3.5 - 5.0m	1,656
	• Magnet instr mentation		
	• Magnetic corrections		
	• Cryogen supply/return		
	• Vacuum (beam and insulating		
	• Safety		
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