TD 99-XXX

HGQ-05 production report

**I. Novitski, N. Andreev, R. Bossert, D.Chichili, J.Kerby, F. Nobrega,
A. Makarov, J. Ozelis, T. Arkan, S. Yadav, A. Zlobin.**

Contents

1. Introduction

HGQ-05 is the fourth of several 2-meter long model IR quadrupole magnets to be built at FNAL in support of the LHC project at CERN. The baseline design is described in the HGQ Conceptual Design Report. This report consists of data collected during magnet fabrication and production tests.

Table 1.1. Magnet logs.

Inner Cable Strand No.	38
Inner Cable lay direction	Right Lay
Outer Cable Strand No.	46
Outer Cable lay direction	Left Lay
Cable Pre-baking	None
Inner Cable Insulation	***25uM x 9.5mm w/ 55% overlap surrounded by 50uM x 9.5mm w/2mm gaps w/Epoxy***
Outer Cable Insulation	***25uM x 9.5mm w/ 43% overlap surrounded by 25uM x 9.5mm w/50% overlap w/Epoxy***
Coil Curing temperature	***135C***
Inner Coil target size	***+.009 in., +225uM***
Inner Coil MOE	***8GPa***
Outer Coil target size	***+.006 in., +150uM***
Outer Coil MOE	***11GPa***
Target Prestress	***65-70MPa***
Coil end azimuthal Shim	Shim ends to be same as body, tapering off toward end of saddle.
End Part Material	***G-10***
End Part Configuration	Iteration #1, 4 block design. Wedges extended in outer coil. Saddles shortened by 21mm.
Splice Configuration	Internal
Voltage Tap Plan	MD-344972/MD-344973
Inter layer strip heaters	Traditional, single element.
Outer layer strip heaters	***McInturff design, double element.***
Key extension	***None***
Inner coil Bearing Strips	***Brass, cut in 3 inch segments, same as collar packs.***
Outer coil Bearing Strips	***Phosphor bronze, cut in 3 inch segments, same as collar packs.***
Collar configuration	***3 inch long "solid" welded packs, with 49 lamination period.***
Collar key configuration	***3 inch long, positioned same as packs.***
Strain Gauges	***4 beam gauges on outer coil, 4 capacitor gauges on inner coil, 4 capacitor gauges on outer coil.***
Spot Heaters	***Pole turn on 2 outer coils, at lead end on parting plane turn on 1 outer coil.***
End Radial Support	***Collets end clamps on both ends. Aluminum exterior cans with G-10 quadrant pieces.***
Collar/Yoke Interface	Radial clearance between collar and yoke.
Configuration	***Single lead with copper only cable for stabilizer***
End longitudinal loading	***Bullets apply load directly to coils, 2000 lbs. force per bullet. End cans are bolted to end plates longitudinally, preventing coils from contracting longitudinally.***
Yoke Key Width	24mm
Strain Gauges on Skin	Yes
End Plate Thickness	50mm
Tuning Shims	***Layed into collared coil/yoke. Fixed in place.***
Other	Inner coils recured to increase MOE. 2 collar packs with thermometers.
Coil Fabrication Start Date	8/17/98
Collared Coil Start Date	1/25/99
Yoke Assy Start Date	2/10/99
Completion Date	2/24/99

2. Superconducting Cable.

2.1 Cable parameters.

Tables 2.1,2.2,2.3 show the mechanical and electrical parameters for the HGQ-05 inner and outer cables.

Table 2.1. Cable Mechanical Parameters

Parameter	Unit	Inner cable by design	Inner cable for HGQ-05	Outer cable by design	Outer cable for HGQ-05
Radial width, bare	mm	**15.4**	**15.4074**	**15.4**	**15.3960**
Minor edge, bare	mm	**1.326**	**1.312**	**1.054**	**1.0542**
Major edge, bare	mm	**1.587**	**1.602**	**1.238**	**1.2372**
Midthickness, bare	mm	**1.457**	**1.4573**	**1.146**	**1.1457**
Keystone angle,	deg	**0.990**	**1.077**	**0.690**	**0.681**
Cable packing factor		0.91		0.901	**0.909**
Number of strands		38	38	46	46
Strand diameter	mm	0.808		0.648	**0.6508**
Pitch direction		right	right	left	left
Pitch length	mm	114	**119**	101.6	**102.441**

Table 2.2. Cable Electrical Parameters

Parameter	Unit	Inner cable	Outer cable
R (295 K)	μohm	15.836	18.22
R (10 K)	μohm	0.400	0.416
RRR		40	44
Cu / Sc		1.36	1.85

Table 2.3. Cable test data

T = 4.22 K	Unit	Inner cable			Outer cable		
B	T	6.00	7.00	8.00	6.00	7.00	8.00
Ic	kA	18.563	14.123	9.682	11.748	8.670	5.593
Jc	A/mm^2	2236	1701	1166	2191	1617	1043

The cable inspection dates are included in Appendix.

2.2. Cable cleaning.

Both inner and outer cables have been cleaned before insulating.
We are, temporarily, cleaning the cable with **Axarel 6100** in the SSC cleaning module.

2.3. Cable and Wedge Insulation

Cable insulation parameters are summarized in Table 2.4.

Table 2.4. HGQ-05 cable insulation parameters.

Parameter	Inner cable	Outer cable
Number of wraps	2	2
Inner wrap:		
-material	Kapton tape 25 μm×9.5 mm	Kapton tape 25 μm×9.5 mm
-adhesive	None	None
-wrap structure	Spiral wrap with 55% overlap	Spiral wrap with 48% overlap
-thickness	50 μm	50 μm
Outer wrap:		
-material	Kapton tape 50 μm ×9.5 mm	Kapton tape 25 μm ×9.5 mm
-adhesive	Scotch 2290 epoxy adhesive on outer side	Scotch 2290 epoxy adhesive on outer side
-wrap structure	Spiral wrap with 2 mm gap	Spiral wrap with 43-46% overlap(.5-.3 mm gap)
-thickness	50 μm	50 μm
Total undeformed thickness	100 μm	100 μm
Cable insulation adhesive	Scotch 2290 epoxy adhesive	Scotch 2290 epoxy adhesive

3. Inner and Outer Coils

Four inner and **five outer** coils had been wound, cured and measured as potential coils for HGQ-05. All inner and four outer coils used in HGQ-05 are included in this report.

3.1 Winding and curing.

The nominal winding tension of 36.28 kG [80 lbs] was used for all turns on both inner and outer coils.
Two wedges, one per octant, were used in each outer and inner coil. 3mm gaps were placed longitudinally between end spacers and wedges on each end.
All inner and outer coils had the three piece wedge configuration on both sides (as noted on traveler).
All coils, both inner and outer, are cured in mold cavities, which are designed to have the precise cross section of the finished after they are assembled with the final design preload applied. Cavity sizes are, however, shimmed to adjust azimuthal coil size. Azimuthal coil sizes are changed to achieve the desired preload in the assembled magnet, based on prior empirical evidence. All inner coils had been recurred once to achieve this goal as well as reduce a difference in elastic coil modulus between inner and outer layers.
Curing mold cavity azimuthal shim was 178 - 711 mm [0.007-0.028 in] for inner coils and 127 mm [0.005 in] for outer coils with respect to design size. The coils are cured under radial and azimuthal pressure. The curing cycle was identical for both inner and outer coils. Temperature and pressure regimes are shown on Fig.3.1 and listed in the procedure below.

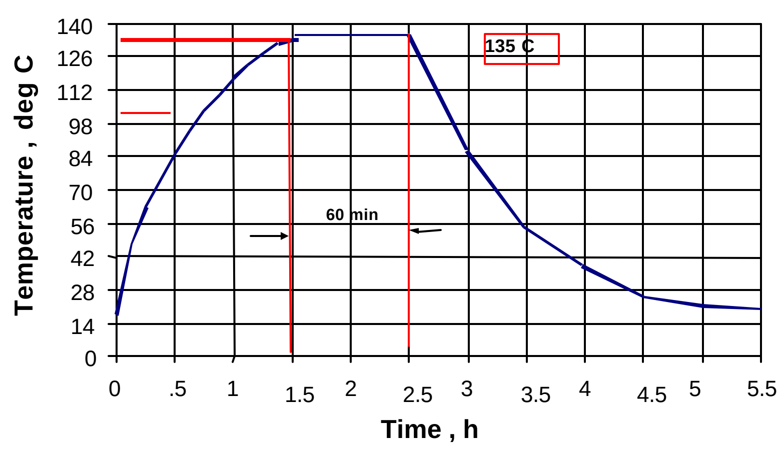

Figure 3.1. Coil curing thermal cycle.

Recuring cycle for HGQi-035 inner coil.

I.Novitski, N.Andreev. 11/20/98

1. Before installing end retainers, mark position of end saddle pushers at ends of mandrel with a permanent marker.
2. Complete packaging according to traveler and put mold into press.
3. Make sure end saddle pushers are inserted up to mark on pushers.
4. Close the last platen cylinder valve on each end. All mandrel cylinders are open.
5. Apply **2500** pump psi mandrel pressure.
6. Apply **1000** pump psi platen pressure.
7. Lower platen pressure to **500** pump psi.
8. Lower mandrel pressure to **500** pump psi.
9. Apply **750** pump psi end cylinder pressure.
10. Increase mandrel pressure to **3000** pump psi.
11. Increase platen pressure to **1000** pump psi.
12. Check gaps between mold stop and upper platen.
13. Starts heat cycle.
14. When T = **65** C check gaps.
15. Increase platen pressure to **4000** pump psi.
16. Verify that mandrel pressure is still **2500** pump psi
17. When T = **90** C check gaps
18. Increase platen pressure to **6000** pump psi.
19. Verify that mandrel pressure is still **2500** pump psi
20. When T = **105** C check gaps.
21. Lower platen pressure to **500** pump psi.
22. Lower mandrel pressure to **500** pump psi.
23. Lower end pressure to **250** pump psi.
24. Increase mandrel pressure to **2500** pump psi
25. Increase platen pressure to **4000** pump psi.
26. Increase end pressure to **750** pump psi.
27. Increase platen pressure to **8000** pump psi.
28. When T = **135** C check gaps.
29. After one hour at **135** C, turn off heaters. Maintain all pressures until coil is below **49** C.
30. After coil is below **49** C, release end pressure.
31. Release platen pressure.
32. Release mandrel pressure.
33. Remove mold from press.

3.2 Stabilizer.

The stabilizer (the same piece of cable ~30 mm long) was soldered on the cable at lead end of coils after curing to protect cable from popping strands and collapsing during the magnet assembly process.

3.3 Coil size and modulus.

Azimuthal size measurements of the coils are taken at a range of pressures encompassing those, which the magnet will experience during operation. Specifically, the coils are measured at pressure of 55MPa, 70MPa, 83 MPa and 97 MPa (8000 psi, 10000 psi, 12000 psi and 14000 psi).

Table 3.2. Inner Coil body size and Modulus.

Coil	Coil average modulus [GPa] at pressure range 55-97 MPa		Coil size at 83 MPa coil pressure [µm]			
	Average	Stand. Div.	Side A	Stand. Div.	Side B	Stand. Div.
I-035	7.9	0.25	221	15	223	12
I-036	8.4	0.37	201	13	220	19
I-037	8.0	0.42	210	28	191	22
I-038	7.8	0.28	212	15	231	22

Table 3.3. Outer Coil body size and Modulus.

Coil	Coil average modulus [GPa] at pressure range 55-97 MPa		Coil size at 83 MPa coil pressure [µm]			
	Average	Stand. Div.	Side A	Stand. Div.	Side B	Stand. Div.
O-028	11	0.36	329	20	306	25
O-029	10.6	0.3	309	18	270	24
O-032	10.5	0.34	339	19	331	18
O-033	11.	0.46	331	21	330	20

Coils are measured azimuthally in increments of 76.2 mm [3 in] along the straight section starting from the Lead End. Position #10 is in the middle of the coil straight section or coil body.

Size measurements and coil modules along inner and outer coils are shown in Figures 3.4 and 3.5.

A- side on which winding of, first turn begins, B- side which includes parting plane lead.

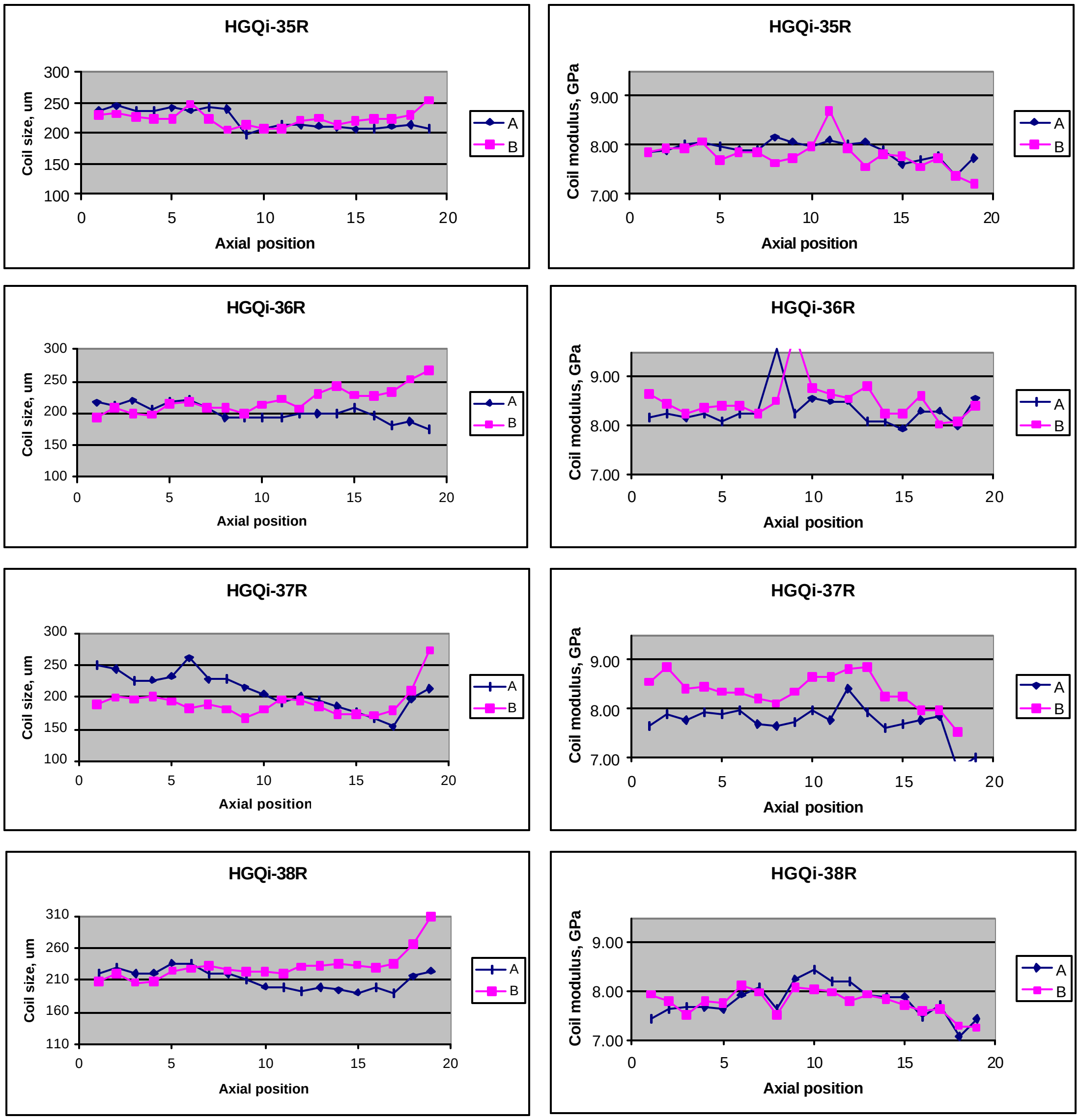

Figure 3.4. Inner coil azimuthal size and modulus along length.

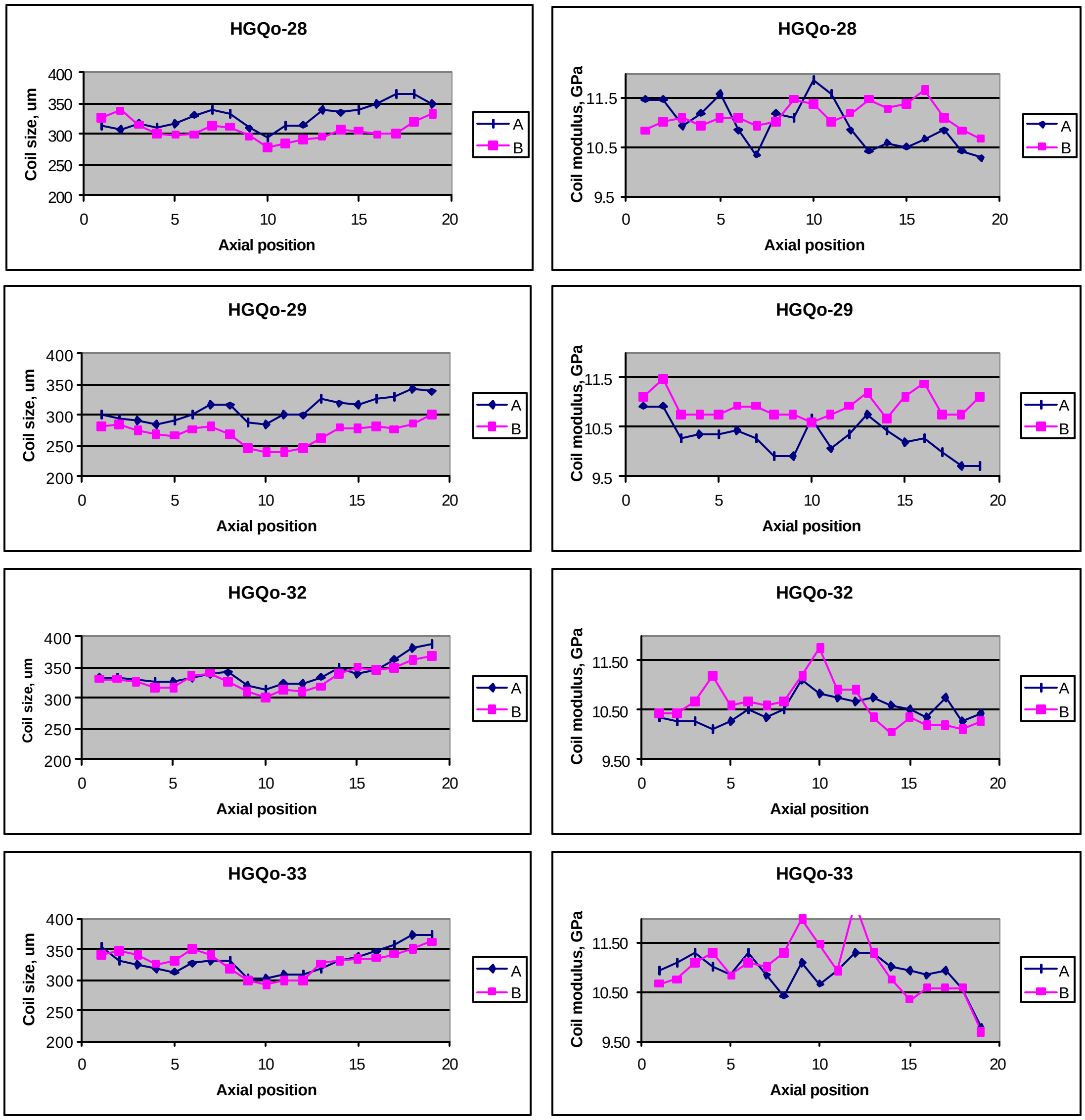

Figure 3.5. Outer coil azimuthal size and modulus along length.

The end fixture was designed to check electrically coil ends for turn-to-turn shorts at azimuthal pressures of 83 MPa (12000 psi). All coils passed this test successfully. This fixture was also used for coil azimuthal end measurements.

The measured area 25.4mm [1 in] was used for sizing along the coil's ends at pressure ~40 MPa. The results have shown on Fig. 3.6-3.9.

The radial and azimuthal pressure distribution on the ends as well as on the transition regions has been checked with 127 mm [5in] block at 83 MPa using a Fuji film.

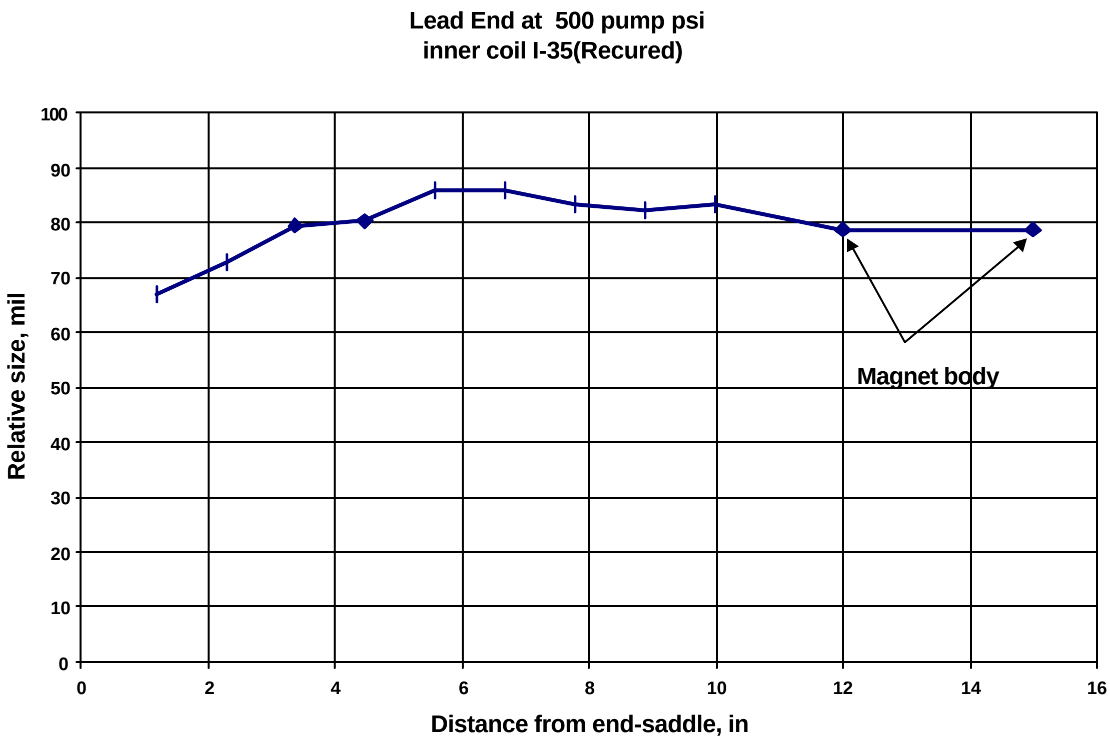

Figure 3.6. Lead End for coil I-35R.

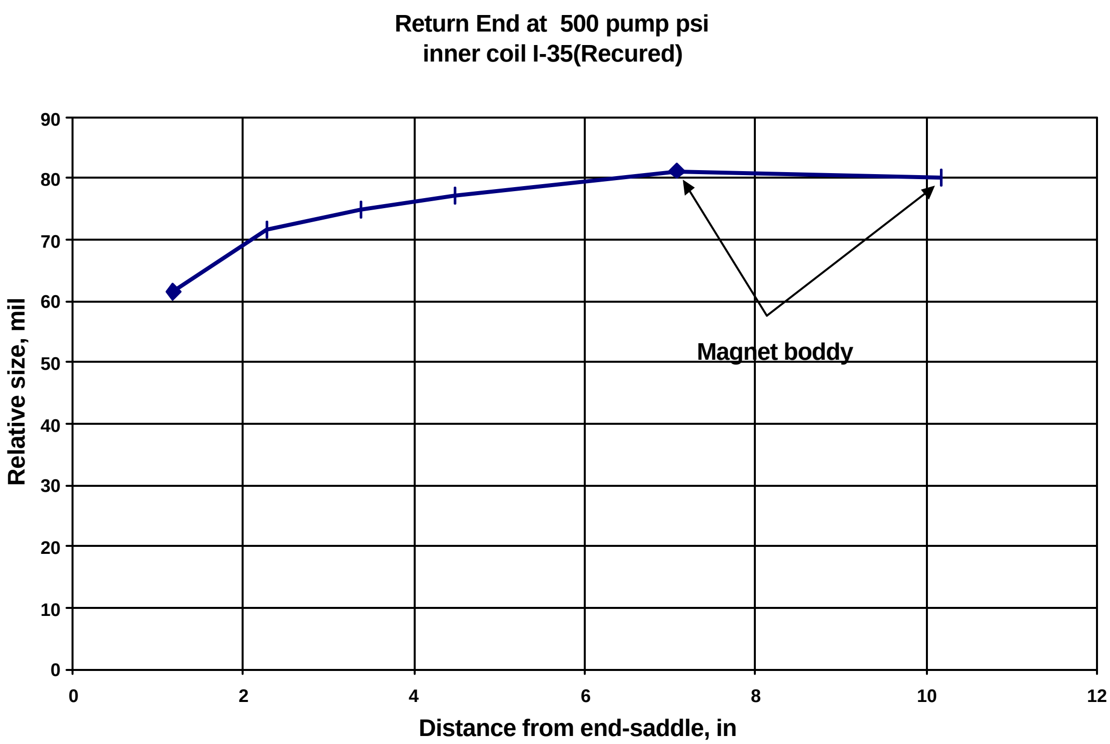

Figure 3.7. Return End for coil I-35R

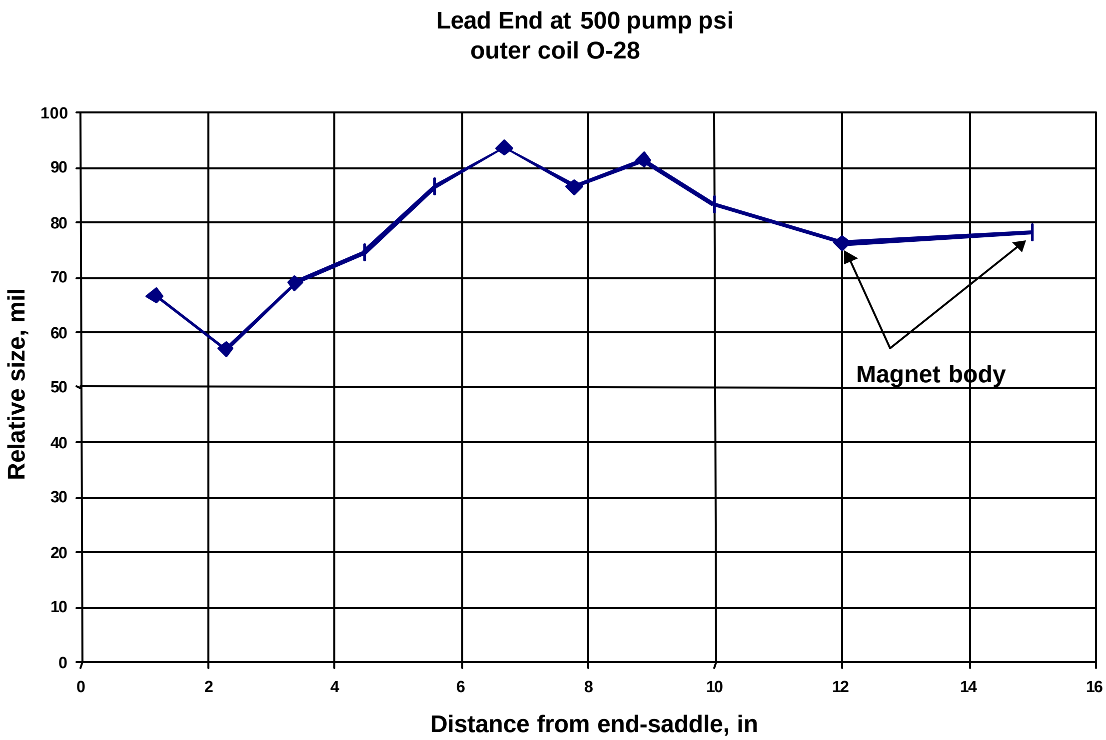

Figure 3.8. Lead End for coil O-28.

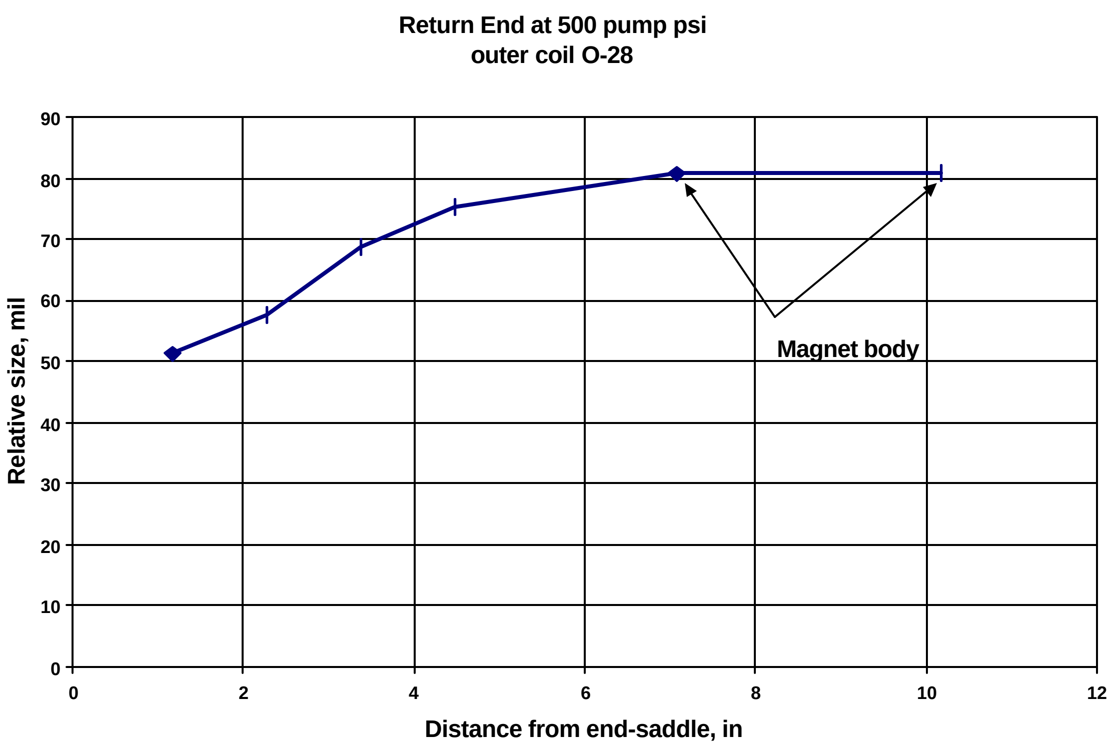

Figure 3.9. Return End for coil O-28.

3.6 Spot heaters and voltage taps.

The drawing numbers for voltage taps and heaters are 5520-MD-344972 and 5520-MD-344973.
All coils were tested in the end fixture after voltage tap installation. No shorts due to voltage taps were discovered during the end compression tests.

4. Collared coil.

4.1 Preload adjustment.

Room temperature preload for HGQ-05 in the inner ~65 MPa and outer layer ~ 70 MPa corresponds to a coil azimuthal size of +225 μm for inner and +150 μm for outer coils measured at 83 MPa. The inner coil size was approximately +215 μm [+0.0085 in], so they had not to be shimmed. The outer coil sizes were +305, +320 μm [+0.012, +0.013 in], so they needed to be shimmed down ward by –170, -155 μm [-0.007, -0.006 in]. One layer of the ground insulation (125 μm, 0.005 in) was removed from mid-plane and from pole regions for the outer coil. Than, one layer 75 μm (0.003 in) Kapton was added to the bearing strip. In additional to the body, the end region shim had been calculated according to end measurements taken every one-inch started from saddle ends.

4.2 Shim plan.

All coils had been shimmed downward at the parting plane and at the pole, uniformly across the coil from end-of-saddle to end-of-saddle. The shim plan is shown on figure 4.1.

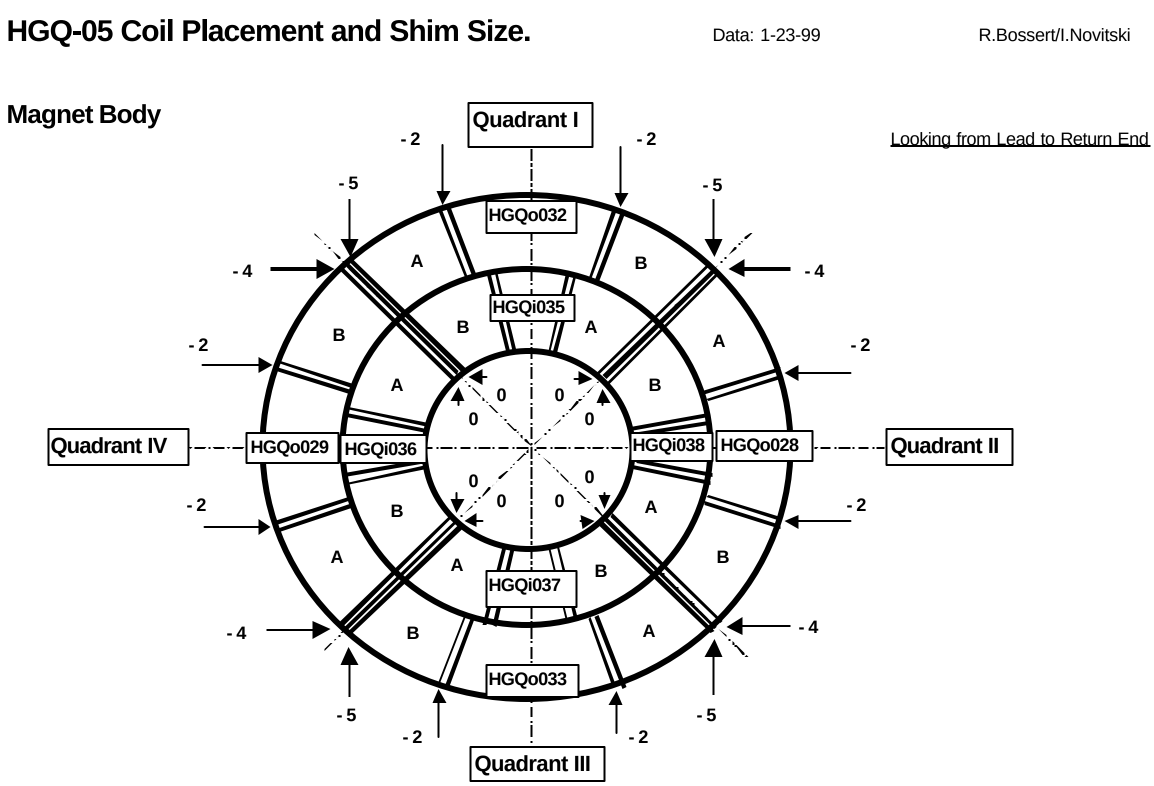

Figure 4.1. Magnet body cross-section.

4.3 Quench protection strip heaters.

Quench protection strip heaters were placed in between the inner and the outer layer and also added to the space between the outer layer and the collars (Fig.4.2). The strip heater assembly is 75 µm (0.003 in) thick for inner and 114 µm (0.0045 in) for outer layers. Inner heater consists of a 25 µm (0.001 in) stainless steel strip covered on each side by a 25 µm (0.001 in) Kapton "cover sheets". Outer layer (copper coated) Mac's heater is double element strip heater. This heater has twice bidder an effective surface and covered completely on quadrant of the coil assembly. To minimize the preload differences due to the strip outer heater, one of the Kapton cover sheets (the one facing the collars) was removed on the body. Finally, we have ~175 µm (0.009 in) Kapton insulation between each strip heaters and the coils body.

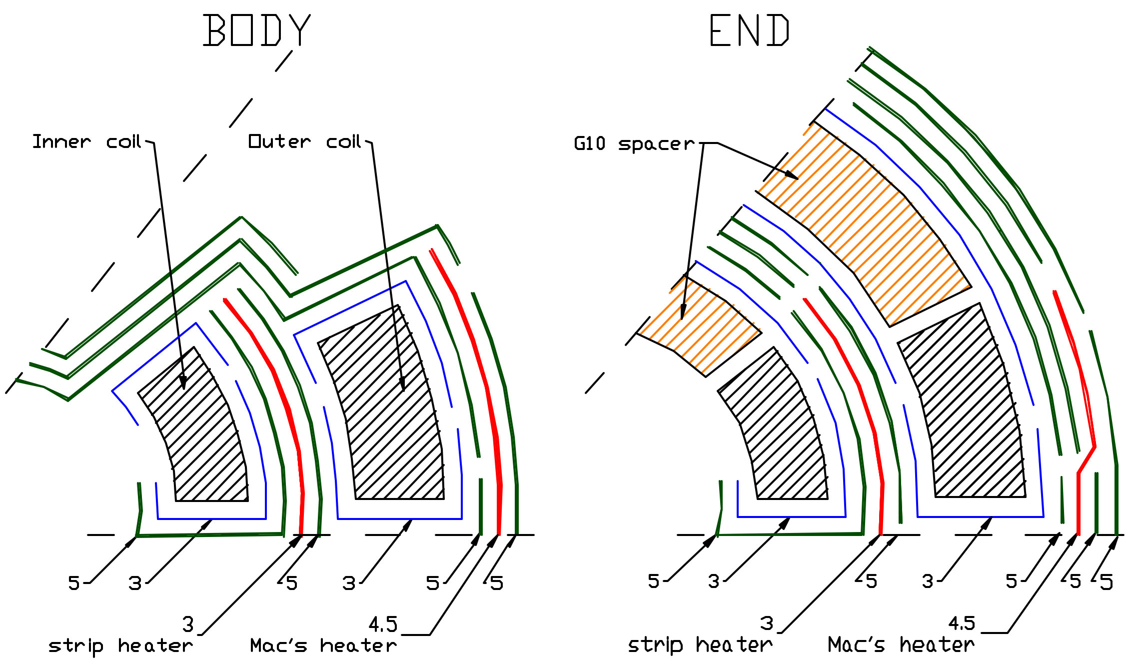

Figure 4.2. Strip heater location and ground wrap system.

At least 125 µm Kapton insulation covered heaters at transition and end areas. The ground wrap was modified specially at Lead and Return Ends to ensure there was no heater-to-collar ground short potential and to obtain end can deflections.

4.4 Strain gauges.

Coil size in the different quadrants along the magnet, which was calculated according to the coil size data, shimming data and coil location in the magnet is shown in Fig. 4.3.

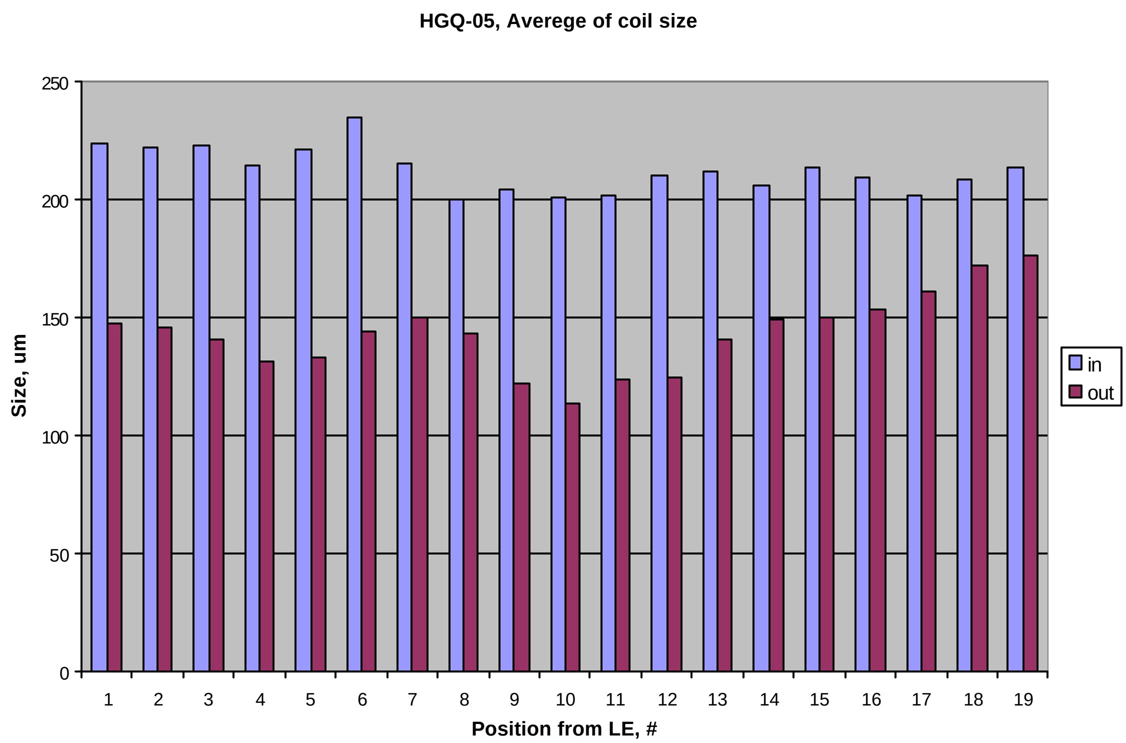

Figure 4.3. Inner and outer coil size by quadrant along the magnet (with respect to nominal).

Longitudinal positions #10 and #18 in the magnet body were chosen for strain gauge installation. Each strain gauge position is instrumented with two beam gauges, four temperature-compensating gauges, and with four capacitance gauges. Gauge locations are shown on Fig.4.4,4.5.

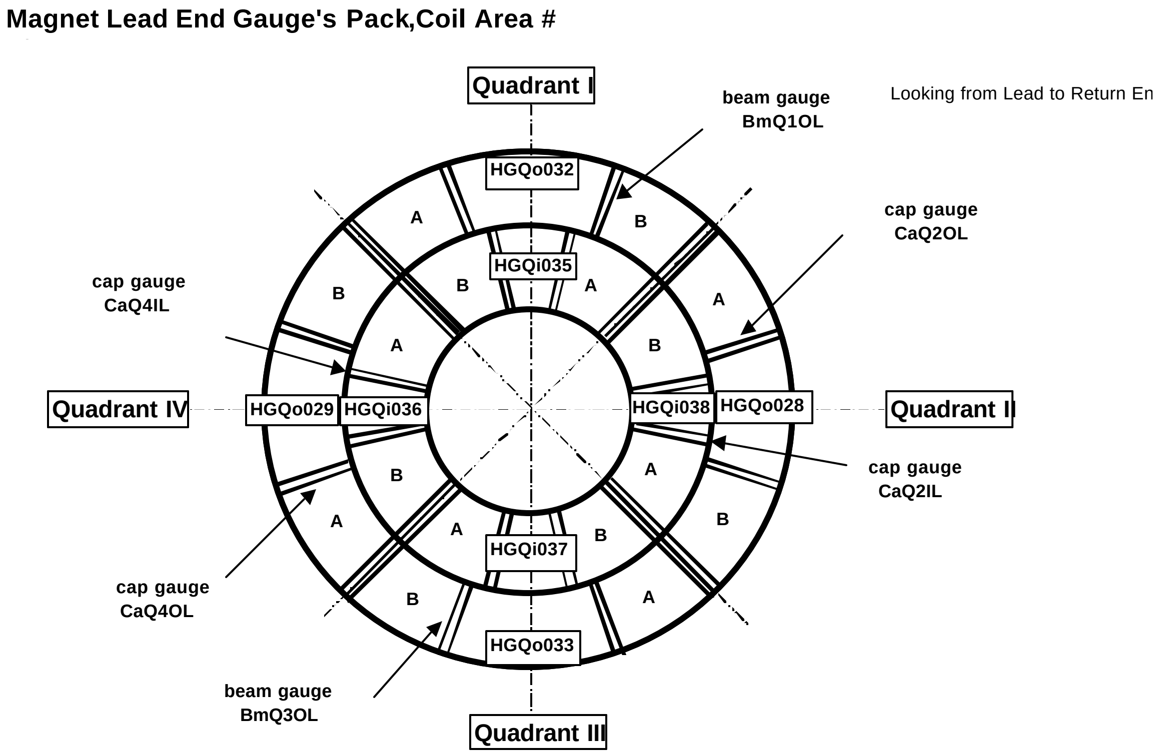

Figure 4.4. Magnet longitudinal position #10.

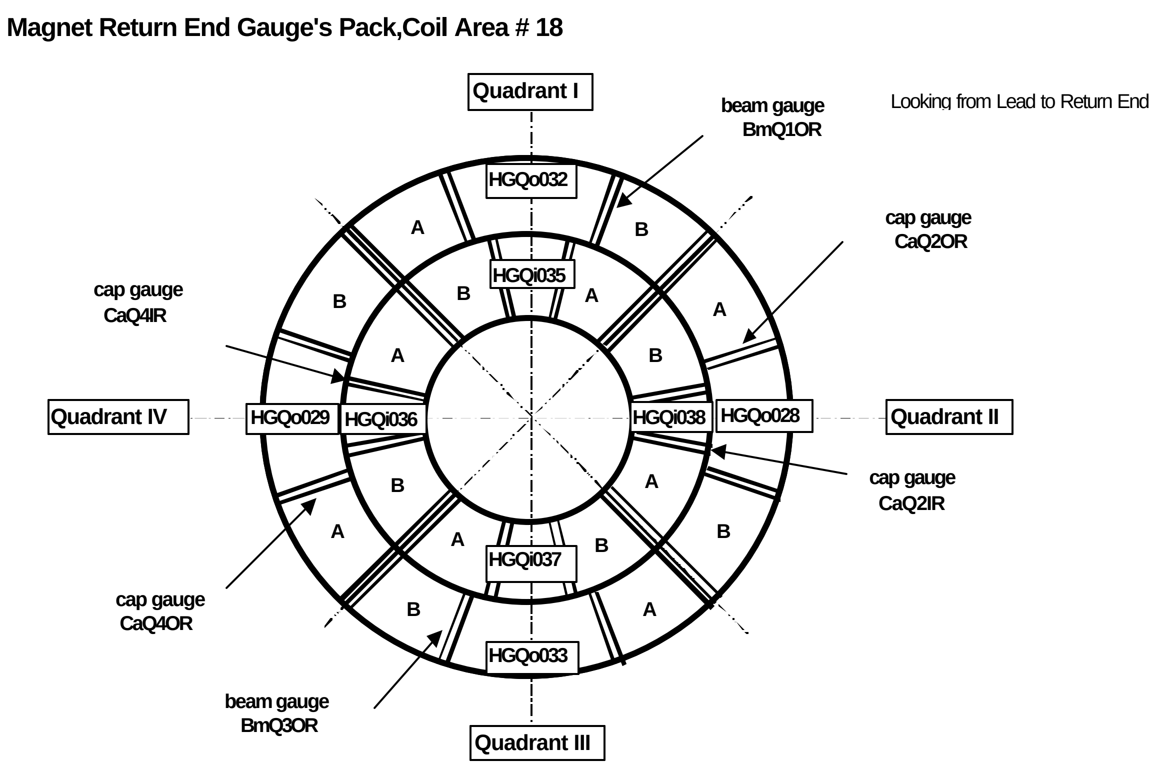

Figure 4.5. Magnet longitudinal position #18.

4.5 Keying.

Special collar pack was used to increase axial rigidity of the coil's body. The collar pack shown on Figure 4.6.

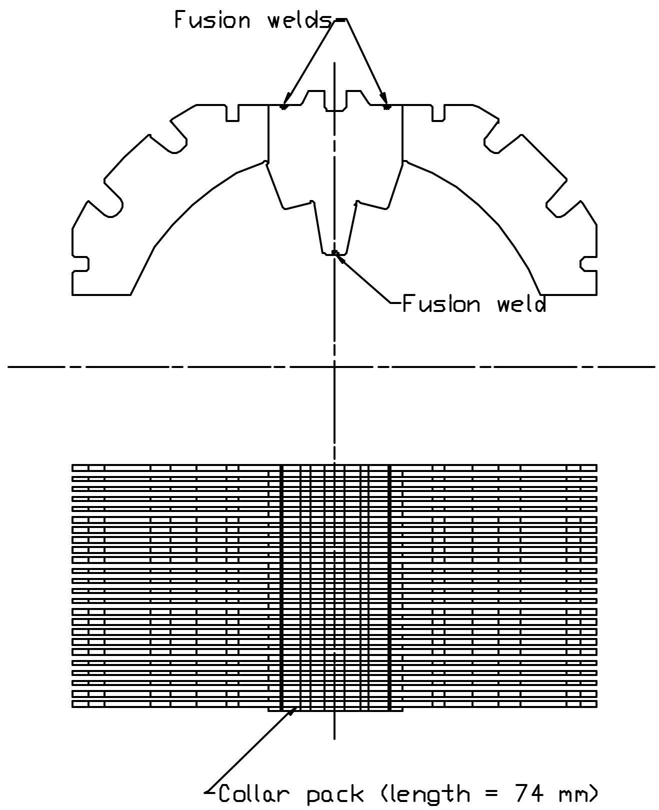

Figure 4.6. Collar pack.

Several different lengths of collar pack had been used, 74 mm (48 pieces), 75.5 mm (49 pieces), 72.5 mm (47 pieces), 48 mm (32 pieces) and 46.5 mm (31 pieces). Small bearing strips approximately same length as packs were placed on the packs. They were attached to the poles at the pack ends using 25 (0.001 in) tick adhesive Kapton tape. First and last packs were insulated at the ends to avoid coil-to-ground shorts, because no key extensions used in the magnet.

The magnet is packed started from Return End using the vertical keying press.

The collared assembly is "massaged" at 1500 and 3000 pump psi of the main pressure (MP), partially keyed by hand at MP=4500 pump psi. Final keying was done at MP=6500 pump psi using 3000 pump psi of the key pressure (KP). Short 3 in keys was used for keying. No shorts to ground during keying had been discovered.

Figure 4.7 shows pack's location along the body and keying procedure in details.

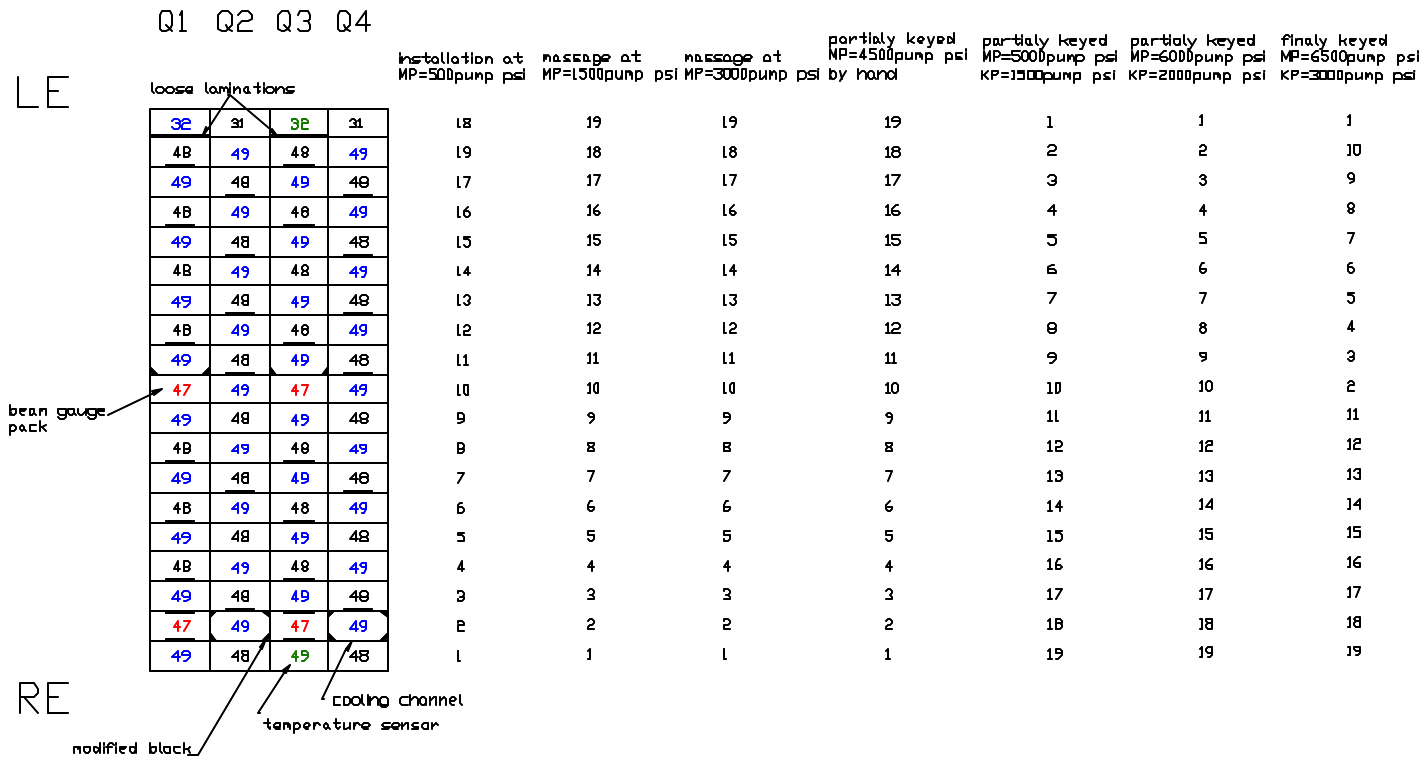

Figure 4.7. Map of packs and keying procedure.

4.6 Final pressures.

The final pressures after magnet keying are shown in Tab. 4.8. The strain gauges nearer the lead end are designated “lead end” and the strain gauges nearer the return end are designated “ return end”, even though the gauges are within the body, and not actually at the lead or return end.

Table 4.8 Final pressures.

Gauge ID	Type	Coil	Function	Quadrant	End	VMTF Name	IB#3 Data	
							Pressure	
							psi	MPa
LHCO025	Beam	O	Active	1	R	BmQ1OR	9233	64
LHCO026	Beam	O	Active	3	R	BmQ3OR	7736	54
LHCO027	Beam	O	Active	3	L	BmQ3OL	5014	35
LHCO028	Beam	O	Active	1	L	BmQ1OL	6766	47
HQCG58	Capacitance	I	Active	4	L	CaQ4IL	13434	94
HQCG59	Capacitance	I	Active	2	L	CaQ2IL	14198	99
HQCG61	Capacitance	O	Active	2	L	CaQ2OL	BAD	
HQCG66	Capacitance	O	Active	4	L	CaQ4OL	11096	77
HQCG62	Capacitance	I	Active	2	R	CaQ2IR	15567	109
HQCG65	Capacitance	O	Active	4	R	CaQ4OR	12004	84
HQCG67	Capacitance	O	Active	2	R	CaQ2OR	BAD	
HQCG68	Capacitance	I	Active	4	R	CaQ4IR	BAD	

4.7 Mechanical measurements.

The OD measurement data for collared coil block after RE can on show on Fig. 4.10, 4.11.

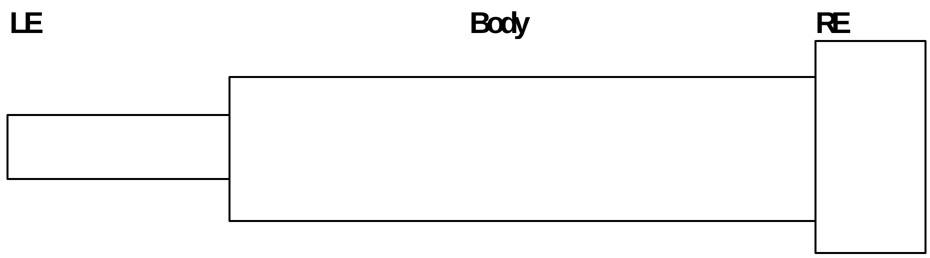

Figure 4.9. Collared coils with RE can on.

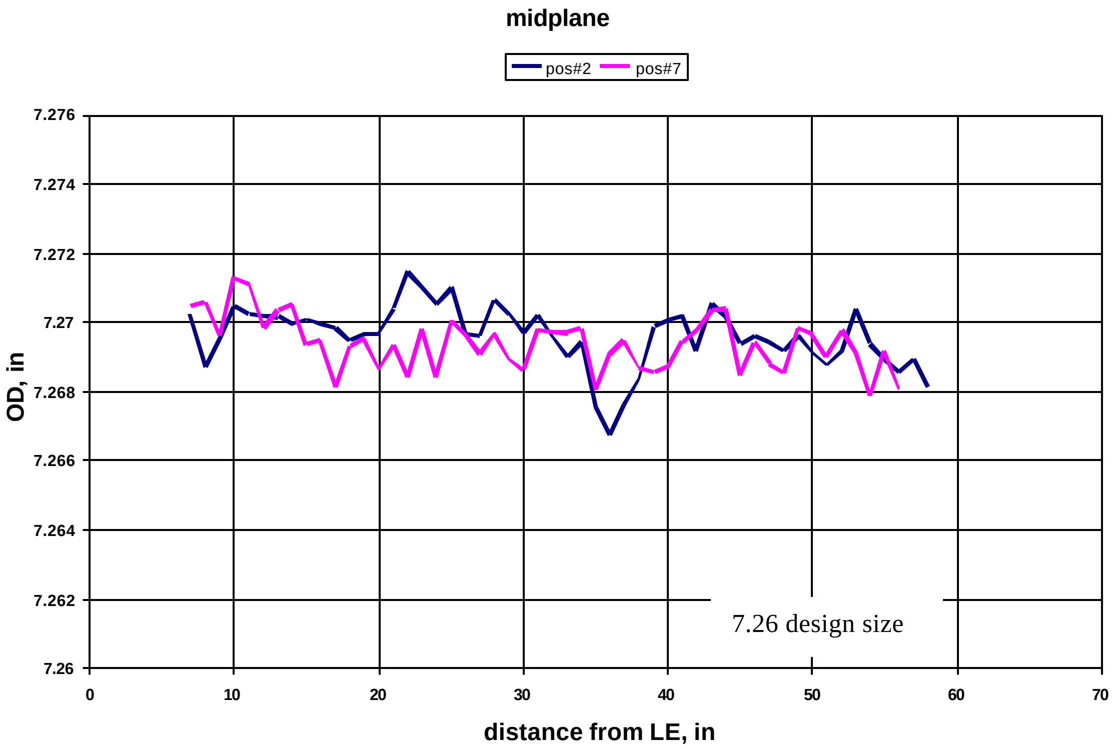

Figure 4.10. Collared coil deflections at midplane region.

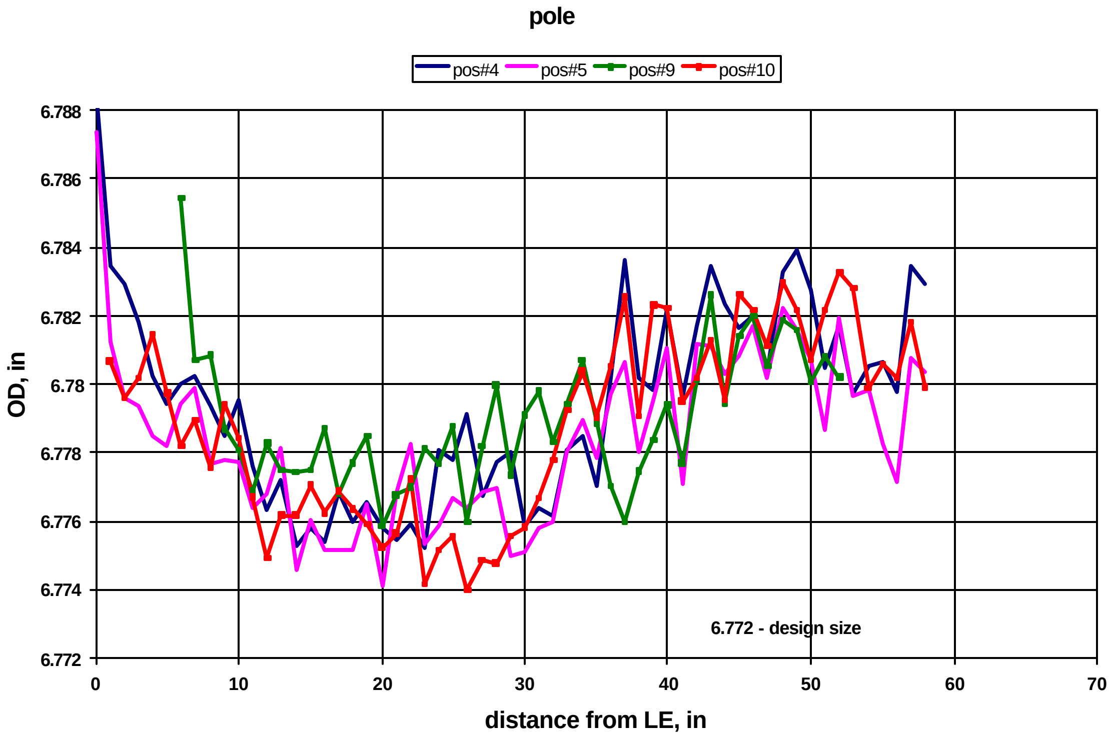

Figure 4.11. Collared coil deflections at pole region.

4.8 Splice.

The pole turn of each inner/outer coil pair needs to be spliced together. The internal splice configuration is used for HGQ-05. Splices are 114 mm long, which is approximately equal to the cable transposition pitch. Areas to be spliced are preformed, or filled with solder before the coil is wound. The tinned sections are then spliced after the magnet straight section is collared, keyed and the Return end can was installed. The maximum temperature for the turn next to the heater during the splicing processes was about 140 F. A cooling fixture was attached at the coil side so that the coil is not heated up. No cooling channels were made in the splice insulation.

4.9 End can.

Fuji film tests were performed before End can final installation.
The results of the Fuji film readings showed that there is a uniform radial pressure distribution from the transition region to the middle of the large current block and gradual, uniform decrease of pressure to the end-saddle.
The thickness of radial ground insulation surrounding the outer coil was increased by 130 μm [0.005 in] from the original design.
The End Cans were installed on the lead and return ends of the coil assembly using a longitudinal force of 66660 and 45000 lbs (at 9750 and 6500-pump psi). The radial deflection of aluminum ring according pi-tape measurements is ~ 140 μm [0.0055 in].

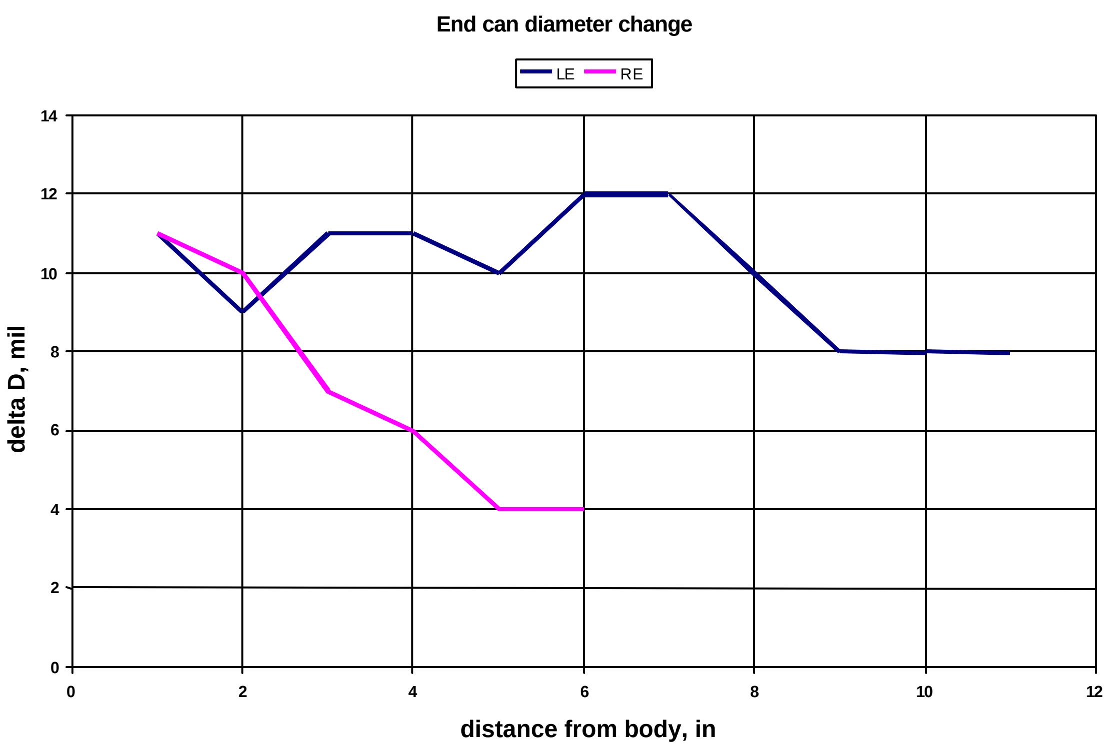

Figure 4.12. End can region.

5. Cold mass assembly

5.1 Yoking and skinning.

The following schematic represents the yoking assembly:

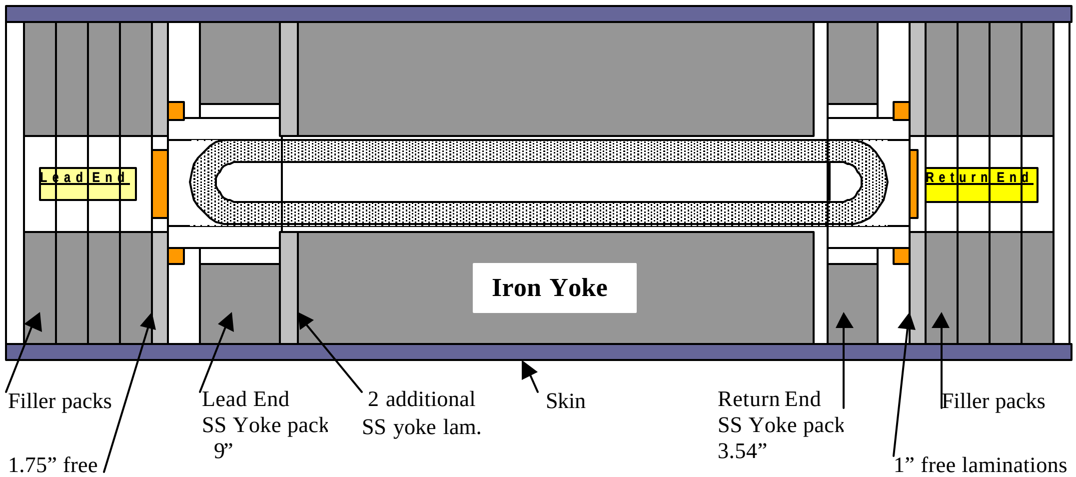

Figure 5.1. Yoke and skin layout.

All lamination packs were fusion welded longitudinally in 7 places (5 welds on outer surface and 2 welds on inner surface).

5.2 Tuning shims.

Tuning shims were bonded together using 5 min epoxy. The assembly was then tack welded into the yoke halves. Five tack welds were used, one in the middle, on both ends and one centered between the center and the ends. (See P0000486 at the web site, http://tspc01.fnal.gov/html/nobrega/HGQ05Yoke/.) One of the tack welds was broken on purpose because the tuning shim was bowed into the body of the yoke and would have interfered with the collar coil assembly insertion. The broken weld is in the second position from the near end on the far right side in figure P0000845A. When the weld was broken, the glue bond also failed and "super glue" was used to bond it back together. In the upper half of the yoke the parting plane welds at the ends were such that they're existed a gap between the tuning shim and the yoke. Using a hammer on the brass shim the weld was smashed and the gap was eliminated between the shim and yoke. Picture P0000484 shows the lower yoke but the tack welds discussed above were on the other end and no picture is available.

We removed the ends of the lifting fixture, as it was too long to pick the collar coil assembly with the collets in place. The center portion of the lifting fixture was strong enough to lift the ~870 lbs. of the coil assembly. For reference, this configuration can NOT be used to lift a main body yoke pack. The collar assembly went into the lower yoke very nicely and with out any problems from the tuning shims or the yoke. This is primarily due to the straightness of the assembly. There was a clearance between the tuning shims and a single collar lamination on the order of 20-30 mils using uncalibrated eye. The upper half of the yoke was the easiest to install of all the model magnets to date. We moved the collared coil assembly to the center building after 8:30 (later than expected) and rolled the magnet into the press by 1:30.

5.3. Welding

The skin alignment key was 24 mm wide same as for HGQ-03. This leaves a gap of 1.75 mm between the yoke and the skin.The magnet was compressed at 600 Psi during welding. The magnet was compressed in the weld tooling with a hydraulic pressure of 600 PSI corresponded to force about 8000 lbs (3600 kg) per pusher or 16000 lbs/ft (23700 kg/meter) of magnet length. A pressure above 500 PSI must be applied to completely collapse the springs in the wheel units of the bottom tooling. The distance between the top and bottom pushers was measured from both the north and south side of the press all along the length of the magnet (see Fig. 5.2).

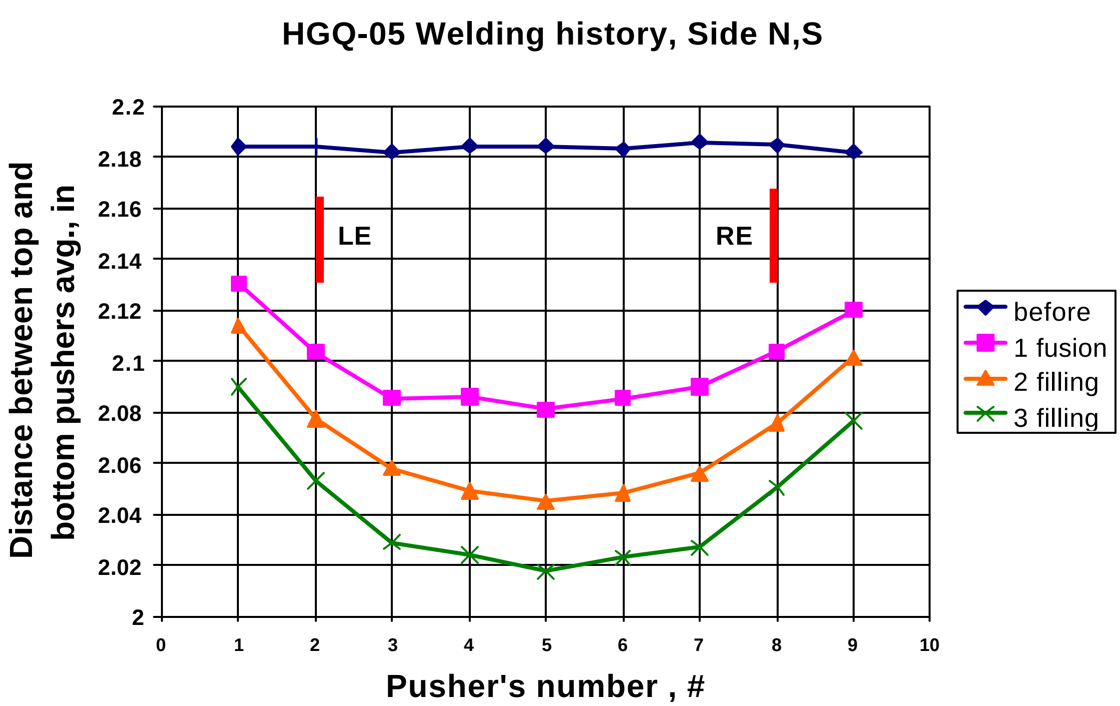

Fig. 5.2. Distance between top and bottom pushers.

The skin diameter measurements after welding are shown in Fig 5.2.

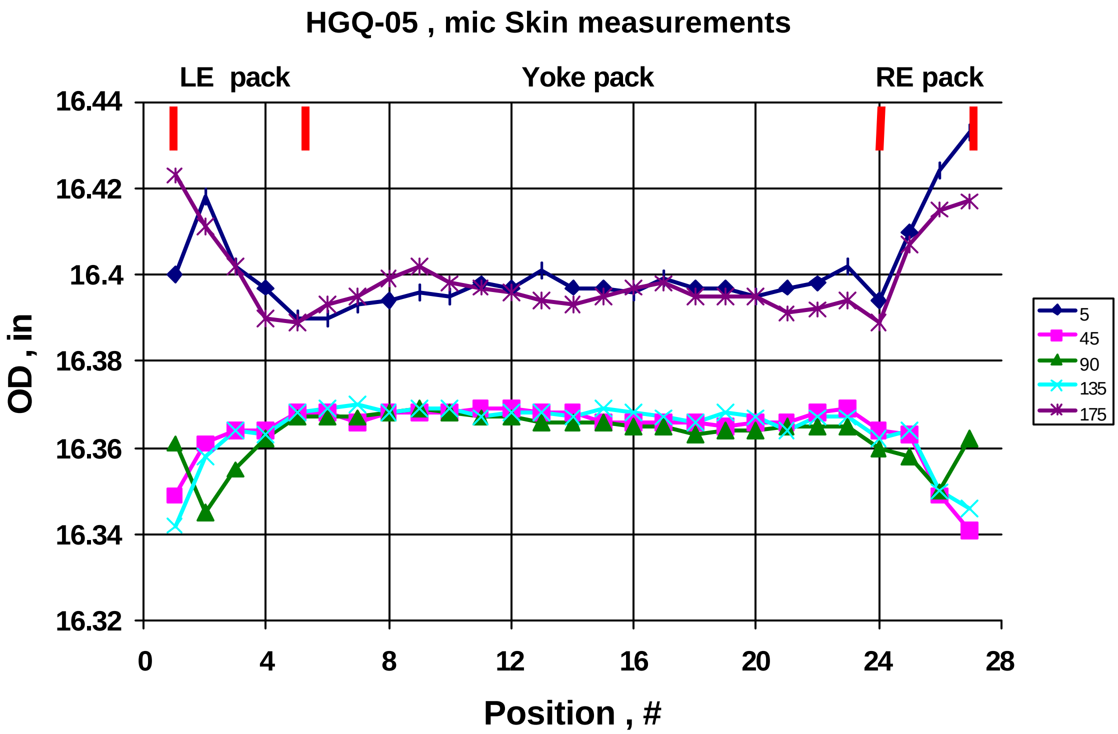

Fig.5.3. Skin outer diameter according to micrometer measurements taken at different angular positions between skin allayment keys.

Magnet lengths as design and as built shown on figures 5.4, 5.5.

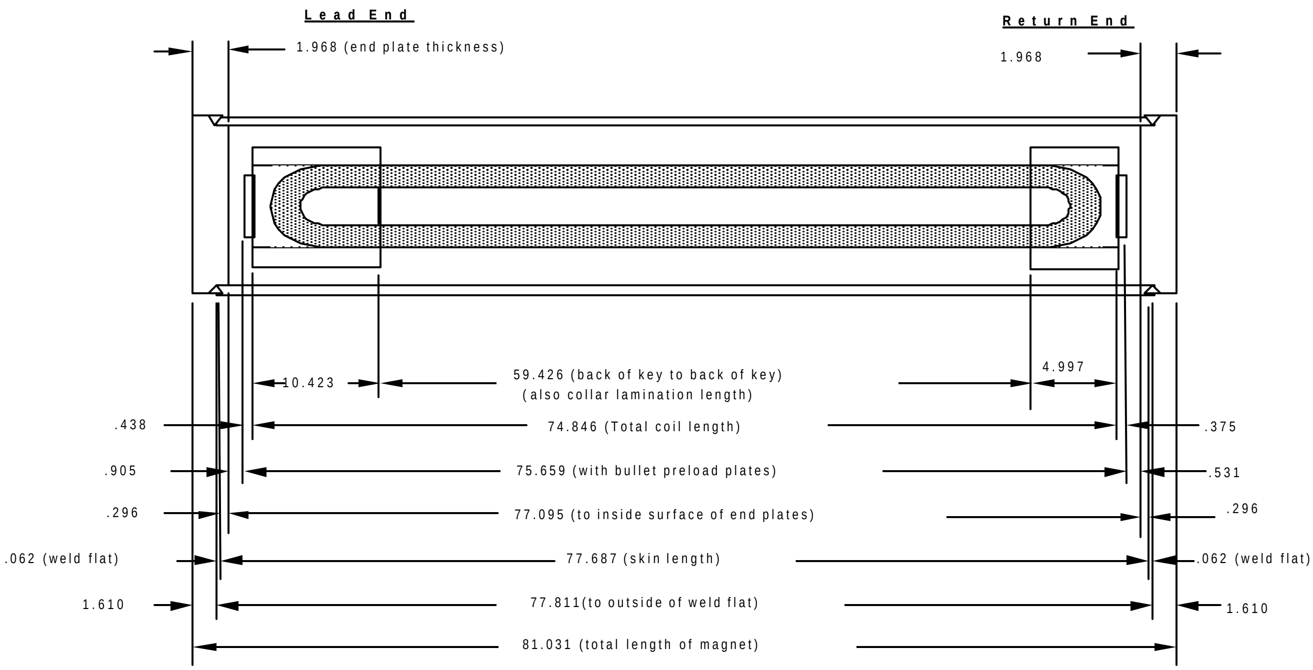

Figure 5.4. The design dimensions for HGQ05

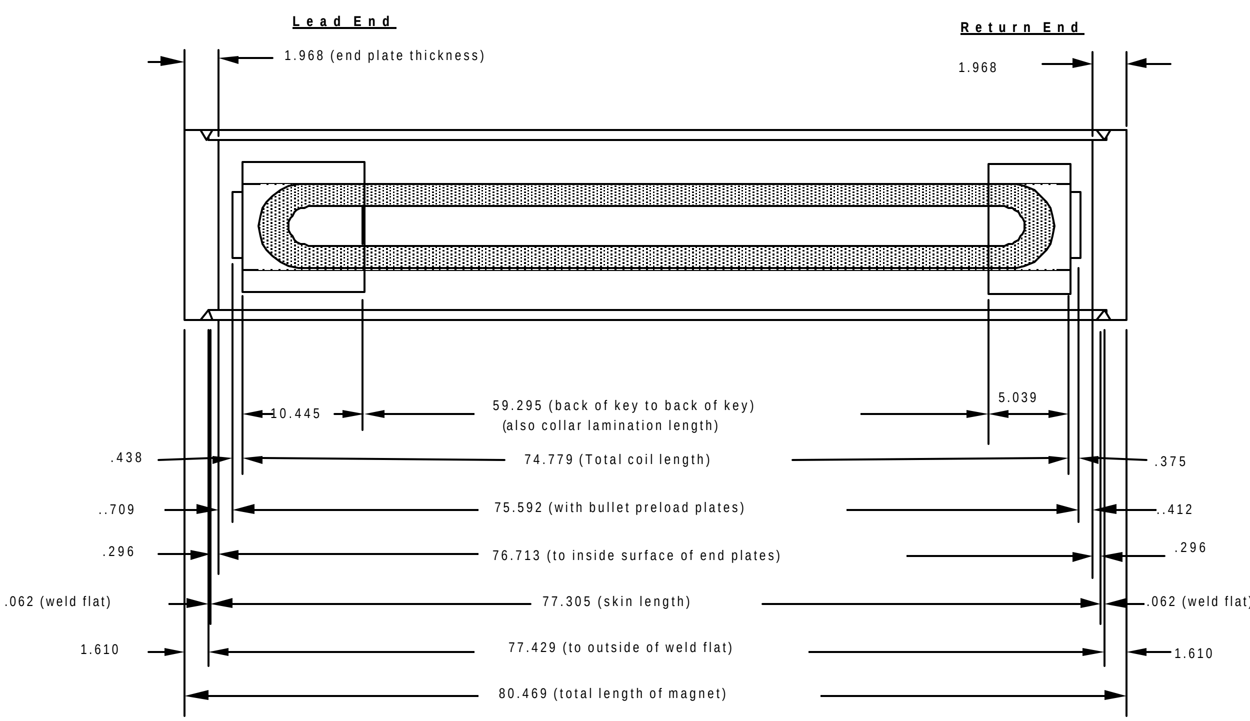

Figure 5.5. These are the measured dimensions for HGQ05

5.4. Bullet installation

The axial support system of the magnet shows below.

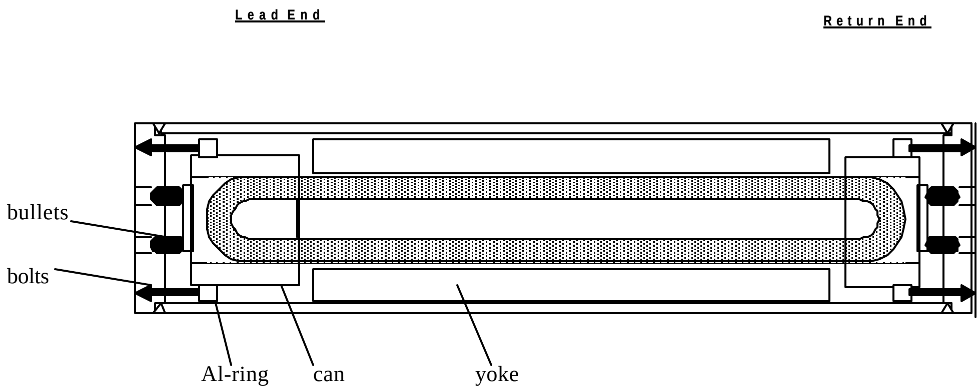

Figure 5.6. The axial support system of the magnet

The end load has been applied by snuggling the bullets to the solid pusher plate, then tightening the bolts. The gaps between coil end-saddles and pusher plat was filled by "green putty". The Lead End was loaded first. The bullet showed about 2400 lbs. At that time the Return End travel was -0.0055 in. The Return End bullets readied ~2000-2200 lbs. We toured RE bullets to achieved more or less equal force situation for both sides, ~2400 lbs. per bullet. Finally, the magnet stretched by total force ~18500 lbs. between two end plates. The magnet elongation was ~0.01 in.

Table 5.7. Bullet's reading.

Gauge ID	Type	Function	Quadrant	End	VMTF Name	IB#3 Data
						force, lbs
LHCBL27A	Bullet	Active	1	R	BuAcQ1aR	2222
LHCBL28A	Bullet	Active	2	R	BuAcQ2aR	2222
LHCBL31A	Bullet	Active	3	R	BuAcQ3aR	2273
LHCBL32A	Bullet	Active	4	R	BuAcQ4aR	2447
LHCBL33A	Bullet	Active	1	L	BuAcQ1aL	2316
LHCBL34A	Bullet	Active	2	L	BuAcQ2aL	2372
LHCBL35A	Bullet	Active	3	L	BuAcQ3aL	2485
LHCBL36A	Bullet	Active	4	L	BuAcQ4aL	2258

5.5. Twist

The twist in the cold-mass assembly after welding the skin was measured and found to be around 0.9 milliradian per meter in the straight section of the magnet. The twist in HGQ-01 was 4.67 milliradian per meter, for HGQ-02 it was 0.6 milliradian per meter, and for HGQ-03 it was 1.0 milli-radian per meter. The direction of the twist is same in all the three magnets and is clockwise looking from LE to RE.
Magnet twist shows on figure 5.8.

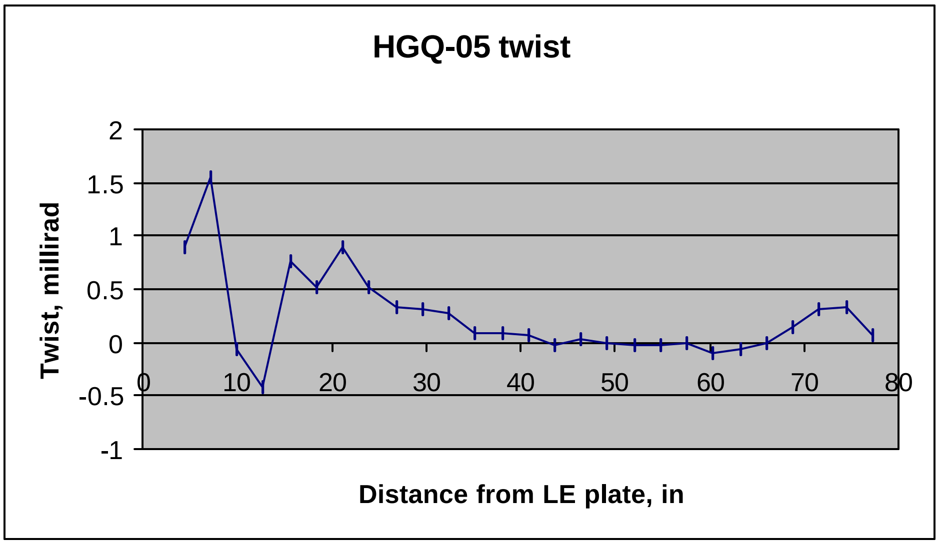

Figure 5.8. Magnet twist.

5.6. Skin gauges

The skin gauges location shown on figure 5.9. and table 5.10.

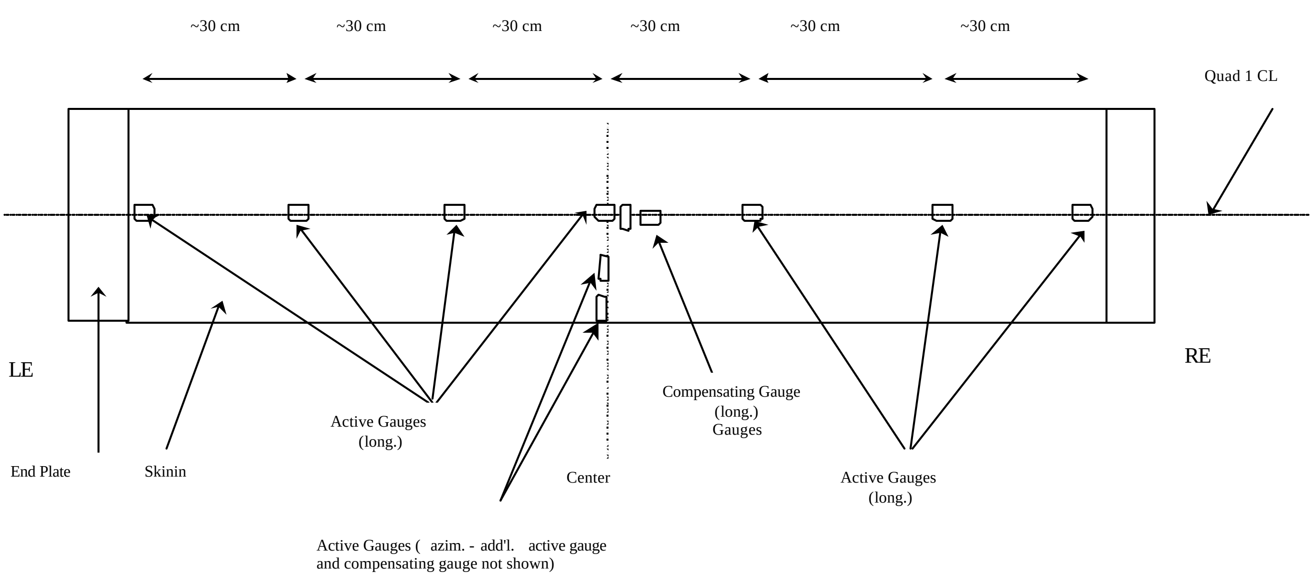

Figure 5.9. Skin gauge layout.

Table 5.10. Shell Gauge List

Gauge ID	Type	Function	Dist from RE (cm.)	VMTF Name
HQSk#51	Longitudinal	Active	10	SkAcL010
HQSk#52	Longitudinal	Active	44	SkAcL044
HQSk#53	Longitudinal	Active	74	SkAcL074
HQSk#54	Longitudinal	Active	104	SkAcL104
HQSk#55	Longitudinal	Active	134	SkAcL134
HQSk#56	Longitudinal	Active	164	SkAcL164
HQSk#57	Longitudinal	Active	194	SkAcL190
HQSk#58	Azimuthal	Active	104, 0 degrees	SkAcA000
HQSk#59	Azimuthal	Active	104, 30 degrees	SkAcA030
HQSk#60	Azimuthal	Active	104, 60 degrees	SkAcA060
HQSk#61	Azimuthal	Active	104, ~90 degrees	SkAcA090
HQSk#37	Longitudinal	Comp	101, 0 degrees	SkCoL101
HQSk#38	Azimuthal	Comp	101, ~90 degrees	SkCoA090
HQSk#39	Azimuthal	Comp	101, 45 degrees	SkCoA045

5.7. Testing at IB3

HGQ-05 was hi-potted coil to ground, heater to ground and heater to coil at 1500 V. Leakage is required to be less than 0.5 μA at 1500 V.
The final electrical data collected before shipping to MTF:

	Resistance ohm	**Ls mH**	**Q**
Q1 - inner	0.0830	179.973	2.04
Q1 - outer	0.1100	312.846	2.28
Q2 - inner	0.0811	179.662	2.03
Q2 - outer	0.1106	310.452	2.20
Q3 - inner	0.0825	179.055	2.10
Q3 - outer	0.1107	312.113	2.26
Q4 - inner	0.0838	179.895	2.07
Q4 - outer	0.1106	312.795	2.26
Q1 – Quadrant total	0.1904	812.223	3.61
Q2 – Quadrant total	0.1907	811.387	3.54
Q3 – Quadrant total	0.1901	810.790	3.52
Q4 – Quadrant total	0.1926	815.937	3.55
	Resistance ohm	**Ls MH**	**Q**
Magnet Total	0.7696	4.71095	4.48

Table 5.11: Magnet Resistance, L and Q measurements.

Heater	**Resistance ohm**	**Heater**	**Resistance ohm**
Q-1/2 – inner	7.150	Q-1/2 - outer	3.009
Q-2/3 – inner	7.164	Q-2/3 – outer	2.978
Q-3/4 - inner	7.112	Q-3/4 – outer	3.001
Q-4/1 - inner	7.161	Q-4/1 – outer	3.008

Table 5.12: Heater resistance measurements.