LHC IR Quad Magnet Design Features

	HGQ01	HGQ02	HGQ03
Inner Cable Strand No.	38	38	38
Inner Cable lay direction	Right Lay	Right Lay	Right Lay
Outer Cable Strand No.	46	46	46
Outer Cable lay direction	Left Lay	Left Lay	Left Lay
Cable Pre-baking	None	None	None
Strand Coating	None	None	None
Cable Cleaning	None	***Axarel 6100***	Axarel 6100
Inner Cable Insulation	25uM x 9.5mm w/ 48% overlap surrounded by 50uM x 4.75mm w/2mm gaps w/Epoxy adhesive	25uM x 9.5mm w/ 48% overlap surrounded by 50uM x ***9.5mm*** w/2mm gaps ***w/QI adhesive***	25uM x 9.5mm ***w/ 54% overlap*** surrounded by 50uM x 9.5mm w/2mm gaps w/QI
Outer Cable Insulation	25uM x 9.5mm w/ 48% overlap surrounded by 25uM x 9.5mm w/48% overlap w/Epoxy adhesive	25uM x 9.5mm w/ 48% overlap surrounded by ***50uM*** x 9.5mm ***butt lapped w/QI adhesive***	25uM x 9.5mm w/ 48% overlap surrounded by 50uM x 9.5mm butt lapped w/QI
Coil Curing temperature	135C	***190C***	190C
Inner coil curing pressure	low	low	low
Outer coil curing pressure	low	***high***	high
Inner Coil target size	+350uM (+.014 in.)	***+375uM, (.015 in.)***	+375uM, (+.015 in.)
Inner Coil MOE	4.5GPa	4.5GPa	***5.3GPa***
Outer Coil target size	+250uM (+.010 in.)	+250uM, (+.010 in.)	+250uM, (+.010 in.)
Outer Coil MOE	7.3GPa	***10.5GPa***	10.5GPa
Target Prestress	83MPa	83MPa	83MPa
Coil end azimuthal Shim System	No end shimming.	***Outer coil ends shimmed to be same as body, tapering off toward end of saddle.*** Inner coil ends not shimmed.	Outer ***and inner*** coil ends shimmed to be same as body, tapering off toward end of saddle.
End Part Material	G-10	***Ultem***	Ultem
End Part Configuration	Iteration #1, 4 block design.	Iteration #1, 4 block design.	Iteration #1, 4 block design. ***Wedges extended in outer coil.***
Splice Configuration	External	External	***Internal***
Voltage Tap Plan	MD-344511A/MD-344512A	***MD-344511B/ MD-344512B***	***MD-344883/MD-344884***
Inter layer strip heaters	Traditional, single element.	Traditional, single element.	Traditional, single element.
Outer layer strip heaters	None	***Traditional, single element***	***LBL version #1, double element***
Key extension	G-10	***Ultem***	Ultem
Inner coil Bearing Strips	Brass, full length except cut for strain gauges.	Brass, full length except cut for strain gauges.	Brass, full length except cut for strain gauges.
Outer coil Bearing Strips	Phosphor Bronze, full length except cut for strain gauges.	Phosphor Bronze, full length except cut for strain gauges.	Phosphor Bronze, full length except cut for strain gauges.
Collar configuration	Individual collars over entire body.	Individual collars over entire body.	Individual collars over entire body.
Collar key configuration	75mm long, stainless, "lined up' together longitudinally.	75mm long,stainless, "lined up' together longitudinally.	75mm long, stainless, "lined up' together longitudinally.
Strain Gauges	4 beam gauges on inner and outer coils, 4 capacitor gauges on outer coils.	4 beam gauges on inner and outer coils, ***4 capacitor gauges on inner and outer coils.***	4 beam gauges on inner and outer coils, 4 capacitor gauges on inner and outer coils.
Spot Heaters	On inner coil pole ramp, on outer coil lead at parting plane.	On inner coil pole ramp, ***on inner coil lead at parting plane,*** on outer coil lead at parting plane.	***On inner coil across from pole ramp,*** on outer coil lead at parting plane.
End Radial Support	Collet end clamp on Lead end, alumimun exterior can with G-10 quadrant pieces. Full Rounds on Return end.	Collet end clamp on Lead end, alumimun exterior can with G-10 quadrant pieces. Full Rounds on Return end.	***Full Rounds on both ends.***
Collar/Yoke Interface	Radial clearance between collar and yoke.	Radial clearance between collar and yoke.	Radial clearance between collar and yoke.
Quadrant Lead Configuration	Single leads with solid copper piece as stabilizer.	Single leads with solid copper piece as stabilizer.	Single leads with solid copper piece as stabilizer.
End longitudinal loading	Initially 350 lbs. force per bullet. 6000 lbs force per bullet on 2nd thermal cycle.	***Initially 3000 lbs. force per bullet on RE and 2000 lbs. force per bullet on LE. 0 lbs force per bullet on 2nd thermal cycle.***	***Bullets installed but "loose", with no force applied.***
Yoke Key Width	19mm	19mm	***24mm***
Strain Gauges on Skin	None	***Yes.***	Yes
End Plate Thickness	50mm	50mm	50mm
Tuning Shims	Yes.	Yes.	Yes
Other	Inner cable has longer twist pitch than design. (131mm instead of 114mm)		
Magnet Fabrication Start Date	4/15/97	1/4/98	2/1/98
Completion Date	1/20/98	5/12/98	8/19/98

LHC IR Quad Magnet Design Features

	HGQ03-1	HGQ04	HGQ05
Inner Cable Strand No.	38	38	38
Inner Cable lay direction	Right Lay	Right Lay	Right Lay
Outer Cable Strand No.	46	46	46
Outer Cable lay direction	Left Lay	Left Lay	Left Lay
Cable Pre-baking	None	None	None
Strand Coating	None	None	None
	Axarel 6100	Axarel 6100	Axarel 6100
Inner Cable Insulation	25uM x 9.5mm w/ 54% overlap surrounded by 50uM x 9.5mm w/2mm gaps w/QI	25uM x 9.5mm ***w/ 55% overlap*** surrounded by 50uM x 9.5mm w/2mm gaps w/QI	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/ 48% overlap surrounded by 50uM x 9.5mm butt lapped w/QI	25uM x 9.5mm w/ 48% overlap surrounded by 50uM x 9.5mm butt lapped w/QI	25uM x 9.5mm w/ 48% overlap surrounded by ***25uM*** x 9.5mm ***w/43% overlap w/Epoxy***
Coil Curing temperature	190C	190C	***135C***
Inner coil curing pressure	low	low	***high***
Outer coil curing pressure	high	high	high
Inner Coil target size	+375uM, (+.015 in.)	+375uM, (+.015 in.)	***+225uM, (+.009 in.)***
Inner Coil MOE	5.3GPa	***4.5GPa***	***8GPa***
Outer Coil target size	+250uM, (+.010 in.)	+250uM, (+.010 in.)	***+150uM, (.006 in.)***
Outer Coil MOE	10.5GPa	***9GPa***	***11GPa***
Target Prestress	83MPa	83MPa	***65-70MPa***
Coil end azimuthal Shim System	Outer and inner coil ends shimmed to be same as body, tapering off toward end of saddle.	Shim ends to be same as body, tapering off toward end of saddle.	Shim ends to be same as body, tapering off toward end of saddle.
End Part Material	Ultem	Ultem	***G-10***
End Part Configuration	Iteration #1, 4 block design. Wedges extended in outer coil.	Iteration #1, 4 block design. Wedges extended in outer coil. ***Saddles shortened by 21mm.***	Iteration #1, 4 block design. Wedges extended in outer coil. Saddles shortened by 21mm.
Splice Configuration	Internal	Internal	Internal
Voltage Tap Plan	MD-344883/MD-344884	MD-344883/MD-344884	***MD-344972/MD-344973***
Inter layer strip heaters	Traditional, single element.	Traditional, single element.	Traditional, single element.
Outer layer strip heaters	LBL version #1, double element	***SSC Design, single element***	***LBL version #1, double element***
Key extension	Ultem	Ultem	***None***
Inner coil Bearing Strips	Brass, full length except cut for strain gauges.	Brass, full length except cut for strain gauges.	***Brass, cut in 75mm segments, same as collar packs.***
Outer coil Bearing Strips	Phosphor Bronze, full length except cut for strain gauges.	Phosphor Bronze, full length except cut for strain gauges.	***Phosphor bronze, cut in 75mm segments, same as collar packs.***
Collar configuration	Individual collars over entire body.	***Regular collars over body, except "solid" welded packs at each end.***	***75mm long "solid" welded packs, with 49 lamination period.***
Collar key configuration	75mm long, stainless, "lined up' together longitudinally.	75mm long,stainless, "lined up' together longitudinally.	***75mm long, stainless, positioned same as packs.***
Strain Gauges	4 beam gauges on inner and outer coils, 4 capacitor gauges on inner and outer coils.	4 beam gauges on inner and outer coils, 4 capacitor gauges on inner and outer coils.	***4 beam gauges on outer coils,*** 4 capacitor gauges on inner and outer coils.
Spot Heaters	On inner coil across from pole ramp, on outer coil lead at parting plane.	On inner coil across from pole ramp, on outer coil lead at parting plane.	***Pole turn on 2 outer coils, at lead end on parting plane turn on 1 outer coil.***
End Radial Support	Full Rounds on both ends, ***supported by yoke.***	***Collet end clamps on both ends. Aluminum exterior cans with G-10 quadrant pieces.***	Collet end clamps on both ends. Aluminum exterior cans with G-10 quadrant pieces.
Collar/Yoke Interface	***Radial interference between collar and yoke.***	Radial clearance between collar and yoke.	Radial clearance between collar and yoke.
Quadrant Lead Configuration	Single leads with solid copper piece as stabilizer.	***Double leads with copper only cable as stabilizer.***	***Single lead with copper only cable for stabilizer***
End longitudinal loading	***Bullet force of 1500-2000 lbs. per bullet (both ends).***	N/A	***2000 lbs. force per bullet on both ends. End cans are bolted to end plates longitudinally, preventing coils from contracting longitudinally.***
Yoke Key Width	***23mm***	N/A	24mm
Strain Gauges on Skin	Yes	N/A	Yes
End Plate Thickness	50mm	50mm	50mm
Tuning Shims	***None.***	N/A	***Layed into collared coil/yoke. Fixed in place.***
Other	This magnet was HGQ03, rebuilt. Yokes were removed and brass shims added to create yoke/collar interference. The collared coil assembly was not disassembled.	2 collar packs with thermometers.	Inner coils recured to increase MOE. 2 collar packs with thermometers.
Magnet Start Date	9/20/98	5/8/98	8/17/98
Completion Date	11/24/98	1/19/99	2/24/99

LHC IR Quad Magnet Design Features

	HGQ06	HGQ07	HGQ08
Inner Cable Strand No.	38	***37***	37
Inner Cable lay direction	***Left Lay***	Left Lay	Left Lay
Outer Cable Strand No.	46	46	46
Outer Cable lay direction	Left Lay	Left Lay	Left Lay
Cable Pre-baking	None	None	***Strand Anneal before cabling***
Strand Coating	None	None	***Stabrite, both inner and outer.***
Cable Cleaning	Axarel 6100	Axarel 6100	Axarel 6100
Inner Cable Insulation	25uM x 9.5mm w/ 55% overlap surrounded by 50uM x 9.5mm w/2mm gaps ***w/QI***	25uM x 9.5mm ***w/ 58% overlap*** surrounded by 50uM x 9.5mm w/2mm gaps w/QI	25uM x 9.5mm ***w/ 61% overlap*** surrounded by 50uM x 9.5mm w/2mm gaps w/QI
Outer Cable Insulation	25uM x 9.5mm w/ 48% overlap surrounded by 25uM x 9.5mm ***w/41% overlap w/QI***	25uM x 9.5mm w/ 48% overlap surrounded by 25uM x 9.5mm w/41% overlap w/QI	25uM x 9.5mm w/ 48% overlap surrounded by 25uM x 9.5mm ***w/46% overlap w/QIX.***
Coil Curing temperature	***190C***	190C	190C
Coil Curing temperature	high	high	high
Inner coil curing pressure	high	high	high
Inner Coil target size	***+175uM, (+.007 in.)***	***+200uM, (+.008 in.)***	***+325uM, (+.013 in.)***
Inner Coil MOE	***9.5GPa***	***8.5GPa***	***10.5GPa***
Outer Coil target size	***+175uM, (+.007 in.)***	***+200uM, (+.008 in.)***	***+325uM, (+.013 in.)***
Outer Coil MOE	***9.5GPa***	***8.5GPa***	***12GPa***
Target Prestress	65-70MPa	***70-75MPa***	***85-90MPa***
Coil end azimuthal Shim System	Shim ends to be same as body, tapering off toward end of saddle.	Shim ends to be same as body, tapering off toward end of saddle.	Shim ends to be same as body, tapering off toward end of saddle.
End Part Material	***G-11CR***	G-11CR	G-11CR
End Part Configuration	***Iteration #2, 5 block design.***	Iteration #2, 5 block design.	Iteration #2, 5 block design.
Splice Configuration	Internal	Internal	Internal
Voltage Tap Plan	***MD-369212/MD-369213***	MD-369212***/MD-369259***	MD-369212/MD-369259
Inter layer strip heaters	***None***	None	None
Outer layer strip heaters	***SSC Design, single element***	***LBL version #2, double element***	***CERN version #1, double element***
Key extension	None	None	None
Inner coil Bearing Strips	Brass, cut in 75mm segments, same as collar packs.	Brass, cut in 75mm segments, same as collar packs.	***None***
Outer coil Bearing Strips	Phosphor bronze, cut in 75mm segments, same as collar packs.	Phosphor bronze, cut in 75mm segments, same as collar packs.	***None***
Collar configuration	75mm long "solid" welded packs, with 49 lamination period.	75mm long "solid" welded packs, with 49 lamination period and dimples for separation.	75mm long solid welded packs, ***but new configuration without bearing strips***
Collar key configuration	75mm long, stainless, positioned same as packs.	75mm long, stainless, positioned same as packs.	75mm long, ***phosphor bronze, positioned across collar pack gaps.***
Strain Gauges	4 beam gauges on outer coils, 4 capacitor gauges on inner coil and outer coils.	4 beam gauges on outer coils, 4 capacitor gauges on inner and outer coils.	***2 beam gauges on inner and outer coils, 2 capacitor gauges on inner and outer coils..***
Spot Heaters	Pole turn on 2 outer coils, at lead end on parting plane turn on 1 outer coil.	Pole turn on 2 outer coils, at lead end on parting plane turn on 1 outer coil.	Pole turn on 2 outer coils, at lead end on parting plane turn on 2 outer coils.
End Radial Support	Collet end clamps on both ends. ***Aluminum exterior cans with G-11CR quadrant pieces.***	Collet end clamps on both ends. Aluminum exterior cans with G-11CR quadrant pieces.	Collet end clamps on both ends. Aluminum exterior cans with G-11CR quadrant pieces.
Collar/Yoke Interface	Radial clearance between collar and yoke.	Radial clearance between collar and yoke.	Radial clearance between collar and yoke.
Quadrant Lead Configuration	***Double lead with copper only cable for stabilizer***	Double lead with copper only cable for stabilizer	Double 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.	***No load applied on first thermal cycle. 2000 lbs. per bullet applied on 3rd thermal cycle, with end cans bolted to end plates longitudinally.***	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	***23.5mm***	***24mm***	24mm
Strain Gauges on Skin	Yes	Yes	Yes
End Plate Thickness	50mm	50mm	50mm
Tuning Shims	***None***	None	None
Other	Return end keys mold released and replaced. 2 collar packs with thermometers. Axial preload bolts were instrumented.	Return end keys mold released and replaced. Thermometers on collar/yoke keys. Axial preload bolts were instrumented.	Return end keys mold released and replaced. Thermometers on collar/yoke keys. Axial preload bolts not instrumented.
Magnet Fabrication Start Date	2/25/99	4/15/99	6/25/99
Completion Date	6/16/99	8/30/99	11/20/99

LHC IR Quad Magnet Design Features

HGQ09

Inner Cable Strand No.	37
Inner Cable lay direction	Left Lay
Outer Cable Strand No.	46
Outer Cable lay direction	Left Lay
Cable Pre-baking	***None***
Strand Coating	***None***
Cable Cleaning	Axarel 6100
Inner Cable Insulation	25uM x 9.5mm ***w/ 58% overlap*** surrounded by 50uM x 9.5mm w/2mm gaps ***w/QIX***
Outer Cable Insulation	25uM x 9.5mm w/ 48% overlap surrounded by 25uM x 9.5mm w/46% overlap w/QIX
Coil Curing temperature	***190C/135C Two step cycle***
Inner coil curing pressure	***high at 135C/ low at 190C***
Outer coil curing pressure	***high at 135C/ low at 190C***
Inner Coil target size	***+275uM, (+.011)***
Inner Coil MOE	***8GPa***
Outer Coil target size	***+275uM, (+.011)***
Outer Coil MOE	***9GPa***
Target Prestress	***75-80 MPa***
Coil end azimuthal Shim System	Shim ends to be same as body, tapering off toward end of saddle.
End Part Material	G-11CR
End Part Configuration	Iteration #2, 5 block design.
Splice Configuration	Internal
Voltage Tap Plan	MD-369212/MD-369259
Inter layer strip heaters	None
Outer layer strip heaters	***CERN version #2, double element***
Key extension	None
Inner coil Bearing Strips	None
Outer coil Bearing Strips	None
Collar configuration	***38mm long solid welded packs*** , using new configuration without bearing strips
Collar key configuration	75mm long, phosphor bronze, positioned across collar pack gaps.
Strain Gauges	2 beam gauges on inner and outer coils, 2 capacitor gauges on inner and outer coils..
Spot Heaters	Pole turn on 2 outer coils, at lead end on parting plane turn on 2 outer coils.
End Radial Support	Collet end clamps on both ends. Aluminum exterior cans with G-11CR quadrant pieces.
Collar/Yoke Interface	Radial clearance between collar and yoke.
Quadrant Lead Configuration	Double 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	***26.5mm***
Strain Gauges on Skin	Yes
End Plate Thickness	***35mm***
Tuning Shims	None
Other	Return end keys mold released and replaced. Thermometers on collar/yoke keys. Axial preload bolts not instrumented.
Magnet Fabrication Start Date	9/20/99
Completion Date	2/1/00

Note: Any feature highlighted in ***red bold italics*** has been changed from the previous magnet.