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Title
SUPERCONDUCTING MAGNET PROGRAM / LARP QXF GENERAL

COIL PACK SUBASSEMBLY WORK INSTRUCTIONS

Coil Pack Subassembly Work Instructions (WI)

Windchill Unique ID: SU-1008-8074

Rev: C

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Contents

Revision History

Revision	Issued	Changes
A	04-26-2019	Original Issue.
B	12-6-2019	Update drawing numbers, some images, G11 goes directly on collar, line up coils by centerline not ends, add coil setback measurement
C	05-22-2020	Add ref to SU-1012-3438, added Step 3 (and VP 1), modified steps 18, 85, bold torque values, dimensions

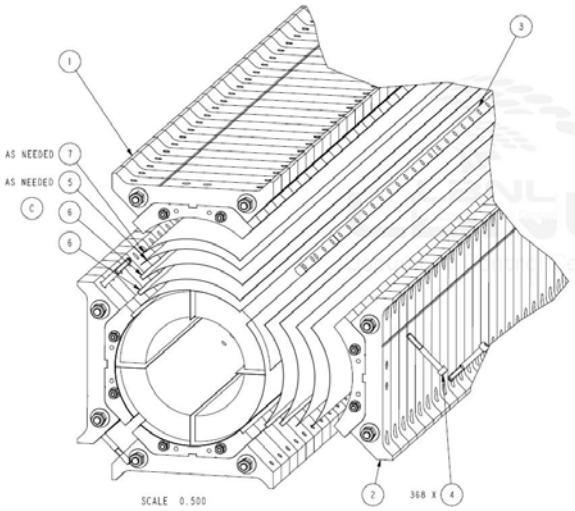
Purpose

The purpose of this Working Instruction is to describe the process of assembling the Coil Pack Subassembly for the MQXFA Magnet. The MQXFA magnet that is being built for the HL-LHC AUP is approximately 15 feet long (4.5 m) and 2 feet in diameter. The Coil Pack is a subassembly of this magnet, and is comprised of four Load Pad-Collar stacks assembled around four Coil Assemblies. Once assembled, these components are inserted in the Shell-Yoke Assembly as a whole unit.

Scope

This document covers the assembly of the Coil Pack Subassembly. It includes both the pre-build using pressure sensitive paper to ensure proper shimming ("Fuji paper build") and the final coil pack assembly. Prior to completing this work instruction, the coils should have undergone mechanical measurements to determine shimming, electrical measurements to ensure they are in good condition, and the Dressed Coil work instructions. The Collars and Load Pads should have been assembled into Pad-Collar assemblies, according to the Pad-Collar work instructions.

Definitions



Reference Documents

- SU-1010-1610 – MQXFA Loadpad-Collar Assembly Work Instructions
- SU-1008-8073 – Dressed Coil Work Instructions
- SU-1010-8225 – MQXFA Coil Pack Subassy
- SU-1012-3438 – Modified Coil Alignment Key
- SU-1012-4477 – Pole Keyway Shift Analysis for MQXFA Magnets
- US-HiLumi DocDB #3048 – Impregnated Coil Dimensional QC Plan at LBNL

Tools Required

Calibrated Tools:

- Torque wrenches
  - Adjustable, 25, 50, 75, 100 and 125 ft-lbs (for M8 screws)

Non Calibrated Tools:

- Crane
  - Associated lifting rings & straps
- 1 of 27K801 – Coil Pack Assembly Table
- 2 of 27K803 – Coil Pack Side Assy Pivot Table
- 1 of 27K919 – Loadpad Collar Assy Mandrel
- 1 of 27L123 – Rollover Tooling on Table
- 1 of 27K678 – Coil Handling – Inner Pick Lift Beam
- 1 of 27K677 – Coil Handling – Outer Pick Lift Beam
- Allen keys – metric & imperial – ¼”-20, 6 mm, others as needed
- 20 dummy coil sections and lead blocks for G11 gluing
- 88 of 27K748 – Clamp, Loadpad Tooling (blue bracket)
- Fixtures to hold the 4 coils together
- Straps

Tools Recommended:

- Power drill
  - Flexible coupling attached to 6 mm SHCS key
  - Magnetic hex-head end for coil lifting fixture (13mm and 12 mm)
- Straight edges
- Levels
- Large, heavy-duty paper cutter for the G11

Figure 1: Tool for cutting G11

Figure 2: Power drill attachments (need both 13mm & 12mm)

Hardware Required

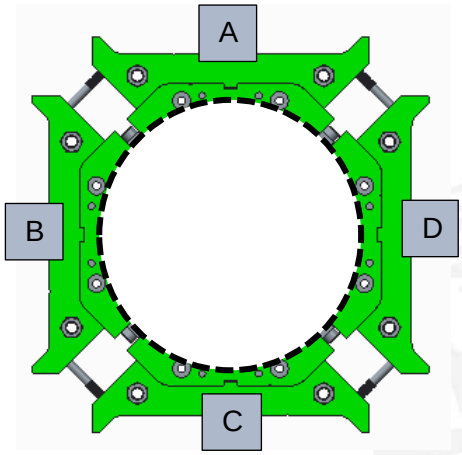
Fabricated Parts & Hardware:

Part #	Description	Req'd
SU-1010-8074	Loadpad Collar Subassembly, Threaded	2
SU-1010-8830	Loadpad Collar Subassembly, Thru	2
SU-1010-2057	Dressed Coil	4

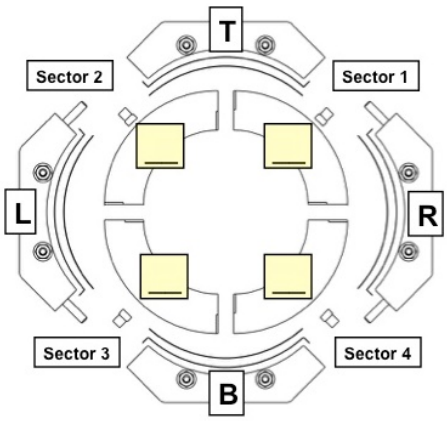
Work Instructions

1 Setup

1. Enter the following information on the Verification Signoff Sheet:
    a. Pad-Collar Stack Serial Numbers (Lead end load pad serial number. Starts with either 27L250 or 27L253)
    b. Coil Serial Numbers
    c. Start date



Pad-Collar Assemblies viewed from lead-end



Viewed From Lead End

Item #	Description
A	Top (Threaded)
B	Left (Thru)
C	Bottom (Threaded)
D	Right (Thru)

2. The Bottom Pad-Collar Assembly should have been built on the Coil Pack Assembly Table (27K801), the Left and Right Pad-Collar Assemblies should have been built on the two Pivot Tables (27K803) and the Top Pad-Collar Assembly should have been built on the Loadpad Collar Assy Mandrel (27K919) while the Mandrel sits on the Rollover Table (27L123).
3. If during the coil acceptance review, we discover that coil has a pole key slot misalignment greater than 250 µm, Cognizant Engineer will fill out chart on SU-1012-3438 "Modified Coil Alignment Key" and specify which Coil and Pole Alignment Key(s) will be modified and how.

VERIFICATION POINT 1

2 Collar Radial Shim Prep

4. Working with the Cognizant Engineer, determine the appropriate shim package.

VERIFICATION POINT 2

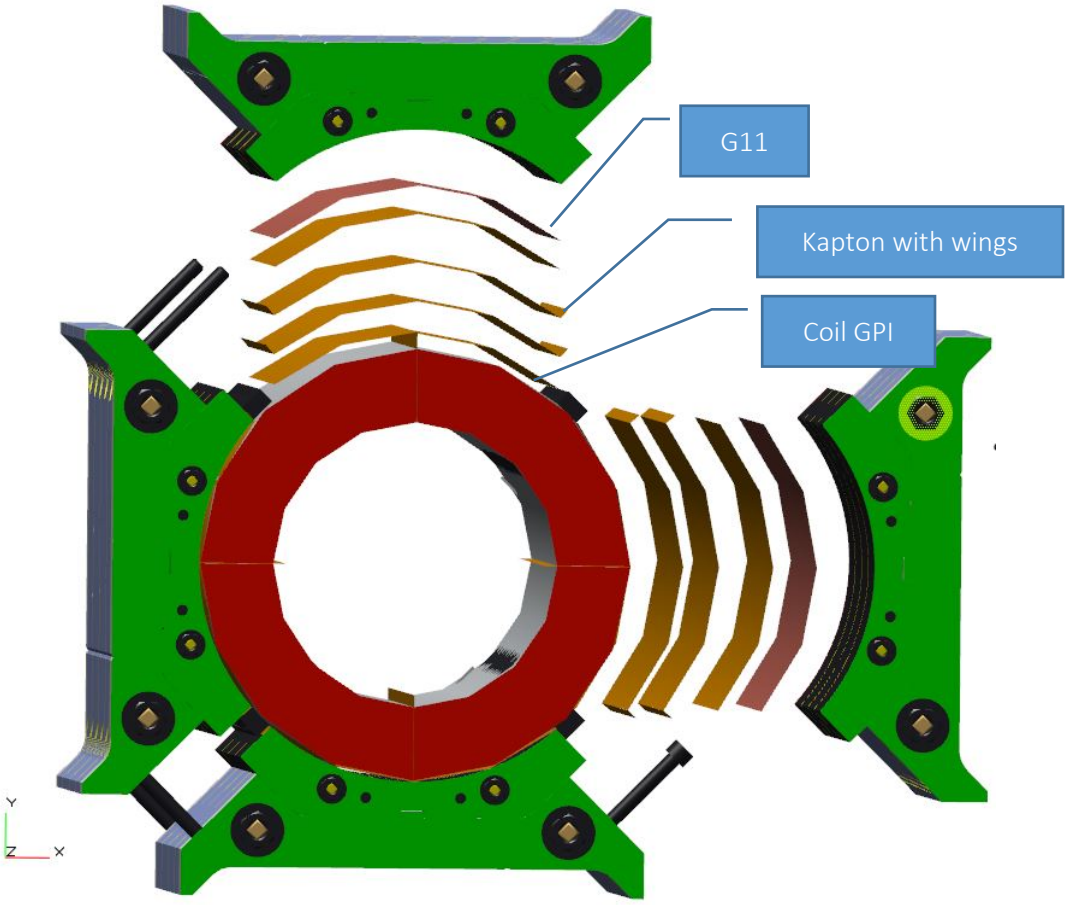


Figure 3: The shimming layers. From Collar to Coil: G11 (one or two layers as needed), Kapton with wings (two layers), GPI on the dressed coil.

5. Cut the Kapton Radial Shim for each of the collar stacks. One sheet of Kapton should cover the entire pad-collar stack. Width is **163 mm** or **185 mm** if it has "wings".
6. Cut G11 pieces. Four sheets of G11 per pad-collar stack are required. Width is **163 mm.**
7. Measure the thickness of each sheet of Kapton (4x) and each sheet of G11 (16x). Record minimum and maximum thicknesses.

VERIFICATION POINT 3

8. Glue G11 to the collars using Araldite 90 minute 2 part epoxy. Put the epoxy only in the corners of each sheet.

Figure 4: G11 attached to collars.

9. Use dummy coil sections and lead weights to hold the G11 down while it cures. Let the epoxy cure overnight.

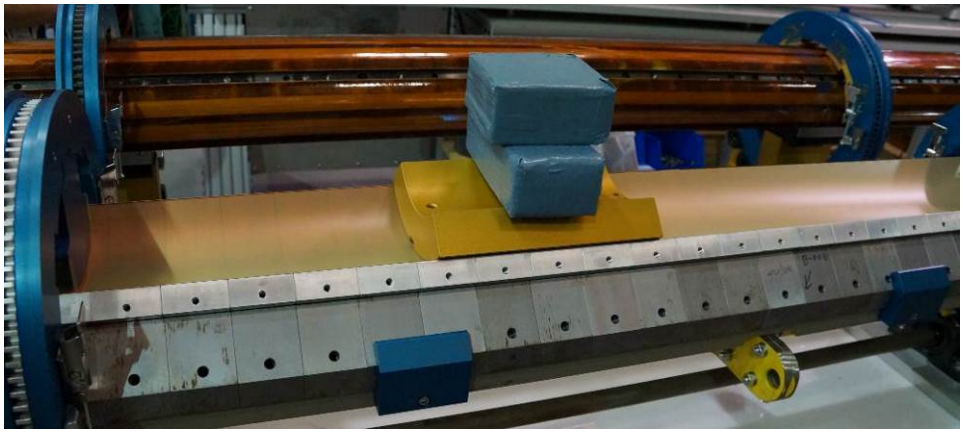


Figure 5: Dummy coil section and lead weights holding down the G11.

10. Check that all the G11 is centered on the collar and hasn't shifted during gluing.

VERIFICATION POINT 4

Figure 6: G11 shifted during epoxy drying stage. Exposed collar. NOT ALLOWED.

11. Attach the 163" wide Kapton Radial Shim (as necessary) to each of the 4 collar stacks on top of the G11. Ensure no wrinkles. Glue using Araldite 90 minute 2 part epoxy
12. Let cure overnight. Verify that the Kapton does not shift.
13. Mark the mechanical midway point on the pad-collar stack.

3 Fuji Paper Build

14. Cut the Fuji Film Prescale LLW R540 6M1 (Fuji Paper) to the length of the coils (green and white pieces, three sets ~**4500 mm long x 163 mm wide**, three sets ~**1500 mm long x 163 mm wide**).
15. Put three shorter Fuji paper sheets on the Bottom pad-collar stack, and two of the full-length Fuji paper sheets onto the Left and Right pad-collar stacks. Reserve the last full-length Fuji paper sheet for the Top.
    a. Do not smudge the Fuji Paper
    b. The matte sides of the two types of Fuji paper face each other. Shiny side out.
    c. The green Fuji Paper is less reactive, and goes on the collar side.
    d. The white Fuji Paper is more reactive and goes on coil side.
    e. Tape the paper to the collar. Minimize the amount of tape touching the paper.
    f. Label the four corners of each sheet of paper with the coil serial number and LE or RE. Label the paper Left, Right, Bottom, Top at each end.
16. Check the thickness of the two sheets of Fuji Paper together (checking on excess paper is ok) and record thickness

VERIFICATION POINT 5

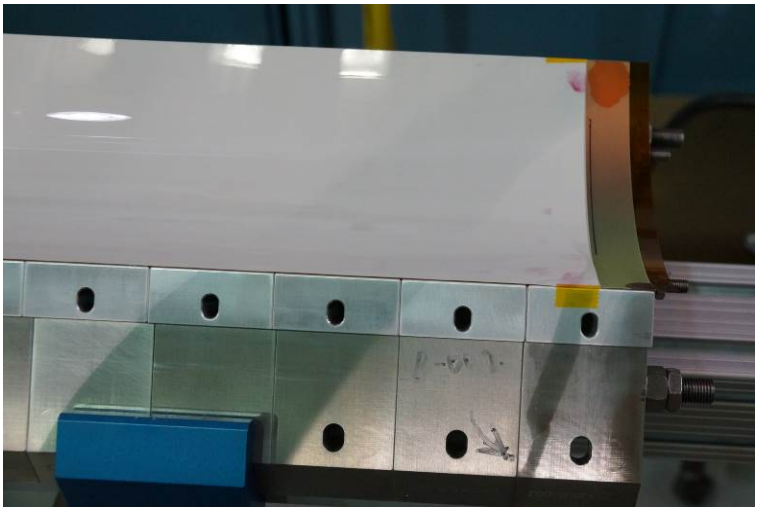


Figure 7: Fuji paper taped to collar

17. Attach the left, right and top pad-collar stacks to the dummy master key using the blue brackets (27K748). Do not put a bracket in the spots where the dummy master key attaches to the pivot bar (left & right only) these will be inaccessible later.

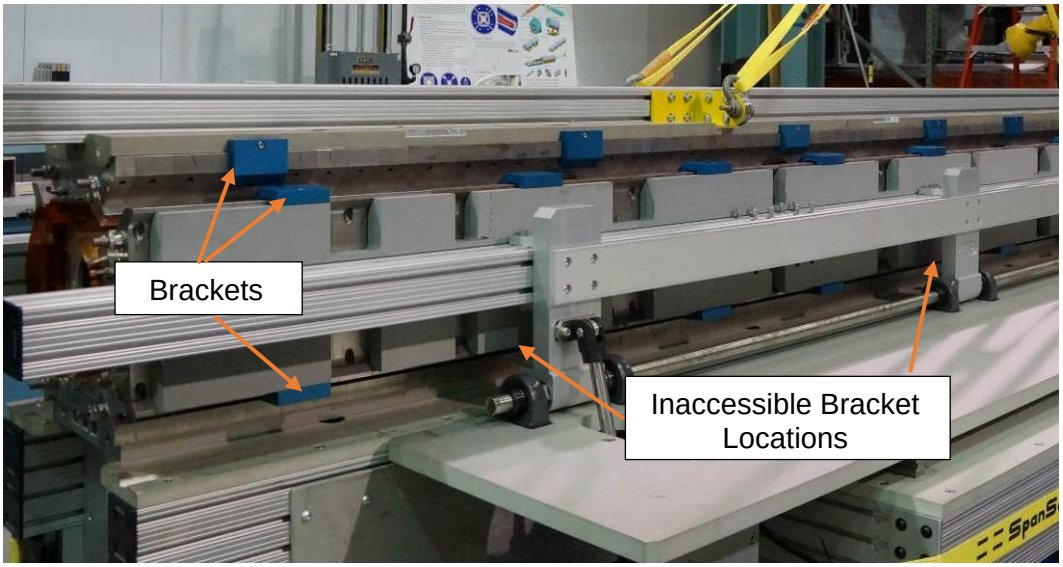


Figure 8: Left and top pad-collar stacks clamped to dummy master keys with blue brackets.

18. Number the pole alignment keys. If any have been modified (see step 3/VP 1), ensure they are clearly marked with their location and orientation.
19. Measure the thickness of each alignment key (there is an extra column to indicate if the key is ultimately used on this magnet).

VERIFICATION POINT 6

20. Insert the alignment keys into the coils.
21. Put the bottom 2 coils (quadrant 3 & 4) onto the Rollover table, next to each other, in the correct orientation. Check that they line up axially with each other by lining up the center lines. (See Dressed Coil Work Instructions for where the coil center lines go)
22. Attach the coils to the Inner Pick Lift Beam (27K678).

Figure 9: Inner Pick Lift Beam

23. Lift the coils and place them on the bottom pad-collar stack.
    a. The center of the coils should line up with the center of the pad-collar stack.
    b. The alignment keys on one coil should be the same distance from the collars the keys on the other coil, and should maintain the distance through the full length
    c. Avoid making too many adjustments so you don't smudge the Fuji Paper.
24. Attach fixtures to keep the coils together, then remove the lifting fixture.

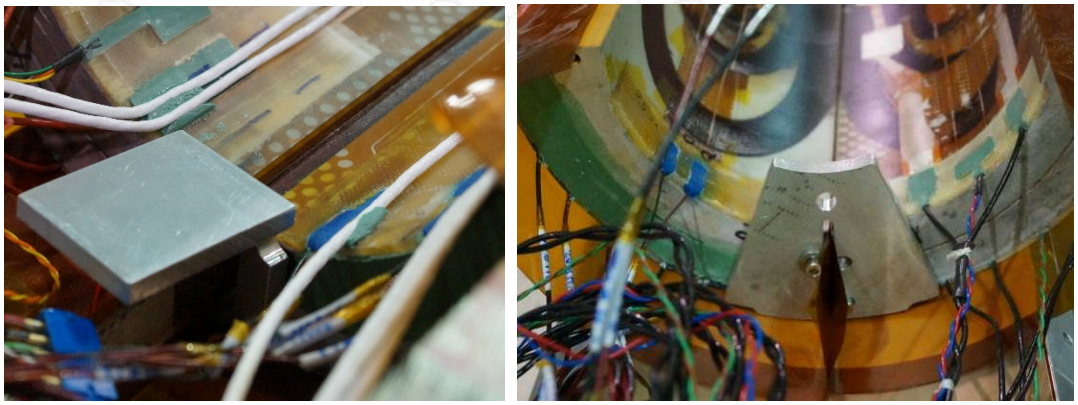


Figure 10: Lead end fixture (left) and return end fixture (right)

25. Put the top 2 coils (quadrants 1 & 2) onto the Rollover table, next to each other, in the correct orientation. Check that they line up axially with each other by lining up the center lines.

26. Attach the coils to the Outer Pick Lift Beam (27K677).

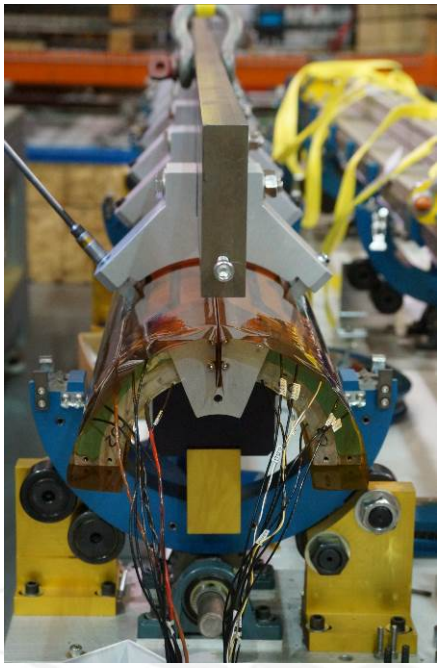


Figure 11: Outer Pick Lift Beam

27. Lift the coils and place them on top of the bottom two coils. Line the coils up with each other by their center lines. Verify that the edges of the Kapton GPI are well aligned and not protruding at the coil midplanes.
28. Attach the fixtures to keep the coils together.

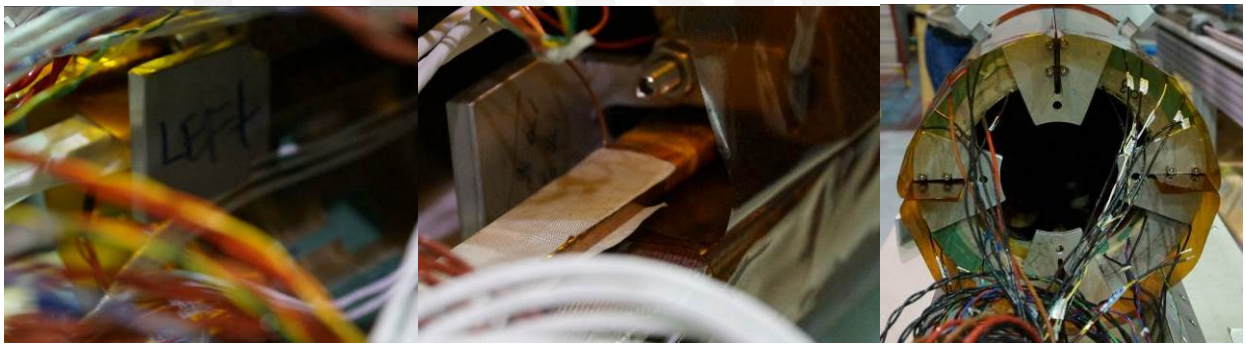


Figure 12: Lead end fixtures (left & center), return end fixtures.

29. Remove lift fixtures.
30. Push the two Pivot Tables up against the center Coil Pack Table. Use a straight edge to make sure the pad-collar assemblies are axially aligned. Adjust Pivot Table locations as necessary.
31. Strap the Pivot Tables to the center table. (Center of gravity will move to the edge as the pad-collar stack is pivoted, could fall over if not strapped).

Figure 13: Pivot table strapped to coil pack table

32. Ensure the pad-collar assemblies are attached to the dummy master keys with the blue brackets and the brackets are tight.
33. The Pivot Tables and Coil Pack Table should all be the same height. If they are not, adjust the jacking screws on the Coil Pack Table.
34. Plug in the pivot tables
35. Pull the Right Pad-Collar Assy away from the coils, and then bring it to a vertical position.
36. Do the same with the Left Pad-Collar Assy
37. The gap between the alignment keys and the collars should be close to equal. Adjust Coil Pack Table height as necessary if not.
38. Check that the screws between load pads will go in.
39. Don't smudge the Fuji Paper. Ensure that the Fuji Paper has remained in place.
40. Push the Left and Right pad-collar stacks against the coils. (Clamp in place)
41. Put the last strip of Fuji Paper on top of the coils.
    a. White shiny side against the coils
    b. Matte sides together
    c. Tape it down at the ends

Figure 14: Top Fuji Paper in place

42. Get the top pad-collar assembly into position to be lifted (roll over if necessary). Ensure blue brackets are in place and tight.
43. Lift the top pad-collar stack and move it over the coils. Check that it is axially aligned and that there is an equal gap between the alignment keys and the top collar. Finish lowering.

Figure 15: Lift top pad-collar stack

44. Insert all screws between loadpads where the holes are reachable. Snug tight, but don't apply any significant torque yet.
45. Remove the brackets keeping the coils together.
46. Remove the blue brackets.
47. Remove the top lifting mandrel. Lower the pivot tables.

48. Have engineer attach strain gauge system to start taking readings.
49. Insert and snug all screws between load pads. (Every load pad in the left and right stacks have 2 screws, one attaching to the top stack, one attaching to the bottom stack).
50. From the center, working out in an alternating and opposing pattern, torque the screws to **125 in-lbs in 25 in-lb increments.**
51. Measure the height and width of the coil pack in 15" increments.

VERIFICATION POINT 7

52. Measure the gap between collars & alignment keys in 15" increments.

VERIFICATION POINT 8

53. Attach strain gauge readings.

VERIFICATION POINT 9

4 Fuji Coil Pack Disassembly

54. Attach the fixtures that keep the coils together to both ends of the coils.

55. Remove the screws, except for the ones that are accessible through the pivot tables.
56. Attach left and right pivot tables to the pad-collar stacks using the blue brackets.
57. Attach the top pad-collar stack to the lifting mandrel using the blue brackets.
58. Remove the remaining screws.
59. Lift the top pad-collar assembly. Ensure that the Fuji paper remains in place.
60. Verify the labeling of the four corners of the Fuji paper (both white and green sheets) indicating lead end/return end and coil number. And verify it is labeled "Top"
61. Lower the left and right pad-collar stacks using the pivot tables.
62. Verify the labeling the four corners of the left and right Fuji paper with LE/RE and coil number. Verify the papers are labeled "Left" and "Right"
63. Attach the Outer Pick Lift Beam to the top 2 coils.
64. Remove fixtures attaching top coils to bottom coils.
65. Lift top 2 coils and put them on a table (i.e. the GPI table on foam blocks). Leave the lifting fixture attached.
66. Use the Inner Pick Lift Beam to lift the bottom 2 coils and put them on the Rollover Table. Ensure that the Fuji paper remains in place.
67. Verify that the bottom Fuji paper is labeled "Bottom" and the four corners are labeled LE/RE and coil number.

68. Lay the white Fuji Paper out on a table with matching corner marks touching (i.e. top/Q1/LE touching right/Q1/LE).
69. Roll up the green Fuji Paper, and keep for reference.

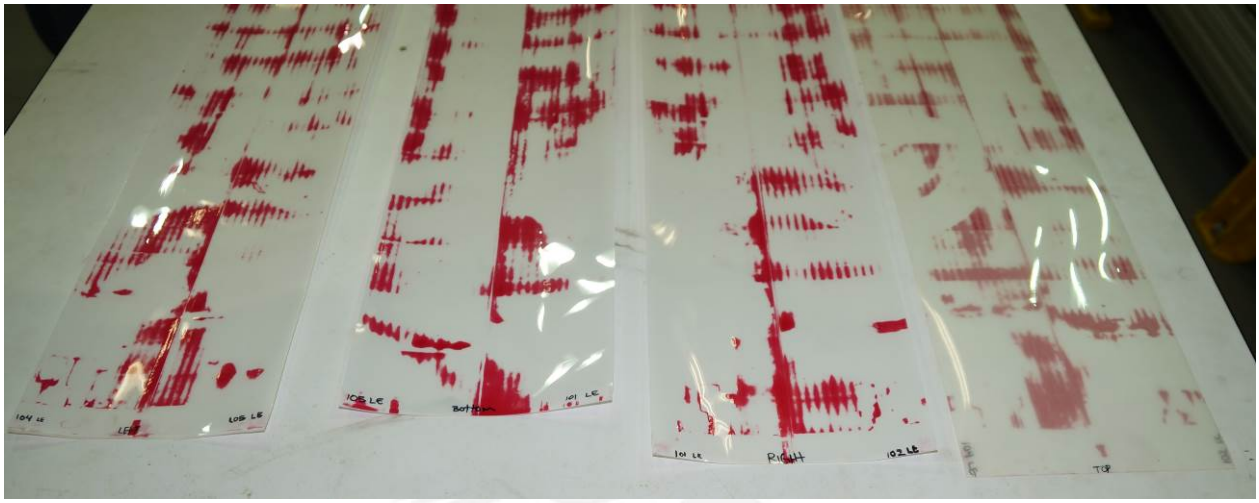


Figure 16: Labeled Fuji Paper

70. Interpret Fuji Paper markings, collar gap measurements and height and width measurements. Fuji paper step may be repeated with possible changes in shimming, as necessary.

VERIFICATION POINT 10

5 Final Coil Pack Assembly

IF NEW G11/Kapton LAYERS ARE NECESSARY:

71. Remove the G11 and Kapton from the Fuji paper build
72. Cut new **185 mm wide** Kapton (with wings).
73. Cut new G11 sheets (**163 mm wide**). Four sheets of G11 per pad-collar stack are required.
74. Measure each Kapton and G11 sheet and record the maximum and minimum thicknesses.

VERIFICATION POINT 11

75. Attach G11 sheets to the Kapton using Araldite 90 minute 2 part epoxy. Put the epoxy only in the corners of each sheet.
76. Use dummy coil sections and lead weights to hold the G11 down while it dries.
77. Attach Kapton to each of the 4 collar stacks on top of the G11. Ensure no wrinkles. Glue.

78. Check that all the shim material (Kapton and G11) is centered on the collar and hasn't shifted during gluing.

VERIFICATION POINT 12

IF NEW G11/Kapton LAYERS ARE NOT NECESSARY, START HERE:

79. Cut new shim material (that replaces Fuji paper thickness) according to new shimming plan.
80. Glue to collars on top of other shim material.
81. Add any extra mid-plane GPI, if required on the coils.
82. Check that center mark on the collars is still in place.
83. Ensure that the Coil Pack Table is level.
84. Wrap each coil lead with **50% overlapping** Kapton tape (**0.001" thick**) to at least **18 inches** beyond the endshoe. Take extra care while installing the tap around the voltage taps on the leads to prevent damage.
85. Ensure the coils still have all the alignment keys inserted. Replace any keys that incurred damage if they needed to be removed. Ensure any modified keys (per Step 3/VP 1) are still in the correct location. Note which alignment keys were used on this magnet.

VERIFICATION POINT 13

86. Ensure that the bottom 2 coils (quadrant 3 & 4) are axially aligned by ensuring that the center lines are lined up.
87. Lift the bottom 2 coils and place them on the bottom pad-collar assembly. The center of the magnet should line up with the center of the pad-collar stack.
88. Check the clocking of the coils by making sure the gap between the alignment keys and the collars looks even.

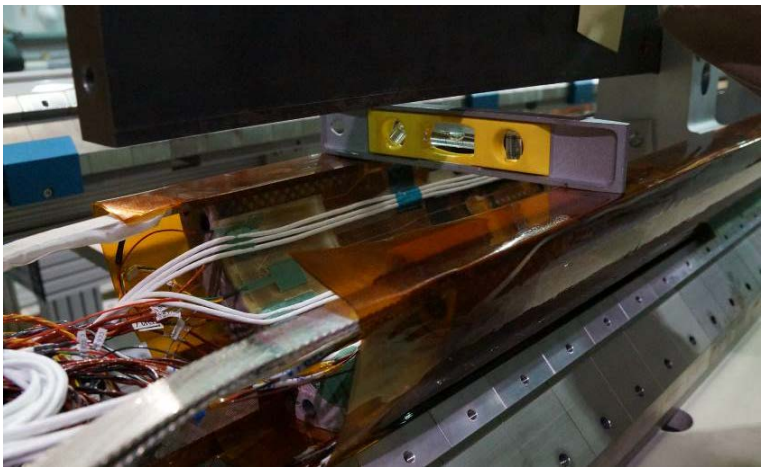


Figure 17: Check clocking of bottom coils

89. Attach fixtures to keep the coils together.
90. Ensure the top 2 coils (quadrants 1 & 2) are axially aligned.
91. Lift the top 2 coils and place them on top of the bottom 2 coils. Ensure all 4 coils are axially aligned by checking that the center lines line up.

Figure 18: Placing top two coils on top of bottom two coils

92. Attach the fixtures to keep the coils together.
93. Push the two Pivot Tables up against the center Coil Pack Table. Use a straight edge to make sure the pad-collar assemblies are axially aligned. Adjust Pivot Table locations as necessary.
94. Strap the Pivot Tables to the center table. (Center of gravity will move to the edge as the pad-collar stack is pivoted, could fall over if not strapped).
95. Ensure the pad-collar assemblies are attached to the dummy master keys with the blue brackets and the brackets are tight.
96. Plug in the pivot tables
97. Pull the Right Pad-Collar Assy away from the coils, and then bring it to a vertical position.
98. Do the same with the Left Pad-Collar Assy
99. The gap between the alignment keys and the collars should be close to equal. Adjust Coil Pack Table height as necessary if not.
100. Check that the screws between load pads will go in.
101. Push the Left and Right pad-collar stacks against the coils. (Clamp in place)
102. Get the top pad-collar assembly into position to be lifted (roll over if necessary). Ensure blue brackets are in place and tight.
103. Lift the top pad-collar stack and move it over the coils. Check that it is axially aligned and that there is an equal gap between the alignment keys and the top collar. Finish lowering.

104. Insert all screws between loadpads where the holes are reachable. Snug tight, but don't apply any significant torque yet.

105. Remove the brackets keeping the coils together.

106. Remove the blue brackets.

107. Remove the top lifting mandrel. Lower the pivot tables.

108. Connect the strain gauge system to the coils to take readings.

109. Insert and snug the remaining screws (all loadpads should have screws).

110. Check the collar gaps. Adjust Pad-Collar Stacks to ensure all collar gaps are equal and even. Ensure that the coil pack remains square. Use levels.

111. From the center, working outward in an alternating and opposing pattern, torque the screws to **125 in-lbs in 25 in-lb increments.**

112. Measure the height and width of the Coil Pack Assembly.

VERIFICATION POINT 14

113. Measure the collar gaps at 15" intervals.

VERIFICATION POINT 15

114. Attach strain gauge readings

VERIFICATION POINT 16

115. Record the coil set-back from the collars (8 measurements, 1 per coil per end)

VERIFICATION POINT 17

6 Completion

116. Ensure all component serial numbers are entered in the Verification Signoff Sheet.

117. Enter the completion date in the Verification Signoff Sheet.

118. Have Verification Signoff Sheet signed and dated by Quality Assurance.

Verification Signoff Sheet

EACH MECHANICAL SYSTEM IS REQUIRED TO HAVE A COMPLETED VERIFICATION SHEET.
VERIFICATION MUST BE DONE BY AN ENTITY OTHER THAN THE ASSEMBLY TECHNICIAN.

TOP LEVEL SERIAL NUMBER:	
ASSEMBLY START DATE:	**ASSEMBLY COMPLETION DATE:**
COMPLETE ASSEMBLY VERIFIED BY (Sign and Date):	

PART NUMBER	DESCRIPTION	QUANTITY REQUIRED	SERIAL NUMBER(S)
SU-1010-8704	Loadpad-Collar Subassembly, Threaded, (Top)	1	27L250-
SU-1010-8704	Loadpad-Collar Subassembly, Threaded, (Bottom)	1	27L250-
SU-1010-8830	Loadpad-Collar Subassembly, Thru, (Left)	1	27L253-
SU-1010-8830	Loadpad-Collar Subassembly, Thru, (Right)	1	27L253-
	Coil, Quadrant 1	1	
	Coil, Quadrant 2	1	
	Coil, Quadrant 3	1	
	Coil, Quadrant 4	1	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
1		Attach Pole Key Modification Chart and reference CMM data for each coil, if applicable Mark if each coil has an issue/modification Q1, (Y/N)? Q2, (Y/N)? Q3, (Y/N)? Q4, (Y/N)?	N/A	
2		Attach Shim Package Diagram to back of sign-off sheet	N/A	
3		Min Kapton Max Kapton Min G11 Max G11	TOOL ID LAST CAL DATE	
4		Sign off that Kapton and G11 completely cover collars	N/A	
5		Fuji Paper Thickness	TOOL ID LAST CAL DATE	
6		Record Alignment Key Widths Below	TOOL ID LAST CAL DATE	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
7		Record Height and Width Measurements Below	TOOL ID LAST CAL DATE	
8		Record Gap Between Collars and Alignment Keys Below	TOOL ID LAST CAL DATE	
9		Attach Strain Gauge Measurements	TOOL ID LAST CAL DATE	
10		Attach New Shim Package Diagram	N/A	
11		Min Kapton Max Kapton Min G11 Max G11	TOOL ID LAST CAL DATE	
12		Sign off that Kapton and G11 completely cover collars	N/A	
13		Note which alignment keys are ultimately used on the magnet in sheet below.	N/A	

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
14		Record Height and Width Measurements Below	TOOL ID LAST CAL DATE	
15		Record Gap Between Collars Below	TOOL ID LAST CAL DATE	
16		Attach Strain Gauge Measurements	TOOL ID LAST CAL DATE	
17		Set Back / Coil 1 / Coil 2 / Coil 3 / Coil 4 LE RE	TOOL ID LAST CAL DATE	

Alignment Key Measurements

Magnet Number: _____ Build (Fuji #, Final):_____

Key #	Thickness	Used? (Y/N)	Key #	Thickness	Used? (Y/N)	Key #	Thickness	Used? (Y/N)	Key #	Thickness	Used? (Y/N)

Height & Width Measurements

Magnet Number: _____ Build (Fuji #, Final):_____

Dist from LE	Height, Left	Height, Right	Width, Top	Width, Bottom
1”				
15”				
30”				
45”				
60”				
75”				
90”				
105”				
120”				
135”				
150”				
165”				
1” from Return End				

Gap Measurements

Magnet Number: _____ Build (Fuji #, Final):_____

Dist from LE	Q1, Coil #		Q2, Coil #		Q3, Coil #		Q4, Coil #	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
1”								
15”								
30”								
45”								
60”								
75”								
90”								
105”								
120”								
135”								
150”								
165”								
1” from Return End								