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Title
SUPERCONDUCTING MAGNET PROGRAM / LARP QXF
GENERAL
DRESSED COIL WORK INSTRUCTIONS

Dressed Coil Work Instructions (WI)

Windchill Unique ID: **SU-1008-8073**

Rev: **L**

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Contents

Revision History

Revision	Issued	Changes
A	10-11-2018	Original Issue.
B	04-04-2019	Add coil length measurement, add extra midplane step, monitoring iron temperature
C	07-24-2019	New wiring diagram, remove monitoring iron temp, new pion pictures
D	11-12-2019	Add coil end leveling, pion drawing, update tools required, wire lengths, cover strain gauges
E	12-16-2019	Do not apply heat to junction between coil and endshoe. Say “center pin” not “center hole”
F	02-28-2020	Coil SG wire length has been changed to 45”. The diagram figure 1 updated Resistances in Item 27 and the sign off sheet updated Coil Schematic drawing number updated. Modified the SG resistance measurement order for better diagnosis. Pion location figure updated, add coil S/N box to 2nd page of VSS
G	08-05-2020	Add extra midplane to outside of GPI (not inside), GPI should hang over the edge 20 mm, crease in the GPI at 1 ¾”, add check for midplane overhang to VP9
H	03-24-2021	Add a second crease to the GPI, increase GPI width from 132 to 136, specify coil connector work, check no gaps under pions, verify that thinner pions go in the correct location – add VP 11, rotate strain gauges so wires point toward RE
J	11-5-2021	Kapton smooth,Trimmed, Midplane verification signoffs removed form VP 9 to create new VP 10.
K	12-15-2021	Add Coil preparation steps; move Level coil ends process to earlier; remove pion installation (move to coil pack WI); add FBG process
L	03-23-2022	Add details to Coil Prep steps; change from do not iron cable-endshoe junction to do not iron cable turns; details about heat of iron during GPI steps; add instruction to tuck leads under table while working

Purpose

The purpose of this Working Instruction is to describe the process of installing the strain gauges, ground plane insulation and the coil bumpers (pions) onto one of the 4 coils. Note: Pions are to be installed after coil quadrant locations have been identified for the magnet assembly.

Scope

This work instruction covers the dressing of one MQXFA coil. (Four are required for one assembly.)

Definitions

Reference Documents

- Dressed Coil, MQXFA Series, SU-1010-2057
- MQXFA Series SG HBM Schematic, SU-1010-7806

Tools Required

Calibrated Tools:

- CMM

Non Calibrated Tools:

- Soldering Iron
- Metric Allen wrench set
- Heating iron curved to match coil outer diameter (for GPI application)
- 1.5" wide by 15 ft long strip of metal for creasing
- 12-15 Soft clamps
- Kapton stretching mechanism
- Roller
- 27K677 – Coil Handling – Outer Pick Lift Beam
- Coil roll-over table
- Coil leveling tooling

Hardware Required

Fabricated Parts & Hardware:

Part #	Description	Req'd
27K950	MQXFA Reference Coil	1
GTS 387630-0136	MQXFA Coil GPI	2
SU-1010-1378	Key, Coil Alignment, LE	1
SU-1010-1396	Key, Coil Alignment, RE	1
27L681	MQXFA2 Coil Alignment Key	6
SU-1010-1713	Coil Bumper, 8mm	5-6
HBM-XC11-3-350-GAGESET	Strain Gage, HBM	1
HBM-XC11-3-350-TC-GAGESET	HBM Temp Compensator	1
Araldite AV/HV 1580	Green putty for coil leveling	A/R

Work Instructions

1 Overview

1. Enter the following information on the Verification Signoff Sheet:
    a. Serial numbers of the coil
    b. Start date

2 Coil Preparation

2. Set the coil on padded blocks with the outer diameter facing up. Tuck the leads into the tubes under the table to protect them.

Figure 1: Coils on table with leads tucked into tubes under the table

3. Measure and mark coil length

VERIFICATION POINT 1

4. Measure and mark center pin from return end (nominal 2265)

VERIFICATION POINT 2

5. Clean all 4 holes on Lead End shoes by drilling with a honing stone
6. Chase all 4 M4 holes on Return End
7. Feel pole groove for proud epoxy or pins. Grind to flush if needed.
8. Chase all 8mm bolt holes on the OD side.
9. Check all putty for high spots
10. Check all wires for insulation breaks
11. Level out endshoes (see next section for instructions).
12. Wrap coil leads with 0.002” x 0.75” Kapton non sticky tape with 50% overlap about 18"

13. Wrap a second layer of non sticky Kapton tape on leads Approx. 12"
14. Trim Return End protection heaters to 19" relabel if needed
    a. Label 4" from endshoe and 6" from end of wire
    b. Label includes Coil # and PH #
15. Check that epoxy flashing on the leads does not extend more than ½" from the coil for each inner and outer lead.
16. Unravel Lead End wiring respool in 1 bundle for protection heaters tie up with wax string Approx. 6-8" from end of coil
    a. Leave 18-24" loose
17. Measure wire lengths
    a. Lead lengths
    b. Protection Heater wire lengths
    c. Voltage Tap wire lengths
18. Prep VT wires tie approx. 4-5" from endshoe
19. Separate the VTA01b and the VTB01b wires
    a. Bundle these 2 together and tie up with wax string
20. Bundle all other VT's in 1 bundle tying up approx. 6-8" from end of coil leaving 18-24" loose

VERIFICATION POINT 3

21. Flip the coils so that the inner diameter is facing up. Tuck the leads under the table again.
22. Mark inner coil layer (Lead end shoe)at 50mm (dremel out groove for fiberoptics)
23. Check Mid plane for flashing. File if needed.
24. Chase all 8mm bolt holes on the ID side.
25. Check all pion locations and ream with 8mm endmill if needed

VERIFICATION POINT 4

3 Level Coil Ends

26. The inner and outer layer of the coil need to match each other in length. This is done by adding Araldite AV/HV 1580 ("Green Putty") to the shorter of the inner or outer layer of the coil at both ends.

27. If the step difference between the inner and outer layer of the coil is minimal (less than 1/16") apply putty to both layers.

28. Prepare the putty and apply it to the end of the coil. Putty must be made flat and coplanar with the other coil layer. Use a fixture to clamp the putty flat (see figure).

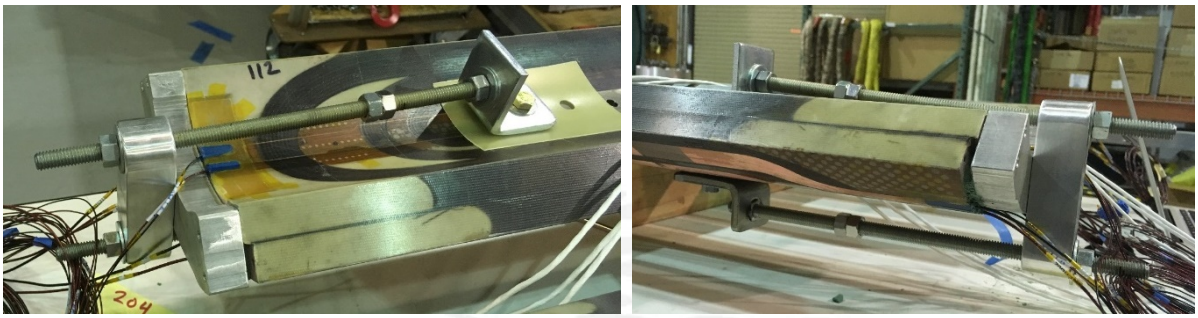


Figure 2: Clamp on the end of the coil for leveling operations

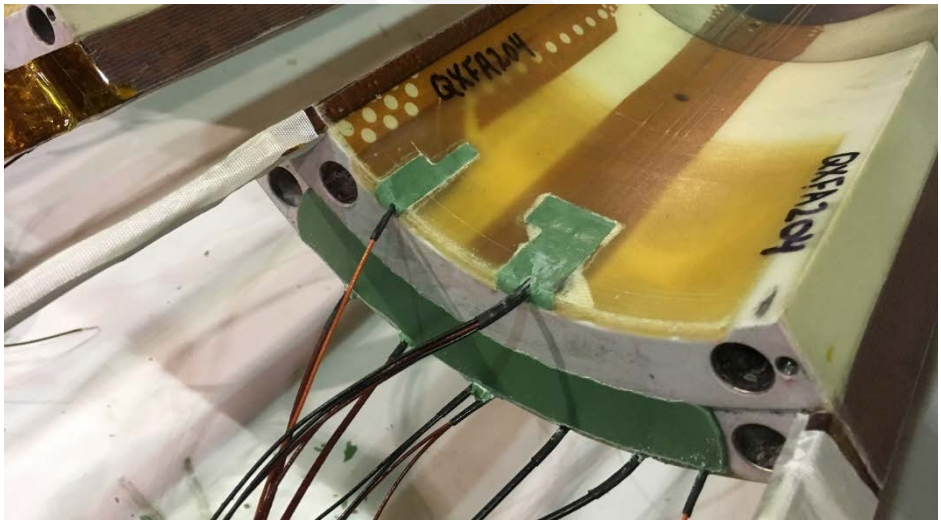


Figure 3: Green putty in place for the leveled coil end (LE shown)

29. Remove putty flashing with a chisel. Be careful not to nick the wires.

4 Strain Gauge Selection Setup

30. For each coil, 2 HBM XC11-3/350 (biaxial) strain gauges are required. Record the lot number(s) as well as the stated gage factor in the verification sign-off. Having all gauges from the same batch is highly preferable.

VERIFICATION POINT 5

5 Strain Gauge Bonding

31. Scribe locating lines on the coil, according to Drawing #SU-1010-2057
32. Additionally, each coil segment requires 1 temperature compensator pads (1 per station). This material is to be made from the same batch as the coil poles.
33. Prepare the surfaces of the coil and compensator pads in preparation for bonding, and set aside each strain gauge required.
34. Remove any debris (fiberglass, epoxy, etc.) from areas of surface that are to be bonded.
35. Sand area and clean with isopropyl alcohol, starting with 220 grit paper
36. Repeat sand and clean operations, working up to 320 grit paper.
37. Clean surface with Vishay M-Prep Conditioner A, scrubbing first with 320 grit paper, then with a cotton swab.
38. Scribe layout lines for gauge placement per Drawing #SU-1010-2057
39. Treat surface with M-Prep Neutralizer 5A.
40. Position the gauge (and terminal strip) on part using the layout scribe lines. Handle by grasping the edge of the gauge backing with tweezers
41. Use the Vishay PCT-2M installation tape to hold the gauge/pad in position.
42. Peel back tape with the gauges and terminal pads to expose bonding surface.
43. Clean area again with M-Prep Neutralizer 5A.
44. Mix Araldite 90-min standard epoxy per instructions. Mix thoroughly for 5 minutes.

    Note: working life is approximately 45 minutes.
45. Apply adhesive to gauge, terminal pad and bonding surface. Try to minimize excess adhesive during this process.

46. Re-tape the gauge in position.
47. Cover gauge with soft rubber pad and backing plate.
48. Clamp in place to approximately 5-20 psi. Wipe any excess glue away.
49. Allow adhesive to cure overnight.
50. Have Cognizant engineer sign off that it is okay to proceed with wiring.

VERIFICATION POINT 6

6 Strain gauge jumpering

51. After strain gauges have cured, wire up each strain gauge per the diagrams below using 32-gauge Kapton®-coated solid copper wire.

    Use ONLY Vishay #361A-20R (63/36.65/0.35 Tin/Lead/Antimony, rosin core) solder for this and all subsequent operations.

52. Have responsible engineer sign off that the strain gauges have been mounted correctly.

VERIFICATION POINT 7

7 Wiring and connectorization

53. For the coil HBM station gauges, obtain 5 twisted pairs of wire of 45” long. Use Vishay Wire.
54. Wire and jumper the gauges per the diagram below. Pinouts given in tables on following page.

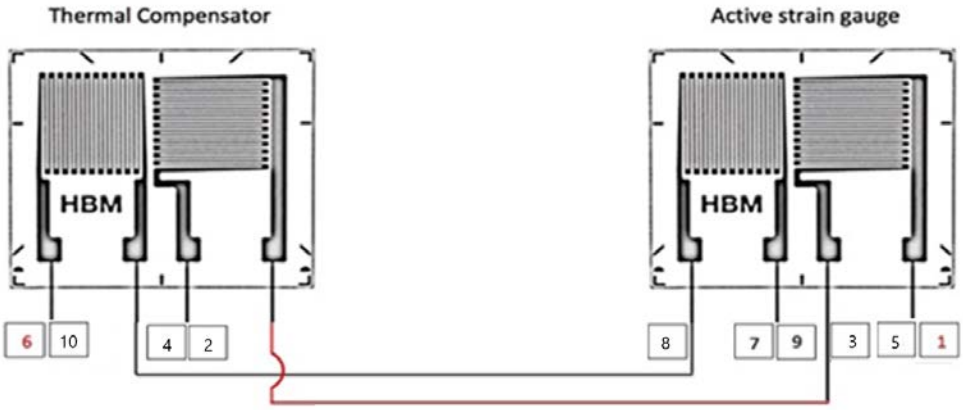


Figure 4: HBM gauge wiring

Table 1: SG Connectors

Conn. ID	Gauge		Cable					
			Wire color	label				pin
CxxxT	Half bridge with compensator	P +	Red	1	Cable 1	White 4-core cable, 45"	5 pin female	1
		S-	White	2				2
		M+	Red	3	Cable 3			3
		P-	Black	4	Cable 1			4
		S+	Green	5				5
CxxxZ	Half bridge with compensator	P +	Red	6	Cable 2		5 pin female	1
		S-	White	7				2
		M+	Black	8	Cable 3			3
		P-	Black	9	Cable 2			4
		S+	Green	10				5

55. Each station needs 3 cables. Cable 3 is the two-wire cable (only red and black)

56. Verify that the pins have the following resistances:

    - pin 3 & 1 = 350 Ohm
    - pin 3 & 2 = 350 Ohm
    - pin 3 & 4 = 350 Ohm
    - pin 3 & 5 = 350 Ohm
    - pin 1 & 5 = 0-0.7 Ohm
    - pin 2 & 4 = 0-0.7 Ohm

    This pattern repeats for every 5 pins, i.e.:

    - pin 8 & 6 = 350 Ohm
    - pin 8 & 7 = 350 Ohm
    - pin 8 & 9 = 350 Ohm
    - pin 8 & 10 = 350 Ohm
    - pin 6 & 10 = 0-0.7 Ohm
    - pin 7 & 9 = 0-0.7 Ohm

VERIFICATION POINT 8

57. Have the responsible engineer sign off to indicate all coil gauge instrumentation wires have been soldered correctly.

VERIFICATION POINT 9

58. Coil up all of the cables and label the bundles for temporary identification. Cables will extend toward the return end (RE) of the coil.
59. Solder all the strain gauge wires to Hypertronics connectors per the schematic shown in the coil schematic SU-1010-7806.
60. Have the responsible engineer sign off to indicate all connectors for the coil have been attached properly.

VERIFICATION POINT 10

61. Place a Kapton cover sheet over the station and tape down.

8 Add Connectors to the Coil Wires

62. Wire the voltage taps (VT) as follows. (Series is A01, A02, B01, B02 only)

Table 2: VT Connectors

Conn. ID		Connector Pinout		
		Conn. Type	Pin	Wires
Coil xxx	LE1	5p LAMSTAH (male)	1	A01
			2	A02
			3	A03
			4	A04
			5	A05
	RE2	5p LAMSTAH (male)	1	N/A
			2	
			3	
			4	A07
			5	A06
	LE3	5p LAMSTAH (male)	1	A08
			2	N/A
			3	
			4	B07
			5	B08
	RE4	5p LAMSTAH (male)	1	N/A
			2	
			3	
			4	B05
			5	B06
	LE5	5p LAMSTAH (male)	1	B01
			2	B02
			3	B03
			4	B04
			5	N/A

63. Wire the protection heaters (PH) as follows. Do NOT add any connectors to the RE PH wires. They will go into the PH jumper block.

Table 3: PH connectors

Coil	Module ID	Connector # on skirt	Pin	wire Label
Coil XXX	LPH1	2pin Male	1	PHB01a
			2	PHB04a
	LPH2	2pin Male	1	PHB02a
			2	PHB03a
	RE No connector	N/A		PHB01b
				PHB04b
	RE No connector			PHB02b
				PHB03b

9 FBG Gauge Installation

64. The gauges will be installed at 715, 1965 and 3725 mm from the Lead End

65. Cut out pads at the three locations (in between holes) Ensure window has sufficient clearance that no damage to the cable occurs.

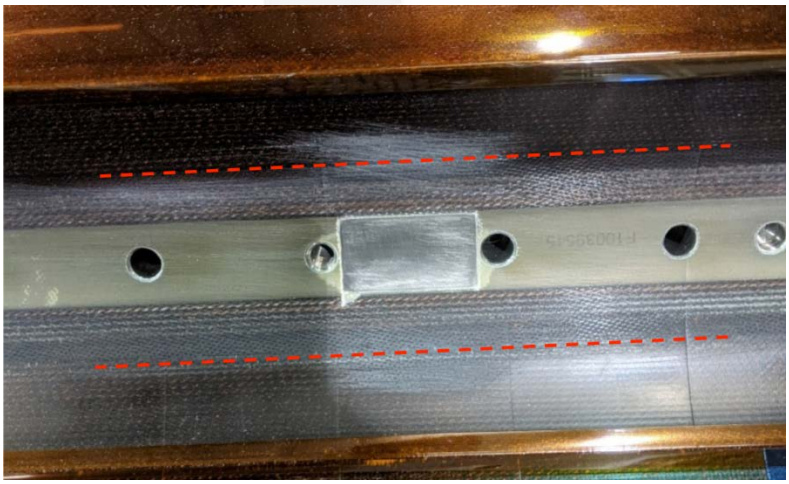


Figure 5: cut out a section of epoxy

66. Use a Scotch Brite bad to remove the mold release from the surface and allow bonding. Only area between the wedges (as shown in Figure 5) from the LE to approximately 3900mm to remove mold release are required. Wipe down with alcohol to remove dust.

67. Cut a groove at the LE (if not already long enough, ~2" long)

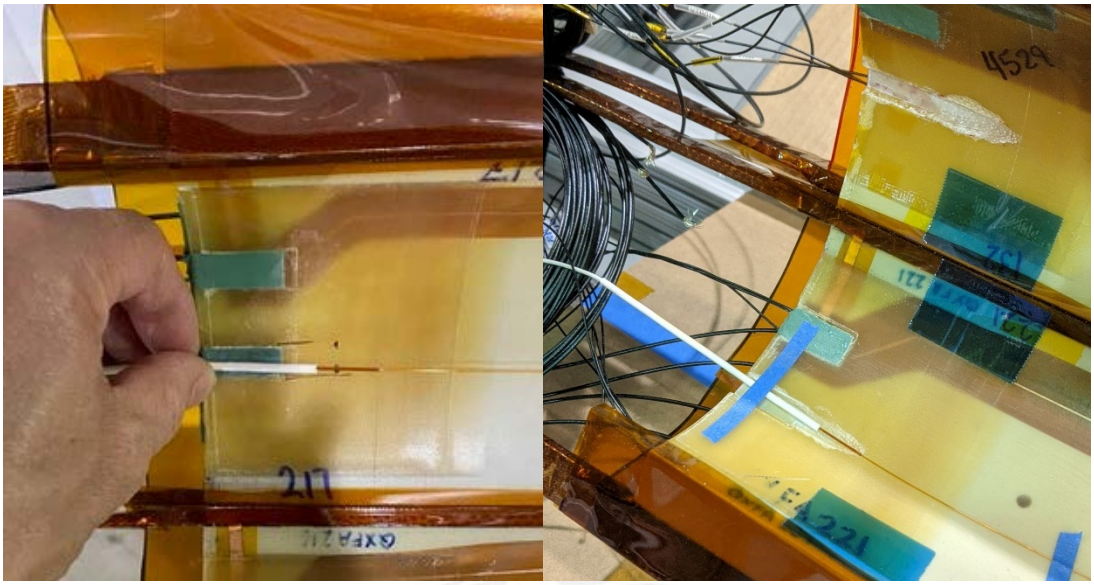


Figure 6: cut out a groove at the LE

68. Prepare the fiber by carefully unwinding it from its packaging, identifying the connectors on each end by laying it out. Mark each end accordingly (Figure 7 will indicate LE on FBG6 end, and RE will be on the FBG1 end).

69. Carefully wind the fiber back into the packaging using a minimal amount of tape to ensure it's held in place just enough during installation. Secure each connector end to prevent swinging that can cause breakage.

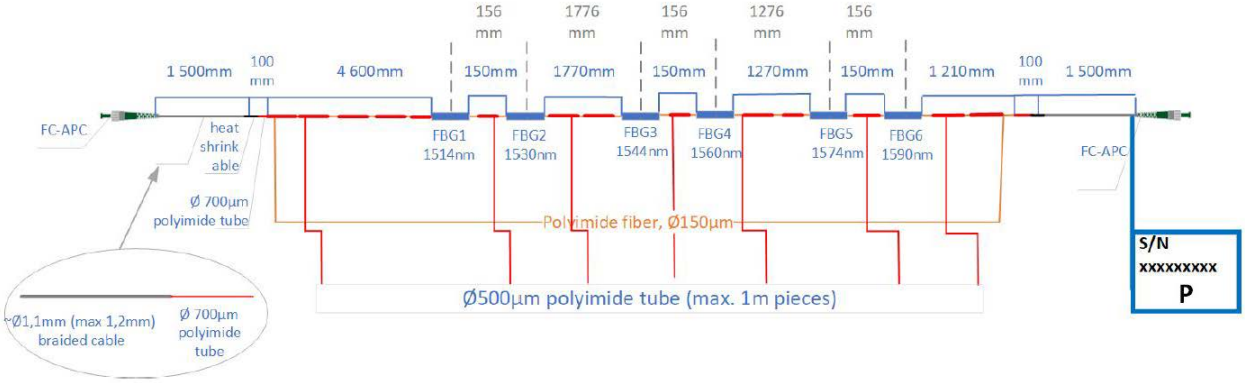


Figure 7: schematic of the cable

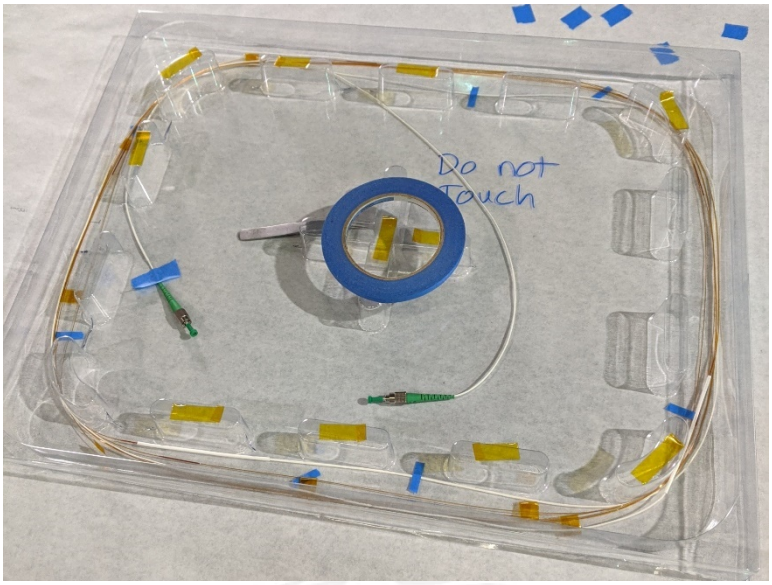


Figure 8: Cable stored before being installed

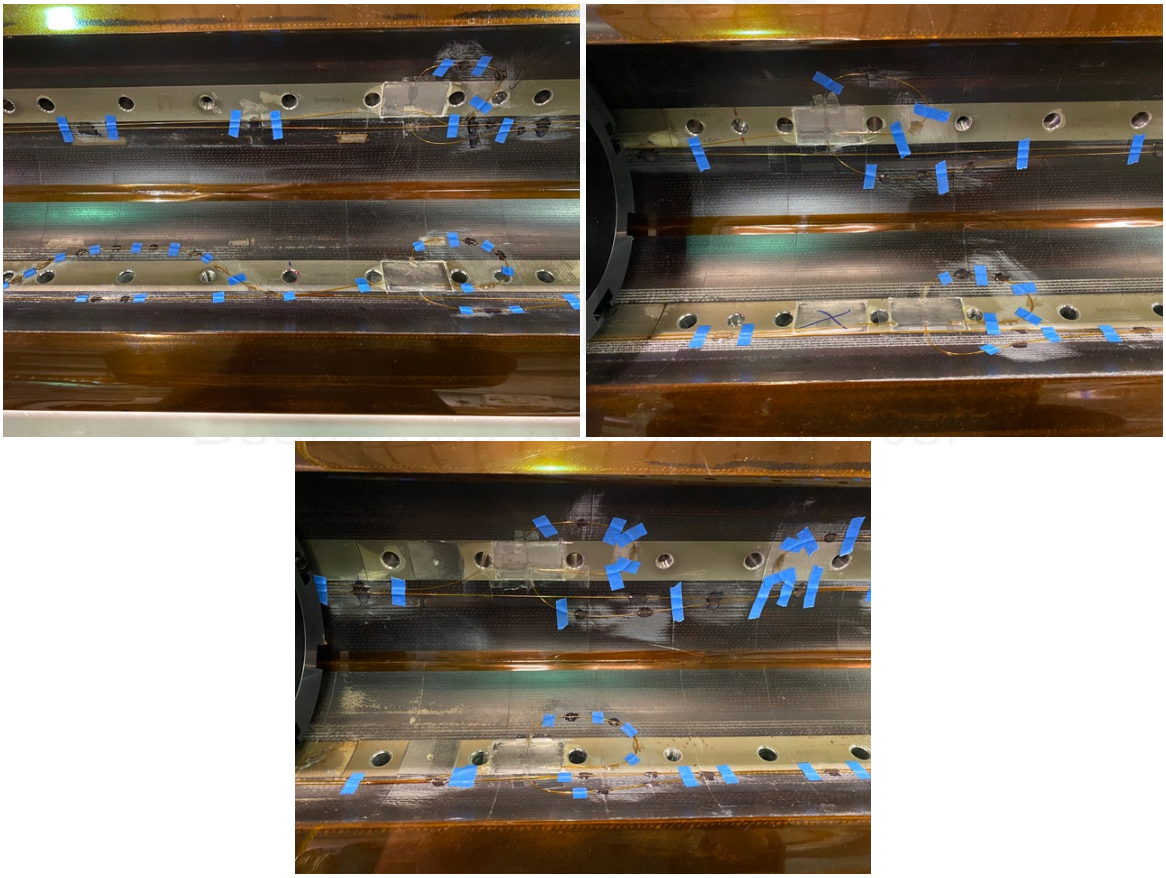


Figure 9: Fiber routing examples

70. Connect the FBG Interrogator and SG system, and connect the gauge to the proper channel.

71. Carefully unwind the fiber onto the coil, starting from the Lead End. Tape locations down for temporary placement, ensuring that the fibers will not be snagged by fingers or tooling. Note that the loops at each strain gauge station in Figure 9 show the axial grating laid out first, then looped up and over for the transverse grating.
    a. For each gauge grating setup, have a second person reading the FBG interrogator during the layout process.
    b. Before taping down the gratings the fiber must be stretched so that the interrogator reports about ~150 nm extension. Tape down the grating, leaving sufficient space for a spot of epoxy that will bond the grating when ready. (Note that it is common for the grating to lose its extension prior to bonding, which is still acceptable.)
72. Bond the cable by applying a small amount of epoxy directly to the grating.
73. Place a piece of tape over the gauges, and the wooden block with a lead block over the fiber as it cures. Ensure that the silicone rubber pieces are resting directly over the gratings when placing the wooden block into place.

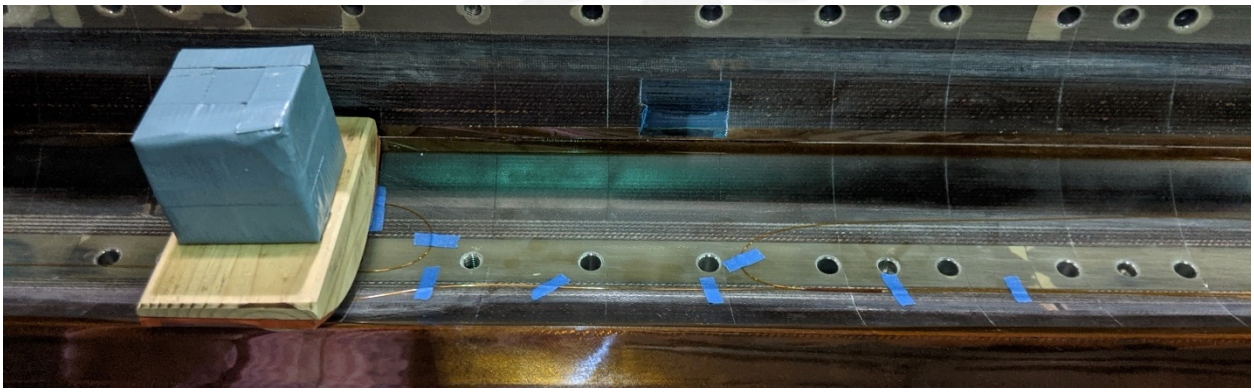


Figure 10: Set tape, a wood block and a lead block over the fiber as it cures

74. Take note of the interrogator values after bonding. Keep the interrogator reading overnight during the curing process.
75. Once cured, remove the wooden block and the weights. Ensure that the interrogator is still seeing each gauge.

VERIFICATION POINT 11

76. Mix epoxy and place small dots of epoxy along the routed fibers.
    a. Ensure that the any fiber, service loop, or location is within the two wedges of the coil.
    b. Ensure that the RE portion of the Fiber service loop is looped and bonded underneath the wired strain gauges. This is because the wired strain gauges will be removed after vertical testing

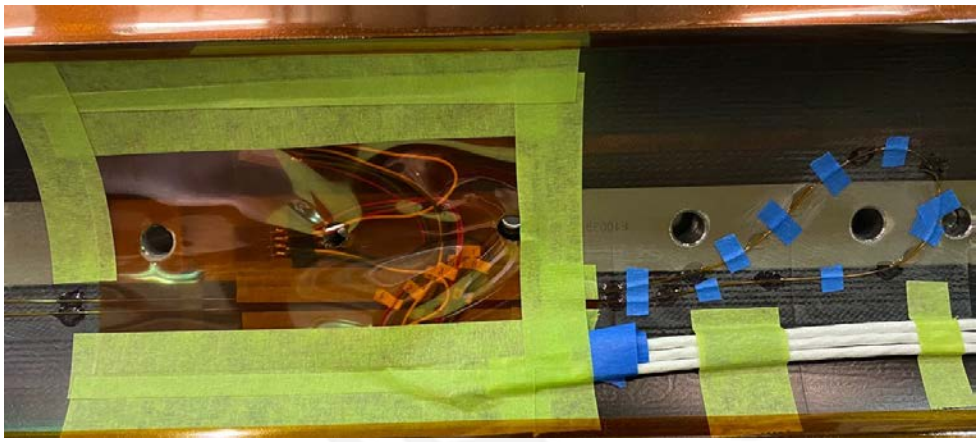


Figure 11: RE portion of fiber is routed underneath the wired strain gauges (wired strain gauges are removed later)

77. Let cure overnight.
78. Remove all the setup tape. Verify that the gauges are all bonded properly.

VERIFICATION POINT 12

79. Use green putty to secure the fibers in the pocket on the lead end, make sure the thick part of the protected fiber doesn't extend into the bore.

Figure 12: Green putty securing the fiber

10 Coil Ground Plane Insulation Installation

80. Make note of the coil's center pin location. Ensure centerlines are on OD of each coil for ease of aligning each during the later assembly operations.

81. Mount the coil on the Kapton stretching mechanism. Capture the leads with the fixtures. Tuck the leads under the table.

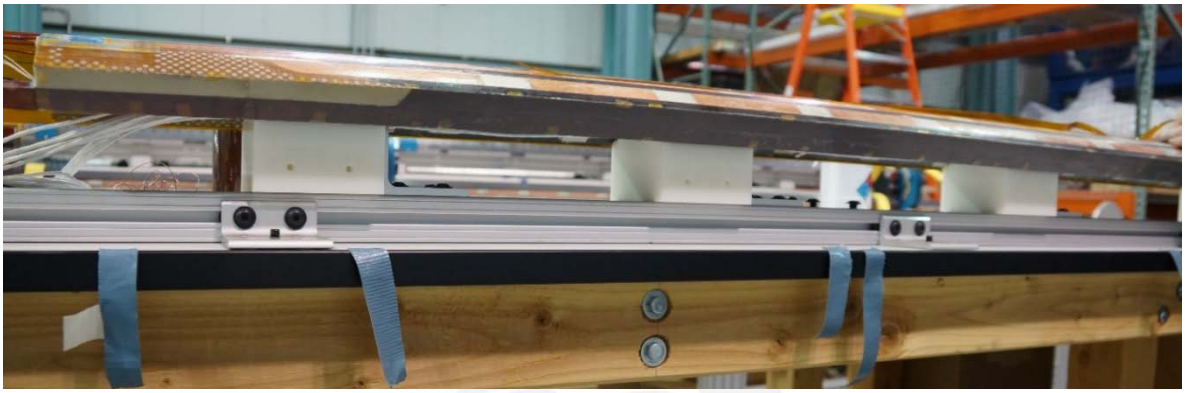


Figure 13: Coil mounted for ground plane installation

Figure 14: Fixtures to capture coil leads

82. Cut sheets of 0.003" thick Kapton with 0.0015 B-stage epoxy on one side (GTS P/N 387630-0136) to 4853 mm (191") long by 136 mm wide. Lay the Kapton down with the epoxy side up. Two sheets per coil are required. Do Not Kink.

83. Mark the Kapton with a fine tip sharpie at 1 ¾" (44.5 mm) and lay 1.5" wide piece of metal on top along the marks. ¼" (6.35 mm) should be exposed on the other side of the metal.

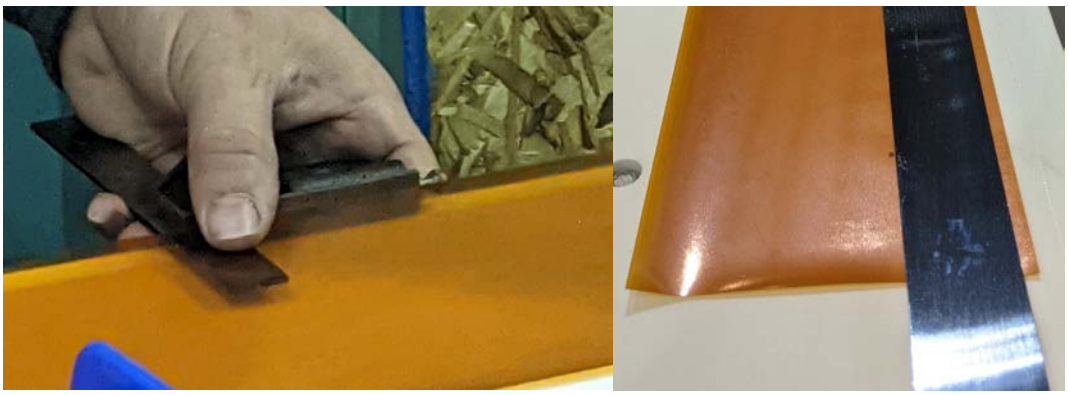


Figure 15: Mark Kapton (left) lay 1.5" wide metal on top of Kapton, along the marks, such that ¼" shows on other side of metal (right)

84. Clamp the metal and Kapton down.

Figure 16: Clamp the metal down on the Kapton. Kapton is epoxy side up.

85. Crease each length of Kapton at ¼" (6.35 mm) and 1 3/4" (44.5 mm) (either side of the metal piece). Make sure to have a sharp crease, but make sure not to cut the Kapton. Will require going over it at least twice.

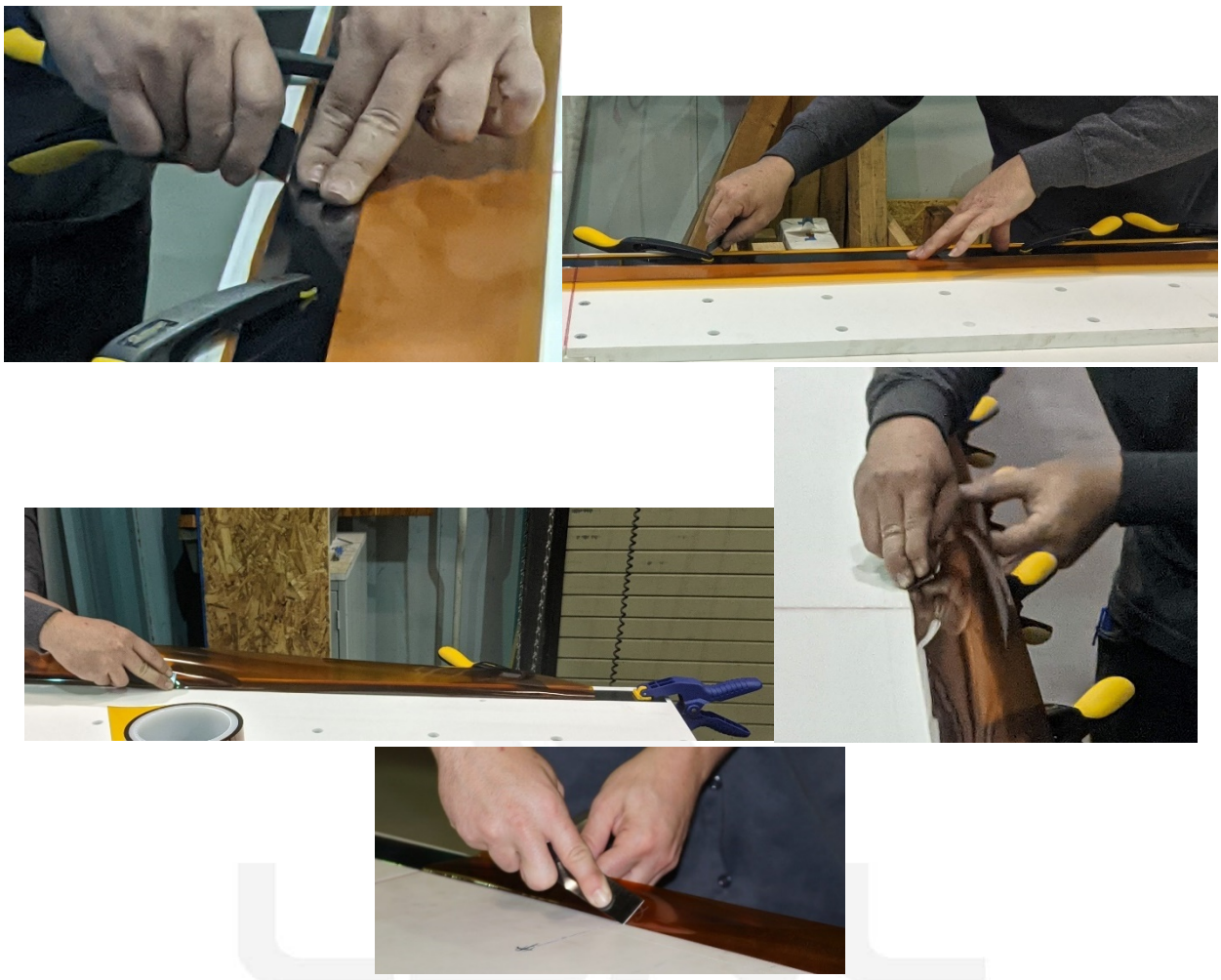


Figure 17: Putting in the ¼" crease (top) Putting in the 1 ¾" crease (middle) another view of the tool used (bottom)

86. Wipe the coil with alcohol to clean. Try not to remove the center line.
87. Mount the Kapton on the stretcher

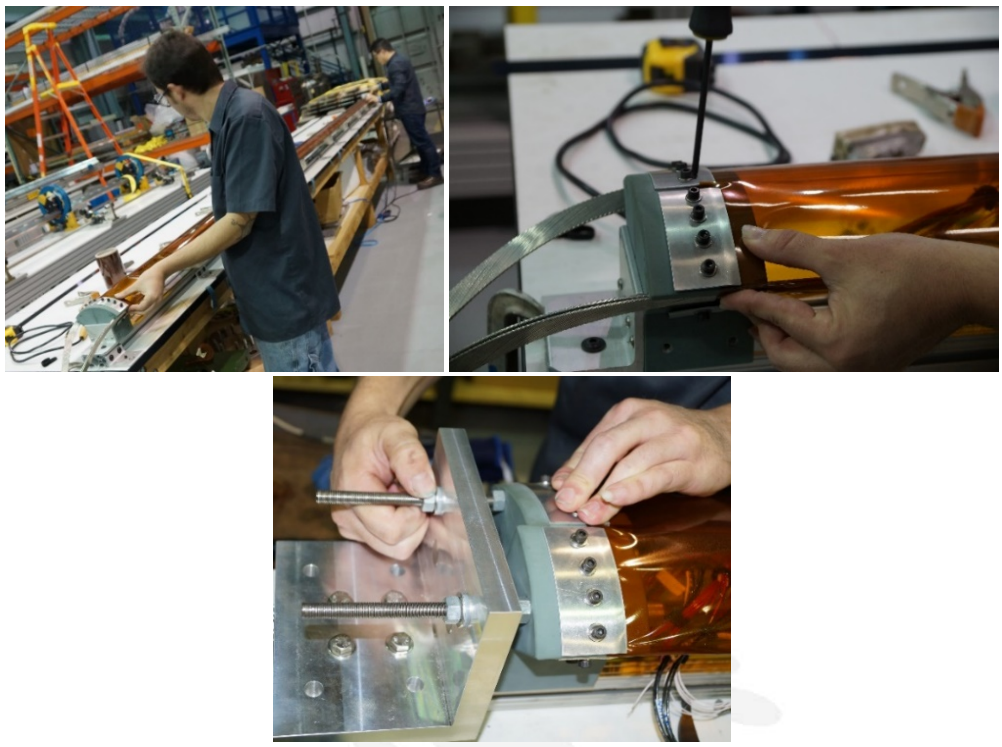


Figure 18: Put the Kapton on the stretcher (top left) Clamp the sheet to the stretcher (top right) stretching mechanism to keep the Kapton sheet taut (bottom)

Figure 19: Tape the Kapton in place. Use 3M 8979 tape.

88. Starting at the lead end, tape the Kapton in place with 3M 8979 tape, taping approximately every 7-8", stretching it tight and making sure that the crease at 1 ¾" is tight on the edge.

89. Watch for any debris between the Kapton and coil, and remove as necessary.

Figure 20: Removing debris

DO NOT apply hot iron to the cable turns

Figure 21: Do not iron the cable turns

90. Using a hot iron, apply the Kapton with the B-stage epoxy to the coil.
    a. Check iron for scratches or burrs
    b. Set Variac to 90-95 max
    c. Iron temperature: 135-140 C (275-284 F)
    d. Hold the iron in place for 15-20 seconds, using 50% overlap
    e. Use a roller on the heated Kapton to press it to the coil
    f. Make sure no color distortion on heaters
    g. A gap of 1 mm down the center of the coil is acceptable.
    h. There should be approximately 6 mm of Kapton protruding into the bore side of the coil.
    i. Ensure that the fold of the Kapton is well aligned with the corner of the coil.

91. Have the responsible engineer sign off to indicate the Kapton has been laid precisely, free of defects.

VERIFICATION POINT 13

Figure 22: Hot iron to bond the Kapton to the coil

92. Trim the Kapton away from the center slot.

Figure 23: Trim the Kapton away from the center groove

93. Mark Kapton at lead end and return end 20 mm (3/4") from coil and trim off excess Kapton. (Use G10 tool for measurement)
94. Transfer the centerline mark to ensure it is visible.
95. Have cognizant engineer sign off.

VERIFICATION POINT 14

11 Install Extra Midplane if Required

96. If extra midplane is required (see Coil Pack Assembly Work Instructions), transfer the coil to the roll-over table.

97. Roll the coil so that the midplane section is pointing upwards.

98. Record how much extra midplane is being added.

VERIFICATION POINT 15

99. Add the correct thickness of extra midplane under the GPI so that it is touching the B-stage epoxy.

100. Clamp one end of the midplane to the lead so it can be stretched flat from there

101. Tape the Kapton in place with 3M 8979 tape, stretching it tight and flat.

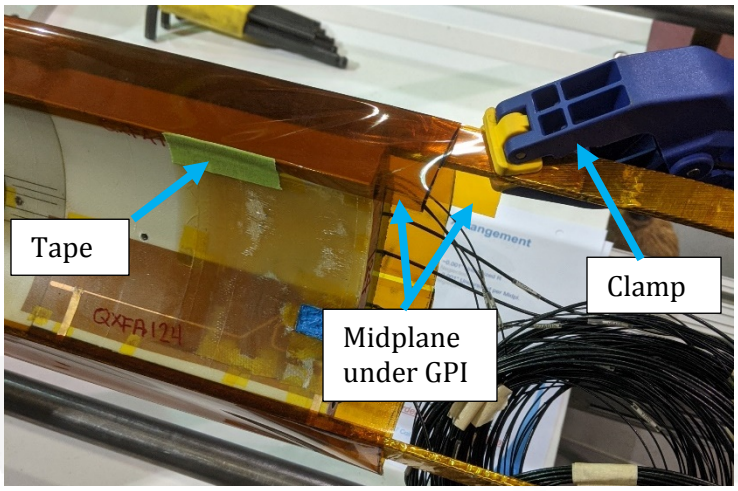


Figure 24: Extra midplane ready to iron

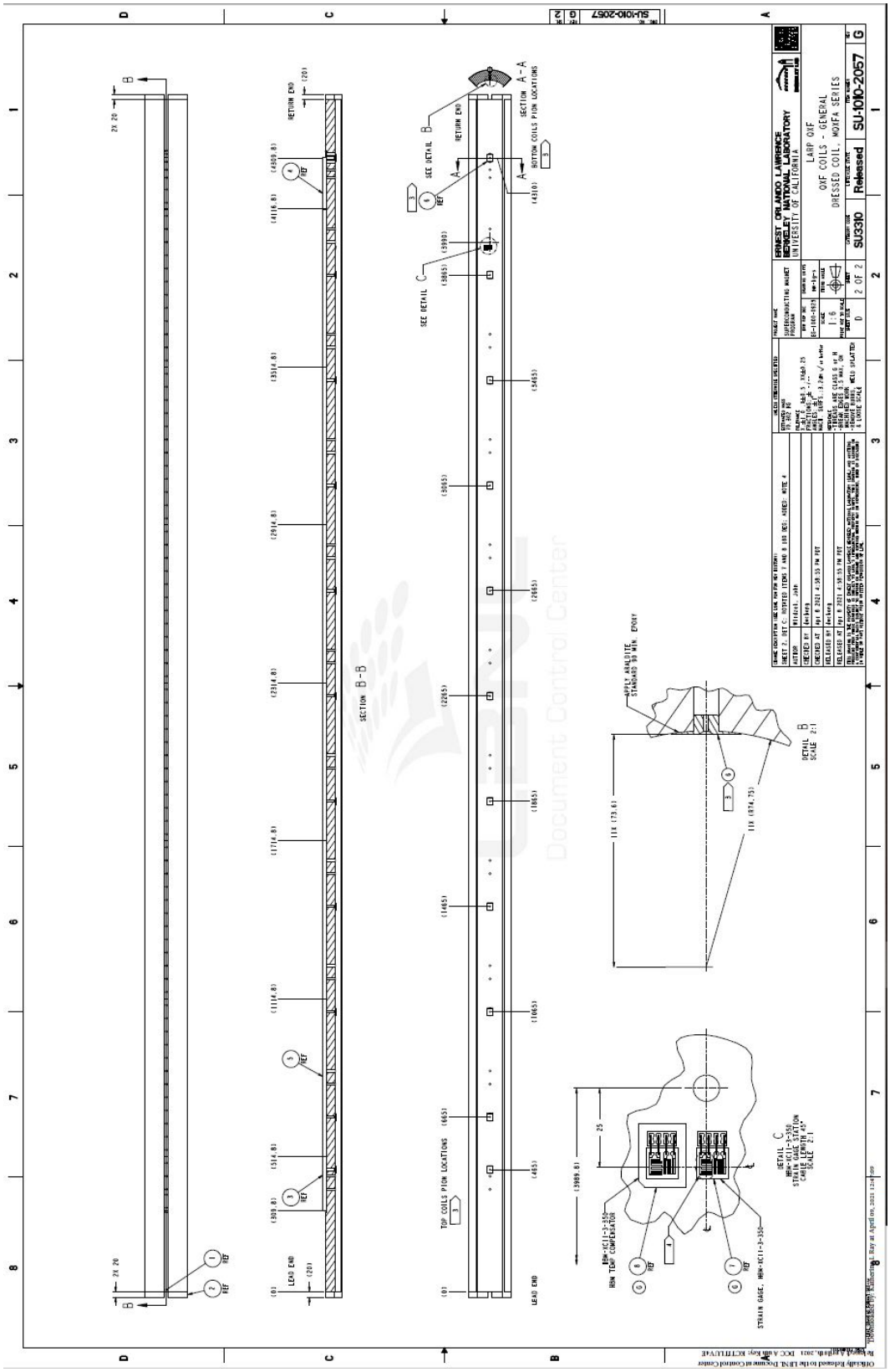
102. Set Variac to 90-95 max. Heat the iron to 135-140 C (275-284 F) to attach the midplane section of the GPI to the extra midplane.

12 Completion

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

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

105. 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.

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

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
1		Coil length	N/A	
2		Distance from RE to Coil center pin (2265 mm nominal)	N/A	
3		Coil prep work with OD up: ☐ Clear/chase 4 holes on LE, M4 holes on RE, 8mm bolts, OD side ☐ Check for proud epoxy/pins, putty high spots ☐ Endshoes leveled ☐ Coil leads wrapped, 2 layers, remove excess epoxy ☐ Trim RE PH wires & relabel ☐ Rebundle PH wires, VT wires	N/A	

COIL SERIAL NUMBER:

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
3 (con't)		Lead length: PH length: VT length:	N/A	
4		Coil prep work with ID up: ☐ Dremel groove for fiberoptics ☐ Check midplane flashing ☐ Chase 8mm bolts, ID side ☐ Chase pion locations	N/A	
5		Lot Number/Gage Factor	N/A	
6		Strain Gauge Bonding Sign-off	N/A	
7		Strain Gauge Jumpering Sign-off	N/A	

COIL SERIAL NUMBER:

VERIFICATION POINT	ASSEMBLY TECHNICIAN (Sign & Date)	RECORDED INFORMATION	CAL INFO	VERIFICATION BY (Sign & Date)
8		Pins resistances: ☐ pin 3 & 1 = 350 Ohm ☐ pin 3 & 2 = 350 Ohm ☐ pin 3 & 4 = 350 Ohm ☐ pin 3 & 5 = 350 Ohm ☐ pin 1 & 5 = 0-0.7 Ohm ☐ pin 2 & 4 = 0-0.7 Ohm	TOOL ID LAST CAL DATE	
9		Strain Gauge Wiring Sign-off	N/A	
10		Strain Gauge Connector Wiring Sign-off	N/A	
11		Interrogator is still sees each gauge after bonding	N/A	
12		FBG process complete, tape removed, fiber doesn't move	N/A	
13		Kapton crease is tight to the edge, midplane extends 6 mm into gap	N/A	
14		Kapton smooth,Trimmed	N/A	
15		Extra midplane amount (if used)	N/A	