Princeton Plasma Physics Laboratory
Procedure

Procedure Title: **Modular Coil Fabrication-Post VPI Activities**

Number:	Revision:	Effective Date: **April 9, 2007**
D-NCSX-MCF-004	**03**	Expiration Date: *(2 yrs. unless otherwise stipulated)*

Procedure Approvals

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RLM: Larry Dudek:

Responsible Division: **NCSX Project**

Procedure Requirements
Designated by RLM

LABWIDE:

X	Work Planning Form # **WP-1188 & 1138** (ENG-032)		Lockout/Tagout (ESH-016)
	Confined Space Permit (5008,SEC.8 Chap 5)		Lift Procedure (ENG-021)
	Master Equip. List Mod (GEN-005)	**X**	ES&H Review (NEPA, IH, etc.) **NEPA 1283**
	RWP (HP-OP-20)		Independent Review
	ATI Walkdown		Pre-Job Brief
	Post-job Brief *		

D-SITE SPECIFIC:

X	D-Site Work Permit (OP-AD-09)		Door Permit (OP-G-93)
	Tritium Work Permit (OP-AD-49)		USQD (OP-AD-63)
	Pre-Job Brief (OP-AD-79)		T-Mod (OP-AD-03)
	** DCA/DCN (OP-AD-104) # _____		

* Required for installations involving internal vacuum installations, critical lifts, and for the initial installation of repetitive work.

** OP-AD-104 was voided by procedure ENG-032. However, DCA's that were open at the time of adoption of ENG-032 are still considered valid for work approval purposes.

REVIEWERS (designated by RLM)	**Rec'd/ Incorp. Comments**
Accountable Technical Individual. **…….J. Chrzanowski**	
Test Director	
Independent Reviewer **Eugene Kearns**	X
D-Site Shift Supervisor	
Independent	
NCSX Dimensional Control Coordinator …….	
Vacuum	
NCSX Field Supervisors… **Tom Meighan**	**X**
Project Engineer for Stellerator Systems (WBS 1) Manager**……Brad Nelson (ORNL)**	
Independent NCSX Engineering ……	
Quality Assurance/Quality Control. …… **Colin Phelps**	**X**
Maintenance and Operations Division	
Energy Conversion System/Motor Control Division	
Engineering ……..	
Environmental Restoration & Waste Management Division	
Environmental, Safety & Health**…….Jerry Levine**	**X**
Industrial Hygiene**…….. Bill Slavin**	**X**
Health Physics**……**	
RLM ……..**Larry Dudek**	

TRAINING (designated by RLM)

No training required _____ Instructor **Jim Chrzanowski**

Personnel (group, job title or individual name)	Read Only	Instruction **Pre-job Briefing**	Hands On
Lead Tech.		**X**	
Technicians performing task		**X**	
Field Supervisors		**X**	
Quality Control Representative		**X**	
Training Rep.			
RLM **Larry Dudek**			

RECORD OF CHANGE

Revision	Date	Description of Change
00		Initial release
01	6/6/06	Revamped entire procedure to reflect changes in manufacturing sequence -Added new figures throughout procedure -Added finalization of diagnostic flux loops -Added joint resistance test section of connectors -Modified table and clarified description of assemblies for cooling tube tests -Added more detail of turning fixture installation -Added more detail for final clamp installations -Removal of prosthetic filler -Added removal of studs and bag mold details
02	9/18/06	-Added safety notes throughout procedure identifying PPE's -Revised pneumatic testing description & added schematic 6.13 -Added reference to use of pneumatic impact wrenches throughout procedure -Added cooling tube termination details 6.9 and 6.10 -Added additional electrical tests
03	3/29/07	General description of changes 1) Added coil resistances from design specifications [6.19.4] 2) Add Safety Notes about blocking hinge during assembly of coil to ring- includes signoff [Sect 6.23] 3) Modified safety note: gloves & steel tip shoes during rigging [Sect. 6.3.1.5 & 6.23] 4) Changed description of stations 3 & 4 [sect 1.1] 5) Added TIG welding as option for diagnostic boxes [6.16.3] 6) Removed steps for filling cooling holes with urethane. 7) Removed reference to name tag. 8) Added sequence of electrical tests [6.19] 9) During electrical test- change QC witness to QC verify [6.19] 10) Added steps and figure for terminating cooling tubes [6.9] 11) Added signoff for preparing joint area prior to testing. [6.19.4 and 6.19.5] 12) Added Hi Pot Test section [6.19.20] 13) Added section for protecting leads [6.23]

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1 Scope

1.1 Introduction

The NCSX Coil Manufacturing Facility is divided into 5 workstations. Each workstation has a specific set of tasks that will be performed as part of the overall fabrication process. This procedure addresses the manufacturing, inspection, test and QC inspection points for a specific workstation required to manufacture the modular coils.

- **Station No. 1…** **Post VPI Activities**
- Station No. 2… Winding/Bag Mold Station
- Station No. 3… Winding/Bag Mold Station
- Station No. 4… Winding Form Preparation Station
- Station No. 5… VPI and Autoclave Activities

1.2 Scope

This procedure identifies the post VPI activities for each Modular Coil (MC) or Twisted Racetrack Coil (TRC). It includes:

- Installing the MC into the turning fixture
- Cleanup of the coil following VPI
- Preparation of coil for final coil clamps
- Installation of the final coil clamps
- Room temperature electrical testing of coil
- Termination of cooling tubes
- Installation of thermocouples & strain gauges
- Disassembly of coil/winding form from support ring

1.3 Identification of winding form being prepared:

Station Number: _____ (Location where work will be performed)

Winding Form Type: _____ [Type A, B, C or Twisted Racetrack Coil (TRC)]

MC Winding Form ID No: _____

2 Applicable Documents

2.1 NCSX-MIT/QA-142-01:
All applicable documents associated with this procedure, are identified in the MIT/QA Plan, document number **NCSX-MIT/QA-142-01**.

2.2 NCSX-PLAN-MFOP-00:
All Modular Coil work processes are governed by the "Manufacturing Facility Operations Plan", document number **NCSX-PLAN-MFOP-00**.

2.3 **D-NCSX-MCF-005** Dimensional Control & Metrology for the NCSX MC

2.4 **D-NCSX-PLAN-MCWDC** Modular Coil Dimensional Control Plan

2.5 **D-L-NCSX-984** Lifting Modular Coil Assemblies

2.6 **D-L-NCSX-996** Lifting Finished Modular Coil Assemblies

3 Safety Requirements:

All work will be performed in a safe manner in accordance with PPPL safety policies **ES&H 5008** and "Integrated Safety Management" (ISM) policy.

3.1 Job Hazard Analysis:

JHA's will be generated for each workstation, identifying existing or potential workplace hazards and to evaluate the risk of worker injury or illness associated with job tasks. (Reference document **ESH-004 "Job Hazard Analysis**") The IH representative will review the JHA's for accuracy as well as completeness. It will be reviewed with all activity participants at the Pre-Job briefings.

4 Prerequisites & Conditions:

4.1 Pre-Job Briefing:

A pre-job briefing will be held prior to the first time that revision of the procedure is used or if being performed by a new crew. The briefing will describe the processes and safety issues [JHA] associated with procedure. Attendance shall be documented via training sign-in sheet.

Pre job Briefing complete: _____ _____
MC Field Supervisor **Date**

4.2 Daily Operations Startup and Shutdown:

Each working day, it is required to complete and initial the daily operations startup log to ensure that the station is ready to commence work activities for the day. The signoff log is located in the Daily Station Log. See section 6.1 and 6.2 for details.

4.3 Reference Torque Values:

Unless a torque value is specified or the fastening material is something other than low carbon steel, the following values shall be used whenever the procedure requires a torquing operation:

3/8-16UNC …… 18 ft-lbs	3/8-24UNF …… 19 ft-lbs	½-13 UNC …… 38 ft-lbs
½ -20 UNF …… 40 ft-lbs	5/8-11 UNC…. 83 ft-lbs	5/8-18 UNF… 95 ft-lbs
¾-10 UNC..…… 105 ft-lbs	¾-16 UNF ……. 102 ft-lbs	1-8 UNC … 236 ft-lbs
1-14 UNF …….. 212 ft-lbs	1 1/4 UNC …… 432 ft-lbs	1 ½-6 UNC …...732 ft-lbs

5 Materials and Parts for this station

The following materials and/or equipment will be used with this procedure. MSDS's for chemicals will be located in a notebook in the winding facility.

General Description	Material	Reference Document/Product No.
Solvent	Acetone	MSDS# 00561
Short Coil Clamp Assembly	316L stainless steel	SE1405-257P
MC Turning Fixture	Equipment	Drawing no. SE144-008
Rolled Ring Assembly	Fixture	Drawing no. SE144-007
Casting to Ring Assy. Fixture	Fixture	Drawing no. SE144-050
Multi-Meter	Equipment	
Megger Electrical Tester	Equipment	

Swagelock fittings	copper	
Teflon tubing for electrical breaks	Teflon	
Expandable foam		
Strain gage adhesive	M-Bond	AE-10
Modular coil stands	Steel	SE144-031

6 Fabrication Process

This fabrication procedure is to be used as guide to complete Post VPI activities. Deviation from this procedure for processes that DO NOT effect the design of the coil can be made with the concurrence of the MC Field Supervisor. These deviations shall be documented in the procedure and initialed by the MC Field Supervisor prior to implementing the deviations. Deviations that may effect the design of the coil requires a Request for Deviation "RFD" approval. The RFD must be approved prior to proceeding. Procedure changes need to be incorporated into the document via "Minor Procedure Changes" or "Revisions".

6.1 Daily Startup Activities:

6.1.1 Check all daily supplies needed:
6.1.2 Verify operation of all equipment needed that day.
6.1.3 Check station for cleanliness
6.1.4 Check that safety guards are intact
6.1.5 Check that safety equipment needed for day's activities are available
6.1.6 Check that the day's travelers and procedures are in their document holder.
6.1.7 Once completed, date and initial daily log at the back of the Station Log Book.

6.2 Daily Shutdown Activities:

6.2.1 Turn off power to equipment not in use.
6.2.2 Clean entire workstation area.
6.2.3 Verify that all Traveler and data sheet information is complete.
6.2.4 The Lead Technician shall verify that the Station's Log Book has been completed and signed for the day activities, plus all appropriate procedure signoffs have been completed.
6.2.5 Once completed, date and initial daily log at the back of the Station Log Book.

6.3 Install MC or TRC in Turning Fixture:

Using the steps outlined in procedure D-NCSX-MCF-003 [VPI], prepare the VPI'd coil for transfer from the autoclave.

Note: Station 1b or station 4 may not be available to receive a coil from station 5. If not, transfer the coil to station 1a and lower/store coil until station 1b or 4 is available.

6.3.1 Station 1b or 4 Preparations:
Activities associated with receiving modular coil at winding stations.

6.3.1.1 Prior to installing the MCWF, compress the springs under the gear box (drive system) until they are bottomed

6.3.1.2 Measure the inside width of the winding form ring (where the roller guide wheels engage) and record the smallest value. [Narrowest dimension]

6.3.1.3 Adjust the lower wheels on the winding station so that they are centered in the frame and are set at a width that is one-half inch greater than the value recorded in the previous step.

6.3.1.4 Lower the MCWF and ring assembly into the turning fixture using the corner brackets for alignment. Bolt up one end loosely (use spud wrenches to align holes).

- **SAFETY NOTE 1:** Use scaffolding or appropriate ladders while working on upper section of turning fixture. Scaffolding must be inspected prior to use per Section 9 Chapter 5 in PPPL ES&H Manual.

6.3.1.5 Install the upper guide rollers and align all of the guide rollers to the support ring. NOTE: The rollers are hinged and swing into position. Lifting is not required.

- **SAFETY NOTE 2:** Safety glasses **MUST** be worn when operating the pneumatic impact wrenches

- **SAFETY NOTE 3:** The use of leather gloves and steel tipped shoes is required during **ALL** rigging operations associated with lifting the Modular Coils.

6.3.1.6 Decompress springs under the gear box (drive unit) until gear is fully engaged with ring gear rack. The upper set of springs **MUST** be completely disengaged. This must be verified prior to proceeding.

Verified by: _____ **Date:** _____
Lead Technician

6.3.1.7 Verify that the upper support/lift beam is in proper position. Then secure the appropriate hardware using a pneumatic impact wrench. Hardware shall be torqued to the proper value. [See section 4.3]

Verified by: _____ **Date:** _____
Lead Technician

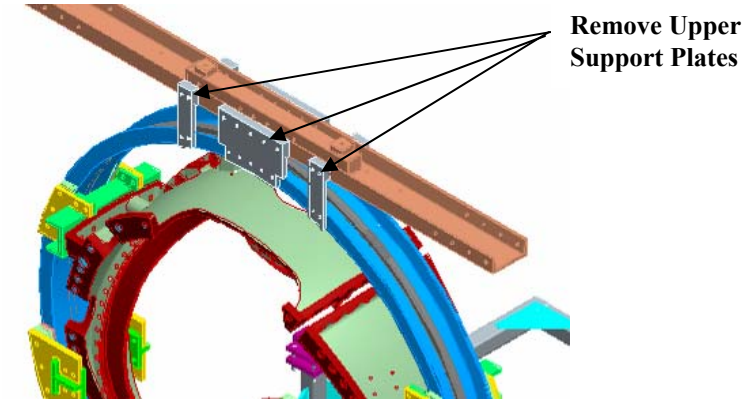


Figure 1- Upper Support Plates

6.3.1.8 Using a pneumatic impact wrench remove the upper support plates between the support-ring and lift beam. This operation must be verified prior to operating turning fixture. [See **Figure 1- Upper Support Plates**]

Verified by: _____ **Date:** _____
Lead Technician

6.3.1.9 Adjust the upper alignment rollers (both on the vertical and horizontal beams) so that the ring is aligned vertically and is centered within the turning fixture frame. A pry bar can be used to position the upper half of the ring so that these adjustments can be made. The rollers should be set so that there is one-quarter inch clearance to the ring flanges.

6.3.1.10 To ensure proper alignment and operation of the turning fixture, rotate the MCWF a full two revolution in either direction, using the foot-pedal control. Re-adjust the alignment rollers as required. Alignment of MCWF to the turning fixture is complete.

Verified by: _____ Date: _____ **Lead Technician**

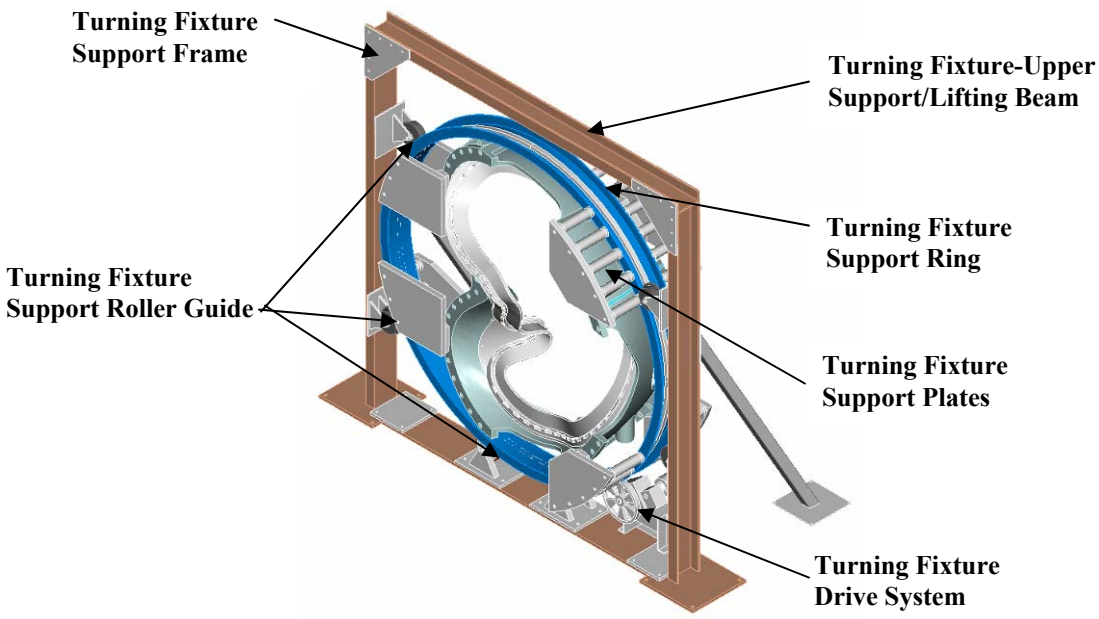


Figure 2- Turning Fixture

6.4 Clamp Removal

6.4.1 Remove the winding clamp side bars, tees and sheet metal mold plates. All hardware and components including the shim washers shall be saved, cleaned and reused for the next coil impregnation.

6.5 Stud Removal

6.5.1 Identify and mark the studs that should be removed from winding form per appropriate drawings provided by NCSX management and the field supervisors. Carefully remove the winding clamp studs using the stud removal tool. This will break the stud from the winding form leaving the stud base.

- **SAFETY NOTE 1:** Technicians shall wear safety glasses and leather gloves while using the stud removal tool

- **SAFETY NOTES 2 for Grinding Operations:**
  - Ensure that the coil is protected. Areas that are not protected by the epoxy/glass shell or bag mold must be covered prior to start of grinding
  - Safety glasses, face shields and leather gloves **MUST** be worn during grinding
  - Notify the ESU and obtain a flame permit prior to starting grinding operations.
  - Prior to starting grinding operations cover the external lead area with plastic

6.5.2 Grind away the tack welds holding the stud adapters [Types B & C only] to the winding form. Measure the magnetic permeability of the tack weld locations after grinding.

6.5.3 Grind the stud bases of both the stainless steel and Inconel studs that were removed. If the clamp studs were Inconel, it is only necessary to remove [grind] any sharp edges that may remain and it is not necessary to measure the permeability. If the clamp studs were 316SS measure the magnetic permeability of the remaining stud base using a calibrated Severn permeability indicator to verify that the relative magnetic permeability is below the acceptance criteria. If the permeability exceeds the acceptance criteria the stud base must be removed by grinding.

Acceptance Criteria: <1.02μ

6.5.4 Removal of the studs and stud adapters has been completed and permeability has been measured and is in compliance.

Verified by: _____ **Date:** _____
Lead Technician

Quality Control Representative: _____ **Date:** _____

6.6 Prosthetic Filler Removal [Type A and B coils only]

Remove the stainless steel prosthetic filler pieces.

6.6.1 Carefully remove the stainless steel prosthetic filler by grinding away the tack welds. **Extreme care** shall be taken to ensure that no harm comes to the coil during the removal of the prosthetic filler.

6.6.2 **DO NOT** damage the prosthetic filler during removal since it will be used for multiple coils.

6.6.3 Measure the magnetic permeability of the tack weld areas using a calibrated Severn permeability indicator to verify that the relative magnetic permeability is below the acceptance criteria. If the permeability exceeds the acceptance criteria additional grinding will be necessary.

Acceptance Criteria: <1.02μ

Verified by: _____ **Date:** _____
Lead Technician

Quality Control Representative: _____ **Date:** _____

6.7 Bag Removal

6.7.1 Carefully remove the epoxy/glass structure from the coil bundle. Note: the epoxy shell can be removed prior to removing the studs. This is at the discretion of the field supervisor.

6.7.2 **CAUTION NOTE**: **Extreme care** shall be taken around the cooling tubes. Do not use sharp instruments or tools near these tubes without tube protection.

- **SAFETY NOTE 1:** Use leather gloves during this process, since the epoxy/glass structure has sharp edges. Safety glasses are also required for this operation.

6.7.3 During the shell/bag removal, do not actively remove the G-11 sprue rings that are attached to the chill plates. However, it is acceptable if rings fall off during the bag removal process. [See **Figure 7- G-11 Pad Location**]

6.7.4 Once the epoxy/glass shell structure has been removed, carefully remove the silicone rubber bag mold that surrounds the coil bundles. This may require some scraping with putty knives. **See caution note in 6.7.2.**

NOTE: The bag shall remain around the coil until all grinding operations have been completed.

6.7.5 The epoxy/glass structural shell and bag mold have been removed and the coil is ready for final inspection.

Verified by: _____ **Date:** _____
Lead Technician

6.8 Coil Inspection:

6.8.1 Carefully inspect boundary of winding packs and winding form for any evidence of epoxy cracks, gaps between winding and winding form, or other relative motion.

6.8.2 Inspect VPI boundary for leaks, "ballooning" or other defects that could affect coil performance or geometry.

Inspection Findings:

Verified by: _____ **Date:** _____
Field Supervisor

_____ **Date:** _____
Q.C. Representative

6.9 Termination of cooling tubes:

Each of the cooling tubes must be terminated to accommodate the final connection to the modular coil cooling system.

6.9.1 Using approved NCSX drawings carefully cut each of the cooling tubes to correct length using a tube cutter.

6.9.2 Once the tubes have been cut carefully form the cooling tubes as shown in Figure 4- Termination of Cooling Lines.

6.9.3 Apply heat shrink Teflon tubing over the cooling tubes from the point where the tubes exit the chill plates through the clearance holes in the winding forms. [**Figure 3 - Cooling Tube Sleeving Insulation**] **Do not** shrink the sleeving at this time.

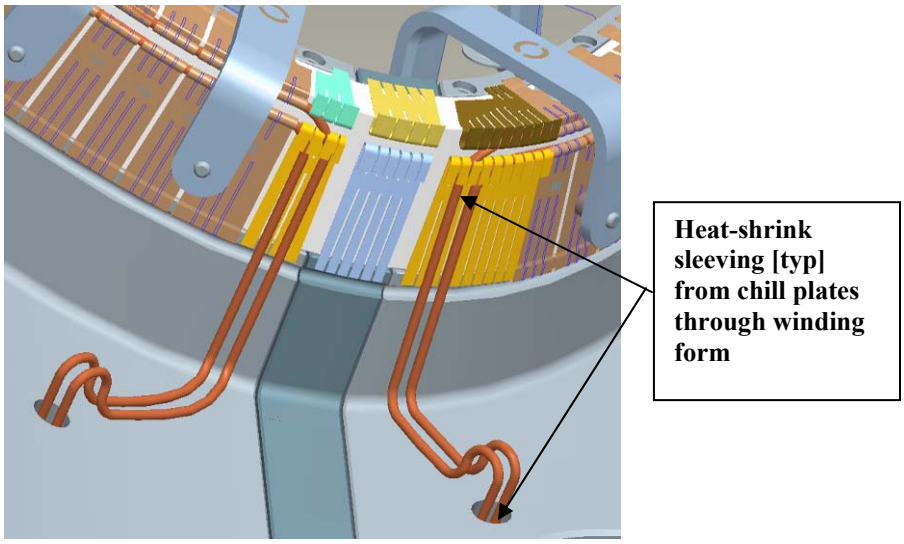
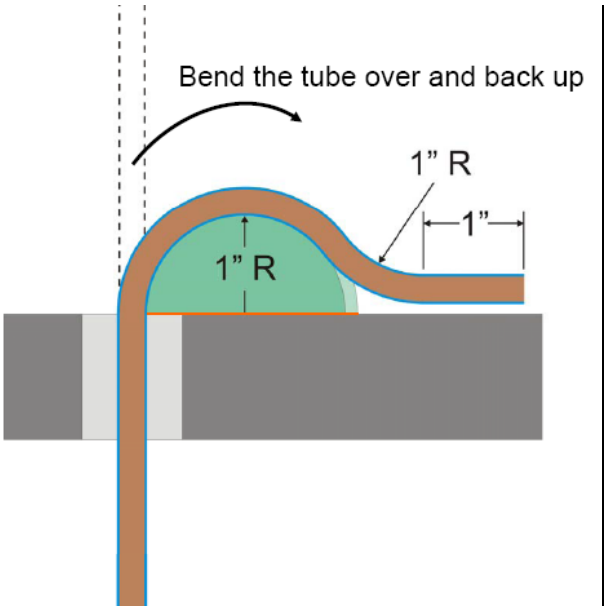


Figure 3 - Cooling Tube Sleeving Insulation



Outside of winding form

Figure 4- Termination of Cooling Lines

6.10 Brazing of couplings to cooling tubes:

6.10.1 Brazing of couplings to cooling tubes and the installation of the manifolds will be performed at a later date, and are no longer a part of this procedure.

6.10.2 The heat shrink Teflon tubing on the cooling tubes shall remain loose and will not be finalized until the brazing operation has been completed.

6.10.3 Once the co-wound diagnostic loops have also been routed through the clearance holes the cooling tubes and diagnostic loops will be secured in place with expanding urethane foam. [See section 6.11] **Not covered by this procedure**.

6.11 Installation of cooling jumper around Poloidal break

6.11.1 Prepare Teflon jumper tubes for installation; to jumper the Poloidal break areas.

6.11.2 Install the Teflon jumper tubes and tighten connections on all outboard circuits

6.12 Cooling Tube Pressure Tests

Perform a final pressure test to verify the integrity of the cooling tubes.

6.12.1 Connect the cooling tubes together using compression fittings to form a series connection so that the entire system can be tested together. If there is a problem, the connections can be broken and the system tested in sections. See Error! Reference source not found.

6.12.2 Using engineering procedure **ENG-014** (Guidelines for Hydrostatic and Pneumatic Testing) test the individual cooling tubes. See **Figure 6-Pressure Test Schematic**

- **SAFETY NOTE 1:** Each member of the test team shall wear goggles and a full face shield whenever pressure is applied to the system being tested.

- **SAFETY NOTE 2:** The area where the test is being performed shall be roped off to prevent access to the general work force with signs posted on the ropes warning about the test.

- **SAFETY NOTE 3:** The test system **MUST** have a pressure relief valve that is set no more than 25 psig over the test pressure.

- **SAFETY NOTE 4:** All safety precautions including the use of PPE's shall be followed as outlined in the Job Hazard Analysis sheet and recommendations made by the PPPL Industrial Hygienist.

6.12.3 Pressurize the coolant tubes with nitrogen to **200 psi** and isolate from the pressure source.

6.12.4 Gauges shall have a minimum **5-psi** graduation.

Verified by: _____ Date: _____
Quality Control Representative

6.12.5 **Acceptance criteria:** The test pressure shall be maintained without any detectable drop in pressure within the resolution of the gauge for at least ten minutes from the time the system was isolated from the pressure source. Any leaks or failure to maintain pressure requires a repair and retesting.

6.12.6 Record test data in the table below [**Table 1- Cooling Tube Inspection Results**]

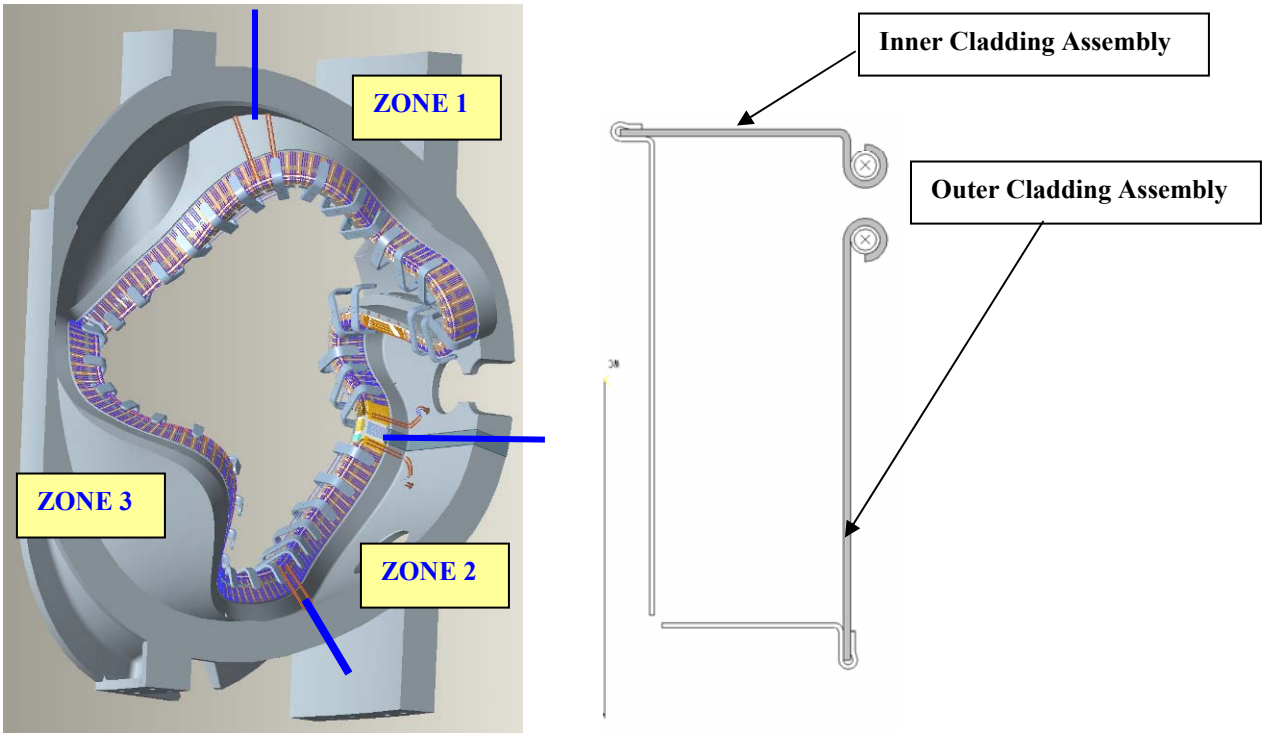


Figure 5- Cooling Tube Zone Identification

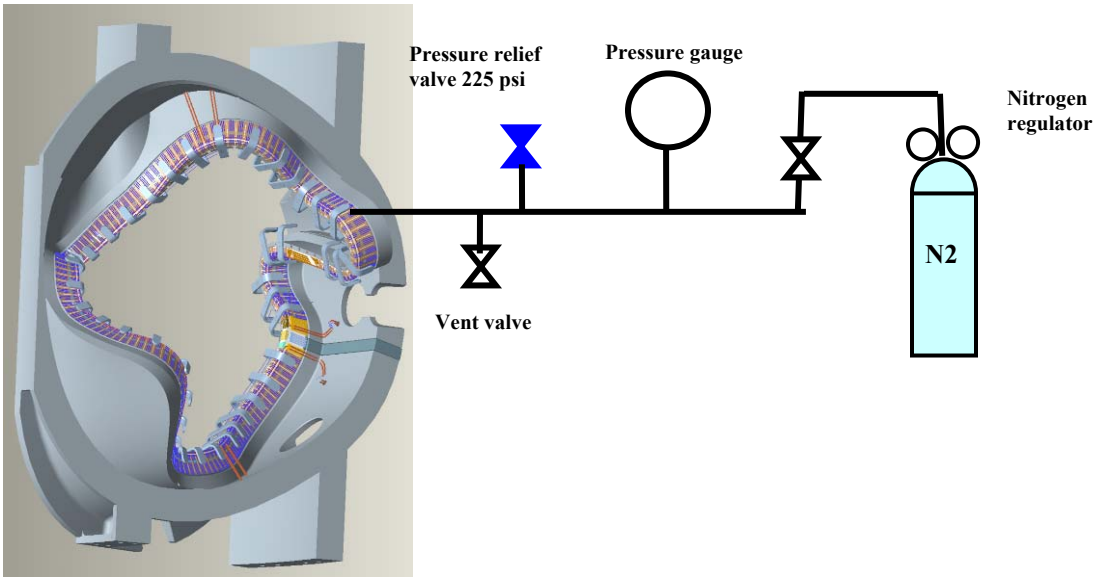


Figure 6-Pressure Test Schematic

6.13 Flow Check:

Flow nitrogen or air through each flow package to verify that there are no blockages.

6.13.1 Record test data in the table below [**Table 1- Cooling Tube Inspection Results**]

6.14 Cooling Tube Electrical Test:

6.14.1 Verify that cooling tubes are electrically isolated from all of the other cooling tubes and from the modular coil winding form using a multi-meter. Document findings in **Table 1- Cooling Tube Inspection Results**

Equipment Name & ID Number: _____ Calibration Date: _____

6.14.2 Record test data in the table below [**Error! Reference source not found.**

Table 1- Cooling Tube Inspection Results

Tube designation	Flow Path Blockage check	Pressure Leak check	Electrical test, tube to ground
Side A Zone 1 Inner			
Side A Zone 1 Outer			
Side A Zone 2 Inner			
Side A Zone 2 Outer			
Side A Zone 3 Inner			
Side A Zone 3 Outer			
Side B Zone 1 Inner			
Side B Zone 1 Outer			
Side B Zone 2 Inner			
Side B Zone 2 Outer			
Side B Zone 3 Inner			
Side B Zone 3 Outer			

Cooling Tube inspections/tests are completed and verified by:

Lead Technician: _____ Date: _____

Field Supervisor: _____ Date: _____

Quality Control: _____ Date: _____

6.15 <u>Dimensional Inspection-</u> DELETE

6.16 Finalization of Diagnostic Loops

6.16.1 Complete the routing of the diagnostic flux loops. The actual position will be determined by NCSX drawings and the Diagnostic representative.

6.16.2 Notify the Diagnostic representative that the final routing of the flux loops and diagnostic boxes is ready to begin.

6.16.3 Position and mount the diagnostic boxes to the outside of the winding form per direction of the Diagnostic representative. Secure the diagnostic boxes to the winding form using Inconel studs. Studs can be mounted using either TIG weld or stud gun.

- Notify the ESU and obtain a flame permit daily prior to starting welding operation.
- **SAFETY NOTE:** Technician MUST wear fire retardant clothing, safety glasses and leather gloves during the stud welding operation.

Verified by Lead Technician **Weld Date: _____ Obtain Flame Permit: _____** Weld Operator: _____ Fire Watch: _____

6.16.4 Carefully route the twisted flux loops (2 inch pitch) per direction of Diagnostic representative from the G-11 lead blocks through the cooling tube clearance holes in the winding form and into the previously installed diagnostic boxes. Initially secure the flux loops in place with adhesive tape. Then tack-weld stainless clips to the winding form.

6.16.5 Using a special cutting tool, strip the outer jacket of the flux loops back about ½ inch. Carefully wrap the inner conductor back and twist it around the outer jacket. The ends of the flux loops shall be secured between 2 washers on the stud holding the diagnostic boxes in place. This should be done before the final electrical test.

6.16.6 Route the co-wound leads from the lead area through the clearance holes in the winding form to the stainless diagnostic boxes mounted in 6.16.3 per directive from the Field Supervisor. Note: the diagnostic leads share the clearance hole with the cooling tubes. A protective tube shall be installed at the entrance to the diagnostic boxes to protect leads from sharp edges of the box. Once co-wound loops are in place, install box cover.

6.16.7 The cooling tube clearance holes through the winding form will be filled with NCSX approved expanding urethane foam at a later date [**Not part of this procedure**].

Routing of Flux Loops complete-Verified: **Lead Technician: _____ Date: _____** **Field Supervisor: _____ Date: _____**

6.17 Coil Clamp Installation

6.17.1 Remove any excess epoxy that may be on the G-11 pads. [See **Figure 7- G-11 Pad Location**]

6.17.2 Use NCSX approved drawings to install a final winding clamp assembly. [See **Figure 8- Coil Clamp Assembly**]

6.17.3 Verify good fit between clamp surfaces and G11 pad surfaces. Adjust clamp as required for best fit.

6.17.4 Secure the top horizontal bar with 3/8-16 UNC socket head cap screw. Torque bolt to 13 ft-lbs. Location no. 5 in Figure 9- Torque Reference Locations

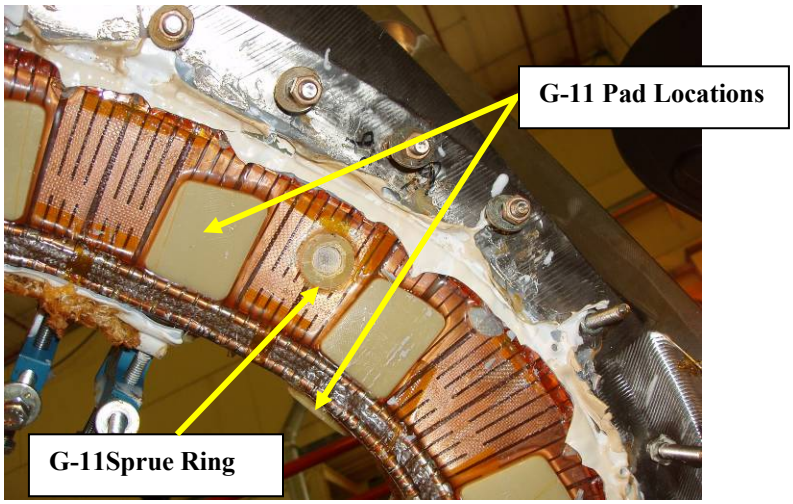


Figure 7- G-11 Pad Location

6.17.5 Each clamp will provide 125 lbs of pre-load. This is accomplished by hand tightening the pusher screw until it is in full contact with the G-11 coil pad. Then turn the screw an additional 1/4 turn. [Locations # 1, 2, 3 and 4] See **Figure 9- Torque Reference Locations** for identification numbers of joints. Record all torque verifications in Error! Reference source not found.

6.17.6 Once all of the final coils clamps have been torqued, the hardware shall be wire-locked and or tack welded using stainless shim stock to ensure that the bolts will not loosen during operation.

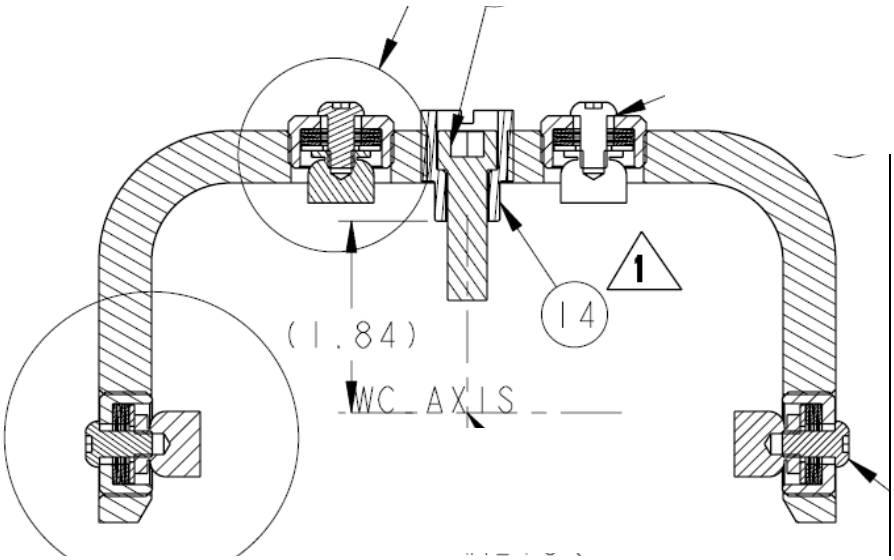


Figure 8- Coil Clamp Assembly

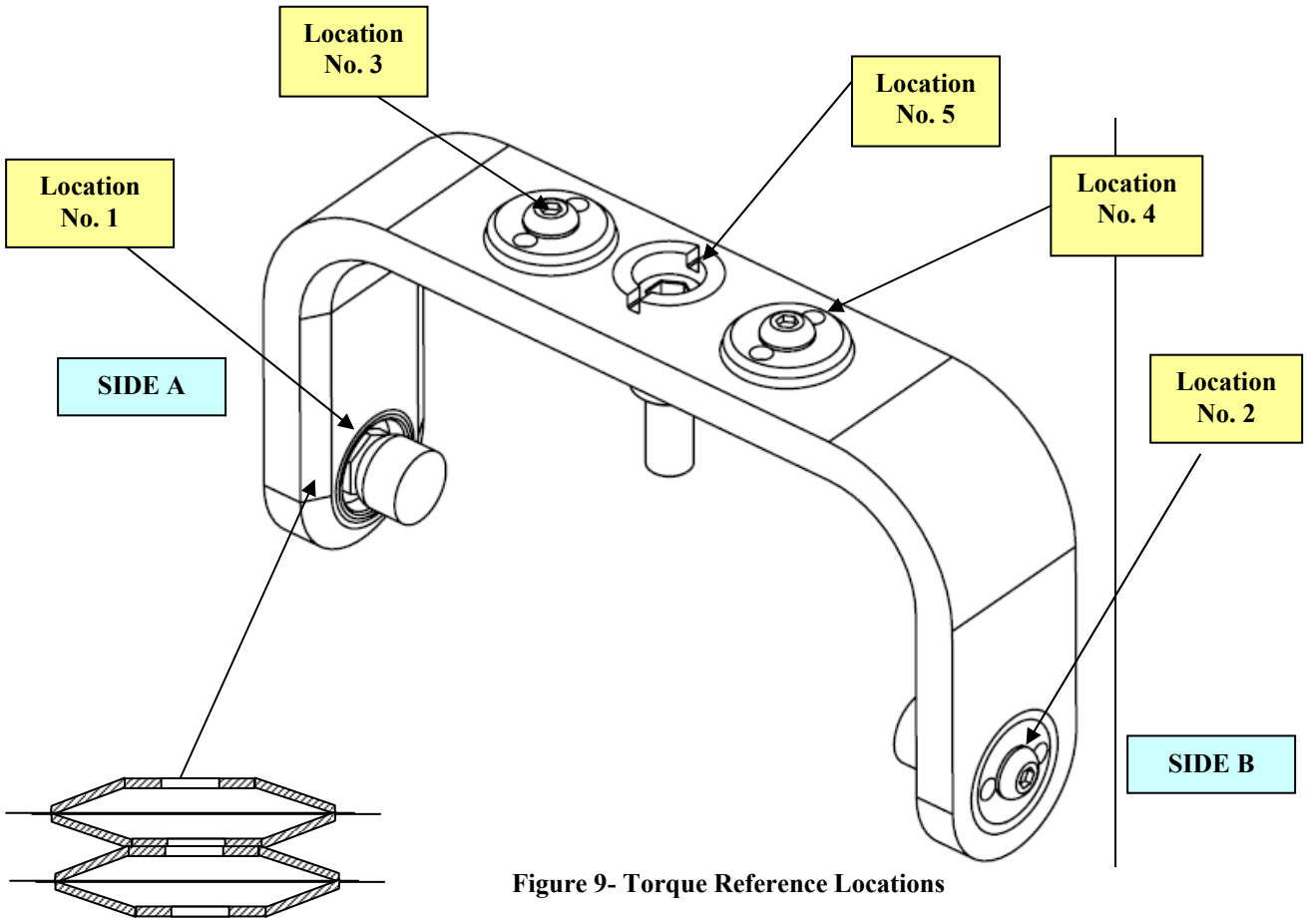


Figure 9- Torque Reference Locations

Figure 10- Typical Spring Washer Stack Up

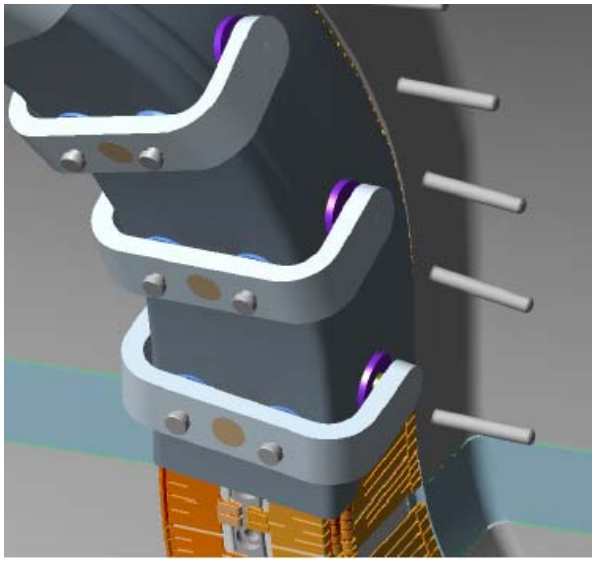


Figure 11-Typical Winding Clamp Arrangement

Table 2 Coil Clamp Torque Data

Verified Clamp No.	Position #1 Torque	#1 Secured	Position #2 Torque	#2 Secured	Position #3 Torque	#3 Secured	Position #4 Torque	#4 Secured	Position #5 Torque	#5 Secured
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
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38										
39										
40										
41										
42										

43										
44										
45										
46										
47										
48										
49										

6.17.7 All of the clamp hardware has been torqued and secured.

Verified By:

Lead Technician: _____ **Date:** _____

Field Supervisor: _____ **Date:** _____

Quality Control: _____ **Date:** _____

6.18 Modular Coil Electrical Joints:

6.18.1 Electrically tie the (3) isolated jumper studs to the lower turn terminal as shown in **Figure 12- Lead Grounding** Jumper**.** First install the G-11cr insulator then the copper jumper. Then secure in place with Belleville washers, flat washer and nut. Torque the stud nuts to 15 ft-lbs. Install the copper jumper onto the terminal lug #A5. Replace the flat and Belleville washers and torque to 15 ft-lbs.

Secure the two copper jumpers together with appropriate hardware as detailed by Test Director.

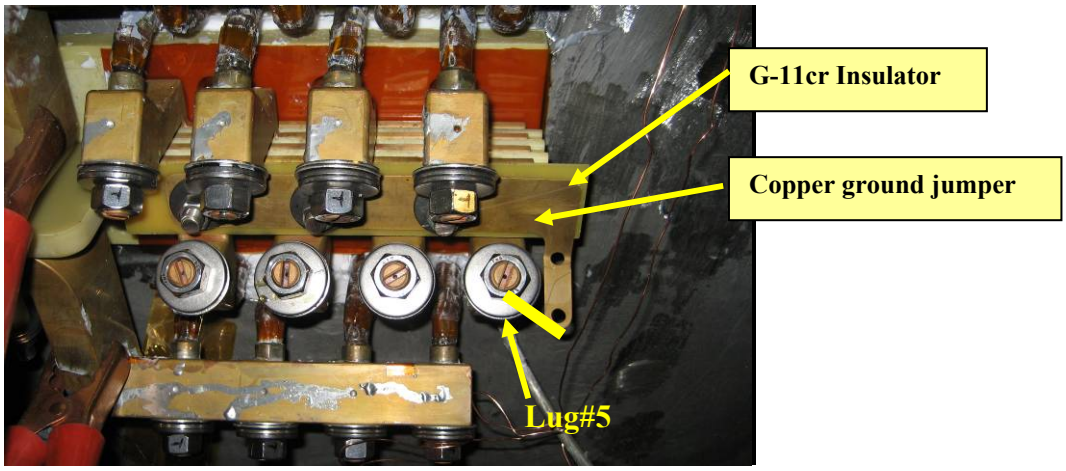


Figure 12- Lead Grounding Jumper

Verified by: _____ **Date:** _____
Field Supervisor

6.18.2 Measure the joint resistance between the connector and the terminal blocks [points A and B]. See **Figure 13-Electrical Joint Test Setup**

Acceptance criteria: ≤ 1 micro-ohms

6.18.3 Verify the torque value of the joint nuts. Torque to 15 ft-lbs

6.18.4 Record the joint resistance and torque verification in Error! Reference source not found. below.

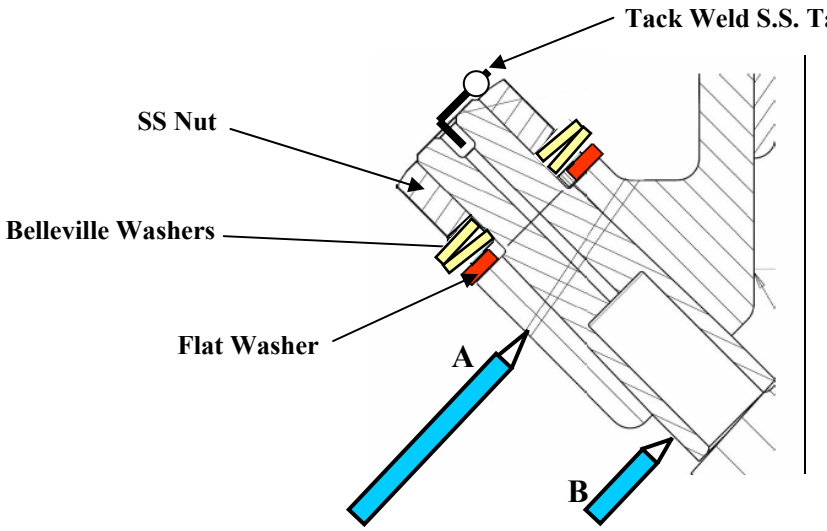
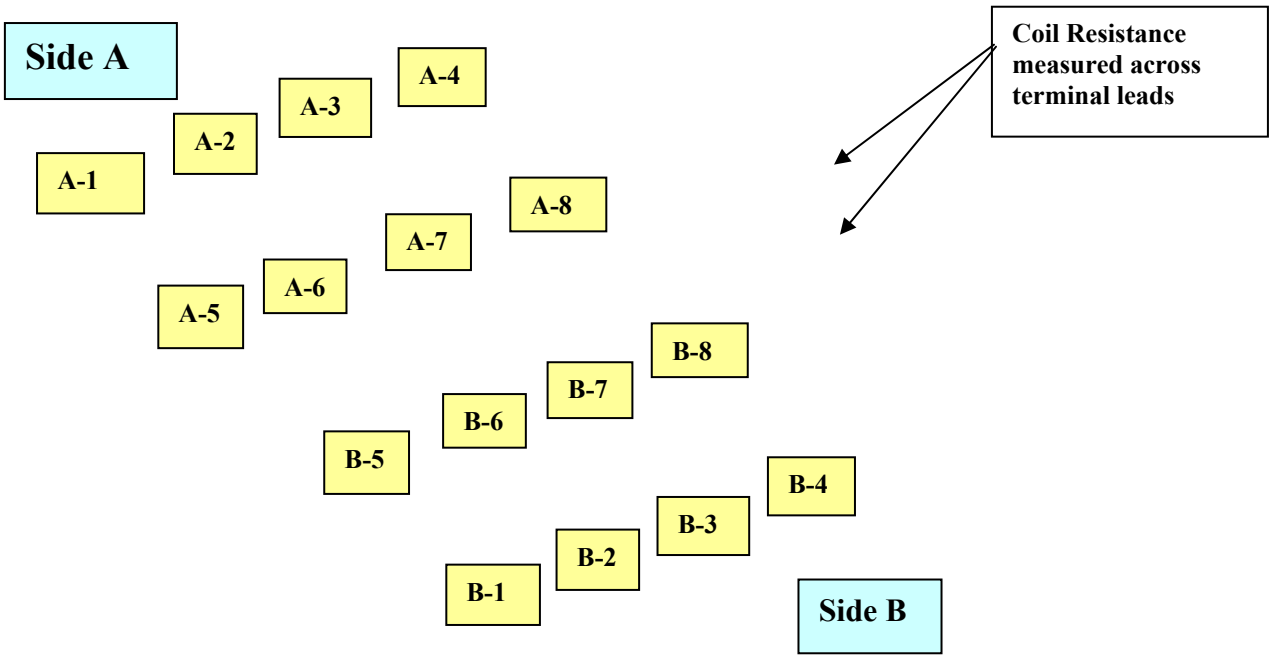


Figure 13-Electrical Joint Test Setup



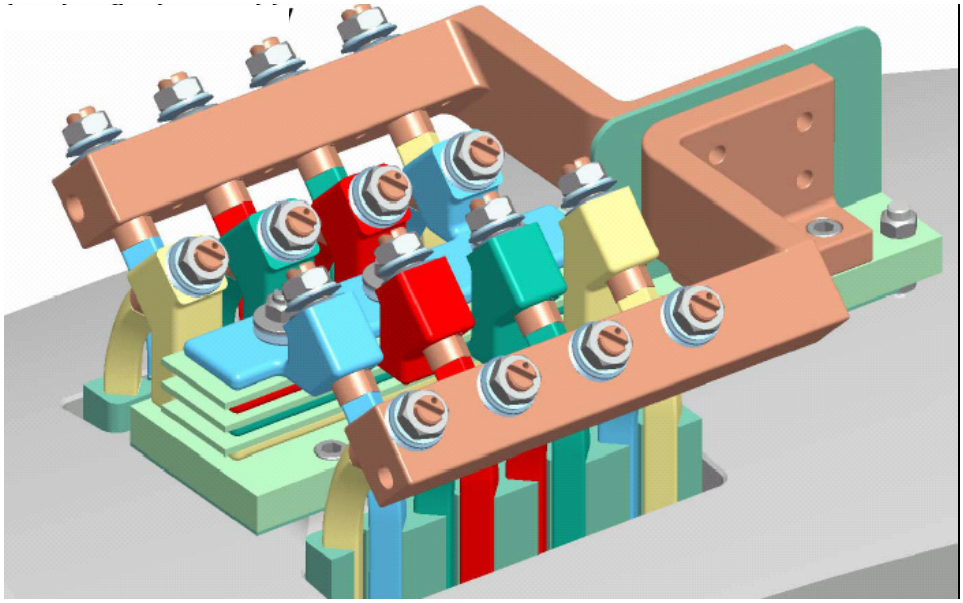


Figure 14- Final Terminal Connections Identification

Table 3-Joint Resistance

Joint ID	Joint Resistance [μ-ohms]	Torque Verify 15 ft-lb	Wire Tie Nuts	Joint ID	Joint Resistance [μ-ohms]	Torque Verify 15 ft-lb	Wire Tie Nuts
A-1				B-1			
A-2				B-2			
A-3				B-3			
A-4				B-4			
A-5				B-5			
A-6				B-6			
A-7				B-7			
A-8				B-8			

6.18.5 Wire-lock and/or tack weld each of the nuts to ensure that during operation they do not loosen. Record verification that joints have been wire tied.

Verified by: _____ Date: _____
Field Supervisor

6.19 Final Electrical Testing of Coil [Room Temperature]

This series of electrical tests will be performed at room temperature to verify the integrity of the coil insulation prior to transporting to the field period assembly area.

The sequence of tests/measurements to be performed:

- Inductance

- Capacitance
- Polarization Index [PI]
- Coil resistance [DC]
- Insulation resistance [Megger Test]
- Leakage Current: [Hipot Test]

6.19.1 Test Director:
Test Director for this test series is: _____

6.19.2 Safety Requirements & Conditions

The following safety requirements and prerequisites shall be used for performing tests on the Modular Coils.

6.19.2.1 All personnel performing these tests shall be familiar with the hazards and work procedure to minimize accidents that may occur.

6.19.2.2 A **"Safety Watch"** shall be appointed by the Test Director. The Test Director shall clearly describe to the Safety Watch his/her responsibilities.

Name of Safety Watch: _____

Responsibilities have been clearly discussed with Safety Watch:

Verified: _____ **Date:** _____
Test Director

6.19.2.3 **Responsibilities of a Safety Watch** include as a minimum:

a) Monitoring the operations in an attempt to prevent careless or unsafe activities.
b) Shutting down the power in case of an accident.
c) Contacting ESU in case of accident
d) Additional responsibilities of a Safety Watch can be found in the ES&H Manual Section 2, Chapter 2.2.6.

6.19.2.4 During the test, the "Test Area" shall be roped-off and suitable "danger high voltage" signs and flashing lights displayed.

Test Area has been safed:

Verified by: _____ **Date:** _____
Test Director

6.19.2.5 The test operator shall stand on an electrical safety mat during the test operation.

6.19.2.6 Approved rubber electrical safety gloves shall be worn by test members during grounding operations which occur once the test has been completed, and the test equipment turned off.

6.19.2.7 Upon completion of test turn off the test equipment and wait until the voltage drops to ≤ 200.0 volts. Then discharge the coil using a "Ground Hook". After a minimum period of 10 seconds, and once the voltage reads zero, and with the ground hook is still in place, attach a ground cable to the winding form and the coil leads. The ground hook may be removed once the ground cable is in place.

6.19.2.8 Electrically ground the winding form, and chill plate cooling tubes. Care must be taken not to damage the tubes with the grounding clips.

6.19.3 **Joint Cleanliness**: The Test Director shall verify that the coil lead area has been thoroughly cleaned of excess RTV and dirt prior to starting any electrical tests. It is recommended that the area be wiped with ethanol as the last cleaning operation.

6.19.4 **Joint Insulation**: The Test Director shall verify that the Kapton insulation has been properly installed and that the coil is ready for testing.

Joint area has been cleaned and coil is ready for testing:

Verified by: _____ Date: _____
Test Director

6.19.5 Coil Inductance and Capacitance Measurements

6.19.6 Due to the sensitivity of the Inductance tests, it is recommended that prior to testing the coil leads are connected together and grounded to the winding structure via clip leads and let set over night. This will ensure we have no capacitance build up in the coil.

MODULAR COIL INDUCTANCE/CAPACITANCE TEST DATA SHEET

Coil No. _____ Test Location: _____ Test Date: _____

Calibration Date: _____ Temperature: _____ Humidity: _____

Equipment Name: _____ Equipment S/N _____

***Voltage Level:* _____**

Frequency [Hertz]	100 Hz		1000 Hz
Inductance Ls [micro-henries] **μH**			
Quality Factor [Q]			
Inductance Lp [micro-henries] **μH**			
Quality Factor [Q]			
Capacitance Cp [micro-farads] **μF**			
Dissipation Factor [D]			
Capacitance Cs			

[micro-farads] **μF**			
Dissipation Factor [D]			
Impedance Z [Ohms] **Ω**			
Angle θ			
DCR [Ohms] **Ω**			

Comments:

Test Director Signoff: _____ Date: _____

Quality Control verify: _____ Date: _____

6.19.7 Polarization Index [PI] Measurement
The Polarization Index (PI) is a RATIO. Insulation 2 kV is taken at 1 minute (R1) and at 10 minutes (R10). The ratio R10/R1 is the PI.

Acceptance criteria: ***Polarization Index [PI] >4***

6.19.8 Due to the sensitivity of the PI tests, it is recommended that the coil leads are connected together and grounded to the winding structure via clip leads and let set over night. This will ensure we have no capacitance build up in the coil.

MODULAR COIL POLARIZATION INDEX TEST DATA SHEET

Coil No. _____ Test Location: _____ Test Date: _____

Calibration Date: _____ Temperature: _____ Humidity: _____

Equipment Name: _____ Equipment S/N _____

Voltage Level: **_____ _____ G ohms**

PI = _____ TC_____ _____nf

1 minute: _____ohms _____ amperes

10 minutes: _____ohms _____ amperes

Comments:

Test Director Signoff: _____ Date: _____

Quality Control verify: _____ Date: _____

6.19.9 Coil Resistance Measurement

Measure the resistance of the entire modular coil at the terminal leads. [See Figure 14- Final Terminal Connections Identification]

Acceptance criteria: ***As specified in Modular coil design specification [A, B and C]***

Type A Modular Coil Resistance: 10.97 milli-ohms

Type B Coil Resistance: 10.73 milli-ohms

Type C Coil Resistance: 9.01 milli-ohms

Coil No. _____ Test Location: _____ Test Date: _____

Calibration Date: _____ Temperature: _____ Humidity: _____

Equipment Name: _____ Equipment S/N _____

6.19.9.1 Using the bridge probe, make pressure contact on the ends of the system bus being tested.

6.19.9.2 Record the resistance readings in **Error! Reference source not found.**.

6.19.9.3 Place temperature sensor on the surface of the bus leads and record the temperature of the copper after the reading stabilizes.

$$R20 = \frac{254.5}{234.5 + Tc} \times Rc$$

Where: Rc = measured resistance of the conductor (milliohms)

Tc = temperature of coil when resistance measurement is made (degrees C)

Table 4- Coil Resistances

Measured System Resistance (Rc) mΩ at Tc	System Resistance corrected to 20 deg. C (R20)	Calculated System Resistance @ 20 C [per MC specification]
Rc:		See accept. criteria
Temp C:		

Resistance Results: ***Acceptable:*** _____ ***Unacceptable:*** _____

Test Director Signoff: _____ **Date:** _____

Quality Control verify: _____ **Date:** _____

6.19.10 Insulation Resistance Measurement- Megger Test

Perform a Final Megger test of the completed coil prior to transporting to the field period assembly.

Acceptance criteria:

Coil Voltage level: ***7500 volts*** **Coil Insulation Resistance:** ***>1K Meg ohms***

6.19.10.1 Complete the steps below and perform the insulation resistance test [Megger] of pancakes "A" and "B". Pancakes "A" and "B" are connected together at the terminal block.

- Test director shall verify that all safety requirements and prerequisites have been performed prior to starting the test.
- Verify that the turning fixture is well grounded to building steel.
- Place the Megger test set on a firm, stable surface.
- Securely connect a ground cable between building steel and the test unit.
- Connect the Megger ground lead to the coil casting.
- Connect a ground cable to the chill plates.
- Connect the Megger power lead to the coil leads.
- Measure the insulation resistance to ground. The test results shall be in compliance with the requirements noted in Section 6.19.10.

6.19.10.2 Upon completion of test turn off the test equipment and wait until the voltage drops to ≤ 200.0 volts. Then discharge the coil using a "Ground Hook". After a minimum period of 10 seconds, and once the voltage reads zero, and with the ground hook is still in place, attach a ground cable to the winding form and the coil leads. The ground hook may be removed once the ground cable is in place.

Table 5-Final Megger Test Results

Test Voltage	Test #1 Insulation Resist. Minimum 1KMΩ	Test #2 Insulation Resist. Minimum 1KMΩ	Observations
1000			
2000			
3000			
4000			
5000			
6000			
7500			

Coil No. _____ Test Location: _____ Test Date: _____

Calibration Date: _____ Temperature: _____ Humidity: _____

Equipment Name: _____ Equipment S/N _____

Megger Results: *Acceptable:* _____ *Unacceptable:* _____

Test Director Signoff: _____ Date: _____

Quality Control verify: _____ Date: _____

Comments:

6.19.11 Insulation Current Leakage Measurement- Hi Pot Test

Perform the hi-pot test [DC high voltage and leakage test] to confirm the integrity of the Modular Coil insulation to ground.

6.19.11.1 Complete the steps below and perform the insulation leakage test [Hi Pot] of pancakes "A" and "B". Pancakes "A" and "B" are connected together at the terminal block.

- Test director shall verify that all safety requirements and prerequisites have been performed prior to starting the test.
- Verify that the turning fixture is well grounded to building steel.

- Place the Hi- Pot test set on a firm, stable surface.
- Securely connect a ground cable between building steel and the test unit.
- Connect the Hi Pot ground lead to the coil casting.
- Connect a ground cable to the chill plates.
- Connect the Hi Pot power lead to the coil leads.
- Measure the current leakage to ground. The test results shall be in compliance with the requirements noted in Section 6.19.11.3.

6.19.11.2 Upon completion of test turn off the test equipment and wait until the voltage drops to ≤ 200.0 volts. Then discharge the coil using a "Ground Hook". After a minimum period of 10 seconds, and once the voltage reads zero, and with the ground hook is still in place, attach a ground cable to the winding form and the coil leads. The ground hook may be removed once the ground cable is in place.

6.19.11.3 Acceptance Criteria:

Coil Voltage level: *5000 volts* **Coil Leakage Current: ≤ *5 μ-amps***

Table 6- Final Modular Coil Hi-Pot Test Results

Voltage Level Volts	Leakage Current @ 0 seconds	Leakage Current @ 30 seconds	Leakage Current @ 60 seconds	Remarks
500				
1000				
2000				
3000				
4000				
5000				

Coil No. _____ Test Location: _____ Test Date: _____

Calibration Date: _____ Temperature: _____ Humidity: _____

Equipment Name: _____ Equipment S/N _____

Test Director Signoff: _____ Date: _____

Quality Control verify: _____ Date: _____

Comments:

6.20 Name Tag Installation: DELETE

6.21 Strain Gages and Thermocouples [Optional at this point]

The strain gages and thermocouples may not be installed at this time. If that is the case the post VPI activities at station 1b are complete. Otherwise install strain gages and thermocouples to the finished coil in the locations identified by the WBS 14 manager. This information will be added as an addendum to this procedure.

6.21.1 Use the following steps to attach the strain gages.

6.21.1.1 Degrease and clean the surface with Isopropyl alcohol.

6.21.1.2 Dry abrade the gauging surface with 220 to 320 grit silicon-carbide paper to remove any scales or oxides on the base material to improve adhesion.

6.21.1.3 Degrease and clean the surface with Isopropyl alcohol.

6.21.1.4 Dry abrade the gauging surface with 220 to 320 grit silicon-carbide paper to remove any scales or oxides on the base material to improve adhesion.

6.21.1.5 Apply M-Prep Conditioner A and wet-abrade the gage area. Then repeat procedure by wet abrading and wiping using 400 grit silicon-carbide paper.

6.21.1.6 Apply liberal amount of M-Prep Neutralizer 5A to the gage area. Remove the Neutralizer by slowly wiping through the gage area using a gauze sponge.

6.21.1.7 Remove the gage from its transparent envelope and place bonding side down on a chemically clean glass plate or empty gage box. Using Kapton tape as a carrier, position the gage/tape assembly onto the specimen. Holding the tape at a shallow angle, wipe the assembly onto the specimen surface.

6.21.1.8 Lift the gage end of the assembly [about a 45 ^{o} angle] until the gage and terminal are free of the specimen surface.

6.21.1.9 Apply a thin layer of prepared adhesive [M-Bond AE-10] to both the specimen and back of the gage.

6.21.1.10 Lift the end of the tape and bridge over the adhesive at approximately a 30^{o} angle. With a piece of gauze, slowly make a single wiping stroke over the gage/tape assembly. Use a firm pressure with your fingers when wiping over the gage.

6.21.2 Using the "Romer" measuring arm, document the position of the sensors that were just installed on to the coil.

Installation of sensors is not required at this time:

Verified by: _____ Date: _____
Field Supervisor

Table 7-Coil Sensor Table

No.	Sensor Type*	Location
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

* Sensor type: Stain gauge or thermocouple

Installation of sensors is complete:

Verified by: _____ Date: _____
Field Supervisor

6.22 Coil Lead protection:

6.22.1 Wrap the copper lead jumpers with a plastic bag or wrap to prevent dirt and debris from depositing around the lead area.

6.22.2 Install a plastic cover or box around the leads to protect them from any damage they may sustain as a result of other work being performed on the coil.

Figure 15- Lead Cover

6.23 Transporting MCWF from Casting Prep Station 1b to Station 1a:

Using lift procedure **D-L-NCSX-984** the modular coil winding form shall be transferred from the turning fixture [**Figure 2- Turning Fixture**] at station 1b to the casting assembly fixture at station 1a.

6.23.1 Install the upper support plates that secure the support ring to the support/lift beam. This operation must be verified prior to proceeding. See Error! Reference source not found.

Verified by: _____ Date: _____ **Lead Technician**

- **SAFETY NOTE 1:** Use scaffolding or appropriate ladders while working on upper section of turning fixture. Scaffolding must be inspected prior to use per Section 9 Chapter 5 in PPPL ES&H Manual.
- **SAFETY NOTE 2:** Safety glasses **MUST** be worn when operating the pneumatic impact wrenches
- **SAFETY NOTE 3:** The use of leather gloves and steel tipped shoes is required during **ALL** rigging operations associated with lifting the Modular Coils.

6.23.2 Remove the balance weights and plates on the bottom of the ring assembly.

6.23.3 Using the lift procedure data sheet rig the upper support/lift beam to the overhead crane.

6.23.4 Once a slight load has been taken, remove the hardware that secures the upper support/lift beam to the turning fixture frame.

6.23.5 Compress the springs under the gear box (drive system) until they are bottomed.

6.23.6 Disengage and remove the upper guide rollers. NOTE: The rollers are hinged and swing into position. Lifting is not required

6.23.7 Carefully raise the winding form/ring assembly from station 1b and transport to stations 1a, directly over the casting assembly fixture.

Verified by: _____ Date: _____
Lead Technician

6.24 Disassembly of coil/casting from Support Ring Assembly:

6.24.1 Secure the coil support ring to the casting assembly fixture. **Figure 16- Casting Assy. Fixture- Vertical Position**

6.24.2 Using the overhead crane, carefully lower the coil/support ring assembly until the coil is in the horizontal position and resting on the support stands. **Figure 17- Casting Assy. Fixture in Horizontal Position**

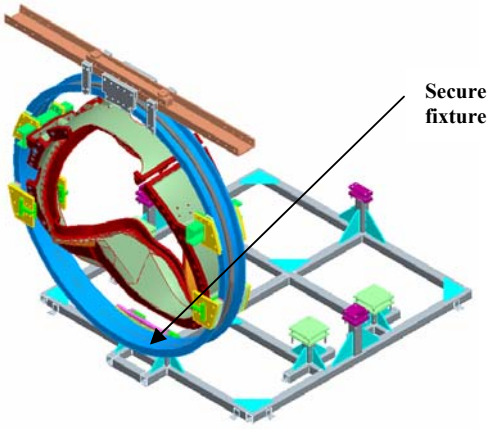


Figure 16- Casting Assy. Fixture- Vertical Position

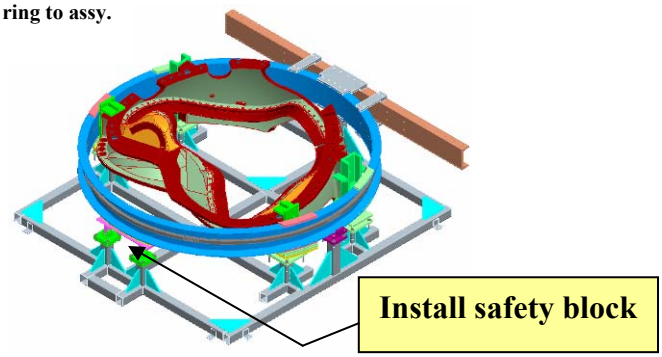


Figure 17- Casting Assy. Fixture in Horizontal Position

6.24.3 Disassemble the support/lifting beam and support brackets between the support ring and casting

- **SAFETY NOTE 1:** The use of leather gloves and steel tipped shoes is required during the assembly of the support brackets and during **ALL** rigging operations associated with joining the winding form and ring assembly.

- **SAFETY NOTE 2:** Verify that the hinge assembly at station 1a is properly blocked to prevent the hinge from swinging down and possibly injuring the assembly and rigging personnel prior to being secured to the ring assembly.

- **Verify that safety block is in position prior to installing support ring**

Verified by: _____ **Date:** _____
Lead Technician

6.24.4 Lift the support ring from the assembly fixture and transport to storage area. **Figure 18- Assy. Fixture without Lift/Support Beam**

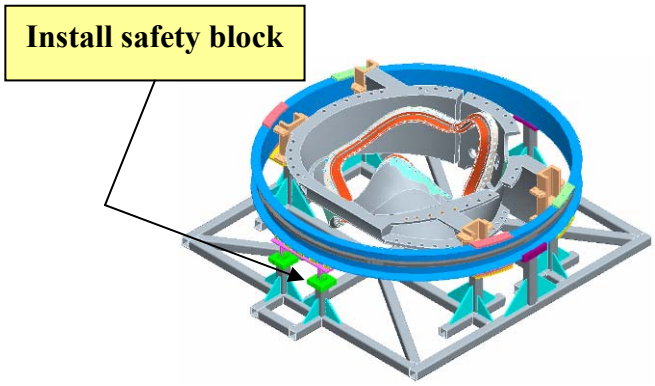


Figure 18- Assy. Fixture without Lift/Support Beam

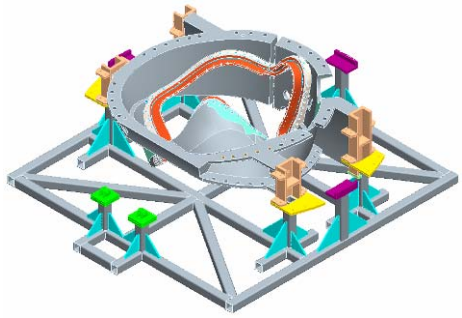


Figure 19- Coil without Support Ring

6.24.5 Mount the coil stands to the completed winding form. [SE144-031]

6.24.6 Using lift procedure **D-L-NCSX-996** [Finished Modular Coil Lift Procedure] transfer the completed modular coil from station 1a to a location determined by the Field Supervisor.

Verified:

Lead Technician: _____ **Date:** _____

Field Supervisor: _____ **Date:** _____

7 Completion of Activities at Post VPI Station:

7.1 Document Verification:
Verify that all pertinent data in the procedure and data sheets have been completed.

7.2 Field Package:
Ensure that all data sheets, photographs, QC inspection sheets, etc are included in the "Coil Field Package".

7.3 Action Ticket:
An "Action Ticket" shall be generated by the Field Supervisor, identifying outstanding tasks that need to be completed prior to the modular coil considered complete. Once all tasks have been

completed it shall be signed by the Field Supervisor and QC representative. The "Action Ticket" shall be secured to the winding form/coil and remain until all tasks have been completed. It shall be displayed in plane view. Place completed "Action Ticket" in the Document Packet once it has been completed.

7.4 Approval:

Prior to releasing a modular coil , it is required that the all-responsible individuals sign the release indicating that all processes at the Post VPI station have been satisfactorily completed. The release will include signatures from the Station Lead Technician, Field Supervisor and the QC representative.

All Post VPI activities have been satisfactorily completed.

Lead Technician: _____ Date: _____

Field Supervisor: _____ Date: _____

QC shall verify completion of documentation:

Quality Control Representative: _____ Date: _____