

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

<b>Princeton Plasma Physics Laboratory Procedure</b>			
Procedure Title: <b>Modular Coil Fabrication-Post VPI Activities</b>			
Number: <b>D-NCSX-MCF-004</b>	Revision: <b>00</b>	Effective Date:	
		Expiration Date: <i>(2 yrs. unless otherwise stipulated)</i>	
<b>Procedure Approvals</b>			
Author: James H. Chrzanowski			Date: 5/31/2005
ATI: James H. Chrzanowski			Date: 5/31/2005
RLM: Larry Dudek			Date: 5/31/2005
Responsible Division: <b>NCSX Project</b>			
<b>Procedure Requirements</b> Designated by RLM			
LABWIDE:			
<b>X</b>	Work Planning Form # <b>WP-1188 &amp; 1138</b> (ENG-032)		Lockout/Tagout (ESH-016)
	Confined Space Permit (5008,SEC.8 Chap 5)		Lift Procedure (ENG-021)
	Master Equip. List Mod (GEN-005)	<b>X</b>	ES&H Review (NEPA, IH, etc.) <b>NEPA 1283</b>
	RWP (HP-OP-20)		Independent Review
	ATI Walkdown	<b>X</b>	Pre-Job Brief
<b>X</b>	Post-job Brief *		
D-SITE SPECIFIC:			
<b>X</b>	D-Site Work Permit (OP-AD-09)		Door Permit (OP-G-93)
	Tritium Work Permit (OP-AD-49)		USQD (OP-AD-63)
<b>X</b>	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.

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

<b>REVIEWERS</b> (designated by RLM)	
Accountable Technical Individual. ....	<b>J. Chrzanowski</b>
Test Director	
Independent Reviewer	
D-Site Shift Supervisor	
Independent	
NCSX	<b>Steve Raftopoulos X Tom Meighan X</b>
Vacuum	
Project Engineer for Stellerator Systems (WBS 1) Manager.....	<b>Brad Nelson (ORNL) X</b>
WBS Manager for Modular Coils (WBS14).. ....	<b>Dave Williamson (ORNL)</b>
Quality Assurance/Quality Control. ....	<b>Judy Malsbury X</b>
Maintenance and Operations Division	
Energy Conversion System/Motor Control Division	
Engineering .....	
Environmental Restoration & Waste Management Division	
Environmental, Safety & Health.....	<b>Jerry Levine X</b>
Industrial Hygiene.....	<b>Bill Slavin</b>
Health Physics.....	
RLM .....	<b>Larry Dudek</b>

<b>TRAINING</b> (designated by RLM)			
No training required _____	Instructor <b><u>Jim Chrzanowski</u></b>		
Personnel (group, job title or individual name)	Read Only	Instruction Pre-job Briefing	Hands On
<b>Lead Tech.</b>		<b>X</b>	
<b>Technicians performing task</b>		<b>X</b>	
<b>Field Supervisors</b>		<b>X</b>	
<b>Quality Control Representative</b>		<b>X</b>	
<b>Training Rep.</b>			
<b>RLM Larry Dudek</b>			

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

**RECORD OF CHANGE**

<b>Revision</b>	<b>Date</b>	<b>Description of Change</b>
00		Initial release

**TABLE OF CONTENTS**

<b>1</b>	<b>Scope</b> .....	<b>1</b>
1.1	<b>Introduction</b> .....	1
1.2	<b>Scope</b> .....	1
1.3	<b>Identification of winding form being prepared:</b> .....	1
<b>2</b>	<b>Applicable Documents</b> .....	<b>1</b>
2.1	<b>NCSX-MIT/QA-142-01:</b> .....	1
2.2	<b>NCSX-PLAN-CMFOP-00:</b> .....	1
2.3	<b>D-NCSX-MCF-005</b> Dimensional Control & Metrology for the NCSX MC.....	1
2.4	<b>D-NCSX-PLAN-MCWDC</b> Modular Coil Dimensional Control Plan.....	1
2.5	<b>D-L-NCSX-984</b> Lifting Modular Coil Assemblies .....	2
<b>3</b>	<b>Safety Requirements:</b> .....	<b>2</b>
3.1	<b>Job Hazard Analysis:</b> .....	2
<b>4</b>	<b>Prerequisites</b> .....	<b>2</b>
4.1	<b>Pre-Job Briefing:</b> .....	2
<b>5</b>	<b>Materials and Parts for this station</b> .....	<b>2</b>
<b>6</b>	<b>Fabrication Process</b> .....	<b>2</b>
6.1	<b>Install MC or TRC in Turning Fixture:</b> .....	3
6.2	<b>General Inspection of MC</b> .....	4
6.3	<b>Cooling Tube inspection</b> .....	4
6.4	<b>Dimensional Inspection</b> .....	5
6.5	<b>Sprue Removal</b> .....	5
6.6	<b>Coil Clamp Installation</b> .....	6
6.7	<b>Installation of cooling jumper around poloidal break</b> .....	9
6.8	<b>Electrical Testing of Coil Prior to Transport</b> .....	9
6.9	<b>Strain Gauges and Thermocouples</b> .....	12
6.10	<b>Removing the Modular coil from the Turning Fixture:</b> .....	12
6.11	<b>Disassembly of coil/casting from Support Ring Assembly:</b> .....	13
<b>7</b>	<b>Completion of Activities at Post VPI Station:</b> .....	<b>15</b>
7.1	<b>Document Verification:</b> .....	15
7.2	<b>Field Package:</b> .....	15
7.3	<b>Approval:</b> .....	15

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

**List of Figures**

Figure 1- G-11 Pad Location .....	6
Figure 2- Coil Clamp Assembly .....	7
Figure 3- Torque Reference Locations .....	7
Figure 4- Typical Winding Clamp Arrangement .....	8
Figure 5- Upper Support Plates .....	13
Figure 6- Casting Assy. Fixture- Vertical Position.....	14
Figure 7- Casting Assy. Fixture in Horizontal Position.....	14
Figure 8- Assy. Fixture without Lift/Support Beam.....	14
Figure 9- Coil without Support Ring .....	14
Figure 8-Sensor Locations for Type C Casting .....	16
Figure 9- Sensor Locations for Type B Casting .....	17
Figure 10-Sensor Location for Type A Casting.....	18
Figure 11- Sensor Locations for Twisted Racetrack Coil.....	19

**List of Tables**

Table 1 Tube inspection results .....	5
Table 2 - Coil Clamp Torque Verification.....	8
Table 3- Coil Resistance .....	10
Table 4-Megger Test Results .....	11
Table 5- Coil Sensor Table .....	12

# Modular Coil Fabrication- Post VPI Activities

## D-NCSX-MCF-004-00

### 1 Scope

#### 1.1 Introduction

The NCSX Coil Manufacturing Facility is divided into 7 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...** Winding Form Preparation & **Post VPI Activities**
- Station No. 2... Winding Station / Molding and VPI Preparation [TRC coil prep & Winding operations]
- Station No. 4... Winding Station C/ Molding and VPI Preparation
- Station No. 5... VPI and Autoclave Activities
- Station No. 7... Coil Testing Facility [Reference only]

#### 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 coil clamps
- Room temperature electrical testing of coil
- Disassembly of coil/winding form from support ring
- Transport of coil to the basement coil test facility

#### 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: \_\_\_\_\_

Modular Coil Identification Number: \_\_\_\_\_

### 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-CMFOP-00:

All Modular Coil work processes are governed by the “Coil Manufacturing Facility Operations Plan”, document number **NCSX-PLAN-CMFOP-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

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

2.5 **D-L-NCSX-984** Lifting 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**

**4.1 Pre-Job Briefing:**

A pre-job briefing will be held, describing the processes and safety issues prior to starting any part of this procedure. Attendance shall be documented via training sign-in sheet.

**Pre job Briefing complete:** \_\_\_\_\_  
**MC Field Supervisor** **Date**

**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.

<b>General Description</b>	<b>Material</b>	<b>Reference Document/Product No.</b>
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	
Mobile Cryo-test Facility Transport Cart	Equipment	
Swagelock fittings	copper	
Teflon tubing for electrical breaks	Teflon	

**6 Fabrication Process**

This fabrication procedure is to be used as guide to complete Post VPI activities. Deviation from this procedure for processes that DOES 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”.

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

**6.1 Install MC or TRC in Turning Fixture:**

6.1.1 Ensure that the Station No. 1b is ready to receive a coil/winding form.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--

6.1.2 All rigging and preparation work in the autoclave requires a confined space permit.

6.1.3 Transport the VPI'd coil from the Autoclave to the Station No. 1 turning fixture using lift procedure **D-L-NCSX-984**. Secure the coil and ring assembly to the turning fixture.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Field Supervisor</b>
---

6.1.4 Install the upper guide rollers, and align all guide rollers to the support ring.

6.1.5 Verify that the support ring gear rack is engaged with the drive unit.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--

6.1.6 Verify that the upper support/lift beam is in proper position and secured with appropriate hardware that is torqued to the proper value.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--

6.1.7 Remove the upper support plates between the support ring and lift beam. This operation must be verified prior to operating turning fixture.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--

6.1.8 To ensure proper alignment and operation of the turning fixture, rotate the coil/ring assembly a full revolution using the foot-pedal control. Re-adjust the alignment rollers as required. Alignment of coil/ring assembly to the turning fixture is complete.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--





**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

6.3.3 Cooling tube electrical test– Verify that cooling tubes are not grounded and electrically isolated to modular coil winding form using a multi-meter. Document findings below in Table 1 Tube inspection results

**Equipment Name & ID Number:** \_\_\_\_\_ **Calibration Date:** \_\_\_\_\_

**Table 1 Tube inspection results**

<b>Tube designation</b>	<b>Flow Path Blockage check</b>	<b>Pressure Leak check</b>	<b>Electrical test, tube to ground</b>
Side A inboard top			
Side A inboard bottom			
Side A outboard, top, Midplane side of poloidal break			
Side A outboard, top, side of poloidal break opposite midplane			
Side A outboard, bottom, midplane side of poloidal break			
Side A outboard, bottom side of poloidal break opposite midplane			
Side B inboard top			
Side B inboard bottom			
Side B outboard top, midplane side of poloidal break			
Side B outboard top, side of poloidal break opposite midplane			
Side B outboard bottom, midplane side of poloidal break			
Side B outboard bottom, side of poloidal break opposite midplane			

<p>All cooling tube inspections/ tests are completed and verified by:</p> <p><b>Field Supervisor:</b> _____ <b>Date:</b> _____</p>
--

**6.4 Dimensional Inspection**

6.4.1 Perform any dimensional inspections as outlined in procedure **D-NCSX-MCF-005** ‘Dimensional Control & Metrology for the NCSX MC’.

<p>Measurements completed and verified by:</p> <p><b>Field Supervisor:</b> _____ <b>Date:</b> _____</p>
---

**6.5 Sprue Removal**

6.5.1 Using a Field Supervisor pre-approved cut-off saw, cut off each of the G-11 sprues from the coil bundle. The sprues shall be cut flush with the outer Structural Shell covering.

6.5.2 Once cut, sand the remaining sprue removing any sharp edges or ledges.

**Modular Coil Fabrication- Post VPI Activities**  
**D-NCSX-MCF-004-00**

6.5.3 All epoxy sprues have been removed, and the coil is ready for installation of final clamps.

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--

**6.6 Coil Clamp Installation**

6.6.1 Begin removing the VPI clamp assemblies from the impregnated coil. Do not remove more than (10) clamps from any one location.

6.6.2 VPI Clamps Locations:

In locations where the clamps were only used for supporting the coil during VPI, simply remove the clamp, pusher pad and hardware.

6.6.3 Final Clamp Locations:

In areas where the final clamps will be located, carefully cut away the vulcanized rubber bag mold and any structural shell that is in the area where the final coil clamp pads are to be installed. This will expose the G-11 pads under the bag mold. See Figure 1- G-11 Pad Location

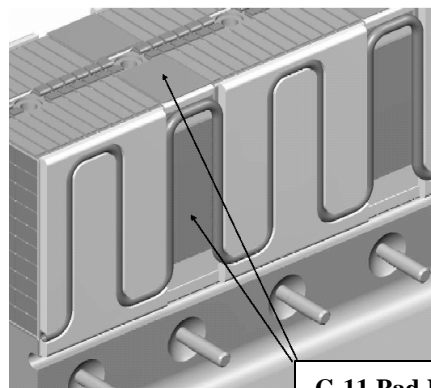


Figure 1 depicts the location of the G-11 pads for information purposes only and does not reflect the final design configuration

**G-11 Pad Locations**

**Figure 1- G-11 Pad Location**

6.6.4 Remove any excess epoxy that may be on the G-11 pad.

6.6.5 Use drawing SE1405-257P [Short Clamp Assembly] and install a final winding clamp assembly. See Figure 2- Coil Clamp Assembly

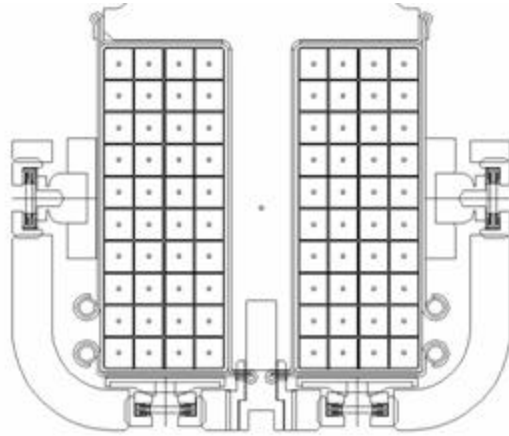
6.6.6 Verify good fit between clamp surfaces and G11 pad surfaces. Adjust clamp as required for best fit.

6.6.7 Secure the top horizontal bar with 3/8-16 UNC socket head cap screw. Torque bolt to 20 ft-lbs.

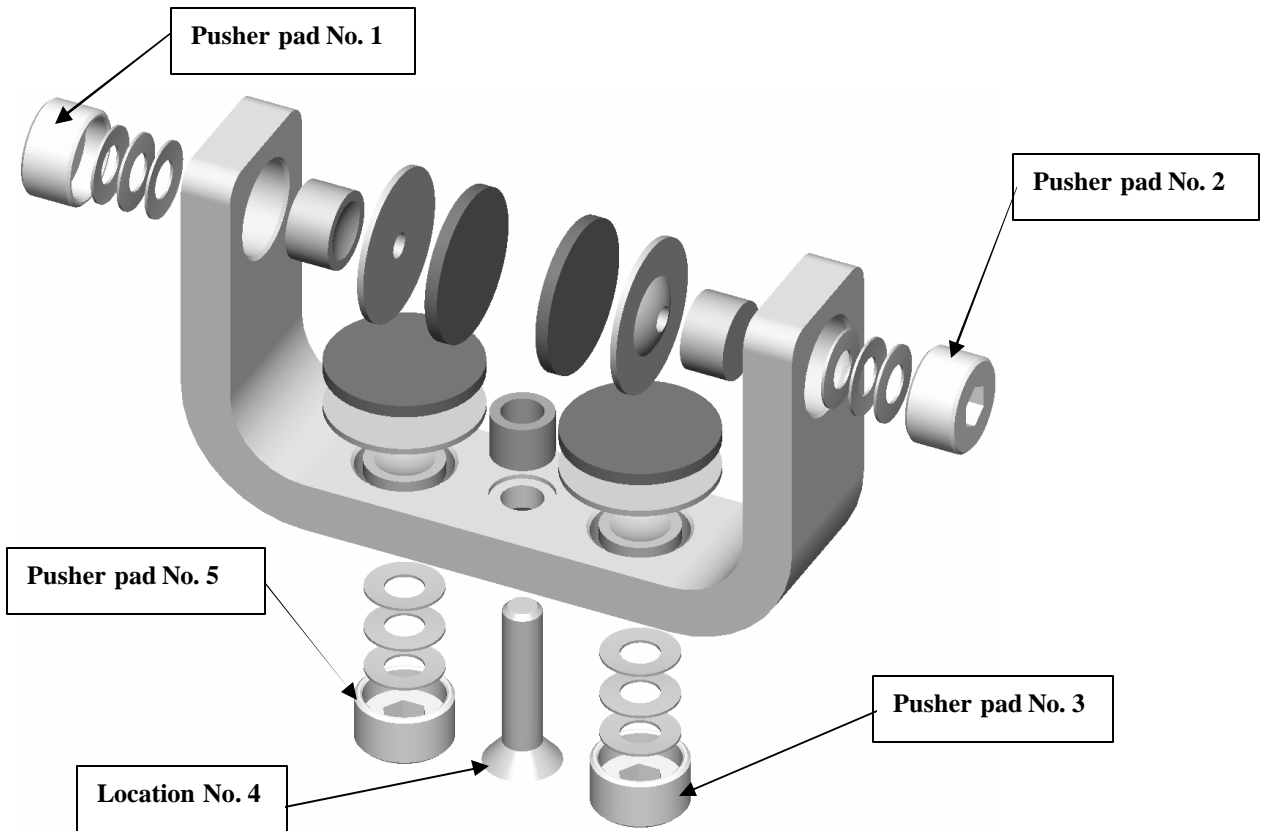
6.6.8 Each clamp will provide 125 lbs of pre-load. This is accomplished by hand tightening the pusher screw until it is in full contact with the G11 coil pad. Then turn the screw an additional \_\_\_\_\_ turns. [Push pads no. 1, 2, 3 and 5]. See Figure 3- Torque Reference Locations for identification numbers of joints. Record all torque verifications in Table 2 - Coil Clamp Torque Verification

**Modular Coil Fabrication- Post VPI Activities**  
**D-NCSX-MCF-004-00**

- 6.6.9 Once all of the final coil clamps have been torqued, wire lock the hardware together so that the bolts will not loosen during operation.

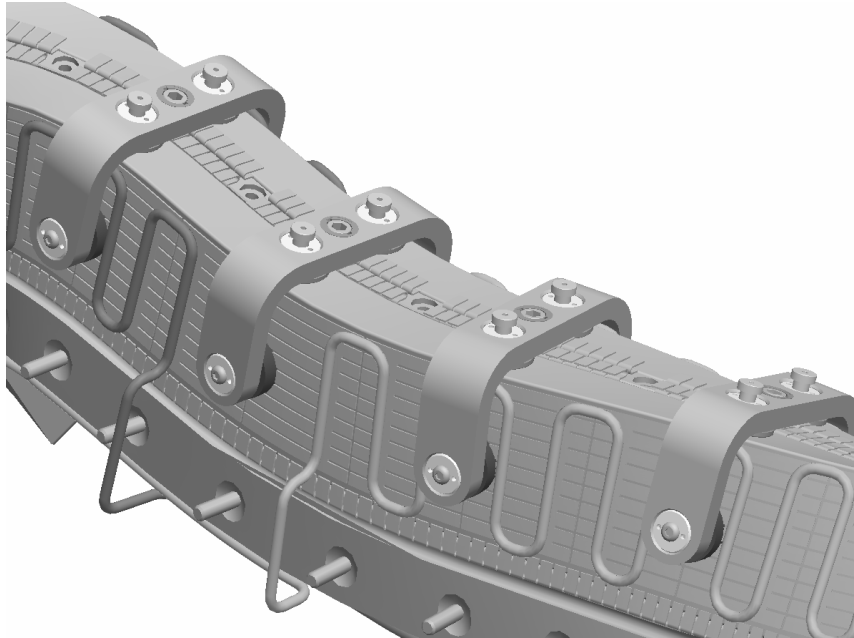


**Figure 2- Coil Clamp Assembly**



**Figure 3- Torque Reference Locations**

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**



**Figure 4-Typical Winding Clamp Arrangement**

**Table 2 - Coil Clamp Torque Verification**

Torque verified	Torque #1	Torque #2	Torque #3	Torque #4	Torque #5	Torque #6	Torque #7
Clamp No.							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
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25							
26							

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

27							
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33							
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42							
43							
44							
45							
46							
47							
48							
49							
50							

**6.7 Installation of cooling jumper around poloidal break**

- 6.7.1 Prepare Teflon jumper tubes for installation, to jumper the poloidal break areas.
- 6.7.2 Install the Teflon jumper tubes and tighten connections on all outboard circuits
- 6.7.3 Re-leak check circuits

<b>Verified by:</b> _____ <b>Date:</b> _____ <b>Lead Technician</b>
--

**6.8 Electrical Testing of Coil Prior to Transport**

This series of electrical tests will be performed at room temperature to verify the integrity of the coil insulation prior to transporting to the Cold Coil Test Facility.

- 6.8.1 Test Director:  
Test Director for this test series is: \_\_\_\_\_
- 6.8.2 Safety Requirements & Conditions
  - 6.8.2.1 The following safety requirements and prerequisites shall be used for performing tests on the Twisted Racetrack and Modular Coils.
  - 6.8.2.2 Technicians and engineers performing these tests shall be familiar with the hazards and work procedure to minimize accidents that may occur.

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

6.8.2.3 There shall be present a second person, “safety watch” monitoring the operator, and capable of removing the power in case of an accident. This person shall be CPR qualified.

**Qualified CPR Member:** \_\_\_\_\_ **Recertification Date:** \_\_\_\_\_

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

**Test Director Verify:** \_\_\_\_\_

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

6.8.2.6 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.

6.8.2.7 Upon completion of test and before the components are declared safe to touch, (dielectric joint) being tested shall be properly discharged using a “Ground Hook”. After a minimum period of 10 seconds, while the ground hook is still in place, attach a ground cable to the casting and poloidal mid-plane. The ground hook may be removed once the ground cable is in place.

6.8.3 Resistance Measurement

6.8.3.1 The test equipment used for this test will be a “Biddle” digital low resistance ohmmeter (DLRO).  
Equipment ID No. \_\_\_\_\_ Calibration Date: \_\_\_\_\_

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

6.8.3.3 Record the resistance readings on the test sheet.

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

$$R_{20} = \frac{254.5}{234.5 + T_c} \times R_c$$

where: R<sub>c</sub> = measured resistance of the conductor (milliohms)

T<sub>c</sub> = temperature of coil when resistance measurement is made (degrees C)

**Table 3- Coil Resistance**

Measured System Resistance (R <sub>c</sub> ) m-ohms at T <sub>c</sub>	System Resistance corrected to 20 deg. C (R <sub>20</sub> )	Calculated System Resistance @ 20 deg.C
<b>R<sub>c</sub>:</b>		
<b>T<sub>c</sub>:</b>		

**Resistance Results:** *Acceptable:* \_\_\_\_\_ *Unacceptable:* \_\_\_\_\_

**Test Director Signoff:** \_\_\_\_\_ **Date:** \_\_\_\_\_

6.8.4 Insulation Megger Test:  
*Test Criteria*

- **Test Voltage:** \_\_\_\_\_ volts

- **Acceptance criteria** for this test: > \_\_\_\_\_ **k-ohms**

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

- 6.8.4.1 Test director shall verify that all safety requirements and prerequisites have been performed prior to starting the test.
- 6.8.4.2 Verify that the turning fixture is well grounded to building steel.
- 6.8.4.3 Place the megger test set on a firm, stable surface.
- 6.8.4.4 Securely connect a ground cable between building steel and the test unit.
- 6.8.4.5 Connect the megger ground lead to the coil casting.
- 6.8.4.6 Connect a ground cable to the chill plates.
- 6.8.4.7 Connect the megger power lead to the coil leads.
- 6.8.4.8 Measure the insulation resistance to ground. The test results shall be in compliance with the requirements noted in Section 6.8.4.

**Table 4-Megger Test Results**

Test Voltage	Insulation Resistance Minimum 1000W	Observations
1000		
2000		
3000		
2500		
5000		
7500		
10000		
12000		

Equipment ID Number: \_\_\_\_\_ Calibration Date: \_\_\_\_\_

Megger Results: *Acceptable*: \_\_\_\_\_ *Unacceptable*: \_\_\_\_\_

<p>Test Director Signoff: _____ Date: _____</p> <p>Quality Control Witness: _____ Date: _____</p>
---

<p><b>Remarks:</b></p>
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## Modular Coil Fabrication- Post VPI Activities D-NCSX-MCF-004-00

### 6.9 Strain Gauges and Thermocouples

Install strain gauges 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. Use the following steps to attach the “FISO” sensors to the TRC or MC.

- 6.9.1 Degrease and clean the surface with alcohol.
- 6.9.2 Dry abrade the gauging surface to improve adhesion.
- 6.9.3 Tape the gage into position.
- 6.9.4 Apply Ultra -violet glue onto the gage.
- 6.9.5 Using the UV gun cure the UV paste in approximately 1 minute.
- 6.9.6 Using a UV lamp, bake the UV attachment for a minimum of 24 hours.
- 6.9.7 Using the “Romer” measuring arm, document the position of the sensors that were just installed on to the coil.
- 6.9.8 Mark the general locations of the sensors on the appropriate coil figure at the back of the procedure [Figure 10-Sensor Locations for Type C Casting; Figure 11- Sensor Locations for Type B Casting; Figure 12-Sensor Location for Type A Casting; Figure 13- Sensor Locations for Twisted Racetrack Coil]

**Table 5- Coil Sensor Table**

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

\* Sensor type: Stain gauge or thermocouple

<p>Installation of sensors is complete:</p> <p><b>Verified by:</b> _____ <b>Date:</b> _____</p> <p style="text-align: center;"><b>Field Supervisor</b></p>
--

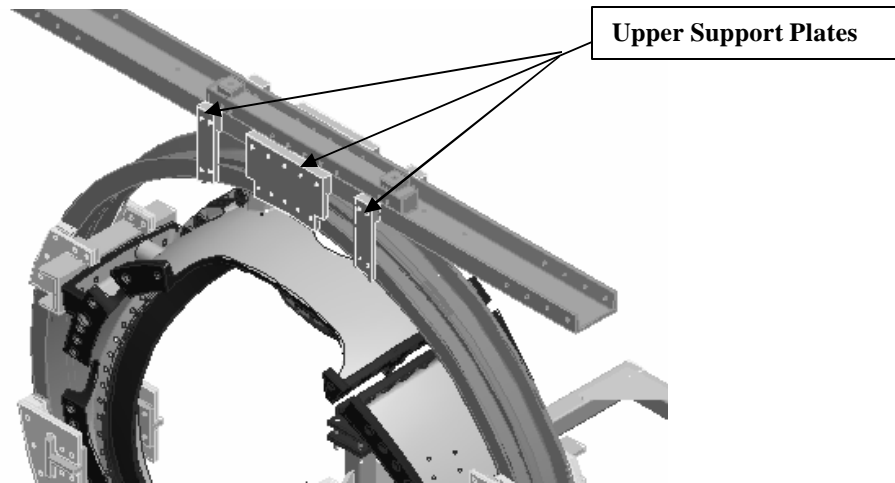
### 6.10 Removing the Modular coil from the Turning Fixture:

- 6.10.1 Install the upper support plates that secure the support ring to the support/lift beam. This operation must be verified prior to proceeding. See Figure 5- Upper Support Plates

<p><b>Verified by:</b> _____ <b>Date:</b> _____</p> <p style="text-align: center;"><b>Lead Technician</b></p>
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**Modular Coil Fabrication- Post VPI Activities**  
**D-NCSX-MCF-004-00**



**Figure 5- Upper Support Plates**

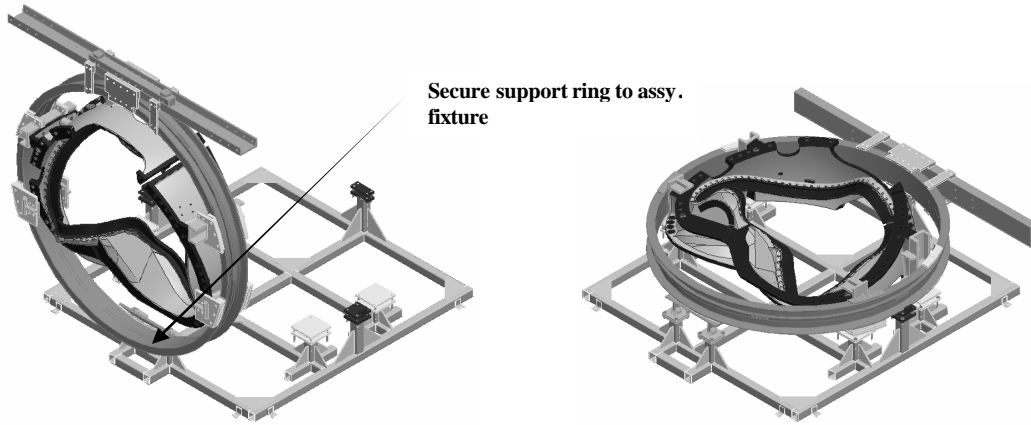
- 6.10.2 Using lift procedure **D-L-NCSX-984** rig the upper support/lift beam to the overhead crane.
- 6.10.3 Once a slight load has been taken, remove the hardware that secures the upper support/lift beam to the turning fixture frame.
- 6.10.4 Disengage and remove the upper guide rollers.
- 6.10.5 Using lift procedure **D-L-NCSX-984** carefully raise the Coil/winding form from the turning fixture and transport/position directly over the casting assembly fixture.

<b>Verified by:</b> _____ <b>Date:</b> _____ <p style="text-align: center;"><b>Field Supervisor</b></p>
--

**6.11 Disassembly of coil/casting from Support Ring Assembly:**

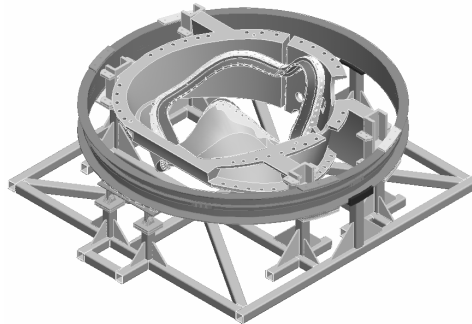
- 6.11.1 Secure the coil support ring to the casting assembly fixture. Figure 6- Casting Assy. Fixture- Vertical Position
- 6.11.2 Using the overhead crane, carefully lower the coil/support ring assembly until the coil is in the horizontal position and resting on the support stands. Figure 7- Casting Assy. Fixture in Horizontal Position
- 6.11.3 Disassemble the support/lifting beam and support brackets between the support ring and casting.
- 6.11.4 Lift the support ring from the assembly fixture and transport to storage area. Figure 8- Assy. Fixture without Lift/Support Beam and Figure 9- Coil without Support Ring

**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

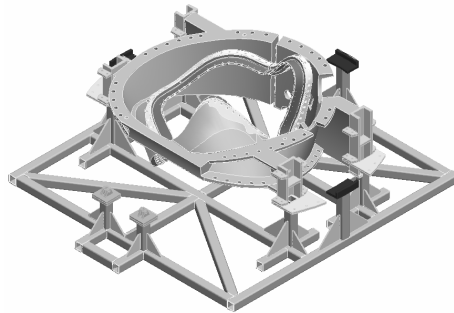


**Figure 6- Casting Assy. Fixture- Vertical Position**

**Figure 7- Casting Assy. Fixture in Horizontal Position**



**Figure 8- Assy. Fixture without Lift/Support Beam**



**Figure 9- Coil without Support Ring**

6.11.5 Position the completed coil onto the mobile cryo-test test facility transport cart.

<b>Verified:</b>	
<b>Lead Technician:</b> _____	<b>Date:</b> _____
<b>Field Supervisor:</b> _____	<b>Date:</b> _____

**Modular Coil Fabrication- Post VPI Activities**  
**D-NCSX-MCF-004-00**

**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 Approval:**

Prior to releasing a modular coil to the Test Facility, 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, VPI Director and the QC representative.

All Post VPI activities have been satisfactorily completed.	
<b>Lead Technician:</b> _____	<b>Date:</b> _____
<b>Field Supervisor:</b> _____	<b>Date:</b> _____
QC shall verify completion of documentation:	
<b>Quality Control Representative:</b> _____	<b>Date:</b> _____

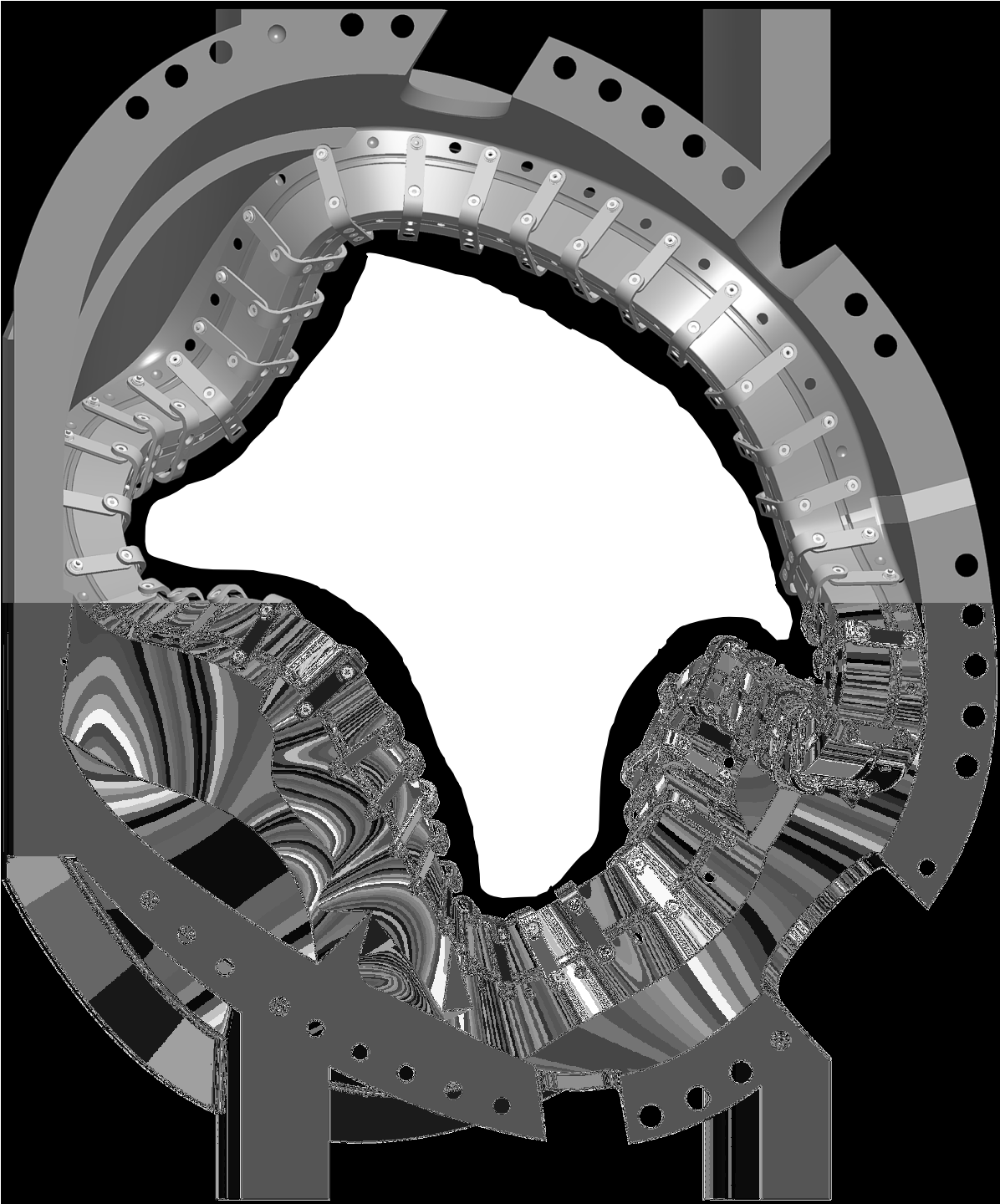
**The completed coil is ready for transfer down the elevator to the basement Coil Test Facility.**

Signature by Test Facility Manager (TFM) indicates that the completed coil has been satisfactorily transported to the coil test facility and that the TFM has assumed responsibility for the coil.	
<b>Test Facility Manager:</b> _____	<b>Date:</b> _____

<b>Comments:</b>     
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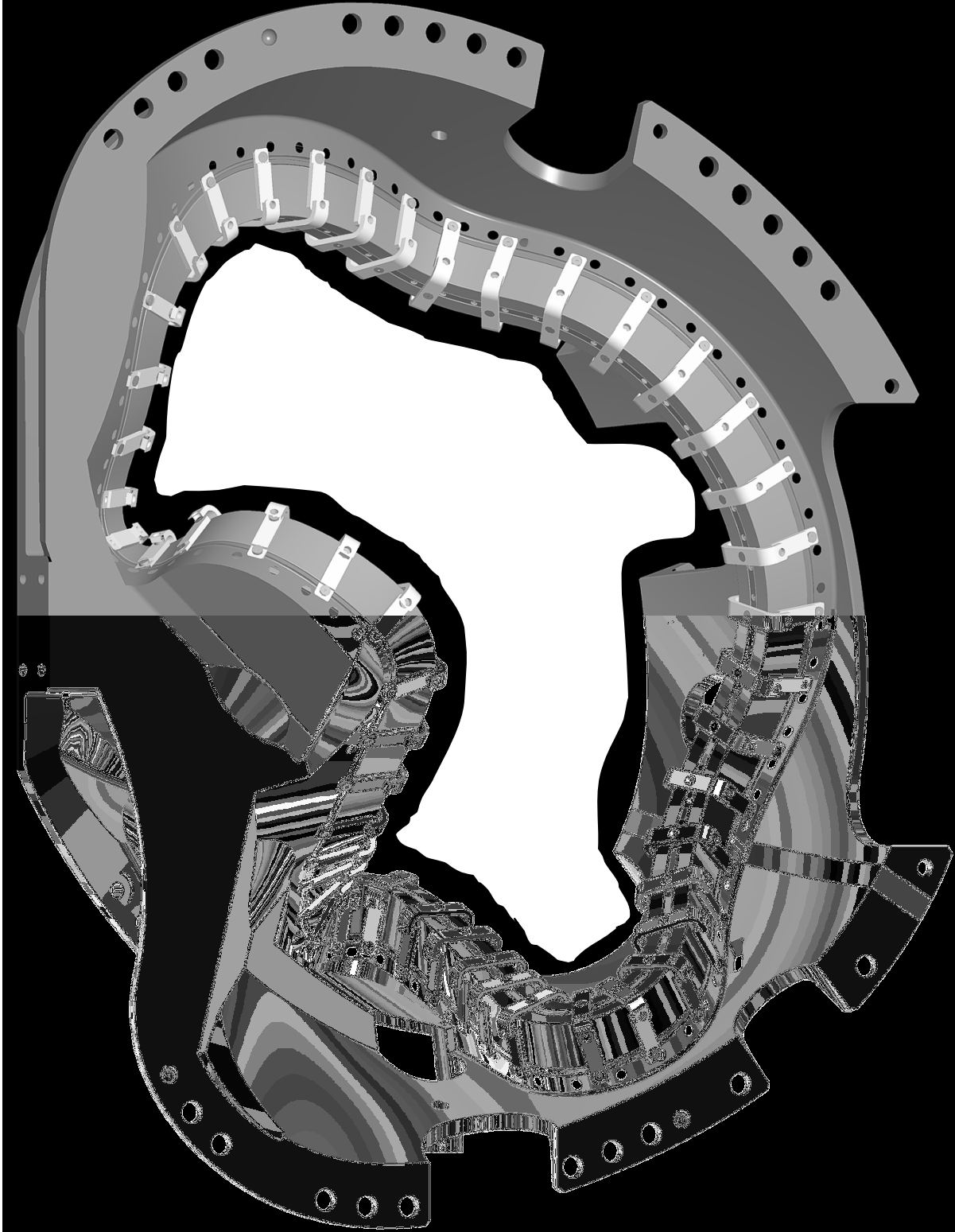
**Modular Coil Fabrication- Post VPI Activities**  
**D-NCSX-MCF-004-00**

**Figure 10-Sensor Locations for Type C Casting**



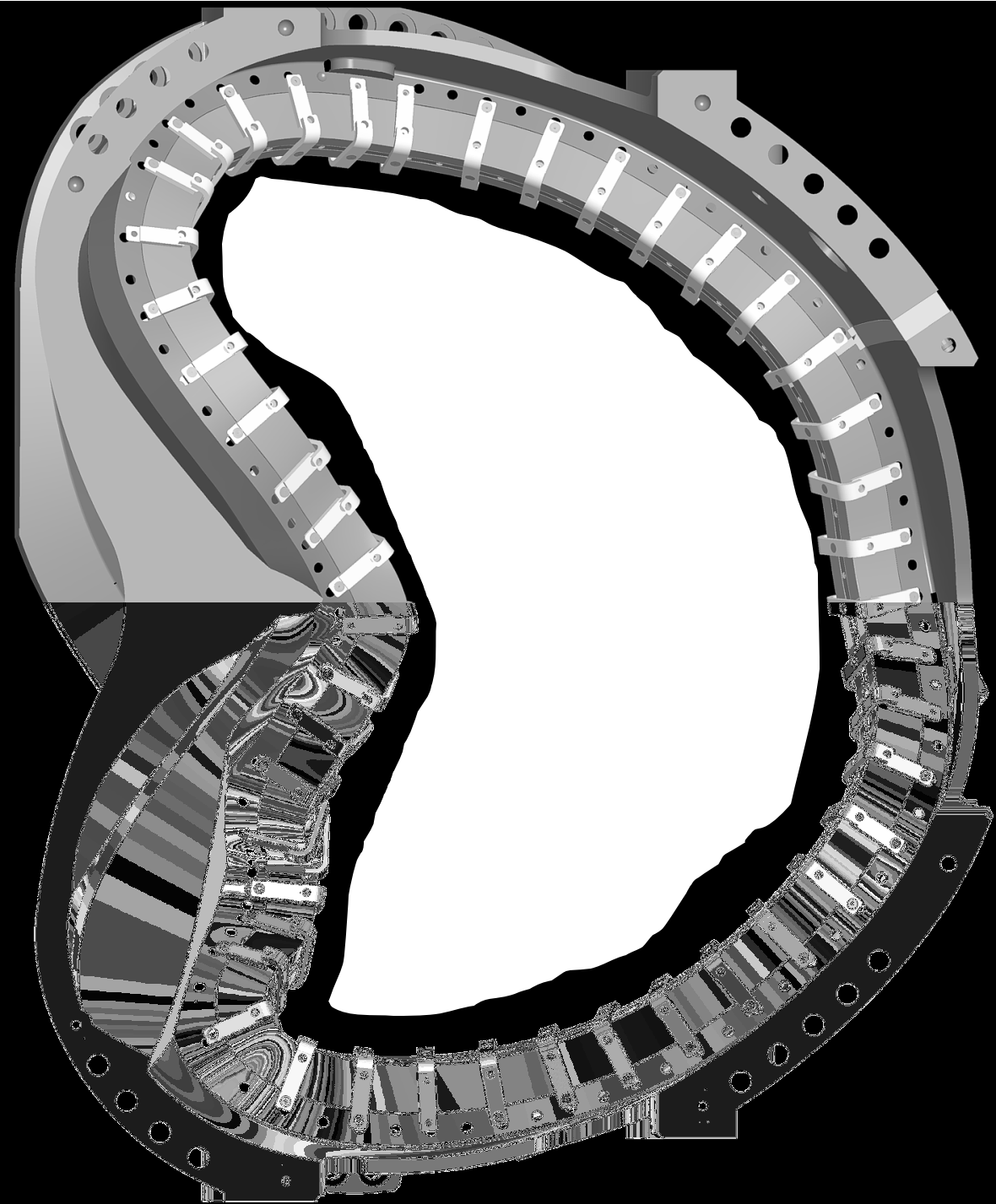
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**D-NCSX-MCF-004-00**

**Figure 11- Sensor Locations for Type B Casting**



**Modular Coil Fabrication- Post VPI Activities**  
**D-NCSX-MCF-004-00**

**Figure 12-Sensor Location for Type A Casting**



**Modular Coil Fabrication- Post VPI Activities  
D-NCSX-MCF-004-00**

**Figure 13- Sensor Locations for Twisted Racetrack Coil**

