

NCSX

Modular Coil  
Manufacturing, Inspection, Test and  
Quality Assurance Plan

NCSX-PLAN-MIT/QA-142-00

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**RECORD OF CHANGE**

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## 1 Introduction and Scope

### 1.1 Introduction

The National Compact Stellerator Experiment (NCSX) Modular coils will be manufactured at Princeton Plasma Physics Laboratory for the NCSX Project. The Modular Coil Set consists of three field periods with 6 coils per period for a total of 18 coils. Due to symmetry, only three different coil shapes are required to make up the complete coil set. Each modular coil is constructed by winding pre-insulated rectangular compacted copper cable onto a stainless steel cast winding form. Each coil consists of two, 4-in-hand pancake windings. Once wound, the entire coil will be vacuum-pressure impregnated (VPI) with epoxy.

### 1.2 Scope

This document addresses the manufacturing, inspection, test and Quality Assurance (QA) plan to complete and deliver the Twisted Racetrack (TRC) and modular coils to the NCSX Project. This document includes the following Sections:

- 2 Applicable Documents
- 3 Safety Requirements
- 5 General notes for fabrication of Modular Coils.
- 6 Materials and Parts
- 7 Fabrication Process
- 8 Documentation Requirements
- 9 Quality Assurance/Quality Control Requirements

1.2.1 This document along with the “Modular Coil Manufacturing Facility Operations Plan” [NCSX-PLAN-MFOP-00] will govern the processes by which the modular coils will be fabricated.

1.2.2 This document meets the requirements of the NCSX Quality Assurance Plan [NCSX-PLAN-QAP].

## 2 Applicable Documents

Identified below are the primary laboratory and project documents that that will be needed to complete the production of the Twisted Racetrack (TRC) and Modular coils.

### 2.1 Laboratory Procedures

<b>Procedure Number (Latest Version)</b>	<b>Title</b>
ESH-004	Job Hazard Analysis
ES&H 5008	PPPL Environmental, Safety and Health Manual
ESH-008	Access to Radiological Areas (RCA's)

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ENG-014	Hydrostatic and Pneumatic Testing
ENG-021	Hoisting & Rigging Procedure
EM-002	General Welding & Brazing Requirements

**2.2 NCSX Project Documents for Modular Coils**

<b>Document No.</b>	<b>Title</b>
NCSX-CSPEC-142-XX	Modular Coil Assembly Specification
NCSX-CSPEC-141-02	Modular Coil Castings Specification
NCSX-CSPEC-142-03	Modular Coil Conductor Specification
NCSX-CSPEC-142-04	Twisted Racetrack Coil Product Specification
NEPA No. 1283	Modular Coil Development and Production
NCSX-PLAN-MFOP-00	Modular Coil Manufacturing Facility Operations Plan
WP-1138	Manufacturing of Production Coils
WP-1188	Mod coil Winding R&D (Twisted Racetrack coil)
D-NCSX-OP-EO-41	NCSX Coil Manufacturing Facility Emergency Response

**2.3 Modular Coil Manufacturing Procedures**

<b>Document No.</b>	<b>Title</b>
D-NCSX-MCF-001	Mod Coil Fab- Casting Preparation Activities
D-NCSX-MCF-002	Mod Coil Fab- Winding/Molding Activities
D-NCSX-MCF-003	Mod Coil Fab- VPI Activities
D-NCSX-MCF-004	Mod Coil Fab- Post VPI Activities
D-NCSX-MCF-005	Metrology for TRC and Modular Coils
D-NCSX-OP-G-159	Coil Test Facility Operation
D-L-NCSX-983	Lifting Modular Coil Castings
D-L-NCSX-984	Lifting Mod Coil Casting & Windings

**2.4 Drawings:**

- 2.4.1 Drawings for each coil type will be provided by the NCSX project. Only signed and “Approved For Fabrication” stamped drawings can be used.
- 2.4.2 A complete list of coil drawings for each coil type shall be added to the back section of this MIT Plan once they have been approved.

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## **2.5 Permits**

### **2.5.1 D-site work permits:**

D-site work permits are required whenever work is being performed at D-site. It identifies the type of work and procedures being used.

### **2.5.2 Confined space permits:**

Confined Space permits are required whenever a person is entering a confined space. It identifies any restrictions, requirements and personnel who are authorized for entry. The PPPL Industrial Hygienist (IH) representative issues the permit. [Requires a “safety watch”] (Example: Autoclave entrances when the dome is in position)

### **2.5.3 Flame/Fire Permit:**

Flame/Fire permits are required whenever open flame activities such as welding, soldering, grinding, etc. are being performed. The permit is issued by PPPL’s Emergency Service Unit (ESU) and requires a fire watch.

## **3 Safety Requirements:**

### **3.1 Integrated Safety Management:**

All work will be performed in a safe manner in accordance with PPPL Environmental, Safety and Health Manual **ES&H 5008** and the “Integrated Safety Management” (ISM) policy.

### **3.2 Job Hazard Analysis:**

JHA’s will be generated for each workstation, identifying existing or potential workplace hazards and evaluating the risk of worker injury or illness associated with job tasks. (Reference document **ESH-004 “Job Hazard Analysis”**) The Industrial Hygiene 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 Training Requirements**

Training of personnel working on the modular coil fabrication is “Key” to successfully completing the manufacturing of the modular coils. There are two categories of training requirements, general and specialized.

### **4.1 General Training Requirements**

General training includes all laboratory-training requirements that are required to enter or work in the Modular Coil Winding Facility. Examples of this training include:

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- General Employee Training [GET]
- Integrated Safety Management [ISM]
- Radiation Safety Training

### **4.2 Specialized Training Requirements**

Specialized training includes specific training or certification required to complete tasks during the fabrication of the modular coils. Examples include:

- Weld or braze certifications
- Confined space
- Modular Coil Manufacturing Facility Operations Plan [MFOP]

### **4.3 Training Matrix**

There exists a Modular Coil Manufacturing training matrix for the Twisted Racetrack Coil and modular coil fabrications which will be posted on the NCSX Web site.

## **5 General Notes for Modular Coil Fabrication:**

### **5.1 General Operating Plan:**

Document “NCSX-PLAN-MFOP-01-01” describes the general operating plan that will be used for the coil manufacturing facility.

### **5.2 Cleanliness/Housekeeping:**

See section 8.2 in the Manufacturing Facility Operations Plan NCSX-PLAN-MFOP-00-01 for the housekeeping and cleanliness rules.

### **5.3 Critical Lifts:**

All lifting of modular coil castings and/or completed coils will be considered a “Critical” lift that requires the presence of a lift engineer. Note: The lift engineer may later identify the lift as repetitive, in which case his presence would not be required.

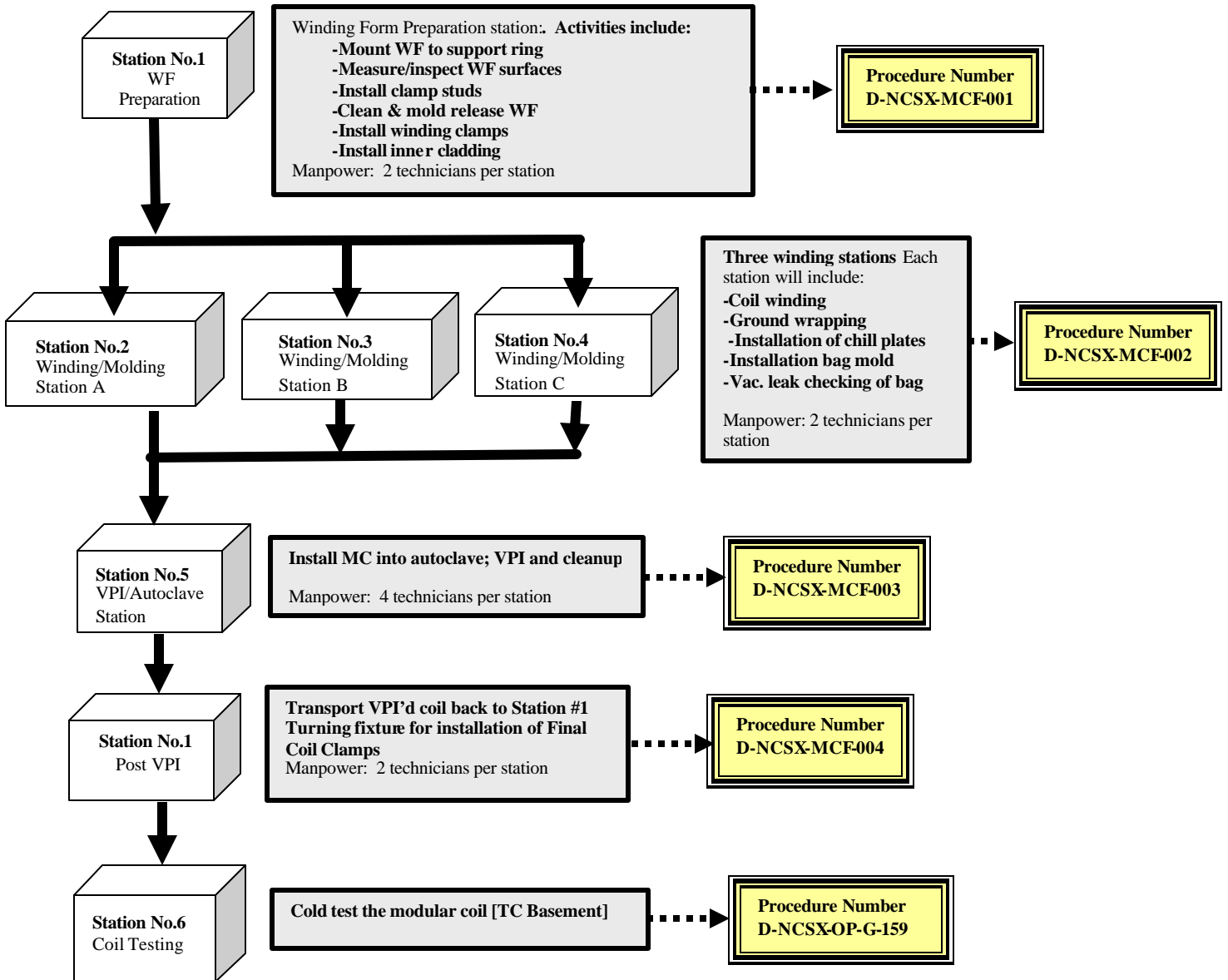
## **6 Materials and Parts**

Each manufacturing procedure has a table of materials and parts identifying the items needed to complete the activities associated with that procedure. They can be found in section 5.0 of each coil manufacturing procedure.

## **7 Fabrication Process**

This section of the MIT/QA plan outlines the processes that are to be performed and procedures required to complete the fabrication of the Modular coils. Procedures for performing the activities are covered by the Modular Coil Fabrication procedures.

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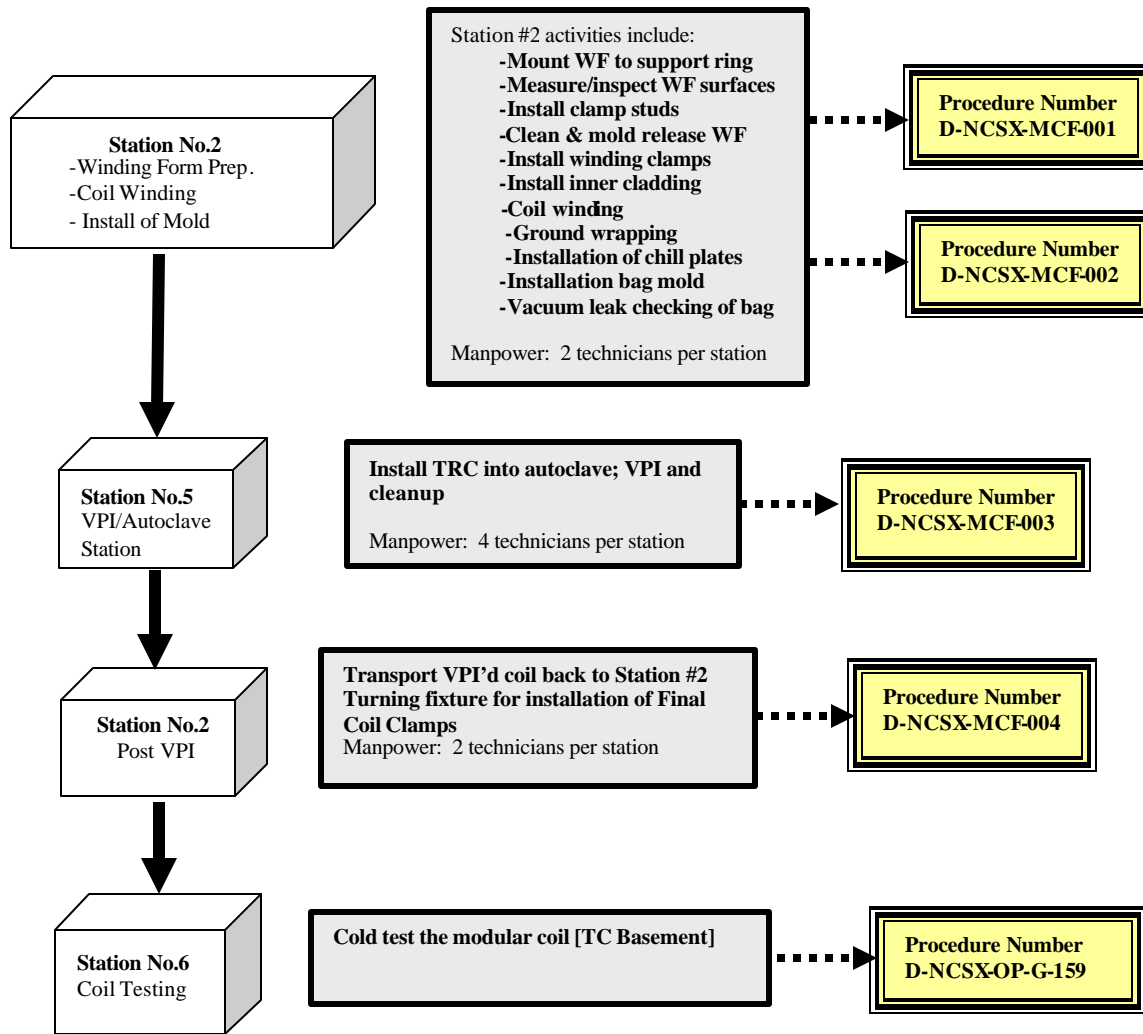


Note: In addition to staff called out above, there will be a Field Supervisor, Station Lead Technician(s), QC representative, metrology engineer, and metrology technician.

**Figure 1- Modular Coil Fabrication Plan Outline**



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Note: In addition to staff called out above, there will be a Field Supervisor, Station Lead Technician(s), QC representative, metrology engineer, and metrology technician.

**Figure 2-TRC Fabrication Plan Outline**

**7.1 Manufacturing Procedures:**

There are (4) manufacturing procedures used to fabricate the Twisted Racetrack Coil (TRC) and Modular Production Coils. Manufacturing Procedures detail the manufacturing processes, identifies inspection and test points and QC witness points.

**7.1.1 D-NCSX-MCF-001- Winding Form Preparation**

Procedure identifies the activities associated with preparing the winding form for coil winding. This procedure includes inspection and measurement of the winding form, installation of coil clamp studs plus the installation of the copper cladding

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7.1.2 D-NCSX-MCF-002- Winding/Mold Activities

Procedure identifies the activities associated with winding the TRC and Modular coils. Includes ground wrap insulation, lead terminals, coil winding, installation of outer chill plates and cooling system; installation of diagnostics and the installation of the “Bag Mold”.

7.1.3 D-NCSX-MCF-003- Vacuum Impregnation Activities (VPI)

Procedure identifies the activities associated with preparing for and the vacuum-pressure-impregnation of the TRC and Modular coils using the autoclave.

7.1.4 D-NCSX-MCF-004- Post VPI Activities

Procedure identifies the activities associated with post VPI, final conditioning prior to cold testing. This procedure includes cleanup of the coil following VPI, installation of final coil clamps and room temperature electrical testing.

**7.2 Electrical Test Procedure:**

D-NCSX-OP-G-159- This procedure outlines the details of the testing of each TRC and Modular coil following fabrication. The coils will be tested at liquid Nitrogen temperatures at full current.

**7.3 Metrology Procedure:**

D-NCSX-MCF-005- This procedure in conjunction with the manufacturing procedures identifies the processes used to measure the physical location of winding surfaces and conductor turns of the TRC and Modular Coils during and after fabrication.

**7.4 Emergency Response Procedure:**

D-NCSX-OP-EO-41- Details of response are discussed in section 9.7 of the Modular Coil Facility Operations Plan “**NCSX-PLAN-MFOP-00**”

**8 Documentation Requirements:**

**8.1 Document Control:**

All NCSX associated documents providing instruction for manufacturing the modular coils (e.g. plans and procedures) will be maintained under NCSX Project document control.

**8.2 Coil Field Package:**

Each coil will have a “Coil Field Package” that will include all coil related documentation associated with the manufacturing of the TRC and modular coils. Documentation in this package will include process procedures, QC inspection reports, photographs, test results, and measurements used to document completion of major activities, as well as any ECNs, non-conformance reports (NCR), or other exceptions to or changes in requirements..

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**8.3 Manufacturing Procedures:**

Manufacturing procedures will be used as a signoff/approval document noting that critical manufacturing steps have been completed. Authorized personnel associated with the manufacturing, inspection and test processes will perform the signoff's. In addition, it will provide witness points as well as reference for test results, and measurements.

**8.3.1 Procedure Completion:**

The Lead Technician or Field Supervisor will document all critical completions on the procedure. This will be completed using the signer's initials or full signature.

The procedures will be filled out in a timely fashion once a particular activity has been completed.

**8.3.2 Authorized Signoff's for Manufacturing Completions:**

The manufacturing procedures will identify what level of signoff is required for a particular step. The following disciplines are the authorized signatures for the in-process procedures.

- Station Lead Technicians
- Field Supervisors
- Quality Control Representative
- Manufacturing Facility Manager

**8.4 Final Document Storage:**

All documents (hard copy) associated with the manufacturing will be stored in the PPPL Operations center, electronic documents will be stored on the NCSX Web site for the lifetime of the NCSX Project.

**9 Quality Assurance/Quality Control Requirements**

**9.1 Mission Statement: -Modular Coil QA/QC Plan**

To observe and obtain any required information as may be necessary to assure that the manufacturing of the Modular Coils is being performed in accordance with the Manufacturing Facility Operations plan, Modular Coil Specifications, the NCSX Modular Coil Manufacturing Procedures and other applicable documents. [See section 2 for document numbers]

**9.2 Inspection/Surveillance and Audit:**

Authorized representatives of the NCSX project will perform inspection and surveillances all during the manufacturing of modular coils. These representatives will include the Field Supervisors; lead technicians as well as the Quality Control (QC) representatives.

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All measurements and tests will be performed by the field crews and engineering and do not require, unless outlined in the procedures, the presence of a QC representative.

Independent Audits may be performed by the Quality Assurance Division to ensure that approved manufacturing processes and quality of product is being observed.

**9.3 Inspection and Test Procedures:**

Inspections and tests shall be performed in accordance with written/approved procedures referencing criteria for acceptance or rejection. Adequate records shall be maintained and available for NCSX Project reviews.

**9.4 Document Traceability and Records:**

The Modular Coil manufacturing team shall maintain a system of documentation whereby objective evidence of required operations, inspections, examinations, and tests is systematically compiled, indexed and stored. Such objective evidence will include “travelers”; and material test, certification, inspection, examination, test and discrepancy reports; which shall be complete and legible and validated by responsible personnel and shall be traceable to subject items.

**9.5 Equipment/Material Identification and Status**

Material and equipment identification shall be maintained throughout the program and be traceable to the records. Status of acceptability shall be readily discernible through the use of tags, stamps, serial numbers or other positive means.

**9.6 Non-conformance & Corrective Actions:**

Nonconforming items shall be positively identified, and, where possible, segregated to prevent use. The Modular Coil Manufacturing Team shall document each non-conformance in accordance with PPPL procedure **QA-005** “Control of Non-conformances”.

**9.7 Calibration of Test and Measuring Equipment:**

Inspections and tests shall be performed using properly calibrated measuring and test equipment in accordance with PPPL procedure **ENG-002** “Control of Measurement Test Equipment & Calibration”.

**9.8 Release for Station Transfer:**

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

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**9.9 Process History:**

The Modular Coil Manufacturing team shall provide a Process History for the modular coils that includes a compilation of documents, detailing the objective evidence of the acceptability of the work performed. Process History for each coil records shall be stored in the Operations Center after fabrication is completed. The Process History shall include as a minimum, but not be limited to the following:

9.9.1 Material Certifications:

The Modular Coil Manufacturing Team shall compile inspection reports, test data, and/or certifications from vendors, showing relevant chemical, mechanical and electrical properties of materials used, where applicable, as well as documents showing adherence to in-process requirements. Material certifications from sub-tier suppliers shall also be submitted. {Certifications for the insulation, epoxy, conductor as well as chill plates and lead materials are required as a minimum}

9.9.2 Inspection/ Test Documents:

Original or copies of filled in and completed process planning and control documents (procedures, etc.), which verify controlled execution of the required work. Each modular coil will have its own set of process planning and control documents.

9.9.3 Inspection Reports:

Copies of the original reports from all required inspections and examinations, that are properly validated by authorized personnel.

9.9.4 Test Reports:

Copies of the original test data sheets or reports of all required tests, both in-process and acceptance, that are properly validated by authorized personnel.