

# NCSX PRODUCT SPECIFICATION

## MODULAR COIL TYPE-C ASSEMBLY

NCSX-CSPEC-142-05-00  
DRAFT-A 6/29/05

Prepared by: \_\_\_\_\_

D. Williamson, WBS14

Concurred by: \_\_\_\_\_

J. Chrzanowski, Coil Windings and Assembly

Concurred by: \_\_\_\_\_

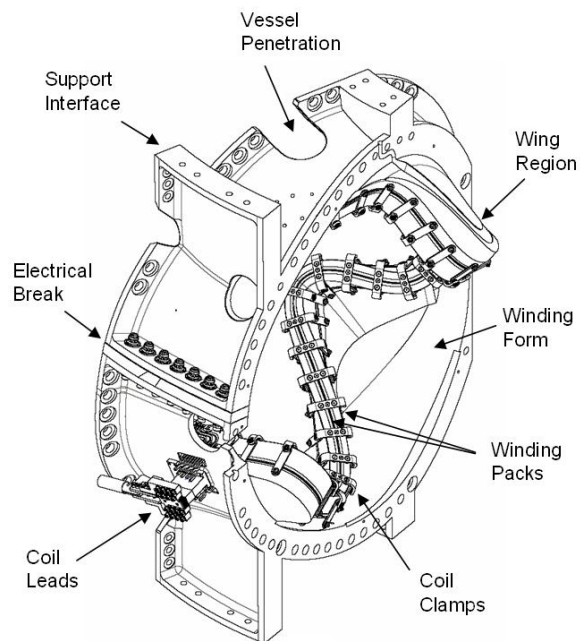
B. Nelson, NCSX Stellarator Core

Concurred by: \_\_\_\_\_

J. Malsbury, NCSX QA Manager

Approved by: \_\_\_\_\_

W. Reiersen, Engineering Manager



-----Controlled Document -----

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**REVISION HISTORY**

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# 1 INTRODUCTION AND SCOPE

## 1.1 Introduction

The National Compact Stellarator Experiment (NCSX) is a quasi-axisymmetric facility that combines the high beta and good confinement features of an advanced tokamak with the low current, disruption-free characteristics of a stellarator. The experiment is based on a three field-period plasma configuration with an average major radius of 1.4 m, a minor radius of 0.3 m, and a toroidal magnetic field on axis of up to 2 T. The modular coils are one set in a complex assembly of four coil systems that surround the highly shaped plasma. There are six each of three coil types in the assembly for a total of 18 modular coils. The coils are constructed by winding copper cable onto a cast stainless steel winding form that has been machined to high accuracy, so that the current center of the winding pack is within  $\pm 1.5$  mm of its theoretical position. The modular coils operate at a temperature of 80 K and are subjected to rapid heating and stress during a pulse.

## 1.2 Scope

This specification defines the modular coil Type-C assembly and requirements for its construction and operation.

# 2 APPLICABLE DOCUMENTS

## 2.2 Standards and Specifications

ASTM A703/M-01	Specification for Steel Castings
ASTM B152/M-00	Standard Specification for Copper Sheet
ASTM B280-03	Standard Specification for Seamless Copper Tube
NCSX-BSPEC-14-00	System Requirements for the Modular Coil System
NCSX-CSPEC-142-03	Modular Coil Conductor Specification
NCSX-MCWFOF-00	Winding Facility Operations Plan
NCSX-MITQA-142-01	Modular Coil MIT/QA Plan
NCSX-PLAN-QAP	NCSX Quality Assurance Plan

## 2.2 Drawings

The Type-C modular coil assembly shall be fabricated per the following Pro/ENGINEER models and drawings, which are stored in the Pro/INTRALINK database:

DRAWING	REV	REL DATE	DESCRIPTION
Top level assembly and layouts			
se140-103.drw	0	WIP	MODULAR COIL ASSEMBLY TYPE-C
se142c-019.drw	0	WIP	TYPE-C WINDING PACK DIMENSIONS
se142c-016.drw	0	WIP	TYPE-C ELECTRICAL SCHEMATIC
se142c-015.drw	0	WIP	TYPE-C COOLING SCHEMATIC

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Winding form assembly, SE141-103			
ds141-036.drw	0	09/23/04	STUD, 1.375-6UNC-2A X 9 LG
ds141-038.drw	0	09/23/04	INSULATING WASHER
ds141-060.drw	0	09/23/04	NUT, 12PT HEX 1.375-6UNC-2B
ds141-079.drw	0	09/23/04	FLAT WASHER
se141-078.drw	1	09/23/04	POL BREAK SHIM ASSEMBLY TYPE-C
se141-103.drw	1	09/23/04	MOD COIL WINDING FORM ASSEMBLY TYPE-C
se141-116.drw	5	04/29/05	PRODUCTION WINDING FORM TYPE-C
se141-123.drw	0	WIP	MCWF TYPE-C STUD WELDMENT
Side-A winding pack assembly, SE142C-018			
se142c-018.drw	0	WIP	TYPE-C SIDE-A WINDING PACK ASSEMBLY
se142c-134.drw	0	06/09/05	TYPE-C SIDE-A LOWER LEAD BLOCK COMBINED
se142c-136.drw	0	WIP	TYPE-C SIDE-A UPPER LEAD BLOCK COMBINED
se142c-382-101_105.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-106_110.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-111_115.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-116_120.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-121_125.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-126_130.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-131_135.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-136_140.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-141_145.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-146_150.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-151_155.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-156_160.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-161_165.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-166_170.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-171_175.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-176_180.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-181_185.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-186_190.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-191_195.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-196_200.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-201_205.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-206_210.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-211_215.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-216_220.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-221_225.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-226_230.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-231_235.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-236_240.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-241_245.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-246_250.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-251_255.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-256_260.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-261_265.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN
se142c-382-266_270.drw	0	04/20/05	TYPE-C SIDE-A UPPER CLADDING FLAT PATTERN







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se142c-388-171_175.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-176_180.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-181_185.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-186_190.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-191_195.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-201_205.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-206_210.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-211_215.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-216_220.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-221_225.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-226_230.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-231_235.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-236_240.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-241_245.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-246_250.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-251_255.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-256_260.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-261_265.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-266_270.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-271_275.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-276_280.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-281_285.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-286_290.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
se142c-388-291_292.drw	0	WIP	TYPE-C SIDE-A LOWER CHILL PLATE FLAT PATTERN
Side-B winding pack assembly, SE142C-017			
se142c-017.drw	0	WIP	TYPE-C SIDE-B WINDING PACK ASSEMBLY
se142c-135.drw	0	06/09/05	TYPE-C SIDE-B LOWER LEAD BLOCK COMBINED
se142c-137.drw	0	WIP	TYPE-C SIDE-B UPPER LEAD BLOCK COMBINED
se142c-482-101_105.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-106_110.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-111_115.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-116_120.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-121_125.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-126_130.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-131_135.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-136_140.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-141_145.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-146_150.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-151_155.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-156_160.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-161_165.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-166_170.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-171_175.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-176_180.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-181_185.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-186_190.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN
se142c-482-191_195.drw	0	04/20/05	TYPE-C SIDE-B UPPER CLADDING FLAT PATTERN





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se142c-486-286_290.drw	0	WIP	TYPE-C SIDE-B UPPER CHILL PLATE FLAT PATTERN
se142c-486-291_292.drw	0	WIP	TYPE-C SIDE-B UPPER CHILL PLATE FLAT PATTERN
se142c-488-101_105.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-106_110.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-111_115.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-121_125.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-126_130.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-131_135.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-136_140.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-141_145.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-146-150.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-151-155.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-156_160.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-161_165.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-166_170.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-171_175.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-176_180.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-181_185.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-186_190.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-191_195.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-201_205.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-206_210.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-211_215.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-216_220.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-221_225.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-226_230.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-231_235.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-236_240.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-241_245.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-246_250.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-251_255.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-256_260.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-261_265.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-266_270.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-271_275.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-276_280.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-281_285.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-286_290.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
se142c-488-291_292.drw	0	WIP	TYPE-C SIDE-B LOWER CHILL PLATE FLAT PATTERN
Leads terminal assembly, SE142C-050			
se142c-047.drw	0	WIP	TYPE-C JUMPERS BASE BLOCK
se142c-049.drw	0	WIP	TYPE-C JUMPERS INSULATOR
se142c-050.drw	0	WIP	TYPE-C LEADS TERMINAL ASSEMBLY
se142c-051.drw	0	WIP	TYPE-C TERMINAL JUMPER #1
se142c-052.drw	0	WIP	TYPE-C TERMINAL JUMPER #2
se142c-053.drw	0	WIP	TYPE-C TERMINAL JUMPER #3
se142c-054.drw	0	WIP	TYPE-C TERMINAL JUMPER #4

se142c-055.drw	0	WIP	TYPE-C SHORT TERMINAL LUG
se142c-056.drw	0	WIP	TYPE-C LONG TERMINAL LUG
se142c-057.drw	0	WIP	TYPE-C TERMINAL LUG CONNECTOR
se142c-058.drw	0	WIP	TYPE-C TERMINAL LUG CONNECTOR
se142c-059.drw	0	WIP	TYPE-C CABLE CONNECTOR
se142c-062.drw	0	WIP	WASHER .53 ID 1.25 OD X .06 THK
se142c-063.drw	0	WIP	FLAT WASHER
se142c-064.drw	0	WIP	1/2-13unc SCREW
se142c-065.drw	0	WIP	.53 ID .875 OD .06 THK FLAT WASHER
se142c-068.drw	0	WIP	INSULATING WASHER
se142c-069.drw	0	WIP	INSULATING SLEEVE
Lead blocks enclosure, SE142C-233			
se142c-226.drw	0	WIP	LEAD BLOCKS WEDGE, SIDE-B
se142c-227.drw	0	WIP	LEAD BLOCKS WEDGE, SIDE-A
se142c-183.drw	0	WIP	LEAD BLOCKS CHILL PLATE, SIDE-A
se142c-241.drw	0	WIP	LEAD BLOCKS CHILL PLATE, SIDE-B
se142c-201.drw	0	WIP	LEAD BLOCKS SUPP COOLING TUBE, SIDE-A
se142c-202.drw	0	WIP	LEAD BLOCKS SUPP COOLING TUBE, SIDE-A
se142c-220.drw	0	WIP	LEAD BLOCKS SIDE PLATE, SIDE-A
se142c-221.drw	0	WIP	LEAD BLOCKS SIDE PLATE, SIDE-B
se142c-184.drw	0	WIP	LEAD BLOCKS TOP PLATE
Clamp assembly, SE1405-275P			
se1405-258p.drw	1	04/04/05	WASHER, BELLEVILLE
se1405-261p.drw	1	04/04/05	SCREW, SET, 15/16-20 UNEF-2A X 3/8
se1405-263p.drw	1	04/04/05	WASHER, SPERICAL, CONVEX
se1405-267.drw	0	04/04/05	TRC CLAMP PAD
se1405-272.drw	0	04/04/05	CLAMP SWIVEL STUD
se1405-273.drw	0	04/04/05	CLAMP SWIVEL PAD
se1405-274.drw	0	04/04/05	TRC FLAT WASHER 3/4 OD
se1405-275p.drw	0	04/04/05	CLAMP ASSEMBLY, SHORT
se1405-276.drw	1	04/04/05	BAR, CLAMP, HORIZONTAL
se1405-277.drw	0	04/04/05	PISTON, SPHERICAL, CONCAVE
se1405-278.drw	0	04/04/05	CLAMP BUSHING

### 3 REQUIREMENTS

#### 3.1 Definition

The modular coil Type-C assembly includes the winding form, conductor and insulation, leads and termination, cooling system, instrumentation, vacuum-pressure epoxy impregnation (VPI) features, and the coil clamps. Figure 1 shows the main subcomponents of the coil assembly:

Winding form – a cast, stainless steel structure with a machined “tee” profile

Cladding – inner layer of copper that cools the winding pack by conduction

Ground insulation – multiple layers of glass cloth surrounding the winding pack

Conductor – stranded copper wire with a compacted, rectangular cross-section

Turn insulation – pre-wrapped layers of glass around each conductor

Lead blocks – insulated supports for conductor entry/exit from winding pack

Terminal blocks – electrical connection to coax power feed

Chill Plates – outer layer of copper and tubes for LN2 cooling

Bag mold – silicone and fiberglass shell that surrounds winding pack

Clamps – support that provides clamping force, preload on winding pack

Instrumentation – strain gages, thermocouples, and voltage taps

Magnetic diagnostics – two wires co-wound on the plasma side of winding pack

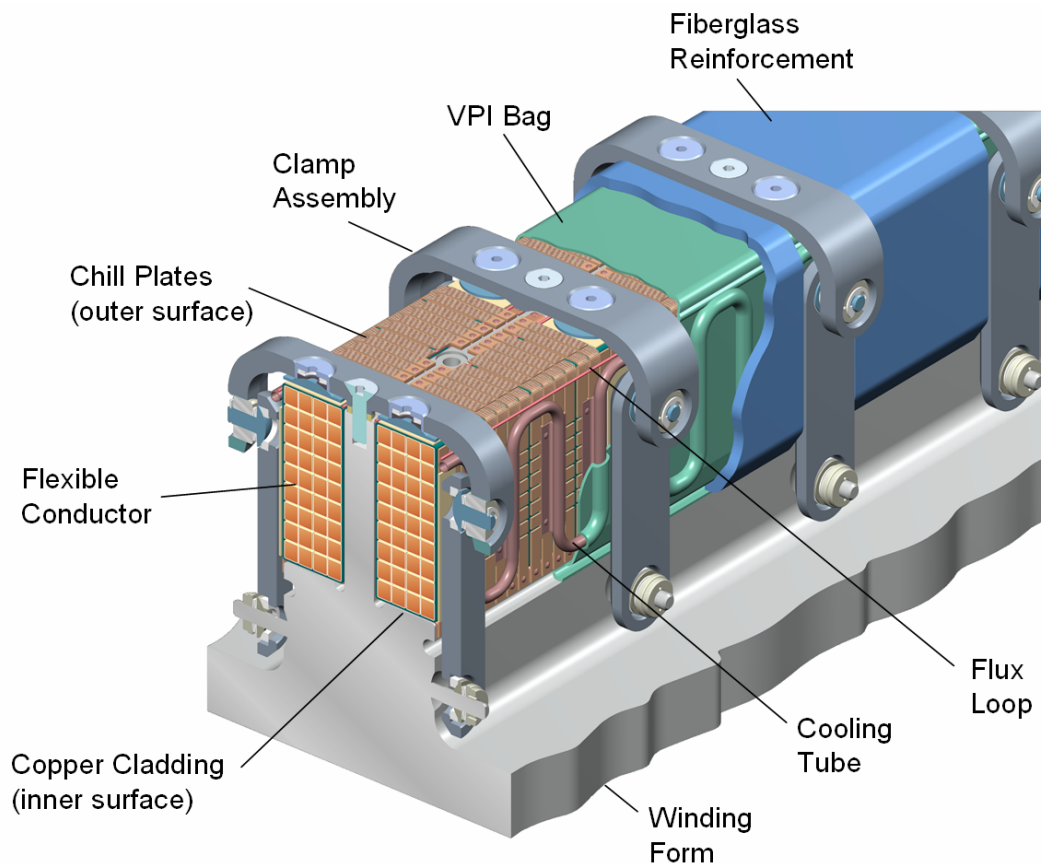


Figure 3-1 – Typical Modular Coil Cross-Section

## **3.2 Characteristics**

Each of the modular coil Type-C assembly subcomponents has performance or physical characteristics that are necessary for proper function of the coil and should be verified prior to or during assembly.

### **3.2.1 Winding Form Assembly**

#### **3.2.1.1 Material**

The winding form material is a cast, stainless steel alloy, similar to CF8M. Poloidal break insulators are composed of NEMA Grade G-11CR laminate.

#### **3.2.1.2 Size and Weight**

The bounding dimensions of the winding form assembly is 45 x 77 x 95-in and the weight is approximately 6100-lbs.

#### **3.2.1.3 Magnetic Permeability**

The relative magnetic permeability of the winding form shall not exceed 1.02.

#### **3.2.1.4 Electrical Requirements**

The resistance of the mid-plane insulation and of the bolt insulation shall be >500 kohms when tested at 100 VDC .

#### **3.2.1.5 Winding Surface Tolerance**

The dimensions of the “tee” section of the winding form are illustrated in Figure 3-2. The winding surface has a profile tolerance of +/- .010-in to the theoretical CAD surface.

#### **3.2.1.6 Surface finish**

All winding surfaces shall have a surface finish <125-u in.

#### **3.2.1.7 Winding Clamp Modifications**

Threaded studs shall be attached to the winding form by welding, as specified in drawing se141-123.drw.

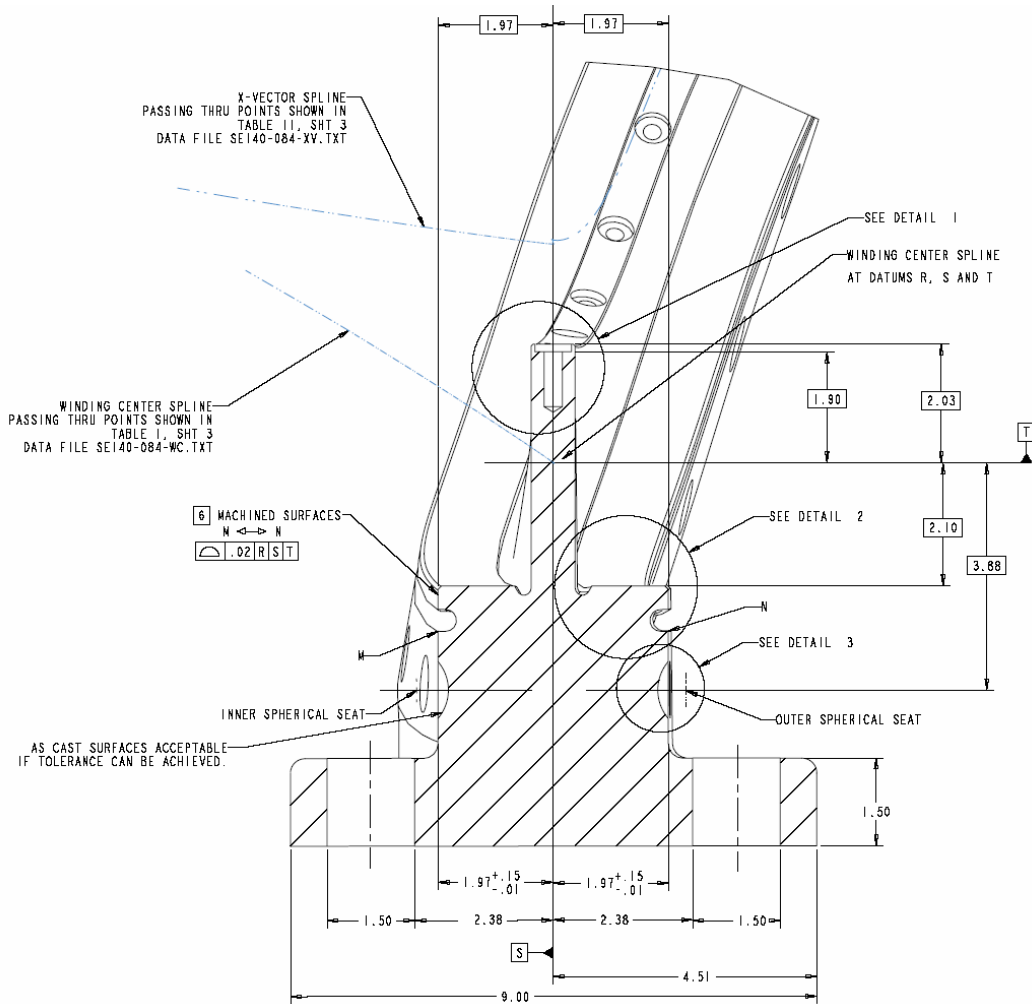


Figure 3-2 – Winding Surface Dimensions and Tolerances (se141-116.drw)

### 3.2.2 Inner Copper Cladding

#### 3.2.2.1 Material

The cladding material is 0.040-in thick copper sheet, UNS No. C10200, with high thermal conductivity and a temper suitable for forming. Annealed condition is acceptable.

#### 3.2.2.2 Quantity, Size, and Weight

There are 384 pieces of cladding, with average dimensions of 1.5 x 4-in. and a total weight of ~30-lbs.

#### 3.2.2.3 Sliding Fit

The cladding shall conform to the winding surface but not be permanently bonded or attached to it. The cladding may be temporarily secured to the winding form during the winding process.



#### **3.2.2.4 Electrical Requirements**

The cladding shall be electrically isolated from the winding form by a half-lapped layer of 0.0035-in thick Kapton tape.

### **3.2.3 Ground Insulation**

#### **3.2.3.1 Material**

The ground insulation is composed of S2 glass and adhesive Kapton.

#### **3.2.3.2 Quantity, Size, and Weight**

The total thickness of 0.0445-in is composed of three layers: 1) a butt-lapped layer of 0.007-in S2 glass, 2) a half-lapped layer consisting of 2-in wide x 0.007-in S2 glass and 1.5-in wide x 0.0065-in adhesive Kapton tape, and 3) a butt-lapped layer of the same composite

### **3.2.4 Conductor and Turn Insulation**

#### **3.2.4.1 Material**

The conductor material is 34-AWG CDA-101 copper wire, and the turn insulation is S-2 glass cloth with S920 Silane finish.

#### **3.2.4.2 Size and Weight**

The nominal size of the conductor with insulation is .374 x .415-in, and the weight is approximately 410-lbs per 1000-ft.

#### **3.2.4.3 Conductor Length**

The total length of conductor for the Type-C coil assembly is ~8 x 220-ft.

#### **3.2.4.4 Electrical Properties**

The resistance of the conductor shall be less than 0.089- $\Omega$  per 1000-ft when measured at room temperature.

#### **3.2.4.5 Current Center**

The wound coil shall have a current center that is within 1.5-mm of the theoretical position.

### **3.2.5 Supplemental Turn Insulation at Leads**

#### **3.2.5.1 Material**

S2 glass and interleaved Kapton with adhesive backing.

#### **3.2.5.2 Size and Weight**

The total thickness of 0.041-in is composed of two half-lapped layers consisting of 1-in wide x 0.007-in S2 glass and 0.75-in wide x 0.0065-in adhesive Kapton tape.

### **3.2.6 Lead Blocks**

#### **3.2.6.1 Material**

The lead blocks are constructed of an insulating material such as NEMA grade G-11CR epoxy laminate.

#### **3.2.6.2 Quantity, Size and Weight**

There are two lead blocks per side, the largest of which is 1.8 x 6.8 x 11-in in size. The total weight of the lead blocks is ~10-lbs.

#### **3.2.6.3 Surface Finish**

The lead blocks shall be free of burrs and sharp edges that can damage the conductor. All surfaces unless machined shall be sanded to remove any high gloss surface, to promote bonding of the epoxy to the lead blocks.

### **3.2.7 Terminal Blocks and Insulators**

#### **3.2.7.1 Material**

The terminal material is copper, UNS No. C10200, with interleaved insulation composed of NEMA Grade G-11CR epoxy laminate.

#### **3.2.7.2 Quantity, Size, and Weight**

There are four jumpers per coil, with average dimensions of 1.5 x 4.5 x 5.5-in and a weight of ~0.5-lb each.

#### **3.2.7.3 Surface Finish**

The terminal blocks and insulators shall be free of burrs and sharp edges that can damage the conductor.

#### **3.2.7.4 Bolted Connections**

Each conductor is attached to the terminal blocks through a bolted electrical connection.

### **3.2.8 Chill Plates**

#### **3.2.8.1 Material**

The cladding material is 0.040-in thick copper sheet, UNS No. C10200, with high thermal conductivity and a temper suitable for forming. Annealed condition is acceptable.

#### **3.2.8.2 Quantity, Size, and Weight**

There are 384+ chill plate parts, with average dimensions of 1.5 x 4 x 4-in. and a total weight of ~30-lbs.

#### **3.2.8.3 Electrical Properties**

The chill plates shall be electrically isolated from both the winding form and the cladding assembly.

### **3.2.9 Coolant Tubes**

#### **3.2.9.1 Material**

The tubing material is UNS C10200, with dimensions 0.25-in dia x 0.030-in wall per ASTM B280-03.

#### **3.2.9.2 Quantity, Size, and Weight**

There are 8 tube segments per coil, with a maximum length of 15-ft.

### **3.2.10 VPI Bag Mold**

#### **3.2.10.1 Material**

The bag mold is composed of self-fusing gray silicone tape, 2-part RTV-11 (white), Nomex felt (Stock No. NX08-6), and Hysol resin/hardener (Part 3561/2039).

#### **3.2.10.2 Quantity, Size and Weight**

[2] layers of silicone tape/ painted with RTV-11/ overwrapped with [2] layers of Nomex felt filled with Hysol epoxy formulation.

### **3.2.11 Clamp Assembly**

#### **3.2.11.1 Material**

All clamp components are to be constructed of a non-magnetic stainless steel, such as alloy UNS S31600.

#### **3.2.11.2 Quantity, Size and Weight**

There are 48 permanent clamps in the coil assembly.

### **3.2.12 Instrumentation -*revise***

#### **3.2.12.1 Strain gages**

##### **3.2.12.1.1 Material**

Fiber optic strain gage

##### **3.2.12.1.2 Quantity, Size, and Weight**

Minimum of 8 strain gages

##### **3.2.12.1.3 Location**

Three each at each end of the coil, located at the tip of the tee web and the inside/outside surface of the tee base. Two additional strain gages to be located near and opposite the coil leads.

**3.2.12.2 Thermocouples**

**3.2.12.2.1 Material**

Type E Chromel/Constantan, 0.010-in diameter.

**3.2.12.2.2 Quantity, Size, and Weight**

Minimum of six thermocouples.

**3.2.12.2.3 Location**

Within a coil plane, opposite the leads region, thermocouples shall be located in the middle of each winding pack and spaced vertically between the layers.

**3.2.12.3 Flux loops**

**3.2.12.3.1 Material**

The flux loops are composed of 0.030-in diameter mineral insulated wire with shrink tubing for insulation.

**3.2.12.3.2 Quantity, Size, and Weight**

Four loops are required, each with a length of approximately 15-ft.

**3.2.12.3.3 Location**

Wires shall be located at the inner and outer corner, plasma side of each winding pack.

**3.2.12.3.4 Termination**

Wires shall be routed along the lead block to the base of the winding form.

**4 QUALITY ASSURANCE**

**4.1 Inspection and Test Requirements**

Inspections and tests shall be performed in accordance with approved procedures referencing criteria for acceptance for rejection. The following table describes the actions to be taken in order to verify the requirements listed in Section 3:

<b>Requirement</b>	<b>Description</b>	<b>Verification</b>	<b>Remarks</b>
3.2.1 Winding Form Assembly			
3.2.1.1	Materials	Vendor supplied certification	
3.2.1.2	Size and weight	Inspection	Note weight of winding form and finished coil.
3.2.1.3	Magnetic permeability	Test	Spot check of vendor tests.
3.2.1.4	Electrical requirements	Test	Check resistance of poloidal break.

3.2.1.5	Winding surface tolerance	Inspection	Perform initial dimensional inspection of winding form.
3.2.1.6	Surface finish	Inspection	
3.2.1.7	Winding form modifications	Inspection	Verify proper alignment re winding law.
3.2.2 Inner Copper Cladding			
3.2.2.1	Material	Supplier certification	
3.2.2.2	Quantity, size, and weight	Inspection	Verify flat patterns per asm drawing.
3.2.2.3	Sliding fit	Inspection	Remove burrs and sharp edges.
3.2.2.4	Electrical requirements	Test	Check resistance between cladding and winding form.
3.2.3 Ground Insulation			
3.2.3.1	Material	Supplier certification	
3.2.3.2	Size and weight		
3.2.4 Conductor and Insulation			
3.2.4.1	Material	Supplier certification	
3.2.4.2	Size and weight	Inspection	Verify conductor dims while winding.
3.2.4.3	Conductor length	Inspection	
3.2.4.4	Electrical properties	Test	Perform continuity check.
3.2.4.5	Current center	Inspection	Perform regular dimensional inspections.
3.2.5 Supplemental Turn Insulation			
3.2.5.1	Material	Supplier certification	
3.2.5.2	Size and weight		
3.2.6 Lead Blocks			
3.2.6.1	Material	Supplier certification	
3.2.6.2	Quantity, size, and weight		

3.2.6.3	Surface finish	Inspection	Remove burrs and sharp edges.
3.2.7 Terminal Blocks			
3.2.7.1	Material	Supplier certification	
3.2.7.2	Quantity, size, and weight		
3.2.7.3	Surface finish	Inspection	Remove burrs and sharp edges.
3.2.7.4	Bolted connection	Test	Check resistance at connections.
3.2.8 Chill Plates			
3.2.8.1	Material	Supplier certification	
3.2.8.2	Quantity, size, and weight	Inspection	
3.2.8.3	Electrical properties	Test	Check resistance between chill plates, cladding, and winding form.
3.2.9 Coolant Tubes			
3.2.9.1	Material	Supplier certification	
3.2.9.2	Quantity, size, and weight		
3.2.10 VPI Bag Mold			
3.2.10.1	Material	Supplier certification	
3.2.10.2	Quantity, size, and weight		
3.2.11 Clamp Assembly			
3.2.11.1	Material	Supplier certification	
3.2.11.2	Quantity, size, and weight		
3.2.12 Instrumentation			
3.2.12.1 Strain gages			
3.2.12.1.1	Material	Supplier certification	
3.2.12.1.2	Quantity, size, and weight		
3.2.12.1.3	Location		
3.2.12.2 Thermocouples			
3.2.12.2.1	Material	Supplier certification	

3.2.12.2.2	Quantity, size, and weight		
3.2.12.2.3	Location		
3.2.12.3 Flux Loops			
3.2.12.3.1	Material	Supplier certification	
3.2.12.3.2	Quantity, size, and weight		
3.2.12.3.3	Location	Inspection	Note position of wire in cross-section.
3.2.12.3.4	Termination	Test	Check electrical continuity of termination.

## 4 DOCUMENTATION

### 5.1 System of Documentation

During coil assembly, the team shall maintain a system of documentation whereby objective evidence of materials used in construction and the functional compliance of the coil can be verified. Such documentation shall include process travelers and any certification, inspection, examination, test, and discrepancy reports that are required.