NCSX

Product Specification
For the
TF Coil Assembly

NCSX-CSPEC-131-01-00

31 January 2006

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Record of Revisions

Revision	Date	ECP	Description of Change

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1 SCOPE

The TF Coil Assemblies are a primary component of the NCSX Device. Eighteen equally spaced D shaped coil assemblies surround the core of the machine. The coil assemblies will be cooled with liquid nitrogen and operate in the temperature range of 77K – 95K. Each of these coil assemblies is comprised of a 12 turn coil wound using a solid copper conductor and then vacuum impregnated with glass insulation. Once cured a pair of stainless steel supports with a wedge shaped cross section is adhered on either side of each of the coils. This specification defines a TF Coil Assembly and the requirements for its fabrication.

2 APPLICABLE DOCUMENTS

NCSX-CSPEC-131-02, Product Specification for the TF Coil Conductor

NCSX-CSPEC-131-03, Product Specification for TF Coil Wedge Castings

NCSX-CSPEC-131-04, Product Specification for TF Coil Wedge Structure Weldment

Assembly Drawings as listed in Section 5

3 REQUIREMENTS

3.1 Item Definition

The Assembly consists of a D shaped coil with its front straight edge assembled to a pair of stainless steel supports and is illustrated in Figure 3-1 TF Coil Assembly. There are two versions of the TF Coil Assembly 131-003-01 and 131-003-02. The two versions are identical with the only exception being the TF coil lead orientation. Major components of the Assembly are listed below.

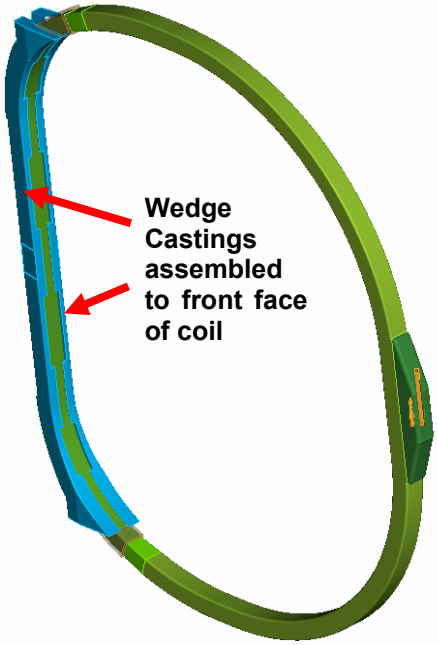

Figure 3-1 TF Coil Assembly

a. Wedge Supports. The product specification NCSX-CSPEC-131-03 or NCSX-CSPEC-131-04 defines the TF Coil Wedge Supports. The wedge support may be fabricated as a casting or as a

weldment. The specification NCSX-CSPEC-131-03 provides the casting requirements while the specification NCSX-CSPEC-131-04 provides the weldment requirements. The Wedge Supports will be supplied as part of the overall assembly.

b. Conductor. The conductor is a continuous length of extruded copper conductor with a center hole. The Product Specification NCSX-CSPEC-131-02 defines the TF Coil Conductor.

c. Ground Insulation. The ground insulation consists of fiberglass tape surrounding the winding pack.

d. Layer to Layer Insulation. The layer to layer insulation consists of first Kapton tape and then fiberglass tape wound around each of the 12 turns.

e. Lead Spurs. The lead spurs are thick machined copper blocks brazed to the ends of the copper conductor to provide lead connections to the TF Coil.

f. Insulating Lead Blocks. Lead blocks surround the lead spurs and provide mechanical support to the TF lead area.

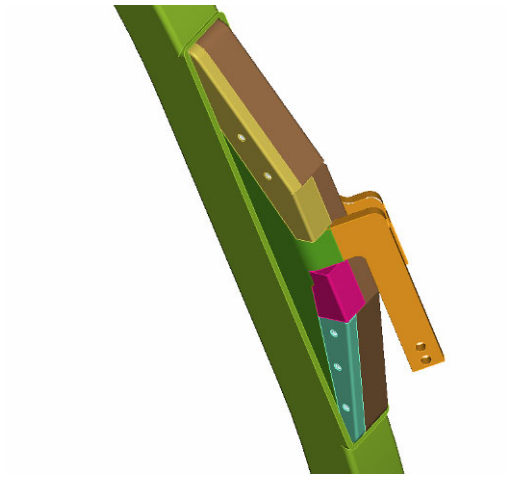

Figure 3-2 TF Joint Lead Area Isometric View

g. Co-wound Diagnostic Loops. Co-wound diagnostic loops are placed on the plasma facing side of each coil assembly. The coil leads are brought out in the vicinity of the lead area where mounting provisions are provided for strain relief.

3.2 Characteristics

3.2.1 Performance

3.2.1.1 Magnetic Permeability

The Assembly shall have a relative magnetic permeability less than 1.02 unless otherwise authorized by the Project.

3.2.1.2 Electrical Requirements

3.2.1.2.1 DC Resistance

The total coil resistance measured at room temperature (20ºC) shall be within 1/2% of 1198 micro ohms.

3.2.1.2.2 Voltage standoff, Terminal- to-ground

The Assembly shall provide the a standoff capability between the electrical circuit (conductor) and ground or any other component of 13.5 kV with leakage current not to exceed 1000 Mega Ohms.

3.2.1.2.3 Voltage Standoff, Turn-to-turn

The Assembly shall provide a voltage standoff capability between adjacent conductors or lead spurs adequate to withstand a peak terminal-to-terminal voltage of 750 V with a maximum of 10 micro amps of current leakage.

3.2.1.2.4 Electrical Isolation of Other Components

Electrical isolation for components of the coil assembly other than the conductor are listed below. Components which are isolated shall have a minimum resistance of 10 mega ohms at 1kV from all other components.

a. Wedge Supports are electrically isolated from all other components and each other.

b. Co-wound diagnostic loops. are electrically isolated from all other components by being placed within the ground wrap and by a Teflon sleeve.

3.2.1.3 Hydraulic Requirements

3.2.1.3.1 Leak Tightness

Completed coil assemblies shall be free of leaks when tested with water at a pressure of 600 psi.

3.2.1.3.2 Flow Characteristics

Completed coil assemblies shall be free of obstructions in the coolant channels when tested with water. The water flow rate shall exceed 11.8 liters per minutes with a pressure drop from inlet-to-outlet of 100 psi.

3.2.2 Physical Characteristics

3.2.2.1 Component Characteristics

3.2.2.1.1 Conductor

The Product Specification NCSX-CSPEC-131-02 defines the TF Coil Conductor.

3.2.2.1.2 Lead Spurs

The Lead Spur material is, UNS C10400, UNS C10500, or UNC C10700 oxygen free silver bearing copper 1/8 Hard with a minimum Rockwell Hardness F of 60. The lead spurs are defined by drawings SE131-057, SE131-058, SE131-088, and SE131-089.

3.2.2.1.3 Brazed Joints

a. Braze material. Sil-Fos braze material, a product of Handy & Harmon, shall be used for all braze joints. No flux shall be used with the Sil-Fos material.

- Composition: 15% Ag, 80% Cu, 5% P
- Melting Point: 1185° F (640° C)

- Brazing Temperature Range: 1300F-1500F (704° C-816° C)

b. Braze technique. Induction brazing is required for all joints (except coolant fittings).

c. Brazed Joints are to maintain a Rockwell hardness F of greater than 55.

d. Braze material certification. Certification of the Sil-Fos braze material shall be in accordance with AWS A5.8-2004, Classification BCuP-5.

3.2.2.1.4 Turn-to-turn Insulation

Turn-to-turn insulation is composed of adhesive Kapton tape wound directly against the conductor, with S2 glass applied to build the insulation to the required thickness. The Kapton tape is one inch wide with a total thickness of .0035 inches (.002 inches Kapton and .0015 inches adhesive). The Kapton tape is to be applied in one half lap layer with the adhesive layer face down. The nominal build of the Kapton tape is .007 inches.

One inch wide by .007 inch thick S2 glass completes the turn-to-turn insulation build up. The S2 glass is applied in three half lap layers. The nominal build of the S2 glass layers is .042 inches bringing the total build of the turn-to-turn insulation to.049 inches.

The glass and tape thicknesses and width may be adjusted to reach the required overall thickness and to facilitate manufacturing requirements with the approval of PPPL. Any changes in the turn-to-turn insulation build up must still meet the TF electrical standoff requirements in Sections 3.2.1.2.2 and 3.2.1.2.3.

3.2.2.1.5 Ground Insulation

The ground insulation is composed of .015 inch thick by two inch wide S2 glass. The S2 glass is applied in half lap layers to bring the total build of the turn-to-turn insulation to .125 inches at the front leg of the coil and .375 inches around the top, bottom, and back leg of the coil (ref. Drawing. SE131-003). The number of layers of the ground wrap insulation shall be determined by measurement and adjusted to achieve a sum total of 10% compression for both the ground wrap and turn to turn glass insulation. The number of layers of glass used shall be approved by PPPL prior to fabrication.

The completed ground wrapped assembly is to be vacuum impregnated using CTD 101K epoxy. The number of layers of ground insulation is to be optimized so that the compression of the coil in the VPI mold minimizes resin rich areas. To eliminate resin rich areas, voids in the corners of the VPI mold are to be eliminated with the use of radiused fillers..

3.2.2.1.6 Insulation for Lead Spurs

The Lead Spur insulation is custom wound Kapton and S2 glass. Where the lead spur is flush with the winding pack the lead spur insulation as a minimum must have the same build up as the turn-to-turn insulation including one half lap layer of Kapton (Ref. 3.2.2.1.2) and a minimum of .125 inch build up of S2 glass ground insulation. Where the lead spur exits the winding pack the exposed copper must have a minimum of two uninterrupted layers of 3.5 mil Kapton tape (achieved for example by two half lap layers) with a minimum of an additional 1/8 inch of S2 glass. The glass and tape thicknesses may be adjusted to reach the required overall thickness and to facilitate manufacturing requirements with the approval of the PPPL. Any changes in lead spur insulation build up must meet the TF electrical standoff requirements in Sections 3.2.1.2.2 and 3.2.1.2.3.

3.2.2.1.7 Insulating Lead Blocks

a. Material. The insulating lead blocks shall be constructed of NEMA grade G-11CR epoxy laminate.

b. Workmanship. The lead blocks shall be free of burrs and sharp edges that can damage the conductor. Any voids in the lead area must be filled with supplied glass material to facilitate complete impregnation.

c. Surface preparation. All surfaces unless machined shall be sanded to remove any high gloss surface, to promote bonding of the epoxy to the lead blocks.

3.2.2.1.8 Co-wound Diagnostic Loops

a. Loop location. Magnetic loops will be incorporated into the Assembly. There shall be one loop per winding pack located outside the primary ground insulation at the center of the inner diameter of the coil. The loop shall be applied to the coil under the last layer of ground wrap. The location of the installed loops shall be measured prior to vacuum pressure impregnation.

b. Loop material. The loops shall be composed of 0.032-in diameter mineral insulated wire with a Teflon shrink sleeve to provide electrical isolation. The overall diameter with the insulated shrink sleeving shall be .047 inches.

c. Loop termination. From where the two ends of each loop leave the inner diameter of the winding pack, they shall be twisted together and routed around the edge of the lead spur area (still under one layer of glass) and exit the insulation between the two mounting holes provided (see drawing SE131-005)

3.3 Design and Construction

3.3.1 Materials, Processes, and Parts

3.3.1.1 Production Drawings

The Assembly shall be fabricated in accordance with the models and drawings listed in Section 5.1.

3.3.1.2 Metrology

Inspections reports for measurements taken to verify the location of the current centroid within the wedge structure as specified on drawing SE131-003 shall be reported as a minimum for the five locations along the straight front face of the wedge as specified on the same drawing. The inspection measurements for the vertical location of the wedge structure with respect to the coil center line shall also be reported.

3.3.2 Labels

The Assembly shall have a permanent label with the following minimum information – NCSX TF Coil Assembly, P/N SE131-003, the serial number of the item (S/N 1 thru 18), the manufacturer of the item, the date of manufacture (month and year) and the weight of the item (in lbs). The label shall be located within 12 inches of the leads on the outer edge (same side as the leads).

3.3.3 Workmanship

During Assembly fabrication and finishing, particular attention shall be given to freedom from blemishes, defects, burrs, and sharp edges; accuracy of dimensioning radii of weld fillets; making of parts; thoroughness of cleaning; quality of brazing, welding,; alignment of parts; and tightness and torquing of fasteners.

4 QUALITY ASSURANCE PROVISIONS

4.1 General

The vendor has sole responsibility for inspection and testing of all TF coil assemblies.

4.2 Verification

4.2.1 Performance Verification

4.2.1.1 Magnetic Permeability

The relative magnetic permeability of each TF coil assembly shall be measured to verify compliance with Section 3.2.1.1

4.2.1.2 Electrical Requirement Verification

4.2.1.2.1 Verification of DC Resistance

The total coil resistance shall be measured at room temperature (20ºC) in order to verify compliance with Section 3.2.1.2.1. This test shall be performed:

- Prior to ground wrapping the coil
- After Coil VPI but before adhesion of the wedge castings
- Final test after adhesion of wedge castings
- For the first article two additional tests are required, one at LN2 temperatures and one more after warming to room temperature

4.2.1.2.2 Verification of Terminal-to-ground Voltage Standoff

Each TF coil assembly shall be megger tested at room temperature (20ºC) to 13.5 kV during acceptance testing to verify compliance with Section 3.2.1.2.2. . This test shall be performed:

- Prior to ground wrapping the coil at 1kV instead of 13.5kV
- After Coil VPI but before adhesion of the wedge castings
- Final test after adhesion of wedge castings
- For the first article two additional tests are required, one at LN2 temperatures and one more after warming to room temperature

4.2.1.2.3 Verification of Turn-to-turn Voltage Standoff

Each TF coil assembly shall be tested by inductively applying an AC (open circuit) terminal voltage of 750V and measuring the conductor current to verify that the circulating current in the coil less than 10 micro amps in order to verify compliance with 3.2.1.2.3. In addition the inductance of each coil is to be measured and recorded. This test shall be performed:

- Prior to ground wrapping the coil
- After Coil VPI but before adhesion of the wedge castings
- Final test after adhesion of wedge castings
- For the first article two additional tests are required, one at LN2 temperatures and one more after warming to room temperature.

4.2.1.2.4 Verification of Electrical Isolation of Other Components

Electrical isolation of the wedge supports and co-wound diagnostic loops shall be tested to verify compliance with Section 3.2.1.2.4. This test shall be performed:

- After Coil VPI but before adhesion of the wedge castings for the diagnostic loop
- Final test after adhesion of wedge castings
- For the first article two additional tests are required, one at LN2 temperatures and one more after warming to room temperature.

4.2.1.3 Verification of Hydraulic Requirements

4.2.1.3.1 Verification of Leak Tightness

Completed coil assemblies shall be hydrostatically tested at 600 psi, using potable water in order to verify compliance with Section 3.2.1.3.1. The hydrostatic pressure shall be 600 psi for 10 minutes with no drop in pressure after the system has been isolated from the pressure supply. The pressure vs. time data is to be recorded periodically during the test. Accuracy shall be within 2 psi, with a range for the pressure gauge sufficient so that 600 psi is in the center. The test is then to be repeated with the pressure held for a minimum of one hour with a loss in pressure of not more than 10 psi. The water shall be completely blown out of the coil after testing.

4.2.1.3.2 Verification of Flow Characteristics

Completed coil assemblies shall be tested for flow vs. pressure to verify that the cooling channel is clear and complies with Section 3.2.1.3.2. The pressure is to be measured directly at the inlet to the coil as well as at the coil outlet using calibrated pressure gauges. If the water is discharged to the room, the outlet pressure measurement is not required. The flow rate measurement may be made with a flow meter or by flowing water into a unit volume and timing it with a stop watch. This test shall be performed using potable water. Purge the system for 2 minutes before beginning the test to ensure all of the air is removed. Record inlet pressure, outlet pressure, and flow for each coil. Completely drain water from the coil at completion of the test.\

4.2.2 Verification of Physical Characteristics

4.2.2.1 Verification of Component Characteristics

4.2.2.1.1 Verification of Conductor

Rockwell hardness measurements shall be taken to verify compliance with paragraph 3.2.2.1.1 immediately prior to winding coil.

4.2.2.1.2 Verification of Lead Spurs Properties

Rockwell hardness measurements shall be taken to verify compliance with paragraph 3.2.2.1.2 after brazing lead spur onto conductor.

4.2.2.1.3 Verification of Brazed Joints

Brazing Alloy material certifications. shall be submitted as part of the documentation package. The supplier shall develop process details, helium leak test and pull test techniques, as well as a technician qualification program to be approved by PPPL. Rockwell hardness measurements shall be taken to verify compliance with paragraph 3.2.2.1.3 after brazing.

4.2.2.1.4 Verification Turn to Turn Insulation

Measurements and parameters such as the insulation build thickness are to be recorded in the winding procedure for each coil to verify compliance with paragraph 3.2.2.1.4

4.2.2.1.5 Verification of Ground Insulation Parameters

Measurements and parameters such as the number of layers are to be recorded in the winding procedure for each coil to verify compliance with paragraph 3.2.2.1.5

4.2.2.1.6 Verification of Insulation for Lead Spurs

Measurements and parameters such as insulation thickness are to be recorded in the fabrication procedure for each coil to verify compliance with paragraph 3.2.2.1.6

4.2.2.1.7 Verification of Lead Block Properties

Lead blocks are to be inspected for sharp edges. The lead area is to be inspected to verify no resin rich areas. Lead blocks are to be inspected to verify roughened surfaces prior to installation.

4.2.2.1.8 Verification of Diagnostic Loop Installation

The location of the installed loops shall be measured prior to vacuum pressure impregnation. The routing of the wire shall be verified per the requirements of 3.2.2.1.8 The measurements shall be documented and approved PPPL. The Teflon sleeving of the loop shall be inspected for cracks or tears. The ends of the wire are to be inspected to be certain they are properly protected prior to vacuum impregnation

5 APPENDICES

5.1 Assembly Models and Drawings

Drawing Reference	Type	Description
se131-003.asm	Assembly	TF COIL ASSEMBLY
se131-005.asm	Assembly	TF COIL ASSEMBLY GROUND WRAPPED
se131-013.prt	Part	TF COIL COOLANT TUBE FITTING DETAIL
se131-014.prt	Part	TF COIL CONDUCTOR DETAIL
se131-031.prt	Part	TF COIL TRANSITION FILLER CENTER
se131-032.prt	Part	TF COIL TRANSITION FILLER LEFT/RIGHT
se131-035.asm	Assembly	TF COIL ASSEMBLY (NO GROUNDWRAP)
se131-041.prt	Part	LEAD FILLER
se131-047.prt	Part	TF COIL LEAD BLOCK SUPPORT
se131-053.prt	Part	TF COIL LEAD LONG RIGHT (BENT)
se131-054.prt	Part	TF COIL LEAD SHORT RIGHT(BENT)
se131-057.prt	Part	TF COIL LEAD LONG LEFT(BENT)
se131-058.prt	Part	TF COIL LEAD SHORT LEFT(BENT)
se131-078.prt	Part	LEAD SUPPORT LOCKING BLOCK TYPE "A"
se131-079.prt	Part	LEAD SUPPORT BLOCK LOCKING
se131-084.prt	Part	LEAD SUPPORT BLOCK LOCKING
se131-085.prt	Part	TF COIL WEDGE STRUCTURE DETAIL
se131-087.prt	Part	SPACER FILLER BLOCK
se131-081.prt	Part	TF COIL LEAD LONG RIGHT (UNBENT)
se131-082.prt	Part	TF COIL LEAD SHORT RIGHT (UNBENT)
se131-088.prt	Part	TF COIL LEAD LONG LEFT (UNBENT)
se131-089.prt	Part	TF COIL LEAD SHORT LEFT (UNBENT)
se131-091.prt	Part	TF COIL LAYER CENTER TRANSITION FILLER