

**NCSX
Specification**

PF Coil Conductor Specification

NCSX-CSPEC-132-04-00

January 17, 2008

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Record of Revisions

Revision	Date	Description of Changes
Rev. 0		Initial issue

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1 SCOPE

The National Compact Stellarator Experiment (NCSX) is an experimental research facility that is to be constructed at the Department of Energy's Princeton Plasma Physics Laboratory (PPPL). Its mission is to acquire the physics knowledge needed to evaluate compact stellarators as a fusion concept, and to advance the understanding of three-dimensional plasma physics for fusion and basic science.

The Poloidal Field (PF) Coils are primary components of the NCSX Device. The PF coil system consists of an assembly of solenoid coils and three pairs of ring coils. Each of the ring coils is wound using a solid copper conductor with an extruded central hole for liquid nitrogen cooling. This specification applies to the copper conductor for the three pairs of ring coils and establishes the manufacturing and acceptance requirements for them. It defines the alloy, form, quantity and integrity of the hollow extruded copper conductor. To minimize the risk of coil failure, strict adherence to these specifications is essential.

2 APPLICABLE DOCUMENTS

SE132-010	PF Coil Conductor Detail [PF-4, PF-5 and PF-6]
ASTM B187-03	Standard Specification for Copper, Bus Bar, Rod, and Shapes
ASTM B193-02	Standard Test Method for Resistivity of Electrical Conductor Materials
ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E18	Standard Test Methods for Rockwell Hardness of Metallic Materials

3 REQUIREMENTS

3.1 Item Definition

The item is a continuous length of extruded copper conductor with a center hole wound into a pancake spool.

3.2 Design and Construction

3.2.1 Conductor Geometry

3.2.1.1 Conductor Height and Width

The conductor height and width shall conform to the PF Coil Conductor Detail SE132-010

3.2.1.2 Conductor Length

Each individual spool shall be wound in a continuous length with no splices. The conductor shall be a minimum of 110 ft long and a maximum of 120 ft long.

3.2.1.3 Conductor Hole

The conductor shall be extruded with a continuous hole centered on the conductor cross section. Dimensions and tolerances are specified in PF Coil Conductor Detail SE132-010

3.2.2 Conductor Characteristics

All specified material properties are at room temperature

3.2.2.1 Copper Grade

The copper shall conform to ASTM B187 UNS#C10700 except that the copper is cold drawn to produce the required yield strength, tensile strength, and hardness specified in paragraphs 3.2.2.2, 3.2.2.3, and 3.2.2.4.

3.2.2.2 Yield Strength

Yield Strength shall be 26,000 psi min. to 30,000 psi max. (0.5% extension under load) at room temperature

3.2.2.3 Tensile Strength

Ultimate Tensile Strength shall be 36,000 psi min. to 42,000 psi max., with a minimum elongation of 25% at room temperature

3.2.2.4 Hardness

The conductor shall have a Rockwell Hardness F between 60 and 65 at room temperature. If there is a discrepancy between the Hardness requirement and the Yield Strength requirement the Yield Strength measurement shall be the governing requirement.

3.2.2.5 Conductor Resistance

The conductor resistance shall be 15.6 micro ohms +/- 3% per foot of conductor at room temperature.

3.2.2.6 Conductor Weight

The weight of the raw conductor shall be approximately 201.5 pounds per 100 feet [Reference].

3.2.2.7 Conductor Integrity

The hole profile shall show neither re-entrant material or notches greater than 0.020 inch. Cracks, laps, fold, scale and any other discontinuity longer than 0.020 inch normal to the hole surface, shall not be visible when inspected at 100x magnification.

3.2.3 Standards of Manufacture

3.2.3.1 Cleanliness

The Subcontractor shall ensure that the finished conductor has been thoroughly cleaned with a solvent adequate for the removal of any trace amounts of lubricants that may have been used. The Subcontractor shall take the necessary precautions to ensure that the finished conductor is clean, free of any oils, or dirt related to processing or handling.

3.2.3.2 Best Practice Requirements

The finished material shall be free from blisters, slivers, laps, seams, cracks and scale, as well as from all other imperfections, such as damaged corners or edges, not consistent with best commercial practice

4 QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Responsibility for Inspection

The responsibility for performing all tests and verifications rests with the supplier. PPPL reserves the right to witness or separately perform all tests specified or otherwise inspect any or all tests and inspections. Methods used for inspection shall be proposed by Subcontractor and approved by PPPL

4.2 Quality Conformance Inspections

This section provides the conformance and inspection requirements for the items specified in Sections 3 and 5.

4.2.1 Verification of Conductor Geometry / Dimensions

4.2.1.1 Conductor Height and Width

The conductor width and height shall be measured to verify compliance with **Sections 3.2.1.1**. Six measurements shall be taken at the start of the conductor length, in the middle of the conductor length, and at the end of the conductor length. The six measurements at each of these locations shall be six inches apart. Measurements at the start and end of the conductor shall be at least 12 inches from terminus of the conductor. All measured values shall be recorded.

4.2.1.2 Conductor Length

The Subcontractor shall perform an in-process measurement of the conductor length to verify compliance with **Section 3.2.1.2**.

4.2.1.3 Conductor Hole

The ends of each conductor shall be checked to verify that the diameter of the cooling hole and the centering of the cooling hole is within the required tolerance as specified in **paragraph 3.2.1.3**.

4.2.2 Verification of Copper Grade

Material certifications showing actual chemical, mechanical, and electrical properties of the conductor shall be provided to verify compliance with **Section 3.2.2.1**.

4.2.3 Verification of Material Properties / Testing

All testing shall be performed at room temperature

4.2.3.1 Test Specimens

A minimum of 10% of the spools shall be selected to provide samples for testing i.e. for 70 spools seven sets of test samples are required. In addition there must be at least two sets of samples from a group of spools that came from any unique lot of billets. If there are fewer than twenty spools that were manufactured from a particular lot of material there must still be a minimum of two sets of test samples from that group of spools. A “set of test samples” refers to the group of test pieces required to provide the yield, tensile, and hardness testing.

4.2.3.2 Yield Testing

Specimens are to be tested to verify yield strength specified in **section 3.2.2.2 per test methods in ASTM E8**

4.2.3.3 Tensile Testing

Specimens are to be tested to verify tensile strength in **section 3.2.2.2 per test methods in ASTM E8**

4.2.3.4 Hardness Testing

A) The conductor shall be tested along its length every 10 ft to verify the hardness specified in **section 3.2.2.4 using test methods in ASTM E18**.

B) The test specimens used to test for yield and tensile strength shall be tested for hardness prior to being pulled so that a correlation between hardness and yield can be documented.

4.2.3.5 Resistance Testing

A resistance measurement shall be made to verify compliance **with Section 3.2.2.5 per ASTM B193-02**. The test method is to be reviewed and approved by PPPL prior to testing.

4.2.4 Verification of Conductor Weight

The weight of conductor for each spool shall be measured and recorded. (see **Section 3.2.2.6.**)

4.2.5 Conductor Integrity

Each conductor test specimen (see **section 4.2.3.1**) shall be examined at 100X magnification for compliance with **section 3.2.2.7**. Each spool of conductor is to be pressure tested and approved by PPPL

4.2.6 Cleanliness

The subcontractor shall provide certification, either separately or as part of other documentation, that the conductor has been cleaned in accordance with **section 3.2.3.1**

4.2.7 General Inspection

Each spool is to be inspected and the inspection documented before shipment to verify the final condition of the finished product meets the requirements stated in **section 3.2.3.2**.

4.2.8 Verification of Preparation for Shipping

The Subcontractor shall verify compliance with the requirements for conductor spooling (Section 5.1), conductor protection (**Section 5.2**), and crating (**Section 5.3**)

5 PREPARATION FOR DELIVERY

5.1 Conductor Spooling

The conductor will be wound into a single pancake layer. The inner diameter of the spool will be of a diameter between 36” and 38”. There will be only one continuous length of conductor per spool. The spools shall be independently restrained with non metallic bands or by other means so that when removed from the crate they can be handled without unwinding.

5.2 Conductor Protection

Each spool of conductor will be plastic wrapped to protect the conductor from moisture, dirt and foreign materials.

5.3 Crating

The spools shall be crated to protect the conductor from shock and weather conditions, including precipitation. The crate shall be built for handling with slings from overhead cranes, and transport by forklifts. Container must be approved by PPPL before shipping.