NCSX

Product Specification

Modular Coil Winding Forms

NCSX-CSPEC-141-03-00

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Prepared By: _____

P. Heitzenroeder, Technical Representative for Modular Coil (WBS 14) Procurements

Concurred By: _____

D. Williamson, WBS Manager for Modular Coils (WBS 14)

Concurred By: _____

B. Nelson, Project Engineer for Stellarator Core Systems (WBS 1)

Concurred By: _____

F. Malinowski, PPPL Procurement QA Representative

Approved by: _____

W. Reiersen, NCSX Engineering Manager

Record of Revisions

Revision	Date	Description of Changes
Rev. 0		Initial issue

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1 INTRODUCTION AND SCOPE

1.1 INTRODUCTION

Stellarators are a class of magnetic fusion confinement devices characterized by three dimensional magnetic fields and plasma shapes and are the best-developed class of magnetic fusion devices after the tokamak. The stellarator concept has greatly advanced since its invention by Dr. Lyman Spitzer, the founding director of the Princeton Plasma Physics Laboratory (PPPL), during the 1950's. A traditional stellarator uses only external magnetic fields to shape and confine the plasma. The National Compact Stellarator Experiment (NCSX) is the first of a new class of stellarators known as "compact stellarators." The differentiating feature of a compact stellarator is the use of plasma current in combination with external fields to accomplish shaping and confinement. This combination permits a more compact device. The NCSX project is managed by PPPL in partnership with the Oak Ridge National Laboratory. This Subcontract will be administered by PPPL. Operation of NCSX is scheduled to begin in July 2008.

The winding forms are austenitic (non-magnetic) stainless steel structures that are one of the most important components of the modular coils and the NCSX device. The winding forms perform two very important functions: (1) the conductors are wound on the winding forms, and are located in precise position by these forms; (2) the winding forms serve as their structural support during assembly and operation. There are three (3) distinct shapes of winding forms. Six (6) of each are required for a total of eighteen (18). The winding forms shall be manufactured by casting followed by machining. A machined winding form is illustrated in Figure 1-1. This figure is intended to be illustrative only and not to be used for manufacture; specific models and drawings shall provide the technical details needed for manufacturing.

Figure 1-1 Typical machined modular coil winding form

1.2 SCOPE

This specification establishes the manufacturing and acceptance requirements for the National Compact Stellarator Experiment (NCSX) Modular Coil Winding Forms. There are total of (18) winding forms: 3 each of Types A, B, and C.

2 APPLICABLE DOCUMENTS

2.1 CODES AND STANDARDS

2.1.1 American Society For Testing and Materials (ASTM) Documents 1

- A703/A703M-01 “Specification for Steel Castings”.
- A800/A800M-01 “Standard Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof”.
- A802/A802M–95 “Standard Practice for Steel Castings, Surface Acceptance Standards, Visual Examination”.
- A903/A903/M–99 “Standard Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle, and Liquid Penetrant Inspection”.

2.1.2 Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry, Inc. Documents 2

- MSS SP-54-2001: “Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components; Radiographic Inspection Method”.

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1 Publications are available from http://www.astm.org/cgi-bin/SoftCart.exe/index.shtml?E+mystore.

2 Publications are available from Manufacturers Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street, NE , Vienna, Virginia 22180 . Tel. (703)-281-6613.

3 REQUIREMENTS

3.1 ITEM DEFINITION

The items covered by this Specification are (6) each of Type A, Type B, and Type C winding forms. This includes the castings, all associated machining, all poloidal break hardware, and all associated processing, testing, quality control, documentation, packaging, and shipping.

3.2 CHARACTERISTICS

3.2.1 Performance

3.2.1.1 Chemical Composition of the Casting Alloy

The winding form is to be cast with the alloy developed and qualified by the subcontractor during their manufacturing development and prototype manufacture activity. The chemical composition shall be in accordance with Table 3-1. **(Note: Entries in the table will be replaced with the exact chemical composition for the successful offeror prior to the award of the subcontract).**

Table 3-1 Chemical constituents in casting alloy

	Min. %	Max. %
Carbon		
Manganese		
Silicon		
Phosphorus		
Sulfur		
Chromium		
Nickel		
Molybdenum		
Copper		
Iron	Balance	Balance

3.2.1.2 Mechanical Properties of the Casting Alloy

The winding form casting alloy shall meet the mechanical properties in Table 3-2.

Table 3-2 Mechanical Properties

Temperature	77K	293K
Elastic Modulus	200 GPa (29 Msi) min.	190 GPa (27.5 Msi) min.
0.2% Yield strength	360 MPa (52.2 ksi) min.	180 MPa (26.1 ksi) min.
Tensile strength	690 MPa (100.1 ksi) min.	360 MPa (52.2 ksi) min.
Elongation	30% min.	30% min.
Charpy V-notch Impact Resistance Load	27.1 J (20 ft-lb) min.	27.1 J (20 ft-lb) min.

3.2.1.3 Electrical Requirements for the Poloidal Electrical Break

3.2.1.3.1 Bolt Insulation

The resistance of the bolt insulation shall be >500 kohms when tested at 100 VDC. The poloidal joint mid-plane shall be electrically connected (jumpered) to the modular coil for this test. The insulation resistance shall be measured between it and each bolt.

3.2.1.3.2 Mid-Plane Insulation

The resistance of the mid-plane insulation shall be >500 kohms when tested at 100 VDC. All of the bolts shall be electrically connected (jumpered) together and connected to the modular coil winding form for this test. The insulation resistance between the electrically connected (jumpered) combination and the mid-plane shall be measured.

3.2.1.4 Surface Finish

All machined surfaces must have a RMS (root mean square) surface finish <125 μ-inches. Uniform "scallops" which exceed 125 μ-inches, which may result from some machining processes, may be acceptable, subject to PPPL approval. The finished part shall be free of sharp edges and burrs.

3.2.1.5 Relative Magnetic Permeability

The local relative magnetic permeability shall not exceed 1.02.

3.3 DESIGN AND CONSTRUCTION

3.3.1 Production Drawings

These items shall be fabricated in accordance with the models and drawings Pro/Engineer CAD files listed in Table 6-1. These file reside in a zip file (se-141-116p.zip) located at the production winding form ftp site (ftp://ftp.pppl.gov/pub/ncsx/manuf/producton_winding_form/).

3.3.2 Dimensions and Tolerances

Strict adherence to the dimensions defined in the production drawings listed in Section 3.3.1. All dimensions are for 20 C; actual measurements shall be temperature compensated for 20 C.

3.3.3 Standards of Manufacture

3.3.3.1 Heat Treatment

The castings shall be heat treated per PPPL-approved heat treatment procedures prior to final measurements of mechanical properties and relative magnetic permeability. Heat treatment records shall be prepared and maintained as defined in S21 of ASTM Spec. A703/A703M , and supplied to PPPL. Test specimens shall be heat treated together with the castings they represent per Supplementary Requirement S22 of ASTM Spec. A703/A703M.

3.3.3.2 Repairs

Unacceptable defects must be repaired. Repairs shall be considered major when the depth of the cavity prepared for welding exceeds 10% of the actual wall thickness or 1 inch, whichever is smaller, or when the extent of the cavity exceeds approximately 10 in2. Major repairs shall be welded and documented as defined in Sections S12 and S20 of ASTM Spec. A703/A703M. Non-conformance reports for major repairs (which include in the disposition the proposed corrective action) shall be prepared for each major weld repair and will be subject to the prior approval of PPPL. Weld preparation shall be per Section S10 of ASTM Spec. A703/A703M. Welding procedure qualification tests shall include evidence of compliance with the magnetic permeability requirements of Section 3.2.1.5.

4 QUALITY ASSURANCE PROVISIONS

4.1 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.

4.2 QUALITY CONFORMANCE INSPECTIONS

4.2.1 Verification of Chemical Composition

The material chemical composition shall be measured and provided for each casting for each heat used in the winding form.

4.2.2 Verification of Mechanical Properties of the Casting Alloy

4.2.2.1 Yield Strength and Elastic Modulus

The yield strength at 0.2% elongation and the elastic (Young's) modulus shall be verified for the cast stainless steel in the as heat-treated condition at room temperature and 77K shall be measured. Test specimen coupons shall be cast with each winding form and tested in accordance with ASTM A703/A703M-03, Paragraph 7 for each heat used in the winding form.

4.2.2.2 Ultimate Tensile Strength and Elongation

The ultimate tensile strength and elongation shall be verified for the cast stainless steel in the as heat-treated condition at room temperature and 77K shall be provided. Tensile test specimen coupons shall be cast with each winding form in accordance with ASTM A703/A703M-03, Paragraph 7 for each heat used in the winding form.

4.2.2.3 Charpy V-Notch Impact Resistance Load

The impact resistance of the casting alloy at room temperature and 77K shall be measured for each casting. Test specimen coupons shall be cast with each winding form in accordance with ASTM A703/A703M-03, Paragraph 7.

4.2.3 Verification of the Electrical Properties of the Poloidal Break

The insulation resistance of the bolt insulation electrical properties and the mid-plane electrical insulation resistance shall be measured for compliance with the requirements stated in Sections 3.2.1.3.1 and 3.2.1.3.2.

4.2.4 Verification of Surface Finish

All machined surfaces shall be inspected for compliance with surface finish requirements specified in Section 3.2.1.4. Either a surface profilometer or comparator can be used.

4.2.5 Verification of Relative Magnetic Permeability

All cast surfaces and features shall be checked with a calibrated Severn Permeability Indicator for compliance with Section 3.2.1.5. Flange faces and edges shall be checked at locations no greater than 4 inches apart and 2 inches apart at all weld repairs. The permeability of any weld repair excavations shall be checked at a minimum of 5 locations. Relative magnetic permeability measurements on all other surfaces shall be made at locations approximately 6 inches apart (to approximate a 6 inch x 6 inch grid). Relative magnetic permeability of any final machined casting that exceeds 1.02 must be documented on a nonconformance report and will require approval on a case-by-case basis. Permeability measurements shall be per Supplementary Requirements S24 of ASTM Spec. A703/A703M and S1 of ASTM A800/A800M, except that the results shall be expressed as relative permeability, □, rather than ferrite content (FN).

4.2.6 Verification of Dimensions and Tolerances

All cast surfaces and features shall be dimensionally checked to assure compliance with Section 3.3.2. The dimensional inspections shall be performed with measurements taken to approximate a 4” x 4” grid on the shell sections and a 2” x 2” grid on all machined sections.

4.2.7 Visual Inspection

All of the casting features shall be evaluated per ASTM A802/A802M (using graded reference comparators available from Castings Technology International3.) Level II with the exception that the surface texture in areas that will not be machined shall be evaluated in accordance with

ASTM A802/A802M, Level III . Treatment of unacceptable surface defects shall be performed per ASTM A703/A703M, Paragraph 10.1.

4.2.8 Liquid Penetrant Inspection

Each casting shall be examined for surface discontinuities using liquid penetrant inspection per Supplementary Requirement S6 of ASTM Spec. A703/A703M. Evaluation criteria shall be per ASTM A903/A903M Level II. Certified test reports are required per ASTM A903, Supplementary Requirement S1. Discontinuities not meeting the evaluation criteria shall be removed by grinding. Complete removal shall be verified by repeating the liquid penetrant inspection. Ground discontinuities which will be removed during the machining operations require no additional attention. Discontinuities which are/ will not be completely removed during machining operations must be repaired per 3.5.3.2, “Repairs”.

4.2.9 Inspection for Internal Defects

Each casting shall be examined for internal defects as defined in ASTM Spec.A703/A703M using radiographic inspection per Supplementary Requirement S5. Acceptance criteria shall be per MSS SP 54 for radiography.

5 PREPARATION FOR DELIVERY

5.1 MARKING

Each winding form shall have the supplier's name and a serial number (drawing number and a unique identifier) and the part weight engraved or stamped with characters ¼ inches high. The marking shall be located as shown in the part drawing.

5.2 CLEANING

The winding forms shall be degreased/cleaned using a solvent which must be able to dissolve grease, oils and other soils, and leave the casting residue free. No chips, burrs, oil, etc. shall remain in any of the tapped holes .

5.3 CRATING

The crate shall protect the winding form from shock and weather conditions, including precipitation. The crate shall be built for moving on rollers, handling with slings from overhead cranes, and transport by forklifts. The part shall be totally wrapped with a plastic protective film.

5.4 SHIPPING

Supplier is responsible arranging shipment, and for the safe arrival of each winding form at PPPL in Princeton, New Jersey, USA. Subcontractor’s name, shipper, purchase order number, contents and gross weight shall be marked on the shipping container.

6 ATTACHMENTS

6.1 TABLE OF MODELS AND DRAWINGS

Table 6-1 Production modular coil winding form models and drawings

Level	Next Assembly	BOM #	Doc / Part #	Type	Rev	Title / Description
1	SE140-101	2	SE141-101	ASM	-	Modular Coil Type-A Winding Form Assembly
1	SE140-101	2	SE141-101	DRW	0	Modular Coil Type-A Winding Form Assembly
1	SE140-101	2	SE141-101	PDF	-	Modular Coil Type-A Winding Form Assembly
1	SE140-101	2	SE141-101	STP	-	Modular Coil Type-A Winding Form Assembly
1	SE140-102	2	SE141-102	ASM	-	Modular Coil Type-B Winding Form Assembly
1	SE140-102	2	SE141-102	DRW	0	Modular Coil Type-B Winding Form Assembly
1	SE140-102	2	SE141-102	PDF	-	Modular Coil Type-B Winding Form Assembly
1	SE140-102	2	SE141-102	STP	-	Modular Coil Type-B Winding Form Assembly
1	SE140-103	2	SE141-103	ASM	-	Modular Coil Type-C Winding Form Assembly
1	SE140-103	2	SE141-103	DRW	0	Modular Coil Type-C Winding Form Assembly
1	SE140-103	2	SE141-103	PDF	-	Modular Coil Type-C Winding Form Assembly
1	SE140-103	2	SE141-103	STP	-	Modular Coil Type-C Winding Form Assembly
2	SE141-101	1	SE141-101_SKEL	PRT	-	Type-A Machining Features Layout
2	SE141-101	1	SE141-101_SKEL	STP	-	Type-A Machining Features Layout
2	SE141-101	2	SE141-114	PRT	-	Type-A Winding Form, 316L SS
2	SE141-101	2	SE141-114	DRW	0	Type-A Winding Form, 316L SS
2	SE141-101	2	SE141-114	PDF	-	Type-A Winding Form, 316L SS

Level	Next Assembly	BOM #	Doc / Part #	Type	Rev	Title / Description
2	SE141-101	2	SE141-114	STP	-	Type-A Winding Form, 316L SS
2	SE141-101	3	SE141-031	PRT	-	Type-A Poloidal Break Lower Insulator, G11CR
2	SE141-101	3	SE141-031	DRW	0	Type-A Poloidal Break Lower Insulator, G11CR
2	SE141-101	3	SE141-031	PDF	-	Type-A Poloidal Break Lower Insulator, G11CR
2	SE141-101	3	SE141-031	STP	-	Type-A Poloidal Break Lower Insulator, G11CR
2	SE141-101	4	SE141-033	PRT	-	Type-A Poloidal Break Shim, 316L SS
2	SE141-101	4	SE141-033	DRW	0	Type-A Poloidal Break Shim, 316L SS
2	SE141-101	4	SE141-033	PDF	-	Type-A Poloidal Break Shim, 316L SS
2	SE141-101	4	SE141-033	STP	-	Type-A Poloidal Break Shim, 316L SS
2	SE141-101	5	SE141-035	PRT	-	Type-A Poloidal Break Upper Insulator, G11CR
2	SE141-101	5	SE141-035	DRW	0	Type-A Poloidal Break Upper Insulator, G11CR
2	SE141-101	5	SE141-035	PDF	-	Type-A Poloidal Break Upper Insulator, G11CR
2	SE141-101	5	SE141-035	STP	-	Type-A Poloidal Break Upper Insulator, G11CR
2	SE141-101	6	SE141-114-WC	TXT	-	Type-A Winding Center Coordinates
2	SE141-101	7	SE141-114-XV	TXT	-	Type-A X-Vector Coordinates
2	SE141-101	8	SE141-114-SL	TXT	-	Type-A Spherical Seat Center Left Coordinates
2	SE141-101	9	SE141-114-SR	TXT	-	Type-A Spherical Seat Center Right Coordinates
2	SE141-102	1	SE141-102_SKEL	PRT	-	Type-B Machining Features Layout
2	SE141-102	1	SE141-102_SKEL	STP	-	Type-B Machining Features Layout
2	SE141-102	2	SE141-115	PRT	-	Type-B Winding Form, 316L SS
2	SE141-102	2	SE141-115	DRW	0	Type-B Winding Form, 316L SS
2	SE141-102	2	SE141-115	PDF	-	Type-B Winding Form, 316L SS
2	SE141-102	2	SE141-115	STP	-	Type-B Winding Form, 316L SS
2	SE141-102	3	SE141-051	PRT	-	Type-B Poloidal Break Lower Insulator, G11CR
2	SE141-102	3	SE141-051	DRW	0	Type-B Poloidal Break Lower Insulator, G11CR

Level	Next Assembly	BOM #	Doc / Part #	Type	Rev	Title / Description
2	SE141-102	3	SE141-051	PDF	-	Type-B Poloidal Break Lower Insulator, G11CR
2	SE141-102	3	SE141-051	STP	-	Type-B Poloidal Break Lower Insulator, G11CR
2	SE141-102	4	SE141-053	PRT	-	Type-B Poloidal Break Shim, 316L SS
2	SE141-102	4	SE141-053	DRW	0	Type-B Poloidal Break Shim, 316L SS
2	SE141-102	4	SE141-053	PDF	-	Type-B Poloidal Break Shim, 316L SS
2	SE141-102	4	SE141-053	STP	-	Type-B Poloidal Break Shim, 316L SS
2	SE141-102	5	SE141-055	PRT	-	Type-B Poloidal Break Upper Insulator, G11CR
2	SE141-102	5	SE141-055	DRW	0	Type-B Poloidal Break Upper Insulator, G11CR
2	SE141-102	5	SE141-055	PDF	-	Type-B Poloidal Break Upper Insulator, G11CR
2	SE141-102	5	SE141-055	STP	-	Type-B Poloidal Break Upper Insulator, G11CR
2	SE141-102	6	SE141-115-WC	TXT	-	Type-B Winding Center Coordinates
2	SE141-102	7	SE141-115-XV	TXT	-	Type-B X-Vector Coordinates
2	SE141-102	8	SE141-115-SL	TXT	-	Type-B Spherical Seat Center Left Coordinates
2	SE141-102	9	SE141-115-SR	TXT	-	Type-B Spherical Seat Center Right Coordinates
2	SE141-103	1	SE141-103_SKEL	PRT	-	Type-C Machining Features Layout
2	SE141-103	1	SE141-103_SKEL	STP	-	Type-C Machining Features Layout
2	SE141-103	2	SE141-116	PRT	-	Type-C Winding Form, 316L SS
2	SE141-103	2	SE141-116	DRW	0	Type-C Winding Form, 316L SS
2	SE141-103	2	SE141-116	PDF	-	Type-C Winding Form, 316L SS
2	SE141-103	2	SE141-116	STP	-	Type-C Winding Form, 316L SS
2	SE141-103	3	SE141-071	PRT	-	Type-C Poloidal Break Lower Insulator, G11CR
2	SE141-103	3	SE141-071	DRW	0	Type-C Poloidal Break Lower Insulator, G11CR
2	SE141-103	3	SE141-071	PDF	-	Type-C Poloidal Break Lower Insulator, G11CR
2	SE141-103	3	SE141-071	STP	-	Type-C Poloidal Break Lower Insulator, G11CR
2	SE141-103	4	SE141-073	PRT	-	Type-C Poloidal Break Shim, 316L SS

Level	Next Assembly	BOM #	Doc / Part #	Type	Rev	Title / Description
2	SE141-103	4	SE141-073	DRW	0	Type-C Poloidal Break Shim, 316L SS
2	SE141-103	4	SE141-073	PDF	-	Type-C Poloidal Break Shim, 316L SS
2	SE141-103	4	SE141-073	STP	-	Type-C Poloidal Break Shim, 316L SS
2	SE141-103	5	SE141-075	PRT	-	Type-C Poloidal Break Upper Insulator, G11CR
2	SE141-103	5	SE141-075	DRW	0	Type-C Poloidal Break Upper Insulator, G11CR
2	SE141-103	5	SE141-075	PDF	-	Type-C Poloidal Break Upper Insulator, G11CR
2	SE141-103	5	SE141-075	STP	-	Type-C Poloidal Break Upper Insulator, G11CR
2	SE141-103	6	SE141-116-WC	TXT	-	Type-C Winding Center Coordinates
2	SE141-103	7	SE141-116-XV	TXT	-	Type-C X-Vector Coordinates
2	SE141-103	8	SE141-116-SL	TXT	-	Type-C Spherical Seat Center Left Coordinates
2	SE141-103	9	SE141-116-SR	TXT	-	Type-C Spherical Seat Center Right Coordinates