NCSX
Product Specification
For The Station Two Assembly

NCSX-CSPEC-185-02-00

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TABLE OF CONTENTS

1 OVERVIEW AND Scope 1
1.1 Overview 1
1.2 Scope 1
2 Applicable Documents 2
2.1 NCSX Documents 2
2.2 Drawings 2
2.3 Other Documents 2
3 Requirements 2
3.1 Item Definition 2
3.2 Characteristics 3
3.2.1 Performance 3
3.2.1.1 Coil Positioning 3
3.2.1.2 Electrical Isolation 3
3.2.2 Physical Characteristics 4
3.2.2.1 Bolted Joints 4
3.2.2.1.1 Stud Engagement 4
3.2.2.1.2 Stud Pre-Load 4
3.2.2.1.3 Shim Length 4
3.2.2.1.4 Shim Contact 4
3.2.2.1.5 Welded Joints 4
3.2.2.1.6 Wing Bladder 4
3.3 Design and Construction 4
3.3.1 Production Drawings 4
3.3.2 Interchangeability 5
3.3.3 Magnetic Permeability 5
3.3.4 Labels 5
4 Quality Assurance Provisions 5
4.1 General 5
4.2 Verification Methods 5
4.3 Quality Conformance 5
4.3.1 Verification of Physical Characteristics 5
4.3.1.1 Verification of Coil Positioning 5
4.3.1.2 Verification of Electrical Isolation 6
4.3.1.3 Verification of Magnetic Permeability 6
4.3.1.4 Verification of Stud Placement 6
4.3.1.5 Verification of Stud Pre-Load 6

4.3.1.6 Verification of Shim Contact 6
4.3.1.7 Verification of Shim Length 6
4.3.1.8 Verification of Shim Welding 6
4.3.1.9 Verification of Wing Bladder 6
Appendix A .... Appendix A - 1

LIST OF TABLES.

Table 3-1 MCHP Labels 5

LIST OF FIGURES

Figure 1-1 Modular Coil Half-Period Assembly 1
Figure 3-1 Type-C Coil 3

1 OVERVIEW AND SCOPE

1.1 Overview

The assembly of the NCSX machine is accomplished at 5 stations. Stations 1 – 3 and Station 5 are located in the NCSX Manufacturing Facility and Station 6 is located in the NCSX Test Cell. Station 4 activities have now been combined into Station 5.

This document details the specifications for a half-period modular coil assembly for the National Compact Stellarator Experiment (NCSX). The Modular Coil System consists of eighteen (18) modular coils of three (3) types, designated as Type-A, Type-B, and Type-C (each shown in Figure 1 below). The half-period (station two) assembly consists of the attachment of a Type-A coil to a Type-B coil, and the Type-B coil to a Type-C coil (for an A-B-C sub-assembly). The NCSX machine assembly sequence can be summarized as follows (refer to the Assembly Sequence Plan, AssySeqPlan_R9.4, for more details):

- Station One – Assembly of the Vacuum Vessel components (covered in NCSX-185-01)
- Station Two – Assembly of the Modular Coil Half Period, MCHP, Type-A, B, and C coils.
- Station Three – Assembly of two MCHP assemblies over the vacuum vessel.
- Station Four –not used.
- Station Five – Final full period assembly. Completes the FPA assembly process by bringing together a period consisting of the VVSA and two MCHP and attaching VV ports, the external trim coils, modular coil lead and coolant connections, and 4 of the 6 TF coils per period.
- Station Six Assembly – full machine assembly, joining three full periods. This also includes the PF coils.

1.2 Scope

This station two specification defines the product requirements for the Modular Coil Half-Period, MCHP, assembly.

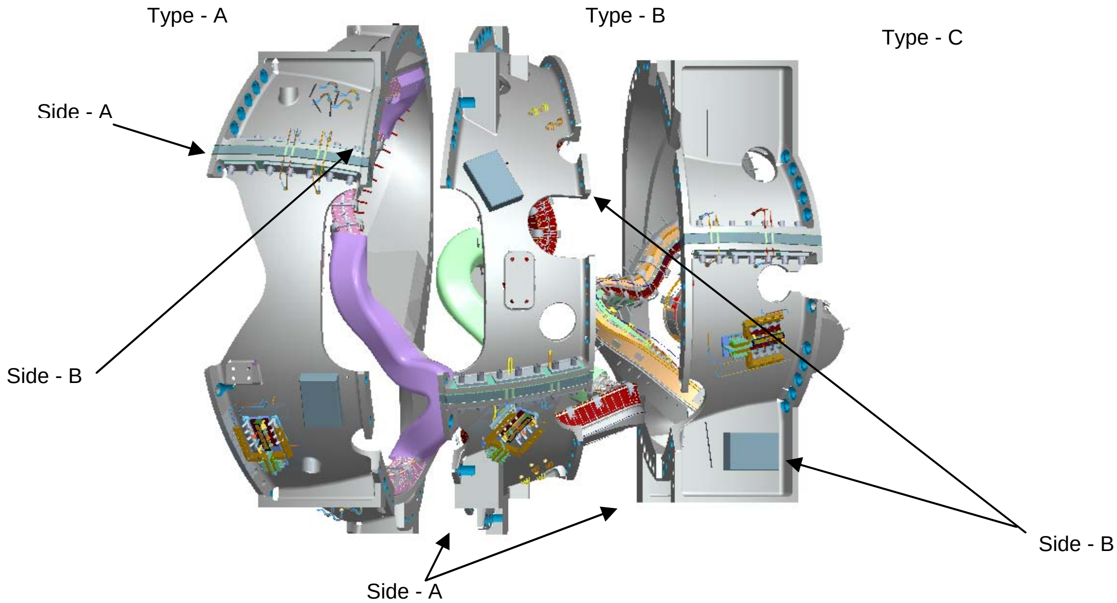


Figure 1-1 Modular Coil Half-Period Assembly

2 APPLICABLE DOCUMENTS

2.1 NCSX Documents

[1] NCSX-ASPEC-GRD, NCSX General Requirements, This document is referred to herein as the GRD.

[2] NCSX-CSPEC-142-05, Product Specification for the Modular Coil Assemblies (Type-A,B,C)

[3] NCSX-BSPEC-14, System Requirements Document (SRD) for the Modular Coil System

[4] NCSX-CRIT-BOLT, Handbook for Bolted Joint Design

[5] NCSX-CRIT-CRYO, NCSX Structural and Cryogenic Design Criteria

[6] NCSX-CALC-14-001, Nonlinear Analysis of Modular Coil and Shell Structure

2.2 Drawings

Drawing	Title
SE 140-003	1/2 FIELD PERIOD ASSY
SE 140-101	MCWF TYPE A
SE 140-102	MCWF TYPE A
SE 140-103	MCWF TYPE A
SE 140-046	MOD COIL SHIM AND SHEAR PLATE LAYOUT
SE 140-190	MCWF FLANGE STUD KITS

2.3 Other Documents

[1] PPPL Procedure ENG-037, General Welding and Brazing Requirements

[2] AWS D1.1, American Weld Specification

[3] NCSX Assembly Sequence Plan

3 REQUIREMENTS

3.1 Item Definition

a. Modular Coil Flange. The Modular Coil Flanges are rims cast into the perimeter of each side of the winding form which support the Modular coil and interface with shims located between the different types of Modular Coils. Flange holes match up between adjoining flanges, and are either countersunk or tapped. Studs inserted in the holes during assembly attach the Modular Coils together and clamp against the shims.

b. Shims. Shims of various thicknesses are placed between adjacent Modular Coil Flanges, and serve to position coils properly, transfer shear loads between flanges, and electrically isolate adjacent coils. Two types of shims are utilized: a) single hole shims which consist of a sandwich of G10, stainless steel, and G10. b) circular shims (also referred to as pucks) that are retained in holes through shear plates that are welded along the inner and outer surface of the inboard flange.

c. Wings. The wing region of the modular coils is the region of the winding form that extends beyond the Modular Coil Flange (as shown below in the upper right hand of Figure 3-1 for the Type-C coil).

d. Wing Support Bladders. Wing support bladders are placed between the wing of one coil and the overlapping region of the adjacent coil. The bladders are made of Teflon and filled with glass cloth and epoxy impregnated. They provide support for the wing region and transfer load between the wind and the adjacent coil.

e. Stud Assembly Kits. Studs are used for attaching modular coils together at the modular coil flanges. Stud assembly kits exist in two types – tapped studs and through studs. A large pre-load is applied to the studs in order to transfer transverse magnetic loading to the shims. The pre-load is applied by a Supernut torqued onto a series of insulating washers, load bearing washers, sleeves, and insulating bushings.

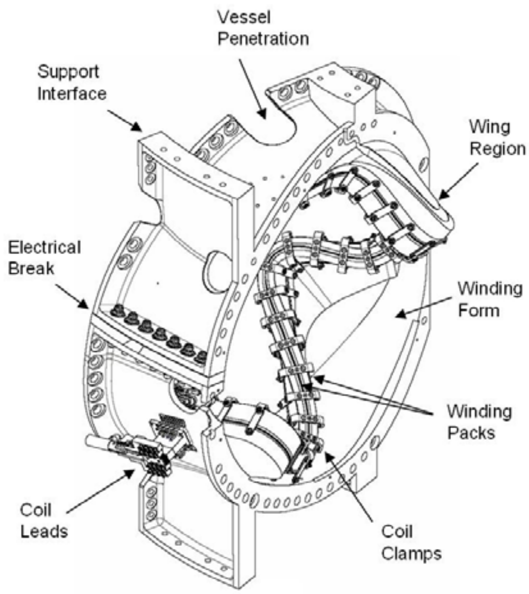


Figure 3-1 Type-C Coil

3.2 Characteristics

3.2.1 Performance

3.2.1.1 Coil Positioning

The current centers of all coils within a MCHP assembly shall be located within +/-0.020in of the desired locations as defined by the global coordinate system shown on the drawings in section 2.2.

3.2.1.2 Electrical Isolation

a. Bolted joints shall electrically isolate adjacent modular coils within a MCHP assembly. (It is recognized that the welded shims joining adjacent modular coils will indeed provide a conducting path between adjacent modular coils.)

b. There shall be no continuous electrical paths poloidally within a MCHP assembly.

c. Electrical requirements in the Modular Coil Assembly product specification [2] shall not be compromised during assembly of MCHP assemblies.

3.2.2 Physical Characteristics

3.2.2.1 Bolted Joints

3.2.2.1.1 Stud Engagement

The studs shall be inserted into the tapped holes in the flange by advancing the stud to the bottom of the thread then reversing direction ¼ turn. Studs inserted into thru holes shall have the bolt kit assembly installed per drawing SE140-190, MCWF FLANGE STUD KITS. The nuts shall be fully engaged on the studs in order to carry the pre- load specified in Section 3.2.2.1.2.

In all cases, at least the minimum thread engagement specified on drawing, SE140-003, MODULAR COILS ASSEMBLY ½ FIELD PERIOD, shall be obtained.

3.2.2.1.2 Stud Pre-Load

The studs shall be pre-loaded to 72,000 pounds force ±5,000lbs (77,000/67,000). The Supernut shall be torqued using the manufactures recommended procedure shown in Appendix A.

3.2.2.1.3 Shim Length

The shim must not extend beyond the flange in such a way that it will interfere with the winding form or wings of the adjacent modular coil or TF coils. The shim length shall be as shown in drawing SE140-046, MODULAR COIL SHIM AND SHEAR PLATE LAYOUT.

3.2.2.1.4 Shim Contact

Shim assemblies shall be in good contact with both sides of adjacent flanges. After sizing all shims and applying a preload of 50% of the stud pre-load as specified in Section 3.2.2.1.2 to the studs each shim shall be tested by performing a "wiggle test" to determine if the shim is loose. Any movement of the shim shall require the shim to be resized and a new shim installed. This test shall be repeated until all shims have successfully met this requirement.

3.2.2.1.5 Welded Joints

Welds shall be applied to the inboard shims as specified in the drawings listed in Sect. 2.2.

Welds shall be completed in accordance with PPPL procedure ENG-037. Deflections produced by the welding must not exceed the requirements of 3.2.1.1 above.

3.2.2.1.6 Wing Bladder

The wing bladders shall be positioned as shown in drawing SE140-003, MODULAR COILS ASSEMBLY ½ FIELD PERIOD. The modulus of the wing bladder shall be within 20% of 13,750 MPa.

3.3 Design and Construction

3.3.1 Production Drawings

MCHP assemblies shall be assembled in accordance with the production drawings shown in Section 2.2.

3.3.2 Interchangeability

Design tolerances shall permit Assemblies of the same part number to be used as replacement parts without degrading the specified performance of the parent item. [Ref. SRD Section 3.3.5 Interchangeability]

3.3.3 Magnetic Permeability

The magnetic permeability of all components and welded areas must be less than 1.02 unless otherwise authorized by the project.

3.3.4 Labels

Each MCHP shall be uniquely identified as shown in Table 1.

Table 3-1 MCHP Labels

Period	MCHP	MCHP
Period 1	MCHP Left Side (C1/B1/A1)	MHCP Right Side (A2/B2/C2)
Period 2	MCHP Left Side (C3/B3/A3)	MHCP Right Side (A4/B4/C4)
Period 3	MCHP Left Side (C5/B5/A5)	MHCP Right Side (A6/B6/C6)

4 QUALITY ASSURANCE PROVISIONS

4.1 General

This section identifies the methods to be used for verification of requirements in Section 3.2 of this specification.

4.2 Verification Methods

Verification of qualification shall be by analysis, inspection, or test. Definition of analysis, inspection, and test is as follows:

Analysis: Verification of conformance with required characteristics by calculation or simulation, including computer modeling based on established material or component characteristics.

Inspection: Verification of conformance by measuring, examining, testing, and gauging one or more characteristics of a product or service and comparing the results with specified requirements.

Test: Verification by physically exercising a component or system under appropriate loads or simulated operating conditions, including measurement and analysis of performance data.

4.3 Quality Conformance

This section establishes the specific methods for verification of requirements in Section 3.

4.3.1 Verification of Physical Characteristics

4.3.1.1 Verification of Coil Positioning

Upon completion of the MCHP, the relative placement of the Type-A, Type-B, and Type-C coils will be confirmed to be as specified in Section3.2.1.1. This will be measured using the position of the fiducials on each coil. Final verification shall be performed after all assembly operations, e.g. welding and analysis has been completed.

4.3.1.2 Verification of Electrical Isolation

A megger test shall be performed to verify the requirements as specified in Section 3.2.1.2 The megger test shall be conducted at 150 volts with a leakage current <100 micro amps.

4.3.1.3 Verification of Magnetic Permeability

Magnetic permeability of components (shims, studs, etc.) and welds shall be verified by use of a calibrated Severn gauge to verify compliance with the magnetic permeability requirement in Section 3.3.3.

4.3.1.4 Verification of Stud Placement

The required minimum thread length for the stud shall be as specified in Section 3.2.2.1.1. Assurance that the stud threads are fully engaged shall be determined by measuring the stud length before installation and comparing to the exposed length of stud. For the studs that have nuts, a visual inspection that shows the threads are fully engaged is required.

4.3.1.5 Verification of Stud Pre-Load

The stud pre-load will be confirmed by ultrasonic inspection using calibrated equipment per requirements in Section 3.2.2.1.2

4.3.1.6 Verification of Shim Contact

The shim shall be tested in accordance with Section 3.2.2.1.4 to show that each side of the shim is in good contact with the adjacent modular coil flanges.

4.3.1.7 Verification of Shim Length

Interference with winding form or coil wings should be checked, and shims cut as specified in Section 3.2.2.1.3 to avoid any interference.

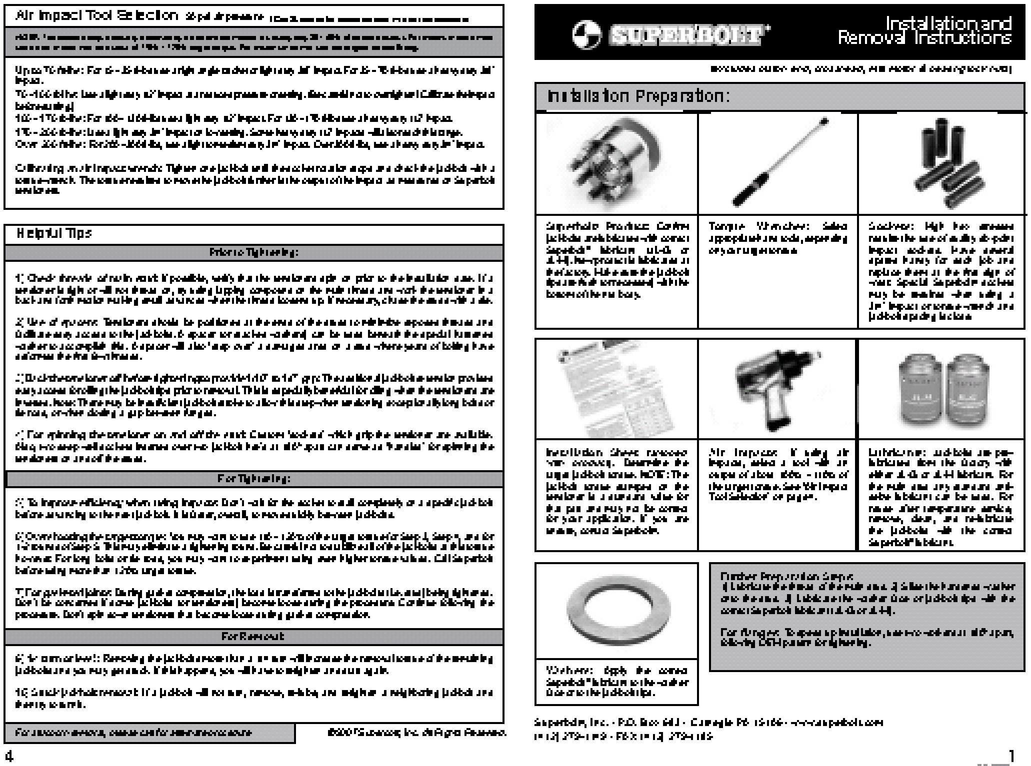
4.3.1.8 Verification of Shim Welding

All welds shall be visually inspected to verify that weld standards are met as specified in the drawings containing the welding requirements.

4.3.1.9 Verification of Wing Bladder

To verify the modulus as specified in Section 3.2.2.1.6 a test sample shall be made during the filling of each bladder. If more than one bladder is being filled at the same time only one sample shall be required. The sample shall simulate the glass fill and volume of epoxy being used to fill the MCHP assembly bladders. The test sample shall be used to determine the modulus and to verify the cure cycle.

APPENDIX A



Air Impact Tool Selection

[illegible]

Helpful Tips

Prior to Tightening:

[illegible]

For Tightening:

[illegible]

For Removal:

[illegible]

4

SUPERBOLT® Installation and Removal Instructions

Installation Preparation:

[illegible]

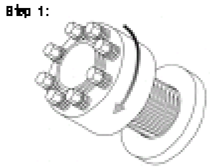
Further Preparation Steps:

[illegible]

1

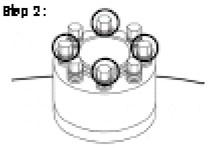
Installation

Step 1:



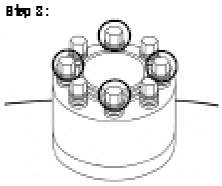
Spin the tensioner onto the main thread until it seats against the washer. You may want to back off the tensioner slightly as mentioned in Helpful Tip #3 on page 4.

Step 2:



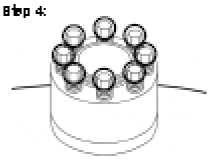
Tighten (4) jackbolts at 90° apart (12:00, 6:00, 3:00, and 9:00) on all studs with a partial torque (50-75%). This serves to seat the flange. If using an air impact, use a reduced setting or lightly pulse the trigger at the full setting.

Step 3:



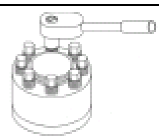
At 100% target torque, tighten the same (4) jackbolts on all studs.

Step 4:



At 100% target torque, tighten all jackbolts in a circular pattern. Do this for all studs (1 round only). See Helpful Tip #1 about using up to 120% torque.

Step 6:



Repeat "STEP 4" until all jackbolts are stabilized (less than 10° rotation). This usually requires 2-4 additional passes. If using air tools, switch to a torque wrench when socket rotation is small. Use the torque wrench to stabilize at the target torque.

NOTE: Product with 4 or 6 jackbolts - use a star pattern for all steps.

2

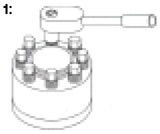
Removal

CAUTION! [illegible]

Service Under 250°F

Preparation: Spray jackbolts with penetrating oil or hydraulic oil prior to removal, especially if product is in corrosive environment.

Step 1:



Loosen each jackbolt 1/8 turn following a circular pattern around the tensioner (1 round only). As you move around and get back to the first jackbolt, it will be tight again. Do this for all studs on the joint prior to the next step.

Step 2: Repeat a 2nd round as above for all studs, now loosening each jackbolt 1/4 turn in a circular pattern.

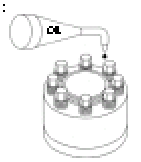
Step 3: Continue loosening 1/4 turn for 3rd and successive rounds until all jackbolts are loose. NOTE: *Usually after the 3rd or 4th round, an impact can be used to completely extract the jackbolts, one by one. For long bolts or tie rods, additional rounds may be required before removing the jackbolts with an impact tool.*

Step 4: Remove, clean and relubricate the jackbolts prior to next use with correct Superbolt lubricant (JL-G or JL-M).

Service Over 250°F

Preparation: Above 250°F the petroleum base of the lubricant burns off. Oil per "STEP 1" below to reduce the removal torque.

Step 1:



As the equipment is cooling down (around 300°F), apply hydraulic oil to the jackbolts and washer and let sit for several hours. Thoroughly "wet-down" all components and re-apply during equipment cool down period. If the tensioner is inverted, squirt oil in the gap between the nut body and the washer. Synthetic oil can be used for oiling above 300°F.

Step 2: Wait for tensioners to cool below 200°F. Using a circular pattern, "crack" each jackbolt only enough to ensure movement. Do not turn beyond the break loose point. Do this for all studs.

Step 3: Now begin with "STEP 1" of the procedure for service under 250°F.

NOTE: Heating Rods can be used to reduce the removal torque required.

3