





**JOB ORDER STATEMENT OF WORK  
&  
TECHNICAL SPECIFICATION  
FOR  
PF-1B SLING COMPONENT FABRICATION**

CAT:  A1  A2  A3

**Revision: 0**

**Requisition No.:**

**Document No.:** NSTXU\_1-1-3-3\_SOW\_106

**Date:** January 21, 2020

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## RECORD OF CHANGES

Rev #	Date	Description of Changes
0		Initial Release



**LIST OF ACRONYMS**

- |      |  |       |  |
|------|--|-------|--|
| AJOA | = <b>A</b> fter <b>J</b> ob <b>O</b> rders <b>A</b> ward               | PPPL  | = <b>P</b> rin <b>c</b> eton <b>P</b> lasma <b>P</b> hysics <b>L</b> aboratory |
| COG  | = <b>C</b> ognizant Engineer   | QA    | = <b>Q</b> uality <b>A</b> ssurance  |
| DP   | = <b>D</b> ye <b>P</b> enetrant Testing                                | TA    | = <b>T</b> echnical <b>A</b> uthority  |
| NSTX | = <b>N</b> ational <b>S</b> pherical <b>T</b> orus e <b>X</b> periment | UT/RT | = <b>U</b> ltrasonic/ <b>R</b> adiographic <b>T</b> esting                     |
| PF   | = <b>P</b> oloidal <b>F</b> ield                                       | VT    | = <b>V</b> isual Inspection (and <b>T</b> esting)                              |

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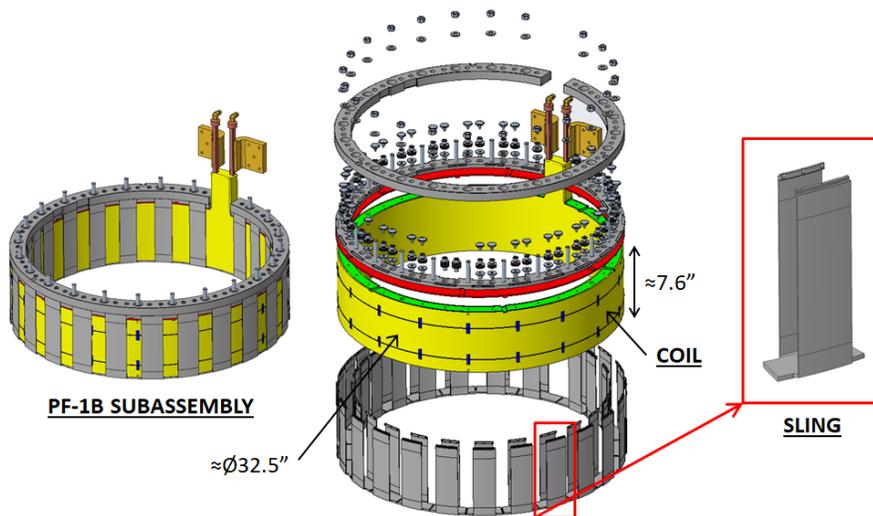
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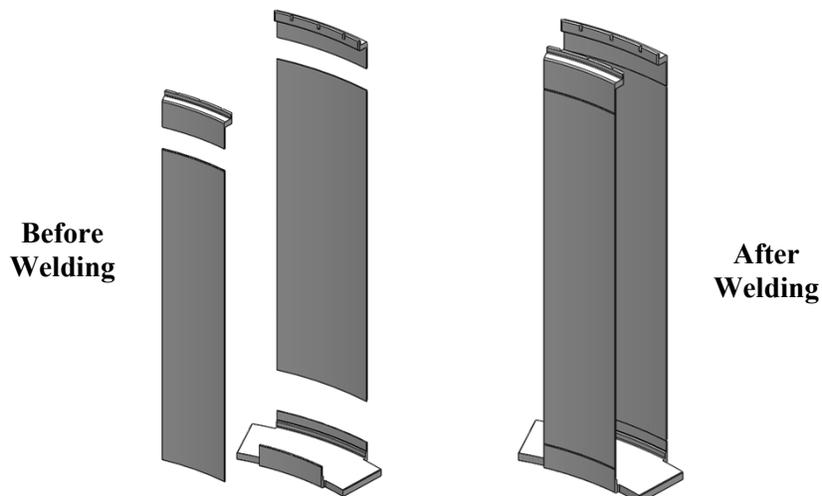
## 1.0 INTRODUCTION & SCOPE

The National Spherical Torus eXperiment Upgrade (NSTX-U) is an experimental research facility funded by the U.S. Department of Energy (DOE) Fusion Energy Sciences (FES) that operates at the Princeton Plasma Physics Laboratory (PPPL). NSTX-U (<http://nstx-u.pppl.gov/home>) employs water-cooled copper electromagnetic coils to confine a hot plasma. The Inner Poloidal Field (Inner PF) coils consist of 3 pairs of coils, namely PF-1A, PF-1B and PF-1C. There is (1) each located at the upper and lower “poles” of the tokamak. The PF-1B coils are held in place by a series of Inconel 718 supports (“slings”) and mounting flanges. See below.



The slings for the PF-1B coils differ by size and quantity due to space constraints. There are (9) different variants of the PF-1B slings. The upper and lower variants of the PF-1B use a different combination and quantity of these slings.

Each sling is made up of 5 components (3 are machined components, 2 are formed sheet metal). These are welded together, heat treated to achieve full strength, and then post-machined to final size and tolerance. The Subcontractor shall provide all materials, labor, supervision, equipment and expertise to fabricate the sling components to the requirements outlined in this technical specification. This scope of work is to fabricate the machined components only.



**2.0 APPLICABLE DOCUMENTS**

- 2.1 NSTXU\_1\_SOW\_100 (Rev 1) - Statement of Work for Fabrication and Machining Shop Services
- 2.2 AMS 5596 REV. M - Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, Foil, and Plate 52.5Ni 19Cr 3.0Mo 5.1Cb 0.90Ti 0.50Al 18Fe Consumable Electrode or Vacuum Induction Melted, 1775°F (968°C) Solution Heat Treated
- 2.3 ASME Y14.5-2018 – Dimensioning and Tolerancing
- 2.4 ASTM A 342-14 – Standard Test Methods for Permeability of Weakly Magnetic Materials

**3.0 APPLICABLE DRAWINGS**

This Job Order Statement of Work documents all materials, labor, supervision, equipment, etc., required fabricate and deliver the PF- 1B sling components.

3.1 APPLICABLE DRAWINGS

*Table 1. List of PPPL Provided Drawings*

Drawing No.	Revision	Description
E-DC11141	2	PF-1B MAIN SLING

3.2 ATTACHMENTS

- 3.2.1 Document Deliverables
- 3.2.2 Component Deliverables – PF-1B Coil Slings

**4.0 RESPONSIBILITIES**

See §4.0 of NSTXU\_1\_SOW\_100.

**5.0 REQUIREMENTS**

5.1 GENERAL

The Subcontractor shall comply with the referenced BOA Subcontract SOW and the requirements defined in this Technical Specification.

5.1.1 Material Acquisition

The Subcontractor shall purchase all materials necessary for the fabrication of all Subcontractor items in Table B.

5.1.2 Manufacturing

The Subcontractor shall fabricate the machined parts listed in Table B and any other requirements referenced in this SOW. The Subcontractor is responsible for the design and fabrication of any jigs or fixtures required to produce components conforming to their respective drawings and this SOW, including all requirements (e.g. instructions and standards/etc.) included by reference.

5.1.3 Dimensional Verification

The Subcontractor shall verify all dimensions noted in the drawing package and document the results throughout the component fabrication process per Section 6.

#### 5.1.4 Project Plan and Schedule

Subcontractor shall provide a schedule with key milestones (machining piece parts, inspection points, etc.) which support the delivery schedule defined in the Deliverables tables.

#### 5.1.5 Points of Contact and Weekly Updates

PPPL and the Subcontractor shall each designate a technical point of contact, a backup technical POC, a Quality Assurance POC, and a backup QA POC. The Subcontractor shall submit weekly updates on the status of fabrication process. These updates shall include, at a minimum: which part is being worked on, the estimated completion date for each part, any delays, the reason for the delay, and may include photos. These updates are to be emailed every Monday. An alternate day can be scheduled for this regular update with PPPL approval.

The Subcontractor shall schedule a weekly meeting with PPPL to discuss these updates.

## 5.2 DESIGN

### 5.2.1 Performance Characteristics

a. Conformance to the dimensions outlined in the drawing package is paramount. It is the Subcontractor's responsibility to design and fabricate any required jig or fixture as outlined in §5.1.2 and §5.1.4.

### 5.2.2 Specification and Standards

A copy of the most recent calibration certificates for each of the machining, metrology and other appropriate equipment/instruments that will be used for critical measurements or manufacturing processes shall be submitted for PPPL review with the MIT plan. The Subcontractor must maintain the equipment calibration throughout the duration of the scope of work. The calibration standards must be traceable to the National Institute of Standards and Technology (NIST) or equivalent.

### 5.2.3 Identification and Marking

Components shall be marked using a non-marring method. The marking method shall not scratch or dent any components, and must be removable without damaging the material surface. Therefore, etching/stamping/scratching/scribing are **NOT** allowed. Subcontractor shall submit an identification and marking method as part of their MIT plan, as outlined in §9.6 of NSTXU\_1\_SOW\_100.

### 5.2.4 Workmanship

- a. General shop cleanliness and housekeeping shall be adequately maintained to prevent tracking contamination of sling components.
- b. Careful handling of the sling parts is required so as not to damage machined surfaces or plastically deform the thin sheet metal legs. The sheet metal legs shall be restrained during shipping to avoid damage.
- c. All fabricated parts shall be free from sharp edges and burrs.
- d. Gouged, pitted, or corroded material will not be acceptable under any circumstances.

- e. All chips/burrs/and sharp edges shall be cleaned and have no loose hanging metal. Holes, channels, slots, and grooves shall be clear of any burrs or chips that could affect form, fit, or function.
- f. Chatter, cutter, and vibrational marks must be avoided through proper tooling care, usage, and inspection. Extra care should be taken to ensure that all surface finish requirements are met during manufacturing.
- g. Counter sinks and counter bores shall be free from chatter and meet the surface finish requirements of the applicable component drawing. Any “witness marks”, ragged edges, or oblong holes on countersinks are unacceptable.
- h. Although fixture and clamping marks are inherently unavoidable, care should be taken to ensure that any fixture/clamping marks accrued on a component during manufacturing do not conflict with any of the above workmanship requirements.

## 6.0 TEST & INSPECTION REQUIREMENTS

### 6.1 PERFORMANCE TESTS

NOT APPLICABLE

### 6.2 ACCEPTANCE AND INSPECTION TESTS

Testing and inspection shall be integrated into each stage of the fabrication of the sling components:

- a. Incoming inspection of raw material (every plate )
- b. Completion of piece parts (machined parts components as defined in §§ 6.2.1 & 6.2.2)

#### 6.2.1 MAGNETIC PERMEABILITY

To verify conformance, relative magnetic permeability shall be measured in accordance with the requirements of ASTM A 342, Test Method No. 3.

- a) The magnetic permeability limits are listed on the associated drawings.
- b) Testing shall use a Severn Engineering Low Mu Permeability Indicator ([Available from Severn Engineering Co. Auburn, Alabama](#)), which has been calibrated within 12 months of use.
- c) Each sheet, plate or bar shall be checked in at least one location before being cut into parts. See drawings for magnetic permeability requirements for base material.
- d) Each machined component shall be checked in at least one location.
- e) If material fails required level of permeability, the lowest permeability Severn Gauge insert which yields passing results should be reported.

#### 6.2.2 DIMENSION INSPECTION

Tolerances are indicated on the manufacturing drawings. Strict adherence to these dimensions and tolerances is critical to the assembly and performance of the subject equipment. All dimensional measurements shall be performed in a

temperature controlled environment, maintained at a temperature of 20°C (+/- 2°C). All inspection reports should be performed in accordance with §9.11 of NSTXU\_1\_SOW\_100.

The sling components shall have 100% of dimensions inspected based on the following sampling plan:

Lot Size	Sample Size
2 to 8	2
9 to 15	3
16 to 25	5
26 to 50	8
51 to 90	13
91 to 150	20

*Sampling plan based on ANSI/ASQ Z1.4-2003, single sampling plan for normal inspection, general inspection level II.*

Samples shall be chosen such that the inspected units are approximately evenly distributed through the manufacturing run. Each sampled lot shall include inspection of the first unit and the last unit.

For example:

*(18) units of E-DC11140-5 are required for the upper PF-1B slings. If all (18) are produced as one lot, only (5) need to be inspected: the first and last units, plus (3) more spread approximately evenly throughout the lot.*

NOTE: For the purposes of executing the above defined sampling plan, a lot shall be defined as a series of components of the same part number manufactured under a continuous process using the same material (same material heat/lot number), fixturing, tooling, and machine. Any change in any of these four characteristics of the machining process shall constitute the end of a lot.

### 6.2.3 ACCEPTANCE TESTS

Subcontractor shall provide details of their inspection process and acceptance tests in the MIT plan as described in §9.6 of NSTXU\_1\_SOW\_100. In addition, PPPL reserves the right to perform random sampling or 100% inspection at any of the points specified in §6 to verify acceptance tests.

### 6.3 SUPPLIER HOLD POINTS

In order to expedite production while minimizing risk, the following hold points will be utilized

Parts for Lower Slings (unfinished parts for slings) - Individual piece parts for slings required for lower PF coils (machining and inspection, but **NO** welding, HT, or post-machining) will require hold points as follows in Table 3.

PPPL will determine where to add additional Witness or Hold points based on reviewing the MIT Plan. Subcontractor shall provide PPPL with notice five working days in advance of such points.

The difference between Hold Points and Witness Points is as follows:

- At Hold Points, the vendor stops work, provides data/documentation to PPPL, and PPPL can approve, reject or send a representative to inspect the relevant parts on-site.
- At Witness Points, a PPPL representative must be on-site to witness the measurements being taken or manufacturing being performed.

**Table 3. Witness and Hold Points**

#	Witness and Hold Points
1	Approval of MIT Plan Hold
2	Hold for approval of CMTRs
3	NCR Approval Hold (as applicable)
4	Approval of Process History and Release for Shipment Form Hold

**7.0 QUALIFICATIONS**

See §7.0 of NSTXU\_1\_SOW\_100 and §9.0 of this document.

**8.0 ENVIRONMENTAL, SAFETY & HEALTH**

**8.1 OVERSIGHT**

Supplier shall allow scheduled access to their facility to review manufacturing processes and perform inspections at the discretion of PPPL. Supplier shall identify and communicate the hazards of the work to be reviewed and the hazards of unrelated work in the facility that could affect the PPPL COG or other PPPL visitors, and the safety protocols (including but not limited to training and personal protective equipment) that will apply to protect visitors from the hazards. Supplier shall provide any required training to PPPL visitors to assure observance of the supplier's safety rules and prevent exposure to any hazard at supplier's facility.

**9.0 QUALITY ASSURANCE REQUIREMENTS**

The following sections of NSTXU\_1\_SOW\_100 shall apply to this award (and are expanded upon as follows):

- 9.1 Inspection/surveillance/Audit by PPPL
- 9.2 Subcontractor's Responsibility for Conformance
- 9.3 Changes to PPPL Approved Documents
- 9.4 Subcontractor Quality Assurance Program
- 9.6 Submittal of Manufacturing/Inspection/Test (MIT) Plan

- 9.7 Process and Sequence
- 9.8 Document Traceability and Records
- 9.9 Inspection and Test Control – Inspection/test records shall include, at a minimum:
  - PO/Contract Number
  - Part number of the item under inspection
  - Reference identification for each reported attribute/feature traceable to the corresponding requirement definition
  - Nominal Values
  - Verification of compliance with all drawing notes
  - Measurement device(s) and calibration due date(s)
  - Inspector's name, signature, and date(s)
- 9.11 Performance and Documentation of Inspections & Tests
- 9.12 Equipment/Material Identification and Status
  - Additionally: Etching/stamping/scratching/scribing are NOT allowed on parts. Subcontractor's method of maintaining traceability to specific Inconel 718 sheets and plates through the manufacturing process shall be provided in the MIT plan.
- 9.14 Document Review, Approval and Control
- 9.15 Acceptability of Purchased Items and Services
- 9.16 Non-conformance & Corrective Actions and Notification
  - Additionally: Any identified non-conformances shall be communicated to PPPL within 2 working days of detection. A Non-Conformance Report (NCR) shall be submitted to PPPL within 5 working days of detection.
- 9.17 Measuring Equipment/Calibration
  - Additionally: Calibration records for equipment to be used in the completion of the work defined herein shall be submitted with the MIT Plan.
- 9.19 Submittal of Completed Release for Shipment Form
- 9.20 Submittal of Completed Process History (Documentation Package)
  - Additionally: The Subcontractor shall provide CMTR's for all raw material consumed in making sling components prior to use.
  - Additionally: The Subcontractor shall provide photos of the packing method for each type of component (photos of packed components prior to container closure)
- 9.22 PPPL Receiving/Inspection

In addition to these requirements, the following shall apply:

## 10.0 **SHIPPING, STORAGE AND HANDLING**

See §10 of NSTXU\_1\_SOW\_100

A Packing and Shipping plan shall be included in the MIT Plan.



**11.0 WARRANTY**

NOT APPLICABLE

**12.0 ATTACHMENTS**

SEE FOLLOWING SECTIONS

**13.0 DOCUMENTATION & DELIVERABLES**

*See Attachments for List of Required Component Deliverables to PPPL*

*Table 4. List of Required Meetings between the Subcontractor and PPPL*

#	Meetings Required	Required	Complete
1	Kickoff Meeting	2 weeks AJOA	
2	NCR Meeting	As required	
3	Status updates	Weekly	

*Exceptions: None*

**ATTACHMENT A. DOCUMENT DELIVERABLES**

*Table A. List of Subcontractor Document Deliverables*

#	Document Deliverables Required	Required By	Format	Location	Rcv'd
1	MIT plan (§ 9.6)	2 weeks AJOA, N	E	Ops Center	
2	Calibration Records (§ 5.2.2)	With MIT Plan	E	Ops Center	
3	Project Plan and Schedule (§ 5.1.5)	2 weeks AJOA	E	Ops Center	
4	CMTRs (for all materials, § 9.20)	PS, N	E	Ops Center	
5	Non-Conformance Reports (§ 9.16)	5 working days of detection, N	E	Ops Center	
6	Process History (§ 9.20)	BSD	E	Ops Center	
7	Product Quality Certification and Shipping Release Form (§9.19)	BSD, N	E	Ops Center	

**Legend**

*AJOA = After Job Order Award*

*BSD = Before Sling part Delivery*

*C = Project Completion*

*D = During Manufacturing/As Required*

*N = Notice to Proceed Requirement*

*P,E = Paper or Electronic*

*PS = Prior to Start of Manufacturing*



**ATTACHMENT B. COMPONENT DELIVERABLES – B COIL SLINGS**

*Table B. List of Subcontractor Component Deliverables to PPPL*

#	Physical Deliverables Required	Required By	Received
1	Thirty one (31) each E-DC11141-1, -2, (Machined parts for slings)	8 weeks AJOA	
2	Nineteen (19) E-DC11141-5 (Machined parts for slings)	8 weeks AJOA	
3	Two (2) each E-DC11141-8 through -13 (Machined parts for slings only)	8 weeks AJOA	
4	Twenty six (26) each E-DC11141-1, -2 (Machined parts for slings only)	Per Subcontractor Project Plan	
5	Eighteen (18) each E-DC11141-5 (Machined parts for slings only)	Per Subcontractor Project Plan	
6	One (1) each E-DC11141-8, -9, -10, -13 (Machined parts for slings)	Per Subcontractor Project Plan	
7	Two (2) each E-DC11141-14, -15 (Machined parts for slings)	Per Subcontractor Project Plan	
8	Jigs, fixtures (§ 5.1.4)	16 weeks AJOA	

Cognizant Engineer: \_\_\_\_\_  
*(Sign-off and provide to the Operations Center when job is completed and deliverables are dispositioned and placed/filed in Operations Center (or other Project, Department or Division designated file center).*