

NSTX  
STATEMENT of WORK

**INNER TF CONDUCTOR ASSEMBLY**

D-NSTX-SOW-13-133 Rev.00

March 22, 2011

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**RECORD OF CHANGE**

Revision	Date	Description of Change
00	3-22-11	Initial release

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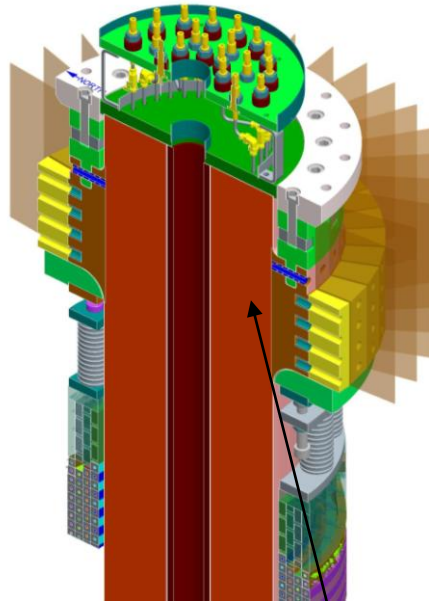
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**1 GENERAL INFORMATION**

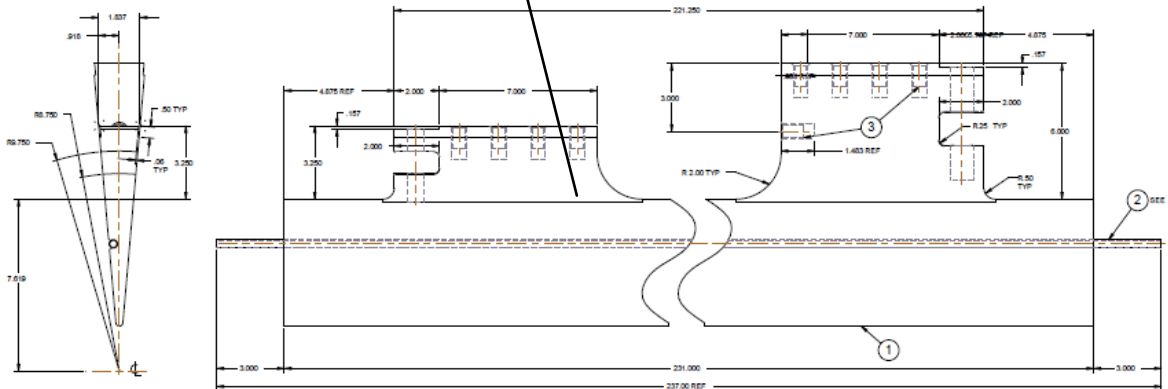
**1.1 INTRODUCTION:**

This statement of Work (SOW) is for the fabrication of fifty-five (55) Inner TF conductor assemblies (Drawing E-DC1412) for the National Spherical Torus Experiment (NSTX).

National Spherical Torus Experiment (NSTX) is a high performance ST research facility that is presently operating at the Department of Energy's Princeton Plasma Physics Laboratory (PPPL). Since starting operation in 1999, NSTX has established the attractiveness of the low-aspect-ratio tokamak ST concept characterized by strong intrinsic plasma shaping and enhanced stabilizing magnetic field line curvature. In 2009 the US Department of Energy approved the initiation of a project to upgrade the NSTX for approved performance. The inner TF conductor assemblies form the inner leg of the upgraded Toroidal Field coils for NSTX.



**Figure 1- Inner TF Bundle**



**Figure 2- Inner TF Conductor Assembly**

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**2 APPLICABLE DOCUMENTS**

Identified below are documents that that will be needed to complete the production of the Inner TF conductor assemblies.

**2.1 DRAWINGS**

2.1.1 Drawings will be provided by PPPL. The manufacturer can only use PPPL signed and “Approved for Fabrication” stamped drawings. The selected manufacturer may develop additional manufacturing drawings if required to complete manufacturing. These, also, must be PPPL approved before use.

<b>Drawing No.</b>	<b>Title</b>
C-DC1402	CSU- Inner TF Bundle Extrusion
E-DC1411 (Shts 1-3)	TF Conductor Details, Machining & FSW Assembly
E-DC1412	TF Conductor Final Machining

2.1.2 Dimensions in drawings and specifications refer to conditions at room temperature (20° C/ 68° F).

**2.2 REFERENCE DESIGN DOCUMENTS**

<b>Document No.</b>	<b>Title</b>
EWI Project No.- 52399GTH	TF Conductor Weld Development-Phase 2
D-NSTX-SPEC-13-128	TF Copper Conductor Extrusion

**2.3 TOLERANCES AND DIMENSIONS:**

2.3.1 Dimensional characteristics for the TF conductor assemblies are identified on the manufacturing drawings.

2.3.2 Tolerances are indicated on the manufacturing drawings. Strict adherence to these dimensions and tolerances are critical to the assembly and performance of the subject equipment.

**2.4 APPLICABLE CODES AND STANDARDS:**

2.4.1 ASME Boiler & Pressure Vessel Code, Section V, 2007 Edition

2.4.2 ASNT SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing, 2006 Edition.

2.4.3 ASTM Standard E8-09: Standard Test Methods for Tension Testing of Metallic Materials.

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- 2.4.4 ASME Section VIII- Pressure Vessels
- 2.4.5 ASME B31.1-2004 Power and Process Piping- Weld Inspection
- 2.4.6 ASME Section IX- Welding and Brazing Qualifications
- 2.4.7 AWS-QC1- Certified Weld Inspector

### **3 WORK REQUIREMENTS**

The supplier shall manufacture, inspect, test and deliver to PPPL (55) inner TF conductor assemblies, that shall conform to the requirements of this document and the approved manufacturing drawings. Processing shall be in accordance with the supplier's PPPL-approved Manufacturing, Inspection, Test and Quality Assurance Plan, and associated procedures. Supplier shall provide all process documentation identified in Section 7.4.3.

#### **3.1 MANUFACTURING/INSPECTION/TEST and QA PLAN (MIT/QA)**

The Subcontractor shall provide PPPL with manufacturing, inspection and test information sufficient to convey an overview of the processing and the adequacy of the controls, inspections, and tests that are part of the manufacturing process. Controls and checks for the Friction Stir Welding (section 3.2) must be completely described in the plan. The submittal, of the Manufacturing, Inspection, Test, and Quality Assurance Plan (MIT/QA Plan), may consist of the Subcontractor's standard documents such as Travelers/Routers/Process Sheets and procedures or may require development of a new document, as long as the submittal accomplishes the following:

- Outlines the sequence of operations
- Identifies critical manufacturing operations
- Identifies inspections, examinations, and tests
- Includes procedures for special processes, inspections, and tests.

The MIT/QA Plan is required for PPPL review and approval prior to start of fabrication. All inspections and tests must be addressed in the MIT/QA Plan. From the plan, PPPL may designate selected operations as mandatory "witness" points. Subcontractor shall provide PPPL with a minimum of five (5) working days notice in advance of these witness points. Such witness points shall be mutually planned to minimize delays. The MIT / QA Plan shall include steps to address the topics listed in this section.

#### **3.2 FRICTION STIR WELDING (FSW):**

The joining of the Cu-Cr-Zr lead extensions to the TF conductors is a critical operation. The selected sub-contractor shall include in their proposal the name of the FSW company that will be performing the Friction Stir Welding of the lead extensions to the TF conductors. PPPL must concur with the sub-contractor's choice of the FSW vendor.

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- 3.2.1 Welding shall be performed in accordance with the requirements ASME Section IX.
- 3.2.2 The FSW vendor should use the PPPL provided “52399GTH Final Report” as the basis for developing procedures and performing the FSW operations. This report, developed by Edison Welding Institute for PPPL, documents the development of procedures, tools, etc., required to FSW the two dissimilar copper alloys together (C18150 [Lead Extensions] to C10700[TF conductor]).
- 3.2.3 The FSW vendor shall develop procedures (Welding Procedure Specification, WPS) following ASME Section IX for performing the FSW operations. These procedures shall be reviewed and approved by PPPL.
- 3.2.4 The FSW vendor shall qualify the process (Procedure Qualification Record, PQR) and operators (Welder Performance Qualification, WPQ) following ASME Section IX. A minimum of (2) successful FSW samples shall be made by the operator to qualify the process and the operators’ ability to perform a successful weld. These documents shall be reviewed and approved by the PPPL Weld Engineer.
- 3.2.4.1 FSW Qualification Requirements: (For Process and Operator)
- Visual Inspection: A visual inspection of the finished joint shall be made to ascertain complete joining of the materials, and that the joint shall be free from all cracks.
  - Radiography: Each specimen shall be inspected by radiography with no flaws along the main section of the weld away from the exit/plunge holes.
  - Ultra-sonic Inspections: Each specimen shall be inspected using ultra-sonic methods. No unacceptable flaws (per B31.1) along the main section of the weld away from the exit/plunge holes shall be found.
  - Tensile Test: Per ASME Section IX. Tensile test the samples to verify joint strength. Ultimate strength shall be >30 ksi.
  - Side Bends: Per ASME Section IX.
  - Test Results: All test results shall be documented and results as well as samples provided to PPPL for their examination and concurrence. PPPL must approve test results prior to the FSW vendor starting work on the Inner TF conductors.
- 3.2.5 The FSW vendor shall develop procedures for making repairs to a production joint that does not meet the inspection requirements. This repair procedure shall be reviewed and approved by the PPPL Weld Engineer.

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3.2.6 Weld inspection shall be performed in accordance with the acceptance criteria of B31.1. Weld inspection shall be performed by a Certified Welding Inspector (CWI) Per AWS QC1. NDE results shall be reviewed and interpreted by a ASNT Level 3 Technician Per SNT-TC-1A.

3.2.6.1 FSW Inspection Requirements:

- Visual Inspection: A visual inspection of the finished joint shall be made to ascertain complete joining of the materials, and that the joint shall be free from all cracks.
- Radiography: Each specimen shall be inspected by radiography with no unacceptable flaws (per B31.1) along the main section of the weld away from the exit/plunge holes.
- Ultra-sonic Inspections: Each specimen shall be inspected using phased array ultra-sonic methods. No flaws along the main section of the weld away from the exit/plunge holes shall be found.
- Test Results: All test results shall be documented and results as well as samples provided to PPPL for their examination and concurrence.

## 4 MATERIALS:

### 4.1 COPPER CONDUCTOR:

The Inner TF copper conductors shall be provided by PPPL to the sub-contractor. A total of fifty six conductors shall be provided to the selected sub-contractor. Fifty five (55) of those conductors shall be used for completing the Inner TF conductor assemblies. One (1) additional conductor provided by PPPL may be used for development of processes by the sub-contractor and the sub-contractor's supplies.

4.1.1 The extruded copper conductor is C10700 (ASTM B187) oxygen free. (Reference: PPPL drawing C-DC1402)

4.1.2 See conductor specification D-NSTX-SPEC-13-128 for conductor details.

4.1.3 All generated scrap and excess material furnished by PPPL shall be returned to PPPL along with the finished assemblies.

### 4.2 LEAD EXTENSIONS:

The sub-contractor is responsible for providing the lead extensions for the TF conductor assemblies.

4.2.1 The lead extensions shall be manufactured using Copper-Chromium-Zirconium C18150 (Cu-Cr-Zr).

4.2.2 Strength requirements: Tensile strength ~ 79 ksi; Yield strength ~ 75 ksi (Full Hard)



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4.2.3 Sub-contractor must supply Certified Material Test Reports (CMTR's) for the material used to manufacture the lead extensions. The certification shall include both chemical and mechanical properties.

**4.3 THREADED INSERTS:**

The sub-contractor is responsible for providing the Heli-coils for the conductor assemblies.

4.3.1 Material: 18-8 Stainless steel wire

4.3.2 Heli-coil specifications (length, size, etc) are identified on manufacturing drawings.

**5 FABRICATION AND INSPECTION:**

This section describes a recommended sequence for fabricating the subject equipment. In accordance with the Statement of Work [SOW], the selected coil manufacturer shall develop and submit an MIT/QA plan and manufacturing procedures per section 3.1. Deviations from the approved MIT/QA plan and procedures will require PPPL approval (see section 6.6).

**5.1 RECEIPT and INSPECTION of MATERIALS**

The sub-contractor shall document inspection of all materials upon receipt and/or fabrication.

**5.2 INITIAL MACHINING:**

5.2.1 The sub-contractor shall machine the inner TF copper extrusions including the cooling tube groove to the dimensions provided on PPPL approved drawing E-DC1411 sheet 2 of 3.

5.2.2 The sub-contractor shall machine the Cu-Cr-Zr lead extensions per dimensions provided on the PPPL approved drawing E-DC1411 sheet 3 of 3.

5.2.3 A complete dimensional inspection shall be made of each machined TF conductor and lead extension. All measurements shall be documented and be available for PPPL review.

5.2.4 The sub-contractor shall crate and transport the machined conductors and lead extensions to the Friction Stir Welding (FSW) vendor for processing.

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**5.3 FRICTION STIR WELDING of LEAD EXTENSIONS:**

- 5.3.1 The FSW vendor shall develop procedures and fabricate specimens that will be tested by the FSW vendor to verify compliance with FSW requirements. This test data as well as the specimens shall be provided to the sub-contractor and PPPL for final acceptance of process. See section 3.2 for qualification details.
- 5.3.2 Upon receiving PPPL's approval, the FSW vendor shall FSW the lead extensions to the Inner TF conductors using PPPL approved FSW procedures.
- 5.3.3 Each FSW joint shall be inspected by qualified personnel and procedures using both radiography and ultrasonic inspection methods. The sub-contractor shall include in their inspection/test plan the FSW inspection plans as provided by the FSW vendor. These inspection/test plans shall require PPPL approval.
- 5.3.4 The FSW vendor shall crate and ship the Inner TF conductors with attached lead extensions back to sub-contractor for final machining.

**5.4 FINAL MACHINING:**

- 5.4.1 The sub-contractor shall perform an inspection of conductors prior to proceeding to the next operation to ensure that they were not damaged during shipment.
- 5.4.2 The sub-contractor shall finish machining the Inner TF conductors with lead extensions per PPPL approved drawing E-DC1412.
- 5.4.3 The sub-contractor shall install the Heli-Coil inserts.
- 5.4.4 PPPL will install the copper cooling tubes into the Inner TF conductors that are identified on drawing E-DC1412.
- 5.4.5 The sub-contractor shall perform a complete dimensional inspection of finished Inner TF conductors. This information shall be documented and included in the Process History that will be provided to PPPL. All non-conformances shall be documented and dispositioned on an NCR.
- 5.4.6 The conductors shall then be crated and shipped to PPPL.

**6 QA/QC CONTROL REQUIREMENTS**

**6.1 INSPECTION/SURVEILLANCE BY PPPL**

Authorized representatives of PPPL and the U. S. Government shall have the right at all reasonable times to visit the Subcontractor's premises and those of Subcontractor's suppliers during the performance of the Subcontract for the purposes of inspection, surveillance, audit and/or obtaining any required

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information as may be necessary to assure that items or services are being furnished in accordance with specified requirements. Such visits shall be coordinated with the Subcontractor's personnel to minimize interference with the normal operations of said premises. The Subcontractor shall make available records and documentation necessary for this function and shall provide all reasonable facilities and assistance for the safety and convenience of PPPL and/or U. S. Government representatives in the performance of their duties. PPPL and the U. S. Government recognize the Subcontractor's right to withhold information concerning proprietary processes. The Subcontractor agrees to insert the paragraph above in each lower-tier-procurement issued hereunder.

**6.2 SUBCONTRACTORS RESPONSIBILITY FOR CONFORMANCE**

Neither PPPL review and/or approval of Subcontractor's documents nor PPPL inspection of Subcontractor's items or services shall relieve the Subcontractor of responsibility for full compliance with requirements of the purchase order/contract. The Subcontractor is responsible for assuring that all requirements and restrictions are imposed on any sub-tier suppliers.

**6.3 SUBCONTRACTOR'S QA PROGRAM**

The Subcontractor shall maintain an effective Quality Assurance Program to assure that the Subcontractor's work meets the standards in this document, the conductor drawings, and is performed in accordance with contractual requirements. Subcontractor's quality assurance function shall be actively involved in the planning, processing oversight, problem resolution, and determination of acceptability of all work under this SOW. The function shall be organized to have sufficient authority and independence to identify quality problems, verify conformance of supplied items or services to specified requirements and obtain satisfactory resolution of conflicts involving quality.

**6.4 INSPECTION AND TESTING**

Inspections and tests shall be performed in accordance with written procedures referencing criteria for acceptance or rejection. Except where specifically stated otherwise, actual data and accept/reject status for each inspection and test shall be documented. Reports shall clearly identify the item inspected, the locations or areas covered by the report, the performing individual, the date performed, equipment used (with calibration status), and the signature of the authorized individual. A test plan (may be part of the MIT/QA Plan) shall be submitted for approval prior to testing. The Test Plan shall include steps to address the topics listed in this section.

**6.5 NON-CONFORMING ITEMS**

Non-conforming items shall be positively identified, and, where possible, segregated to prevent use. PPPL must be notified of non-conformances within one (1) business day. The Subcontractor shall document each nonconformance, identifying the extent and location of the non-conformance and proposing a disposition. The written concurrence of PPPL is required prior to implementing the disposition. The Subcontractor's system shall provide not only for timely resolution of non-conformances but also for analysis of non-conformances to determine root causes and to implement appropriate and effective corrective actions.

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**6.6 DEVIATIONS to the APPROVED MIT/QA PLAN OR PROCEDURES**

Deviations to the approved documents shall be included in the weekly report. The Subcontractor is required to obtain PPPL's written approval for deviations which may adversely affect conformance to the contracted delivery schedule or product specification.

**6.7 PROCESS HISTORY:**

The Subcontractor shall maintain a system of documentation whereby objective evidence of required operations, inspections, examinations, and tests is systematically compiled, indexed, stored and ultimately provided to PPPL. This documentation or "Process History" shall include but not limited to:

6.7.1 Material Certifications:

The sub-contractor shall provide traceable inspection reports, test data, and/or certifications from suppliers, showing relevant chemical and mechanical properties of materials used. Material certifications shall be submitted to PPPL when the sub-contractor accepts the material for use. Certified Material Test Reports are required for the lead extension material. It is recognized that only certificates of grade or of compliance to manufacturer's specification may be available for materials such as threaded inserts.

6.7.2 Inspection/ Test Documents:

Original or copies of filled in and completed process planning and control documents (procedures, travelers, etc.), which verify controlled execution of the required work. Each Inner TF conductor assembly will have its own set of process planning and control documents.

6.7.3 Inspection Reports:

Copies of the original reports from all required inspections and examinations showing actual values that are properly validated by authorized personnel.

6.7.4 Test Reports:

Copies of the original test data sheets or reports of all required tests, both in-process and acceptance, with actual values measured. Reports shall be properly validated by authorized personnel. Non-destructive testing reports shall include sufficient detail to reproduce the testing and shall comply with ASME Section V.

6.7.5 Shipping Release:

Manufacturer shall not ship (full or partial) without a "Product Quality Certification and Shipping Release" Form (Exhibit 1) signed by Princeton's Representative. Manufacturer shall complete and sign the certification section, deliver the form to Princeton's Quality Assurance (QA) Representative, and hold shipment until Princeton signs and returns the form, authorizing shipment. A copy of the fully executed form shall accompany each full or partial shipment.

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**6.8 EQUIPMENT/MATERIAL IDENTIFICATION and STATUS**

Material and equipment identification shall be maintained throughout the program and be traceable to records. Status of acceptability shall be readily discernible through the Subcontractor's use of tags, stamps, serial numbers or other positive means.

**6.9 CALIBRATION of TEST and MEASURING EQUIPMENT**

Inspections and tests shall be performed using properly calibrated measuring and test equipment. Calibration standards shall be traceable to the National Institute for Standards and Technology (NIST) or equivalent acceptable to PPPL and shall not be used for shop inspections, but instead be protected against damage or degradation.

**6.10 CONTROL of SPECIAL PROCESSES**

Subcontractor shall use trained and qualified personnel and qualified written procedures in accordance with specified requirements for the performance of certain special processes, including but not limited to, FSW, dimensional inspection, non-destructive examination, etc. Copies of special process procedures and personnel qualifications shall be submitted to PPPL for review and approval a minimum of ten (10) working days prior to performance of the work.

6.10.1 Personnel performing non-destructive testing shall be certified to Level II, at minimum, in accordance with ASNT SNT-TC-1A.

6.10.2 FSW Personnel shall be qualified in accordance with section 5.3.

**6.11 PPPL RECEIVING and INSPECTION**

PPPL will perform Receiving Inspection on items supplied by Subcontractor.

**7 DELIVERABLES**

**7.1 PRIOR to FABRICATION RELEASE**

7.1.1 MIT/QA Plan, and Associated Procedures

The Supplier shall provide their MIT/QA plan and all associated procedures (section 3.1) at least 10 workdays to PPPL for approval prior to beginning fabrication. Procurement of materials may start prior to plan approval.

**7.2 IN PROCESS DELIVERABLES:**

7.2.1 Material Certifications

A copy of the material certifications (section 6.7.1) shall be submitted to PPPL as soon as the sub-contractor has determined that the material is acceptable for use.

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**7.2.2 NDE Personnel Certifications**

A copy of the certifications (section 6.10) shall be submitted to PPPL at least 10 work days prior to testing.

**7.2.3 Weekly Reports**

Brief weekly status reports covering technical, administrative, and quality activities as well as problems or issues and including progress photographs shall be submitted as e-mail. The report shall be submitted to PPPL on each Friday following subcontract award.

**7.2.4 Monthly Reports**

Subcontractor shall submit via e-mail, to be received by PPPL by the third week of each month, a report that includes a schedule of major tasks to be performed under the Subcontract, and actual/projected completion dates. Include a narrative explanation of schedule delays.

**7.3 INNER TF CONDUCTOR ASSEMBLY DELIVERY**

**7.3.1 Final Product**

The manufacturer shall deliver to PPPL fifty-five (55) completed Inner TF conductor assemblies. The TF conductor Assemblies shall conform to this SOW and the applicable drawings.

**7.3.2 Shipping Release Form**

Prior to each shipment, the Subcontractor shall submit to PPPL a completed and signed "Product Quality Certification and Shipping Release" form (Attachment 1 of this SOW), along with a copy of the Process History (ref. Paragraph 6.7), and received from PPPL written acceptance to ship. Shipping shall not commence until subcontractor receives PPPL's written acceptance to ship.

**7.3.3 Process History**

Subcontractor shall provide to PPPL one (1) "paper" copy or one (1) "electronic" copy of the Process History, which includes a compilation of documents, detailing the objective evidence of the acceptability of the work performed. The Process History shall be complete and available at the time the Subcontractor requests Release for Shipment. The Process History shall include as a minimum, but not be limited to:

7.3.3.1 Material certifications

7.3.3.2 Radiographs and radiograph interpretation reports for each FSW joint

7.3.3.3 Ultra-sonic inspection results for each FSW joint

7.3.3.4 Completed nonconformance reports

7.3.3.5 Validated inspection and test reports, including inspection measurements and any digital photographs

7.3.3.6 Completed shop travelers or process sheets with digital photographs.

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7.3.3.7 Personnel qualifications for Special Processes (Non-Destructive Examination, etc)

7.3.3.8 Signed Shipping Release

## 8 SHIPPING STORAGE AND HANDLING

8.1 The subcontractor shall provide a shipping container adequate to maintain the geometry of the Inner TF Conductor Assembly within tolerances and to guarantee that is not damaged in transit.

8.2 The shipping container shall be of wood construction and built for moving on rollers, handling with slings from overhead cranes and forklifts.

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EXHIBIT 1: Shipping Release Form

**PRINCETON UNIVERSITY PLASMA PHYSICS LABORATORY—PPPL  
PRODUCT QUALITY CERTIFICATION & SHIPPING RELEASE**

To be completed by supplier and submitted to PPPL with the Documentation package. Shipment (full or partial) is not authorized until PPPL returns this form signed.

<b>Completed by Supplier</b>	PPPL SUBCONTRACT/ ORDER #	ITEM #(s)	QUANTITY SHIPPED
	ITEM DESCRIPTION	SUPPLIER REFERENCE #	SHIPMENT #
	<b>SUPPLIER'S CERTIFICATION</b>		
<p>This is to certify that the products and services identified herein have been produced under a controlled quality assurance program and are in conformance with the procurement requirements including applicable codes, standards and specifications as identified in the above-referenced documents unless noted below. Any supporting documentation will be retained in accordance with the procurement requirements.</p>			
<p>SIGNED: _____ DATE: _____</p>			
<p>TITLE: _____ COMPANY: _____</p>			

<b>Completed, signed, and returned by PPPL before shipment</b>	<b>PPPL (AUTHORIZED REPRESENTATIVE) SHIPPING RELEASE</b>	
	<p>This is to certify that evidence supporting the above Supplier's Certification statement has been reviewed and no product/service nonconformances from procurement requirements have been identified unless noted below. This product/service is hereby released for shipment.</p>	
	<p>This section serves as the Quality Assurance release for the above described product for shipment. It does not constitute an acceptance thereof and does not relieve the Supplier, Manufacturer or Contractor of any and all responsibility or obligation imposed by the purchase contract. It does not waive any rights the Purchaser may have under the purchase contract, including the Purchaser's right to reject the above described material upon discovery of any deviations from requirements of the purchase contract, drawings and specifications.</p>	
	NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS:	
	REMARKS/PRODUCT SERIAL NUMBERS:	
BY PPPL QA REPRESENTATIVE (OR DESIGNEE)	DATE	

*Rev. 1 November 15, 2010*