



# ENG-006 - SPEC - TECHNICAL SPECIFICATION

## NSTX-U PLASMA SPRAY CERAMIC COATING ON METALLIC SUBSTRATES

*NSTXU\_1\_SPEC\_100*

*Rev. 1*

Work Planning #:

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NSTXU\_1\_SPEC\_100

## TECHNICAL SPECIFICATION

FOR

### *NSTX-U PLASMA SPRAY CERAMIC COATING ON METALLIC SUBSTRATES*

CAT: ☒ A1 ☐ A2 ☐ A3

UNIQUE IDENTIFIER: NSTXU\_1\_SPEC\_100

REFERENCE WORK PLANNING NO:

REVISION 1

DATED *02/04/2020*

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**NSTXU\_1\_SPEC\_100**

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## RECORD OF CHANGES

Rev.	Date	Description of Change(s)
0	01/15/20	Initial release
1	02/04/20	Change of title name in DMS

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**LIST OF ACRONYMS**

NSTX	= <u>N</u> ational <u>S</u> pherical <u>T</u> orus e <u>X</u> periment	PTR	= <u>P</u> inceton <u>T</u> echnical <u>R</u> epresentative
PPPL	= <u>P</u> inceton <u>P</u> lasma <u>P</u> hysics <u>L</u> aboratory	QA	= <u>Q</u> uality <u>A</u> ssurance
PP	= <u>P</u> assive <u>P</u> late	TA	= <u>T</u> echnical <u>A</u> uthority
		VV	= <u>V</u> acuum <u>V</u> essel

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## **1.0 INTRODUCTION & SCOPE**

This document describes the plasma sprayed ceramic coating for use in the National Spherical Torus Experiment (NSTX). The ceramic coating is to be used as a high friction surface as well as an insulator. This document serves to outline the general requirements for the ceramic coating, and is meant to be used on an ongoing basis for multiple parts and applications within NSTX.

## **2.0 APPLICABLE DOCUMENTS**

- [1] ASTM C633 , Standard Test Method for Adhesion or Cohesion Strength of Thermal Spray Coatings
- [2] AWS C2.16/C2.16M, Guide for Thermal Spray Operator Qualification
- [3] ASTM D257, Standard Test Methods for DC Resistance or Conductance of Insulating Materials

The revisions of the applicable documents in place at the time of issuance of this technical specification shall apply.

## **3.0 RESPONSIBILITIES**

### **3.1 PRINCETON PLASMA PHYSICS LABORATORY**

#### **3.1.1 PROJECT MANAGEMENT & OVERSIGHT**

PPPL will designate a technical contact, the Princeton Technical Representative (PTR) and a Quality Assurance (QA) contact as well as alternate contacts for those individuals at the time of contract award.

#### **3.1.2 PPPL DELIVERABLES TO SUBCONTRACTOR**

3.1.2.1 Any drawings of parts calling out this specification.

3.1.2.2 Approved PPPL Shipping Release Form (Attachment A) prior to shipment.

### **3.2 SUBCONTRACTOR**

#### **3.2.1 PROJECT MANAGEMENT**

The Subcontractor shall provide a single-point of contact and an alternate for any communication between PPPL and the Subcontractor.

The Subcontractor shall furnish a comprehensive schedule and timeline for coating and testing of parts with milestones clearly identified.

#### **3.2.2 DELIVERABLES TO PPPL**

The Subcontractor is responsible for providing the physical and document deliverables in § 12.0 to PPPL when noted and as required.

#### **3.2.3 MATERIAL ACQUISITION**

Unless otherwise noted, the Subcontractor shall be responsible for purchasing all raw and shop materials necessary for the coating of all components, including materials for jigs or fixtures.

#### **3.2.4 MANUFACTURING**



The Subcontractor is responsible for the coating of all furnished components referenced on the requisition and drawings supplied by PPPL, and any other instructions/standards/etc., referenced in this Technical Specification.

#### 3.2.5 DIMENSIONAL VERIFICATION

The Subcontractor shall verify all dimensions noted in the requirements § 4.1

#### 3.2.6 SHIPPING RELEASE FORM

Before shipping, the Subcontractor must complete the Shipping Release Form, see attachment A, and send it to PPPL's QA department. The Subcontractor shall not ship the physical deliverables back to PPPL until PPPL returns the signed form and provides written authorization.

### **4.0 REQUIREMENTS**

#### **4.1 DESIGN PERFORMANCE REQUIREMENTS**

The coating must meet the following performance requirements:

- 4.1.1 The material shall be  $\text{Al}_2\text{O}_3$ , 99.4% minimum, and have an appropriate shear-enhancing bond coat to a total thickness, including the bonding layer as defined on the drawing notes.
- 4.1.2 The Subcontractor shall submit the chemical composition of the coating, and shall propose the shear-enhancing bond coat for PPPL approval prior to use.
- 4.1.3 The coating shall be applied to all surfaces indicated on the drawing. Coating shall not be applied to any surfaces not indicated.
- 4.1.4 The surface roughness on the outer surface shall be between 125 and 400  $\mu\text{-in}$  RMS.
- 4.1.5 The coating shall provide a level of electrical insulation as specified on the drawing.

#### **4.2 IDENTIFICATION AND MARKING**

Identification of coated components shall be maintained. The Subcontractor shall assign a serial number to each coated component. The coated components shall be individually bagged and tagged with the drawing number and serial number.

#### **4.3 WORKSMANSHIP**

General shop cleanliness and housekeeping shall be adequately maintained to prevent contamination of the coating.

### **5.0 TESTING AND INSPECTIONS**

#### **5.1 GENERAL REQUIREMENTS**

Each coated component has several acceptance tests required. These checks and their associated data and reports shall be furnished to PPPL along with the Product Quality Certification and Shipping Release Form (Attachment A) prior to shipment of the coated components. Each test will be completed on 100% of the coated parts, except destructive testing and adhesion testing.

##### 5.1.1 ELECTRICAL INSULATION

The electrical acceptance test shall be performed with two soft electrodes that conform to the surfaces of the coated part, as described in [3]. Acceptable parts will show a resistance versus applied voltage between each soft electrode and the parent part, as called out on the drawing referencing this specification.

#### 5.1.2 DIMENSIONAL INSPECTION

Coating thickness shall be verified using a dry film thickness (DFT) gauge. Alternate methods of coating thickness verification may be acceptable with PPPL review and approval. These measurements shall be used to verify the coating thickness. The surface roughness shall be measured using a profilometer.

#### 5.1.3 ADHESION TESTING

Adhesion of the ceramic coating shall be tested by the supplier using methods defined in [1] or an alternate method (agreed upon with PPPL) on a sampling basis listed below. Adhesion tested parts shall be disposed of, and do not factor into the total quantity to be coated and delivered to PPPL. Alternatively, coupons may be used along with batch sizes for adhesion testing (if agreed upon with PPPL).

Lot or Batch Size	Sample Size
2 to 9	1
10 to 19	2
20 to 29	3
30 to 49	4
50 to 99	6
100 to 149	8
150 to 249	10
250 to 500	15
501 to 1,200	25

Note: For the purposes of executing the above defined sampling plan, a lot/batch shall be defined as a quantity of parts intended to have uniform character and quality, within specified limits, and is produced according to a single manufacturing order during the same cycle of manufacture.

#### 5.1.4 VACUUM BAKING

The coated parts will be vacuum baked by PPPL to 600 degrees Celsius. The rate of temperature rise during the acceptance test will not exceed five degrees Celsius per minute. Acceptable parts will not show any visual peeling or cracking.

#### 5.1.5 DESTRUCTIVE TESTS

A number of sacrificial coated parts or representative coupons, as agreed upon with PPPL shall be sectioned, in two places for metallographic sections with acceptance criteria as defined by the Technical Representative based on the substrate.

## 5.2 SUPPLIER HOLD POINTS

PPPL defines an event, referred to as Hold Point, which requires the Subcontractor to halt manufacturing operations pending PPPL approval to continue:

- Hold Point – A point during the process whereby the Subcontractor shall halt activities and submit documentation, items, or materials to PPPL as defined within the contract documents. PPPL will review the submittals and provide approval to continue.

The following Hold points apply to this contract:

- 5.2.1 Successful completion of a Manufacturing Readiness Review
- 5.2.2 First article coating, which shall be sacrificial and be subject to all testing and inspections outlined in §5.1
- 5.2.3 Approval of process history and release for shipment (refer to §§ 8.17 & 8.18)

## 6.0 QUALIFICATIONS

### 6.1 GENERAL REQUIREMENTS

Relevant personnel are required to be trained in the operation of all equipment used in the execution of the work defined within this Technical Specification. A copy of training records/certifications for personnel shall be provided, and approved by PPPL, in writing, before the coating work begins. The training must be up-to-date and maintained by each individual throughout the fabrication performed in the execution of this scope. The certifications shall be per the referenced standards listed in § 2.0, or by a PPPL approved alternative.

## 7.0 ENVIRONMENT, SAFETY, AND HEALTH

### 7.1 SAFETY

Work shall be performed under an established safety program including documented policies. Workers shall be trained to these policies and procedures and records of their training shall be kept.

### 7.3 SAFETY OF VISITING PPPL REPRESENTATIVES

In the event that PPPL personnel visit the Subcontractor's premises, the Subcontractor shall work with the PPPL PTR and PPPL visitors to identify the hazards of the work to be reviewed and the hazards of unrelated work in the facility that could affect the 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.

### 7.4 SAFETY AND HAZARD MITIGATION PLAN

A Job Hazard Analysis (JHA) shall be completed prior to the execution of the tests outlined in this plan if a test is conducted at PPPL. The JHA shall identify the hazards of the test and the safety protocols (including but not limited to training and personal protective equipment) that will apply to protect workers and visitors from the hazards.

## 8.0 QUALITY ASSURANCE REQUIREMENTS

### 8.1 GENERAL REQUIREMENTS

The Subcontractor shall immediately contact PPPL regarding non-compliance or damage to any part or coating mistakes. Details of the damage, including pictures, shall be discussed

and documented, and a mitigation plan shall be developed. Work shall not resume on the damaged items, until an NCR is approved and issued by PPPL.

Material(s) and/or product(s), including those components, parts, and materials that are permanently installed into systems, sub-systems, and/or assemblies, etc. furnished under this purchase order/subcontract shall be new. Parts and components that have been rebuilt, refurbished, or modified are specifically prohibited unless approved by PPPL in writing. Evidence of deliberate misrepresentation of any item(s)/component(s)/material(s) provided under this order may result in an investigation by the Office of the Inspector General, U.S. Department of Energy. Examples of such misrepresentation include the following:

- Remanufactured, rebuilt, or used parts represented as new
- Counterfeit parts (fraudulently labeled or marked with another manufacturer's name).
- Misrepresented parts.

## 8.2 SUBCONTRACTOR'S RESPONSIBILITY FOR CONFORMANCE

Neither PPPL's review and/or approval of Subcontractor's documents nor PPPL's inspection of Subcontractor's items or services shall relieve the Subcontractor of responsibility for full compliance with requirements of the purchase order/contract.

## 8.3 PERFORMANCE AND DOCUMENTATION OF INSPECTIONS AND TESTS

Each item to be delivered to PPPL shall be inspected and tested by the Subcontractor to verify that they meet PPPL's requirements. All produced parts must be inspected and tested unless an alternate plan is agreed upon with PPPL in writing. Results shall be documented and reported to PPPL. Any exceptions to PPPL requirements must be approved by PPPL in writing.

Inspection/test report(s) shall indicate the results of all tests and compliance with all drawing notes. Actual values for all drawing dimensions, including Basic, but excluding Reference, must be reported (if applicable). Inspection/test reports shall include reference to the PO #, drawing #/Rev., & serial number of the unit being reported (if applicable). Each reported dimension or feature must be traceable to the drawing either by reference to the drawing sheet and zone or by use of an accompanying bubbled drawing. The tool/equipment used for the measurement/test of each dimension or feature shall be identified. The completed report shall be signed and dated by an authorized representative of the Subcontractor.

## 8.4 INSPECTION / SURVEILLANCE / AUDIT 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 procurement for the purposes of inspection, surveillance, audit and/or obtaining any required 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.

## 8.5 SUBCONTRACTOR QUALITY ASSURANCE PROGRAM

The Subcontractor shall establish and maintain an effective Quality Assurance Program to assure that the Subcontractor's work meets the required level of quality and is performed in accordance with contractual requirements.

Subcontractor's quality assurance 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.

#### 8.6 MANUFACTURING, INSPECTION AND TEST PLAN

The Subcontractor shall submit a Manufacturing, Inspection and Test (MIT) plan for PPPL approval prior to the start of manufacture. The MIT must delineate the sequence of all processes and operations affecting quality, including in-process and final acceptance inspections and tests. The plan shall identify parts; show their integrated flow into end items; identify critical manufacturing operations; and show inspections and the characteristics/dimensions to be inspected. The Plan may include flow chart(s), Process Sheets, Shop Travelers, and inspection sheets, etc. Equipment to be used for all fabrication, inspections and tests shall be specified. The contents of the MIT Plan shall include, at a minimum:

- Equipment to be used for all coating, inspections and tests
- Part(s) being coated.
- Critical manufacturing operations (e.g. cleaning, masking, etc.) and their sequence
- Inspections and the characteristics/dimensions to be inspected
- Packaging and shipping methods

Revisions or changes to the approved MIT or its subordinate documents such as flow chart(s), process and inspection sheets, or travelers shall be reviewed and approved by PPPL prior to use.

#### 8.7 MANUFACTURING READINESS REVIEW

The Subcontractor shall prepare for and participate in a Manufacturing Readiness Review with PPPL at either the Subcontractor's facility or by phone and video conference prior to the start of work. This review shall include the proposed process, as defined in the MIT, in order to effectively execute the tasks outlined in this Technical Specification, including equipment, work flow and scheduling. As part of this review the Subcontractor shall be prepared to provide/discuss the necessary deliverables, including but not limited to the following:

- Proposal of shear-enhancing bond coat and chemical composition of coating
- Tooling and fixture drawings and hardware
- MIT Plan and associated procedures
- Personnel Certification/Qualification records
- Calibration records

All of the above required materials are to be submitted to PPPL a maximum of two (2) weeks after contract award. The Subcontractor shall be responsible to respond to and/or execute any comments provided by the PTR prior to the scheduled MRR. After successful completion of the MRR, PPPL will authorize the start of fabrication in writing.

#### 8.8 CHANGES TO PPPL APPROVED DOCUMENTS

Revisions or changes by the Subcontractor to documents approved by PPPL shall be reviewed and approved by PPPL prior to use.

## 8.9 MEASURING AND TEST EQUIPMENT/CALIBRATION

Inspections and tests shall be performed using properly calibrated measuring and test equipment. The Subcontractor shall maintain equipment calibration throughout the duration of the scope of work to fulfill those items delivered by the Subcontractor to PPPL. The calibration standards must be traceable to the National Institute of Standards and Technology (NIST) or equivalent. Where such standards do not exist, the basis used for calibration shall be documented. Standards used for calibration shall not be used for shop inspections, but instead shall be protected against damage or degradation. A copy of the most recent calibration certificates for each of the machining, metrology and other appropriate equipment or instruments used for critical measurement or manufacturing processes shall be submitted for PPPL approval, at least one week prior to beginning fabrication.

## 8.10 NONCONFORMANCES & CORRECTIVE ACTIONS AND NOTIFICATION

Nonconforming items or services shall be positively identified, and, where possible, segregated to prevent use. The Subcontractor shall document each nonconformance. The written approval of PPPL is required in the form of a signed NCR prior to the use or continued fabrication of the nonconforming item or service. The Subcontractor's system shall provide not only for timely resolution of nonconformance but also for analysis of nonconformance to determine causes and to implement appropriate and effective corrective actions (determination of cause and corrective action may be waived by PPPL PTR).

## 8.11 SUBMITTAL OF MATERIAL CERTIFICATIONS

The Subcontractor shall submit manufacturer's Certified Material Test Reports (CMTRs) showing actual relevant chemical, mechanical, and electrical properties of the coating material intended for the execution of this technical specification. The CMTRs shall be traceable to the material and submitted prior to procuring the material.

## 8.12 INSPECTION AND TEST CONTROL

Inspections and tests shall be performed by personnel independent of those doing the work inspected or tested. They shall be performed in accordance with written procedures referencing criteria for acceptance or rejection. Adequate records shall be maintained and available for PPPL's review.

## 8.13 PPPL INSPECTION

PPPL reserves the right to inspect items as they are packaged prior to shipment. PPPL will perform Receiving Inspection on items or services supplied by Subcontractor, using either a sampling plan or 100% inspection. Discrepant items or services may be rejected and returned to Subcontractor.

## 8.14 EQUIPMENT/MATERIAL IDENTIFICATION AND STATUS

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

## 8.15 CONTROL OF SPECIAL PROCESSES

Subcontractor shall use trained and qualified personnel and qualified written procedures in accordance with specified requirements for the performance of Special Processes, including but not limited to coating, plating, heat treatment, and nondestructive examination. Copies of special process procedures and qualifications shall be made available to PPPL for acceptance upon request.

## 8.16 PROCESS SEQUENCE



The Subcontractor shall maintain a system to define the sequence and document the performance of manufacturing, inspection, installation, and test activities. These shall provide for signoff and date by designated inspection personnel at specified process, inspection, and test points and shall be traceable to the items.

#### 8.17 SUBMITTAL OF COMPLETED PROCESS HISTORY

Subcontractor shall provide PPPL, along with the completed Release for Shipment Form (§ 8.18), a digital copy of the Process History. The Process History is a compilation of documents detailing the objective evidence of the acceptability of the work performed, and shall include as a minimum the following:

##### 8.17.1 CERTIFICATE OF CONFORMANCE

Subcontractor's Certificate of Conformance, signed by the Subcontractor's Quality Manager (or equally authorized Subcontractor Representative), stating that the work performed conforms in every respect to PPPL physical configuration and functional inspection/test requirements and that personnel performing or interpreting the results of special processes (i.e., welding, soldering, electronic assembly, brazing, nondestructive examination, etc.) were properly trained and qualified. Where the Subcontractor has used PPPL-furnished material, such certification shall also include the statement: "Material furnished by PPPL has been inspected by the Subcontractor and used by the Subcontractor as specified by PPPL with no unauthorized substitutions".

##### 8.17.2 MATERIAL CERTIFICATIONS

Manufacturer's Certified Material Test Reports (CMTRs) showing actual relevant chemical, mechanical, and electrical properties of materials used and providing traceability to the delivered items.

##### 8.17.3 INSPECTION & TEST REPORTS

Copies of all inspection and test reports.

##### 8.17.4 NONCONFORMANCE REPORTS

Copies of any processed non-conformance reports (§ 8.10 – As applicable).

#### 8.18 SUBMITTAL OF COMPLETED RELEASE FOR SHIPMENT FORM

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

### 9.0 SHIPPING STORAGE AND HANDLING

The Subcontractor shall be responsible for packing, crating, and shipping the required deliverables. A Packing and Shipping plan shall be included in the MIT.

### 10.0 ATTACHMENTS

- A. *Product Quality Certification & Shipping Release Form*

### 11.0 DOCUMENTATION & DELIVERABLES

RFI / PO / Subcontract / BOA / BPA #: \_\_\_\_\_

*Table 1. List of Required Meetings between the Subcontractor and PPPL*

#	Meetings Required	Date Required	Complete (✓)
1	Manufacturing Readiness Review	PS	
2	First article hold point, manufacturing review	D	
3	Destructive testing as outlined in §5.1.5	D	

*Exceptions: None*

*Table 2. List of Subcontractor Document Deliverables*

#	Document Deliverables Required	Date Required	Format	Storage Location	Rev'd (✓)
1	Personnel training/certification records per § 6.1	PS, N	E	Ops Center	
2	Calibration records per § 8.9	PS, N	E	Ops Center	
3	Manufacturing, Inspection & Test Plan per § 8.6	PS, N	E	Ops Center	
4	Certified Material Test Reports (CMTRs) per § 8.11	PS, N	E	Ops Center	
5	Process History per § 8.17	BS	E	Ops Center	
6	Product Quality Certification & Shipping Release Form per § 8.18	BS, N	E	Ops Center	

***Legend***

*N = Notice to Proceed Requirement*

*PS = Prior to Start of Work*

*D = During Work/As Required*

*C = Project Completion*

*BS = Before Shipment*

*P,E = Paper or Electronic*

Princeton Technical Representative: \_\_\_\_\_

*(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)).*



**ATTACHMENT A. 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.

Completed by Supplier	PPPL SUBCONTRACT/ ORDER #	ITEM #(s)	QUANTITY SHIPPED
	ITEM DESCRIPTION	SUPPLIER REFERENCE #	SHIPMENT #
	<b><u>SUPPLIER'S CERTIFICATION</u></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>		

Completed, signed, and returned by PPPL before shipment	<b><u>PPPL (AUTHORIZED REPRESENTATIVE) SHIPPING RELEASE</u></b>	
	<p>This is to certify that evidence supporting the above Supplier's Certification statement has been reviewed and no product/service non-conformances 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

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