National Compact Stellarator Experiment (NCSX)

Statement of Work

Vacuum Vessel Manufacturing Development and Prototype Fabrication

NCSX-SOW-121-01-00

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Record of Revisions

Revision	Date	Description of Changes
Rev. 0	11/14/02	Initial release

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1 GENERAL INFORMATION

1.1 INTRODUCTION

In preparation for fabrication of critical components for the National Compact Stellarator Experiment (NCSX), PPPL is initiating manufacturing development activities. This Statement of Work is for one of these activities – manufacturing development for the vacuum vessel, including fabrication of a prototype segment of the vessel. This vessel, fabricated of UNS 06625, is toroidal (donut-shaped) in major diameter, but highly shaped in the poloidal (short) direction.

NCSX is the first of a new class of stellarators known as "compact stellarators." 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 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 stellarator design.

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 2007. Further description of the NCSX can be found at http://www.pppl.gov/ncsx/.

1.2 BACKGROUND

Figure 1 is a sectional view of the NCSX device showing its major components. Note in particular the vacuum vessel, which is the subject of this Statement of Work. In Figure 2, all but the vacuum vessel and its ports are removed from this drawing so the vessel and its ports can be clearly viewed. Note the symmetry in the vessel. It is comprised of 3 identical 120º vessel segments in the toroidal direction. Furthermore, Figure 3 shows that each segment is symmetric around its vertical midplane – the right 60º half segment is identical to the left half segment, but is inverted. Consequently, the vessel consists of six identical half segments. Figure 3 shows the three ports which will be installed at the factory. The others will be field installed at PPPL by PPPL; this is necessary to allow assembly of the other machine components around the vessel. The figures below are only for illustration and should not be used in the performance of this Scope of Work.

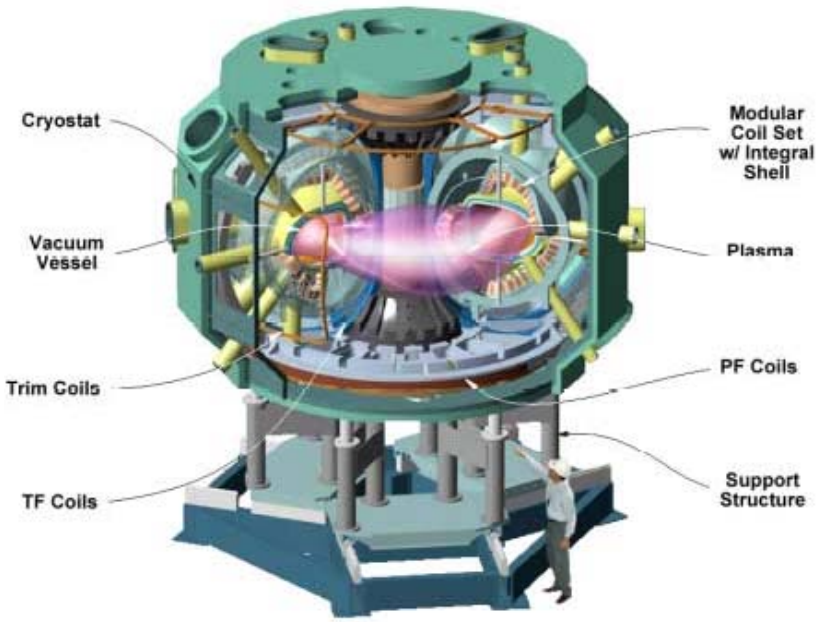

Figure 1 - The NCSX device and definition of its major components

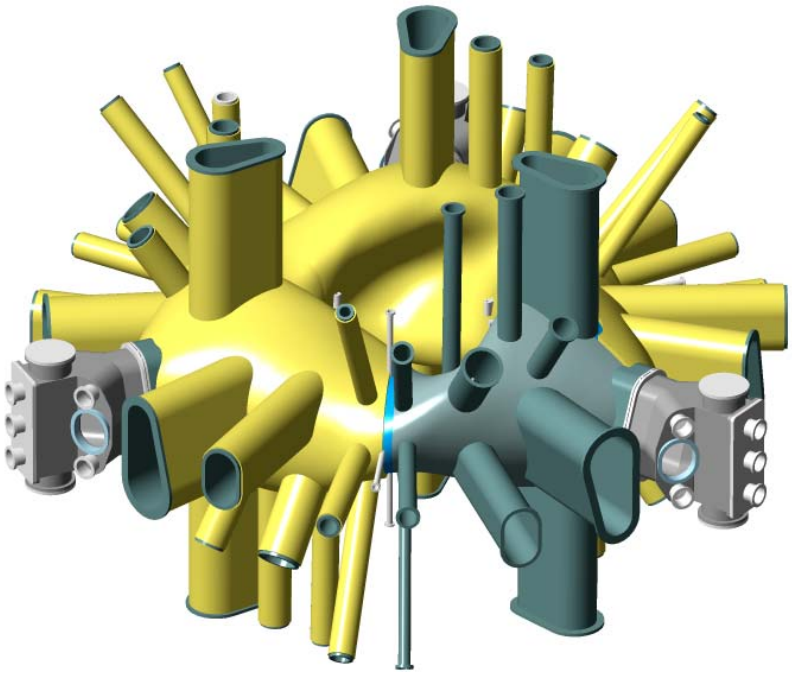

Figure 2 - NCSX with all components removed except the vacuum vessel and its ports

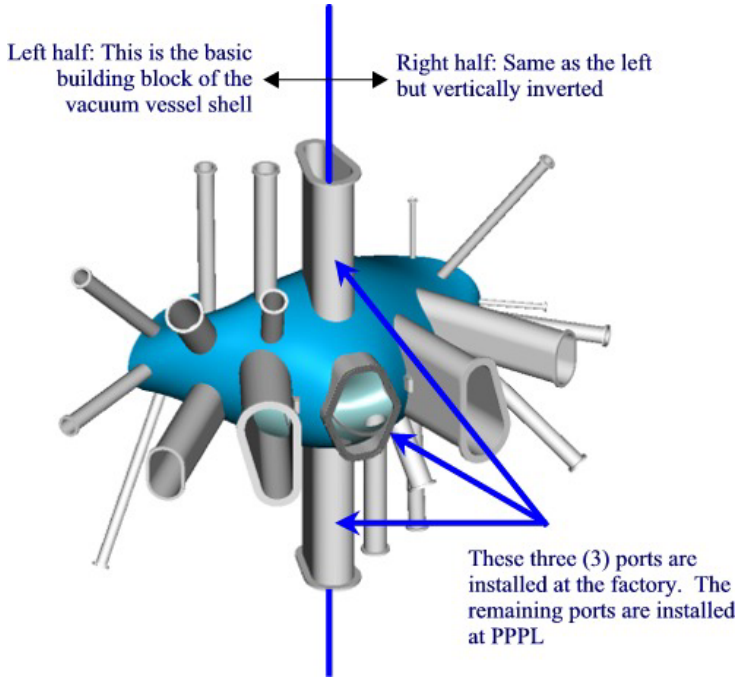

Figure 3 - Vacuum vessel sub-assembly with all ports installed

1.3 SCOPE

This SOW defines the manufacturing development activities for the 120º Vacuum Vessel Sub-Assembly (VVSA) and the production of a full-scale 20º prototype vacuum vessel segment (PVVS). The PVVS is defined in Specification NCSX-CSPEC-121-01-00; the VVSA is defined in Specification NCSX-CSPEC-121-02-00.

This SOW focuses on the critical aspects of manufacturing the vessel: forming of the complex geometry; accurate location and fabrication of vessel ports; tolerance control; producing vacuum quality welds with low distortion; maintenance of low magnetic permeability; location and repair of vacuum leaks in welds, and timely, low-cost fabrication of the vessel. These activities are meant to give the Subcontractor the experience needed to develop and submit a firm fixed price and schedule proposal for producing the three (3) VVSA units.

There are three groups of activities and deliverables:

1. Manufacturing studies and budgetary cost estimate of the VVSA. This information is required to support the Preliminary Design Review for the Vacuum Vessel.

2. PVVS Manufacture. A prototype 20º vessel segment is required to support the Final Design Review for the Vacuum Vessel and to demonstrate manufacturing capabilities.

3. A Firm Fixed Cost and Schedule Proposal for Production of Three (3) VVSA's. As a final deliverable, the Subcontractor shall provide a firm fixed cost and schedule proposal for the three (3) production articles.

The due dates for these deliverables are specified in Section 5.

2 APPLICABLE DOCUMENTS

2.1 PRODUCT SPECIFICATION FOR THE PVVS

The product specification for the Prototype Vacuum Vessel Segment (NCSX-CSPEC-121-01-00) is the complete specification for the 20º PVVS. This specification is available on the PPPL Procurement Web at http://oorm-1.pppl.gov/public/procurement/. This version should be used only for planning and proposal preparation. A revised version, which will incorporate improvements and comments generated during the proposal phase, will be provided prior to the performance of this Statement of Work.

The specification identifies applicable Pro/Engineer drawings and models that define the geometry of the PVVS. Preliminary drawings and models of the PVVS (identified in NCSX-CSPEC-121-01-00, Section 3.3.1) will be available on the Vendor FTP server (ftp://ftp.pppl.gov/pub/ncsx/manuf/index.htm) in late November 2002. These should be used only for planning and proposal preparation. Currently, the exact shape of the vessel is being refined. The changes are expected to be minor with respect to manufacturing issues (i.e., slight changes of the vessel shape required to obtain proper clearances, and a likely angular orientation change in the end flanges.) Drawings and models that are released for prototype fabrication will be provided prior to the performance of this Statement of Work.

2.2 PRODUCT SPECIFICATION FOR THE VVSA

The product specification for the VVSA (NCSX-CSPEC-121-02-00) is the complete specification for the 120º VVSA. This specification will be similar in content to the specification for the PVVS (NCSX-CSPEC-121-01-00) and will be provided prior to the performance of this Statement of Work. A revised version of this specification will be provided late in 2003, after the PVVS is delivered. This later version will include any revisions made as a result of knowledge gained during the manufacturing development activities and prototype manufacture. This later version is to be used by the Subcontractor in preparation of a firm fixed price bid and schedule proposal and will identify the Pro/Engineer drawings and models that define the geometry of the VVSA. Preliminary drawings and models of the VVSA, to be used

only for planning and proposal preparation, will be available on the Vendor FTP server (ftp://ftp.pppl.gov/pub/ncsx/manuf/index.htm) in late November 2002. Drawings and models that are to be used for the performance of this SOW will be provided prior to the performance of this Statement of Work. Drawings and models that are released for fabrication will be provided for the Subcontractor to develop a firm fixed price and schedule proposal in late 2003, after the PVVS is delivered.

3 WORK REQUIREMENTS

The tasks described below should be performed approximately in the order indicated. It is expected that the Subcontractor may be working on several in parallel. Schedule requirements are described in Section 5.

3.1 MANUFACTURING DEVELOPMENT ACTIVITIES FOR THE VVSA

Manufacturing development activities will be conducted to support the Preliminary Design Review (PDR) for the Vacuum Vessel (WBS 12). Manufacturing methods for fabricating the VVSA will be identified. Recommendations for improving the design of the vacuum vessel and performing additional manufacturing development activities will be solicited from the Subcontractor. Preliminary Manufacturing, Inspection, and Test (MIT) and Quality Assurance (QA) Plans will be developed that document the steps required for the manufacture, inspection, and testing of the VVSA's. These documents will provide the basis for the budgetary cost and schedule estimates to be developed in support of the PDR.

3.1.1 Manufacturing Methods for Fabricating the VVSA

The Subcontractor shall describe the proposed manufacturing methods for forming, machining and finishing, welding and weld repair, heat treatment, vacuum testing, and inspecting the VVSA and accomplishing the specified Quality Assurance provisions.

3.1.2 Subcontractor Recommendations

The Subcontractor may recommend changes to the design or specification that could simplify manufacture of the VVSA, reduce costs, improve the fabrication schedule, or reduce risk. The Subcontractor may also recommend additional manufacturing development activities to reduce costs, improve the fabrication schedule, or reduce risk. PPPL reserves the right to accept or reject any or all of the Subcontractor's recommendations, even in the event that the subcontract awarded is to another subcontractor. Additional manufacturing development activities accepted by PPPL will be set forth in a revised Statement of Work.

3.1.3 Preliminary MIT and QA Plans for the VVSA

The Subcontractor shall produce preliminary Manufacturing, Inspection, and Test (MIT) and Quality Assurance (QA) Plans (per guidelines provided in Section 4.5) for the VVSA meeting the requirements of NCSX-CSPEC-121-02-00. These plans shall, at a minimum, include the following manufacturing steps:

- Forming methods to be used in the fabrication of the shell
- Fabrication methods for the port reinforcements
- Methods for locating, machining, and welding the ports. (The spatial and angular orientation of ports is critical on NCSX.)
- Methods of controlling distortion of the vessel shell and maintaining the required tolerances
- Welding and NDE
- Vacuum testing (both to locate leaks in welds and verifying leak rate and base pressure)
- Cleaning and surface finishing operations
- Measurements of the complex formed surfaces and comparison with the reference Pro/Engineer model
- Magnetic permeability control and verification
- Quality assurance plans that address all of the requirements of this SOW and the applicable specifications

3.1.4 Budgetary Cost and Schedule Estimate for the VVSA

The Subcontractor shall prepare a Budgetary Cost and Schedule Estimate for the VVSA and required tooling in the format provided in the subcontract.

3.2 PVVS MANUFACTURE

3.2.1 MIT and QA Plans for the PVVS

The Subcontractor shall develop MIT and QA Plans for the PVVS that follow the guidelines provided in Section 4.5 and address all the manufacturing steps identified in Section 3.1.3.

3.2.2 PVVS Manufacture

The Subcontractor shall manufacture the PVVS and any required tooling.

3.3 FINAL PROPOSAL

3.3.1 Final MIT and QA Plans for the VVSA

The Subcontractor shall develop final MIT and QA Plans (per guidelines provided in Section 4.5) for the VVSA based on the updated documentation. PPPL will provide an approved specification and associated Pro/Engineer models and drawings that are released for fabrication at least thirty days before the Final MIT and QA Plans for the VVSA are due. These documents are expected to be similar to those used in the performance of this SOW, but with updates based on the knowledge gained during the performance of these manufacturing development activities and the production of the PVVS.

3.3.2 Firm Fixed Cost and Schedule Proposal

The Subcontractor shall prepare a Final Firm Fixed Cost and Schedule Proposal for manufacturing the three (3) production VVSA's and required tooling.

4 GENERAL QUALITY ASSURANCE PROVISIONS

4.1 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 Subcontract 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. The Subcontractor agrees to insert the paragraph above in each lower-tier procurement issued hereunder.

4.2 SUBCONTRACTOR'S 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 contract. The Subcontractor is responsible for assuring that all requirements and restrictions are imposed on any sub-tier suppliers.

4.3 NONCONFORMANCES AND DEVIATIONS

Nonconforming items shall be positively identified, and, where possible, segregated to prevent use. PPPL must be notified of nonconformances within 24 hours. The Subcontractor shall document each nonconformance, identifying the extent and location of the nonconformance 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 nonconformances but also for analysis of nonconformances to determine root causes and to implement appropriate and effective corrective actions.

4.4 SUBCONTRACTOR'S QUALITY ASSURANCE PROGRAM

The Subcontractor shall maintain an effective Quality Assurance Program to assure that the Subcontractor's work meets the required 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.

4.5 MANUFACTURING, INSPECTION, AND TEST (MIT) AND QUALITY ASSURANCE (QA) PLANS

Within the MIT Plan, the Subcontractor shall identify processes and materials and show their integrated flow into end items. The plan shall also identify critical manufacturing operations and inspections and tests. Procedures and/or protocols for contaminant control and cleanliness shall be included with the MIT. Preparing the Plan may include developing a flow chart and generating Process Sheets/Shop Travelers, etc. PPPL may designate selected manufacturing, inspection and/or test operations as mandatory "witness" points based on the MIT plan. Subcontractor shall provide PPPL with a minimum of five (5) working days notice in advance of witness points described in the MIT plan. Such witness points shall be mutually planned to minimize delays.

The Quality Assurance Plan shall describe the specific quality assurance and quality control procedures and practices to meet the requirements of this subcontract and associated

specification. If the requirements of the QA Plan are addressed in the MIT Plan, then a separate QA Plan is not required.

4.6 INSPECTION AND TEST PROCEDURES

Inspections and tests shall be performed in accordance with written procedures referencing criteria for acceptance or rejection. Actual data and accept/reject status for each inspection and test shall be documented.

4.7 DOCUMENT TRACEABILITY AND RECORDS

The Subcontractor shall maintain a system of documentation whereby objective evidence of required operations, inspections, examinations, and tests is systematically compiled, indexed and stored. Such objective evidence may include "travelers"; and material test, certification, inspection, examination, test and nonconformance reports; which shall be complete, legible, and validated by responsible personnel and shall be traceable to subject items.

4.8 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.

4.9 CALIBRATION OF TEST AND MEASURING EQUIPMENT

Inspections and tests shall be performed using properly calibrated measuring and test equipment. Subcontractor shall have in its possession the necessary equipment to perform the required inspections and tests. 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.

4.10 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, welding, dimensional inspection, heat treatment, nondestructive examination, etc. Copies of special process procedures and personnel qualifications shall be submitted to PPPL for review and approval prior to performance of the work.

5 DELIVERABLES

5.1 WEEKLY REPORTS

Brief weekly status reports covering technical, administrative, and Quality activities and notable problems/issues shall be provided to PPPL's Technical and Administrative Representatives by e-mail every Friday during the period of performance.

5.2 MONTHLY EARNED VALUE REPORTS

The Subcontractor shall prepare and submit monthly e-mail reports indicating earned value achieved. This will be a simplified earned value reporting requirement that will require the following actions by the Subcontractor in preparation for earned value reporting:

- The Subcontractor shall submit a resource-loaded (fully loaded dollars only) schedule that clearly indicates the tasks to be accomplished, the time frame over which each task will be accomplished, and the resources assigned to that task. This schedule will be submitted within three (3) weeks of contract award.
- The Subcontractor shall report (e-mail report satisfactory) costs and percent complete monthly. The first report shall be submitted at the end of the first full calendar month of the contract award (i.e., if contract awarded in January 2003, the first report will be provided at the end of February 2003 and cover the entire first period of performance).
- On an exception basis, PPPL will request explanation and proposed corrective action plan for those tasks that develop significant unfavorable schedule or cost variances.

5.3 TECHNICAL REPORTS

Provide one (1) electronic copy in Adobe Acrobat (.pdf) format of all reports. Required reports include the following:

- Report on manufacturing methods for fabricating the VVSA (ref. Section 3.1.1) and Subcontractor recommendations (ref. Section 3.1.2). Due nine (9) weeks after effective date of subcontract.
- Preliminary MIT and QA Plans for the VVSA (ref. Section 3.1.3). Due nine (9) weeks after effective date of subcontract.
- Budgetary cost and schedule estimates for the three (3) production VVSA units (ref. Section 3.1.4). Due nine (9) weeks after effective date of subcontract.
- MIT and QA Plans for the PVVS (ref. Section 3.2.1). Due two (2) weeks before start of fabrication.
- Report on additional manufacturing development activities (if any) accepted by PPPL (ref. Section 3.1.2). Due eight (8) months after effective date of subcontract.

- Final MIT and QA Plans and firm fixed cost and schedule proposal for the three (3) production VVSA units (ref. Section 3.3.1). Due twelve (12) months after effective date of subcontract.

5.4 PROTOTYPE VACUUM VESSEL SEGMENT

Provide a completed PVVS (ref. Section 3.2.2) per this SOW. Packaging and shipping details shall be subject to prior PPPL approval. The completed PVVS and associated documentation (ref. Sections 5.4.1 and 5.4.2) are due eight (8) months after effective date of subcontract.

5.4.1 Shipping Release Form

Prior to shipment of the PVVS, the Subcontractor must have submitted to PPPL a completed and signed "Product Quality Certification and Shipping Release" form (Attachment 1 of this SOW) and received from PPPL written acceptance to ship.

5.4.2 Process History

Subcontractor shall provide to PPPL three (3) "paper" copies or one "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, material certifications and inspection and test reports.

5.4.3 PPPL Receiving and Inspection

PPPL will perform Receiving Inspection on items supplied by Subcontractor.

5.5 TOOLING

All tooling specially fabricated for the performance of this SOW shall become the property of the United States Government. Disposition will be per direction of PPPL.

ATTACHMENT 1

PRINCETON UNIVERSITY
PLASMA PHYSIC LABORATORY—PPPL

PRODUCT QUALITY CERTIFICATION AND SHIPPING RELEASE

PROJECT	ITEM DESCRIPTION			SHIPMENT NUMBER	
PPPL Subcontract / Order No.	REV.	ITEM NO.	SUBCONTRACTOR REFERENCE NO.	REV.	QUANTITY SHIPPED

SUBCONTRACTOR'S CERTIFICATION

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.

SIGNED: _____ DATE: _____

TITLE: _____ COMPANY: _____

PPPL (AUTHORIZED REPRESENTATIVE) SHIPPING RELEASE

This is to certify that evidence supporting the above Subcontractor's Certification statement has been audited and no product/service nonconformances from procurement requirements have been found unless noted below. This product/service is hereby released for shipment.

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 Vendor, Manufacturer or Subcontractor 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.

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS:

REMARKS/PRODUCT SERIAL NUMBERS:

BY PPPL QA REPRESENTATIVE (OR DESIGNEE)	DATE