NCSX
Specification

Product Specification
For the
Vacuum Vessel System Sub-Assembly

NCSX-CSPEC-121-02-01

Draft F

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Record of Revisions

Revision	Date	ECP	Description of Change
Rev. 0			Initial Release

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1 SCOPE

This specification covers the fabrication of three Vacuum Vessel Sub-Assemblies (VVSA's) for the National Compact Stellarator Experiment (NCSX), including the supply of all required labor and materials, machining, fabrication, and factory acceptance inspections and tests. The Seller shall deliver each VVSA to the Princeton Plasma Physics Laboratory (Laboratory) site as a complete subassembly, including a spacer assembly, and separate (unattached) port extension assemblies. All of the labor for the final installation and assembly of the VVSA will be supplied by the Laboratory.

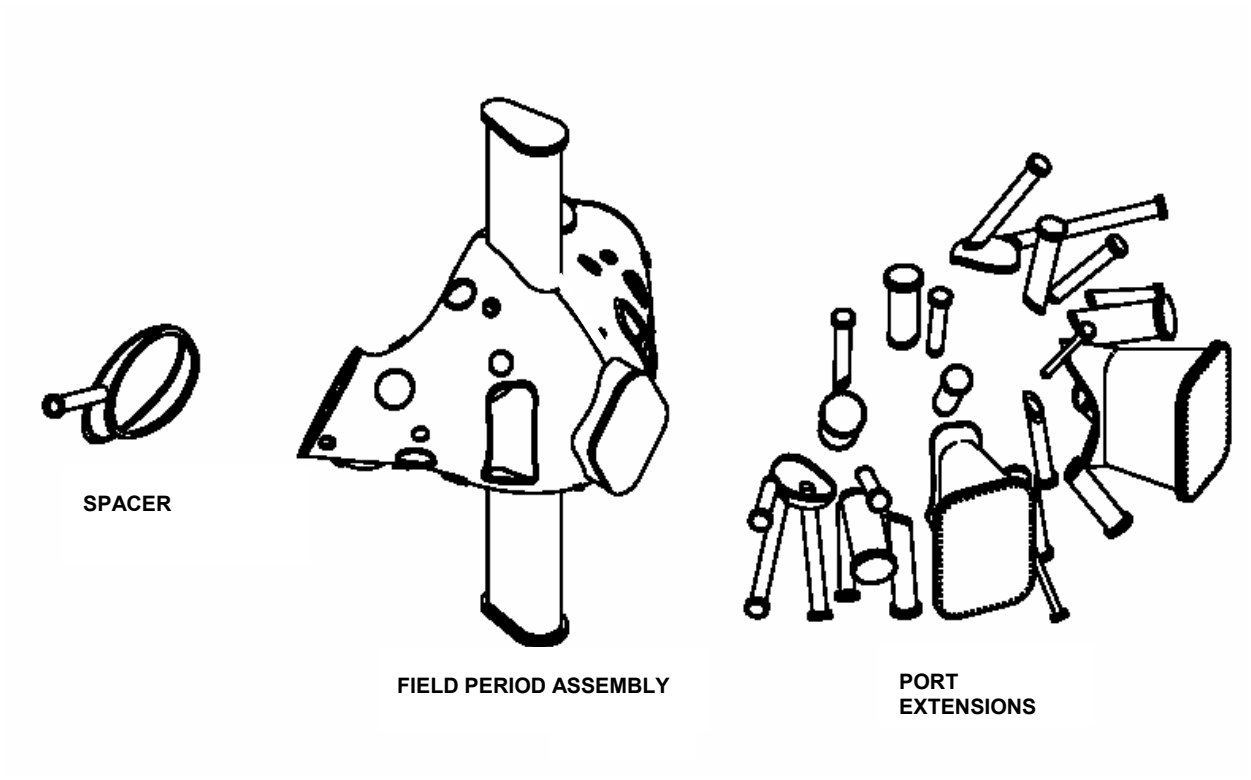

Figure 1 – VVSA Components

2 APPLICABLE DOCUMENTS

The versions of the United States Codes and Standards defined below are to be used in the performance of this work. Other equivalent foreign codes may be proposed:

ASME SFA 5.14 Nickel and Nickel Alloy Bare Welding Rods Electrodes.

American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Sections V (Articles 6 and 9), VIII (Division 1), and IX, 1998 with 2000 Addendum.

ASTM B 443-00 Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219)* Plate, Sheet, and Strip.

ASTM B 444-00 Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219)* Pipe and Tube.

ASTM B 705-00 Standard Specification for Nickel-Alloy (UNS N06625, N06219 and N08825) Welded Pipe.

ASTM B 446-00 Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219)* Rod and Ba.r

ASTM A 240-02 Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.

ASTM A193/A193M-01b Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.

ASTM A1014 Standard Specification for Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service

AWS D1.6: 1999 Structural Welding Code - Stainless Steel, (Paragraph 6.29.1).

American Welding Society (AWS) QC1, Standard and Guide for Qualification and Certification of Welding Inspectors, 1996.

American Society of Nondestructive Testing (ASNT) 2055, Recommended Practice SNT-TC-1A, 1996.

ASTM E 498-95 Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector or

Residual Gas Analyzer in the Tracer Probe Mode1,2.

ASTM A 800/A 800M–01 Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof.

The above Standards and Codes set forth the minimum requirements. They may be exceeded by Seller with written permission from the Laboratory if, in Seller's judgment, superior or more economical designs or materials are available for successful and continuous operations, as required by the specification.

ASME Code stamping of the VVSA is not required.

3 REQUIREMENTS

3.1 System Definition

3.1.1 Geometry

The NCSX Vacuum Vessel, SE120-001 REV O, is a contoured, three-period torus with a geometry that repeats every 120º toroidally. The geometry is also mirrored every 60º so that the top and bottom sections of the first (0º to 60º) segment, if flipped over, are identical to the corresponding sections of the adjacent (60º to 120º) segment.

3.1.2 Vacuum Vessel Subassembly (VVSA)

The VVSA, consists of a vessel shell referred to as a Vacuum Vessel Period Assembly (Period Assembly), SE121-002 REV O, a Spacer Assembly (Spacer), SE121-019 REV O, and the port extension assemblies with their associated blank flanges, seals, and fasteners. Three VVSA units, including all hardware in the referenced drawings, are to be procured, fabricated, and delivered by the Seller. The three VVSA units will be welded together to form the vacuum vessel during final assembly at the operation site. The final assembly will be the responsibility of the Laboratory.

3.1.3 Description

The subassembly sequence will entail welding the port extension assemblies onto the Period Assembly wall and then cutting off all except the large vertical ports and the neutral beam port located mid-segment, leaving stubs which will serve as reinforcement and locating positions for subsequent reinstallation of the port extensions. The cut off port extensions will be re-welded onto the Period Assemblies after installation of the modular coils and toroidal field coils as part of the NCSX vacuum vessel final assembly operation. Reinstallation of port extensions will be the responsibility of the Laboratory. The VVSA configuration and a definition of terminology used in this specification may be referenced in Figure 1. The structure will be supported from the modular coil shell structure via adjustable hangers. The interfacing structural bosses are a part of the VVSA and shall be supplied by the Seller. The port attachment concept is shown in Figure 2. The VVSA coordinate system is defined in the reference engineering drawings.

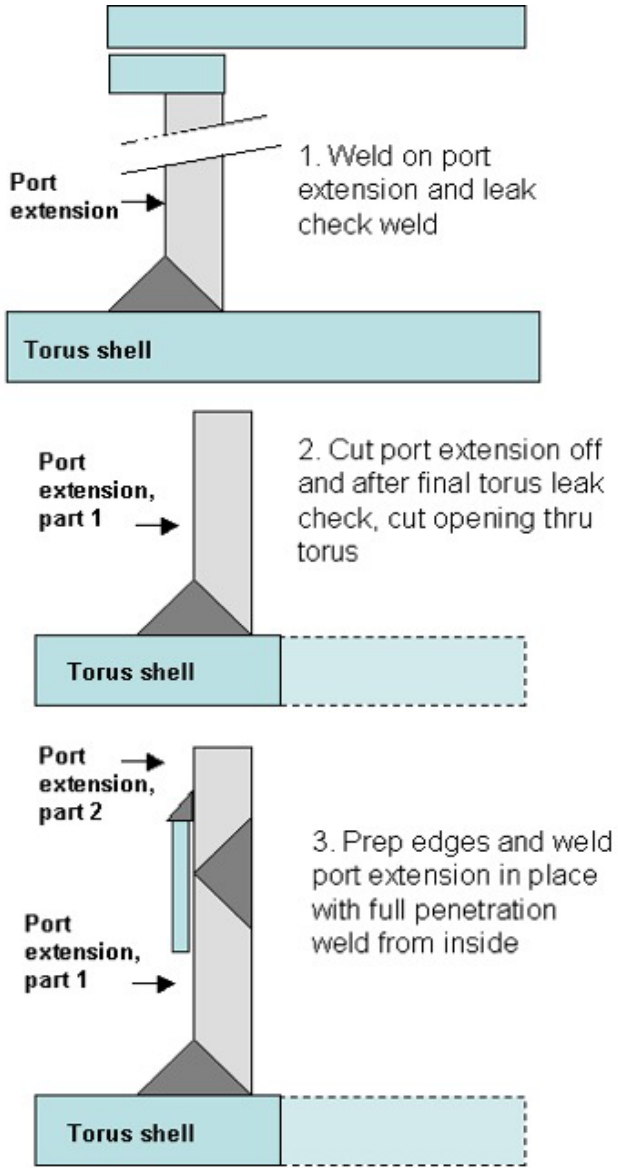

Figure 2 - Port attachment concept

3.2 Characteristics

3.2.1 Vacuum Performance

Leak checking shall be done after completion of all surface preparation and polishing operations. A Turbomolecular Pump (TMP) and a mechanical vacuum pump shall be used to evacuate the assembly under test. A mass spectrometer leak detector shall be connected to the TMP fore-line. A detection sensitivity of 10-10 scc/sec shall be provided. No detectable leaks are acceptable with the base pressure below 10-5 torr. All leaks found shall be documented and repaired. If a leak requires more than one repair cycle, it must be documented on a nonconformance report. Seller's leak repair procedures shall be submitted to the Laboratory for approval prior to use. This requirement applies to individual port attachments and to the assembly. Testing shall be in accordance with ASTM E 498

3.2.2 Interior Surface Finish

3.2.2.1 Interior (vacuum) surfaces

Interior of the Period Assembly wall, Spacer, and port extensions shall be polished to a 32 micro-inch finish. Interior weld beads, scratches, and tooling marks resulting from fabrication shall be polished to a 32 micro-inch finish. Interior wall surface weld beads shall be ground to within .032 inch of the surface prior to polishing. Scratches, pits, weld pin holes and other surface imperfections exceeding depth limits set forth in the Engineering Drawings shall be repaired by welding before finish polishing.

3.2.2.2 Tools

Tools utilized in polishing and lapping operations shall be nonferrous ceramics or nonmagnetic stainless steel, which have never been in contact with materials other than Inconel.

3.2.3 Exterior Surface Finish

Mill finish on the exterior surfaces is acceptable, but any imperfections greater than 0.04 inches deep shall be weld repaired and ground smooth.

3.2.4 Magnetic Permeability

Relative magnetic permeability of all components shall not exceed 1.02 except for welds (and heat affected zones) joining stainless steel to nickel chromium, which shall not exceed 1.2.

3.3 Design and Construction

3.3.1 Fabrication Drawings

All the Drawings and CAD models are provided in Pro-E® format and it is the Seller's responsibility to work with this format. Vacuum Vessel Contour Pro-E® models are referenced on the fabrication drawings. Figures provided in the text of this document are to provide clarity and are for information only; equipment shall be provided in conformance with the following drawings and electronic files:

SE120-002 shts 1-22 VACUUM VESSEL PERIOD ASSEMBLY

SE121-010 VACUUM VESSEL SPACER ASSEMBLY MACHINING

SE121-013 VACUUM VESSEL FLANGE DETAIL

SE121-014 VACUUM VESSEL SPACER ASSEMBLY WELDMENT

SE121-015 VACUUM VESSEL SPACER LEAK CHECK ASSEMBLY

SE121-016 VACUUM VESSEL SPACER FLANGE DETAIL

SE122-104 VACUUM VESSEL PORT COVER TEST FLANGE DETAIL

SE122-172 VACUUM VESSEL PORT COVER TEST FLANGE WELDMENT

SE121-096 VACUUM VESSEL BLANK OFF COVER

SE121-097 VACUUM VESSEL SEAL

SE121-098 VACUUM VESSEL SPACER SEAL

The Pro/Engineer models and drawings of the VVSA components are available through the PPPL anonymous FTP server. The following FTP commands can be used to access the files:

ftp> ftp.pppl.gov	
User: anonymous	<- login as anonymous
Password:	<- enter your email address
ftp> cd pub/ncsx/manuf	<- lowercase
ftp> bin	<- binary transfer mode
ftp> mget *	<- retrieve files
ftp> quit	
The files may also be accessed through a web browser using the following URL address:	
ftp://ftp.pppl.gov/pub/ncsx/manuf/	

3.3.2 Materials/Processes/Parts

3.3.2.1 Sheet, Strip, and Plate

All as-supplied sheet, strip, and plate shall be annealed Alloy (UNS N06625) and meet the requirements of ASTM B 443.

3.3.2.2 Tubing and Piping

All tubing and pipe shall be seamless or welded Alloy (UNS N06625) and meet the requirements of ASTM B 444 or ASTM B 705.

3.3.2.3 Bar and Structural Shapes

All bar and structural shapes shall be annealed Alloy (UNS N06625) and meet the requirements of ASTM B 446.

3.3.2.4 Conflat Flanges

The conflat flange shall meet the requirements of ASTM A 240.

3.3.2.5 Weld Filler Metal

Weld filler metal shall meet the requirements of the applicable AWS A series specifications or ASME SFA specifications. Certified material test reports shall be supplied for all materials (see section 4.3).

Welding of stainless steel conflat flanges to Inconel 625 (UNS N06625) ports shall use ASME/AWS SFA/A 5.14 ERNiCr-3 or ERNiCrMo-3 filler metal

3.3.2.6 Bolts

Conflat flange bolts shall be ASTM A 193, Grade B8; silver-plated, 12-point bolt kits provided with flanges from the flange manufacturer.

Rectangular o-ring ports shall use ASME SA 453 Grade 660 bolts.(A286) The neutral beam port, whose flanges are Inconel 625, shall use Inco 718 bolts per ASTM A1014.

3.3.2.7 Seals

3.3.2.7.1 Metal Seals

Seals for Conflat flanges shall use standard copper seals provided from the flange manufacturer.

3.3.2.7.2 Custom Flanged

Custom racetrack-shaped and rectangular flanges will be sealed with Viton A o-rings on both the vacuum side and on the air side. Dimensions and o-ring grooves shall conform to specifications listed in the Engineering Drawings as shown in section 3.3.1.

3.3.2.8 Welding

All welding shall be done by qualified personnel using written and qualified welding procedures in accordance with the ASME Code, Section IX. Welds may be made by the GTAW or GMAW processes. Welds using SMAW process are not permitted.

3.3.2.9 Cutting, Forming and Bending

For the fabrication of the Vessel, all cutting, forming and bending shall be done in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

3.3.2.10 Cleaning

After completion of assembly and surface preparation, the interior surfaces shall be cleaned using materials and procedures mutually agreed upon. As a minimum this procedure will include:

a. Vapor degreasing to remove oils, greases, and die lubricant residues resulting from handling and fabrication of the Vessel.

b. Solvent (e.g. non-chlorinated) wipe down of the surfaces.

c. Blow drying of surfaces with oil-free instrument air.

d. Use of lint-free wipes.

3.3.3 Fabrication

Wall [shell] components of the Period Assembly and Spacer are to be made up of contoured plate segments, welded together and mated to end flanges. The contoured plate segments shall be fabricated by forming, pressing, or other related processes that result in a contour, conforming to the Pro-E® model and tolerances supplied by the Laboratory. The Seller's segmentation scheme (number of segments and approximate seam locations) shall be approved by the Laboratory.

3.3.4 Dimensions/tolerances

The overall dimensions and dimensional tolerances shall be in accordance with the referenced Engineering Drawings. Compliance shall be verified with the dimensions and tolerances with the assembly completed, i.e. the port extensions cut off to form stubs, the holes bored, and vessel end flanges installed and after any required thermal cycling operations.

Dimensional stability over an operating temperature range of room temperature to 375 C is a primary requirement. Dimensional stability of the Period Assembly and Spacer, in an unconstrained state and following thermal cycling between room temperature and 375 deg C, shall be demonstrated.

4 QUALITY ASSURANCE PROVISIONS

4.1 GENERAL

4.1.1 Responsibility for Tests

Tests and inspections shall be conducted at the Seller's facility or otherwise suitable location. The responsibility for performing all tests and verifications rests with the Seller. The Laboratory reserves the right to witness or separately perform all tests specified or otherwise inspect any or all tests and inspections

4.1.2 Special tests and inspections

NA

4.2 QUALITY CONFORMANCE INSPECTION

4.2.1 Test Documentation

Actual data, except where otherwise stated within this document, and accept/reject status for each inspection and test shall be documented. The reports shall contain sufficient information to accurately locate the area involved and to reproduce the inspection or test performed. This can be accomplished by clear and direct reference to other Subcontractor-provided documents. The procedure, and, as applicable to the process, the technique and equipment used shall be clearly identified. References to calibrated measuring and test equipment shall include date of latest calibration. Inspection and test reports shall identify the personnel performing the inspection or test and their certification level, where applicable. The reports shall be dated and verified by authorized personnel.

4.2.2 Verification of Vacuum Performance

Room temperature helium leak tests shall be performed to verify that the requirements stated in Section 3.2.1 are met. The Seller shall furnish and install all temporary test fixtures, flanges, blanking off plates, and gaskets required to seal the Period Assembly and Spacer for leak checking purposes. All such equipment shall be delivered to the Laboratory at the conclusion of testing. Prior to leak checking, the assembly shall be cleaned as defined in Sect. 3.3.2.10.

4.2.2.1 Period Assembly Leak Check

The leak testing of the Period Assembly shall be after welding on the port extensions and prior to thermal cycling. The end flanges, large vertical ports, and neutral beam midline ports shall be blanked off with the appropriate flange covers.

4.2.2.2 Period Assembly Port Extension Leak Check

Each of the port extensions and attachment welds to the Period Assembly shall be leak checked. The port configuration during vacuum leak testing shall be with the port extension welded to the vessel as shown in Figure 2, step 1. Port covers with vacuum porting shall be installed with appropriate seals and fasteners.

4.2.2.3 Spacer Leak Check

The testing of the Spacer shall be after its completion, with its port attached. The end flanges and port shall be blanked off with the appropriate flange covers.

4.2.3 Thermal Cycling

After leak checking, and prior to cutting off the port extensions, the Period Assembly and Spacer shall be thermally tested while under vacuum. The temperature shall be cycled from room temperature to 375+25 C a minimum of three times. No port extension flanges, except for the neutral beam ports, shall exceed 150 C during these tests. The Seller shall prepare a test plan detailing the thermal cycling procedures and equipment setup for approval by the Laboratory.

4.2.4 Verification of Surface Finish

The interior surface finish shall be checked with a profilometer to verify compliance with Section 3.2.2. The exterior surface finish shall be visually examined to verify compliance with Section 3.2.3. Actual values need be recorded only for any out-of-tolerance conditions

4.2.5 Verification of Magnetic Permeability

To verify conformance to Section 3.2.4, magnetic permeability shall be measured in accordance with the requirements of ASTM A 800, Supplementary Requirement S1, but with the measurements taken in relative permeability, rather than ferrite content. All surfaces and features shall be checked with a calibrated Severn Permeability Indicator1 for compliance with Section 3.24. The surfaces of the VVSA components shall be checked and documented in a 6" x 6" grid. The welds at the conflat flanges and at the junction between the port extension, reinforcement, and shell shall be checked every 1/2" (both inside and outside surfaces wherever possible). Actual values need be recorded only for any out-of-tolerance conditions.

4.2.6 Verification of Dimensions and Tolerances

The Seller will be required to perform dimensional checks on the Period Assembly and Spacer using full surface 3-D measurement equipment (e.g. laser tracker) to ensure that the surfaces are within the prescribed limits. The Seller shall also perform wall thickness measurements using suitable method (e.g. ultrasonic).

With the Period Assembly and Spacer unrestrained on a surface measuring table and the port extension supported to compensate for gravity load, all surfaces shall be dimensionally checked on a grid no coarser than 1-inch centers. Welds seams and each end of the Period Assembly and Spacer shall be dimensionally checked on 1” centers. Instruments shall have a resolution at least ten times the tolerance. These measurements shall be compared to the tolerances indicated on the applicable drawings. Verification of dimension and tolerances shall be done both before and after attachment of the port extension.

4.2.7 Materials

Material certifications traceable to the materials used shall be provided as defined below. Subcontractor is to develop and utilize process controls to assure traceability of materials to their certifications.

a. N06625: showing actual chemical and physical properties

b. Bolts: Manufacturer’s certification of grade

c. Conflat flanges: Manufacturer’s certification of grade

d. Filler metal: showing actual chemical properties

1 Available from Severn Engineering Co. Annapolis, Md.

4.2.8 Weld Inspection and Examination

4.2.8.1 Visual

All welds are to be visually inspected using a written procedure prepared in accordance with Article 9 of Section V of the ASME Code, with 8X magnification. The acceptance criteria for the visually inspected welds are given in AWS D1.6, Paragraph 6.29.1. All welds that do not meet the stated acceptance criteria shall be documented, repaired, and re-inspected.

Visual weld inspection shall be done by inspectors certified to perform visual inspection of welds in accordance with AWS QC1 or ASN, 2055, SNT-TC-1A, Level II or Level III.

Copies of welding heat treatment, Non-Destructive Examination (NDE) and special process procedures and qualification test records shall be available for review by the Laboratory. Welding procedures qualifications shall include evidence of compliance with special magnetic permeability criteria.

4.2.8.2 Volumetric Testing

Ten (10) % of the length of each seam weld in the Period Assembly wall shall be radiographically inspected. Radiographical inspection must be done with certified personnel and a written procedure in accordance with Article 2 of Section V of the ASME Code. The inspection and acceptance criteria shall be in accordance with ASME Section VIII, Division 1, UW-51. Detection of defective welding may require, at the discretion of the Laboratory, an increase to 100 % radiographic inspection of the welds. All welds that do not meet the stated acceptance criteria shall be documented, repaired, and re-inspected

4.2.9 Verification of Cleaning Requirements

Visually inspect the VVSA components and examine records for compliance with Section 3.3.2.10.

5 PREPARATION FOR DELIVERY

5.1 LABELING

Subassemblies and components, except bolts and standard hardware, shall be marked with a unique identifier that includes the drawing number, serial number, approximate weight, Seller's name, and date of manufacture to provide positive identification. When such markings would impair proper functioning of the equipment, a metal, non-corrosive, non-magnetic tag shall be used. Match markings shall be provided to uniquely identify the location of all port extensions relative to the Period Assembly.

5.2 PACKING AND SKIDDING

All components shall be sealed, packaged, and skidded to provide protection against contamination, deterioration and damage during shipment. Vacuum sealing surfaces shall be protected from damage during shipping and handling.

A plan shall be provided to the Laboratory prior to shipment which includes a description of methods to be used to preserve, package, skid, and identify equipment. The Seller shall contact the Laboratory ten days prior to shipment of the machine to confirm shipping method and route.

5.3 MARKING

Each shipping skid shall be marked with the name of the Seller, Laboratory Purchase Order Number, the component name, and gross weight. Boxes containing loose parts, attachments, and accessories shall be marked identifying the assembly to which they belong, and where possible, boxes are to be secured to the skid of the unit.