NCSX
Specification

Product Specification
For the
Vacuum Vessel System Sub-Assembly

NCSX-CSPEC-121-02-04

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Record of Revisions

Revision	Date	ECP	Description of Change
Rev. 0	5/9/2003	NA	Pre-release version for cost estimating purposes
Rev. 1	6/23/2004	NA	Updated to FDR configuration
Rev. 2	9/1/2004	NA	Updated paragraphs 3.1.3, 4.1.3 4.1.4, 4.2.1, 4.2.1.1, 4.2.1.2, and 4.2.1.3 to reflect supplier's requested exceptions to change the assembly sequence and allow leak checking of the entire completed assembly. Moved weld procedure qualification criteria from 4.2.6.1 to 3.3.2.8 Promoted 4.2.7
Rev 3	11/24/2004	NA	Updated paragraphs 2.1 to reflect latest versions of codes and standards. Added standards for stainless steel tubing in Section 2.1 and 3.3.2.2. Added standards for Sections VIII and Section IX of the ASME Code to reflect requirements set forth in Section 4.2.6.2 and Section 3.3.2.8. Added standard for A286 material in 2.1. Corrected standard under 3.3.2.6. Revised Appendix A to only reference zip files and link to the Supplier FTP Site where all the models and drawings can be found.
Rev 4	12/13/2004	N/A	Revised Appendix A to correct drawing/model zip file from: VV_Prod_step_Rev1 to VV_Prod_step_Rev1b

Table of Contents

Table of Figures

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 and its constituent components to the Princeton Plasma Physics Laboratory (Laboratory). All of the labor for the final installation and assembly of the VVSA will be supplied by the Laboratory.

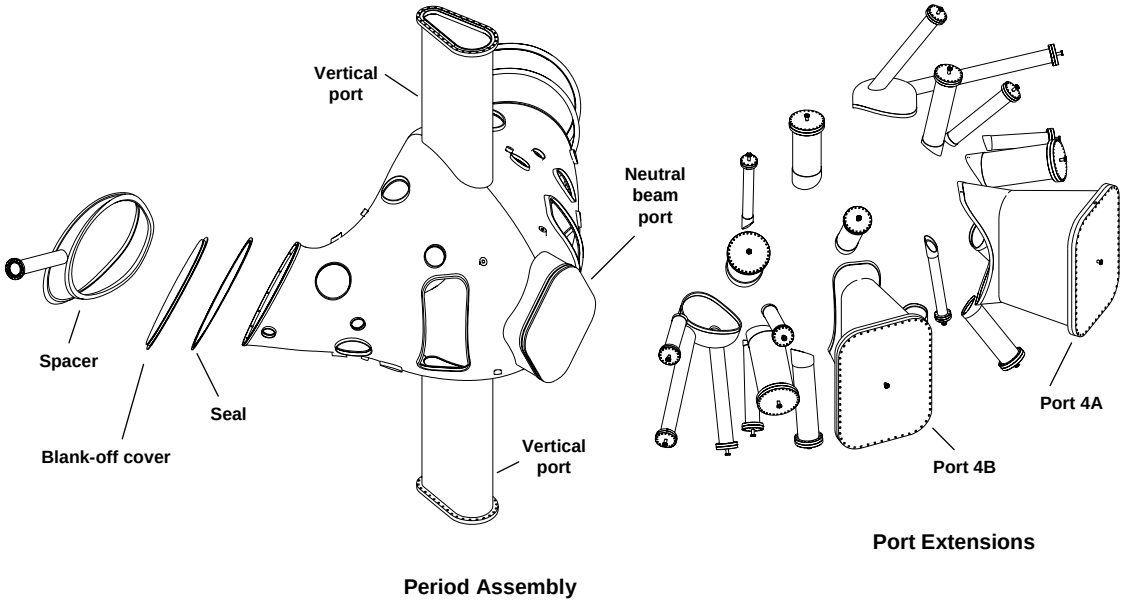

Figure 1 - VVSA Components

2 APPLICABLE DOCUMENTS

2.1 Codes and Standards

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:

a. ASME SFA 5.14 Nickel and Nickel Alloy Bare Welding Rods Electrodes. 1997

b. American Society of Mechanical Engineers (ASME), 2001 Boiler and Pressure Vessel Code, Section V (Articles 2 and 9). 2003 Addenda

c. 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.

d. ASTM B 444-03 Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219)* Pipe and Tube.

e. ASTM B 705-03 Standard Specification for Nickel-Alloy (UNS N06625, N06219 and N08825) Welded Pipe.

f. ASTM B 446-03 Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219)* Rod and Bar

g. ASTM A 240-04A Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.

h. ASTM A193/A193M-04 Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.

i. ASTM A1014-03 Standard Specification for Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service

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

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

l. American Society of Nondestructive Testing (ASNT) 2055, Recommended Practice SNT-TC-1A, 2001.

m. ASTM E 498-2000 Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode 1, 2.

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

o. ASTM A 249/A 249 M-04A Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condensor Tubes

p. ASTM A 213/A 213M-03 Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, Heat-Exchanger Tubes.

q. American Society of Mechanical Engineers (ASME), 2001 Boiler and Pressure Vessel Code, Section VIII, Division 1. 2003 Addenda

r. American Society of Mechanical Engineers (ASME), 2001 Boiler and Pressure Vessel Code, Section IX. 2003 Addenda

s. ASTM A 453/A 453M-04 Standard Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels

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 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, SE120-002, consists of a vessel shell referred to as a Vacuum Vessel Period Assembly (Period Assembly), SE120-003, a Spacer Assembly (Spacer), SE121-014, two (2) Vacuum Vessel Blank Off Covers, SE121-102, two (2) Vacuum Vessel Seals, SE121-095, 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. Bills of material are provided in drawings listed in Appendix A. 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 vessel wall and then cutting off all except the large vertical ports, the neutral beam port located mid-segment, and the Spacer port, 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 VVSA coordinate system is defined in the reference engineering drawings. While the original PPPL concept of attaching port extensions prior to boring the holes is preferred because it provides localized leak checking and improved distortion control, the manufacturer has flexibility in their sequence as long as it meets the requirements of this specification.

3.2 Characteristics

3.2.1 Vacuum Performance

The spacer assembly, period assembly, and port extensions shall remain leak tight after thermal cycling three times to the maximum operating temperature. No detectable leak greater than 2×10^{-8} t-l/s is acceptable with the base pressure below 10^{-5} torr.

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 Models and 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 Pro-E® models are referenced on the fabrication drawings. Appendix A provides a list of models and drawings (including Bills of Material) to be used for fabrication of the VVSA. 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 models and drawings listed in Appendix A.

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/production_vessel <- 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/production_vessel
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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 Inconel tubing and pipe shall be seamless or welded Alloy (UNS N06625) and meet the requirements of ASTM B 444, or ASTM B 705.

All austenitic stainless steel tubing shall be seamless or welded 316L alloy and meet the requirements of ASTM A 249/A 249 M-04A or ASTM A 213/A 213M-03.

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 flanges 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 4.2.7).

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.

Non-circular o-ring flange bolts, with the exception of the neutal beam port, shall use ASTM A453 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 Flanges

Custom non-circular flanges, with the exception of the neutral beam port, will be sealed with two Viton A ® [1]o-rings, and differentially pumped between the seals. The neutral beam port will be sealed with two Helicoflex Delta ® [2]metal o-rings, type HNV, and will also be differentially pumped. Dimensions and o-ring grooves shall conform to specifications listed in the drawings as shown in Appendix A.

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. Welding procedures qualifications shall include evidence of compliance with special magnetic permeability criteria. 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 per a mutually agreed upon written procedure. As a minimum this procedure will include:

a. 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.

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[1] Registered trademark of DuPont Dow Elastomers

[2] Registered trademark of Garlock Helicoflex, Sealing Technologies.

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

3.3.4.1 Measurements

The overall dimensions and dimensional tolerances shall be in accordance with the referenced Engineering Drawings. Compliance with the dimensions and tolerances shall be verified 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.

3.3.4.2 Fiducials

A minimum of four (4) fiducials on each end flange of the Period Assembly and six (6) fiducials on the Period Assembly wall (three in each half-period) shall be permanently installed to establish a reference system to be used for dimensional inspection. The wall mounted fiducials shall be accessible from both the exterior and the interior of the Period Assembly. Three (3) fiducials shall be provided on each port extension flange. The goal shall be to permit replication of Seller measurements by the Laboratory. The fiducials may be mounts for removable tooling balls or some other system proposed by the Seller. The nature, location, and installation of these fiducials shall be submitted by the Seller for approval by the Laboratory.

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 Test Hardware

The Seller shall furnish and install all temporary test fixtures, flange covers, blanking off plates, and gaskets required to seal the Period Assembly and Spacer for testing purposes. All such equipment shall be delivered to the Laboratory at the conclusion of testing.

4.1.3 Inspection and 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 Seller-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 Quality Conformance

4.2.1 Verification of Vacuum Performance

The Period Assembly and completed Spacer Assembly with port extension installed, shall be thermally cycled from room temperature to 375 $\pm$25 C, a minimum of three times. Port extension flanges shall be cycled from room temperature to only 150C +5C/-15C. The interior shall be evacuated below 1 x 10^{-3} torr during the thermal cycling.

Room temperature helium Leak checking shall be performed to verify that the requirements stated in Section 3.2.1 are met after completion of a thermal vacuum bakeout of a minimum of 48 hours at 375 $\pm$25 C (this may be combined with the required thermal cycle), surface preparation, polishing operations, and cleaning as defined in Section 3.3.2.10. Ports may be tested individually or as part of the assembly. A minimum of a 1500 LPS Turbomolecular Pump (TMP) and a minimum of a 50 LPS mechanical vacuum pump shall be supplied by PPPL and used to evacuate the assembly under test connected to the large assembly end flange with a minimum length 10" diameter pipe. A mass spectrometer leak detector shall be connected to the TMP fore-line. A detection sensitivity of 10^{-10} t-l/s shall be provided. Ultra high Vacuum Valves shall be provided to valve the leak detector and backing pump separately into the TMP fore-line. A Standard Leak of 1 x 10^{-8} t-l/s shall be installed at the end of the furthest port extension and be detectable by the leak detector. The total assembly leak rate shall not be greater that $5x10^{-6}$ t-l/s. All leaks shall be documented, reported to the Laboratory, and repaired. The documentation shall include the location of the leak. If a leak requires more than one repair cycle, it must be documented on a nonconformance report. Testing shall be in accordance with ASTM E 498.

4.2.2 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

4.2.3 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 Indicator[3] for compliance with Section 3.2.4. The surfaces of the VVSA components shall be checked and documented in a 6" x 6" grid. The weld seams in the shell wall, 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.

4.2.4 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 except for gravity supports, 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 inch centers. The minimum resolution of the instruments shall be at least ten times smaller than tolerances being measured. Final acceptance testing of the Period Assembly dimensions shall be performed after the ports have been cut off and holes bored out.

4.2.5 Materials

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

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3 Available from Severn Engineering Co. Auburn, Alabama.

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

4.2.6 Weld Inspection and Examination

4.2.6.1 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 ASNT 2055, SNT-TC-1A, Level II or Level III.

4.2.6.2 Volumetric Testing

Ten (10) % of the length of each seam weld in the Period Assembly wall shall be radiographically inspected. The 10% inspection shall include regions of seams which intersect holes cut in the wall for port extensions. 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

4.2.7 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 unique serial numbers 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 and positioning 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.

APPENDIX A – LIST OF APPLICABLE DRAWINGS AND MODELS

The following table provides the complete listing of zip files which includes all the approved drawings, ProE models, and STEP files. These zip files may be found on the Supplier FTP site at:

ftp://ftp.pppl.gov/pub/ncsx/manuf/production_vessel/

ZIP File	Model Description (from Pro/Intralink database, edited)	Rev
VV_Prod_pdf_Files_Rev1.zip	**ZIP file containing pdf drawing files including Rev 1 changes**	**1**
VV_Prod_ProEModels_Rev1.zip	**ZIP file containing all ProE models including rev 1 changes**	**1**
VV_Prod_step_Rev1b.zip	**ZIP file containing all step files including Rev 1 changes. Also contains step files for the die geometry.**	**1b**