MANUFACTURING SPECIFICATION & STATEMENT OF WORK

FLARE (Facility for Laboratory Reconnection Experiments) Project

Fabrication of Flux Cores

FLARE-Spec-03- Rev.00

WP1995

REVISION 0

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PREPARED BY: Phil Heitzenroeder
Digitally signed by Phil Heitzenroeder
DN: cn=Phil Heitzenroeder, o=MED, ou=PPPL, email=pheitzen@pppl.gov, c=US
Date: 2015.03.19 11:59:49 -04'00'

Cognizant Individual: Phil Heitzenroeder

REVIEWED BY: Michael Kalish
Digitally signed by Michael Kalish
DN: cn=Michael Kalish, o=PPPL, ou=Engineering, email=mkalish@pppl.gov, c=US
Date: 2015.03.19 15:16:01 -04'00'

Project Manager: Michael Kalish

REVIEWED BY: Barry L. Jedic
Digitally signed by Barry L. Jedic
DN: cn=Barry L. Jedic, o=PPPL, ou=QA, email=bjedic@pppl.gov, c=US
Date: 2015.03.20 07:29:16 -04'00'

Quality Assurance: Barry Jedic

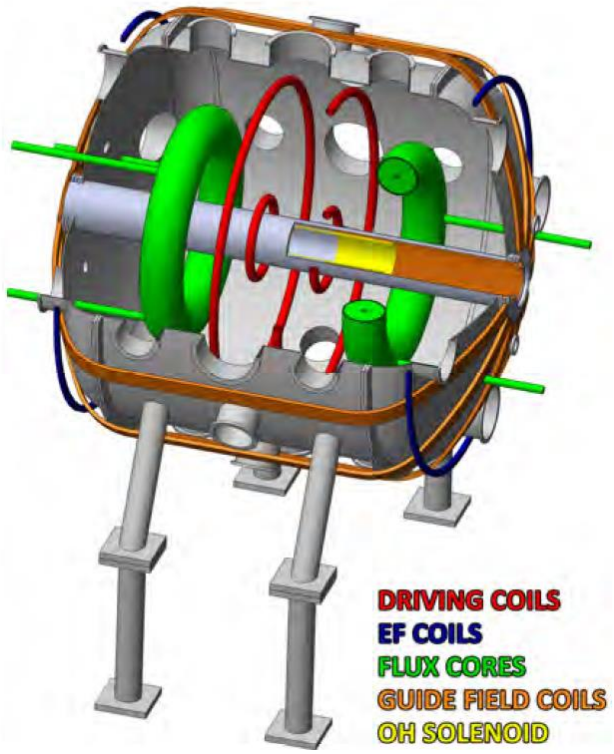
APPROVED BY: Hantao Ji
Digitally signed by Hantao Ji
DN: cn=Hantao Ji, o, ou, email=hji@pppl.gov, c=US
Date: 2015.03.20 08:11:12 -05'00'

Physics Manager: Hantao Ji

PRINCETON UNIVERSITY
PLASMA PHYSICS LABORATORY
P.O. BOX 451
PRINCETON, N.J. 08543
609-243-2000

1.0 INTRODUCTION AND SCOPE

This document addresses the manufacturing, inspection, test and Quality Assurance (QA) plan to fabricate and deliver to Princeton University (PU) two (2)-flux core assemblies which are key components of the FLARE experimental device, shown below. This device will study plasma reconnection events which, for example, occur in solar flares and occur in plasma instabilities in fusion research devices.



2.0 APPLICABLE DOCUMENTS

N/A

3.0 APPLICABLE DRAWINGS

3.1 Coil Drawings

A basic set of coil drawings showing the overall size and tolerance of the coil will be provided by PU. The manufacturer can only use PU- signed and "Approved for Fabrication" stamped drawings. The selected coil manufacturer is expected to develop additional drawings with the details necessary for manufacturing. These, also, must be PU approved before use.

See Addendum 1 for complete list of drawings that PU will supply.

3.2 Tooling Drawings

All tooling drawings are the responsibility of the selected subcontractor. PU must approve drawings for the molds in writing prior to start of manufacture. Tooling inspection reports to be provided to PU for verification of critical dimension.

4.0 RESPONSIBILITIES

4.1 Princeton University

Michael Kalish will be the contact for managing the flux core procurement.

4.2 Subcontractor

The subcontractor shall provide a single point contact to interface with P.U.

5.0 REQUIREMENTS

5.1 FLUX CORE ASSEMBLIES

The selected subcontractor shall deliver to PU two (2) flux core assemblies. They shall also include reports of all the required inspections and tests, showing actual values, properly validated by authorized personnel.

5.2 MANUFACTURING DRAWINGS

5.2.1 The selected coil manufacturer is expected to develop drawings with the details necessary for manufacturing the coils. These, also, must be PU (Princeton University) approved before use.

5.2.2 All tooling drawings are the responsibility of the selected subcontractor. PU must approve drawings for the tooling in writing prior to start of manufacture.

5.3 COIL MANUFACTURING PACKAGE

Subcontractor shall supply copies of the Coil Manufacturing Package in pdf format- consisting of the Process Procedures defined in section 9.8.

5.4 CAD/CAM Files:

The supplier shall provide PU electronic copies of CAD/CAM files generated in the performance of this SOW.

5.5 COIL MANUFACTURING & TEST PROCEDURES

The final coil manufacturing and test (MIT) procedures will be developed by the selected subcontractor and approved by PU.

5.6 TOLERANCES AND DIMENSIONS:

Dimensional characteristics including insulation builds for the EF coils are identified on the coil manufacturing drawings.

5.7 COIL IDENTIFICATION

5.7.1 Coil Labels: Each Flux Core shall have a unique identification name/number for the purpose of tracking materials, and process/testing results. The identification numbers shall be:

- FC-1
- FC-2

5.7.2 Lead Labels

The (+) and (-) leads shall be labeled along with their winding type (i.e., PF-1 (+), PF-1 (-) etc.).

(+) designation for the flux core PF windings is for a counter clockwise current direction (upwards poloidal field) when looking downwards on the coil from the lead side of the coil. See Fig. 5.7.2.2.

(+) designation for the TF windings is for the magnetic field produced in the bore of the winding being in a counter clockwise direction when looking downwards on the coil from the lead side of the coil, using the right hand rule. See Fig. 5.7.2-1.

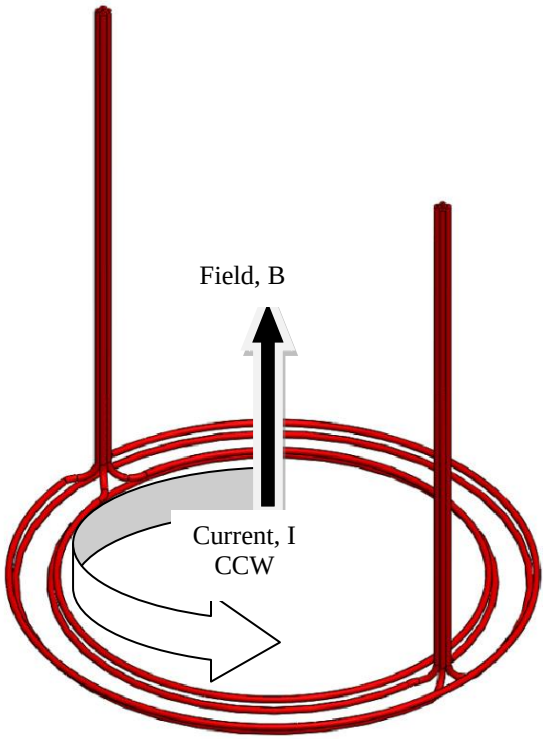


Fig. 5.7.2-1. Field and Current Directions for PF Lead Labels

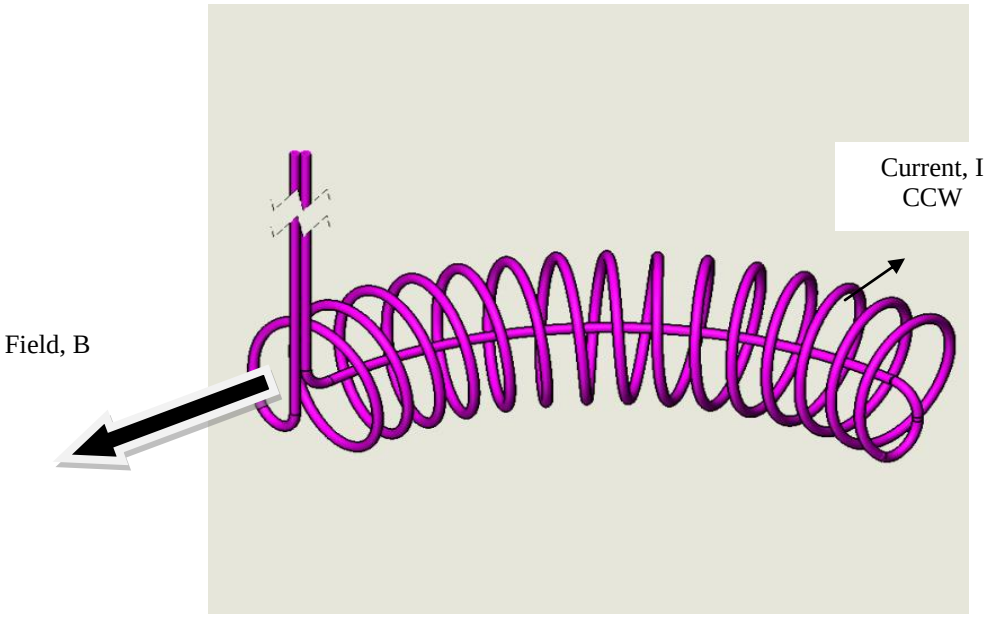


Fig. 5.7.2-2. Field and Current Directions for TF Lead Labels

5.8 MATERIALS

The materials required to fabricate the flux core are listed in the table below. With the exception of the low outgassing epoxy resin (Items 5.6 and 5.8), the supplier can propose materials that can be locally sourced that have equivalent properties, but Princeton University approval must be obtained before they are substituted.

General Description	Material	Details
5.1 Flux Core	NEMA grade G-10 or equiv.	Dwg. #A-FL7000014 (5 sheets)
5.2 Support tubes	Type 316 SS	PF: Dwg. #A-FL700-042 TF: Dwgl. #A-FL700-041
5.2a Support leg seals	O-Ring type 337	Dwg. #A-FL700-006, part no. 26
5.3 TF cable	133 MCM water cooled cable	Manufactured by New England Wire & Cable
5.3a PF cable	238 MCM water cooled cable	Manufactured by New England Wire & Cable
5.4 Fasteners (bolts, washers, and lock washers)	Type 316 SS	Commercial. Refer to drawings for quantities and details.
5.5 Fiberglass cloth tape for over-wrap	E-glass(satin weave) / 0.006" thk., 2" width	Commercial
5.6 Epoxy resin for first wet wrap section	Low vacuum outgassing epoxy	Master Bond EP29LPSP
5.7 Fine silica powder	To mix with epoxy resin to form paste as required for Steps	Available from http://www.jamestowndistributors.com/
5.8 Epoxy resin for gel coating or final coating	low vacuum outgassing epoxy	Master Bond EP29LPSP
5.9 Ripple reduction aluminum shell	Aluminum spinning	Dwg. # A-FL700-062 and -064
5.10	*****	******
5.11 RTV 108 Caulking equivalent(to hold cables in grooves)	Silicone Rubber	GE Commercial
5.12 Heat shrinkable electrical sleeving for PF and TF leads.	Polyvinylidene Flouride 0.5 mm. wall thickness after shrinking	Commercial; dielectric strength 800 V/mil (800 V/0.025 mm)
5.13 Kapton tape	2 mil + adhesive backing	Commercial
5.14Water fitting	Brass 37 degree JIC	Commercial
5.15Thread sealing compound	Loc Tite 542 or equivalent	Commercial
5.16 RTV11 001	2-component silicone rubber	Commercial; Momentum Performance Materials
5.17 Degreasing Solvents	Components shall be degreased/cleaned using a solvent that is able to dissolve grease, tar, wax, adhesives, and oils and must be residue free.	Solvent selected by subcontractor must be approved by PU.
5.18 Fiberglass wool	Pure fiberglass wool without binder	Commercial

6.0 TEST AND INSPECTION REQUIREMENTS

This section describes a recommended procedure for fabricating and testing the subject equipment. The subcontractor shall develop submit a Manufacturing, Inspection, and Test and Quality Assurance (MIT/QA) plan and manufacturing procedures for approval by PU which must be approved by PU in writing before work begins. Deviations from the approved MIT plan and procedures will require PU approval

SUPPLIER HOLD POINT 1: All pre-winding electrical, vacuum, and hydraulic results must be reviewed with the Princeton University representative . Written approval must be obtained before work continues.

6.1 Pre-Winding Electrical Tests:

Lengths of cables shall be cut to the required length for each winding and electrically tested before proceeding. The electrical tests include resistance and hipot tests.

6.1.1 Resistance Tests
Measure the resistance of each winding with a digital low resistance bridge and record the results in the table below. The resistance of like windings and its calculated value shall be within +/- 5%.

FC-1

Winding Designation	Measured resistance	Winding temperature during resistance measurement –deg. C	Temperature corrected resistance
TF-1			
TF-2			
TF-3			
TF-4			
PF-1			
PF-2			
PF-3			
PF-4			

FC-2

Winding Designation	Measured resistance	Winding temperature during resistance measurement –deg. C	Temperature corrected resistance
TF-1			
TF-2			
TF-3			
TF-4			
PF-1			
PF-2			
PF-3			
PF-4			

6.1.2 HiPot Tests

The winding portions on the flux core are insulated from each other by the G-10 winding form in addition to the cable insulation. The critical regions of the windings are the cable sections for the lead-outs, located in the support legs and in the regions at the base of the legs, where four cables are coming together. For that reason, two layers of heat shrinkable sleeving (Item 5.12) are to be installed over the cable in the lead-out regions of the cable. For this test, the cables are to be wrapped with aluminum foil and hipot tested between the foil and conductor for 1 minute at 2E+1=42 kV. Record the leakage current at the beginning and end of the test. Acceptance criteria: No breakdown and all leakage currents within +/-10%.

FC-1

Winding Designation	Leakage current at beginning of test	Leakage current at 1 minute
TF-1		
TF-2		
TF-3		
TF-4		
PF-1		
PF-2		
PF-3		
PF-4		

FC-2

Winding Designation	Leakage current at beginning of test	Leakage current at 1 minute
TF-1		
TF-2		
TF-3		
TF-4		
PF-1		
PF-2		
PF-3		
PF-4		

6.1.3 Pre-Winding Hydraulic Tests

The test pressure shall be maintained at 1.55 MPa without any change for at least ten minutes after the system has been isolated from the pressure source and the pressure has stabilized. The water and coil temperature shall be equal and maintained throughout the test. During this time there shall be no change in the pressure reading on a calibrated pressure gauge. The pressure gauge shall have increments no greater than .01 MPa.

Measure the water flow rate through each TF and PF cable. Throttle the flow using a valve so that there is a differential pressure of 0.50 MPa for

every 10 meters of cable length. The pressure measurement must be directly at the inlet and outlet of the cable. It is acceptable for the flow to be measured by timing the discharge into a bucket. The flow rate shall be 1.34 liter/min +/-10%

Record results in the tables below.

FC-1

Winding Designation	Pressure at beginning of test, Pa	Pressure after 10 min., Pa	Flow test pressure drop Pa	Flow rate l/s
TF-1				
TF-2				
TF-3				
TF-4				
PF-1				
PF-2				
PF-3				
PF-4				

FC-2

Winding Designation	Pressure at beginning of test, Pa	Pressure after 10 min., Pa	Flow test pressure drop Pa	Flow rate l/s
TF-1				
TF-2				
TF-3				
TF-4				
PF-1				
PF-2				
PF-3				
PF-4				

6.1.4 Electrical cable jacket vacuum test

Using temporary vacuum test fittings which have been custom designed by the subcontractor for test purposes, each length of electrical cable shall be tested to ensure the vacuum integrity of the cables.

With a vacuum leak detector pumping on the cable length, coil the cable length and insert into a plastic bag. Flood the bag with helium and monitor the leak detector for at 1 minute for a rise in the leak detector monitor for helium. Acceptance criteria: There shall be no increase in the leak detector signal for helium.

FC-1

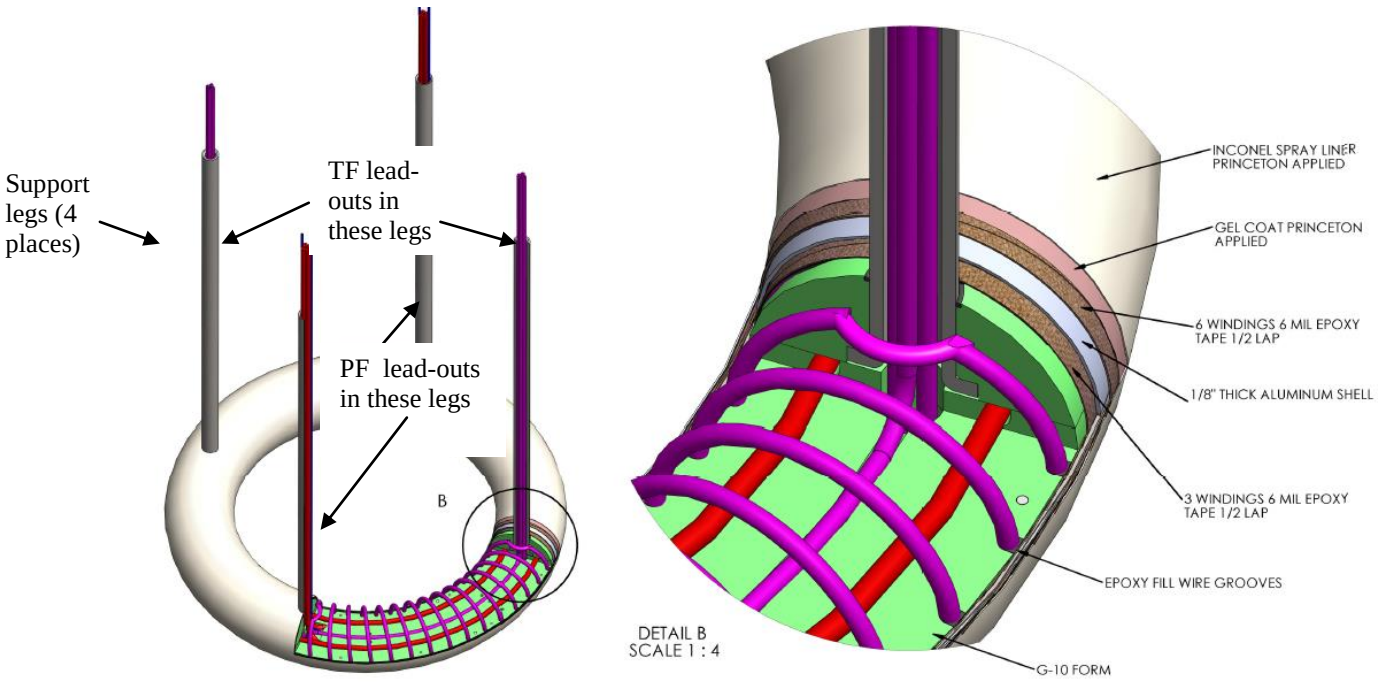
Winding Designation	Indicate pass or fail
TF-1	
TF-2	
TF-3	
TF-4	
PF-1	
PF-2	
PF-3	
PF-4	

FC-2

Winding Designation	Indicate pass or fail
TF-1	
TF-2	
TF-3	
TF-4	
PF-1	
PF-2	
PF-3	
PF-4	

6.2 Major Flux Core Components

Fig. 6.2-1. Sectioned view of a flux core assembly identifying major components



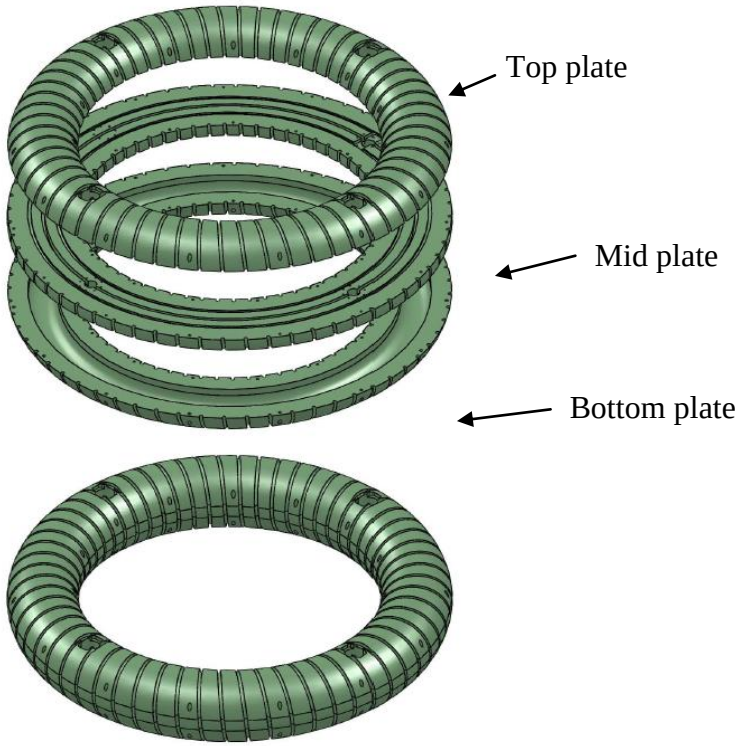


Fig. 6.2-2. G-10 Glass/Epoxy Flux Core Winding Form. Upper view shows the plates which, when assembled, form a toroidal shaped winding form shown in the lower view with internal grooves to support the (4) PF turns and the TF cancellation turn and external grooves to support the (4) 15-turn segments of the TF windings.

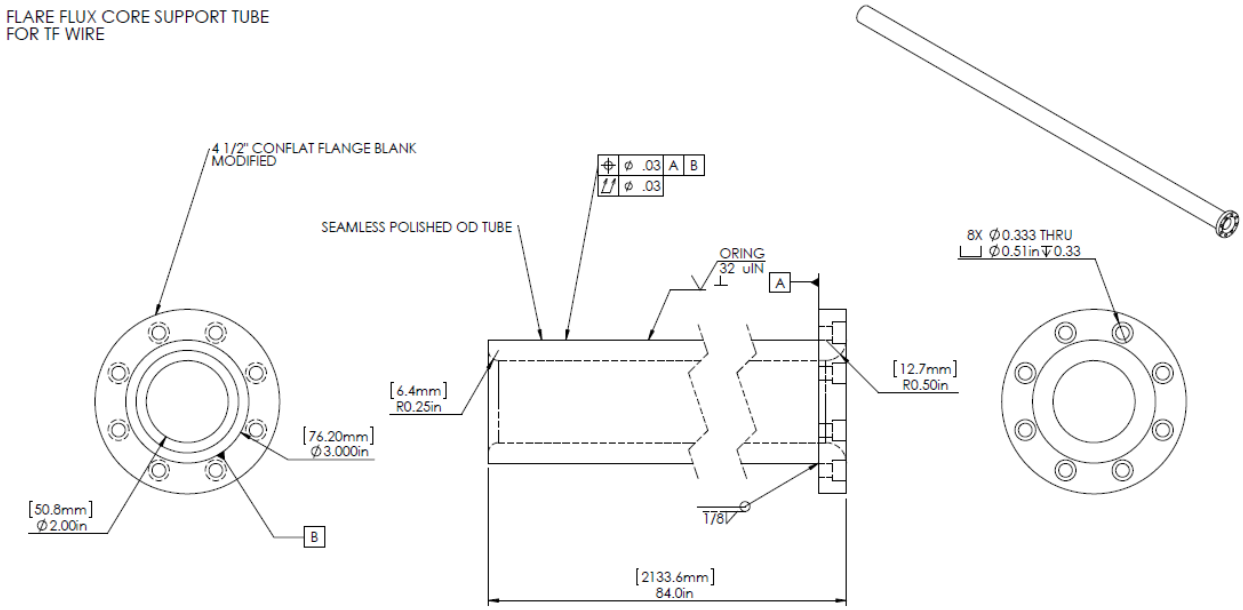


Fig. 6.2-3. Flux Core Support Tubes. The flux core is supported by (4) support tubes. Two act as lead-out conduits for the PF windings, and two act as lead-out conduits for the TF windings.

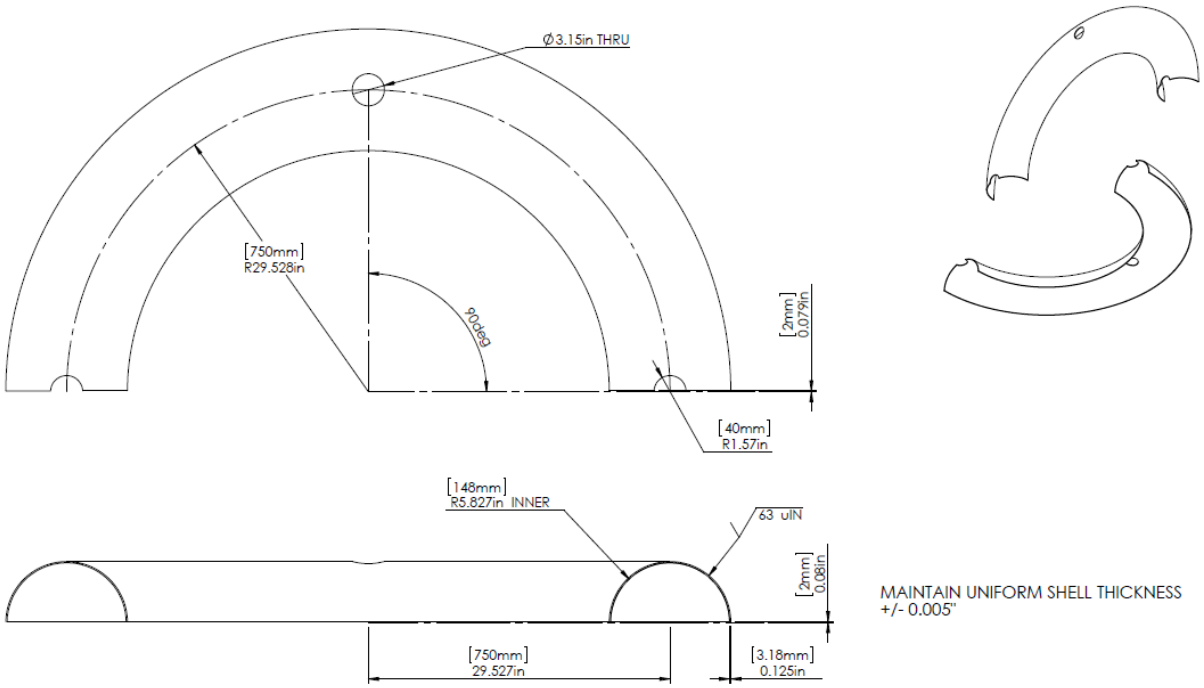


Fig. 6.2-4. Aluminum Ripple Reduction Toroidal Shell. A segmented aluminum shell is used to reduce the magnetic ripple caused by the discrete TF coil turns. The shell is segmented into 4 pieces to reduce circulating currents. All edges must be insulated with Kapton tape.

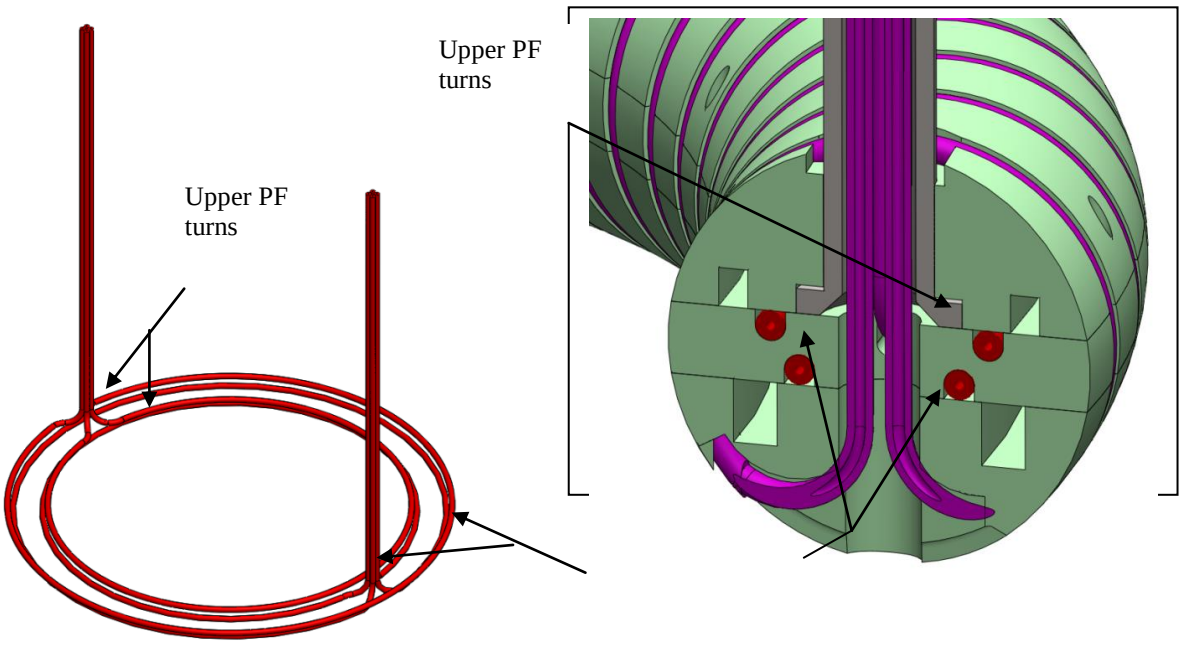


Fig. 6.2-5. Poloidal Field Turns. There are two upper and two lower PF turns.

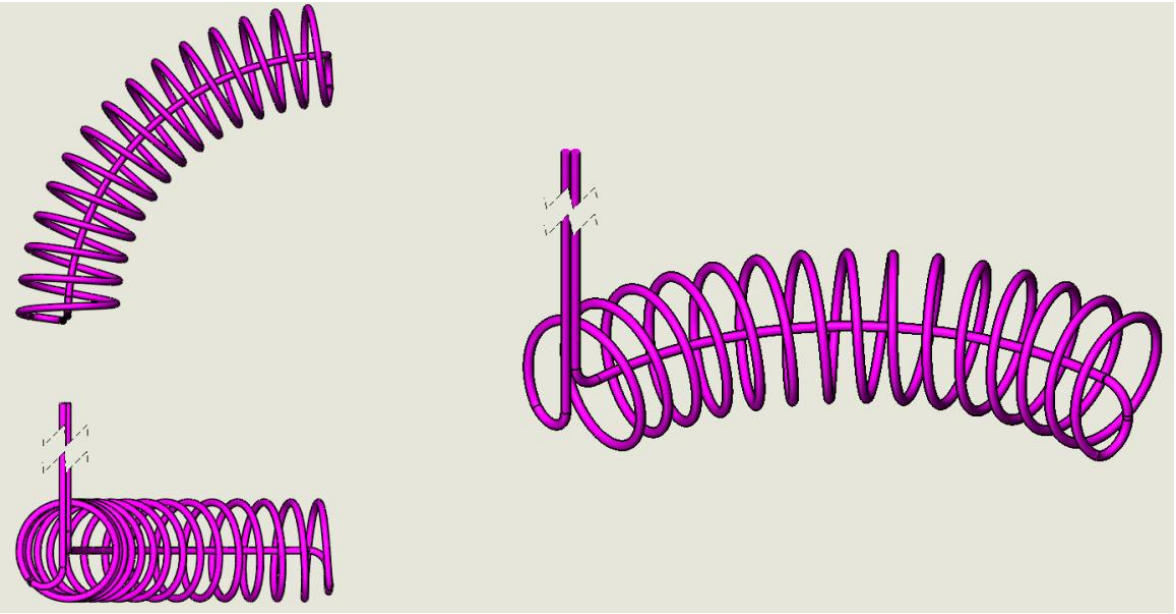


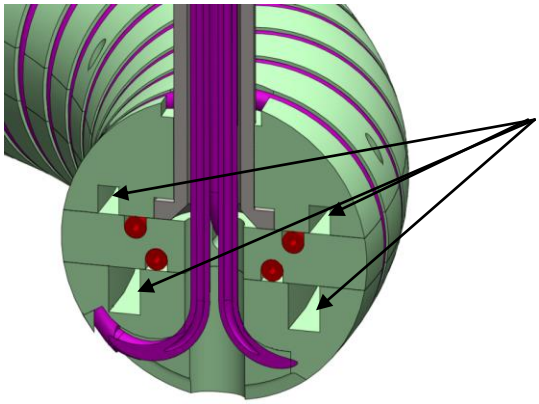
Fig. 6.2-6. One of (4) 15-turn Toroidal Field (TF) Windings. Note the centrally located cancellation segment, which cancels the poloidal field component due to the helical geometry of the turns.

6.3 Manufacturing Outline

6.3.1 Winding Form

The winding form (item 5.1) is to be machined from NEMA Grade G-10 Glass/Epoxy plates. Round all edges to a minimum of 1 mm radius. Temporarily stack the 3 plates of each winding form and check the toroidal grooves for smoothness between the plate sections. Hand smooth the toroidal grooves as required. Drill the (2) holes indicated to 15 mm. These holes will be used for 15 mm dowel pins (light press fit) to assure that the plates when re-stacked are maintained in proper relative alignment. After overall inspection and dimensional inspection, the winding form is to be cleaned with degreaser to remove any grease or impurities.

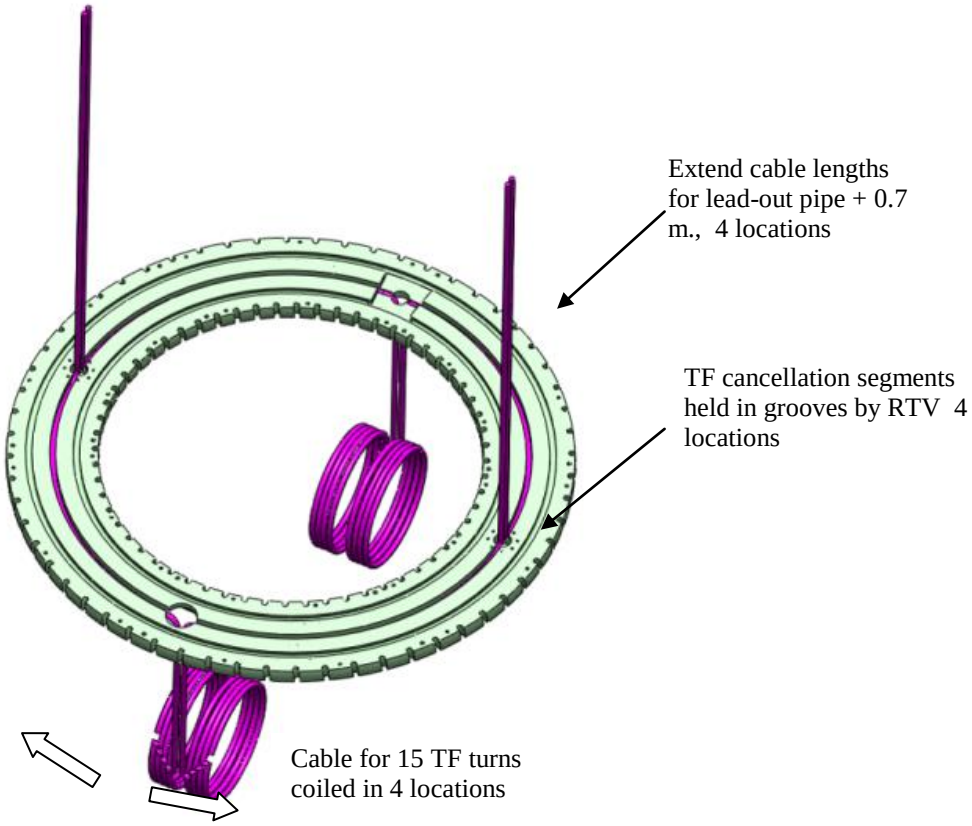
Loosely pack the cavities shown with fiberglass wool (Item 5.18). This is necessary to inhibit plasma generation during operation.



6.3.2 TF Cancellation Segments & Cable for TF Windings

Identify the (2) legs that will house the TF leads. Mark corresponding locations in the mid and lower plates. Cut 4 lengths of Item 3.3 TF cable for the winding, cancellation segment, and leads after carefully verifying these lengths.

Starting with the first TF winding, extend cable through the TF winding lead-out hole in the mid-plate. Run a bead of Item 5.11 RTV 108 along the cancellation groove for this segment. Bend the cable for the cancellation segment into the groove and temporarily clamp in place. Bend the lead-out segment upwards at the lead-out location. Repeat for the (3) other TF winding segments.

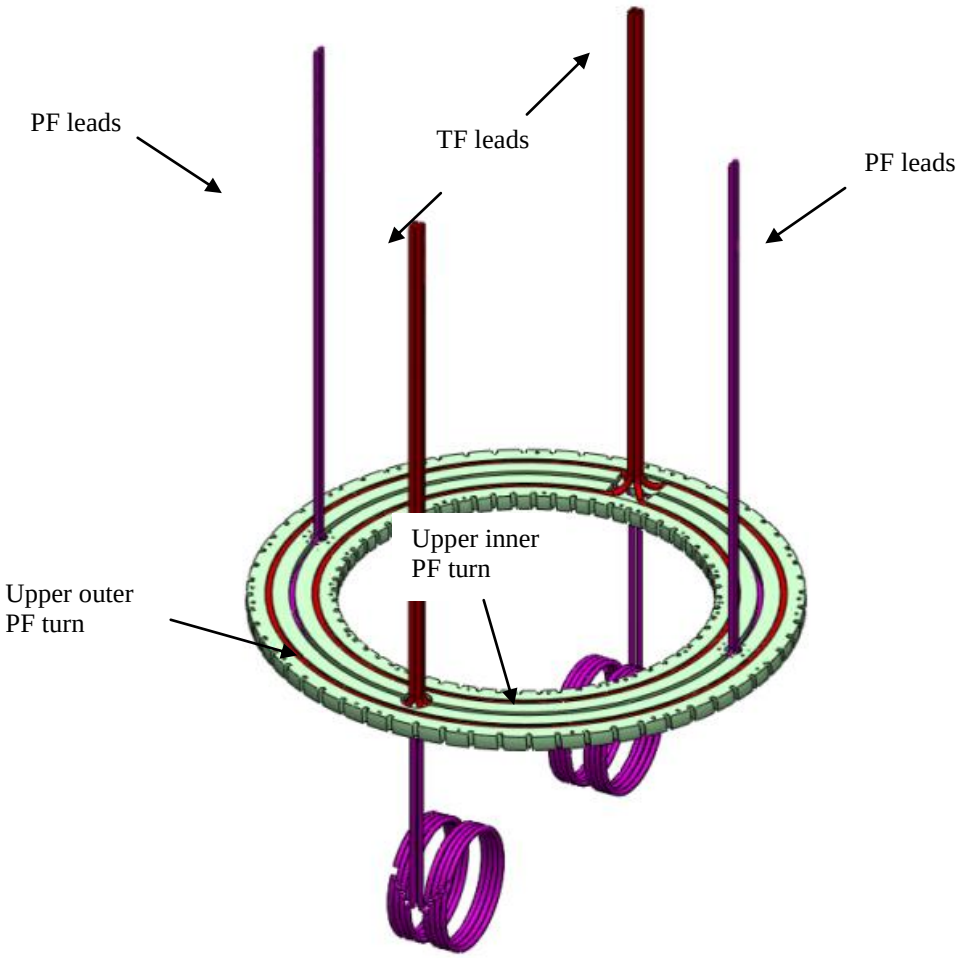


6.3.3 PF Turn Installation

Identify and mark the upper and lower PF turn lead-out locations. Form the PF cables as shown in Dwg. A-FL700-051.

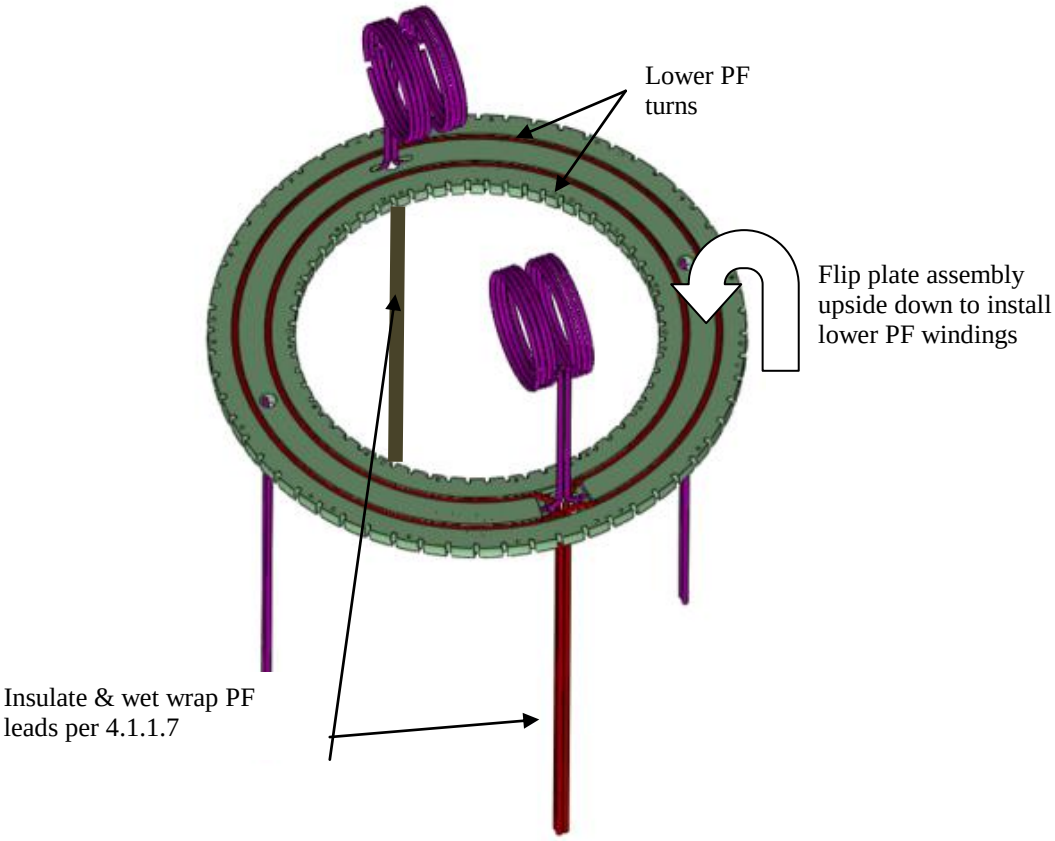
6.3.4 Upper PF Turns

Run a bead of Item 5.11 RTV 108 around the first PF groove. Install the PF cable into the groove, temporarily clamping it as required. Continue with the second upper PF turn.



6.3.5 Lower PF Turn

Flip the mid-plate assembly over. Run a bead of Item 5.11 RTV 108 around the first lower PF groove. Install the turn into the groove, clamping it as required. Continue with the second lower PF turn.



6.3.6 PF Lead Areas

Add (2) layers of shrinkable sleeving (Item 5.12) on each lead. Wet wrap lead bundles together in areas that will be within support legs with 3 layers half lapped of fiberglass tape (item 5.5) saturated with epoxy resin(item 5.6). Allow to cure before proceeding.

6.3.7 Installation of Upper Plate

Assemble 4 support tubes to upper plate. Using a custom made template / fixture, verify that all 4 legs are parallel to each other within the tolerances on the drawings. Carefully trial fit the upper winding form plate with lead-outs over the PF leads to check fit-up. Adjust cable bends as required.

IMPORTANT NOTE: Make an epoxy paste by mixing silica powder (item 5.7) with epoxy resin (item 5.6). Carefully pack the cross-hole region in the lower plate where the TF cable ends. This is important to avoid motion and potential damage to the cables during operation. Use care to assure that the paste also extends into and seals the bottom of the lead support tube so that when resin to poured into the lead stem in Step 6.3.17 it is contained.

The following figures are sectional views through the lead areas.

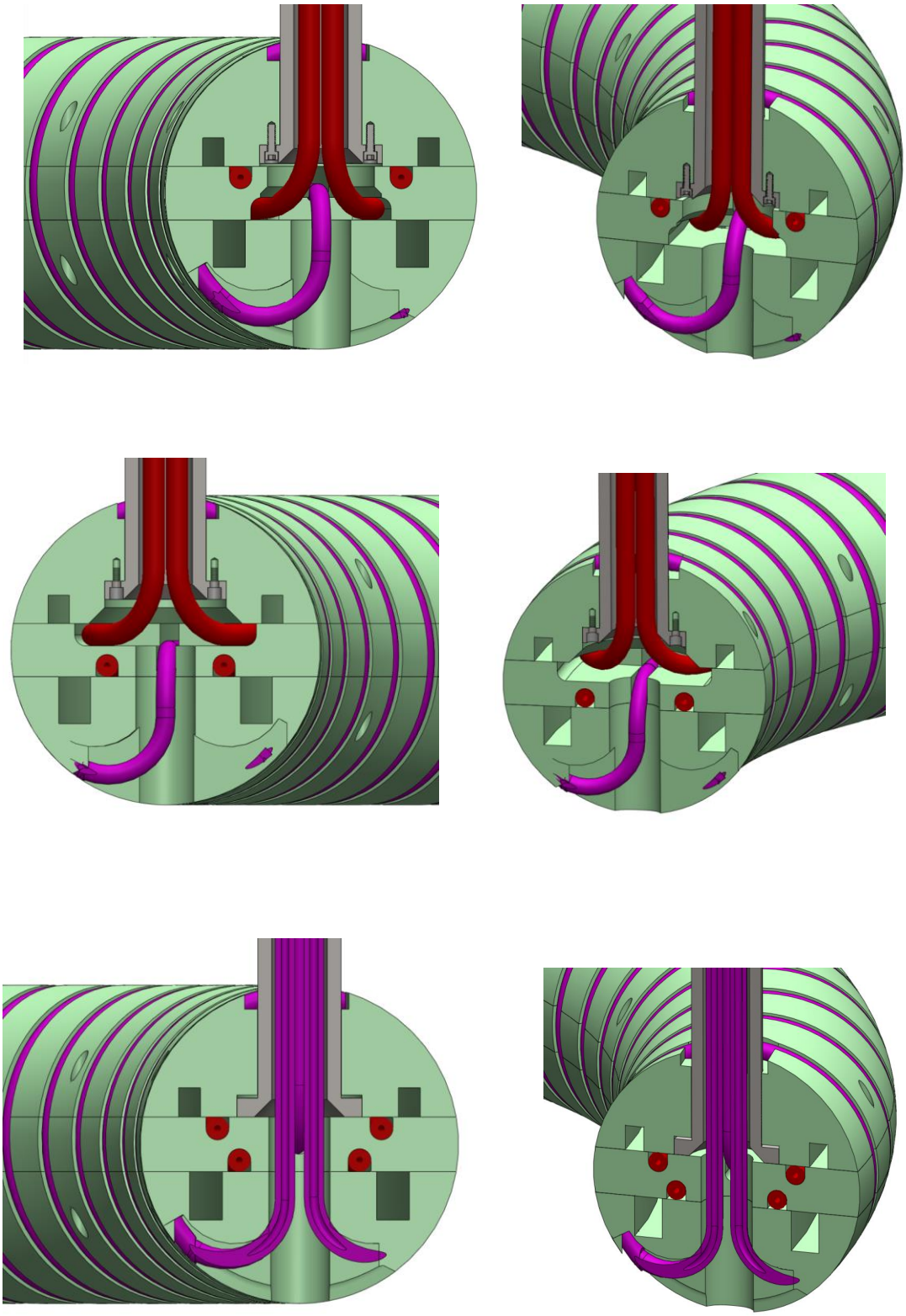
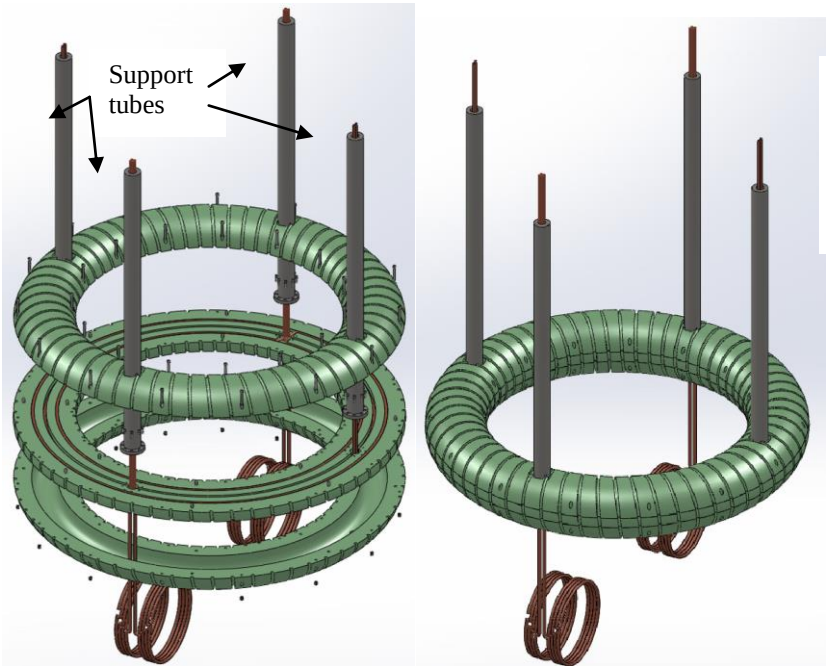


Fig. 6.3.7-1 Sectional views of flux core in lead areas.



Assembly of support tubes and 3 flux core winding form sections in preparation for winding the TF

6.3.8 Installation of Lower Plate

Flip the assembly over. Carefully fit the lower plate over the lower PF turns. Install the 2 alignment dowel pins (refer to 6.3.1) Adjust cable bends as required.

6.3.9 Installation of Fasteners

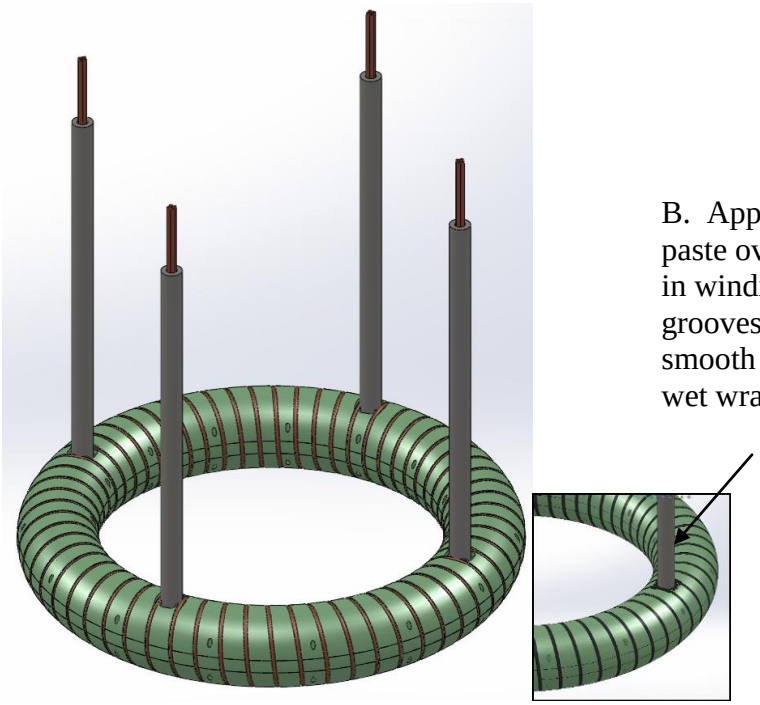
Install all bolts and washers (item 5.4). Torque per requirements on drawings.

6.3.10 TF Windings

There are 4 sections of cable extending from the bottom of the flux core winding form. These sections are to form the 4 (15) turn windings and lead-out. For each of the 4 sections, carefully push the cable into the grooves and finally insert the cable into end termination hole in the flux core and feed through the support leg.

IMPORTANT NOTE: Make an epoxy paste by mixing silica powder (item 5.7) with epoxy resin (item 5.6). Carefully pack the cross-hole region in the lower plate where the TF cable ends. This is important to avoid motion and potential damage to the cables during operation. Use care to assure that the paste also extends into and seals the bottom of the lead support tube so that when resin is poured into the lead stem in Step 6.3.17 it is contained.

A. Winding (4) TF coil sections



B. Applying epoxy paste over TF cables in winding form grooves to provide a smooth surface for wet wrapping

6.3.11 Pre-Wet Wrap Tests

Hold Point 2: All pre-wet wrap electrical, vacuum, and hydraulic results must be reviewed with the Princeton University representative and written approval must be obtained before work continues.

6.3.11-1 Flow Test and Hydrostatic Test

Repeat the tests as defined in 6.1.3 and record results below.

FC-1

Winding Designation	Pressure at beginning of test, Pa	Pressure after 10 min., Pa	Flow test pressure drop Pa	Flow rate l/s
TF-1				
TF-2				
TF-3				
TF-4				
PF-1				
PF-2				
PF-3				

FC-2

Winding Designation	Pressure at beginning of test, Pa	Pressure after 10 min., Pa	Flow test pressure drop Pa	Flow rate l/s
TF-1				
TF-2				
TF-3				
TF-4				
PF-1				
PF-2				
PF-3				

6.3.11-2 Megger Test

Perform a megger test of each winding at 20 kV with all other windings grounded. Record values at beginning of test and after 2 minutes and calculate polarization index. Acceptance criteria: Differences in megger values between all TF tests shall be less than +/- 10 %; similarly differences in megger values between all PF tests shall be less than +/- 10 %.

FC-1

Winding Designation	Insulation resistance at beginning of test	Insulation resistance after 2 minutes
TF-1		
TF-2		
TF-3		
TF-4		
PF-1		
PF-2		
PF-3		
PF-4		

FC-2

Winding Designation	Insulation resistance at beginning of test	Insulation resistance after 2 minutes
TF-1		
TF-2		
TF-3		
TF-4		
PF-1		
PF-2		
PF-3		
PF-4		

6.3.11-3. Electrical cable jacket vacuum test

Using temporary vacuum test fittings which have been custom designed by the subcontractor for test purposes, each length of electrical cable shall be tested to ensure the vacuum integrity of the cables.

With a vacuum leak detector pumping on the cable length, coil the cable length and insert into a plastic bag. Flood the bag with helium and monitor the leak detector for at 1 minute for a rise in the leak detector monitor for helium. Acceptance criteria: There shall be no increase in the leak detector signal for helium.

FC-1

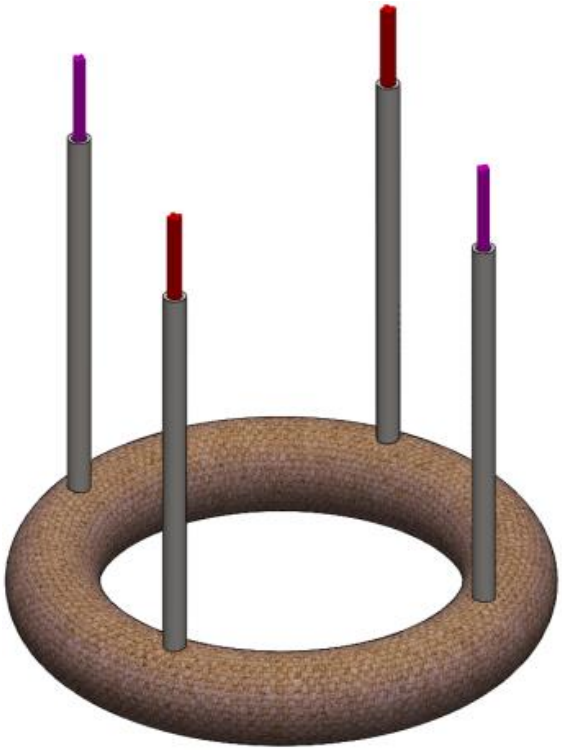
Winding Designation	Indicate pass or fail
TF-1	
TF-2	
TF-3	
TF-4	
PF-1	
PF-2	
PF-3	
PF-4	

FC-2

Winding Designation	Indicate pass or fail
TF-1	
TF-2	
TF-3	
TF-4	
PF-1	
PF-2	
PF-3	
PF-4	

6.3.12 Wet Wrap Inner Layer

Wet wrap flux core with 3 layers 50% overlapped on the inner diameter of the flux core of with Item 5.5 fiberglass tape saturated with epoxy resin, item 5.6. Over wrap with 2 layers mold released shrinkable tape; shrink with a heat gun. Allow to cure, and then remove shrinkable tape and sand off any epoxy drips.

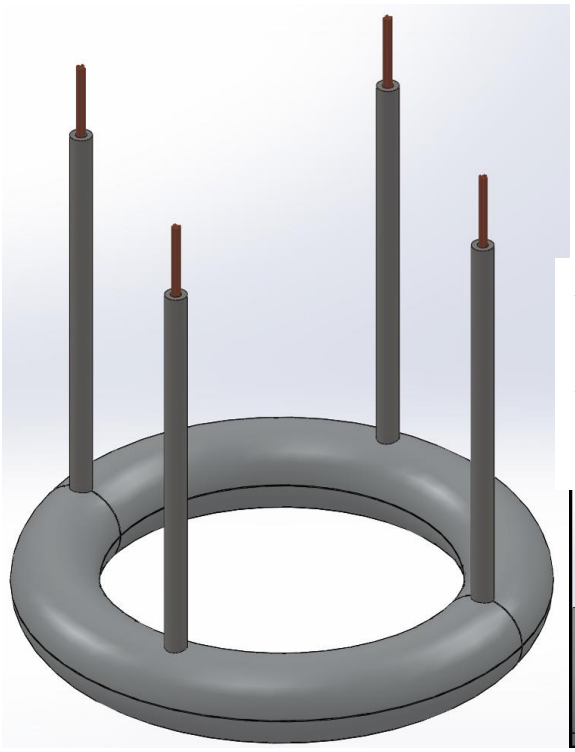


First epoxy-glass wet wrap over TF windings

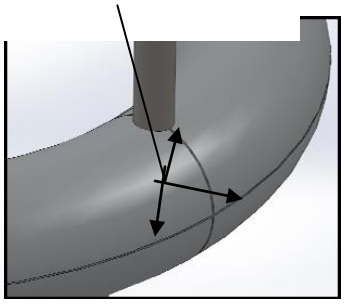
6.3.13 Installation of Aluminum Shell

Round all edges of the aluminum shell. Do an initial fit-up of shell segments. If necessary for a good fit, apply more layers of wet wrap (step 6.3.12) and allow to cure. Wipe all shell surfaces with Acetone or alcohol. Carefully apply Kapton tape item 5.13 to all edges to avoid arcing between shell segments and shell and flux core legs. Make an epoxy paste by mixing silica powder (item 5.7) with epoxy (item 5.6) . Apply a layer of this paste on the back side of each shell segment just prior to installation. Use strap clamps to fit the shell tightly onto the core. Carefully fill gaps between shell segments and shell segments and legs with epoxy paste, being careful to avoid drips and to form a smooth surface. It may be desirable to add more silica to make a stiffer paste for this step.

Electrical insolation test of segments: With all segments grounded except for the segment under test, sequentially megger each section to the other at 100V to ensure electrical insolation between segments.

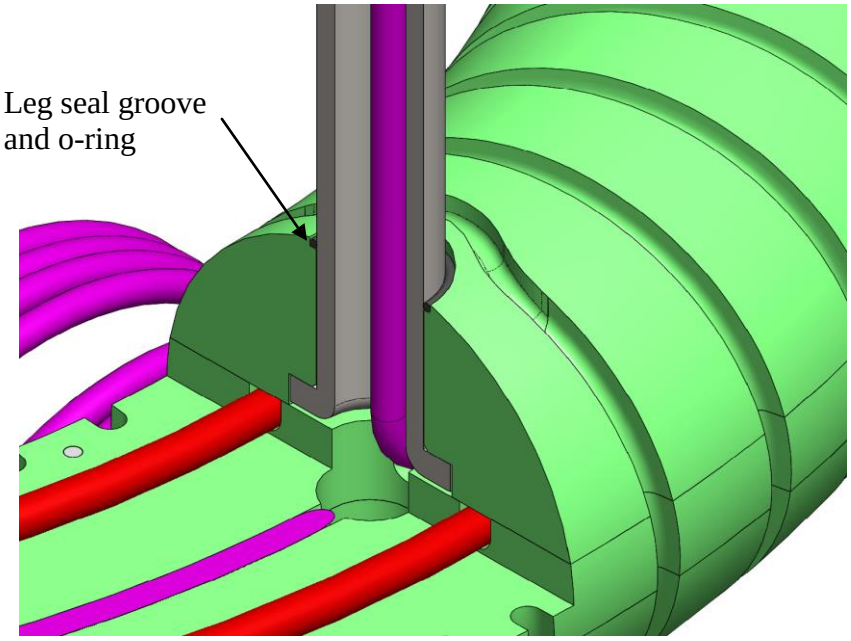


Apply epoxy paste in all gaps to provide a smooth surface for the vacuum sealing membrane.



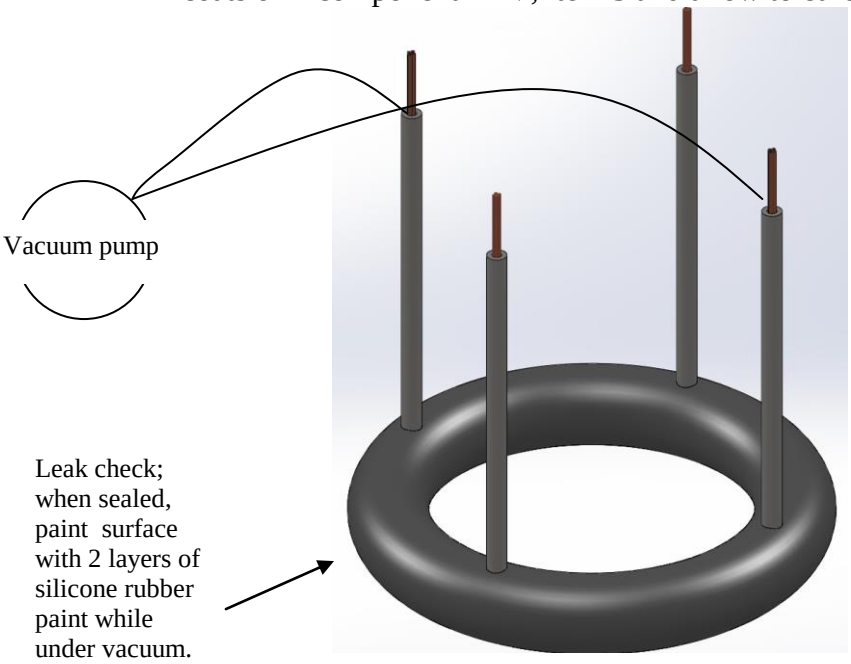
6.3.14 Installation of Leg Seals

Refer to Dwg. A-FL700-006 . Apply a thin uniform coat of Master Bond EP29LPSP epoxy to the machined seal grooves in the upper G-10 plates to make good surfaces for the leg o-ring to seal against. After the epoxy is cured, push the o-ring down support leg and bottom it into the seal groove. Check for complete sealing between the leg and seal groove. Apply masking tape on the G-10 surface around the seal groove and then apply RTV-108 silicone rubber above the seal and smooth with the G-10 surface. Allow to thoroughly cure before proceeding. Remove the masking tape and clean the surface with degreasing agent.



6.3.15 Preliminary Vacuum Test

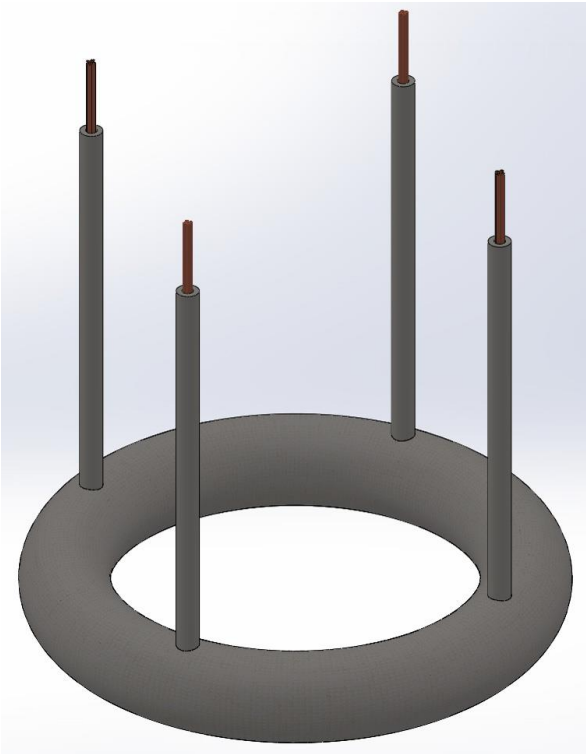
Pump on the (2) vacuum pumping tubes with mass spectrometer leak detectors. Flow helium gas over the outside to locate any leaks. Repair leaks. Once the entire core is leak tight, coat the outside surface with 2 coats of 2-component RTV, item 3 and allow to cure.



6.3.16 Wet Wrap Outer Layer

Wet wrap flux core with 3layers of item 3.5 fiberglass tape (50% overlapped on the flux core ID), saturated with ***low outgassing*** epoxy resin

item 3.7. Wrap tightly to avoid wrinkling as more layers are applied and shrinkable tape is applied. Apply the last 3 layers, again 50% overlapped on the coil ID. Use care as these 3 layers are applied so that the toroidal surface is uniformly smooth glass/epoxy. Over wrap with 2 layers mold released shrinkable tape,. Shrink with heat gun. Allow the resin to cure, then remove shrinkable tape and sand off any epoxy drips and sand surface smooth.



6.3.17 Potting of Lead Stems

Fill all 4 lead stems with room temperature epoxy (item 5.3). Be sure to also fill the central areas between cables. This is required to resist electromagnetic motions of the cable during operation. The epoxy must not leak into the G10 section. The plug of epoxy in step 6.3.10 should keep the epoxy in the legs and keep epoxy from leaking into the G10 vacuum cavities.

6.3.18 Final Pre-Shipment Tests

All of the tests defined in Sect. 6.1.3 are to be repeated below.

Hold Point 3: All final pre-shipment electrical, vacuum, and hydraulic results must be reviewed with the Princeton University representative and written approval must be obtained before work continues.

6.3.18-1 Flow Test and Hydrostatic Test

Repeat the tests as defined in 6.1.3 and record results below.

FC-1

Winding Designation	Pressure at beginning of test, Pa	Pressure after 10 min., Pa	Flow test pressure drop Pa	Flow rate l/s
TF-1				
TF-2				
TF-3				
TF-4				
PF-1				
PF-2				
PF-3				

FC-2

Winding Designation	Pressure at beginning of test, Pa	Pressure after 10 min., Pa	Flow test pressure drop Pa	Flow rate l/s
TF-1				
TF-2				
TF-3				
TF-4				
PF-1				
PF-2				
PF-3				

6.3.18-2 Megger Test

Perform a megger test of each winding at 20 kV with all other windings grounded. Record values at beginning of test and after 2 minutes and calculate polarization index. Acceptance criteria: Differences in megger values between all TF tests shall be less than +/- 10 %; differences in megger values between all PF tests shall be less than +/- 10 %.

FC-1

Winding Designation	Insulation resistance at beginning of test	Insulation resistance after 2 minutes
TF-1		
TF-2		
TF-3		
TF-4		
PF-1		
PF-2		
PF-3		
PF-4		

FC-2

Winding Designation	Insulation resistance at beginning of test	Insulation resistance after 2 minutes
TF-1		
TF-2		
TF-3		
TF-4		
PF-1		
PF-2		
PF-3		
PF-4		

6.3.18-3. Electrical cable jacket vacuum test

Using temporary vacuum test fittings which have been custom designed by the subcontractor for test purposes, each length of electrical cable shall be tested to ensure the vacuum integrity of the cables.

With a vacuum leak detector pumping on the cable length, coil the cable length and insert into a plastic bag. Flood the bag with helium and monitor the leak detector for at 1 minute for a rise in the leak detector monitor for helium. Acceptance criteria: There shall be no increase in the leak detector signal for helium.

FC-1

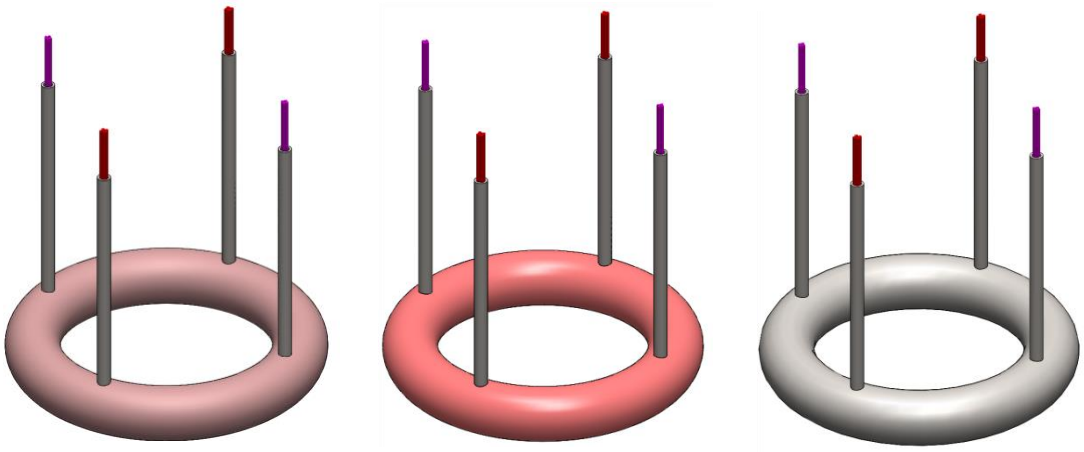
Winding Designation	Indicate pass or fail
TF-1	
TF-2	
TF-3	
TF-4	
PF-1	
PF-2	
PF-3	
PF-4	

FC-2

Winding Designation	Indicate pass or fail
TF-1	
TF-2	
TF-3	
TF-4	
PF-1	
PF-2	
PF-3	
PF-4	

6.3.19 Final Surface Preparation ***(This is to be performed at Princeton University by PU Personnel)***.
R&D is presently underway to compare the two processes and allow a final selection.

Apply multiple coats of epoxy (item 5.8) until a build of 0.5 mm. is obtained. It is permissible to thicken the epoxy with silica powder (item 5.7) if this provides a more uniform, sag-free coating.



a. Apply Gel Coat b. Lightly sand smooth c. PPPL will apply Inconel coating

7.0 QUALIFICATIONS

N/A

8.0 ENVIRONMENT, SAFETY, AND HEALTH

N/A

9.0 QUALITY ASSURANCE REQUIREMENTS

9.1 INSPECTION/SURVEILLANCE and AUDIT

It is the responsibility of the selected subcontractor to perform daily inspections and surveillances throughout the manufacturing of the coils. Authorized representatives of PU will periodically visit the selected subcontractor to perform inspection and surveillances as well.

All measurements and tests will be witnessed and signed-off by the subcontractor's QC representative. PU may designate specific measurements or tests as mandatory witness points for PU.

Subcontractor's Quality Assurance representatives shall observe the work area regularly to ensure that approved manufacturing processes are followed. QA shall

ensure the work place is kept clean and the possibility of contamination in the insulation system is minimized.

9.2 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.

9.3 INSPECTION and TEST PROCEDURES:

Inspections and tests shall be performed in accordance with approved procedures referencing criteria for acceptance or rejection. Adequate records documenting the specific item tested or inspected, the results (actual measurement, where applicable), any instruments used with calibration date, and the inspector/test operator shall be maintained and available for PU reviews.

9.4 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 will include completed Process Procedures- "(travelers) per 4.7"; and relevant data such as materials certifications, material test reports, inspection reports, discrepancy reports, etc. This information shall be complete and legible and validated by responsible personnel and shall be traceable to subject items.

9.5 EQUIPMENT/MATERIAL IDENTIFICATION and STATUS

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

9.6 PROCESS PROCEDURES:

Process procedures will be used as a signoff/approval document noting that critical manufacturing steps have been completed. Authorized personnel associated with the manufacturing, inspection and test processes shall initial and date the procedure records for this purpose. In addition, the process procedures are to provide witness points as well as references for test results, and measurements. Each EF coil assembly will have its own set of procedures or travelers.

NOTE: The procedures shall be filled out in a timely fashion once a particular activity has been completed.

9.7 CALIBRATION of TEST and MEASURING EQUIPMENT:

Inspections and tests shall be performed using properly calibrated measuring and test equipment. Calibration standards shall be traceable to the National Institute for Standards and Technology (NIST) or equivalent. Where such standards do not

exist, the basis used for calibration shall be documented. Calibration standards shall not be used for shop inspections, but instead be protected against damage or degradation.

9.8 SUBMITTAL of MANUFACTURING/INSPECTION/TEST (MIT) PLAN

The Supplier shall provide their MIT/QA plan and all associated procedures to PU for approval at least 5 workdays prior to beginning fabrication. Procurement of materials may start prior to plan approval, but coil fabrication shall not.

The Manufacturing, Inspection, Test and Quality Assurance Plan (MIT/QA Plan) is required for PU review and approval prior to start of fabrication. All inspections and tests referenced in the Specifications listed in Section 2 must be addressed in the MIT/QA Plan. From the plan, PU may designate selected operations as mandatory "witness" points. Subcontractor shall provide PU with a minimum of five (5) working days' notice in advance of these witness points. Such witness points shall be mutually planned to minimize delays. The MIT/QA shall include as a minimum the following:

1. Outline of the sequence of operations Outline of the sequence of operations
2. Identify critical manufacturing operations
3. Identify inspections, examinations, and tests (Receipt, In-process, and Final)
4. Include procedures for special processes, inspections, and tests.
5. Identify the documentation to be provided.
6. Approvals for each critical area must be included as these areas are completed.
7. Areas to record the required tests, inspections, etc. must be included.

Deviations from the MIT/QA Plan, other than simple, minor sequence changes, require written PU approval prior to implementation. All deviations shall be identified in the subsequent progress report.

9.9 WITNESS/HOLD POINTS and NOTIFICATION OF PRICETON IN ADVANCE

Princeton reserves the right to designate selected manufacturing, inspection and/or test operations as mandatory Witness or Hold points. Subcontractor shall provide Princeton with five (5) working days' notice in advance of such points.

NOTE: Hold points are indicated in the applicable sections of this document.

9.10 SUBMITTAL of MATERIAL CERTIFICATIONS

Subcontractor's Certified Material Test Reports (CMTRs) showing relevant chemical, mechanical and electrical properties of materials used, where applicable, shall be submitted to PU. Certifications for the insulation, epoxy, copper material [lead blocks, etc.], braze material and fillers are required as a minimum. It is recognized that only certificates of grade may be available for materials such as fillers. Certifications shall be provided to PU when the subcontractor approves the material for use (start of job). A copy of the material certifications shall be submitted to PU as soon as the sub-contractor has

determined that the material is acceptable for use. Details can be found in the FLARE EF Coil Manufacturing Specification

9.11 INSPECTION and TEST REPORTS

Reports from all required inspections and tests shall provide the test or inspection parameters, actual results measured, and identification of the inspector/tester. Reports shall be reviewed by appropriate subcontractor's personnel prior to submittal. Please refer to the MIT Plan for details.

9.12 NONCONFORMANCES & CORRECTIVE ACTIONS and NOTIFICATION OF PU

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 Princeton is required prior to the use of the nonconforming item or service. 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.

9.13 WEELKY REPORTS

The selected subcontractor shall provide weekly status reports covering technical, administrative, and quality activities and notable problems/issues and. The report may be short in bullet format as long as all important issues are noted. The report may be submitted as e-mail and should include photographs. A "GoToMeeting" can be used instead of the report for better communication.

9.14 MONTHLY STATUS REPORTS

Subcontractor shall submit via e-mail, to be received by PU by the last working day of each month, a report that includes a schedule of major tasks to be performed under the Subcontract, and actual/projected completion dates. Include a narrative explanation of significant schedule delays. Photos are recommended to support the narrative.

9.15 SUBMITTAL of COMPLETED RELEASE for SHIPMENT FORM

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

10.0 SHIPPING STORAGE AND HANDLING

10.1 Each flux core assembly shall be drained of all water, flushed with a 50/50 ethylene glycol/water mixture and then dried and sealed for storage and subsequent shipment.

10.2 Each flux core shall have a name tag that, as a minimum provides the coil name and ID Code; date the coil was completed and coil weight in lbs.

10.3 Each flux core shall be wrapped in minimum 0.005 inch (0.127 mm) thick polyethylene and crated for shipment. The crate shall be wooden and built for handling with slings from overhead cranes and forklifts.

10.4 Packing and shipping details shall be approved by PU. The crate shall protect the coil from shock, damage from load shift, and weather conditions, including precipitation.

A. Vendor name, shipper, purchase order number, coil number and gross weight shall be marked on the shipping container.

B. Coil manufacturer is responsible for arranging shipment, and for the safe arrival of the flux cores at their final destination site

10.5 Each flux core shall be prepared for shipment is such a manner as to ensure acceptance by common carrier for transportation at the lowest applicable rate and to afford protection from normal hazards of transportation.

11.0 WARRANTY

N/A

12.0 ATTACHMENTS

12.1 Exhibit 1: Product Quality Certification & Shipping Release

12.2 Addendum I: List of Drawings.

13.0 DOCUMENTATION AND DELIVERABLES

#	Physical Deliverables Required	When Deliverable Is Required	Deliverable Received (✓)
1	Two Flux Cores	@completion	
2	Flux Core Leg inspection fixture	@completion	
2	Remainder of TF and PF cables	@completion	
Exceptions (Add justification for any missing physical deliverables that will not be received):			

#	Document Deliverables Required	When Deliverable Is Required	Deliverable format (paper, electronic etc.)	Storage Location for Deliverable	Deliverable Received (✓)
1	Complete data packages for each Flux Core Including MIT Plan with signed off steps, Test Records, and Inspection Records from sections 5.3, 5.5, 6.0, 9.8, 9.10, & 9.11	@completion	electronic	Ops Center	
2	CAD/CAM Files per section 5.4	@completion	electronic	Ops Center	
3	Progress Reports per section 9.13 & 9.14	Weekly	electronic		
3	Shipping Release per section 9.15	@completion	electronic	Ops Center	
Exceptions (Add justification for any missing document deliverables that will not be received):					

Procurement Technical Representative/COG:_____

(Sign-off and provide a copy to Procurement Division when job is completed and deliverables are dispositioned and placed/filed in the correct locations (e,g., Operations Center.)

EXHIBIT 1: Shipping Release Form

PRINCETON UNIVERSITY—PU
PRODUCT QUALITY CERTIFICATION & SHIPPING RELEASE

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

Completed by Supplier

PU SUBCONTRACT/ ORDER #	ITEM #(s)	QUANTITY SHIPPED

ITEM DESCRIPTION	SUPPLIER REFERENCE #	SHIPMENT #

SUPPLIER'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: _____

Completed, signed, and returned by PU before shipment

PU (AUTHORIZED REPRESENTATIVE) SHIPPING RELEASE

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.

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.

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS:

REMARKS/PRODUCT SERIAL NUMBERS:

BY PU QA REPRESENTATIVE (OR DESIGNEE)	DATE

Rev. 1 November 15, 201

Addendum I: Drawing List

Drawing Title	**Drawing Number**
FLARE Flux Core RING ONLY	A-FL700-004 (2 sheets)
FLARE Flux Core Assem REV H	A-FL700-006 (4 sheets)
FLARE Flux Core TOTAL Assem	A-FL700-001
FLARE FLUX CORE REV H TOP	A-FL700-011 (7 sheets)
FLARE FLUX CORE REV H Bottom	A-FL700-014 (5 sheets)
FLARE FLUX CORE REV H MID	A-FL700-021 (6 sheets)
FLARE FLUX CORE Support Tube TF	A-FL700-041
FLARE FLUX CORE Support Tube PF	A-FL700-042
FLARE Flux Core PF Wire Assem	A-FL700-051
FLARE FLUX CORE TF Wire Right quarter	A-FL700-052
FLARE FLUX CORE Al Shell, lower	A-FL700-062
FLARE FLUX CORE Al Shell, upper	A-FL700-064