Manufacturing Process Outline/Traveler
For the Inner PF-1A Coils
ETI Doc #: 53156-603

Coil Identification Number: PF-1A-UPPER

Everson Tesla Inc. # 53156 Work Order# 5789

Customer: Princeton University Plasma Physics Laboratory
PO Box 451
Princeton, NJ 08543

PPPL Purchase Order Number: S012485-G Date: 3/14/13

Original Author(s): BLAKE KOOP	APPROVED BY (Signature & Date)
Date: 12/10/13	Project Engineer: 2/11/14
Revised by:	Manufacturing Rep: 2/11/14
Revision Date:	Quality Assurance: 2/11/14
Revision:	PPPL Rep.: Steve Raftopoulos

The original completed Traveler and the Test Record Sheets shall be maintained in the Everson Tesla QA Department.

Revision Table

Revision	Description	Date
A	Initial Document Release	2/10/14

1.0 Applicable Documents

1.1 PPPL Drawings: (all inner PF Coil drawings)

DOCUMENT NO.	REVISION
E-DC1417	4
E-DC1434	
E-DC1440	
E-DC1444	3
E-DC1445	3
E-DC1446	
E-DC1447	
E-DC1448	
E-DC1449	3
E-DC1450	3
E-DC1451	
E-DC1452	
E-DC1453	
E-DC1465	2
E-DC1466	2
E-DC1467	2
E-DC1468	2
E-DC1470	1
E-DC1471	
E-DC1472	1
E-DC1486	

PPPL Specifications:

D-NSTX-SOW-134-137	Statement of Work	Dated:11/16/2012
D-NSTX-SPEC-134-137	Manufacturing Specification	Dated:12/9/2012

It is the intent of this MPO to fabricate the coils in strict accordance with the drawings and specifications and meet the requirements of Princeton Plasma Physics Laboratory.

1.2 ETI Drawings:

53156-A&B-T-200_B	Mandrel Mounting Adapter for the A and B Coils
53156-C-T-200_B	Mandrel Mounting Adapter for the C Coil

1.3 Standards and Codes

1.3.1 **ASTM American Society for Testing and Materials**

1. ASTM B32 – Standard Specification for Solder Material
2. ASRM B188 – Standard Specification for Seamless Copper Bus Pipe and Tube
3. B170 – Standard for oxygen free electrolytic copper refinery shapes

1.3.2 **AWS American Welding Society**

1. AWS A5.8 Classification: BCuP-5, Brazing Alloys
2. AWS QC1 Standard for AWS Certification of Welding Inspections

1.3.3 **ASME American Society for Mechanical Engineers**

1. ASME Boiler and Pressure Vessel Code Section IX Welding and Brazing Qualification

1.3.4 **IEEE Institute of Electrical and Electronic Engineers**

1. IEEE #4, Techniques for Dielectric Tests

1.3.5 **NEMA National Electrical Manufacturers Association**

1. Grades and specifications for materials developed for the electric and electronics industries. [For insulating materials like G10.]

GENERAL NOTES FOR COIL FABRICATION:

- **Correct errors by line, signature, and date. Do not write over or use white out!**
- **No MPO step shall be omitted in the manufacture of the coil without prior approval from PPPL and the project engineer. Discrepancies require an NCR. Sequence changes and process variations that do not affect specification values or omit processes may be authorized by the Project Engineer.**
- **No repair of any discrepancy shall be initiated without prior approval from PPPL and the project engineer. All discrepancies require an NCR.**
- **All work up to and including installation of the coil into the mold must be performed in the designated PPPL clean room.**
- **Clean, lint-free gloves and lab coats are required to be worn during the handling of insulated conductor, insulation, G-10 fillers or other coil components. Coil components that are inadvertently handled with bare hands or otherwise soiled must be cleaned with acetone.**
- **Take protective measures to prevent contamination. Keep parts and conductor covered at all times. Also cover winding during work stoppage.**
- **Only "Sharpie" brand name permanent markers may be used on or near the coil. No pencils are allowed in the winding room.**

- **Keep metal cuttings and filings out of winding, leads and insulated conductor during metal cutting, filing, sanding and polishing operations. This type of work shall be minimized near the coils whenever possible.**
- **Never use forced air to remove particles or debris. Use a vacuum.**
- **Round all sharp edges on conductor (.02" radius typical) that contacts the insulation. The surfaces shall then be cleaned with acetone and dried prior to use.**
- **Surfaces on G-10 filler materials shall be sanded to remove any high gloss surface, to promote bonding of the epoxy. The surfaces shall then be cleaned with acetone and dried prior to use.**
- **Fill all voids between turns or near lead areas with S-2 glass or G-10 fillers to minimize resin rich areas.**
- **Glass tape filler material shall be inserted between all G-10 to G-10 mating surfaces.**
- **When cutting conductor to length, arrange the airflow to expel particles away from the conductor bore.**
- **Acetone and ethanol are acceptable solvents for use on this program.**
- **All Everson Tesla safety procedures must be followed at all times.**
- **Any bare spots on the conductor, one-inch or greater in length, need to have primer applied. Primer applied during coil winding must be cured by heat lamp at ≥ 100°C until dry.**

2.0 Parts, Materials, and Certifications

2.1 The following provides a list of the parts and materials required to fabricate the coils.

REQUIRED	ASSY.	53156-2A, PF-1A, LOWER ASSEMBLY PF-1A	DWG #	REQ.
PER COIL QTY	STOCK ID.	DESCRIPTION	DWG	PER COIL QTY
1.0	53156-02A	MANDREL LOWER ASSY, PF-1A	E-DC1447	1.0
1.0	53156-002A	SUPPORT MANDREL WELDMENT -LOWER	E-DC1444-01	1.0
1.0	53156-003	SHIM, PF-1A COIL BUNDLE-TYPE A	E-DC1446-1	1.0
1.0	53156-004	SHIM, PF-1A COIL BUNDLE-TYPE B	E-DC1446-2	1.0
1.0	53156-005	SHIM, PF-1A COIL BUNDLE-TYPE C	E-DC1446-3	1.0
1.0	53156-006	SHIM, PF-1A COIL BUNDLE-TYPE D	E-DC1446-4	1.0
4.0	53156-007	SHIM, PF-1A COIL BUNDLE-TYPE A	E-DC1446-5	4.0
1.0	53156-008	LEAD SUPPORT BLOCK,PF-1A TYPE A	E-DC1465-1	1.0
1.0	53156-010	FILLER PIECE, PF-1A COIL-TYPE A	E-DC1465-3	1.0
1.0	53156-011	FILLER PIECE, PF-1A COIL-TYPE B	E-DC1465-4	1.0
1.0	53156-012	FILLER PIECE, PF-1A COIL-TYPE C	E-DC1465-5	1.0
1.0	53156-013	FILLER PIECE, PF-1A COIL-TYPE D	E-DC1465-	1.0

			6	
1.0	53156-014	FILLER PIECE, PF-1A COIL-TYPE E	E-DC1465-7	1.0
1.0	53156-015	FILLER PIECE, PF-1A COIL-TYPE F	E-DC1465-8	1.0
1.0	53156-016	FILLER PIECE, PF-1A COIL-TYPE G	E-DC1465-9	1.0
1.0	53156-017	FILLER PIECE, PF-1A COIL-TYPE H	E-DC1465-10	1.0
1.0	53156-018	LEAD SUPPORT BLOCK, PF-1A COIL TYPE C	E-DC1468-1	1.0
1.0	53156-019	LEAD SUPPORT ANGLE PF-1A TYPE A	E-DC1468-2	1.0
1.0	53156-020	LEAD SUPPORT ANGLE, PF-1A TYPE B	E-DC1468-3	1.0
2.0	53156-023	COOLING ADAPTER FITTING, PF-1A	E-DC1471-1	2.0
2.0	53156-024	COOLANT FITTING ELBOW, PF-1A,1B,1C	E-DC1471-3	2.0
2.0	53156-025	LEAD FLAG, PF-1A	E-DC1472-1	2.0
1.0	91950A031	FLAT WASHER 3/8",SAE 316 SS	91950A031	18.0
3.0	93190A630	3/8 -16 UNC 2A X 1.75 LG HEX HD CAP SREW	93190A630	2.0
1.0	93150A626	3/8 -16 UNC 2A X 1.25 LG HEX HD CAP SREW	93190A626	18.0
1.0	M0310	TAPE KAPTON ADH .002 X 4.0 X 36 YDS.	SPEC 3.3.7	1.5
1.0	M3112R12	ALLOY BRAZE .063 DIA X 18 QQ-B-654A	SPEC 3.5	0.12
1.0	M7229	EPOXY RESIN CTD 425	SPEC 3.4.1	90
1.0	M7230	PRIMER, CTD-450	SPEC 3.2.1	0.42
2.0	M8007	GLASS TAPE .004 X 1" X 36 YDS S2 SILANE	SPEC 3.3.2.2	64
2.0	M8008	GLASS TAPE .010 X 2" X 36 YDS S2 FINISH	SPEC 3.3.3	16
1.0	W4004CS	CU CDA10700 1.066 X .564 OD .205 CUSTOMER SUPPLIED	C-DC1466	6.5

2.2 Items Requiring PPPL Approval

2.2.1 Tooling Drawings

Drawings for the following Inner PF Coil tooling items shall be submitted to PPPL for approval prior to purchasing the tooling:

- VPI potting enclosure along with the filling design scheme

2.2.2 Manufacturing Drawings and Documents

Everson Tesla shall submit the following in-house drawings and documents for the TF Coil to PPPL for approval prior to implementation of any specific process:

- Manufacturing drawings

- Manufacturing, inspection, and test plan; quality assurance plan and manufacturing procedures
- Damaged insulation repair procedure
- Soldering manufacturing procedure
- Brazing manufacturing procedure
- Braze repair procedure
- VPI procedure
- Packaging and shipping details

2.2.3 Material Selection

Everson Tesla offers the following materials for consideration and approval by PPPL:

- Cleaning solvent for conductor and insulation materials – Everson Tesla offers acetone and/or ethanol as the desired cleaning solvents.
- VPI mold release – Everson Tesla offers RAM 225 as the desired mold release. ETI uses this mold release successfully with CTD 101K as well as CTD Cyanate Ester products.

2.3 Mandrel Subcontract In-Process Monitor

2.3.1 The mandrels are being fabricated by VAL-FAB, Inc., located at 218 Jackson Street, Neenah, WI 54956.

2.3.2 The final machining work was completed by Precision Boring Co., Clinton Twp., Michigan 48036.

2.4 Required PPPL Notifications (3 day notice)

2.4.1 Coil Support Receipt Inspection
2.4.2 Pre-VPI hydrostatic pressure test
2.4.3 Pre-VPI flow test
2.4.4 Pre-VPI electrical tests
2.4.5 Post-VPI hydrostatic pressure test
2.4.6 Post-VPI flow test
2.4.7 Post--VPI electrical tests

2.5 Material Certifications

2.5.1 Everson Tesla shall obtain the following material certifications and provide copies of the certifications to PPPL:

Description	ETI Part #	Certification
Turn Insulation	M8007	Boron Free
Ground Insulation	M8008	Boron Free
CTD 425	M7229	Cert of Analysis

Mandrel 316 SS	53156-002B	MTR
G10 Materials	53156-040 thru 53156-050	Cert of Grade
Lead Flag Copper (C101 or C102)	53156-052 53156-053	C101 or C102
Braze Alloy (Sifos)	M3112-R12	MTR

2.6 Equipment (or equivalent):

ETI 00014, Biddle DC High Potential Tester, Model 22005
ETI 00173, Megger, Model MEG 10-01
ETI 00369, AEMC Micro-Ohmmeter, Model 6240
ETI 00423, Leader Inductance Meter, Model LCR-745

3.0 Fabrication Process Preparations

3.1 Safety

All Everson Tesla company safety policies must be followed

3.2 Non-Conformance

All non-conformances to the requirements of this specification shall be reported to the department supervisor, QA, or the project Engineer. Actual nonconforming conditions will be reported to PPPL and corrective actions will require PPPL approval.

3.3 Part Inspection

All coil components shall be inspected by a quality inspector prior to incorporating the component into the product. A valid inspection sticker shall be present for each component or lot of components.

3.4 Implement Cleanliness Protocol

3.4.1 Clean Environment

This operation shall be carried out, at all times possible, in our clean room area. This area minimizes all debris such as dust, dirt, or filings. While working maximum effort should be employed to keep materials clean.

3.4.2 Step-Off Pads

Step-Off pads are to be placed at the doorways to the clean room.

3.4.3 Gloves and Lab Coats

Latex, rubber or cotton lint free gloves and Lab coats will be worn during the handling of insulated conductor or the insulation.

3.4.4 Markers and Pencils

Only "Sharpie" brand name markers may be used in fabrication. This product has been electrically tested by PPPL.

3.4.5 Chips and Filings

Extreme care will be taken when using files, grinders, etc. that could generate chips or filings. Surrounding areas will be protected from contamination from chips or filings. This type of work will be avoided near the coil whenever possible.

3.4.6 Material Protection

Cleaned copper conductor and insulation, whether bare or insulated, shall be stored and processed in the clean room. The copper and insulating materials will be protected from skin oils by the use of cotton, lint free gloves.

3.4.7 Operator, Quality, Assurance, Engineering Signatures

All persons who initial any portion of the MPO shall print their name, sign their name, and write their initials on the form in appendix 1 of this document.

4.0 Coil Fabrication and VPI Process

Operation-001	Conductor Inspections

4.1 Conductor Inspection

4.1.1 Inspect all shipping containers upon receipt for shipping damage by the coil manufacturer vendor and / or shipping company.

4.1.2 Assign an identification number to each conductor spool.

4.1.3 Inspect conductors for slivers, scratches, nicks, burrs, cracks and damaged edges. An NCR shall be issued for damaged conductor.

4.1.4 Remove any nicks or burrs with emery paper or scotchbrite while catching slivers or dust with a vacuum.

4.1.5 Measure and record conductor width, height, and bore diameter at both ends. Deviations greater than .010" on the height/width shall be documented and presented to PPPL in the form of an NCR. Deviations greater than .005" in the bore diameter will also require an NCR.

	Height		Width		Hole ø	
Spool	Nominal	Measured	Nominal	Measured	Nominal	Measured
PF-1A-001	0.564	.563	1.086	1.084	0.205	.201
PF-1A-002	0.564	.565	1.086	1.085	0.205	.201
PF-1A-003	0.564	.566	1.086	1.086	0.205	.201
PF-1A-004	0.564	.563	1.086	1.085	0.205	.201
PF-1A-005	0.564	.564	1.086	1.085	0.205	.201
PF-1A-006	0.564	.563	1.086	1.084	0.205	.202
PF-1A-007	0.564	.564	1.086	1.086	0.205	.201
PF-1A-008	0.564	.565	1.086	1.085	0.205	.202
PF-1A-009	0.564	.563	1.086	1.086	0.205	.201
PF-1A-010	0.564	.563	1.086	1.086	0.205	.201

Attach documentation for receipt of copper containers.

QA Initial: [signature] (ROSH) **Date:** 1/28/14

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 2

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/23/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 3

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/22/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/23/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 4

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/21/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 5

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/21/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 6

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: David Smith **Date:** 7/20/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: David Smith **Date:** 7/20/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/21/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 7

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/21/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 8

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/20/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/21/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 9

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/22/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 10

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/22/13

Operation-002	Conductor Grit Blast

4.6 Grit Blast

4.6.1 Spring the conductor coil and place it onto the fixture that holds the turns apart. Avoid excessive twisting of the copper to minimize work hardening. Clean the conductor outer surface with acetone and then ethanol. Wipe and rinse.

Record Spool ID # 11

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.2 Grit blast the conductor using 80 grit alumina sand particles and 80 psi nominal air pressure until the copper is uniform in appearance and all areas are grit blasted. The blast nozzle shall be approximately 1" to 2" from the copper surface and 75 to 105 degrees relative to the surface being blasted.

Blastco Operator Signature: David Smith **Date:** 7/21/13

4.6.3 Blast the conductor surfaces with 100 psi of compressed nitrogen (clean and filtered) gas to remove any embedded grit. The nozzle shall be 1" to 2" from the conductor surface to dislodge any embedded sand particles from the copper surface.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.4 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.5 Bag each conductor and insert an inert gas such as Nitrogen or Argon into the bag to minimize oxidation until the conductor can be primed.

Blastco Operator Signature: _____ **Date:** 7/21/13

4.6.6 The above steps were performed at Blastco. Verify spool ID number and completeness of grit blasting. Inadequate blasting shall be documented on an NCR.

QA signature: _____ **Date:** 7/22/13

4.3 Rinse and Prime Conductors

4.3.1 Clean and rinse the conductor surface with ethanol to ensure complete removal of visible contaminants. Allow the surface to dry for ten minutes.

4.3.2 Apply CTD-450 primer by lint-free cloth to all exterior conductor surfaces. Primer thickness is expected to be between .001" and 0.003". Remove any primer build-up or excess by re-wiping the surface with the same primer-moistened lint-free cloth.

4.3.3 Place a hood over the conductor to minimize air movement on the conductor surface while the primer is curing in the oven.

4.3.4 Place conductor windings into an oven and ramp from 20°C to 110°C over a 3-hour period (~30°C per hour) and hold at 110°C for 8 hours.

4.3.5 Ramp from 110°C to 150°C over a 2-hour period (~20°C per hour) and hold at 150°C for 4 hours. Cool to room temperature.

4.3.6 Inspect conductor. Any bare spots on the conductor, one-inch or greater in length, need to have primer applied. Primer applied during coil winding must be cured by heat lamp at ≥ 100°C until dry.

4.3.7 Bag the conductors.

4.3.8 Document coil identification number, oven cure temperature, oven cure time, primer application and cure operator, and primer application and cure date on the form in appendix 3 of this document. Attach oven chart to documentation.

Attach documentation for primer curing operations.

Op. Initial: KA **Date:** 12/4/13

4.4 Mandrel Insulation

4.4.1 The mandrel will be insulated with a 0.006" thick Kapton layer. Using 4" wide adhesive Kapton tape, completely cover the outer mandrel surfaces with a single layer. Both the cylindrical surface and flanges shall be covered.

4.4.2 Because the winding and potting are being done on the mandrel, the ground wrap must be applied before the winding begins. Secure the approved 0.010" thick S-2 glass to the mandrel while leaving enough slack to close the ground wrap around the coil when the winding is finished. The build should be .100" per side.

4.4.3 Damaged or contaminated insulation shall be replaced. This involves removal of the section of defective insulation and applying a new strip of

insulation to the area, lapping the tape layers to capture the ends of the strip and to hold the tape down securely. A small piece of adhesive Kapton tape may also be required, depending upon the extent of the repair. Photograph each damaged area before and after repair and record each in appendix 5 of this document. Attach the photograph(s).

4.5 Electrical Leads and Water Fitting Braze (layer 1 lead)

4.5.1 The PF-1A coil is 4 layers of 16 turns each. First the lead entry bend should be secured. Leaving 14" of extra length away from the mandrel, bend the entry lead to an inside radius of 3.41" and secure it with the Lead Support Block according to the following table.

Assembly	Dwg No.	Description
PF-1A Lower	E-DC1465-1	Lead Support Block Type A
PF-1A Upper	E-DC1465-2	Lead Support Block Type B

4.5.2 The leads and fittings will be both be brazed with Silfos braze material. A material certification of the chemical composition of the Silfos and operator qualification will be submitted to PPPL.

4.5.3 The adapter and fitting are shown in drawing E-DC1471. The lead flag is shown in E-DC1472.

4.5.4 Drill a .220"ø counter bore into the end of the conductor to a depth of .125".

4.5.5 Thoroughly clean the mating surfaces of the conductor, flag, adapter, and fitting with acetone to remove any dirt or oil prior to the braze. The procedure and inspection will follow the process described in: **Everson Specification: Brazing Procedure for Type 1 Grade A Brazing of Copper and Copper Alloys.**

Operator Signature: Joseph Salvia **Date:** 5-1-14

4.5.6 Clamp lead flag to the conductor surface as shown in E-DC1447 (sheet 8) with a Silfos brazing strip (M3119) between the mating surfaces

4.5.7 Insert the adapter into end of the conductor, and insert the fitting into the adapter.

4.5.8 Using Silfos rod (M3112-R12), braze the water connection joint and the lead flag simultaneously.

4.5.9 Clean the braze area with scotchbrite and acetone. Wipe surfaces with alcohol to remove acetone residue. Allow the region to dry.

4.5.10 Perform a visual inspection of the braze area to ascertain that the region is free of cracks.

Operator Signature: Joseph Salvia **Date:** 5-1-14

4.6 Winding

4.6.1 The turn insulation will be applied via 2 taping machines. There will be 1 layer of co-wound Kapton/glass (Glass facing the copper) insulation followed by 1 layers of 0.004" thick S-2 glass insulation. Be sure that both arms of both taping machines are set to produce a ½ lap insulating scheme. An additional layer of ½ lap .004" thick insulation is to be applied in the lead area.

4.6.2 The winding of the PF-1A coils requires the use of fillers and shims. These pieces are made of G10. For all G10 items, the material shall be de-glossed with sand paper prior to installation.

4.6.3 The winding will start from the lead side of the mandrel. Install the lead-side shims as shown in E-DC-1447.

4.6.4 The PF-1A coil is 4 layers of 16 turns each. First the lead entry bend should be secured. Leaving 12" of extra length away from the mandrel, bend the entry lead to an inside radius of 3.41" and secure it with the Lead Support Block according to the following table.

Assembly	Dwg No.	Description
PF-1A Lower	E-DC1465-1	Lead Support Block Type A
PF-1A Upper	E-DC1465-2	Lead Support Block Type B

4.6.5 During the winding process, **four** splice joints will be required. Each reel of conductor is approximately 100 ft long. Each braze shall be performed according to the procedure outlined in ETI Document 53156-601 Induction Braze Qualification. Note the location of each splice.

Splice	Turn	Angle (approx)
1	14	9 oclock
2	29	12 oclock
3	44	12 oclock
4	58	6 oclock

4.6.6 Wind the first layer. Upon reaching the opposite flange, be sure that the remaining shims are installed to fill any void space between the coil and flange. The thickness of the shims can be made as needed.

4.6.7 The transitions are aided by G10 pieces detailed in E-DC1447.

4.6.8 Between each layer, apply .010" of S-glass insulation.

4.6.9 Repeat this process for 4 layers. Drawing E-DC1447 contains turn by turn details.

4.6.10 When the final turn is completed, clamp the wire to the coil pack with a clean G10 or nylon block as a buffer. Then form the exit lead to the lead support block and cut the wire 12" from the coil.

4.6.11 The ground wrap can now be finished. The initial lengths of tape can be folded over the coil. The coil can then be wrapped with shrink Mylar to secure the insulation.

4.7 Electrical Leads and Water Fitting Braze (layer 4 lead)

4.7.1 The leads and fittings will be both be brazed with Silfos braze material. A material certification of the chemical composition of the Silfos and operator qualification will be submitted to PPPL.

4.7.2 The adapter and fitting are shown in drawing E-DC1471. The lead flag is shown in E-DC1472.

4.7.3 Drill a .375"ø counter bore into the end of the conductor to a depth of .125".

4.7.4 Thoroughly clean the mating surfaces of the conductor, flag, adapter, and fitting with acetone to remove any dirt or oil prior to the braze. The procedure and inspection will follow the process described in: **Everson Specification: Brazing Procedure for Type 1 Grade A Brazing of Copper and Copper Alloys**.

Operator Signature: _____ **Date:** 5/19/14

4.7.5 Clamp lead flag to the conductor surface as shown in E-DC1447 (sheet 8) with a Silfos brazing strip (M3119) between the mating surfaces

4.7.6 Insert the adapter into end of the conductor, and insert the fitting into the adapter.

4.7.7 Using Silfos rod (M3112-R12), braze the water connection joint and the lead flag simultaneously.

4.7.8 Clean the braze area with scotchbrite and acetone. Wipe surfaces with alcohol to remove acetone residue. Allow the region to dry.

4.7.9 Perform a visual inspection of the braze area to ascertain that the region is free of cracks.

Operator Signature: _____ **Date:** 5/19/14

4.8 Pre-VPI Electrical Tests

NOTE: White (lint-free) gloves or surgical Latex gloves shall be worn when handling insulated conductor, insulation, G-10 fillers or other components during manufacture of the Trim Coils.
NOTE: Customer must be notified 3 days prior to test.

4.8.1 Ground Insulation Resistance

The insulation resistance of the Inner PF coil shall be verified by applying a Megger between the coil and its ground plane. Apply aluminum foil wrap around OD of the coil and then ground both the foil and coil support structure. Hold at

1000 V for 1 minute. Record insulation resistance at the start and end of the 1 minute test period.

Coil Temperature 70°F Air Temperature 70°F % Humidity 40

Insulation resistance [spec: > 1000 MΩ]: > 2000 MΩ

Circle one: (Pass) Fail

Megger ETI #: 313 Calibration Due Date: 12/14

Operator Signature: [signature] **Date:** 5/23/14

QA Signature: [signature] **Date:** 5/23/14

4.9 Preparation for Hydraulic Tests

4.9.1 Check all pressure and flow gauges have current calibrations

4.9.2 Record water and coil temperatures. These temperatures must be within 10 °F (5.5 °C) of each other.

NOTE: WRAP THE COIL IN PLASTIC TO PROTECT THE COIL AND INSULATION FROM WATER IN THE EVENT OF A LEAK.

Water temperature: 81.3 °F

Coil temperature: 77.6 °F

Calculated temperature difference: [spec: <10 °F]: 3.7 °F

Equipment ETI #: 00546 Calibration Due Date: 7/24/14

Operator Signature: [signature] **Date:** 5/23/14

4.10 Hydrostatic Pressure Test

4.10.1 Apply a test pressure of 350 psi to the coil. Maintain this pressure without any change for at least ten minutes after the system has been isolated from the pressure source and the pressure has stabilized. It may take some time for the gage to stabilize due to any small temperature difference. Any leaks or failure to maintain pressure shall be reported, repaired and retested. The pressure gauge shall have increments no greater than 2 psi.

NOTE: WRAP THE COIL IN PLASTIC TO PROTECT THE COIL AND INSULATION FROM WATER IN THE EVENT OF A LEAK.

Pressure gauge model ETI #: 525 Calibration Due Date: 3/15

Pressure at zero minutes: 350 psi (+/- 2 psi)

Pressure after ten minutes: 349 psi (+/- 2 psi)

Pressure difference: [spec: 0 psi]: 1 psi

Circle one: (Pass) Fail

Operator Signature: [signature] **Date:** 5/23/14

QA Signature: [signature] **Date:** 5/23/14

4.11 Water Flow Test

4.11.1 Again measure the water and coil temperatures.

Water temperature 81.3 °F

Coil temperature: 77.6 °F

Calculated temperature difference: [spec: <10 °F]: 3.7 °F

Equipment ETI #: 00546 °F

Calibration Due Date: 7/24/15

4.11.2 Set inlet pressure to 430 psi and leave the outlet valve open. The flow rate shall be no less than 0.87 GPM

Coil	Water Temperature	Inlet Water Pressure (psi)	Outlet Water Pressure (psi)	Lbs/minute (spec > 7.2)	Water Flow Rate (spec > .87)
PFIB-LOWER	81.3	430	0	8.0	.96

Operator Signature: [signature] **Date:** 5/23/14

QA Signature: [signature] **Date:** 5/23/14

4.12 Install Coil in Mold

***NOTE: PPPL shall be notified at least 3 days prior to performing vacuum pressure impregnation (VPI).

Eng. Signature: Joe KOSr **Date:** 5/23/14

Notes:

- **Use only red silicone rubber O-ring material.**
- **Make certain potting mold wedge cavities are clear of all resin residues to ensure proper seating of the wedge.**

4.12.1 Wrap two layers of M0380 Tedlar, ½ lap, over the glass ground tape on the finished coil. Then apply a layer of ½ lap shrink Mylar.

4.12.2 The mold outer wall will consist of ½" rolled plate fitted to the mandrel. Seal the plate against the o-ring grooves in the mandrel and form the smooth outer surface of the finished coil. Steel banding will squeeze the plate to the coil.

4.12.3 Silicon RTV can be used to seal any mating surfaces. The RTV has a 24 hour cure cycle.

4.12.4 Remove the coil from the winding plates. Install the fittings that will be used for the fill process.

4.12.5 Protect the lead area tape with Tedlar and RTV. Plug any holes in the lead as well as the cooling channel.

Eng. Signature: Joe KOSr **Date:** 5/27/14

Operator Signature: [signature] **Date:** 5/27/14

QA Signature: [signature] **Date:** 5/27/14

4.13 Mold Bake Out

Notes:

- Engineering or QA shall check and initial the oven chart periodically during each shift to assure that there is no interruption in oven temperature during any bake cycle. Critical observations are to be noted by engineering or QA initialing the temperature chart.
- **All temperatures and cycle times used during the impregnation and curing processes will be accurately measured and recorded on the Traveler. Attach all oven charts to this section of the Traveler.**

4.13.1 The coil mold will be equipped with 3 temperature sensors to monitor uniform heating and cooling of the coils. One sensor on the coil lead, one on the mold surface and one measuring oven air temperature.

4.13.2 Place the mold on an oven buggy and heat to 120°F for 8 hours.

No transfer required. BK 5/30/14

4.13.3 After heating, move the assembly from the oven to the vacuum tank. Connect the fill lines with copper tubes connected to the resin basin. Be sure the valve to the resin basin is closed.

4.13.4 Initiate the vacuum pump. After stabilizing the tank should maintain <0.5 Torr.

Eng. Signature: 5/28/14 PVL KD JR **Date:** 5/28/14

QA Signature: [signature] **Date:** 5/29/14

4.13.5 Degas the mold to 0.5 Torr or less for 8 hours at 120°F. After vacuum has stabilized, check for leaks by closing the valve to the pump and monitoring the vacuum gage. When the vacuum gauge reaches 1.0 Torr, hold for 2 minutes and record the vacuum level. The maximum allowable leak rate is 0.35 Torr/minute. Prior to filling the mold with resin, raise the mold vacuum level to 0.5 Torr higher than the resin component mixing and degassing pressure for a minimum of 1 hour.

Leak rate data: .10 rack
Start pressure [1 Torr]: 1.00 Torr
Pressure after 2 minutes: 1.34 Torr
Average leak rate [0.35 max T/min.]: .34 Torr per minute

Operator Signature: B.E. KC JR **Date:** 5/30/14

QA Signature: [signature] **Date:** 5/30/14

4.14 **VPI**

4.14.1 Prepare Resin:

Heat CTD-425, parts A and B to 60°C for ½ hour to dissolve any solid particles that may appear in the resin system. Maintain the temperature of both parts between 40°C to 60°C during mixing and impregnation. The pot life of the system is greater than 100 hours at 45°C.

4.14.2 Mixing Ratios:
Mix CTD-425 as follows:

CTD-425 part A	60 pbw	45.6 ✓
CTD-425 part B	40 pbw	30.4 ✓
Total	100 pbw	76 ✓

Record the lot number from the resin drum and the hardener drum:
Resin, part A, drum lot number: 7332-030

Hardener, part B, drum lot number: 7332-030

4.14.3 Degas Mixture
Reduce pressure of the mixture to 200 milliTorr for 30 minutes or until bubbles evolve infrequently from the mixture.

Total weight of mixture:		76 pounds
Mix resin and hardener:	Start time:	7:30 AM End time: 10:00 AM
Resin and hardener temperature:		55 °C
Vacuum level for degas:		0.37 Torr
Degas :	Start time:	7:30 AM End time: 10:00 AM

Operator Signature: [signature] **Date:** 5/30/14

QA Signature: [signature] **Date:** 5/30/14

4.14.4 Bring the resin mixing tank to atmospheric pressure and remove the tank from the mixer. The tank must remain connected to the water heater to maintain resin temperature between 45°C to 60°C. Connect the tank to the fill lines coming from the mold.

4.14.5 Impregnate the mold at a pressure between 1.5 - 2.0 Torr and a temperature of 45°C to 60°C. Prior to opening resin tank valve open all fill line valves to evacuate the lines. Close all fill valves except the valve for the lowest fill point.

4.14.6 Open the main fill line to establish a slow but steady flow of epoxy. As the level of epoxy in the basin decreases, make note of the decreasing heights in the table below. Record start and finish times and any pertinent data in the table below. If the fill rate is too slow, the fill line may be opened further. The fill should take 3 to 6 hours.

FILLING RECORD:

Start Time: 10:10 AM 5/30/14

Finish Time: 12:05 PM 5/30/14

Comments:

TIME	HEIGHT	TIME	HEIGHT
10 12	7 1/32	11 15	4 5/32
10 18	6 4/32	1125	4 4/32
1025	5 25/32	1135	4 2/32
1030	5 18/32	1145	4
1035	5 18/32		
10 40	5 17/32	11 55	3 31/32
10 45	5 12/32	1205	3 30/32
10 50	5 4/32		
10 55	5 1/32		
11 00	4 25/32		
1105	4 16/32		

4.14.7 Let the entire system soak at atmospheric pressure at 120°F for 12 hours. Remove all reservoirs and install plugs in the mold lid.

Weight of unused resin mix: 35 pounds

Operator Signature: [signature] **Date:** 6/3/14

QA Signature: [signature] **Date:** 6/3/14

4.14.8 Cure the resin according to the following cycle with a maximum ramp rate of 5°C / hour from 50°C to 100°C (10 hours) and 5°C / hour from 100°C to 170°C (14 hrs).

Operator Signature: [signature] **Date:** 6/2/14

QA Signature: [signature] **Date:** 6/2/14

4.14.9 After the coil has completed its cure cycle, the oven temperature will ramp down at a rate of 25°C per hour until it reaches 25°C. The coil temperature will cool naturally within the closed oven, following the oven temperature as it ramps down. Do not force cool. Approximately 13 hours are required for cool down. When the coil and mold have cooled to 25°C or less, the mold may be removed from the oven. Attach the oven recorder chart(s) and temperature sensor chart to this traveler and write the coil identification number and date on all charts.

Task Schedule	Start Time	Finish Time
Ramp from 50°C to 100°C at 5°C/hour maximum (≥ 10 hours)	0830 5/30/14	0800 5/31/14
Hold at 100°C for 15 hours	0800 5/31/14	0100 6/1/14
Ramp from 100°C to 170°C at 5°C/hour maximum (≥ 14 hours)	0100 6/1/14	2300 6/1/14
Hold at 170°C for 24 hours 10 hours	2200 6/1/14	0800 6/2/14
Ramp oven from 170°C to 25°C at 25°C/hour maximum (≥ 13 hours)	0800 6/2/14	0800 6/3/14

RJK 6/2/14

Note: all times shown are minimum.

4.15 Remove from Mold and Clean Coil

4.15.1 Remove the outer wall of the mold. Excess resin around the lead area will have to be chipped away.

4.15.2 Remove the Tedlar wrap and clean the resin from regions where it is undesirable. The outer surface of the resin should have a smooth finish. Do not mar the finish while removing undesirable areas of resin. When cleaning the copper leads, care must be taken to keep the contact area flat.

4.15.3 Resin Repair Procedures:

Surface imperfections may be lightly buffed, down to the outermost layer of glass insulation, if necessary, and then coated with a layer of Hysol RE2039 epoxy resin and HD3561 hardener as follows:

- Mix ratio, parts by weight: 100 parts RE2039 / 30 parts HD3561
- Mix ratio, parts by volume: 100 parts RE2039 / 33 parts HD3561
- Pot life is 35 minutes.

The resin cures in 24 hours at room temperature, or three hours at 60C, or two hours at 70C.

4.15.4 Imperfections deeper than 1/8 inch in the resin surface may be repaired by roughening the surface, and then filling the void with chopped S-glass mixed into the Hysol mixture specified above. After curing the resin, lightly sand the resin to obtain a uniform surface. Then apply and cure a layer of Hysol RE2039 epoxy resin and HD3561 hardener as described above. Record location of areas on coil where voids were filled with this procedure.

4.15.5 Syringe procedure to fill sub-surface voids:

Before and after photos should be taken.
Repair process:
Note: A representative from PPPL shall be alerted as to the date of the procedure.

1. Holes shall be drilled by hand (no power tools) through the resin / ground tape down to the affected area. The drill diameter shall be 1/32-inch (0.79 mm). The drill shall be marked 0.100" (3.6 mm) from the point so that the drilled hole will not exceed the thickness of the ground insulation.
2. A hole shall be drilled at each end of the void to allow the air to escape during the fill process. This process shall be performed one turn at a time across the resin-poor region.
3. Hysol RE2039 / IID3561 resin shall be injected below the surface via syringe to fill the void areas. 4. A vacuum pump may be employed to assist the flow of the resin through the voids.
4. The resin cures in 24 hours at 77°F. After the resin has cured, the ground insulation test (MPO paragraph 4.18.4) and the surge test

4.15.6 Clean mold with acetone and/or use a buffer to remove cured resin.

N A.

Operator Signature: _____ **Date:** _____

Engineering Signature: _____ **Date:** _____ No Repairs Need

4.16 Install Support Hardware

4.16.1 The lead support hardware shown in E-DC1468 should be installed as shown in E-DC1447.

4.17 Electrical Tests (turn to turn and hi-pot to foil)

4.17.1 Conductor Resistance

Measure the DC resistance of the coil. Record below.

Coil ID	Temperature (°C) 77.6°F	Resistance (ohms)	Resistance @ 20°C spec: 6.01 ohms +/- 5%
PF-1A-LOWER	25.3°C	5.45 mΩ	~~5.34mΩ~~ 5.99 mΩ

3K ohm/ohm

Temp. Gauge ETI #: 546 Calibration Due Date: 7/2015

Ohm-meter ETI #: 106 Calibration Due Date: 11/2014

Operator Signature: [signature] **Date:** 6/9/14

QA Signature: [signature] **Date:** 6/9/14

*Temperature correction formula:

$$R_{20} = \frac{254.5}{234.5 + Tc} * Rc$$

where:
Rc = measured resistance of the conductor (milliohms)
Tc = temperature of the coil when resistance measurement is made (°C)

4.17.2 Surge Test

Surge the coil at 5000 volts peak to stress the insulation. Ring test the coil with the Sencore LC 103 at 5 volts peak. Print and attach the plotted results.

Coil ID	No. Rings
PF-1A-LOWER	8

Surge Equip. ETI #: 350 Calibration Due Date: 3/2015

Sencore ETI #: 157 Calibration Due Date: 10/14

Operator Signature: [signature] **Date:** 6/9/14

QA Signature: [signature] **Date:** 6/9/14

4.17.3 Ground Insulation Test

Perform an insulation resistance check with the Megger test equipment. Apply 9,000 volts DC between the coil and the ground plane. Hold at 9,000 volts until there is no change in resistance for at least one minute.

Insulation resistance [spec: > 1000 MΩ]: 32,200 MΩ

Equipment ETI #: 173 Calibration Due Date: 11/14

4.17.4 Insulation Current Leakage Measurement – [High Potential Test]

Apply 9,000 volts DC between the coil and the ground plane. When the leakage current has settled with 9,000 volts applied, the leakage current shall be less than 2 microamperes.

Leakage current [spec: ≤ 2 μA]: < .2 microamperes

Equipment ETI #: 335 Calibration Due Date: 7/2014

Operator Signature: [signature] **Date:** 6/9/14

QA Signature: [signature] **Date:** 6/9/14

4.18 Preparation for Hydraulic Tests

4.18.1 Check that all pressure and flow gauges have current calibrations.

4.18.2 Record water and coil temperatures. These temperatures must be within 10 °F (5.5 °C) of each other.

Water temperature 70.3 °F

Coil temperature: 74.5 °F

Calculated temperature difference: [spec: 10 °F]: 4.2 °F

Equipment ETI #: 546 Calibration Due Date: 7/15

Operator Signature: [signature] **Date:** 6/9/14

QA Signature: [signature] **Date:** 6/9/14

4.19 Hydrostatic Pressure Test

Apply a test pressure of 350 psi to the coil. Maintain this pressure without any change for at least ten minutes after the system has been isolated from the pressure source and the pressure has stabilized. Any leaks or failure to maintain pressure shall be reported, repaired and retested. The pressure gauge shall have increments no greater than 2 psi.

Pressure gauge model ETI #: 525 Calibration Due Date: 2/2015

Pressure at zero minutes: ~~350~~ 365 psi (within 2 psi accuracy)

Pressure after ten minutes: 365 psi (within 2 psi accuracy)

Pressure difference: [spec: 0 psi]: 6 psi

Pass X Fail _____

Operator Signature: [signature] **Date:** 6/9/14

QA Signature: [signature] **Date:** 6/9/14

4.20 Water Flow Test

4.20.1 Again measure the water and coil temperatures.

Water temperature 70.3 °F

Coil temperature: 73.4 °F

Calculated temperature difference: [spec: <10 °F]: 3 °F 2 °F BL 6/9/14

Equipment ETI #: 546 °F

Calibration Due Date: 7/15

4.20.2 Set inlet pressure to 430 psi and leave the outlet valve open. The flow rate shall be no less than 0.87 GPM

Coil	Inlet Water Pressure (psi)	Outlet Water Pressure (psi)	Lbs/minute (spec ≥ 7.25)	Water Flow Rate (spec ≥ .87 GPM)
PF1A-LOWER	430	0	½(15 ¼) = 7.62	.91

Operator Signature: [signature] **Date:** 6/9/14

QA Signature: [signature] **Date:** 6/9/14

4.21 Pack and Ship

Operation-019	Prepare the Coil for Shipment

4.21.1 A "Product Quality Certification and Shipping Release" form must be completed, signed, and submitted to Princeton's Quality Assurance Representative for approval prior to coil shipment. A copy of the completed and approved form is to accompany each shipment.

4.21.2 Place plastic caps over all coil fittings.

4.21.3 Complete and attach a name tag to the coil that contains:

- Coil name: Inner PF-1A Lower or Inner PF-1A Upper
- Coil completion date
- Coil weight in kilograms

4.21.4 Wrap the coil in minimum 0.005" thick polyethylene and crate the coil. Place desiccant packets inside the crate and polyethylene wrap.

4.21.5 The crate shall be wooden and built for moving on rollers, handling with slings from overhead cranes and forklifts.

4.21.6 The coil will rest in rubber lined cradles within the crate.

4.21.7 Two shock sensors shall be added to opposite ends of the crate for shipment monitoring.

4.21.8 In addition, one shock sensor shall be placed inside the crate, hidden from view.

4.21.9 Include the following information on the shipping crate

- Company name: Everson Tesla, Inc.
- Shipper
- Purchase order number
- Coil name: Inner PF -1A Lower or Inner PF-1A Upper
- Coil weight in kilograms

Appendix 1
Signature Log

Printed Name	Signature	Initials
R. SAMUEL HEFFNER	R. S. Heffner	RSH
JOSEPH SCRIBANO	Joseph Scribano	JS
Blake Kond Jr	[illegible] Jr	RK
Kevin Altenfurr	[illegible]	KA
JOHN STAFFORD	[illegible]	JS

Appendix 2
Conductor Inspection Log

Conductor Identification Number	Conductor Inspection Operator	Conductor Bag and Ship Date
See page 9		

Appendix 3
Primer Application Log

Conductor Identification Number	Primer Operator	Completion Date
003 & 005	KA	12/4/13
007 & 006	KA	12/16/13

Appendix 5
Insulation Repair Log

Location	Description	Op. Init.	Date

P&J SURGE TESTING RECORD

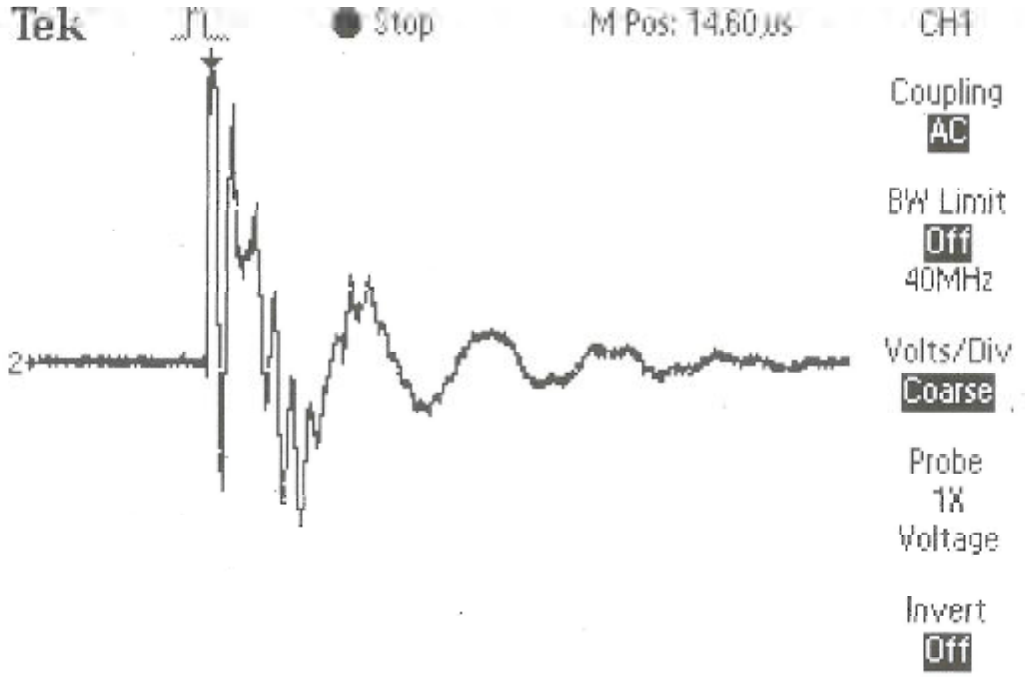
W O # 5789

COIL # PF-1A-UPPER

VOLTAGE 5000 V

SIGNATURE [signature] 5/23/14

BEFORE / AFTER VPI (CIRCLE ONE)



8 Rings

P&J SURGE TESTING RECORD

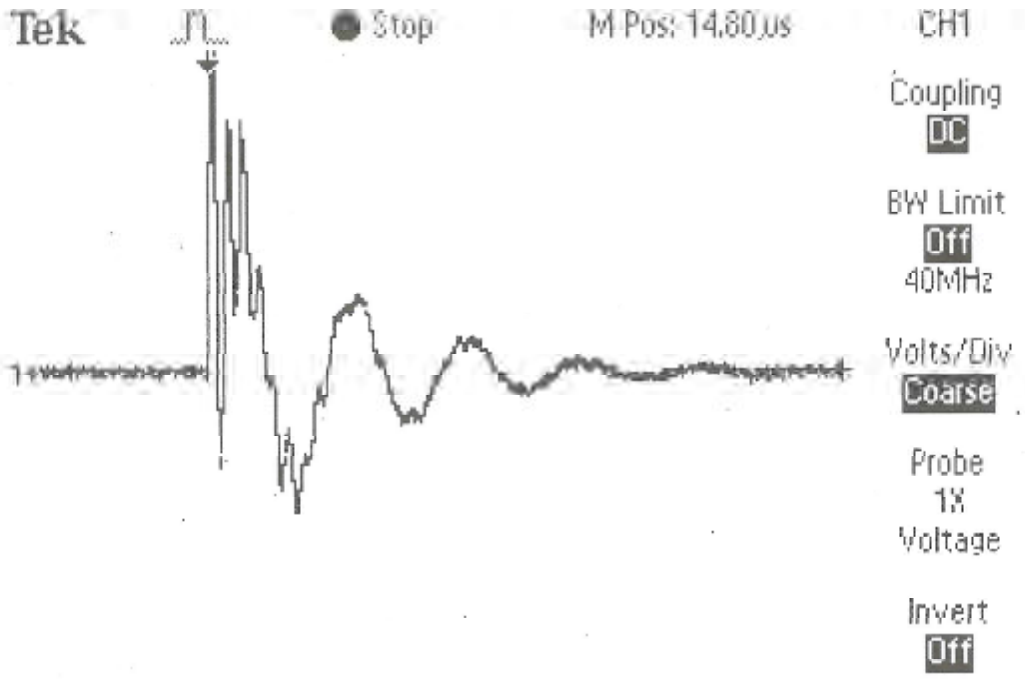
W O # 5789

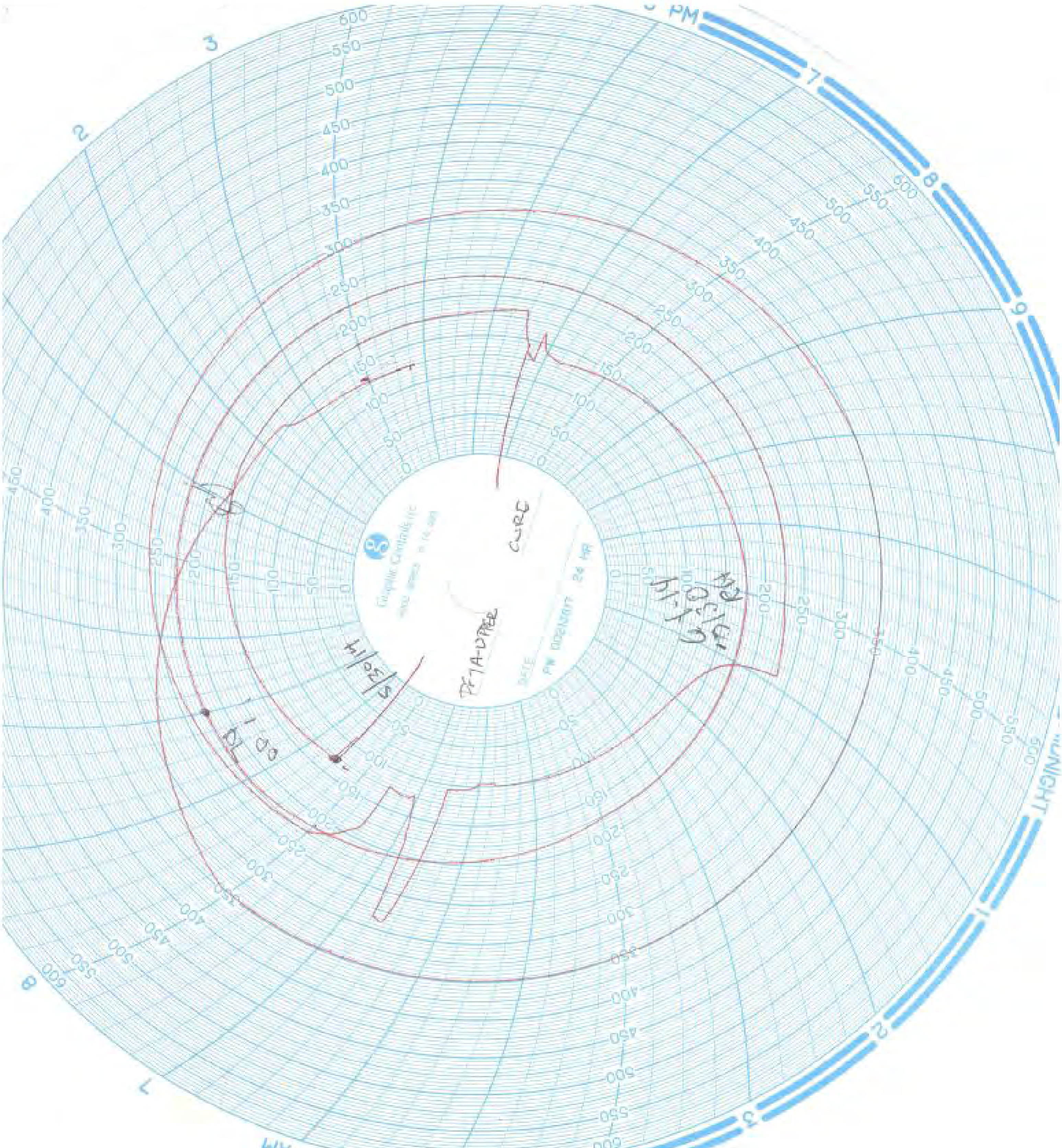
COIL # PF-1A - UPPER

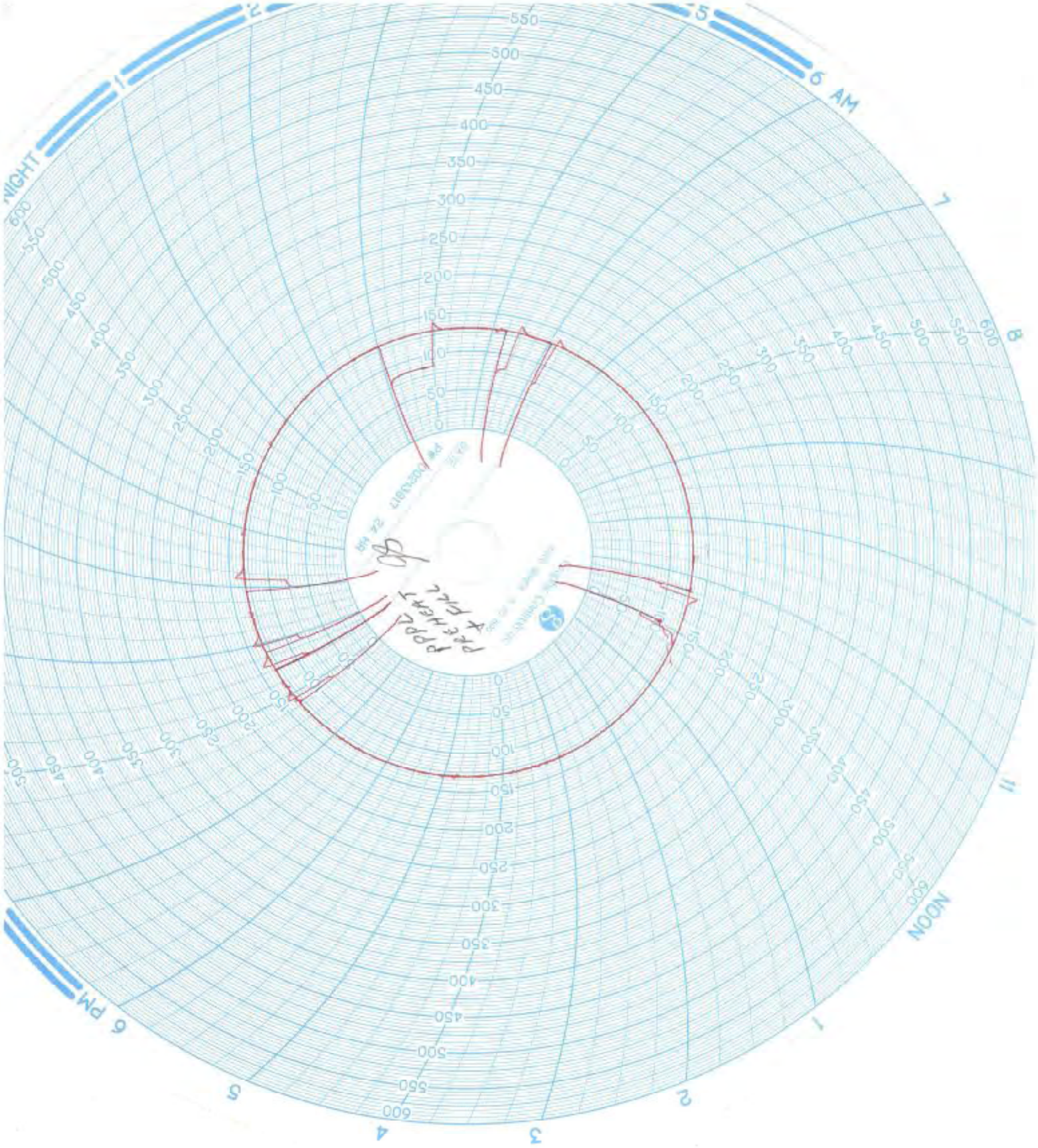
VOLTAGE 5000 V

SIGNATURE [signature] 6/9/14

BEFORE / AFTER VPI (CIRCLE ONE)






NIGHT
6 AM
NOON
6 PM
550
500
450
400
350
300
250
200
150
100
50
0