MANUFACTURING SPECIFICATION

FLARE

FABRICATION OF EQUILIBRIUM FIELD (EF) COILS

FLARE-SPEC-01

WP1995

REVISION 1

January 15, 2015

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1.0 INTRODUCTION AND SCOPE

This specification addresses the manufacturing, inspection, test and Quality Assurance (QA) plan for the fabrication and delivery of four (4) each of EF (Equilibrium Field) Coils for FLARE (Facility for LAboratory Reconnection Experiment).

2.0 APPLICABLE DOCUMENTS

2.1 FLARE SOW-01 – FLARE EF Coil Statement of Work

2.2 STANDARDS and CODES

The following Standards and Codes set forth the minimum requirements. The subcontractor is encouraged to recommend superior or more economical designs, processes, or materials. Changes which are jointly agreed to must be formally documented in a signed revision to this specification before being instituted.

1. ASTM American Society for Testing and Materials
   - ASTM B188-Standard Specification for Seamless Copper Bus Pipe and Tube
   - ASTM B170- Standard for oxygen free electrolytic copper refinery shapes
2. AWS American Welding Society
   - AWS A5.8 Classification: BCuP-5, Brazing Alloys
3. ASME American Society for Mechanical Engineers
   - ASME Boiler and Pressure Vessel Code Section IX Welding and Brazing Qualification
4. IEEE- Institute of Electrical and Electronic Engineers
   - IEEE #4, Techniques for Dielectric Tests

3.0 APPLICABLE DRAWINGS

3.1 E-FL100-001 FLARE EF Coil Assembly

4.0 RESPONSIBILITIES

4.1 Princeton University

Michael Kalish will be the contact for managing the EF Coil procurement

4.2 Subcontractor

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

5.0 REQUIREMENTS

5.1 MANUFACTURING DRAWINGS

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.
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.

5.2 COIL MANUFACTURING & TEST PROCEDURES

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

5.3 TOLERANCES AND DIMENSIONS:

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

5.4 COIL IDENTIFICATION

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

- EF-1A
- EF-1B
- EF-2A
- EF-2B

5.5 MATERIALS:

1. COPPER CONDUCTOR:

See coil drawing for conductor details.

Copper Type	**Height**	**Width**	**Hole Dia.**	**Temper**	**Approximate Continuous length**	**No. lengths req'd.**
UNS102	16 mm (0.63")	16 mm (0.63")	8 mm (0.315")	As drawn	260 ft.	4

2. INSULATION SYSTEM:

All insulating materials shall be supplied by selected subcontractor. Insulating material procurement or records shall be reviewed by PU prior to purchase to verify compliance with this specification.

A. Turn insulation
- Two-half lapped layers of 1 inch wide adhesive backed Mylar tape, 3 M Polyester Film Tape 56 or equivalent (1 mil of polyester film; 2.3 mils total thickness). The Mylar tape is applied directly to the copper conductor.
- Two-half lapped layers of 1 inch wide B Stage, Fusa Fab insulation, temperature rating 180° C. The Fusa Fab is applied over the Mylar Tape.
- Width of Fusa Fab and Mylar tape can be adjusted as required to improve fit especially in lead-out areas with P.U. approval

B. Ground Wrap insulation
- Four half-lapped layers of 1.5 inch wide Fusa Fab insulation, temperature rating 180° C . Wrap tightly to minimize bumps and wrinkles.
- Width of Fusa Fab can be adjusted as required to improve fit especially in lead-out areas with PU approval

C. Void Areas:
- Fill small voids between turns or near lead areas with Fusa Fab tape and or epoxy putty that is compatible with the FusaFab bakeout temperatures. Choice of epoxy putty to be approved by PU.

3. BRAZE MATERIALS AND PROCESS:

<u>Braze Material</u>:
- Sil-Fos Braze material BCuP-5, a product of Handy & Harmon, shall be used for all braze joints. No flux shall be used with the Sil-Fos material.
- Composition: 15% Ag, 80% Cu, 5% P
- Melting Point: 1185° F (640° C)
- Brazing Temperature Range: 1300F-1500F (704° C-816° C)
- Braze material certification: Certification of chemical composition of the Sil-Fos Braze material shall be provided and shall demonstrate compliance with AWS A5.8-2004, Classification BCuP-5

4. COIL LEAD AND TURN TRANSITION FILLERS:

- Material:
  The insulating lead blocks and coil fillers shall be constructed of G-10 epoxy/glass laminate.

- Workmanship:
  The lead blocks shall be free of burrs and sharp edges that can damage the insulation.

- Surface preparation:
  All surfaces unless machined shall be sanded to remove any high gloss surface, to promote bonding of the epoxy to the lead blocks. The blocks shall be cleaned with an appropriate solvent prior to use.

5. COIL TERMINAL BLOCKS [ELECTRICAL CONNECTIONS]:

Machined blocks for coil terminals shall be fabricated from copper bar or plate. Alloy shall be either Copper alloy C10200 or C10100 OFC [oxygen free copper]. Certifications shall include chemistry and verification that material is C10200 or C10100 OFC.

6. DEGREASING/CLEANING SOLVENTS:

All conductors and insulation blocks shall be degreased/cleaned using a solvent that is able to dissolve grease, tar, wax, adhesives, oils and other soils, and is residue free. Solvent selected by subcontractor must be approved by PU.

7. COIL FABRICATION AND INSPECTION:

This section describes a recommended procedure for fabricating the subject equipment. In accordance with the Statement of Work [SOW], the selected subcontractor shall develop submit a Manufacturing, Inspection, and Test and Quality Assurance (MIT/QA) plan and manufacturing procedures for approval by PU. Deviations from the approved MIT plan and procedures will require PU approval.

8. CLEANLINESS/HOUSEKEEPING:

"Good House-Keeping" is an essential element to the success of the manufacturing of the EF coils. The following steps shall be taken by the selected subcontractor during the fabrication of the EF coils to enforce this practice.

A. Clean Environment

It is *necessary* that during the application of the coil insulation, both turn and ground wrapping, and mold preparation stations will be housed in an environment that minimizes the risk of debris and dust particles such as metal chips, dirt, etc., from entering the coil insulation prior to VPI. The work area should have a ceiling directly over the coil to prevent dirt and debris from falling onto the coil. Walls or side panels would also provide a barrier from adjacent work activities.

B. Step-Off Pads

It is *recommended* that step-off pads be used at the entrances of the workstations, to minimize transport of foreign particulate and dirt into the work area.

C. Gloves and Lab Coats

Latex, vinyl, rubber or cotton lint-free gloves and Lab Coats will be required to be worn during the handling of insulated conductor, insulation, G-10 fillers or other components used in the construction of the EF coils.

D. Markers and Pencils:

The use of lead pencils or non-approved markers is **prohibited** in the fabrication stations due to electrical tracking concerns. Only "Sharpie" brand name permanent markers may be used without prior approval by PU. The "Sharpie" product has been electrically tested by PU.

E. Chips and Filings:

Extreme care must be taken when using files, grinders, etc. that could generate metal chips or filings. Surrounding areas must be protected from contamination from chips and filings. This type of work should be minimized near the coils whenever possible.

F. Material Protection:

Cleaned copper conductor, whether bare or insulated, shall be stored and processed in an environment free from metallic dust or other contaminants. The copper surface and insulating materials shall be protected from skin oil, etc., by requiring shop personnel to handle conductors only while wearing clean, lint free, white cotton gloves. Insulation and in-process subassemblies shall be processed and stored in controlled clean areas.

9. COPPER CONDUCTOR AND INSULATION APPLICATION:

A. Copper Conductor Receipt and Inspection:

- An identification number shall be assigned to each conductor for traceability during processing.

- Upon arrival of the copper conductors from the supplier, the subcontractor shall inspect and verify that the conductors provided are per conductor drawing.

B. Conductor Cleaning:
Each conductor shall be wiped down with degreasing solvent to remove excess oil, lubricant and grease.

C. Damaged Insulation:
Care shall be taken to avoid damage to the insulation in subsequent handling. Damaged or contaminated insulation shall be replaced with new insulation in accordance with a repair procedure, approved by PU, which will maintain insulation continuity.

D. Pre-Cure Electrical Tests:
Each EF coil assembly shall be electrically tested per 6.1 B.

6.0 TEST AND INSPECTION REQUIREMENTS

The subcontractor has sole responsibility for inspection and testing of all EF Coil assemblies. Mechanical and electrical inspections and tests shall be performed on each EF coil. Results of the inspections and tests are to be provided to PU as part of the Process History (reference FLARE-SOW-01). The coil manufacturer shall notify PU in advance to permit PU's representatives to witness any of the inspections or tests, either in process or final acceptance.

6.1 IN-PROCESS TESTING AND INSPECTION:

These tests are to be performed during the manufacturing process.

A. Inspection of Each EF Flag Braze Operation:

Perform the following inspections on each EF Flag braze joint once the excess braze material has been removed:

Visual Inspection:
A visual inspection of the finished joint shall be made to ascertain complete flow of braze material into the joint area.

Acceptance criteria The joint shall be free from all cracks and gaps

B. Tests after Coil Fabrication and Prior to Curing:

Insulation Resistance Ground
Prior to curing the insulation resistance of the EF coil shall be verified by applying a 500 Volt Megger between the coil and an aluminum foil ground plane. Apply aluminum foil wrap around OD of the coil and then ground both the foil and coil support structure. Hold at 500 V until there is no change in resistance for at least 1 minute.

Acceptance criteria: Coil Insulation Resistance: *>1K Meg ohms*

6.2 FINAL ACCEPTANCE TESTING AND INSPECTION:

These tests and inspections shall be performed once each EF coil is in a deliverable configuration. All test data, including results, shall be recorded in the Coil Manufacturing Package. If the coil fails any of the tests, a Nonconformance Report [NCR] documenting the failure shall be generated and provided to PU. The subcontractor may elect to perform additional tests with the approval of PU. [For electrical tests, temporarily wrap the outside diameter of each EF coil assembly with conducting material (e.g. Aluminum foil or wet rags) in intimate contact with the coil to provide a ground plane] The final disposition of failed coils shall be documented in the NCR.

A. Dimensional Inspection:

A dimensional check shall be made on each finished EF Coil to verify that it meets the tolerance requirements as stated in the applicable drawings.

B. Coil Resistance Measurement

Measure the resistance of the completed coil at the terminal leads.

Acceptance Criteria: measurements @ 20°C

Acceptance criteria: EF Coil Resistance: 6.4 milliohms +/- 2 milliohms

Temperature correction formula:
Place temperature sensor on the surface of the coil leads and record the temperature of the copper after the reading stabilizes.

$$\mathbf{R20 = \frac{254.5}{234.5 + Tc} \times Rc}$$

Where:
Rc = measured resistance of the conductor (milliohms)
Tc = temperature of coil when resistance measurement is made (C^o)

C. Insulation Current Leakage Measurement- [Hi Pot Test]:

Perform the hi-pot test [DC high voltage and leakage test] to confirm the integrity of the Coil insulation to the aluminum foil ground plane defined in 6.1B.

Acceptance Criteria:* Maximum coil Leakage Current: ≤ *2 micro amps

TEST VOLTAGE LEVELS

	OTF
Mfg. Test Voltage [DC]	***3800 volts***

D. Hydraulic Pressure and Flow Tests:

It is necessary to test the integrity of the cooling system and fittings of each EF coil assembly.

Hydrostatic Test:

The test pressure shall be maintained at 225 psi without any change for at least ten minutes after the system was 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 2 psi.

Acceptance criteria: Any leaks or failure to maintain pressure shall be reported, repaired and retested.

Water Flow Test:

Measure the water flow rate through each EF coil at a differential pressure of 40 +/- 2 psi. The pressure measurement must be directly at the inlet and outlet of the coil. It is acceptable for the flow to be measured by timing the discharge into a bucket. If it is desired to use tap water pressure this is acceptable if the pressure is greater than 40psi. P.U. will provide new flow rate acceptance criteria for higher pressure differentials.

Acceptance criteria: flow rate shall be ≥ 1.1 gpm at a pressure differential of 40 +/- 2 psi.

7.0 QUALIFICATIONS

See EF Coil Statement of Work (FLARE-SOW-01)

8.0 ENVIRONMENT, SAFETY, AND HEALTH

N/A

9.0 QUALITY ASSURANCE REQUIREMENTS

See EF Coil Statement of Work (FLARE-SOW-01)

10.0 SHIPPING STORAGE AND HANDLING

See EF Coil Statement of Work (FLARE-SOW-01)

11.0 WARRANTY

N/A

12.0 ATTACHMENTS

N/A

13.0 DOCUMENTATION AND DELIVERABLES

See EF Coil Statement of Work (FLARE-SOW-01)