US HL-LHC Accelerator Upgrade Project

QXFA Series Coil Fabrication Electrical QC plan

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Revision History

Revision	Date	Section No.	Revision Description
v0	6/27/17	All	Initial Release
v1	4/10/18	3	Changed in 3.1 Trace Hipot from 3500 V to 5000 V; and in 3.14 and 3.16 QH to Coil Hipot from 3200 V to 4800 V
v2	5/16/18	All	- Added Ranges for acceptable RLQ, Voltage tap, and Quench heater measurements - Updated Impulse testing procedure - Updated Hipot location for testing - Merged Sec. 2 into Sec. 1
v3	5/31/18	2	Changed in 2.14 & 2.16 the QH to Coil Hipot from 4800 V to 3680 V
v4	5/31/18	2	Changed in 2.1 the Trace Hipot value from 5000 V to 3800 V
v5	6/11/19	2	Changed in 2.1 Trace Hipot after receiving from 3800 V to 3700 V (value used at CERN before delivery to AUP)
v6	9/13/19	2	Changed in 2.14 & 2.16 the Coil to Pole Hipot from 500 V to 100 V
v7	4/17/20	1	Added to Impulse test: - Acceptance is a two-step process: 1) a subject matter expert reviews data looking for anomalies. If no anomalies are present, then 2) oscillation frequency is compared with benchmark set. Coil is accepted if 1) there are no anomalies, and 2) the times of the first seven V=0 are within 2 sigma of the benchmark average.
V8	9/24/20	all	Updated ranges of RLQ measurements. Ranges are reported separately for FNAL and LBNL. Ranges for impulse test zeros have been added. All references to IL heaters have been removed Voltage Taps have been updated, and ranges are reported only for taps A1, A2, B1, B2. The ranges have been changed to the taps difference, instead than absolute values Added a step on coil-pole hipot. In case of no contact among IL and OL pole, they should be connected with external wire during hipotting Title changed from “QXFA coil fabrication electrical QA” to “QXFA series coil fabrication electrical QC”

Contents

1 Comments

- All electrical QC tests must be performed at T = 20±3 °C and humidity lower than 60%.
- **Hipot tests**:
  - Power the component listed first, keep untested components floating.
  - Test each Quench Heater separately.
  - Connect the 11 pole segments together to perform Coil to Pole Hipot. Be sure that Inner and Outer pole segments are connected.
  - Set the maximum leakage current threshold to 10 μA. The maximum leakage current must not be exceeded neither during Ramp up nor at Plateau.
- **Impulse tests**:
  - Impulse tests with direct polarity (High Outer Layer – Ground Inner Layer) at 1000 V, 1500 V, 2000 V and 2500 V
  - Impulse tests with reversed polarity (High Inner Layer – Ground Outer Layer) at 1000 V, 1500 V, 2000 V and 2500 V
  - Acceptance is a two-step process: 1) a subject matter expert reviews data looking for anomalies. If no anomalies are present, then 2) oscillation frequency is compared with benchmark set. Coil is accepted if 1) there are no anomalies, and 2) the times of the first seven V=0 are within 3 sigma of the benchmark average.
- **Electrical Measurements:**
  - Coil inductance (LQ) measurements at 20 Hz (unless otherwise specified)
  - Coil resistance (R) and VT measurements at 1 A. After Impregnation, connect Multimeter Terminals at **7 inches from the Splice Blocks**.
- **Ranges**
  - Acceptance ranges have been defined using data from coils produced before QXFA119 at FNAL, and coils produced before QXFA212 at BNL. Ranges are based on average and standard deviation. A range of ± 3σ respect to the average has been used.

2 Fabrication Process

Pre-Fabrication Tests

1. Trace Hipot after receiving: 3700 V

Coil Fabrication Tests:

2. Coil winding: ·Real-time monitoring of continuity between coil, parts and mandrel

3. After curing, coil on curing mandrel, OD up: ·Coil RLQ
   R: (517.0 –547.0 mV) (FNAL/BNL)

Ls: (10.1 – 11.6 mH) (FNAL)
Ls: (10.6 – 11.3 mH) (BNL)
Q: (2.10 – 2.50) (FNAL)
Q: (1.9 – 2.3) (BNL)

·Continuity check:
coil-to-RE saddles,
coil-to-LE saddles,
saddle-to-saddle,
coil-to-end spacers,
coil to pole

4. Before reaction, fixture open, w/o mold blocks and SS shell, OD up:

·Coil RLQ
R: (517.0 –547.0 mV) (FNAL/BNL)
Ls: (5.8 – 6.8 mH) (FNAL)
Ls: (6.2 – 6.5 mH) (BNL)
Q: (1.3 – 1.5) (FNAL)
Q: (1.3 – 1.5) (BNL)

·Continuity checks:
coil-to-RE saddles,
coil-to-LE saddles,
saddle-to-saddle,
coil-to-end spacers,
coil to pole

5. Before reaction, After close and flip, fixture open, ID up:

·Coil RLQ

R: (517.0 –547.0 mV) (FNAL/BNL)
Ls: (6.20 – 6.40 mH) (FNAL)
Ls: (6.3 – 6.5 mH) LBNL)
Q: (1.10 – 1.70) (FNAL)
Q: (1.3 – 1.5) (BNL)

·Continuity checks:
coil-to-RE saddles,
coil-to-LE saddles,
saddle-to-saddle,
coil-to-end spacers,
coil to pole

6. After reaction, fixture open, OD up:

·Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.10 – 6.40 mH) (FNAL)
Ls: (6.30 – 6.50 mH) (BNL)
Q: (1.10 – 1.30) (FNAL)
Q: (1.1 – 1.3) (BNL)

·Continuity checks
coil-to-RE saddles,
coil-to-LE saddles,
saddle-to-saddle,
coil-to-end spacers,
coil to pole

7. After splicing, OL trace installed, OD up:

·Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.20 – 6.40 mH) (FNAL)
Ls: (6.3 – 6.5 mH) (BNL)
Q: (1.10 – 1.30) (FNAL)
Q: (1.1 – 1.3) (BNL)

·OL Voltage tap
B1-B2: 0.00 – 0.13 mV (FNAL/BNL)

·OL Heater R
B01: 1.70 – 2.40 Ω
B02: 1.70 – 2.40 Ω
B03: 1.70 – 2.40 Ω
B04: 1.70 – 2.40 Ω

8. After fixture bolted closed, OD up:

·Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.40 – 7 mH) (FNAL)
Ls: (6.8 – 7.1 mH) (BNL)
Q: (1.10 – 1.40) (FNAL)
Q: (1.1 – 1.3) (BNL)

·Continuity checks
coil-to-OL Heaters

9. After flip, fixture open, ID up:

·Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.40 – 6.90 mH) (FNAL)
Ls: (6.6 – 6.8 mH) (BNL)
Q: (1.10 – 1.40) (FNAL)
Q: (1.2 – 1.4) (BNL)

·Continuity checks:
coil-to-RE saddles,
coil-to-LE saddles,
saddle-to-saddle,
coil-to-end spacers,
coil to pole

10. After IL trace installed, ID up:

·Coil RLQ

R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.40 – 6.9 mH) (FNAL)
Ls: (6.6 – 6.8 mH) (BNL)
Q: (1.20 – 1.40) (FNAL)
Q: (1.20 – 1.40) (BNL)

·IL Voltage tap
A2-A1: 0.00 – 0.08 mV (FNAL/BNL)

11. After fixture bolted closed, ID up:

· Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.7 – 7.60 mH) (FNAL)
Ls: (7.5 – 7.7 mH) (BNL)
Q: (1.10 – 1.40) (FNAL)
Q: (1.2 – 1.4) (BNL)

12. After impregnation, fixture open, OD up:

·Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.50 – 7.0 mH) (FNAL)
Ls: (6.2 – 6.3 mH) (BNL)
Q: (1.20 – 1.40) (FNAL)
Q: (1.2 – 1.4) (BNL)

·Continuity checks:
coil-to-RE saddles,
coil-to-LE splice blocks,
coil-to-OL Heaters,
saddle-to-saddle,
OL Heaters-to-saddles,
coil to pole,
pole segm to pole segm

·OL Voltage tap
B1-B2: 0.00 – 0.13 mV (FNAL/BNL)

·OL Heater R
B01: 1.70 – 2.40 Ω
B02: 1.70 – 2.40 Ω
B03: 1.70 – 2.40 Ω
B04: 1.70 – 2.40 Ω

13. After flip, ID up:

·Coil RLQ
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (6.20 – 6.50 mH) (FNAL)
Ls: (6.6 – 6.9 mH) (BNL)

Q: (1.20 – 1.40) (FNAL)
Q: (1.2 – 1.4) (BNL)

·Continuity checks:
coil-to-RE saddles,
coil-to-LE splice blocks,
coil-to-IL Heaters,
saddle-to-saddle,
IL Heaters-to-saddles,
coil to pole,
pole segm to pole segm

·IL Voltage tap
A2-A1: 0.00 – 0.08 mV (FNAL/BNL)

/* Steps 12 and 13 can be reverse depending on the process*/

14. Before shipping, coil on bench and on shipping Mandrel, OD up:

·Coil RLQ (20 Hz, 100 Hz, 1 kHz)

@ 20 Hz
R: (590.0 –625.0 mV) (FNAL/BNL)
Ls: (3.7 – 6.1 mH) (FNAL)
Ls: (4.6 – 5.2) (BNL)
Q: (0.40 – 1.20) (FNAL)
Q: (0.7 – 0.9) (BNL)

@ 100 Hz
Ls: (2.90 – 3.70 mH) (FNAL)
Ls: (2.9 – 3.7) (BNL)
Q: (1.50 – 1.70) (FNAL)
Q: (1.5 – 1.7) (BNL)

@ 1k Hz
Ls: (1.80 – 2.00 mH) (FNAL)
Ls: (1.7 – 2.0) (BNL)
Q: (1.70 – 2.10) (FNAL)
Q: (1.8 – 2.1) (BNL)

·Continuity checks:
coil-to-structure,
heaters-to-structure,
coil-to-RE saddles,
coil-to-LE splice blocks,
coil-to-heaters,
saddle-to-saddle,
heaters-to-saddles,

coil to pole
pole segm to pole segm
IL pole to OL pole

·Voltage tap

A2-A1: 0.00 – 0.08 mV (FNAL/BNL)
B1-B2: 0.00 – 0.13 mV (FNAL/BNL)
B1-A1: 590.0 – 627.0 mV (FNAL/BNL)

·Heater R

B01: 1.70 – 2.40 Ω
B02: 1.70 – 2.40 Ω
B03: 1.70 – 2.40 Ω
B04: 1.70 – 2.40 Ω

·**Hipots:**

QH to Coil	3680 V
Coil to Pole	100 V
(if IL pole is not in contact with OL pole, connect them together)	
Coil to Endshoes (all)	1000 V
QH IL to Endshoes IL	2500 V
QH OL to Endshoes OL	2500 V
Endshoes IL to Endshoes OL	1000 V

·**Impulse tests** (Direct and Reverse)

Zero crossing # 1: 6.6 – 7 μs (FNAL)
Zero crossing #1: 9.5 – 12.5 μs (BNL)
Zero crossing #2: 16 – 17.2 μs (FNAL)
Zero crossing #2: 27.6 – 28.8 μs (BNL)
Zero crossing #3: 22.8 – 25.0 μs (FNAL)
Zero crossing #3: 40.5 – 42.9 μs (BNL)
Zero crossing #4: 30.5 – 32.9 μs (FNAL)
Zero crossing #4: 53.8 – 56.8 μs (BNL)
Zero crossing #5: 37.0 – 41.2 μs (FNAL)
Zero crossing #5: 66.7 – 70.9 μs (BNL)
Zero crossing #6: 44.4 – 49.2 μs (FNAL)
Zero crossing #6; 79.7 – 85.1 μs (BNL)
Zero crossing #7: 51.2 – 57.2 μs (FNAL)
Zero crossing #7: 92.6 – 99.2 μs (BNL)

15. After receiving, coil in the crate on shipping Mandrel, OD up: ·Coil RLQ (20 Hz, 100 Hz, 1 kHz)

·Continuity checks:
coil-to-structure,
heaters-to-structure,
coil-to-RE saddles,
coil-to-LE splice blocks,
coil-to-heaters,
saddle-to-saddle,
heaters-to-saddles,
coil to pole
pole segm to pole segm
·Voltage tap & Heater R.

16. After receiving, coil on Wooden Table

·**Hipots:**

QH to Coil	3680 V
Coil to Pole	100 V
Coil to Endshoes (all)	1000 V
QH IL to Endshoes IL	2500 V
QH OL to Endshoes OL	2500 V
Endshoes IL to Endshoes OL	1000 V

·**Impulse tests** (Direct and Reverse)