US HL-LHC Accelerator Upgrade Project

QXFA Coil Fabrication Electrical QA

Prepared by:
Guram Chlachidze, US HL-LHC AUP 302.4.4 Manager, FNAL
Carlo Santini, US HL-LHC AUP, FNAL
Marcellus Parker, US HL-LHC AUP, FNAL

Reviewed by:
Giorgio Ambrosio, US HL-LHC AUP Magnets L2 Manager, FNAL

Approved by:
Alfred Nobrega, US HL-LHC AUP 302.5 Manager, FNAL
Jesse Schmalzel, US HL-LHC AUP 302.6 Manager, BNL
Giorgio Ambrosio, US HL-LHC AUP Magnets L2 Manager, FNAL
James Blowers, US HL-LHC AUP QA Manager, FNAL
Ruben Carcagno, US HL-LHC AUP Deputy Project Manager, FNAL
Giorgio Apollinari, US HL-LHC AUP Project Manager, FNAL
## Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Section No.</th>
<th>Revision Description</th>
</tr>
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<tr>
<td>v0</td>
<td>6/27/17</td>
<td>All</td>
<td>Initial Release</td>
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<tr>
<td>v1</td>
<td>4/10/18</td>
<td>3</td>
<td>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</td>
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<tr>
<td>v2</td>
<td>5/16/18</td>
<td>All</td>
<td>- Added Ranges for acceptable RLQ, Voltage tap, and Quench heater measurements</td>
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<td></td>
<td></td>
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<td>- Updated Impulse testing procedure</td>
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<td>- Updated Hipot location for testing</td>
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<td>- Merged Sec. 2 into Sec. 1</td>
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<tr>
<td>v3</td>
<td>5/31/18</td>
<td>2</td>
<td>Changed in 2.14 &amp; 2.16 the QH to Coil Hipot from 4800 V to 3680 V</td>
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<tr>
<td>v4</td>
<td>5/31/18</td>
<td>2</td>
<td>Changed in 2.1 the Trace Hipot value from 5000 V to 3800 V</td>
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<tr>
<td>v5</td>
<td>6/11/19</td>
<td>2</td>
<td>Changed in 2.1 Trace Hipot after receiving from 3800 V to 3700 V (value used at CERN before delivery to AUP)</td>
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## Contents

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1 Comments

- **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 1 μA (10 μA when 1 μA does not work). 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

- **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.

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: (520.00 - 540.00 mV)
   - Ls: (10.40 – 11.00 mH)
   - Q: (2.20 – 2.50)
   - 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: (520.00 - 540.00 mV)
  - Ls: (6.10 – 6.80 mH)
  - Q: (1.40 – 1.60)
  - 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: (520.00 - 540.00 mV)
  - Ls: (6.20 – 6.40 mH)
  - Q: (1.40 – 1.50)
  - 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: (590.00 -610.00 mV)
  - Ls: (6.10 – 6.40 mH)
  - Q: (1.20 – 1.30)
  - 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: (590.00 -610.00 mV)
  - Ls: (6.00 – 6.40 mH)
  - Q: (1.10 – 1.30)
- OL Voltage tap
  - B1: 590.00 – 610.00 mV
  - B2: 590.00 – 610.00 mV
  - B3: 490.00 – 430.00 mV
  - B4: 260.00 – 280.00 mV
  - B5: 260.00 - 280.00 mV
  - B6: 260.00 – 280.00 mV
  - B7: 260.00 – 280.00 mV
  - B8: 260.00 – 280.00 mV
8. After fixture bolted closed, OD up:
   - OL Heater R
     B01: 1.70 – 2.20 Ω
     B02: 1.70 – 2.20 Ω
     B03: 1.70 – 2.20 Ω
     B04: 1.70 – 2.20 Ω
   - Coil RLQ
     R: (590.00 -610.00 mV)
     Ls: (6.50 – 6.90 mH)
     Q: (1.20 – 1.40)
   - Continuity checks
     coil-to-OL Heaters

9. After flip, fixture open, ID up:
   - Coil RLQ
     R: (590.00 -610.00 mV)
     Ls: (6.50 – 6.80 mH)
     Q: (1.20 – 1.40)
   - 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: (590.00 -610.00 mV)
      Ls: (6.50 – 6.80 mH)
      Q: (1.20 – 1.40)
    - IL Voltage tap
      A1: 0.00 – 1.00 mV
      A2: 0.00 – 1.00 mV
      A3: 190.00 – 210.00 mV
      A4: 240.00 – 260.00 mV
      A5: 240.00 - 260.00 mV
      A6: 250.00 - 270.00 mV
      A7: 250.00 – 270.00 mV
      A8: 260.00 – 280.00 mV
    - IL Heater R
      A01: 3.40 – 3.70 Ω
      A02: 3.40 – 3.70 Ω

11. After fixture bolted closed, ID up:
    - Coil RLQ
      R: (590.00 -610.00 mV)
      Ls: (7.20 – 7.50 mH)
      Q: (1.30 – 1.50)
    - Continuity checks
      coil-to-IL Heaters
12. After impregnation, fixture open, OD up:

- Coil RLQ
  R: (590.00 - 620.00 mV)
  Ls: (6.60 – 6.90 mH)
  Q: (1.30 – 1.50)

- 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: 590.00 – 610.00 mV
  B2: 590.00 – 610.00 mV
  B3: 260.00 – 280.00 mV
  B4: 260.00 - 280.00 mV
  B5: 260.00 – 280.00 mV
  B6: 260.00 – 280.00 mV
  B7: 260.00 – 280.00 mV
  B8: 260.00 – 280.00 mV

- OL Heater R
  B01: 1.70 – 2.20 Ω
  B02: 1.70 – 2.20 Ω
  B03: 1.70 – 2.20 Ω
  B04: 1.70 – 2.20 Ω

13. After flip, ID up:

- Coil RLQ
  R: (590.00 - 620.00 mV)
  Ls: (6.10 – 6.50 mH)
  Q: (1.20 – 1.50)

- 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
  A1: 0.00 – 1.00 mV
  A2: 0.00 – 1.00 mV
  A3: 190.00 – 210.00 mV
  A4: 240.00 – 260.00 mV
  A5: 240.00 - 260.00 mV
  A6: 250.00 - 270.00 mV
  A7: 250.00 – 270.00 mV
  A8: 260.00 – 280.00 mV
14. Before shipping, coil on bench and on shipping Mandrel, OD up:

- IL Heater R
  A01: 3.40 – 3.70 Ω
  A02: 3.40 – 3.70 Ω

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

- Coil RLQ (20 Hz, 100 Hz, 1 kHz)

  @ 20 Hz
  R: (590.00 -610.00 mV)
  Ls: (4.80 – 5.10 mH)
  Q: (0.80 – 0.90)

  @ 100 Hz
  Ls: (3.20 – 3.50 mH)
  Q: (1.50 – 1.70)

  @ 1k Hz
  Ls: (1.80 – 2.00 mH)
  Q: (1.90 – 2.10)

- 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 (Ok if open, Hipot if resistance > 1 MΩ, fail if < 1 MΩ),
  pole segm to pole segm

- Voltage tap
  A1: 0.00 – 1.00 mV
  A2: 0.00 – 1.00 mV
  A3: 190.00 – 210.00 mV
  A4: 240.00 – 260.00 mV
  A5: 240.00 - 260.00 mV
  A6: 250.00 - 270.00 mV
  A7: 250.00 – 270.00 mV
  A8: 260.00 – 280.00 mV
  B8: 260.00 – 280.00 mV
  B7: 260.00 – 280.00 mV
  B6: 260.00 – 280.00 mV
  B5: 260.00 – 280.00 mV
B4: 260.00 - 280.00 mV
B3: 410.00 - 430.00 mV
B2: 590.00 – 610.00 mV
B1: 590.00 – 610.00 mV

- Heater R
  A01: 3.40 – 3.70 Ω
  A02: 3.40 – 3.70 Ω
  B01: 1.70 – 2.20 Ω
  B02: 1.70 – 2.20 Ω
  B03: 1.70 – 2.20 Ω
  B04: 1.70 – 2.20 Ω

- Hipots:
  QH to Coil 3680 V
  Coil to Pole 100 V
  (to be performed only if continuity check is not open, and resistance > 1 MΩ)
  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)

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 (Ok if open, Hipot if resistance > 1 MΩ, fail if < 1 MΩ),
      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
    (to be performed only if continuity check is not open, and resistance > 1 MΩ)
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)