



# Report of the MQXFA14

## Coils Acceptance Review

US-HiLumi-doc- 4769

Other:

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## US HL-LHC Accelerator Upgrade Project

### Report of the MQXFA14 Coils Acceptance Review

*December 16 2022*

- Steve Gourlay (chairperson), LBNL
- Arup Ghosh, BNL retired
- Susana Izquierdo Bermudez, CERN



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## Coils Acceptance Review

### 1. Goal and scope

The HL-LHC AUP project is planning to start assembly of MQXFA14. This is the 7th series low-beta quadrupole magnet (MQXFA) for the Inner Triplet of the High Luminosity LHC. If MQXFA14 meets MQXFA requirements [1] it will be used in a Q1/Q3 cryo-assembly to be installed in the HL-LHC.

For MQXFA14 assembly AUP is planning to use these QXFA coils (including a spare one): 142, 143, 230, 231, and 220. Coil 220 was reviewed during the *MQXFA10 Coils Acceptance Review* [2] and during the *MQXFA12 Coils Acceptance Review* [3].

Conductor and series coil specifications are presented in [4-8]. Discrepancy or Non-conformity Reports are generated whenever a component does not meet specifications.

The reviewers are requested to review discrepancies and non-conformities in strands, cables, and coils for the following coils: 142 (cable P43OL1172), 143 (P43OL1173), 230 (P43OL1166), 231 (P43OL1168).

### Technical details

#### Committee

Steve Gourlay (chairperson), LBNL

Arup Ghosh, BNL retired

Susana Izquierdo Bermudez, CERN

#### Date and Time

Dec 16, 2022. Start time is 7/9/10/16 (LBNL/FNAL/BNL-FSU/CERN)

#### Location/Connection

Video-link by Zoom, info by email.

#### Link to agenda with talks and other documents

<https://indico.fnal.gov/event/57433/>



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### 2. Review Charges responses

The committee is requested to answer the following questions:

1. *Have all recommendations from previous reviews been adequately addressed?*

We did not have any recommendations. From the prior review.

2. *Have Discrepancies and Non-conformities been adequately documented and processed?*

*In summary: Yes.*

3. *If there are critical Discrepancies/Non-conformities, have they been adequately documented and processed?*

Yes, all critical DR's were properly documented and processed.

4. *Did the L3s properly identified critical Discrepancies/Non-conformities?*

Yes.

5. *Is there any coil that you recommend not to use in MQXFA14?*

All coils are suitable for magnet assembly.

6. *Do you have any other comment or recommendation regarding these coils and their conductor for allowing MQXFA14 to meet MQXFA requirements [1]?*

To summarize:

Strand  $I_c$  and RRR are well above specifications.

Insulation thickness is oversize for a couple of cable lengths which were judged to be acceptable for coil winding.

Coil fabrication at FNAL and BNL were completed with only non-critical discrepancies that were properly recorded and processed.

Except for Coil 143, overall Coil lengths are within specifications. FNAL coils typically are slightly longer than BNL coils.



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There are no major concerns regarding coil dimensions measured for the coils at LBNL.

There are many options available for coil assembly for a voltage criterion of  $< 353$  V. One in particular would likely be favored for coil assembly where opposing coils are from the same lab.

### 3. Comments

**Strand and Cable:** The non-conformance of the furnace temperature control for strand sample heat-treatment is not significant as the sample RRR measured were well above the requirement.  $I_c$  of the strands are well above minimum requirement of 315A. Corrective action for the temperature monitoring and control has been implemented.

The non-conformances observed for the cables were mostly judged to be minor and unlikely to affect coil dimensions. However, specific mention should accompany the cable traveler to indicate the various observations that need to be checked before and during coil winding.

The insulation thickness for cable 1172 and 1173 were higher than specification – 4 to 6  $\mu\text{m}$  above the maximum limit of 150  $\mu\text{m}$ . This should not impact the coil dimension as the cable thickness averaged below the nominal thickness of 1.525 mm which has a range of  $\pm 5$   $\mu\text{m}$ . Insulation thickness discrepancy was due to 10-stack equipment being out of calibration towards the end of the yearly calibration cycle done at the vendors. The QA measurement at LBNL is a good check on this issue.

**FNAL Coils 142 and 143:** Discrepancies in coil winding, reaction and impregnation steps were carefully noted and recorded for these coils.

For Coil 142 several DR's were recorded, none critical.

For Coil 143 several DR's were recorded, only one critical – 12955 – relating to coil length. Coil length exceeded maximum length by 0.4 mm. Another significant DR (non-critical) was recorded during coil winding due to cable roping. This DR is like that observed for an earlier coil - 139.

The cable roped coming off the reel while prepping for L2 winding. Loss of cable tension caused cable layer turns to slide down during cable back-wind.

Roped cable areas were located on the L2 pole turn straight section. Repairs were made and the region was inspected carefully and judged to be acceptable. Corrective action has since been put into practice: a 3<sup>rd</sup> tech has been added to monitor cable tension and layer position during L2 winding setup.



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**BNL Coils 230 and 231:** Here too, all discrepancies were recorded and where required corrective action was implemented. None of the DR's were critical. However, the Committee was a little concerned regarding the apparent assumption that, despite the observed defects on the inner surface of Coil 231, the coil was fully impregnated.

**Coil Dimensions:** There are no significant deviations in the dimensions measured. None of the coils have any excess arc lengths. In fact, some of them are smaller than specs. The coils will be shimmed on the mid-plane to compensate

Pole inner radial deviations are observed in all coils at certain locations along the length. Coil bumpers will need to be adjusted.

**Coil Ordering:** Based on RRR measurements of rolled strands and minor edge RRR of extracted strands, there are many possible assembly options.

**Cable Insulation:** There was some initial concern regarding the number of DR's generated by the insulation vendor. It was later learned that since the time these cables were insulated that there were several vendor visits and meetings resulting in significant improvement of the insulation process and reduction of DR's.

### 4. Recommendations

**NONE**

### 5. References

- 1) *MQXFA Functional Requirements Specification*, US-HiLumi-doc-36
- 2) *Coils Acceptance Review for MQXFA07b and MQXFA11*, US-HiLumi-doc-4224.
- 3) *MQXFA10 Coils Acceptance Review*, US-HiLumi-doc-4186
- 4) *Specification for Quadrupole Magnet Conductor*, US-HiLumi-doc-40
- 5) *Cable Specification*, US-HiLumi-doc-74
- 6) *Quadrupole Magnet Cable Insulation*, US-HiLumi-doc-75
- 7) *QXFA Series Coil Production Specification*, US-HiLumi-doc-2986
- 8) *QXFA Series Coil Fabrication Electrical QC plan*, US-HiLumi-doc-521