US HL-LHC Accelerator Upgrade Project

Report of the MQXFA07 Coils Acceptance Review

December 17th 2020

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

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1. Goal and scope

The HL-LHC AUP project is planning to start assembly of MQXFA07 magnet in December 2020. MQXFA07 is the fifth and last pre-series low-beta quadrupole (MQXFA) to be used in Q1 and Q3 Inner Triplet elements for the High Luminosity LHC.

If MQXFA07 meets MQXFA requirements [1] it will be used in a Q1/Q3 cryo-assembly to be installed in the HL-LHC. For MQXFA07 assembly (including a spare coil) AUP is planning to use QXFA coils: 114, 117, 124, 212 and 214. Coil 117 was approved for use in MQXFA05 [2] and is assumed approved for use in MQXFA07.

Conductor and pre-series coil specifications are presented in [3]. 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: 114 (cable P43OL1097), 124 (cable P43OL1131), 212 (cable P43OL1124), and 214 (cable P43OL1127).

2. Technical details

Committee

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

Date and Time

December17, 2020. 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/46767/

3. Review Charges responses

The committee is requested to answer the following questions:

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

Yes. Non-conformities in strand diameter, discrepancies in coil winding, reaction and impregnation steps were carefully noted for all the coils. Most of the discrepancies were non-critical except a few critical ones for coil 214, 114 and 124.

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

Yes. The critical discrepancies and non-conformance to specification were adequately recorded and processed. It is noted that the overall coil lengths for those fabricated at BNL and those at FNAL typically differ by 5 mm. BNL coils tend to be at the low end of the specification.

3. Did the L3s properly identify critical Discrepancies/Non-conformities?

Yes. Coil 114 has a significant critical DR related to epoxy-impregnation. All the paperwork is in order and it was decided and approved by L2 to accept the coil as fabricated. The imperfections seen on the coil inner surface of 114 due to the “fast” impregnation were judged to have a low probability of causing a failure during magnet testing.

4. Is there any coil that you recommend not to use in MQXFA07?

Not Categorically. But it should be confirmed that 117 is not a better choice than 114. Slide 23 (outer radius deviations), coil 117 has an outlier in the second section. It is still within tolerances, but it might be an error on the measurement or something very local in the coil, this section could be cross-checked.

5. Do you have any other comment or recommendation regarding these coils and their conductor for allowing MQXFA07 to meet MQXFA requirements [1]?

General comments below.

The new format of the slides is easier to follow and allows us to focus on the main points during the review. Also, the fact that all the information is still available in additional slides is greatly appreciated since it allows the reviewers to study in the data in more detail. Thanks for the effort!

In the future, it would be good to report something about the cable insulation in the main slide, with an explicit statement that the insulation thickness is within specifications and that there are not particular problems. Nevertheless, the information is in additional slides and everything is ok. Measurements between NEWT and LBNL are now very consistent, so the issue raised in the MQXFA06 review is now solved.

All cables are dimensionally within specification and fairly uniform. Although no Coil-reaction witness sample tests were presented, we find that, based on the lowest I_c measured, the expected cable performance as presented for all the coils is remarkably similar. Cable performance has significant margin at operating current and temperature to ensure easily reaching the required operating current. See Table below.

The one parameter that is tagged with each coil and which is still unsatisfactory is the RRR attributed to the cable after coil reaction. Past information has shown that the BNL coils have RRR that are considerably higher than the FNAL coils.

In MQXFA03, the coil RRR is more consistent with measurements from rolled samples. In MQXFA04, the coil RRR correlates better with the minor edge. Part of the source of the different behavior might be the differences in length of dwell3 (50 vs 75 hours). It would be useful to add this information to the plots in slide 3 and 4 for future reference and studies.

Using the RRR of the extracted strands that were performed at LBNL after cable fabrication, in our view, is not a suitable one to use for coil ordering studies. It is noted that for future coils a reference wire will be measured to compare coil-reactions at the two facilities. For now, the analysis presented for coil ordering using the minor edge RRR of the extracted strands as measured at LBNL is deemed acceptable. Seems like there are many options available for coil assembly for a voltage criterion of < 353 V.

COIL SUMMARY PERFORMANCE	**114**	**124**	**212**	**214**
Margin along load line at 16230 A	26.70%	27.00%	27.90%	28.80%
Current and field at 100% SSL	22.1 kA, 15.1 T	22.2 kA, 15.1 T	22.5 kA, 15.3 T	22.8 kA, 15.5 T
Current margin	62.00%	63.10%	63.80%	65.10%
Current capacity at operating field, KA	42.8	44.0	44.9	46.5
Temperature margin, K	5.4	5.4	5.6	5.7
Temperature where scaled SSL crosses I_op	7.3	7.3	7.5	7.6
Temperature where scaled SSL crosses I_ult	6.4	6.4	6.6	6.7

4. Recommendations

None

5. References

1) MQXFA Functional Requirements Specification, US-HiLumi-doc-36.

2) MQXFA05 Coils Acceptance Review Report, US-HiLumi-doc-2742.

3) MQXFA Final Design Report, US-HiLumi-doc-948-v10 (version 10 was valid at the time pre-series coils were fabricated) sections 3 and 5.1.1; QXFA Coil Fabrication Electrical QA, US-HiLumi-doc-521 step 16. For Series coils: QXFA Series Coil Production Specification, US-HiLumi-doc-2986; and QXFA Series Coil Fabrication Electrical QC plan, US-HiLumi-doc-521.