Comments and Recommendations from the BNL Winding and Curing Review, July 12, 2018

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Introduction:

The HL-LHC AUP project is going to have two coil fabrication sites (BNL and FNAL). Both sites will make identical coils for the MQXFA magnets to be used in Q1 and Q3 of the High Luminosity LHC.

MQXF short model coils and prototype coils were fabricated using the "LARP scheme": all coils wound-and-cured at FNAL, half coils reacted-and-impregnated at BNL, half coils reacted-and-impregnated at FNAL.

In preparation for the AUP project LARP initiated procurement of parts for a wind-and-cure line for MQXFA coils at BNL. The AUP project took over this effort including installation and commissioning of this line. AUP aims at starting MQXFA coil production at BNL on October 31, 2018.

During practice winding the BNL team found seven issues and reported them to the MQXFA magnet L2. The L3s involved with these issues discussed them and found a solution to four of them. This internal review is called to address the three remaining issues.

Review Charges:

1. What are your recommendations and comments (optional) for addressing each one of the three remaining issues?
2. Do you have any other comment or recommendation regarding these issues or the issues closed by the L3s?
3. Do you have any comment or recommendation for next steps in commissioning the MQXFA wind-and-cure line at BNL?

Findings:

Seven issues were noted during the winding of the first layer of the practice coil. These were discussed with FNAL, listed briefly here:

1. Binder formulation.
2. Flexible spacers did not perform well (cable turns not fully in place, plasma spray prevents flex, etc.)
3. Poor fit between first coil end spacer and turn
4. The fiberglass tape around the pole island is "taller" (wider) than the height of the pole island. Excess is trimmed, but concerns about radial spacing.
5. Wedges needed deburring and degreasing prior to being able to install.
6. First turns after the wedge experience popped strands
7. The height of the insulated wedges appear to be greater than the height of the pole island.

Open issues remaining are:

1. BNL would like the L1 1st spacer (and perhaps other parts) to be more flexible.
2. Pole insulation width needs 1.5 mm to be trimmed after curing (~1 tech hour). Alternative is to buy new glass tape ~$5k.
3. Pole & wedge design issue. Smallest pole within tolerance and the largest wedge within tolerance are line to line. The design does not account for the .1mm wedge insulation. Currently the problem is mitigated by the pole being on the plus side of the tolerance and the outer wedge on the minus side of the tolerance. The inner wedge is on the plus side of the tolerance but is adjacent to the inner layer blanket.

Comments and/or Recommendations:

More Flexible L1 1st spacer

1. In CERN's experience, after having completed the winding of around 20 coils, shows CERN's team did not encounter any particular issue when mounting the coil spacers. It is obvious that some of them, in particular IR1, are difficult to install at their correct position. There is agreement with BNL's remark that there is room for improvement on the flexibility (in particular on radial direction). That being said, the CERN team did not have big difficulties when inserting the spacers with cleaned slits after the coating operation. The team paid particular attention on the protection of the slits while plasma coating the spacers and rejected pieces with ceramic bridges over the slits. This non-conformity reduces the flexibility and induces some ceramic cracks and coating delamination when manipulating the spacers.
2. CERN's clamping tooling is also slightly different from the one used in BNL (it is more similar to that used at FNAL and LBNL). The team uses a side bar placed between the lateral pushers and the conductor, which presses the coil azimuthally during winding operation. The longitudinal position on the lateral pushers can be adapted and optimized during the winding process. This guarantees getting the correct azimuthal coil size while inserting the spacer. The last pusher is placed as close as possible to the end-spacer to install. Some of the spacers are also gently tapped into their final position using a Teflon piece and a small hammer.

   We recommend checking if the present pushers design can push the coil to its nominal azimuthal position while inserting the spacer. Otherwise, we recommend adapting the position of BNL pushers to be able to azimuthally compress the turns at coil extremities.

Pole Insulation

3. At CERN, the team uses a fiberglass strip narrower than the pole is tall. So there is no need to trim the pole insulation after the first turn winding. CERN's provider can guarantee the production of the fiberglass ribbon at nominal dimension +0 mm/+0.5 mm.

   We recommend ordering a new batch of ribbon with the adapted dimension to avoid the trimming operation so that the fiber excess would not be trapped in between the pole and the form block.

Wedge Insulation

4. BNL tooling design seems to be slightly different from the others (FNAL/LBNL/CERN). At CERN the team uses a manual winding machine. The wedges are clamped using metallic sectors pushed against the pole outer radius, used as radial reference. The team has not encountered any particular issue when clamping the wedges during winding. The operator can adapt the pressure applied to the clamping sector to guarantee that the wedge could slide into its final position. The team has not noted any concerns about this clamping system, nor have they seen any insulation damage due to an interference of the clamping system with the outer wedge radius.

   We recommend machining a relief on the inner radius of the clamping tool to not impinge on a potentially oversized wedge (the relief can be shimmed if the wedges are on-size, though).

Summary of Review Charges:

1. What are your recommendations and comments (optional) for addressing each one of the three remaining issues?

   Answer: See the above comments/recommendations.

2. Do you have any other comment or recommendation regarding these issues or the issues closed by the L3s?

   Answer: No other comments.

3. Do you have any comment or recommendation for next steps in commissioning the MQXFA wind-and-cure line at BNL?

   It appears that the ability to compress the turns azimuthally, especially at the extremities, is important and provisions to do so should be explored.