Results of Coil Concerns at BNL

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This report presents the results of a series of meetings between the Fred, Miao, and Jesse, the HiLumi L3 managers, to address coil concerns at BNL. Of the 7 concerns reported in blue, all but 3 have been resolved. Below is a summary of the open issues. Addition information is in the body of the report.

Open issues:

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.

1. In recent LARP/AUP videoconferences we have been informed that the binder used to temporarily hold coils together until installed in the reaction fixture had not worked well for the past year and a half.  When we were informed we were also told that this information was not previously communicated among the FNAL staff.  After initially being told that the binder would be changed we have most recently been advised that due to a lack of opportunity to qualify the new binder the original formulation will continue to be used.

The use of binder on the coil ends is the baseline for U.S. coil winding.  It has shown to be advantageous in keeping strands from popping out of lay in the coil ends. There is reverse bending of cable as it exits the spool onto the coil at FNAL, a process that doesn’t occur in the BNL winding process. Practice coil winding of the inner layer at BNL has been completed without the use of binder on the ends so there is no experience with the binder whether it be with the original binder or the new yet to be qualified binder. Practice coil winding has been with the inner coil which is wound in the “favorable” winding direction. Winding the outer coil is needed for a comprehensive understanding of winding issues and the binder effectiveness. Out of lay strands are a possibility after the turn is wound without the use of binder.

There are 2 activities taking place to better understand the 2-part binder CTD1202 and the modified binder CTD1290. Marcellus is working with reacted cable using CTD1290 to take electrical measurements. Additionally, he will need to repeat tests with CTD1202 then pot all the samples and repeat the electrical measurements. Estimated duration ~3 months. Steve is doing beam shear tests and decided not to use fixtures used in past studies because shimming adds variability to the study. He is having new fixtures made. Estimated time to complete study ~ 3-5 months. Once these activities are finish we will review the results.

1. We have discovered that the “flexible” coil end spacers which are coated with insulating ceramic in many instances are not at all flexible due to the coating (in some parts in fact the coating has bridged the cuts in the part which are intended to open).  When forced to flex, the ceramic cracks at the flexure point, revealing bare, uninsulated stainless steel near the edge of the part.  When asked about the issue the response was “yes we see that also, but a few cracks are better than a lack of flexibility”.  Again it was revealed that this information had not been shared among the FNAL staff.  *We have two proposals for improving this design which we would like to share at the earliest opportunity.*

Miao has communicated to the vendor that slits are to open after plasma coating and the part will not be accepted if it loses the flexible feature after coating. Chipped parts during shipping will also be returned to vendor for rework.

Jesse proposed an alternative spacer design with slits that addresses chipping plasma coating and flexibility. Part manufacturing would require additional setup operations. Implementation and testing of the design is challenging as there are no model coils being fabricated.

Flexible end parts will be re-visited after BNL completes practice coil winding and perhaps 1-2 additional coils. During this time, BNL will look at ways to compress the coil turns during winding especially in the ends to reduce coil fluff to determine if end part installation improves. Another possibility to reduce fluff is to increase cable tension in the straight section.

1. One of the first coil end spacers to be installed fit very poorly against the adjacent coil turn (touched at the straight section and the apex but developed a several-millimeter gap to the coil in between (pictured below – see also chipped ceramic.  *Note that the layer of fiberglass normally installed between end spacer and coil turn is not in place yet, making the mismatch between surfaces more readily apparent*.).  We have no immediate solution for this as significant effort would be required to redesign the surface but are surprised that the poor fit in a high field region had not been reported.  Perhaps this area is being filled with fiberglass (in addition to the single layer that is place between spacers and coil turns) before cure.

End parts move into final position after curing. The significant gaps reported are a result of fluff in the coil due to a lack of azimuthal pressure during the winding of each turn. During winding, the coil must be as close as reasonably possible to its final shape to install this spacer. The gap will be closed after curing as shown in the photos.



1. The fiberglass that we received that is placed against the island prior to winding is too tall by several millimeters.  We have been informed that this is left in permanently as is.  This material must interfere with the radial cavity as it can only be trapped either between island and formblock or coil and formblock.  Perhaps the material used to date is a stock width, but this material should be purchased and supplied at the correct width even if it requires a custom order.

The with width of the pole is 18.7 mm. The nominal tape width is 19 mm + 1.5 mm - 0.0 mm. The measured width of the tape is 20.2 mm a difference of 1.5 mm (60 mils) from the pole width. The process calls for the excess glass to be trimmed. The activity takes 2 techs approximately 30 min per layer. The project has procured all glass needed for the coils fabricated at FNAL and BNL at a cost of $5k

1. Wedges have been received with significant burrs and machining oil buildup.  The needed cleaning and deburring represents unnecessary risk and assembly labor.  Wedges should be purchased from vendors properly packaged,  free of all oils and other foreign materials and deburred with edges broken per the engineering drawings.

FNAL will clean and deburr wedges prior to shipping to BNL.

1. The first block of coil turns for this test coil was wound without incident without the aid of go-no go gauge or binder.  After the wedge was installed the next turn resulted in a popped wire.  The turn was intact until after it was forced to bend around the sharp edge of the wedge which protruded significantly beyond the end spacer due to the fluff of the coil end turns (see photos below).  Some of the subsequent turns yielded the same result.  In each case the wire has been put back into place and binder has been coated and cured onto the cable insulation locally, but it is not felt that this application is providing any support.  It has long been conceded that this Project would utilize unstable cable.  Given that, it is incumbent on coil manufacture to provide the safest design to prevent un-cabling.  Adding flexibility to the wedges locally as previously proposed by Steve Krave to eliminate issues with gaps between wedges would solve this problem.  (Note, though, that Juan Carlos independently reports that he does not see this issue at CERN.  He says the wedge doesn’t stick out as pictured.  I do not understand this as, although CERN’s model coil winding procedure is quite different from ours, the geometry is the same and so should be the results.  Perhaps this effect goes unnoticed with better cable, and what we are using right now is unusually unstable?)

As mentioned in #1 above, accumulated fluff during coil winding and the lack of binder on the end turns is the reason for the problems seen by BNL during coil winding. This is based on the photo’s provided by BNL in the original email.

1. The wedge has been difficult to install under the radial coil clamps and the clamps needed to be loosened to permit installation (Our clamps use the island as the determining annular spacer.  Are FNAL clamps spaced higher to preclude this problem?).  We have not had an opportunity to inspect the wedges (all are installed and we were not sent spares) but a review of the engineering drawings (attached) reveals that when corrected for the fiberglass insulation later added to the wedge, the nominal wedge height is 0.05 mm less than the island.  However, the wedge and island have surface tolerances of 0.1 mm and 0.05 mm respectively, so the worst case can result in the wedge being 0.10 mm taller than the island.  Since the islands set the radial spacing inside the curing cavity, this is a design error that should be fixed (could an oversized outer layer wedge have contributed to the trace electrical failure in MQXFA1?).

Radial winding clamps at BNL are made of steel forming a fixed radial gap between the winding mandrel and the upper surface of the pole piece. As mentioned in #1 above, coil fluff will exacerbate the installation of wedges due to additional rotation of the wedge at installation. The rotation of the wedge in the fixed radial space will make the wedge seem larger than design. The inner wedge is within tolerance and on the plus size by 25 microns in the radial direction. Pole pieces are oversized by the same amount so the net effect is zero.

Per the inspection report, the outer wedge is undersized in the radial direction by ~70 microns. That coupled with the outer pole being large by 25 microns in the radial directions means the wedge could not have contributed to the trace electrical failure of MQXFA1.

The wedge design approach used the 2D cross section to develop the maximum wedge envelope. Then each side was offset by -0.1 mm to account for the wedge insulation. The wedge tolerance is +/- 0.05 mm as is the pole piece tolerance. The minimum pole width and the maximum wedge width (without insulation) are in line with each other by design. In this situation the insulation would be locally highly compressed.

Parts fabricated have been within tolerance with one minor exception, the outer wedge radial width is small and out of tolerance. Wedges are made using an extrusion die so the wedge size will remain constant. If for any reason a new die is manufactured, the wedge tolerance will be changed to be unilateral in the minus direction. The outer pole piece is within tolerance on the plus side.