U.S. MAGNET DEVELOPMENT PROGRAM

Nb_3Sn CCT Updates and Next Steps

USMDP Bi-Weekly Meeting - 10/23/2024

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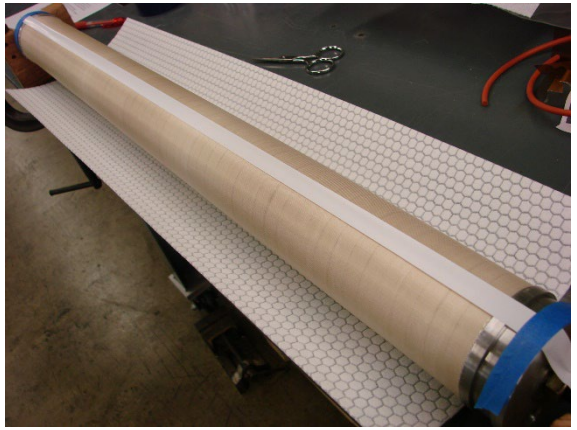
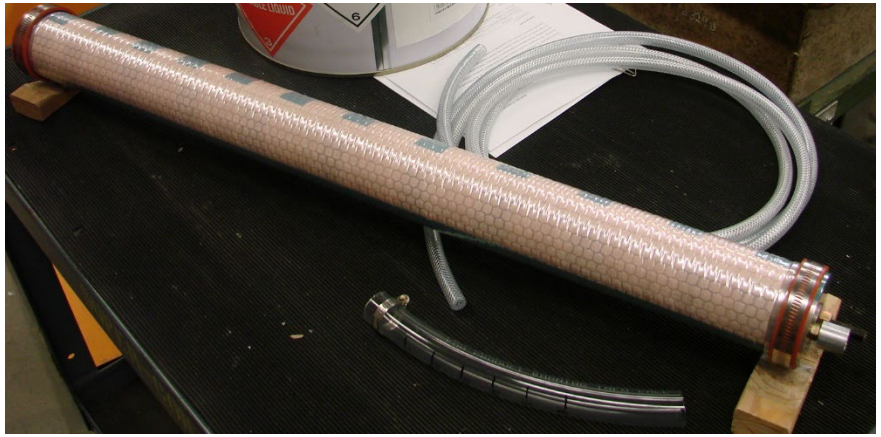
Outline

- General Updates
  - CCT subscale updates and plans
  - CCT5 Hybrid updates and plans
  - CCT5-W update and plans
  - CCT6 updates and plans

CCT Subscale Current Activities

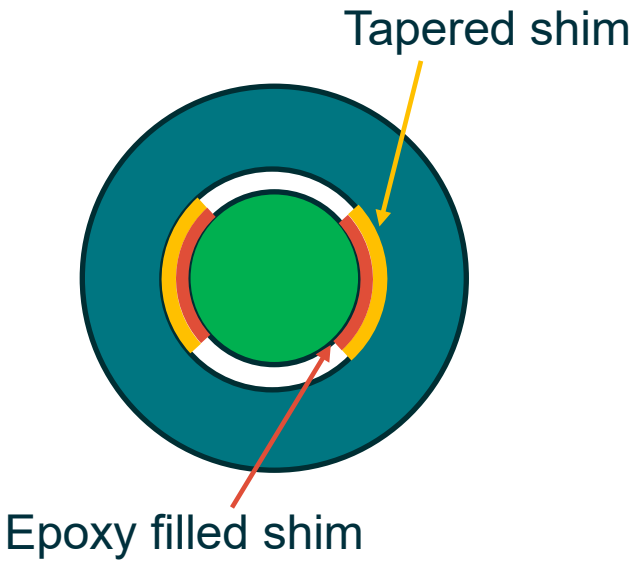
- Working with E. Barzi towards test of Telene impregnated CCT subscale magnet
- Inner layer coil has been heat treated but decided to test impregnation process on “dummy” coil before proceeding with impregnation of real coil
- Plan is to impregnate the coils at FNAL, we will start with the “dummy” coil which has been prepared for potting and will ship out imminently

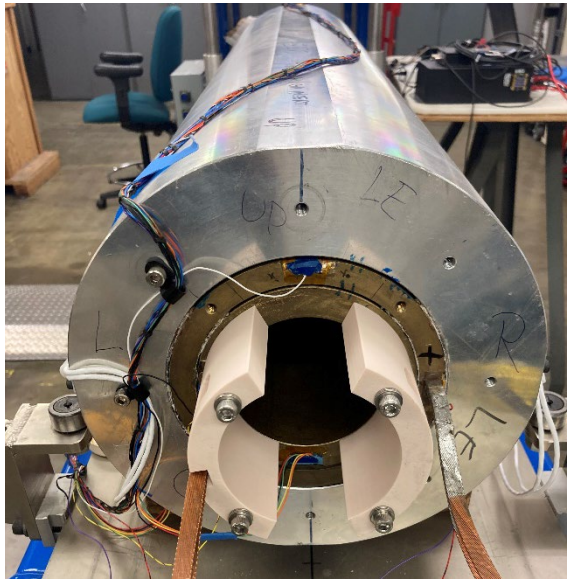


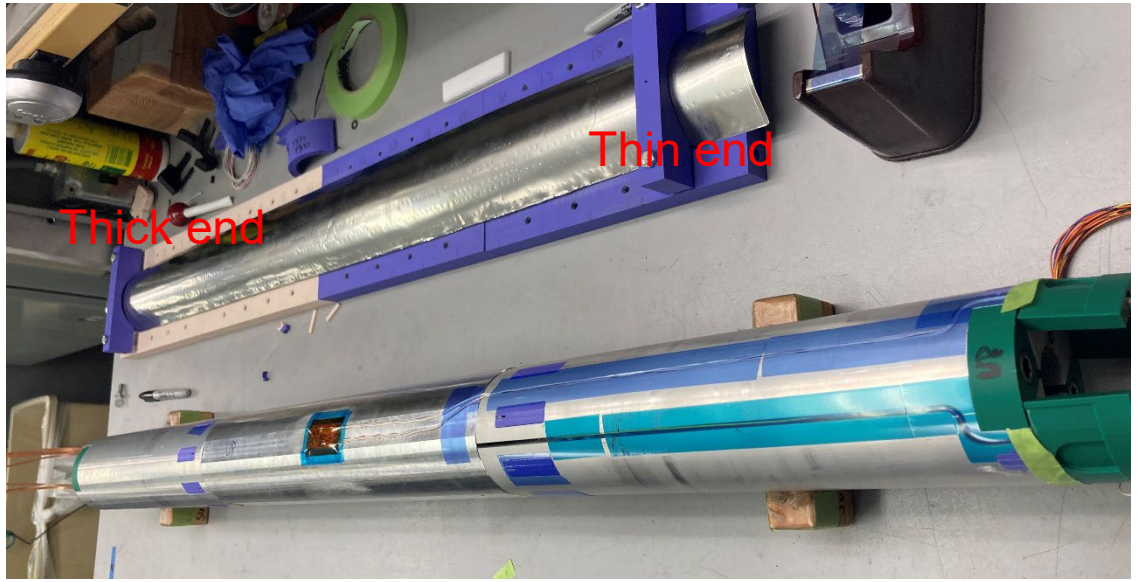


Preparation of CCT5 / Bin5 Hybrid Assembly

- Decided to use “smartshim” method to couple the insert and the outsert
- Introducing tapered shim to reduce force required for disassembly
  - Shim is made by stack of thin stainless steel sheets of varying lengths
  - Sheets are spot welded while clamped on a fixture with the appropriate curvature

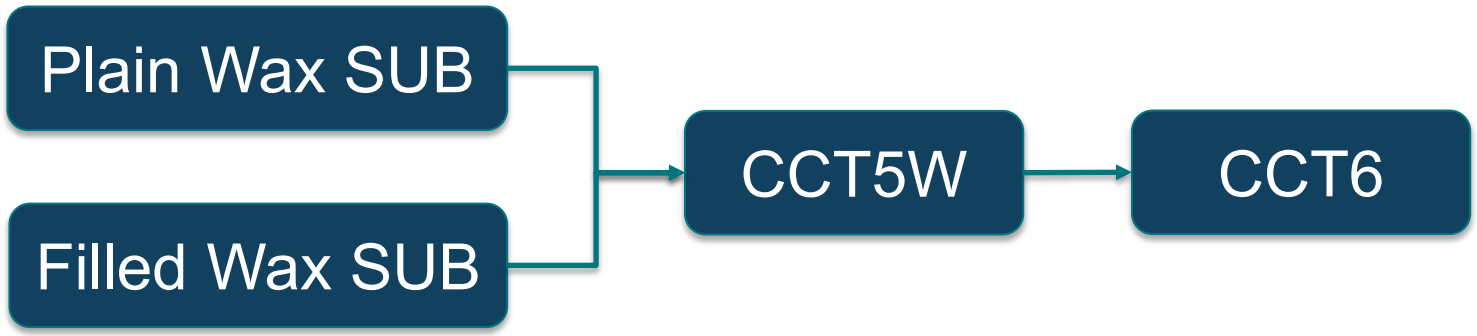






CCT5-W (Wax Impregnated) Motivation

- Desire to operate close to the conductor limit with minimal training for CCT6
- Selected filled wax as impregnation material since it exhibited minimal training in subscale test (1 quench before reaching expected SSL) and provides improved mechanical properties over plain wax
- Preparing filled wax impregnated CCT5 @10T (CCT5-W) as a stepping stone towards CCT6
  - Average radial stress of CCT5 at 10 T is representative of CCT6 at ~12 T. Subscale stresses are significantly lower
  - The cost and effort to build CCT5W is only slightly more than for a subscale magnet since the process is the same, the machining cost is only slightly higher, and cable was available



Stress on Turn from Lorentz Force

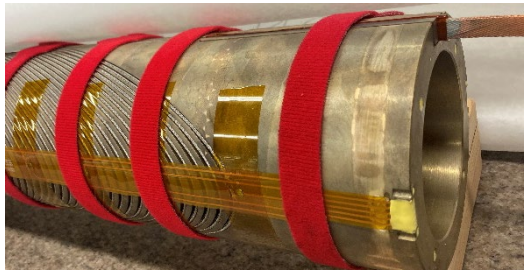
			2D FE - Magn	
Magnet	**Current**	**Field**	**srr_em**	**stt_em**
	kA	T	MPa	MPa
Subscale	9.5	5.3	15	10
CCT5	17.8	**10.0**	**71**	3
CCT6	10.67	**12**	**85**	5
CCT6	14.22	16	152	9

Analysis performed by G. Vallone and M. Juchno

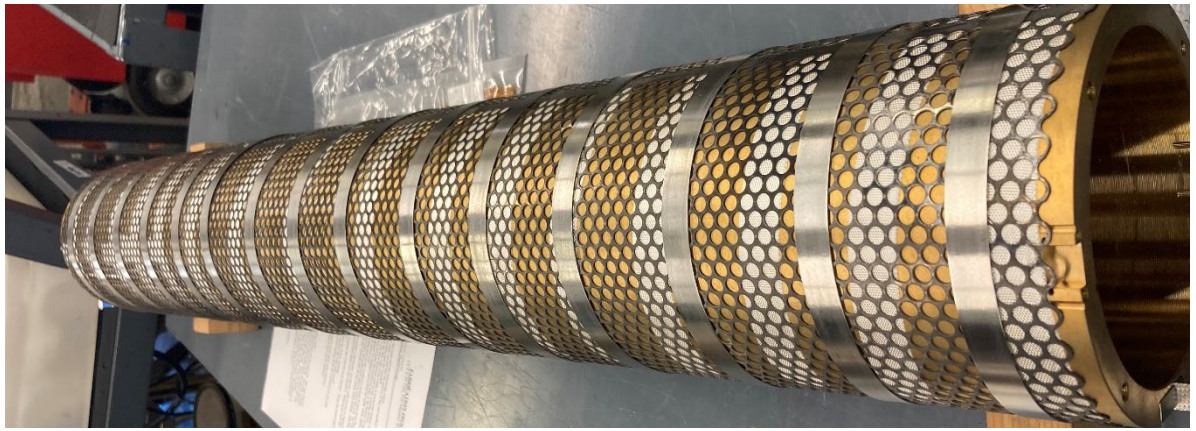
CCT5-W Status and Next Steps

- Inner layer is being prepared for impregnation, splices and voltage gap wiring is complete
- Outer layer is ready for reaction
- Coil impregnation and magnet assembly expected early in 2025
  - Plan to impregnate 20-turn CCT6 coil to test process before proceeding with CCT5-W coil impregnation

Inner Coil

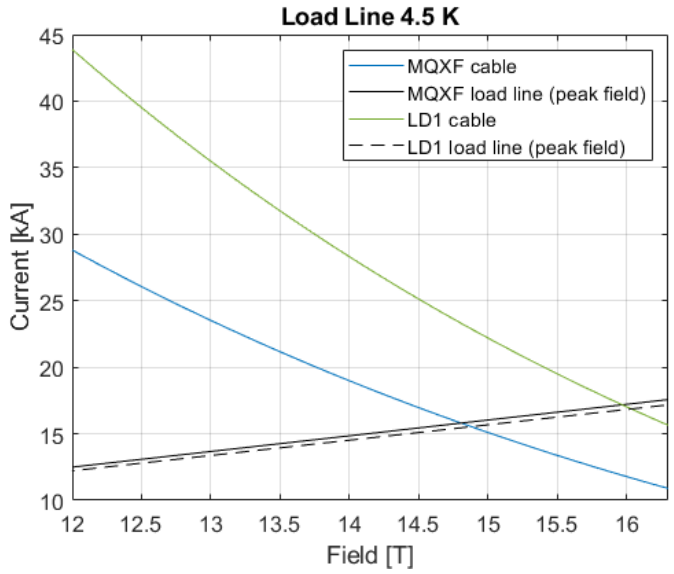


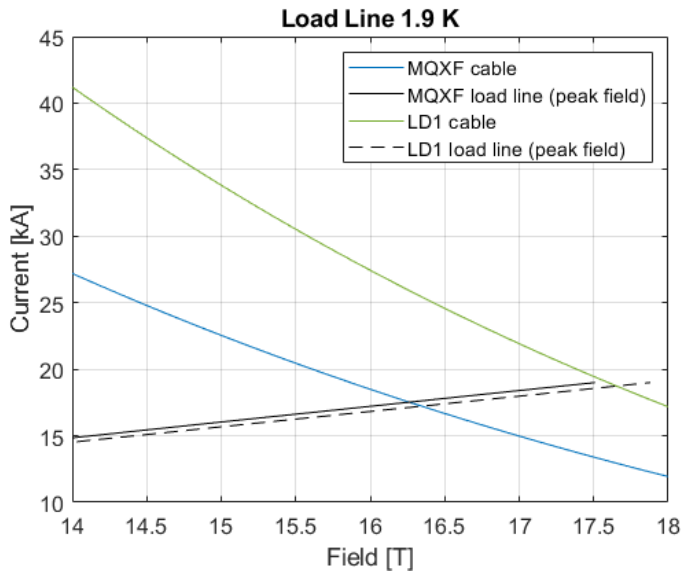
Outer Coil



CCT6 Updates

- Working towards final decision on which cable to use for inner 2 layers (LD1 vs MQXF)
  - Maximum achievable field (approximately higher 8% for LD1 vs MQXF)
  - Machining time / risk (early indication is that MQXF groove can be machined approximately 2x faster than LD1)
  - Ease of winding (risk of popped strands)
- 20-turn mandrels fabricated for both cases, currently completing testing on these

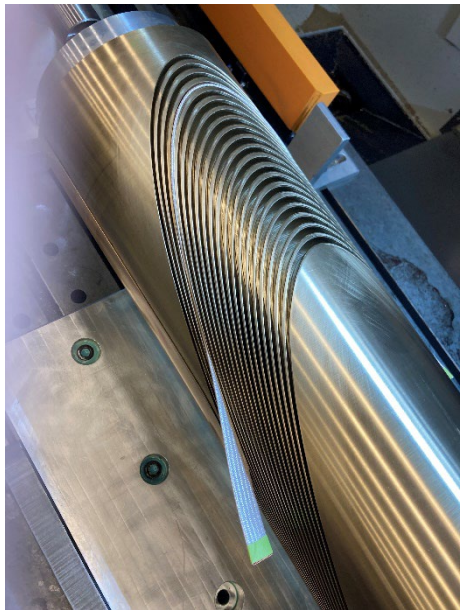




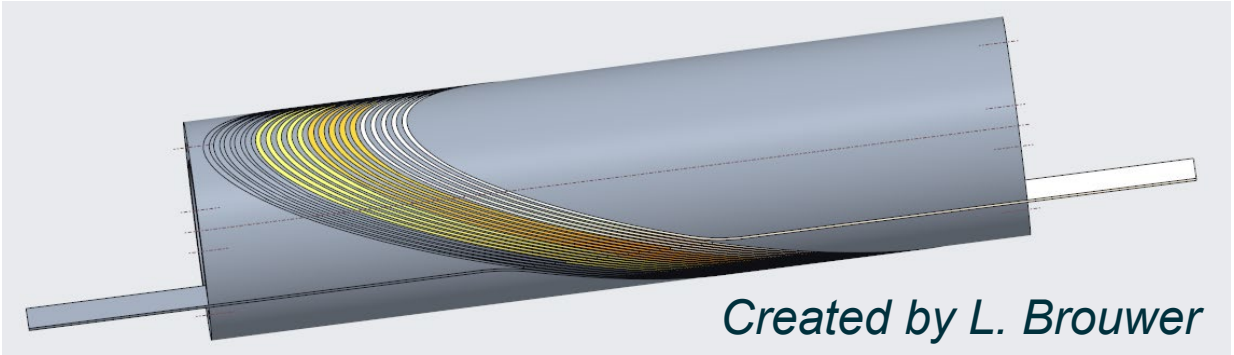
Load lines based on 2D calculations performed by L. Brouwer

CCT6 Machining Updates

- 20-turn coils for LD1 and MQXF cases completed
  - Coil using LD1 cable (51 x 0.8 mm diameter strands, 22.0 mm x 1.38 mm)
  - Coil using MQXF cable (40 x 0.85 mm diameter strands, 18.2 mm x 1.53 mm)
- Each coil has four different sets of groove geometries
- Feedback on machining time for 20-turn coils (~5 times long for full length coil)
  - 219 hrs of machining time for LD1 version
  - 86 hrs of machining time for MQXF version



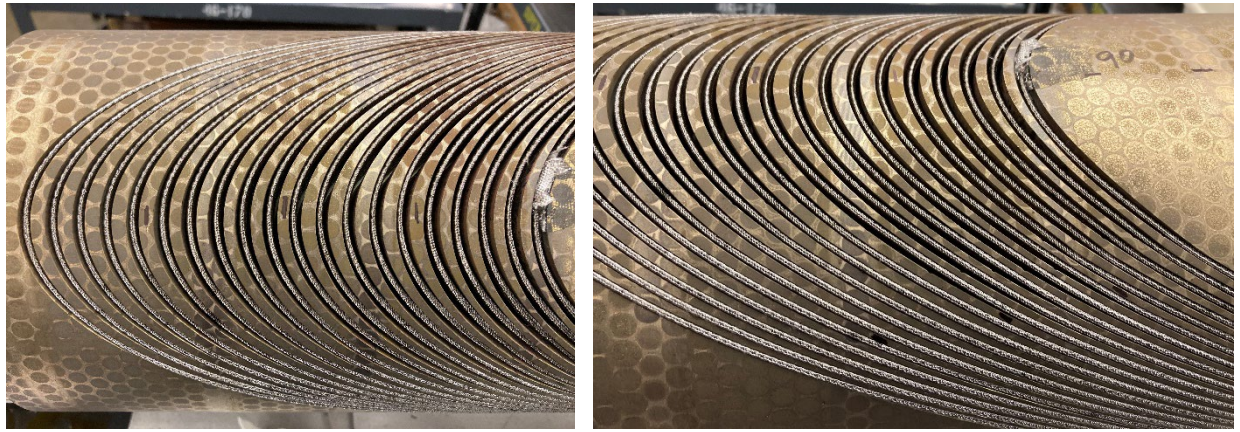
20-Turn mandrel with four different groove segments



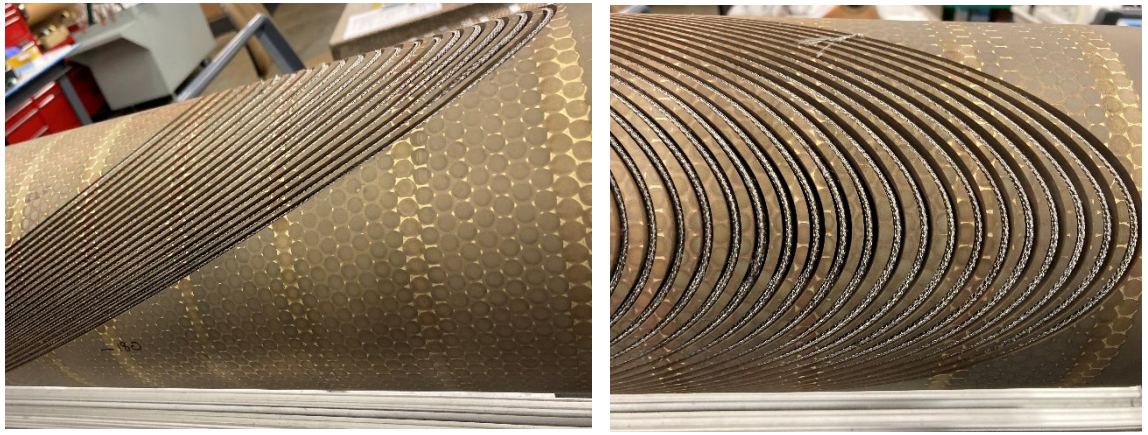
CCT6 20-Turn Coils Post-Reaction

- Goals of these tests are:
  - Define optimal groove geometry (investigate trade-off between pole gap and total path length) based on reacted cable position
  - Determine if there are any issues with cable stability from winding and reaction
- Observations
  - MQXF cable is easier to wind (tends to remain at bottom of channel after winding)
  - After reaction, the LD1 cable protrudes from the surface for all gaps (larger gaps are better)
  - Smallest gaps seems to be sufficient for the MQXF cable, for larger gaps the cable ends up closer to the inner edge of the turn

LD1 Cable

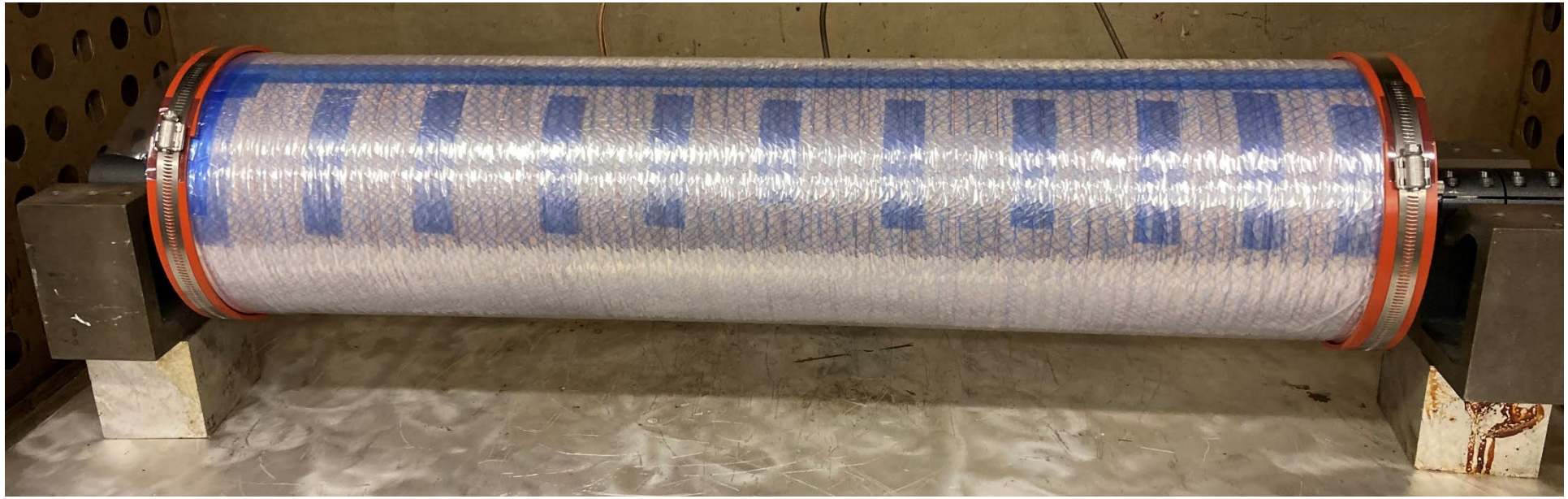


MQXF Cable



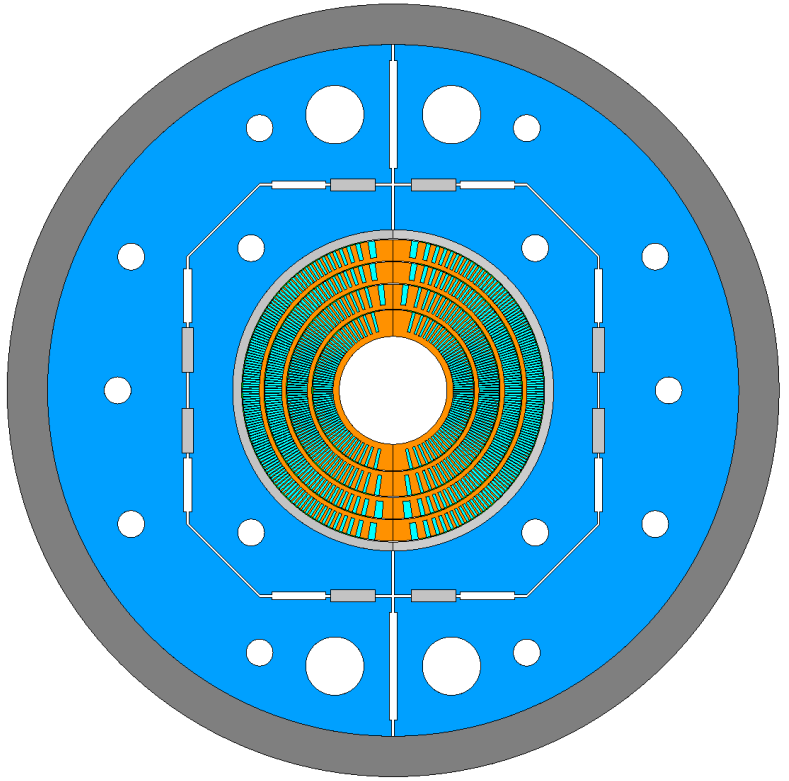
CCT6 20-Turn Coils Potting

- Preparing to impregnate MQXF 20-turn coil with filled wax
- Will cut coil after impregnation to observe cut sections
- Test to ensure that filled wax impregnation is successful on “large” coil in preparation for CCT5-W impregnation



CCT6 Next Steps

- Design and Analysis
  - Structural analysis of structure continues
  - CAD design of mandrels including splice / alignment / instrumentation features
  - CAD design of key-and-bladder structure
- Mandrel Fabrication
  - Perform final winding test of LD1 20-turn to determine if windability can be improved with tooling, make final decision on inner layer cable
  - Start machining of CCT6 inner layer
- Fabrication Technology
  - Investigating possible use of filled wax for CCT6 through subscale and CCT5-W tests



Summary

- Subscale progress
  - Prepared “test” coil for impregnation with Telene
- Larger model progress (i.e. CCT5 type)
  - CCT5-W fabrication is in progress and planned to be complete early in 2025
- 20-turn CCT6 tests mostly complete, will proceed with machining of first layer in November