U.S. MAGNET DEVELOPMENT PROGRAM

C3 status

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MDP bi-weekly meeting, 21 August 2024

U.S. DEPARTMENT OF ENERGY | Office of Science

C3 is our latest vehicle to collaborate with conductor vendors to develop REBCO magnet and conductor technology

- Six-layer CCT dipole aiming at the 5 T milestone
  - Built on what we learned from C1 and C2
- 145 m of CORC® wires in six pieces, maximum piece length 35 m
  - Specified the minimum tape I_c for HM tapes
- First attempt to consider mechanics
  - Aluminum shell + Stycast filling
- Test idea of machine-aided winding and distributed fiber-optic sensing

Advanced Conductor Technologies
www.advancedconductor.com

SuperPower Inc.
A Furukawa Company

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Status as of August 2024

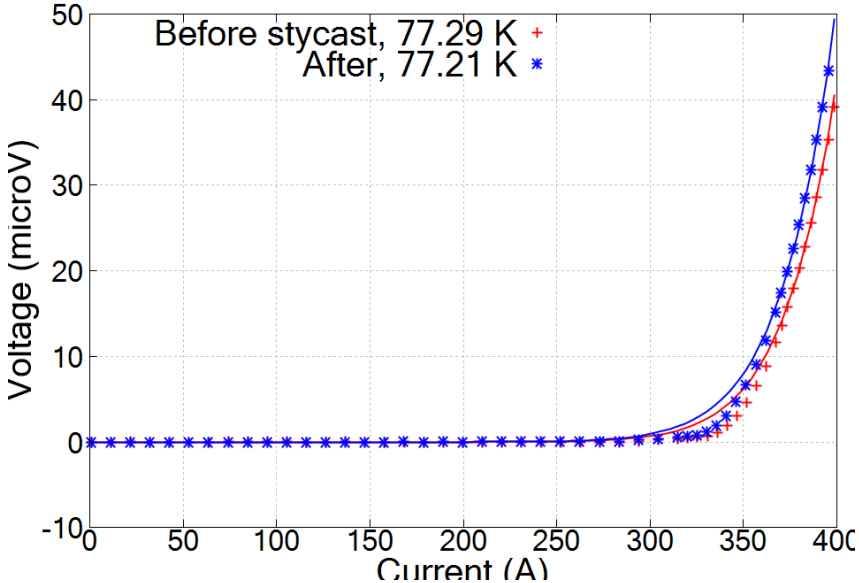
- Layers 1, 2, 3 tested at 77 K
- Layer 4 wound yesterday

- Next steps
  - Complete Layers 5 and 6 by December 2024
  - Make the iron yoke by December 2024
  - Assemble C3 by February 2025
  - Make the magnet/cryostat support plate by November 2024
  - Set up the magnetic measurement system by March 2025
  - Test C3 by March 2025

The coils look like this

Layer 1, image courtesy of Paolo Ferracin

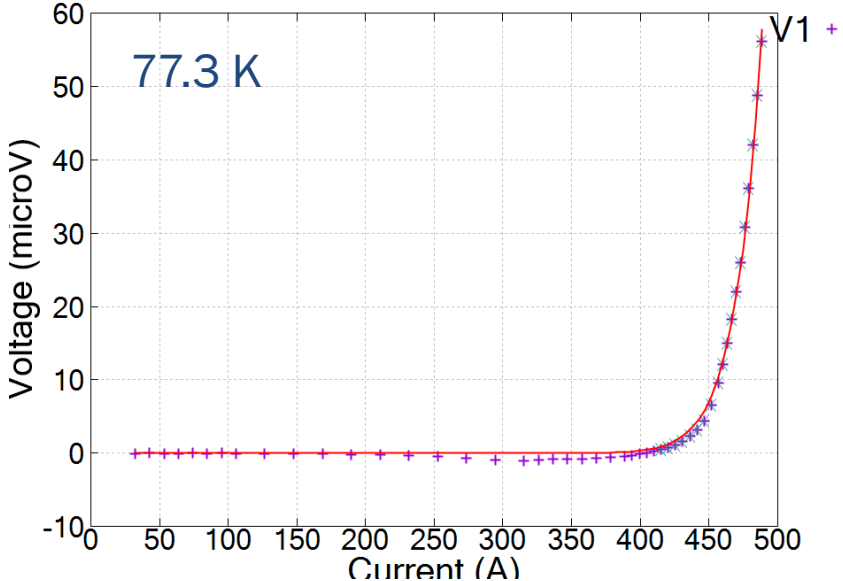
I_c reduced by 2% after painting Stycast for Layer 1, consistent with the previous coils in C2 and C3a



	I_c (A)	n
Before painting	380	14.3
After	374	13.9

- **Skip the measurement before painting Stycast for the remaining layers**

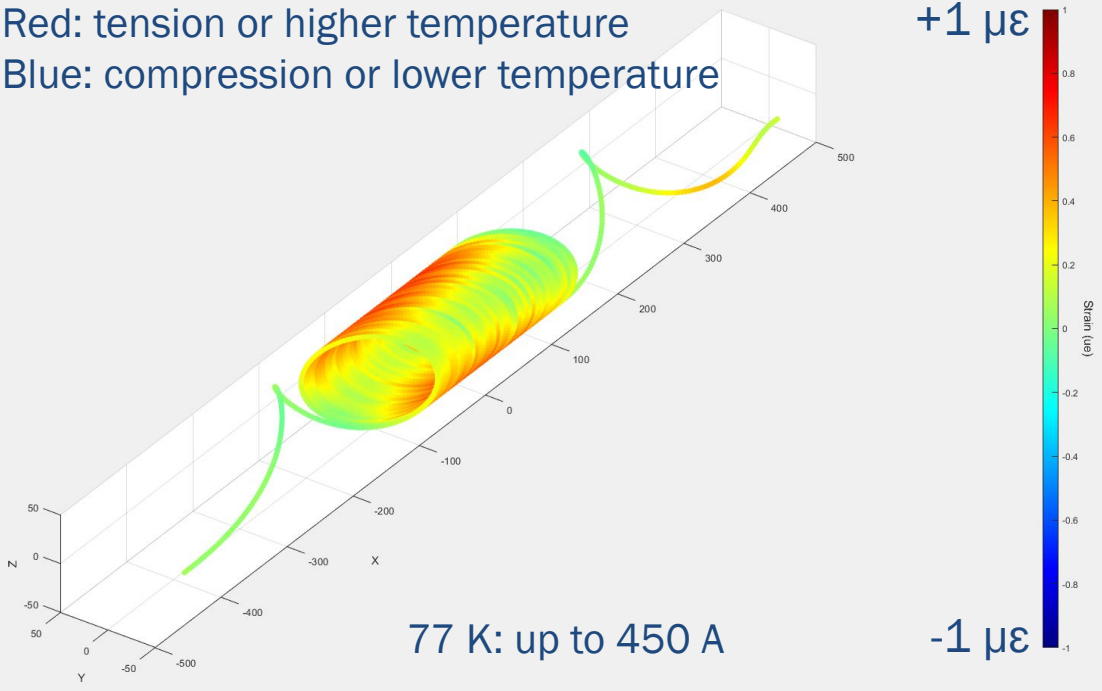
Layer 2

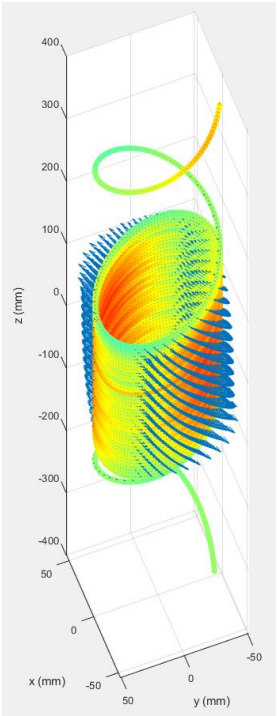


- I_c = 469 A at 20 μV criterion
- n = 25.5

Optic fiber measured the conductor regions under tension at 450 A, coinciding with the expected distribution of Lorentz forces

Red: tension or higher temperature
Blue: compression or lower temperature

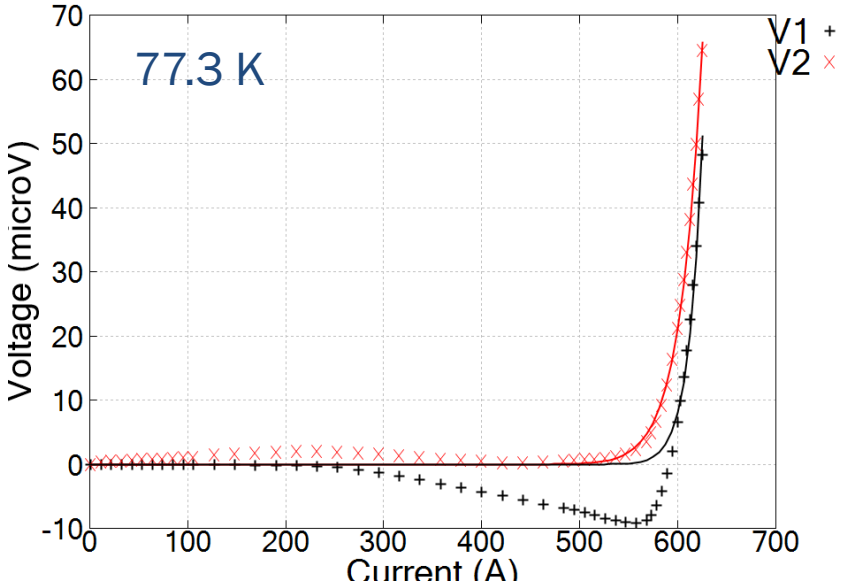




Vectors: local Lorentz force

Analysis and data by Linqing Luo at LBNL

Layer 3 showed an unusual V(I) behavior



- Strong negative voltage in V1 before transition
- V1 and V2 transitioned at similar current
- V2 wire insulation can be damaged and made a contact near V1

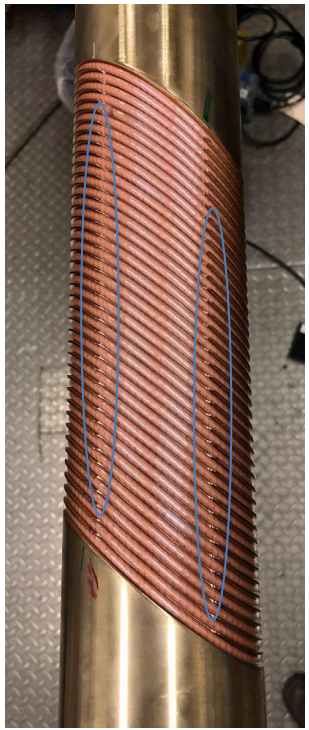
- I_c ~ 607 A at 20 μV criterion
- n = 35.2

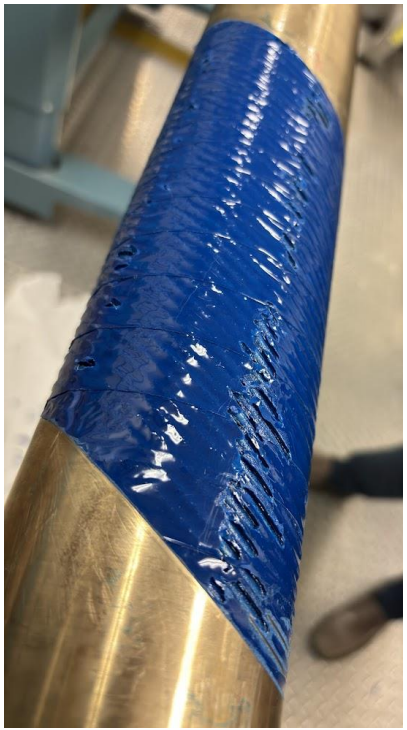
We ran into several issues that keep us on our toes

- Some can be fatal to the coil
- Some reveal new features not seen in 3-turn coils

- All trying to tell us that fabrication is critical

Layer 1: a surprising number of voids appeared after the Stycast cures





- Addressed by the second filling
- Also started using a professional mixing machine to mix and degas Stycast/catalyst.
  - Thanks to Tom Johnson at the Composite Shop for loaning us a Thinky machine and Ian/Jean-Francois/Andy ordering the supplies.

- Clustered around the edge of the discontinued ribs
- Another reason to have continuous ribs?

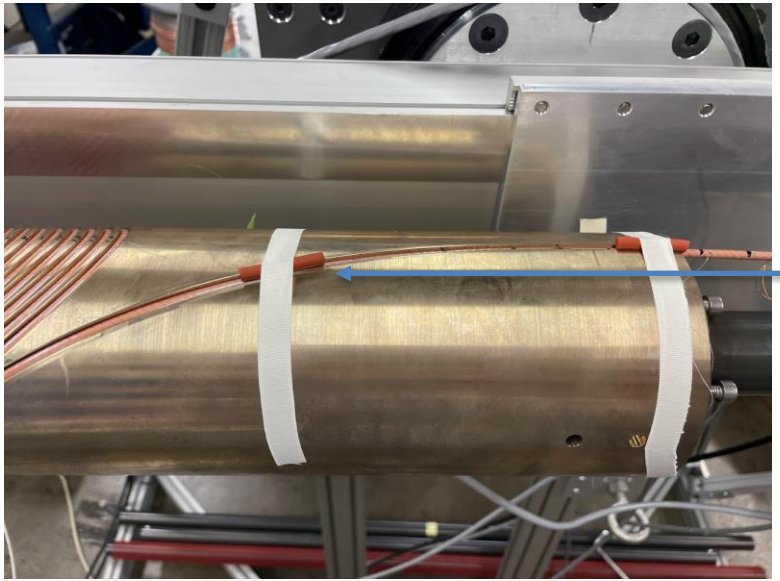
Layer 3: winder broke down during test winding

- The linear drive no longer engaged with the rotation drive
  - Screw are loose after a few years of operation
  - C3 mandrels are the heaviest that the winder has dealt with

- Replaced with a new drive and inspected the screws
- Check the engagement every time we wind

- Thanks to Tom Lipton for encouraging us to open the drive and found out the root cause

Layer 3: wire detached from the groove at the exit



- The gradual curve at the exit does not constrain the wire that is under tension
  - May overbend the wire
- Need external force to keep the wire in the groove
- It was in the procedure but was not followed…

Layer 4: wire badly kinked by accident

- Wire detached from the return end groove under tension before we got a chance to apply the rubber stopper
- The wire on the far end popped out of the spool and got caught and bent by the nut
- We started from the end of the wire on the spool. Thanks to Hugh for the idea. The additional wire length helped.

A few thoughts on magnet efficiency

- We may characterize and compare dipole magnet efficiency in T/kA, when magnets can be made as designed on paper
- Different from Nb-Ti and the W&R Nb_3Sn and 2212, fabrication is critical for REBCO magnet technology
  - REBCO comes as reacted. “Risk is upfront”
- Efficiency therefore needs to consider fabrication – can we make REBCO coils with minimum degradation?
- We need to make more coils