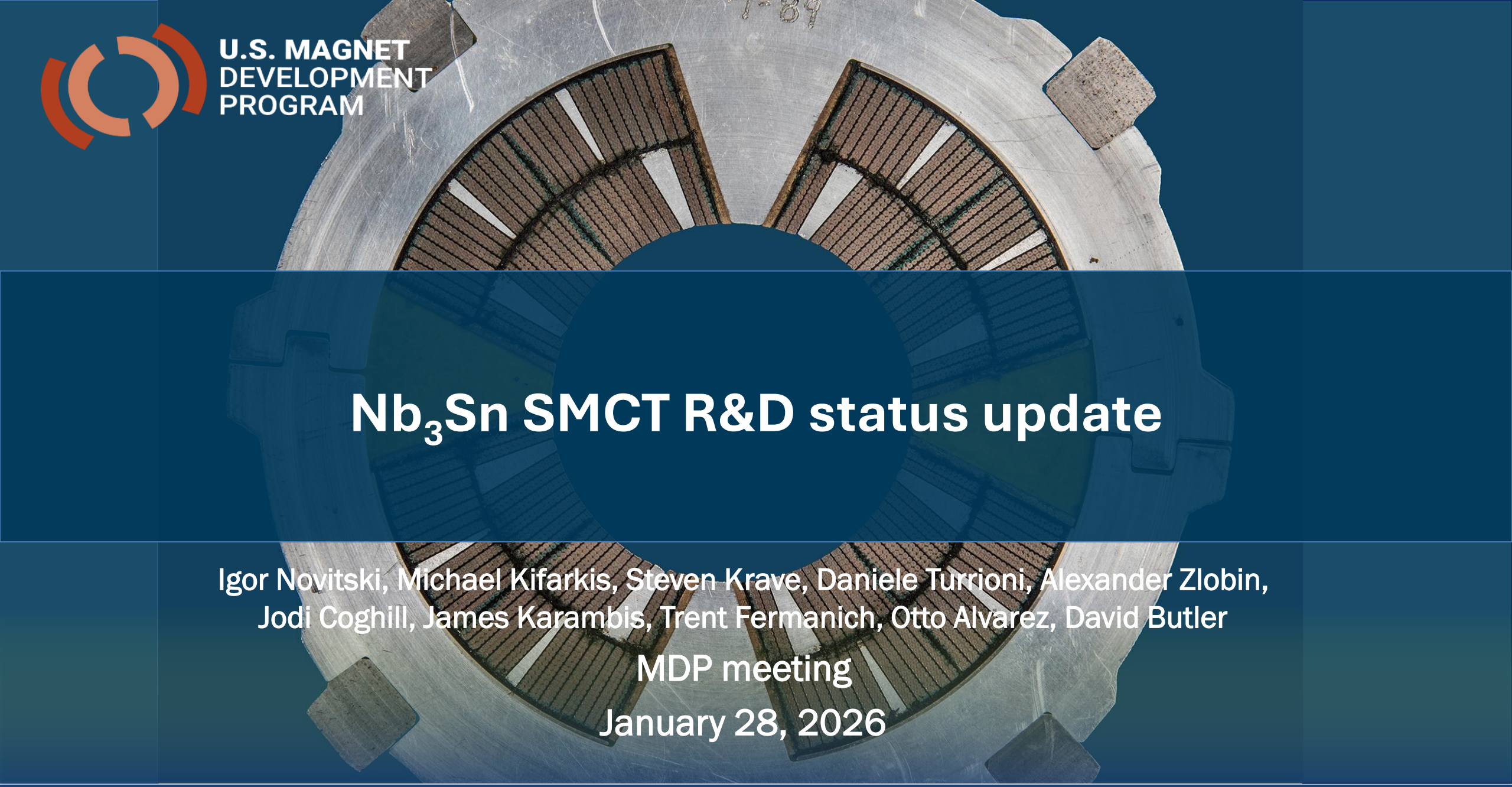


U.S. MAGNET DEVELOPMENT PROGRAM

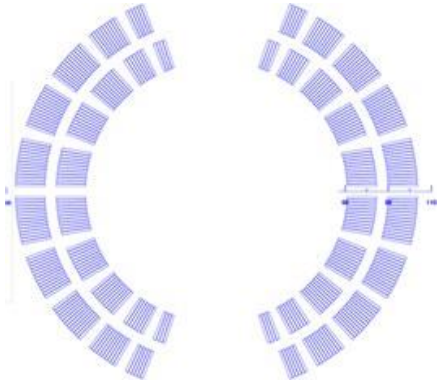
Nb_3Sn SMCT R&D status update

Igor Novitski, Michael Kifarkis, Steven Krave, Daniele Turrioni, Alexander Zlobin,
Jodi Coghill, James Karambis, Trent Fermanich, Otto Alvarez, David Butler

MDP meeting

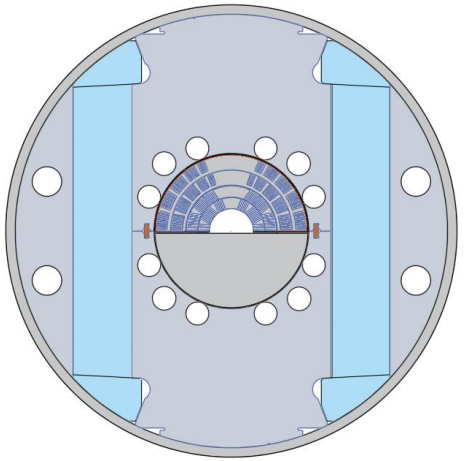
January 28, 2026

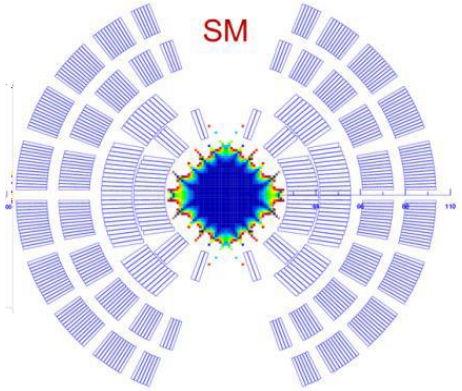
US-MDP Task: Nb_3Sn SMCT R&D status



ID=123 mm, B_{des}~11 T

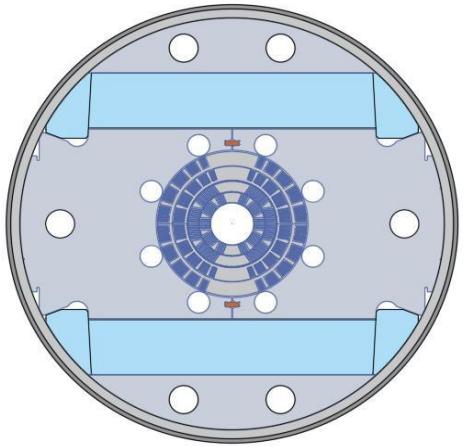
I.a.M2 I.a.M3	Development of the SMCT coil technology and test of stress management concept in a 2-layer 120-mm SMCTD1 with the field up to 11 T and in a 4-layer 60-mm dipole with the field up to 15 T.	Q1-Q2 FY27



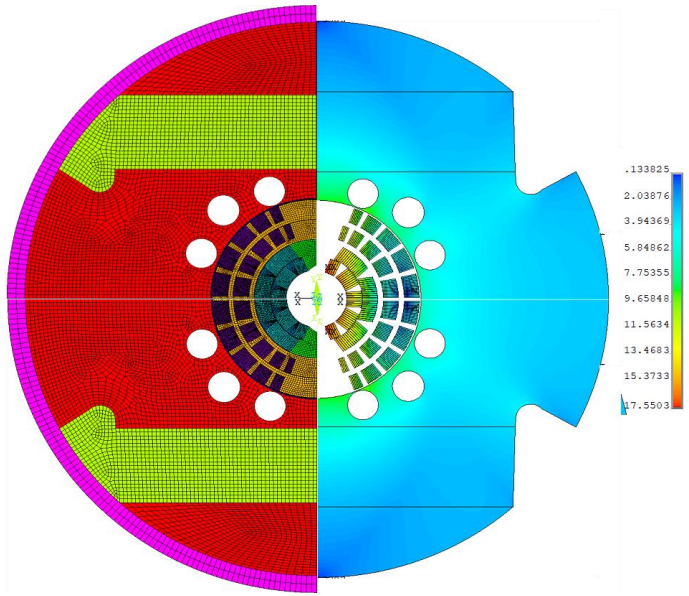


ID=60 mm, B_{des}~17 T

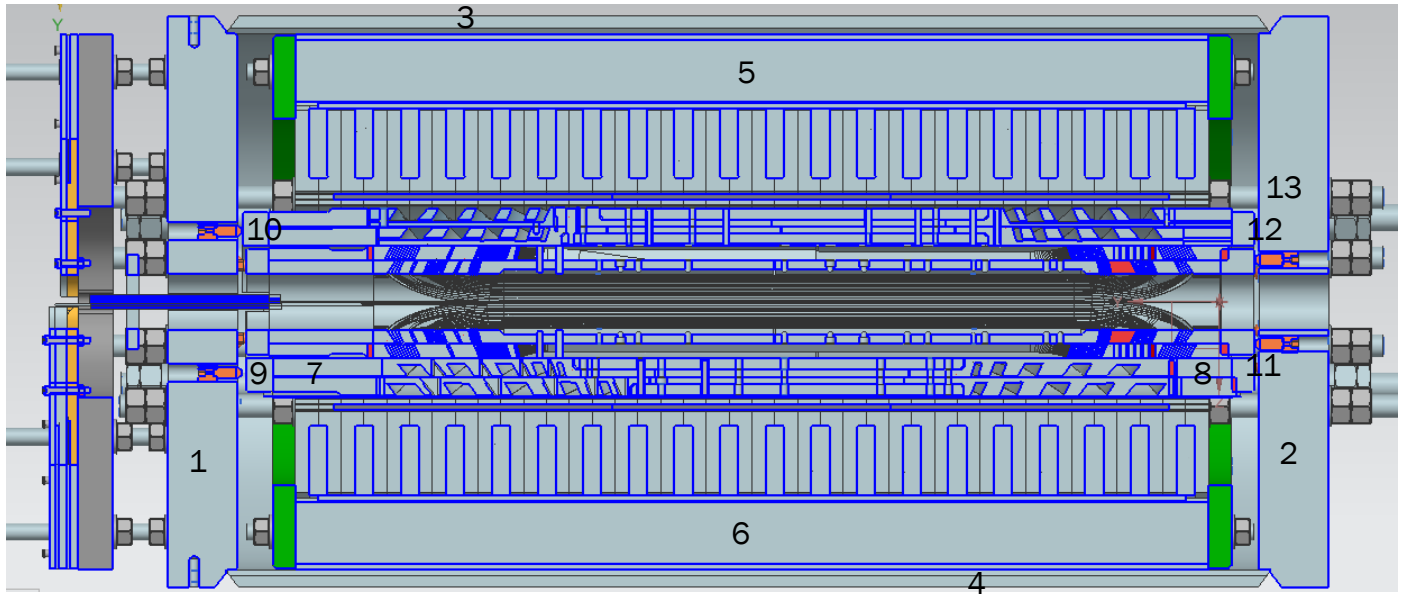
- SMCT D1 dipole - parts in procurement
- SMCT coil #2 - coil in production
- SMCT coil #3 - design in progress
- Practice coil - production and TELENE impregnation



Dipole Magnet SMCTD1 with Stress Managed Cos-Theta Nb_3Sn Coils

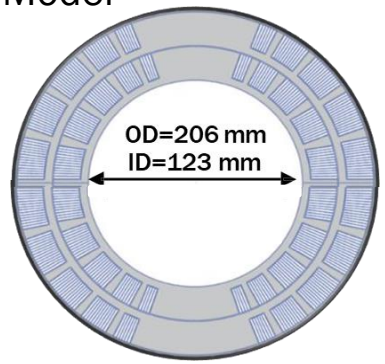


SMCTD1 FEA Model

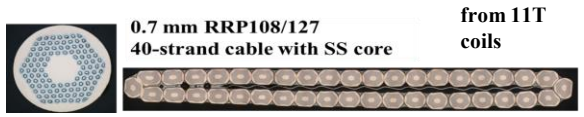


SMCTD1 CAD Model

SMCT Coils



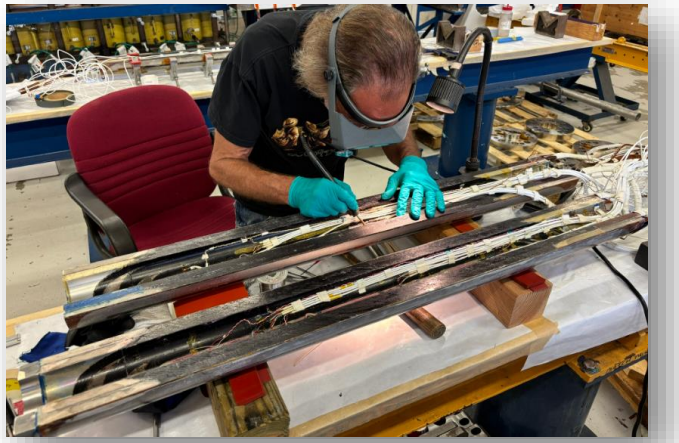
Nb3Sn Cable



reacted dimensions: 15.1x1.319 mm
Jc(12T, 4.2K)=2650A/mm²

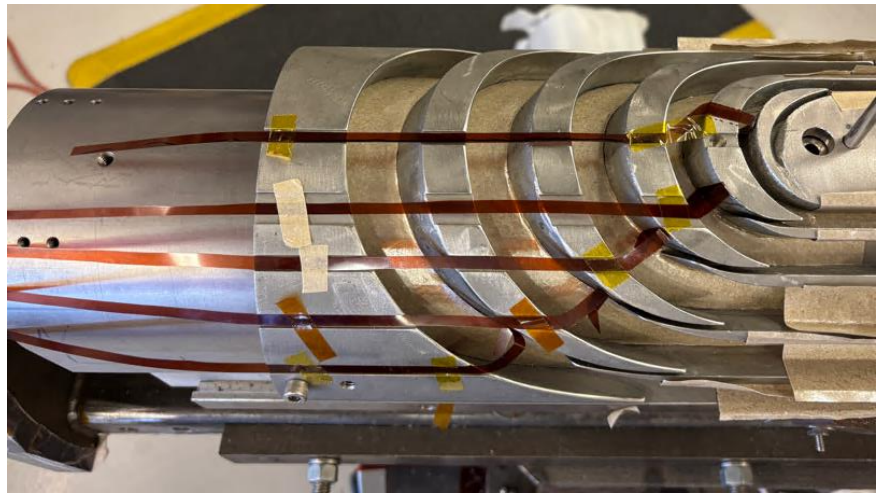
Design and drawings completed
NbTi cable for leads received from CERN
Parts in procurement:

- End plates for both ends 1,2
- New 19 mm-thick SS skins 3,4
- Fillers 5,6
- Splice and extension blocks 7,8
- Pusher blocks 9,10,11,12
- Rods 13
- Contact tooling for skin welding

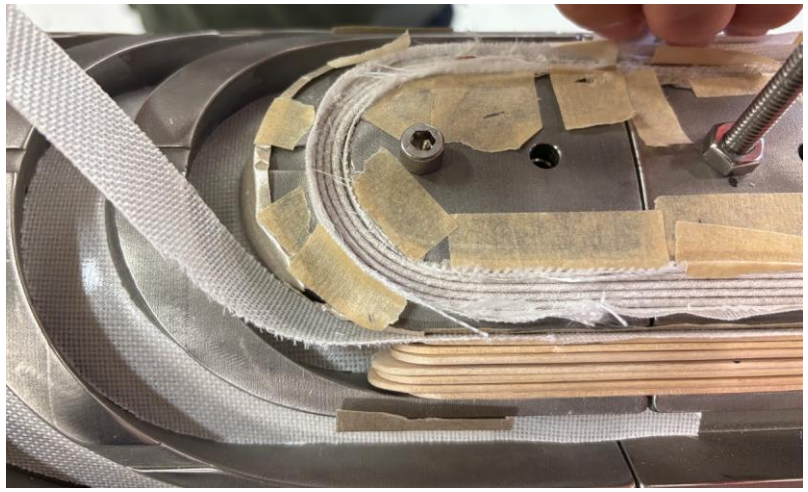


Inner Coil instrumentation completed

Stress Managed Cos-Theta Nb_3Sn Coils #2 – coil winding



Coil#2 VT's templates for layer 1



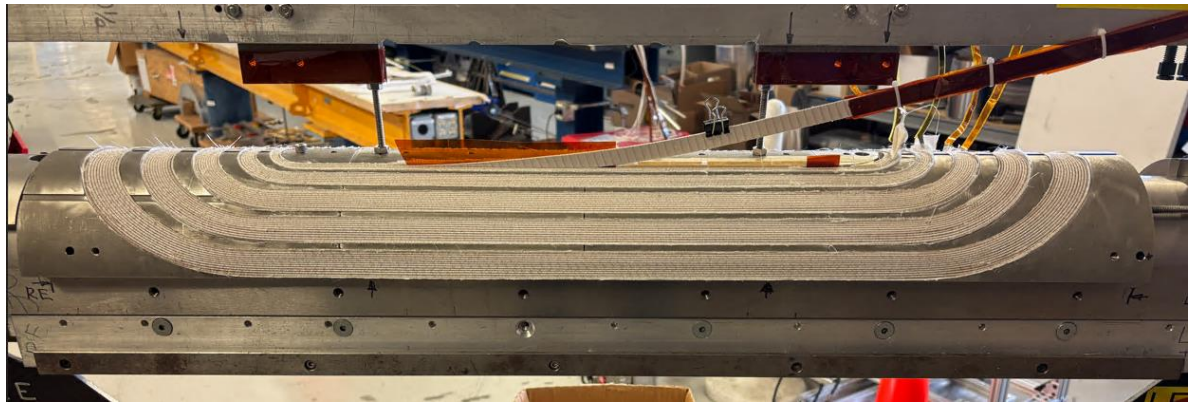
First groove winding

Coil#2 winding in progress

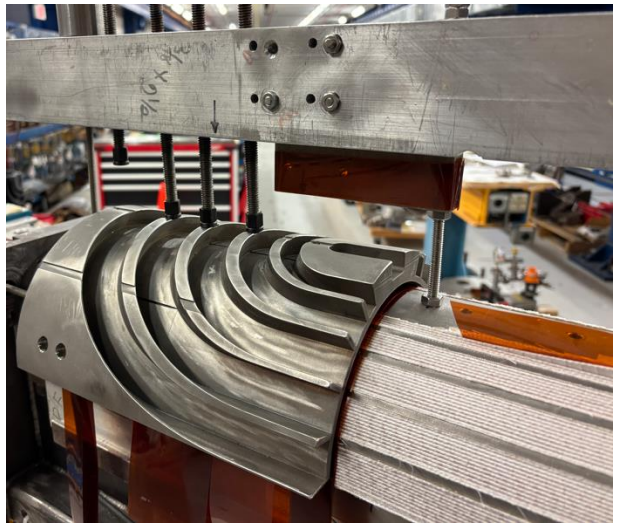
Single cable in transition channel

Cable winding around return end area

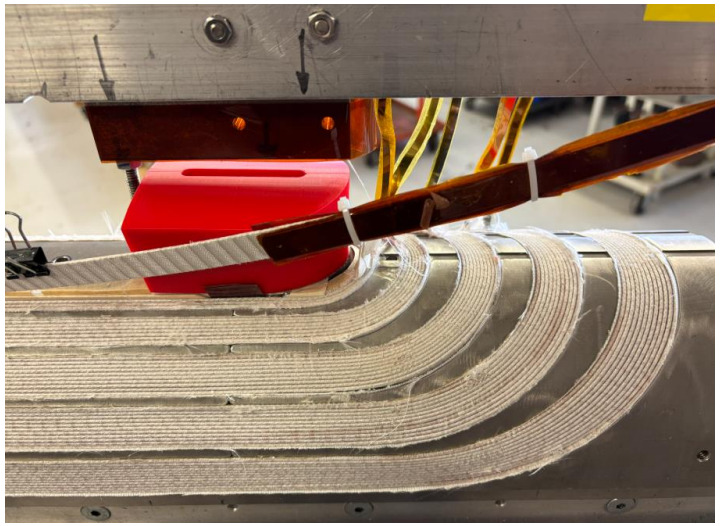
Stress Managed Cos-Theta Nb_3Sn Coils #2 – coil winding



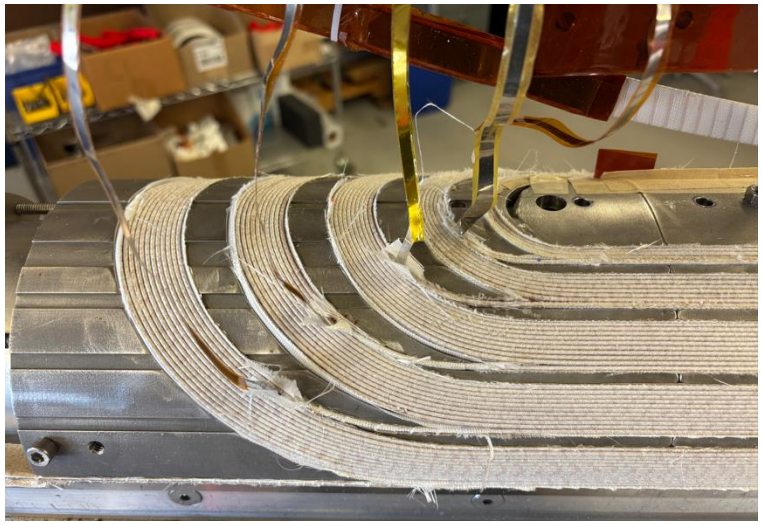
Coil#2 winding of layer 1 complete



Layer 2 parts fitting



Layer jump forming



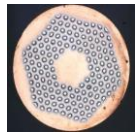
VTs location for layer 1

Design in progress on Nb_3Sn SMCT Coils #3, 28-strand cable

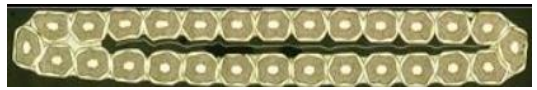
Top view of coil#3 mandrels for, layer 1 and 2

Design in progress on Nb_3Sn SMCT Coils #3, ramp geometry

from 11T
Inner coils



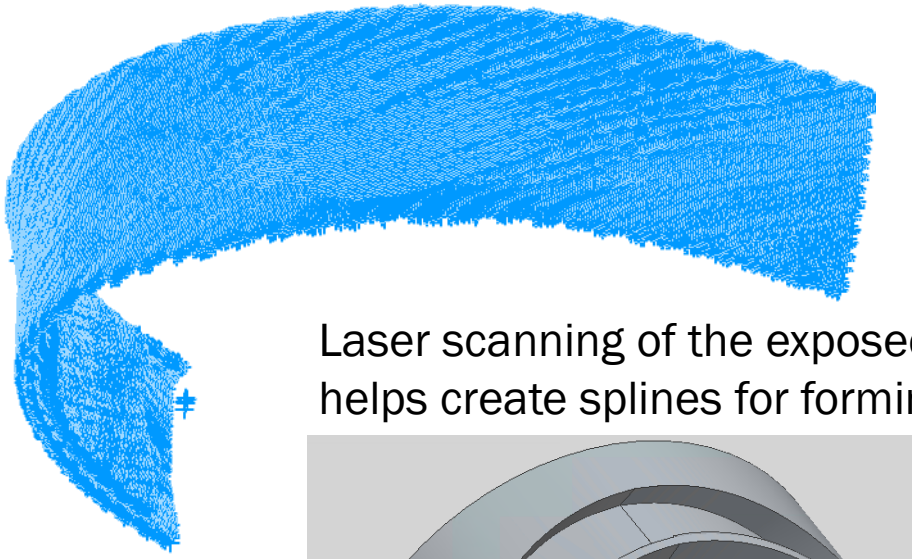
1.0 mm RRP 150/169 wire,
28 strands cable with SS core



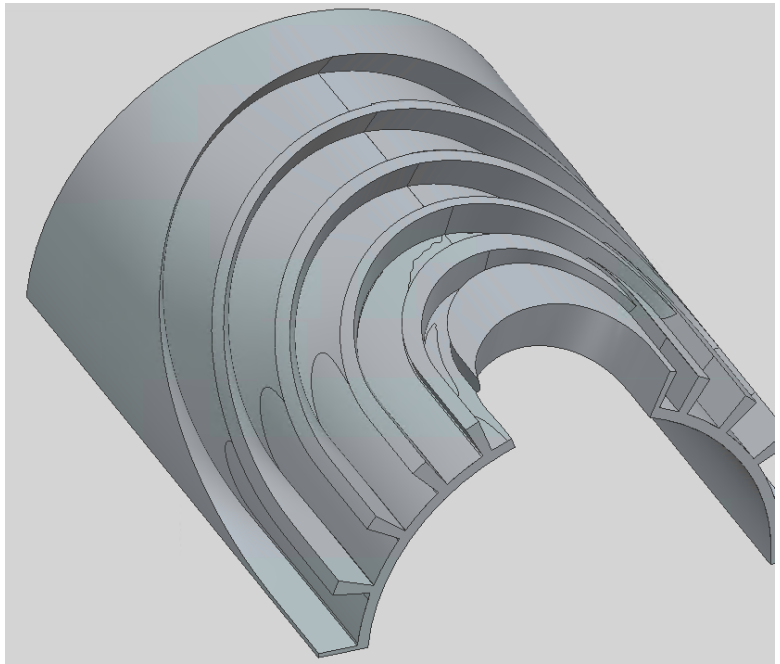
reacted dimensions: 15.1x1.87 mm

Nb_3Sn Cable

Cable ramp mockup



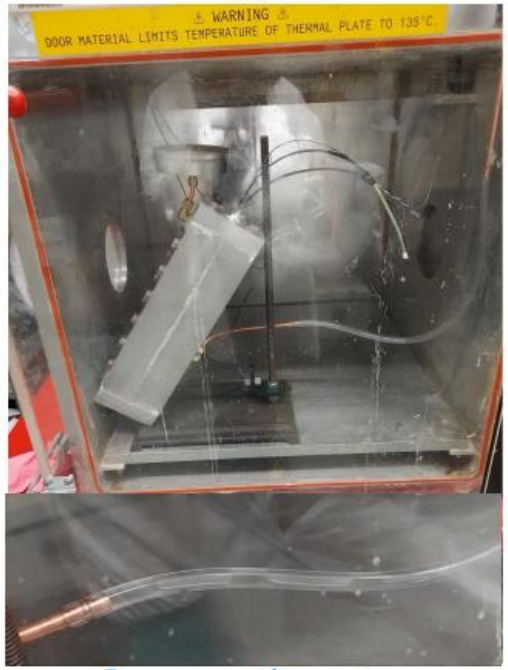
Laser scanning of the exposed copper cable helps create splines for forming the ramp



End part design

Practice Coil for TELENE Impregnation Test - new task

Mixing TELENE



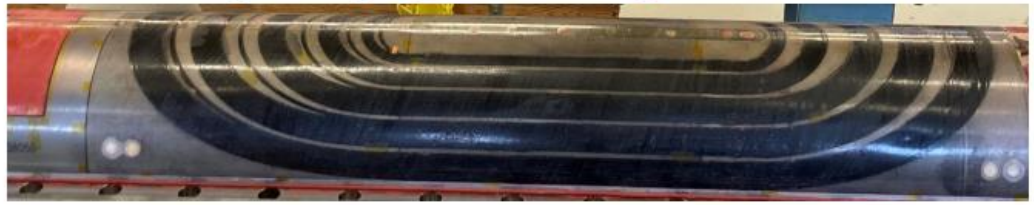
Impregnation setup

TELENE Recipe

1. Mix 100 parts of DCP monomers with 2 parts of hardener at 5° to 30°C.
2. Cure cycle is 1.5 hours at 25°C followed by 1 hour at 120°C.
3. Perform in low vacuum

Setup for impregnation tooling - SMCT coil

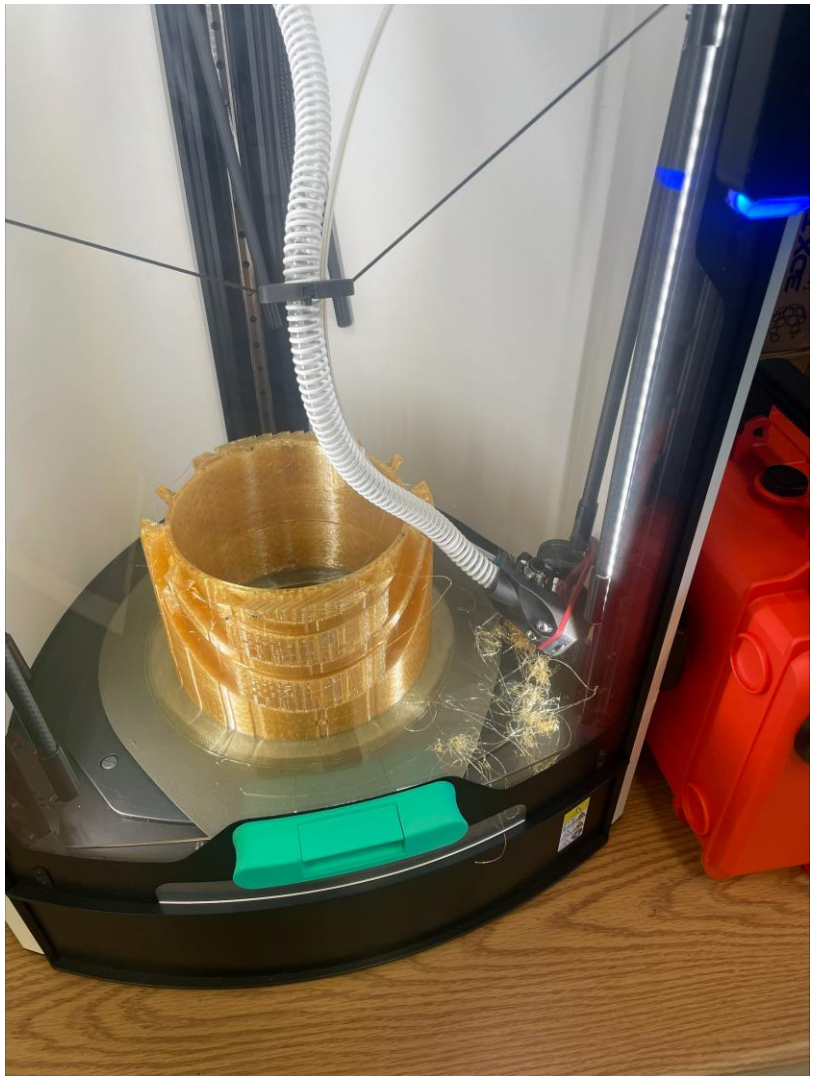
Impregnated coil a foot long



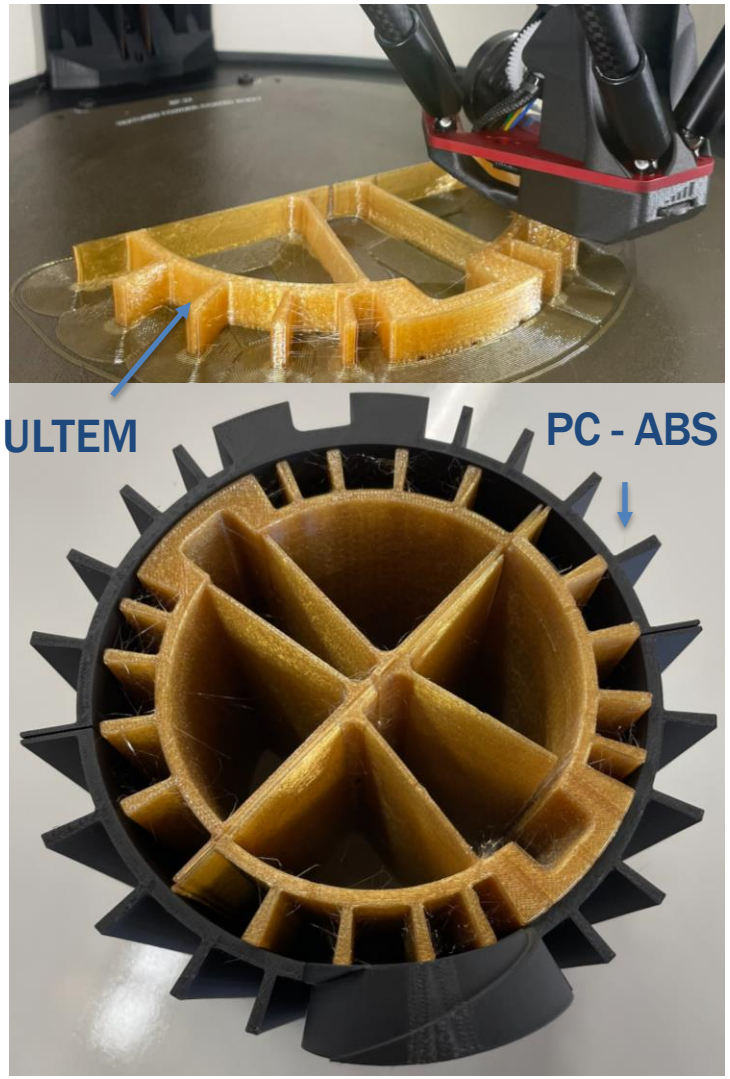
Coil view after epoxy impregnation

Plan:
- print plastic mandrels,
- wound new 1-miter long coil,
- impregnate coil with TELENE using existing fixture,
- cut coil for inspection

SMCT Coil Parts – printing of high temperature materials



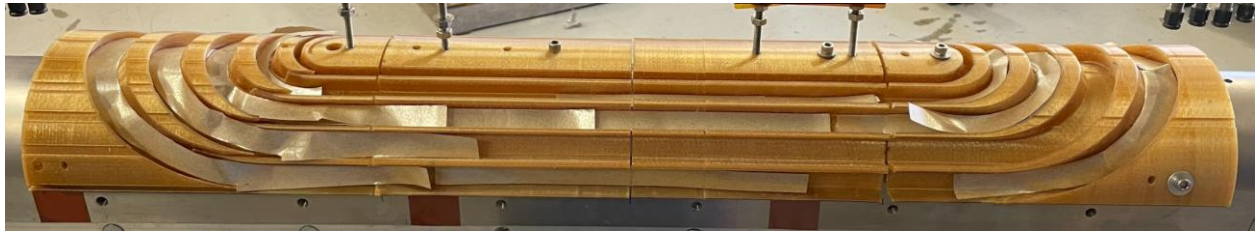
Printing of mandrel from ULTEM



Parts printed from ULTEM and PC -ABS

Printing PC – ABS parts

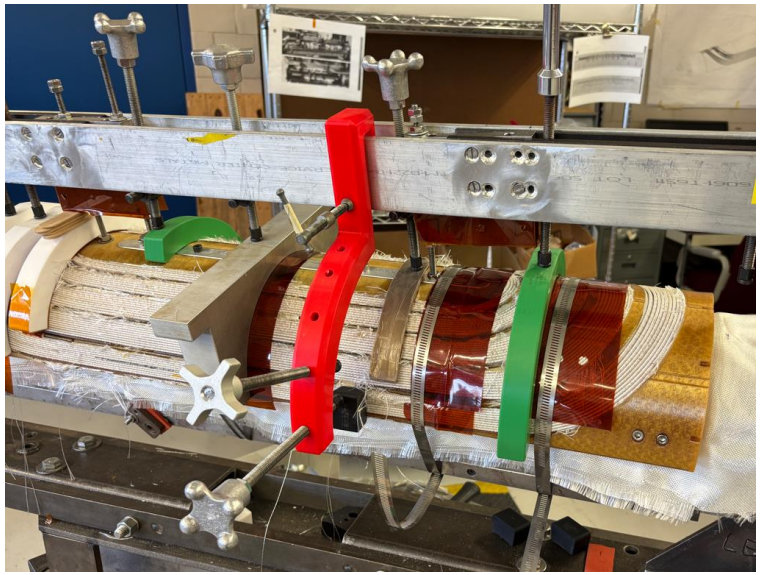
Practice Winding of 28-strands Cooper Cable into SMCT2 Coil Mandrel



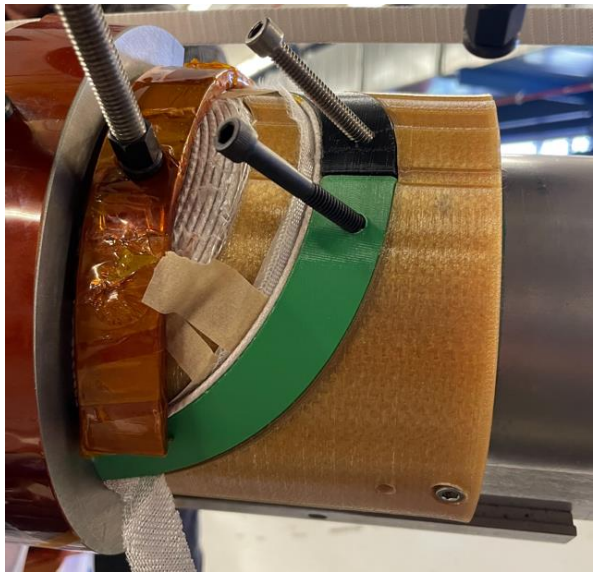
SMCT layer 1 printed from ULTEM

SMCT layer 2 printed from ULTEM

New winding setup for the flex mandrel and rigid cable

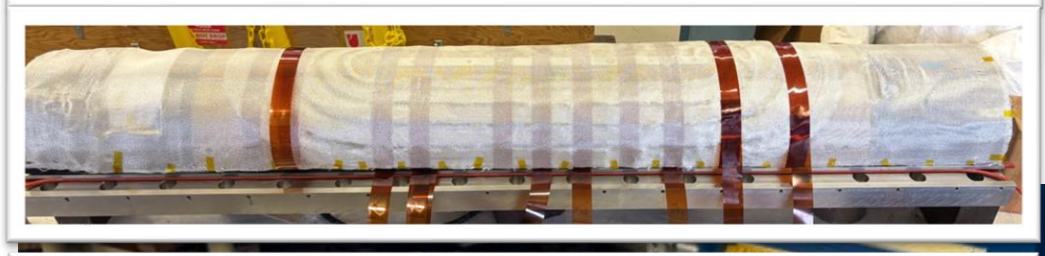


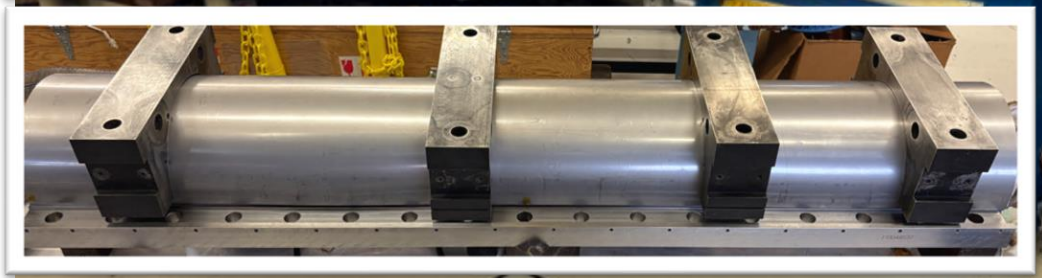
Cable holding arm and spacers

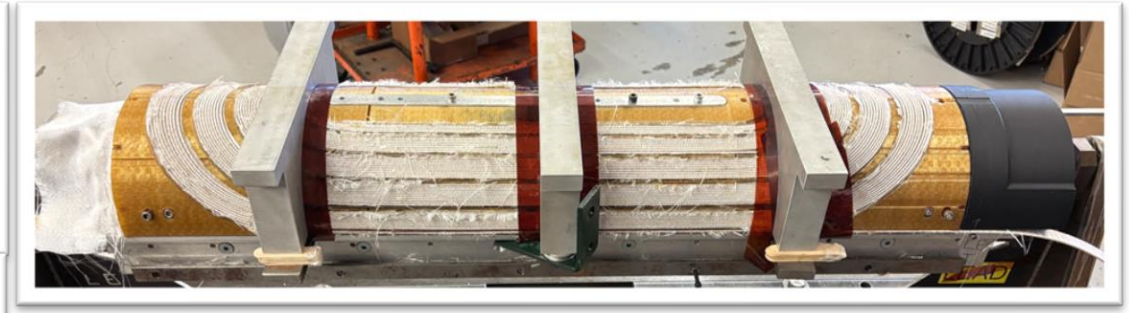


Forming spacers at the end

SMCT Coil Practice Winding







Layer 2 winding completed, and coil packed into the impregnation tooling

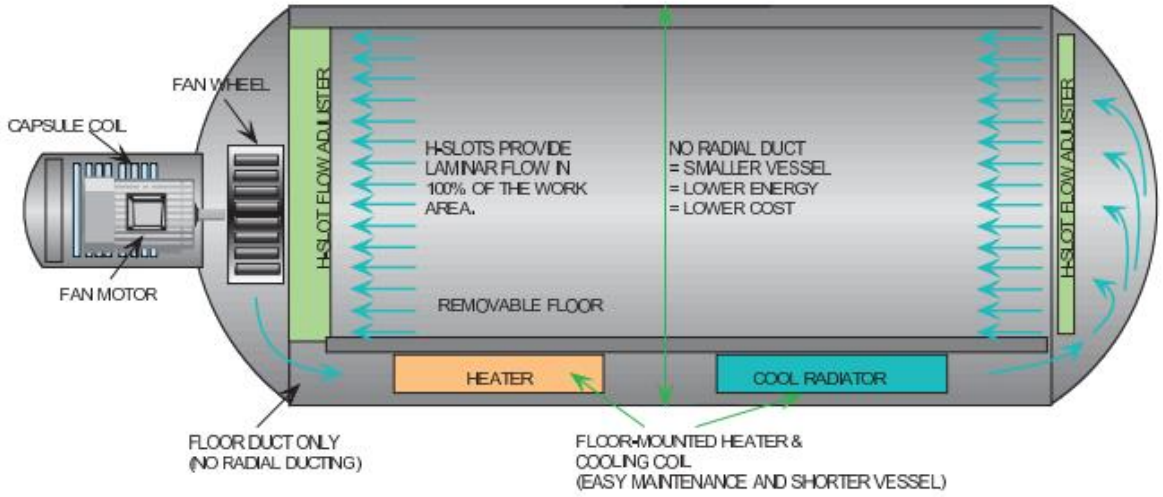
Chilling test perform on impregnation tooling

Critical Considerations for TELENE

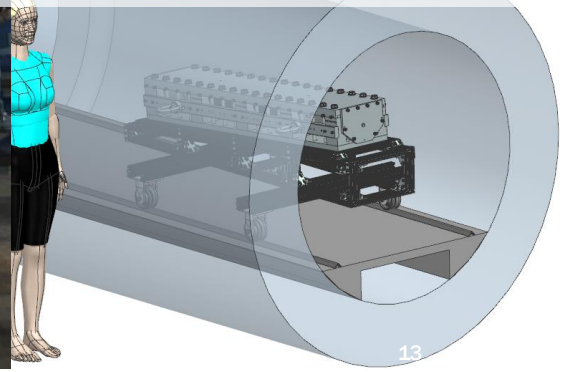
- **Safe work**
- Maximum volume of Telene to mix
  - specifications indicate volume larger than 100mm^3 can reach up to 200°C due to exothermic reaction
- Cold environment to extend working time
  - 20min at 25°C and 3h at 5°C
- Risk of absorbing moisture
- Vacuum and TELENE $T_{boiling}$
- Filling rate
- Bubbling

New Autoclave @FNAL

- ASC Econoclave 4x10 autoclave
- 4 ft inner diameter, 10 ft clear length, max. pressure 10 bar, max. temperature 450ºF
- Standard curing pressure for carbon fiber laminates is 6-8 bar



ASC's Econoclave ®



- Oven has exhaust fan - ventilates to outside environment
- Facility available on Fridays only
- Has capability of applying temperature and pressure simultaneously
- May reduce size of bubbles – increasing pressure in gas its volume will decrease
- Has 2 feeds, no window – cannot see inside

Preparation for impregnation of a 1-miter long practice coil using TELENE. Setting up equipment, conducting tests, and preparing documentation.

Mixing and leak tests

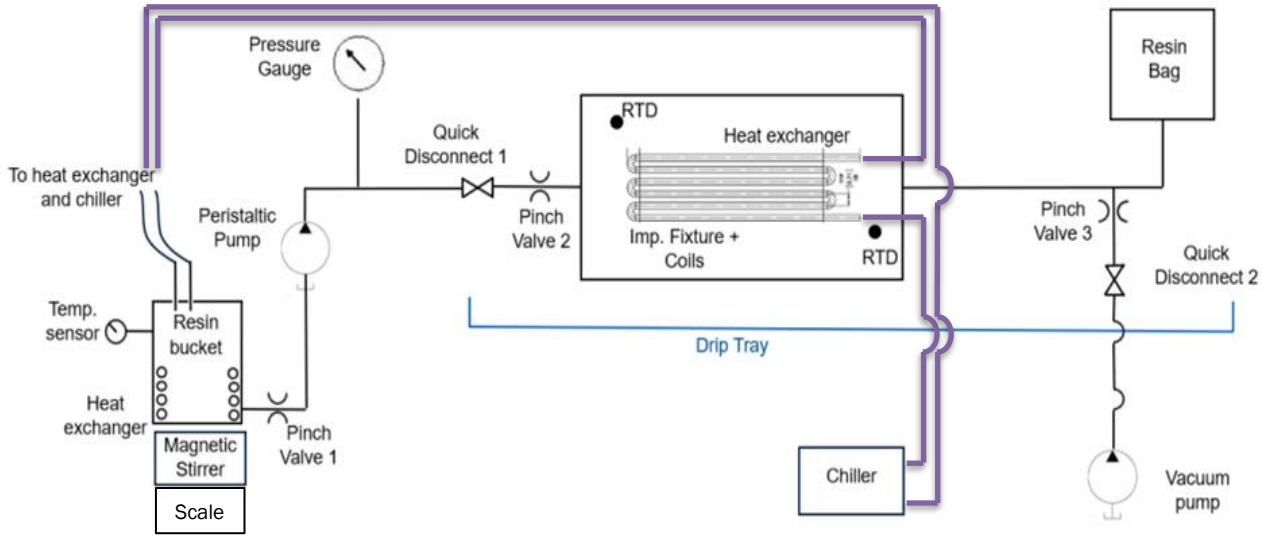
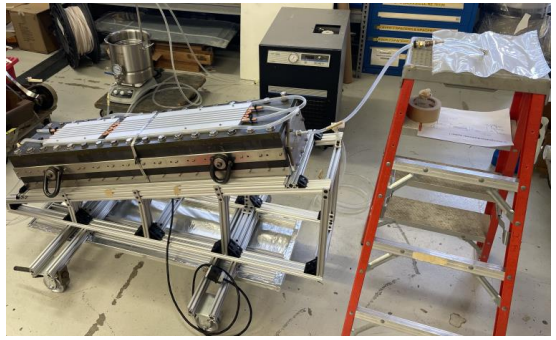
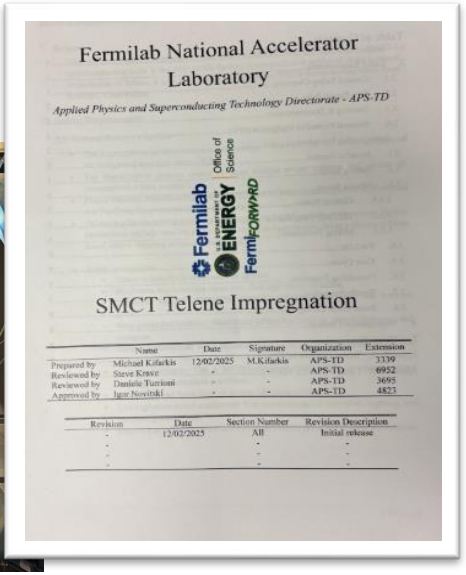


Fig. 1. Displays the impregnation schematic.

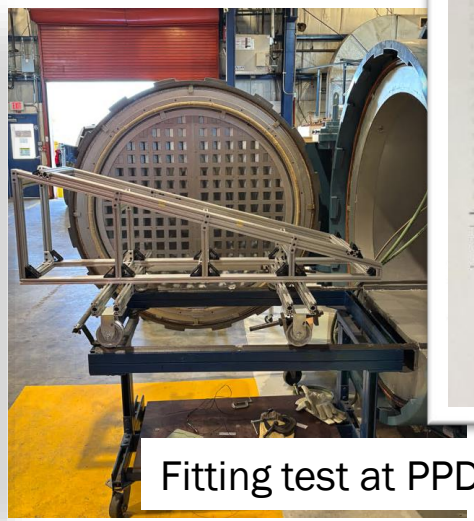


"Dry run" setup and SMCT impregnation traveler draft



Structural tests

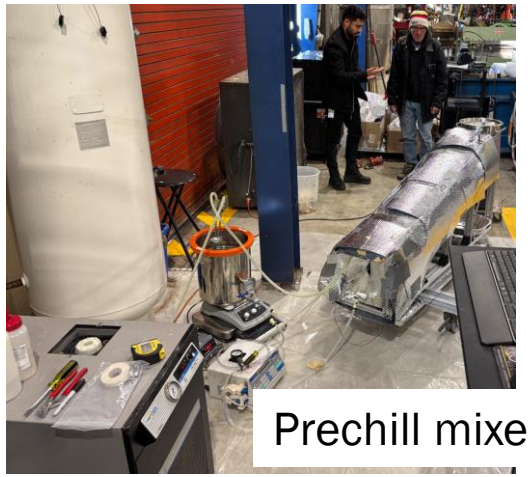
Flow rate estimation and cooling test

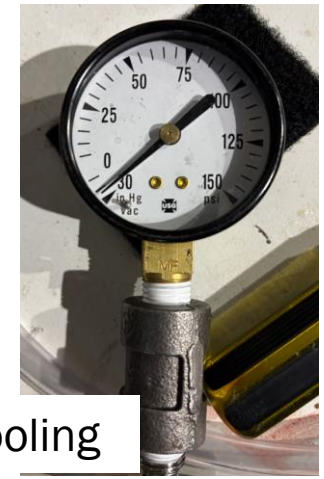


Fitting test at PPD MAB facility

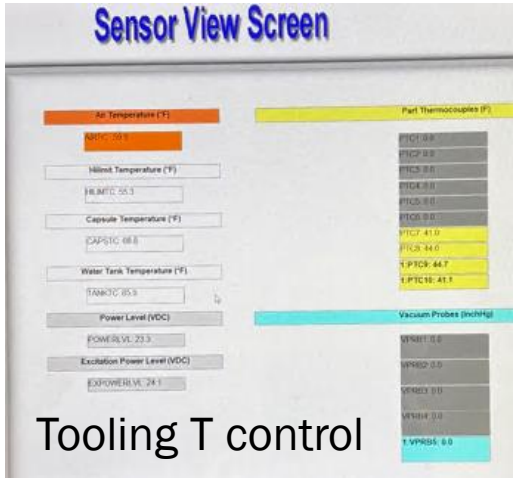
Impregnation of a 1-miter long practice coil using TELENE.
Setting up equipment, cooling tooling, safety protocol for mixing TELENE.

Set up equipment



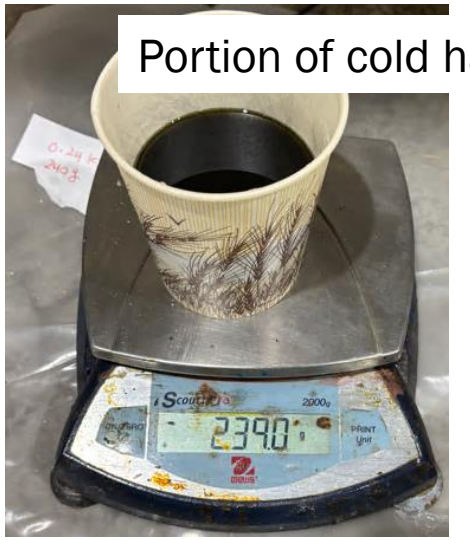


Prechill mixer and tooling; vacuum tooling

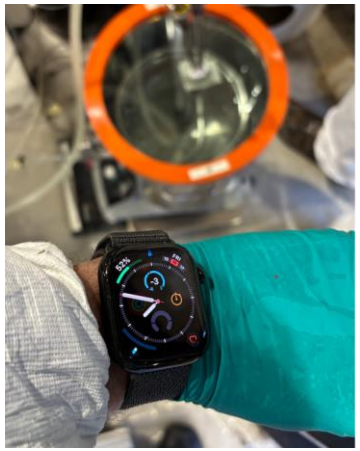


Tooling T control

Pour 12L of prechill TELENE and mix it



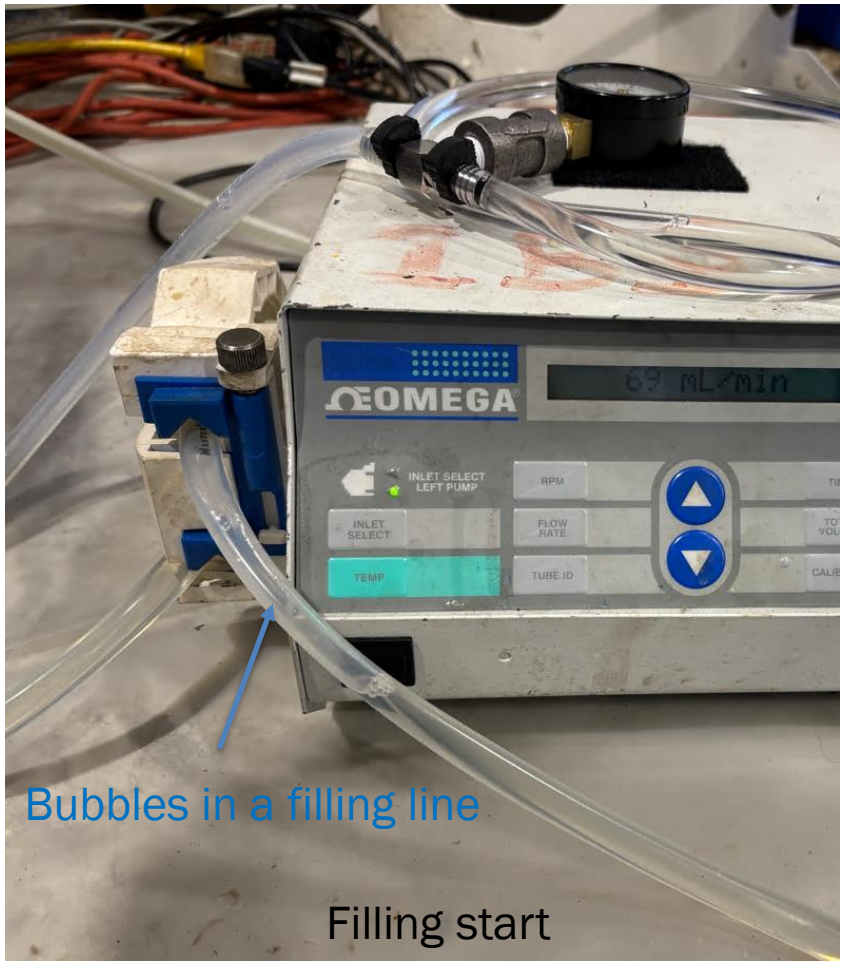
Portion of cold hardener mix with TELENE for 5min



Impregnation of a 1-miter long practice coil using TELENE.

The filling process at PPD site using appropriate PPE and with adequate ventilation.

Mixing

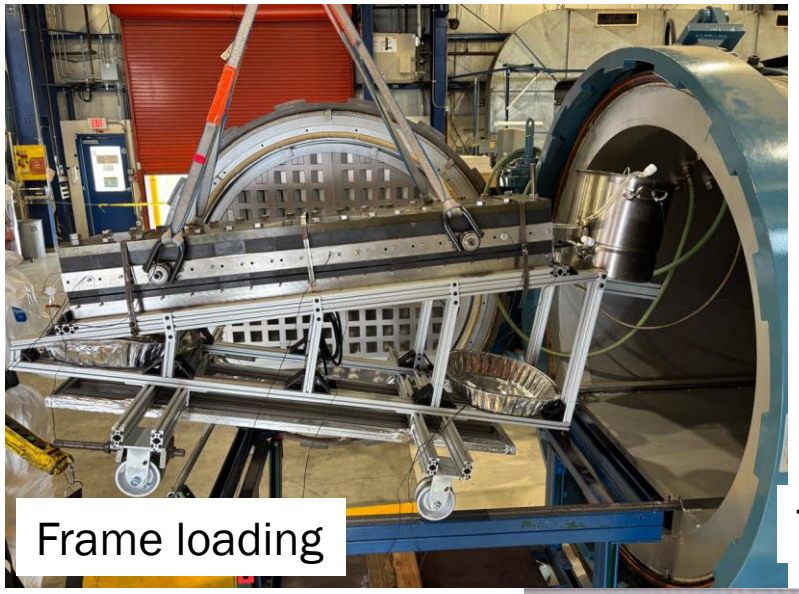


Bubbles in a filling line

Filling start

Filling ends when overflow bag 50% full

Impregnation of a 1-miter long practice coil using TELENE.
Curing step

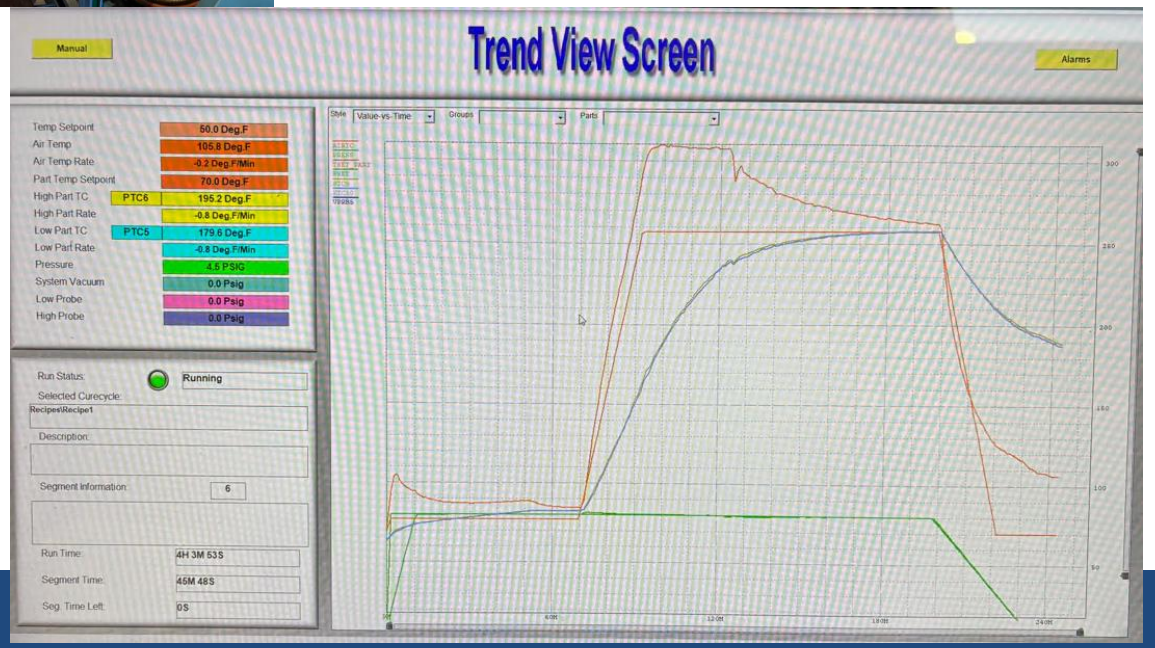


Frame loading

Thermocouple's connection

Door closing

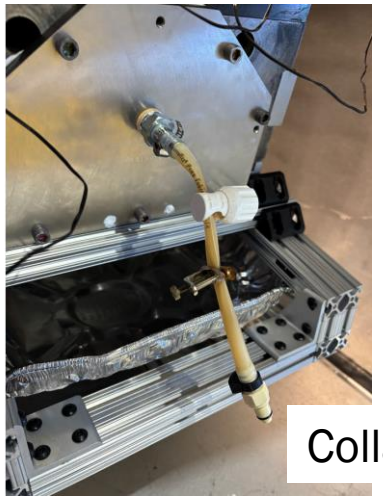
Left over TELENE



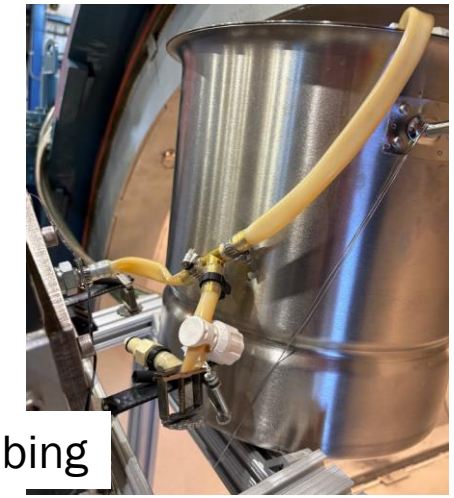
Cure cycle:

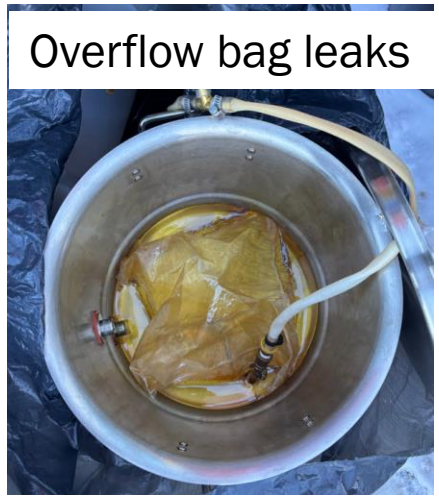
- applying 80 psi of pressure at 25C for 1.5 hours
- increasing temperature to 120C for 1 hour while keeping pressure at 80 psi

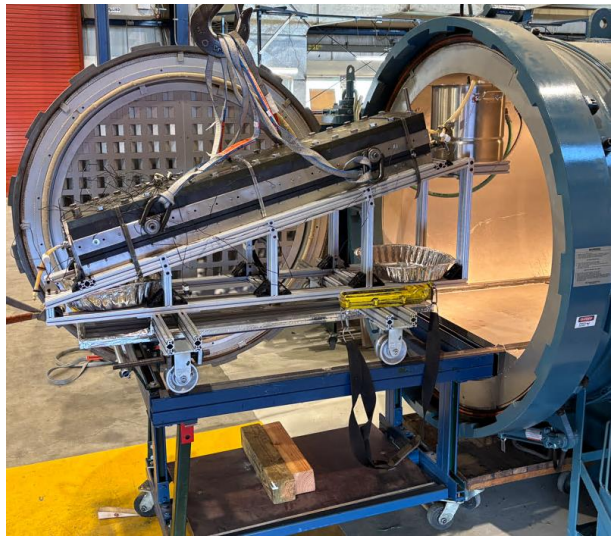
Impregnation of a 1-miter long practice coil using TELENE. Post curing.



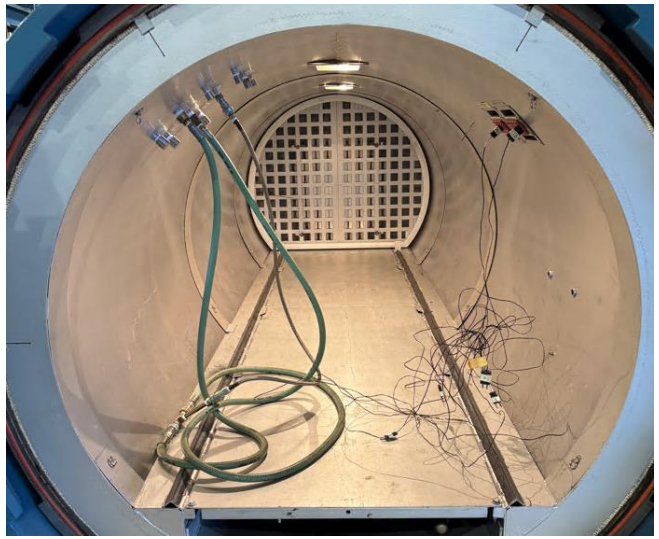
Collapsed tubing



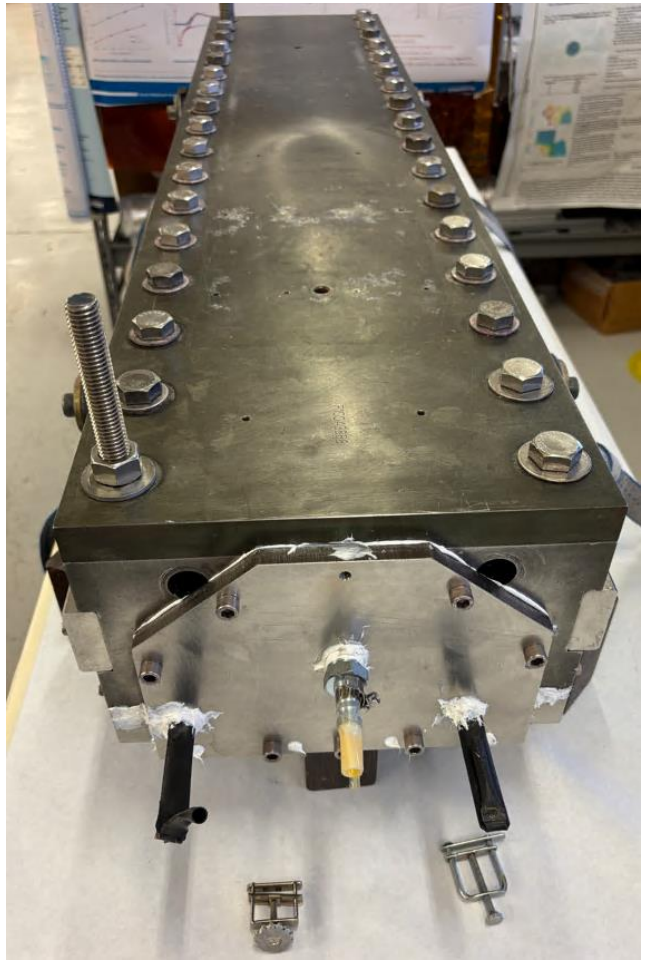




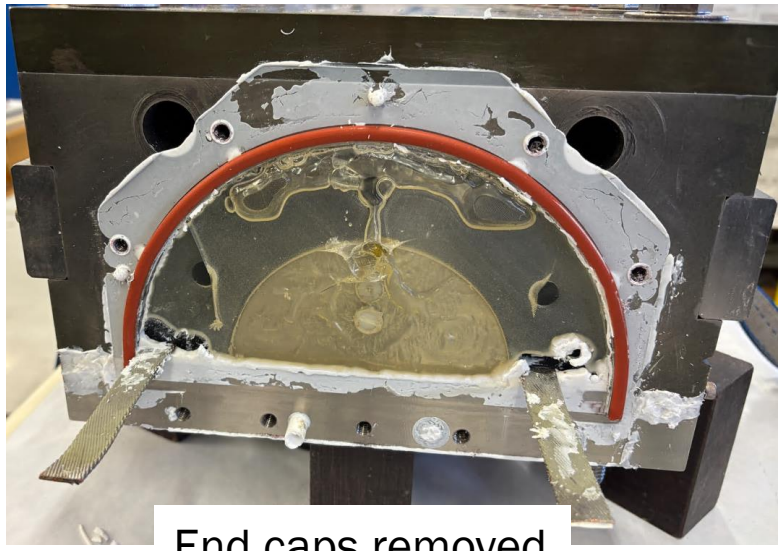
No leaks found



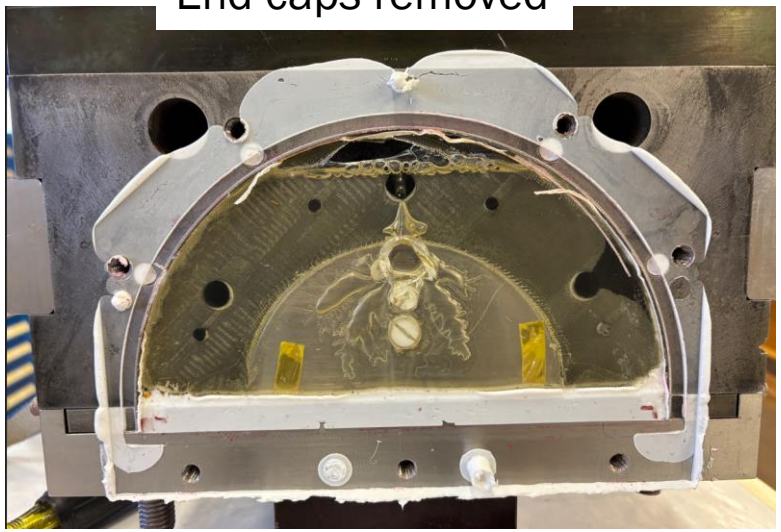
Impregnation of a 1-miter long practice coil using TELENE.
Opening the impregnation fixture

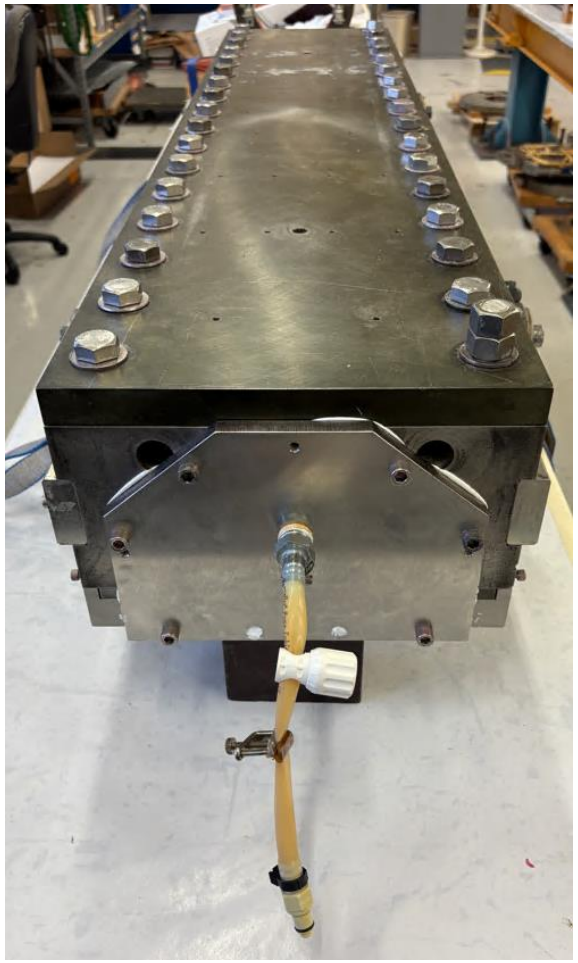


Overflow side



End caps removed





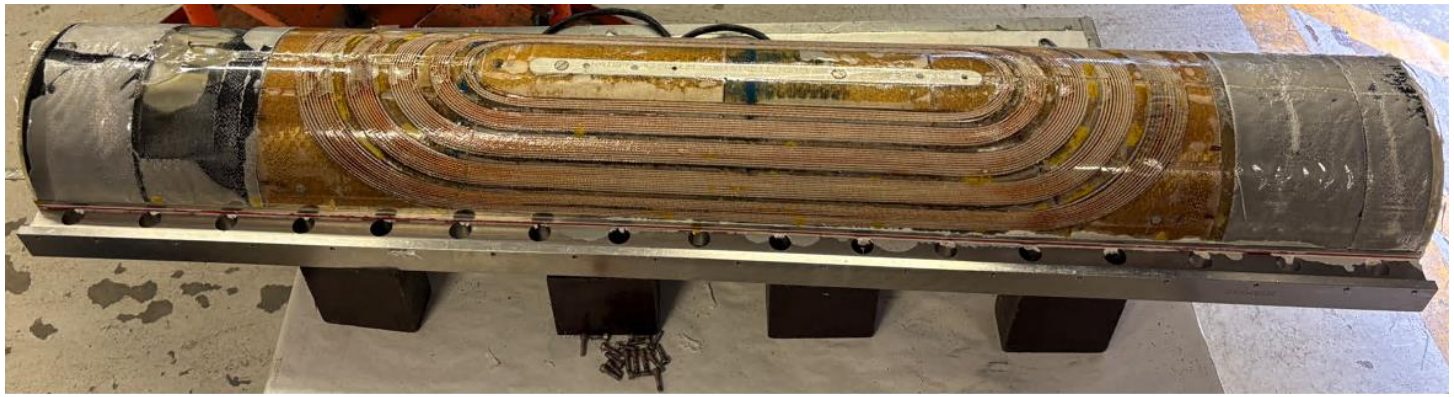
Filling side

Impregnation of a 1-miter long practice coil using TELENE.
Block and shell removal performed at the large gates for better ventilation.

Removing fixture block

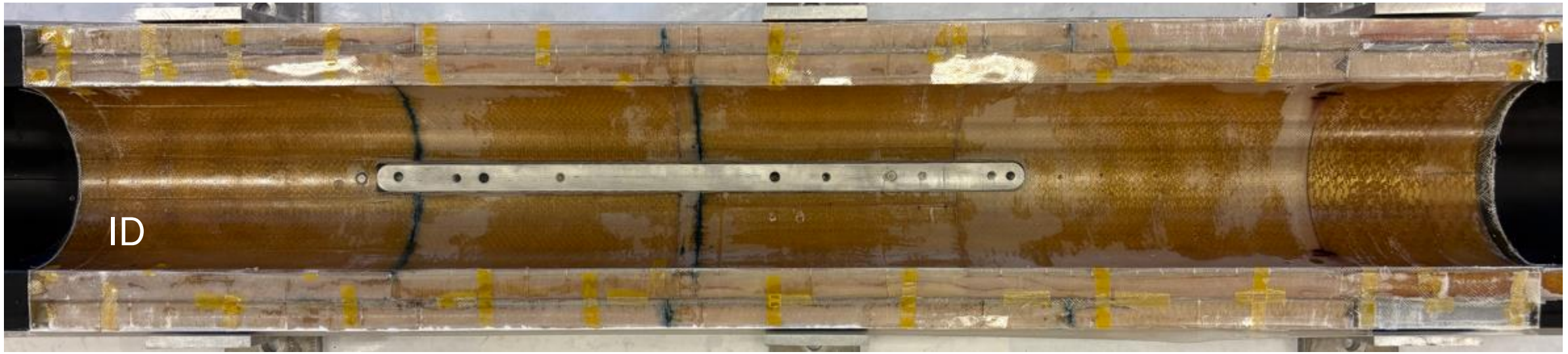
Coil OD w Mylar shell

Removing stainless steel shell



Coil OD w/o Mylar shell

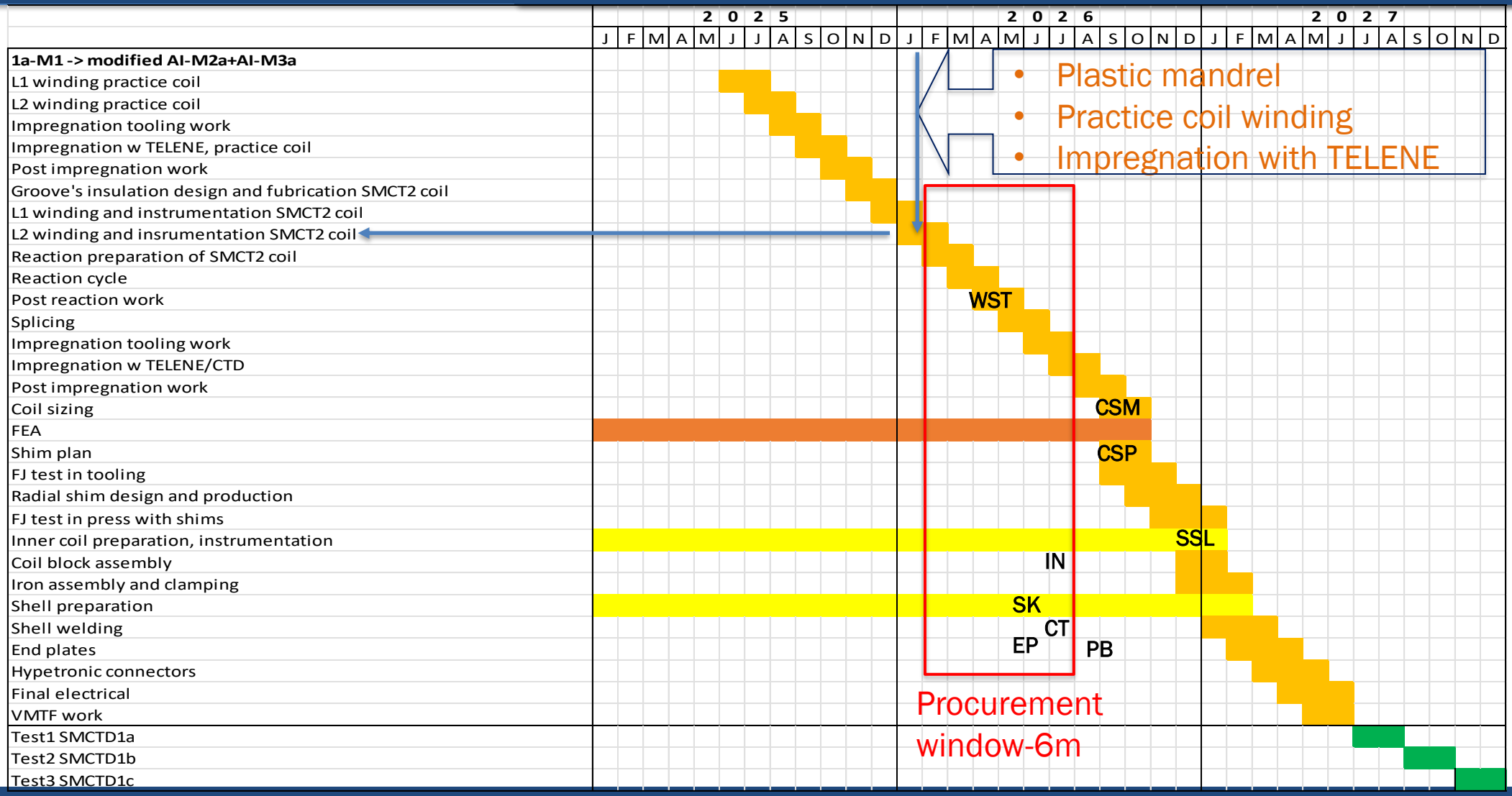
Impregnation of a 1-miter long practice coil using TELENE.
Practice coil surfaces after impregnation.



Summary and next steps

- parts procurement for SMCTD1 dipole - 6 months “open window” to be on schedule
- SMCT2 coil winding with 40-strand cable - L2 winding in progress
- design work for SMCT3 coil with 28-strand cable - in progress
- 1m long practice coil: parts printing, coil winding and impregnation with TELEN
  - completed, data analysis in progress

SMCTD1 development and test schedule (updated)



~1 month delay due to uncertainty in budget and resources

IN - ground insulation, PH
SK - 19 mm skin
CT – contact tooling
EP - end plates, fillers, rods
PB - pizza box
WST - witness sample test
CSM - coil size measurement
CSP - coil shim plan
SSL - short sample limit