AUP Coil Fabrication Status at FNAL

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Acknowledgment

- US HL-LHC Accelerator Upgrade Project (AUP)
  - Fermilab Coil Fabrication Team
    - Engineering:

      A. Bracero, S. Krave, F. Nobrega, M. Parker, M. Yu,
    - Quality inspection:

      O. Lira, R. Riley
    - Technician's:

      A. Coon, P. Fox, C. Korleski, M. Walls, C. Cuautle, L. Flores, M. Cook, S. Homer, S. Ransom, M. Vallejo

Coil Fabrication at FNAL

- Scope
- Schedule
- Peak production
- Coil status

FNAL Coil Fabrication Scope

- Fabricate 51+1coils (QXFA108-158+QXFP106)
  - Fabrication includes winding, curing, impregnation, CMM, and shipping.
  - Insulated cable and coil parts provided by another AUP team.
  - Completed coils shipped to LBNL.

FNAL Coil Fabrication Schedule

- Production start Oct 2017 – May 2023
  - Coil production on schedule.
  - Coil production is more than 50% complete.
  - 85-day duration per coil.
  - Peak rate of 1 coil every 18 days.
  - Currently on schedule at peak production rate, started July 2020.

Peak Production

- Production based single shift, 8 hours long.
- Selva Spirex machine used at project start. The second coil winder was the rotating table and now is the main winder.

Coil Production vs. Tooling and Tech Crew (per site)													
Tooling/Infrustructur Quantities						Tooling/Infrustructure Occupancy							
Winding Machine	Winding Mandrel	Reaction Oven	Reaction Tooling	Impregnation Station	Impregnation Tooling	Winding Machine	Winding Mandrel	Reaction Oven	Reaction Tooling	Impregnation Station	Impregnation Tooling	Tech Crew FTE	Rate (days per coil)
1	1	1	1	1	1	53%	85%	24%	100%	12%	68%	5.4	**34**
1	1	1	2	1	1	62%	100%	28%	59%	14%	79%	6.4	**29**
1	2	1	2	1	1	78%	63%	35%	74%	17%	100%	8.0	**23**
1	2	1	3	1	2	100%	81%	44%	63%	22%	64%	10.2	**18**
2	2	1	3	1	2	60%	97%	53%	76%	27%	77%	12.3	**15**

Peak Production

Peak Production

Design specific tooling

- 2 winding mandrels
- Curing mold
- 3 reaction fixtures
- 2 impregnation fixtures
- Coil lifting fixture
- 3 coil shipping fixtures
- 5 coil storage mandrels

Lab supported infrastructure

- Winding station (s)
- Curing press
- Reaction oven
- Impregnation vacuum tank

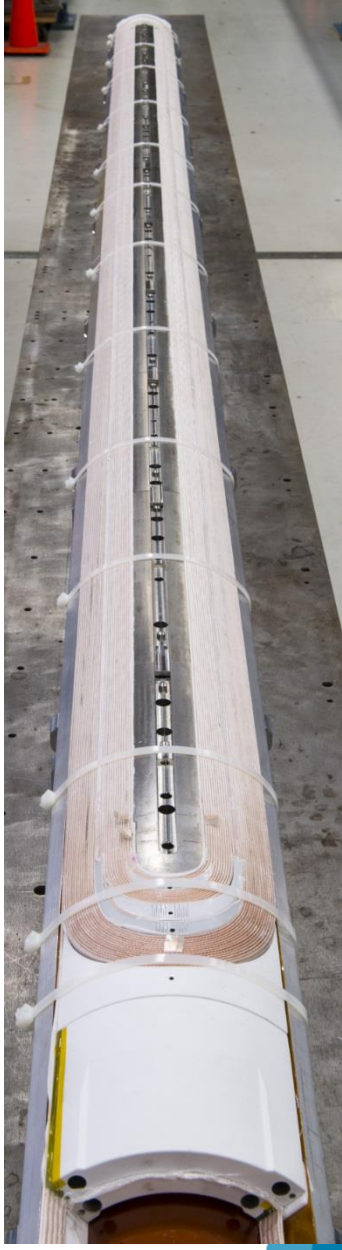
Coil Winding & Curing

Selva Spirex coil winding

- 28-day duration
- 2 technicians

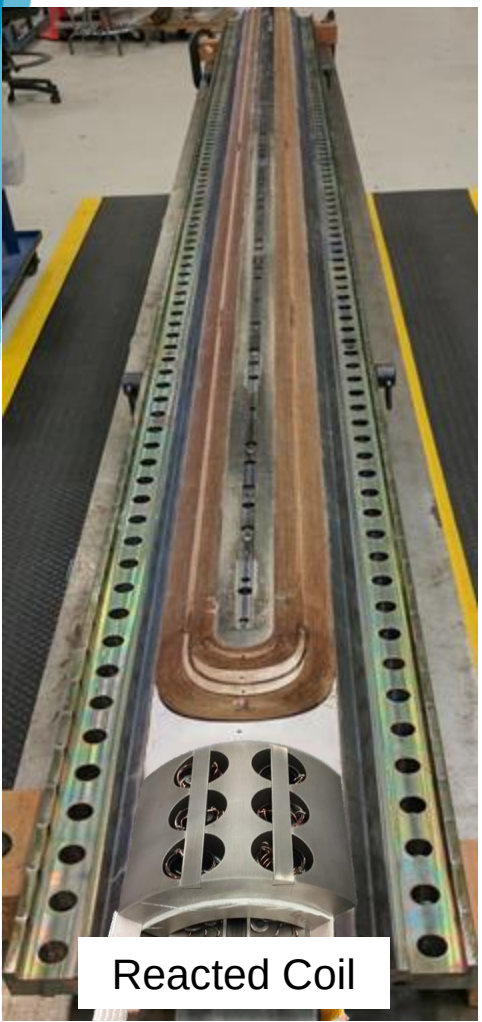

QXFA rotating table coil winding


FNAL curing press


QXFA Coil

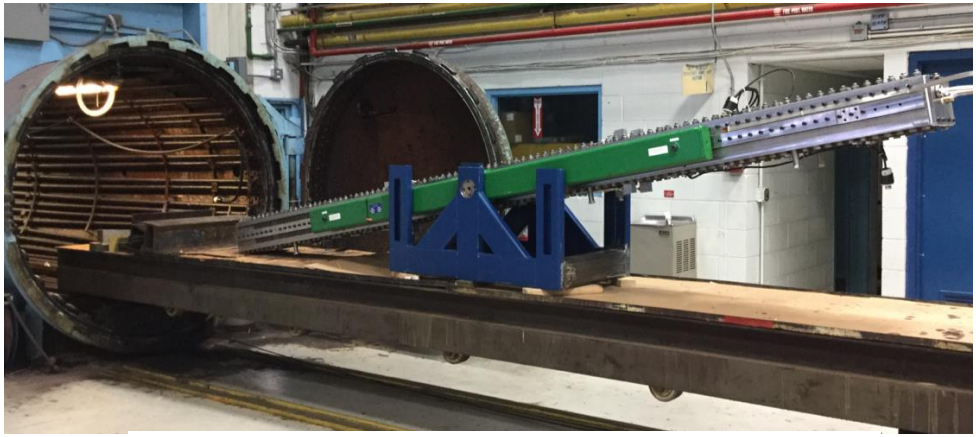
Reaction & Impregnation

- 56-day duration
- 2 teams of 2 technicians

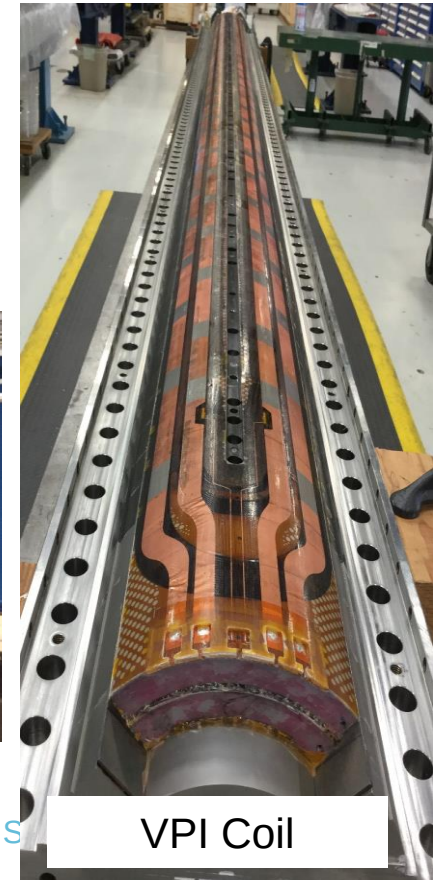


Reacted Coil

Reaction Tooling & Oven



Vacuum Tank & Impregnation Tooling



VPI Coil

Shipping and Handling

Coil Lifting Fixture

Coil Shipping Fixture

FNAL Coil Status

- Coils ‘In Fabrication’
  - A133, A136 – A140
- Coils ‘Rejected’
  - A108 – multiple shorts from excess binder. Reduced volume of binder as corrective action.
  - A118 – cable damage from Selva boom height
  - A120 – Selva tensioner caused cable damage and taken out of service as part of the corrective action. Coil winding parts recovered, Backup winding system, rotating table, put into service. Winding system validated with coil QXFP06.

Coils at FNAL Summary	
Accepted	22
In Fabrication	6
Rejected	3
On Hold	4
Total	35
Remaining	17

FNAL Coil Status

- Coils ‘On Hold’
  - A109 – saddle to coil short developed after shipping, chipped plasma coating at tip one leg. It is thought to be repairable. Likely caused by swapping flexible end saddles with ridged saddle after coil curing. The swapping process ended with this coil. Redesigned flexible saddles are cured with and remain with the coil.
  - A121 – reacted coil lead displaced about 18 mm hard way bend while removing mandrel blocks. Extent of damage, if any, is unknown. Plan is to recreate issue and inspect for broken filaments. Process revised and tooling added to removed mandrel blocks after reaction.
  - A125 – midplane epoxy flash filing exposed cable. Repaired with Stycast. Team discussion and additional training implemented to prevent future occurrence.
  - A127 – S2 glass bead caused heater to coil hipot failure. Glass bead removed and coil went thru 2nd impregnation cycle and passed all electrical measurements and tests including hipot. Preventive measures included tuning the laser cuter prior to each use. Cloth visual inspection and shaking of fabric.

Conclusion

- AUP coil fabrication at FNAL is at peak production and > 50 % complete.
- Preventative measures implemented with each lesson learned.
- Coil fabrication is scheduled to finish in May 2023.

Thank you!