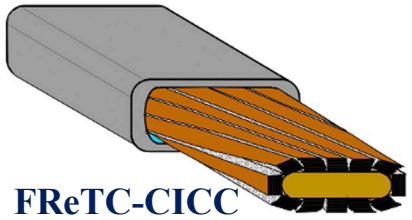

REBCO Rutherford-Type Cables (FReTC) for High-Current and High-Field Applications

Makoto Takayasu[1], Vyacheslav Solovyov[2], and Luisa Chiesa[3]

[1]Massachusetts Institute of Technology, Plasma Science and Fusion Center, Cambridge, MA 02139, USA.

[2]Brookhaven Technology Group, Stony Brook, NY 11794, USA.

[3]Tufts University, Mechanical Engineering Department, Medford, MA 02155, USA.

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The REBCO/copper cable used for this project was supplied by Dr. A.E. Haight, CTD.

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 60, Sept. 2025. Presentation given at MT29, Boston, MA, USA, July 2025.

Outline

1. REBCO Tape Cabling Method Review
   - CORC
   - Roebel
   - TSTC
   - Rutherford-type cabling (FReTC)

FReTC

2. FReTC
   - FReTC cabling
     - *Method I*
     - *Method II*

3. FReTC Fabrication Device

Cabling device developed for FReTC

4. FReTC Characteristics:
   - Current density, hysteresis loss, bending, and mechanical loads, compared with TSTC

5. Closing

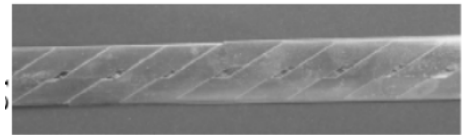
IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 60, Sept. 2025. Presentation given at MT29, Boston, MA, USA, July 2025.

REBCO Tape Cabling Method Review

Transposed or Twisted Multi-Tape Basic-Cables

1. CORC

2. Roebel



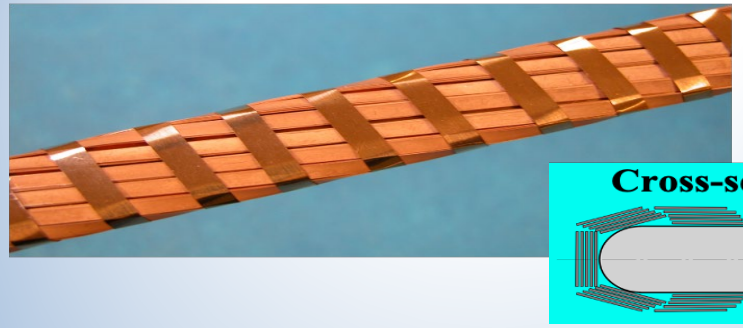
3. TSTC

Winding

Stacking

NEW CABLING

REBCO Rutherford-Type Cable (FReTC)

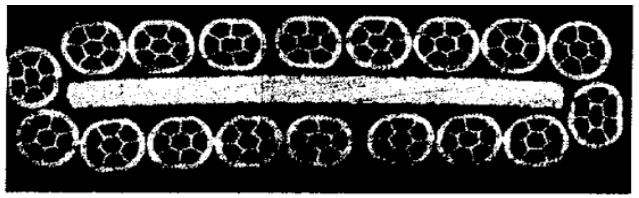


Full-size cable from tape spools in a single process.

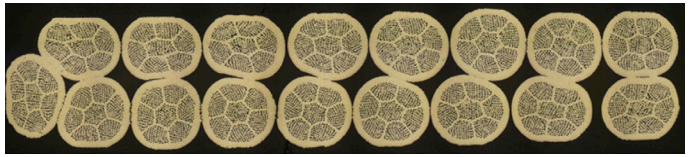
M. Takayasu, et al, *Supercond. Sci. Technol.* 25, 014011, 2012.

HTS Rutherford-Type Cable Review

BSCCO-2212 Round Wires



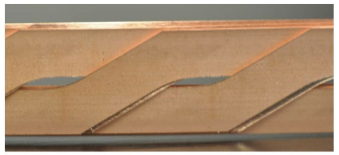
T. Hasegawa et al., *IEEE Transactions on Applied Superconductivity*, 1, 3034, 2001.



T. Shen and L. Garcia Fajardo, *Instruments,* 4, 17, 2020.

REBCO Tapes

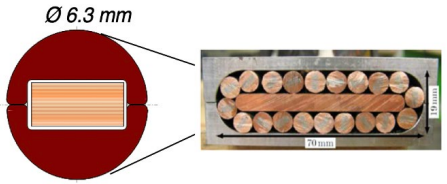
Roebel Cable

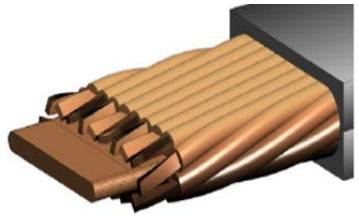


A. Kario et al., *Supercond. Sci. Technol.*, 26, 085019, 2013.

EPFL SWISS PLASMA CENTER

20 strands x 16 tapes,
60 kA at 12 T

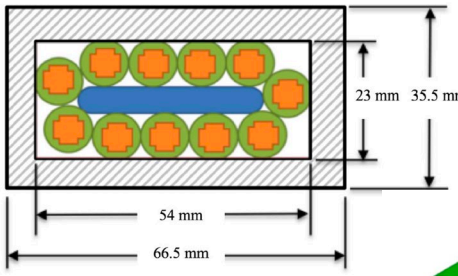


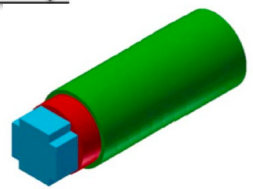


D. Uglietti et al., *Supercond. Sci. Technol.*, 28, 124005, 2015.

HTS-CroCo Cable

11 HTS-CroCo strands (each 20 x 6 mm W + 10 x 4 mm W tapes)

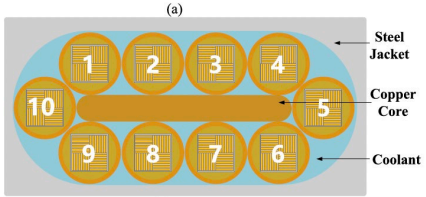




W.H. Fietz et al., *IEEE Trans. Appl. Supercond*, 26, 4800705, 2016.

North China Electric Power University

Quasi-Isotropic strands



Y. He et al., IEEE Transactions on Applied Superconductivity, 35, 4800207, 2025.

REBCO Rutherford-type cable

FReTC

IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 60, Sept. 2025. Presentation given at MT29, Boston, MA, USA, July 2025.

Cabling Methods

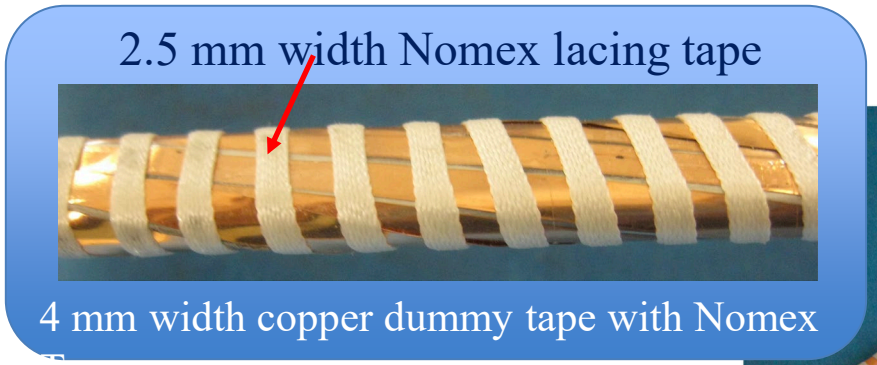
FReTC

(Flat Round-edge-former Tape Cable)

Method I

Tightly winding on a round-edge-former.

To secure REBCO tapes on a round-edge former, the tapes are wrapped with Nomex lacing or copper tapes.

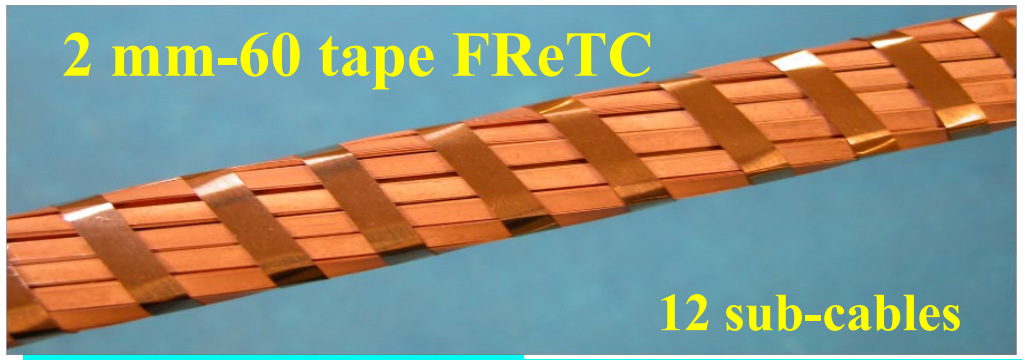


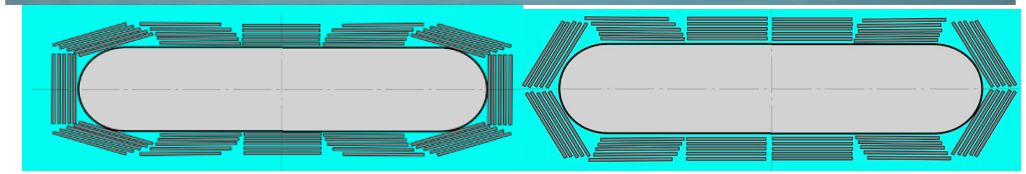
Method I can be suitable for wide tapes.

M. Takayasu, *Supercond. Sci. Technol.*, vol. 34, 2021.

Method II

Winding stacked-tape sub-cables around a flat round-edge former.





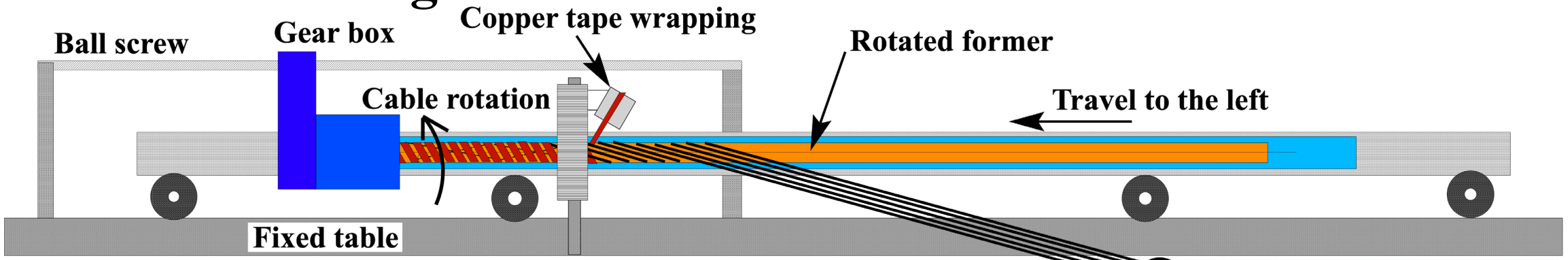
Cross-section illustrations

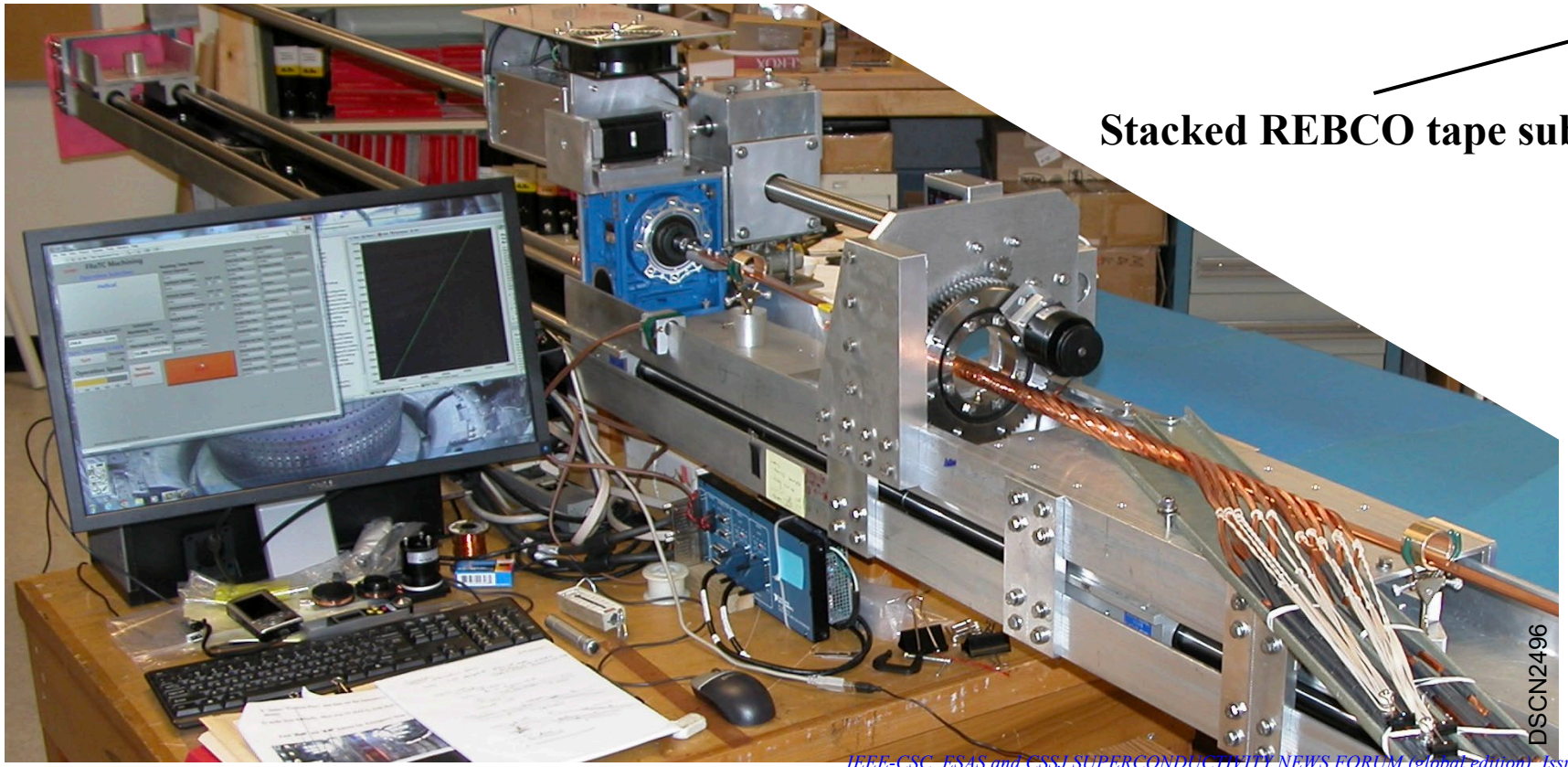
Cabling fabrication can be simplified.

M. Takayasu, *IEEE Trans. Appl. Supercond.*, vol. 34, 2024.

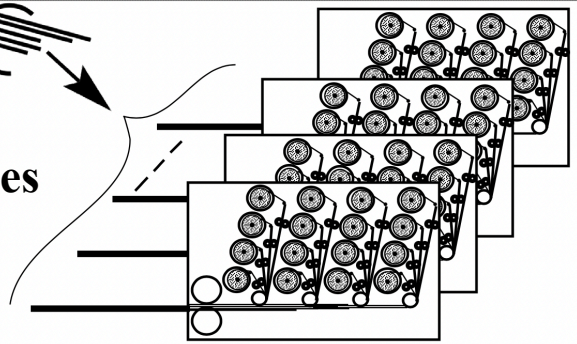
FReTC Fabrication Device

3 m FReTC cabling





Stacked REBCO tape subcables

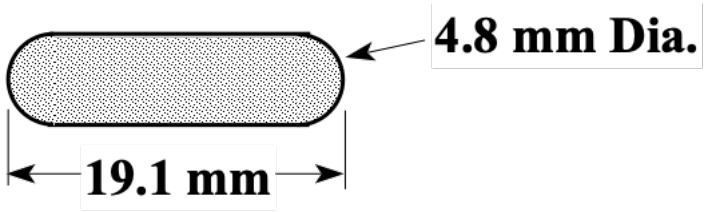


REBCO tape spool assemblies

3 m-FReTC
cabling machine

Fabricated 400 Tape FReTC

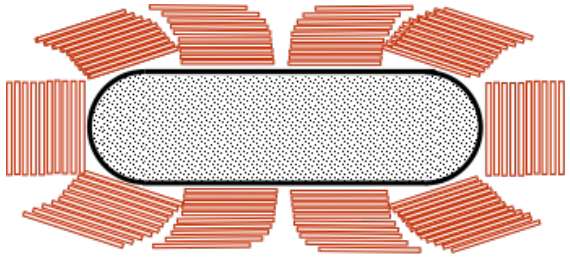
Former: **19.1 mm width, 4.8 mm round edge copper rod**



Former cross-section

Cable: **10 sub-cables of 40 Tapes (5 REBCO tapes and 35 copper tapes)***

4 mm wide, 1.2 m long 400 tapes (10 sub-cables x 40 tapes).



Schematic view of FReTC cross-section

If all tapes are REBCO,

***Ic* = 60 kA (150 A x 400 tapes at 18 T and 20 K)**

(Tape *Ic* = 150 A at 18 T, 20 K)

*** The stacked tape dummy cables were previously used for a CTD project (Dr. A.E. Haight).**

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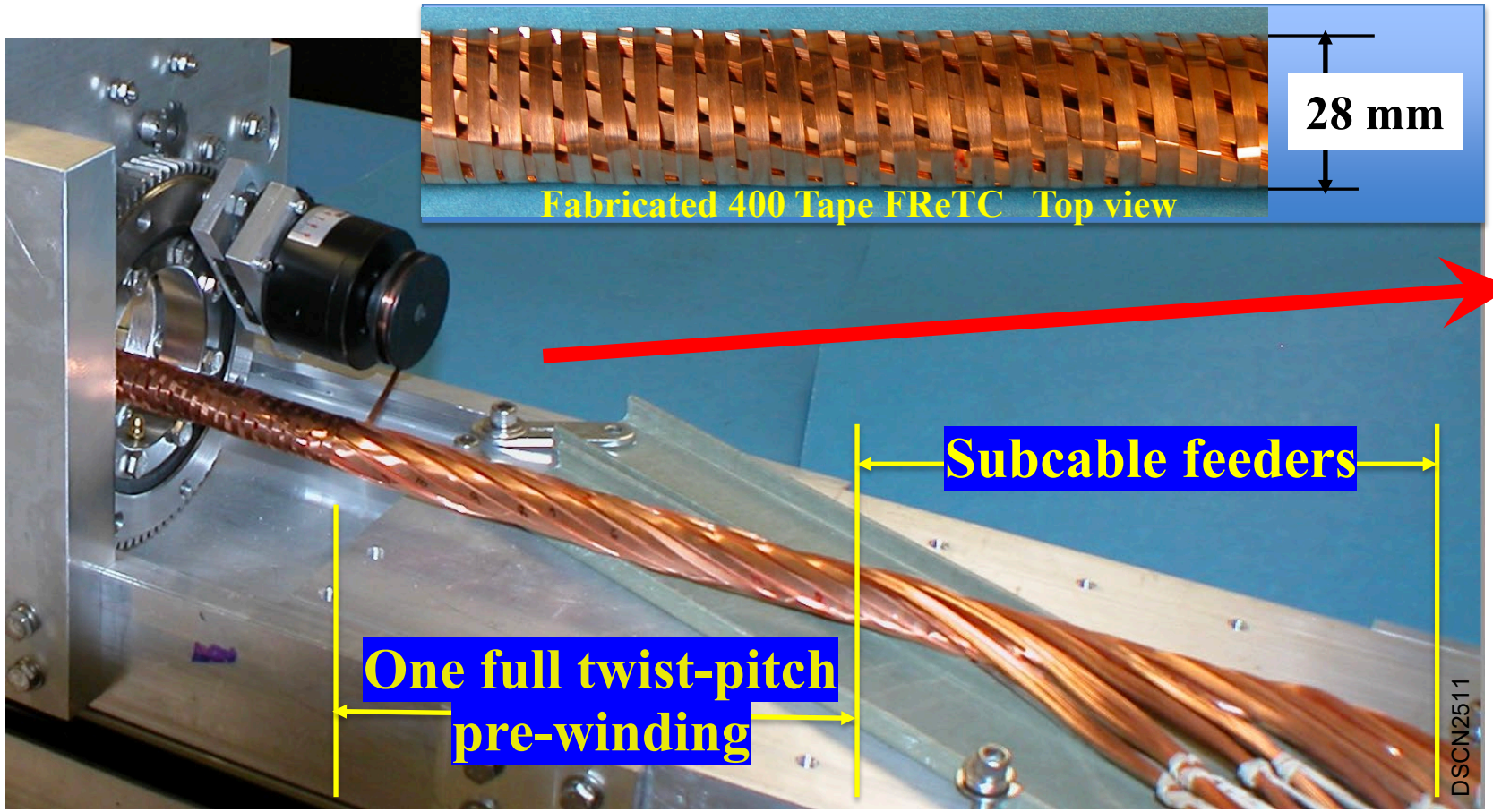
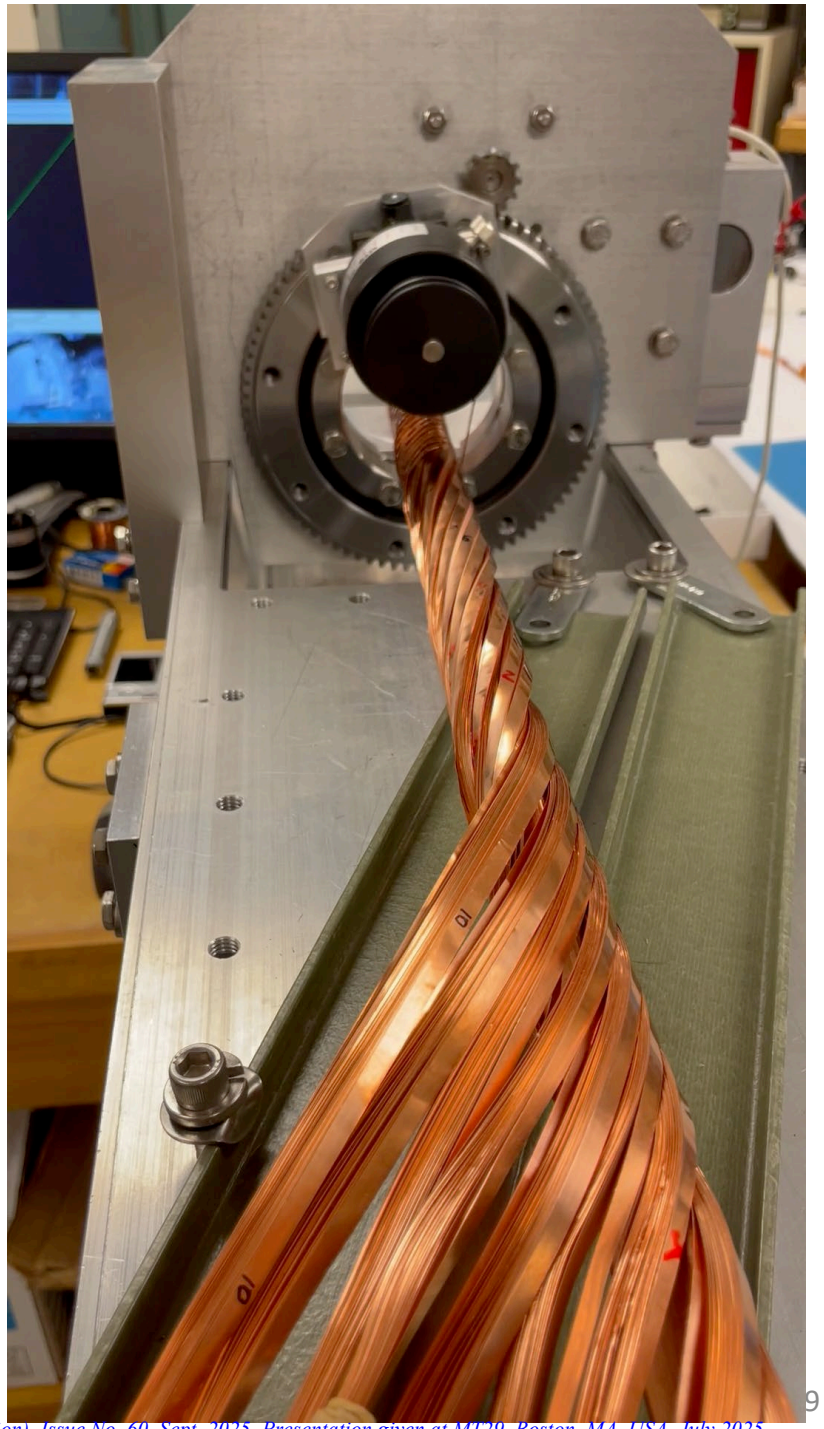
FReTC Fabrication Device (cont'd)

Demo fabrication of a 4 mm wide 400 tapes FReTC for a 60 kA FReTC.





Twist-pitch = 250 mm

Rotate a former, and move to the left.

Cabling speed : 1 m / 30 min.

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Other Fabricated FReTC Samples

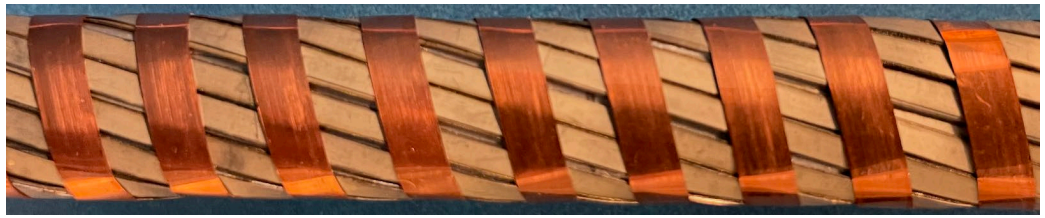
REBCO tapes : BTG exfoliated 4 mm and 2 mm

(BTG : Brookhaven Technology Group, Inc.)

BTG 2 mm, 42 tape

REBCO tapes: 42 tapes

(14 stacks of 3 taps)

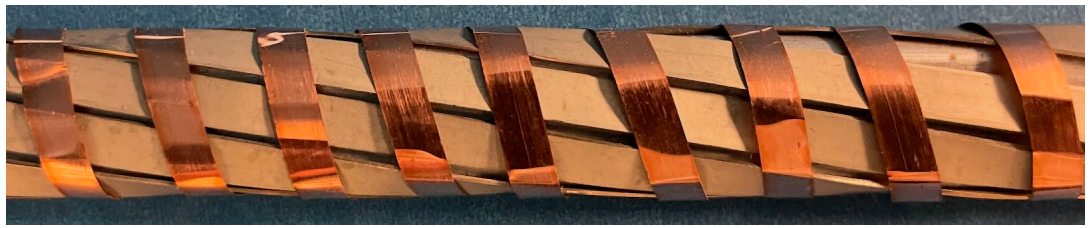


Top view

BTG 4 mm tape striated to 1 mm filaments

REBCO tapes: 28 tapes

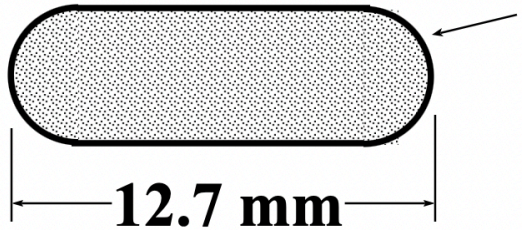
(7 stacks of 4 tapes)



Top view

Twist-pitch = 200 mm

Former: 12.7 mm wide, 4.8 mm round edge aluminum rod



Former cross-section

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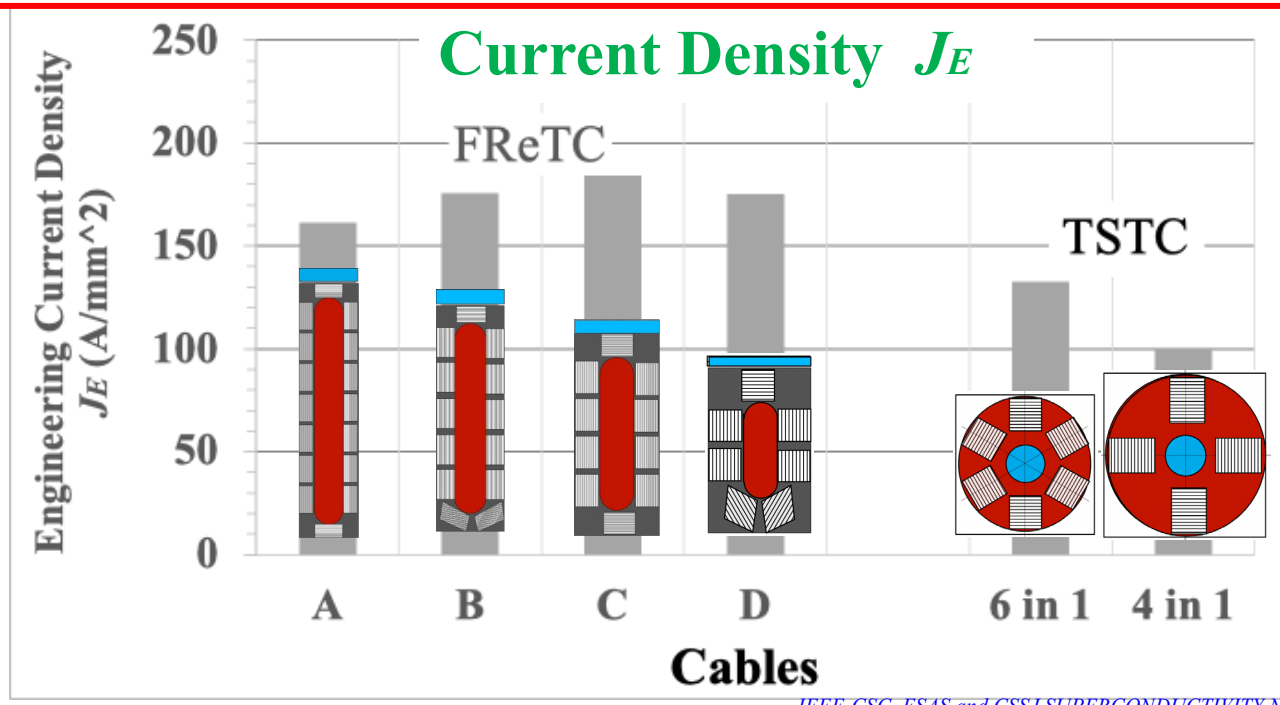
FReTC Compared with TSTC : Current Density J_E

50 kA Cables at 18 T and 20 K

Cable Parameters	Units	FReTC A	FReTC B	FReTC C	FReTC D	TSTC 6 in 1	TSTC 4 in 1
Subcables		16	13	10	7	6	4
Tapes in subcable		21	26	34	48	56	84
Total tapes		336	338	340	336	336	336
Former dimension	[mm x mm]	33.4 x 4.2ϕ	26.1 x 4.2ϕ	19.1 x 4.2ϕ	12.5 x 4.2ϕ		
Cable outer dimention	[mm x mm]	37.2 x 8.0	30.7 x 8.9	25.3 x 10.3	21.1 x 12.8	19.5ϕ	22.5ϕ
Aspect Ratio		4.7	3.4	2.5	1.6	1.0	1.0
Cable cross-section	[mm^2]	312.5*	289.0*	276.7*	287.5*	380.1	505.3
Engineering current density	[A/mm^2]	161.3	175.5	184.3	175.3	132.6	99.7

REBCO Tape:
4 mm wide, 90 μm thick
I_c = 150 A at 18 T, 20 K)

* Cooling channel space of 4 mm x 4 mm is added.



FReTC could provide better current density J_E than TSTC.

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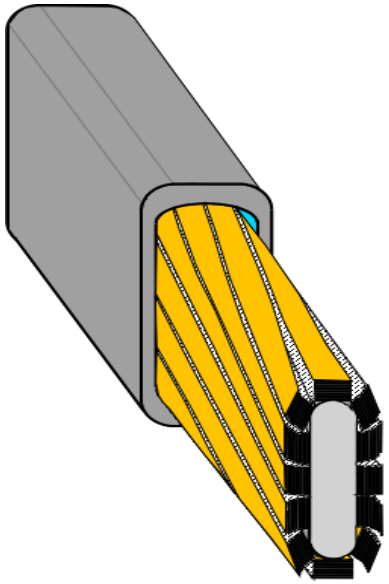
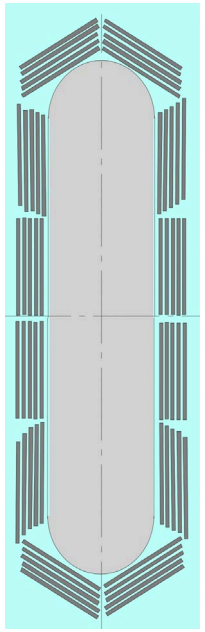
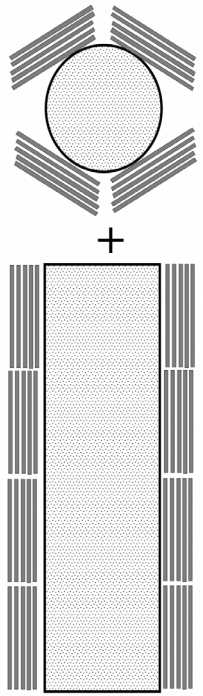
Characteristics of FReTC







TSTC

Tapes are parallel to former surfaces

AC losses

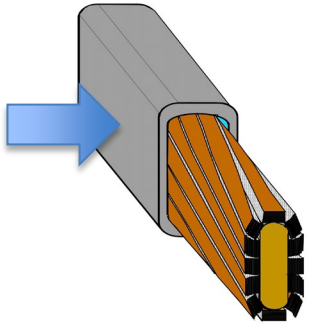
REBCO tapes are parallel to the magnetic field.
Therefore, hysteresis loss can be reduced.

Bending

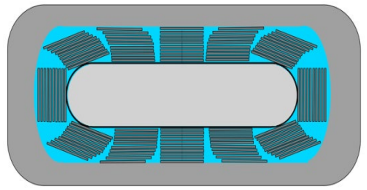
Bending characteristics are similar to TSTC conductors.

Transverse forces

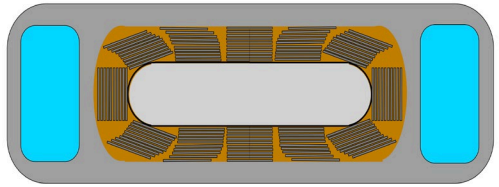
Good structure supports against electromagnetic transverse forces.



CICC (Cable-In-Conduit Conductor)



Direct cooling



Conduction cooling

M. Takayasu, L. Chiesa, C. Navarro, P. Moore, and V. Solovyov, *IEEE Trans. Appl. Supercond.*, vol. 35, 2025.

Closing

- **REBCO Rutherford-type cabling of FReTC could provide cost-effective high-current cables, good for;**

  - Mechanical support structure against electro-mechanical forces
  - Easy fabrication
  - Minimizing AC losses
  - Design flexibility
  - Excellent tape usage

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Thank you for your attention

Acknowledgments

This work was partially supported by the U. S. Department of Energy (DOE), Office of Fusion Energy Science, and Office of High Energy.

The REBCO/copper cable used for this project was supplied by Dr. A.E. Haight, CTD.