

Over-current test on an intra-layer no-insulation (LNI) REBCO coil under a high background field

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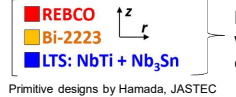
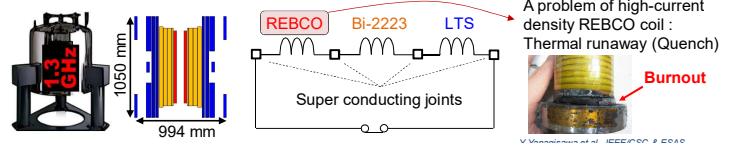
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1 : Chiba University, 2 : RIKEN, 3 : Sophia University, 4 : NIMS, 5 : JASTEC, 6 : JST

1. Background : Towards 1.3 GHz NMR

Our target : Persistent mode 1.3 GHz NMR magnet

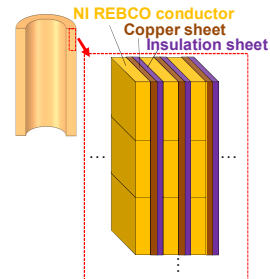


Requirements

- To generate 30.5 T by LTS/Bi-2223/REBCO layer-wound coil
- To protect a high-current density (>300 A/mm²) REBCO layer-wound coil against thermal runaway(quench)

Possible protection method for a REBCO layer-wound coil

"intra-Layer No-Insulation (LNI)" method



Advantage

- ✓ Short field delay
- ✓ Self-protection

The effectiveness of an LNI coil under the following conditions has not been revealed.

- Practical number of layers (~100)
- Under high-fields (~20 T)

It is possible that an LNI-REBCO coil will be mechanically broken due to unbalanced electromagnetic forces as seen in cases of NI DP coils.

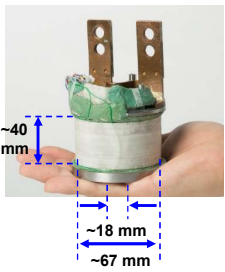
Objective of this study

To reveal self-protection behaviour of an LNI-REBCO coil comprising practical number of layers under high-fields.

Two cases of quench in LNI-REBCO coils are studied in this work.

2. Quench experiments in LNI-REBCO coils

Test LNI-REBCO coils

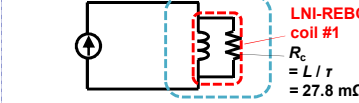


Parameters	#1 coil	#2 coil
Conductor Type	SuperPower Inc. SCS4050	
Winding	LNI	
Inter-layer material	Cu+PET sheet (26 μm)	
Impregnation	Paraffin wax	
Overbanding material	Ni-alloy tape	
Coil I.D. / O.D. (mm)	17.5 / 63.18	17.6 / 66.95
Coil height (mm)	40.1	40.1
Number of turns	1442	1604
	(~9 × 162)	(~9 × 180)
Field constant for coil center (mT/A)	32.2	35.1
Self-inductance (mH)	36.2	47.7
*Field delay time constant at 4.2 K and Self-field (s)	1.3	0.36

*Measured by an energy dump experiment at just before the following experiments.

CASE I : Accidentally high-speed charging (LNI-REBCO coil #1)

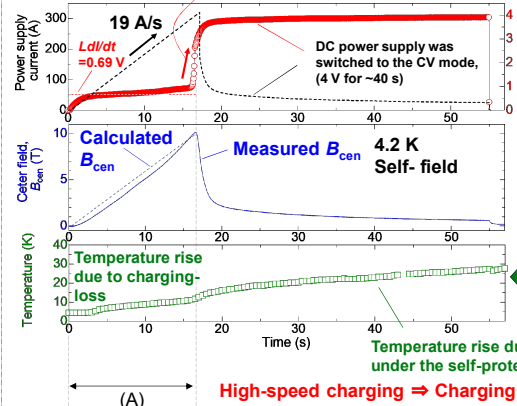
Test circuit



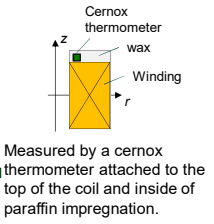
The LNI-REBCO coil #1 was charged in LHe bath under self-fields.

- Accidentally, the coil was charged very fast due to a DC power supply control error.

Test results Premature quench at 300 A (47% for the estimated coil Ic)



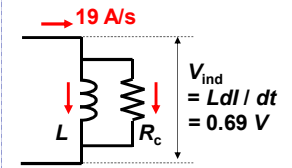
The coil was charged to 300 A in 16.8 s (19 A/s).



Measured by a cernox thermometer attached to the top of the coil and inside of paraffin impregnation.

$T_{cs} = 57.9$ K at 300 A. Thus, max. temperature in the winding should have reached this value just before the quench.

(A) Heating by charging-loss due to high-speed charging



About 17 W of charging-loss was generated in the coil during the 19 A/s charging, which led the coil to the premature quench.

Such charging-loss is a specific phenomenon to an NI (including LNI) coil, which was numerically investigated on a NI pancake coil.

Power of charging-loss $Q = V_{ind}^2 / R_c = 17$ W

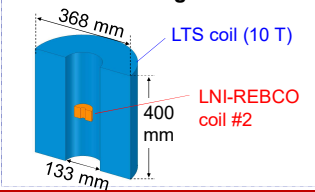
In high-fields regions (> 25 T) where He bubbles are generated, this kind of charging-loss must be considered. We will conduct a further investigation on this issue.

Short summary

17 W charging-loss was generated in the LNI-REBCO coil during a 19 A/s charging, which led the coil to a premature quench.

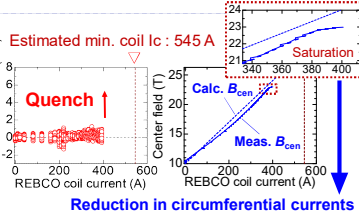
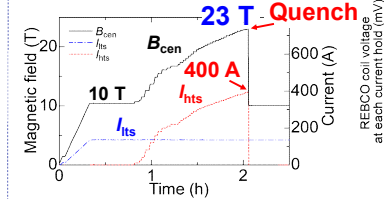
CASE II : Quench under 23 T (LNI-REBCO coil #2)

Test coil configuration and circuit



LNI REBCO coil was charged in LHe under 10 T of the LTS coil field.

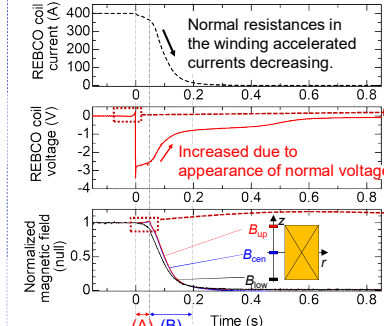
Test results : Overview



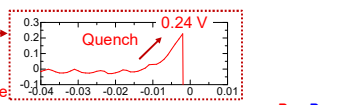
$I_{RE} = 400$ A, $J_{cond} = 1000$ A/mm², $J_{wind} = 648$ A/mm²
 $BJR = 326$ MPa, $\sigma_z = 26$ MPa

The quench occurred at 400 A corresponding to 73% of an estimated coil Ic. Premature quench. The cause is not clear.

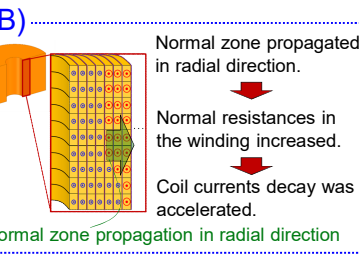
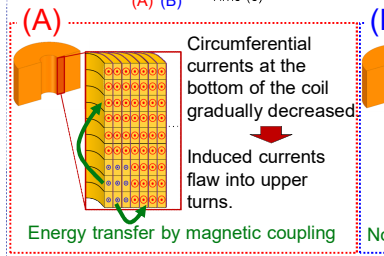
Test results : During quench



The DC power supply was shut down with the detect voltage of 0.24 V and discharged.



The quench was initiated from the bottom of the coil.



After the test, the coil showed no degradations.

Short summary

The LNI REBCO coil was protected from a quench under a high-field of 23 T.

Conclusion

- High-speed charging led the LNI-REBCO coil to a premature quench. It is important to care about a sweep rate under high-fields with He bubbles.
- The LNI-REBCO coil was protected from the quench under 23 T without mechanical degradation due to unbalanced electromagnetic forces.

	CASE I : #1 coil High speed charging quench	CASE II : #2 coil 23 T quench	CASE III : #2 coil 31 T quench ⇒ Fri-Mo-Or27-02
Center field (T)	10	23	31
External field (T)	-	10	17
Quench currents (A)	300	400	290
Quench type	Premature	Premature	Premature
Cause of quench	Temperature rise due to charging-loss	? (Ic estimation error?)	? (He bubbles + Joule heating?)
Action after quench	Continuous charging under the CV mode of 4 V for 40 s	Detection with 0.24 V and discharge in 0.2 s	Detection with 0.2 V and discharge in 3 s