Conductor Characterization, Test Coil Evaluation, and Quench Protection of Bi-2212 Magnets

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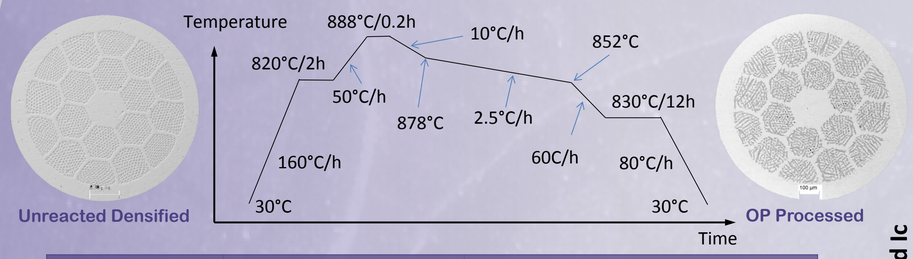
Conductor Characterization

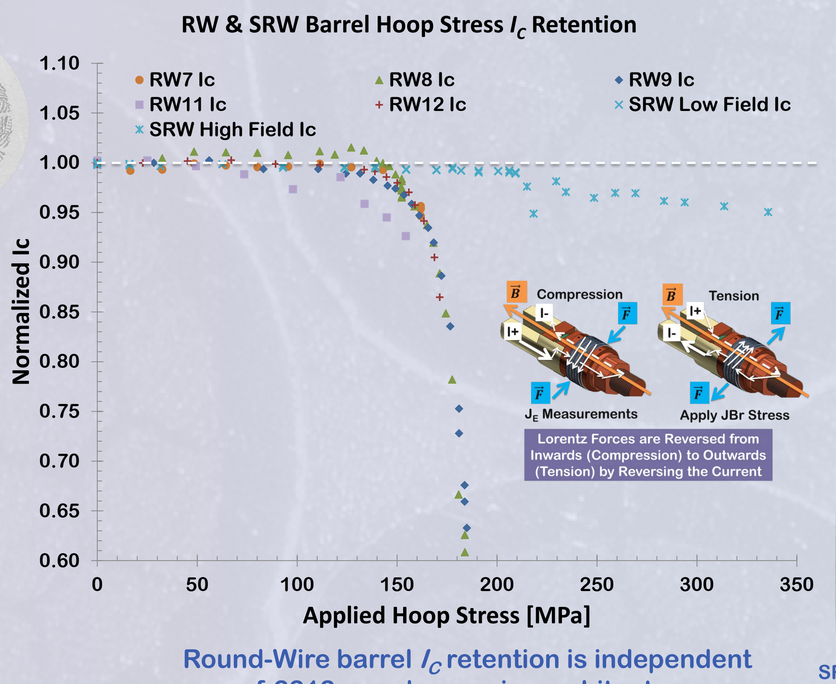
Heat Treatment and Sample Detail



Bi-2212 Spiral Samples	Powder Architecture	Unreacted Wire Dimensions	Product ID
R.W. 7 & 8	Nexans lot 87 (121 x 18)	1.0 mm	PMM151103
R.W. 9 & 12	Metamateria (85 x 18)	1.2 mm	PMM160719
R.W. 11	Nexans lot 77 (37 x 18)	0.8 mm	PMM100913
R.W. 13	Nexans lot 82 (37 x 18)	0.8 mm	PMM130723
SRW 1 & 2	Nexans lot 77 (85 x 18)	1.45 x 0.56 mm (1.2 mm)	PMM111018
SRW 5	Nexans Lot 78 (85 x 18)	1.43 x 0.62 mm (1.2 mm)	Pmm130125
SRW 3, 4, 6 - 8	Metamateria (85 x 18)	1.19 x 0.75 mm (1.2 mm)	PMM160719

J_E improved for newer 2212-powder and reinforcement
See 4MO1-03, 3MP4-01 for more detail

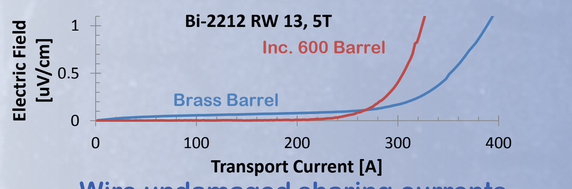
Expanding Barrels Under Hoop Stress



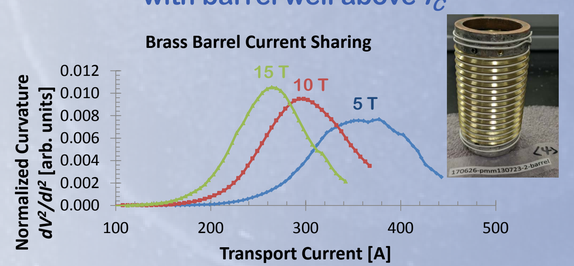
Round-Wire barrel I_C retention is independent of 2212-powder or wire architecture

SRW cross section improvement, oldest top (A. Otto S.M.S.)

I_C Distribution Measurements



Wire undamaged sharing currents with barrel well above I_C



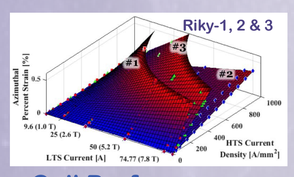
I_C distribution broader at low field

Field [T]	I_{peak} [A]	ΔI_{FWHM} [A]	Short Sample I_C [A]	Short Sample n	Inc.600 I_C [A]	Inc.600 n	Brass "I_C" [A]	Brass n
05	377	130	217-360	15	326	11.4	390	9.8
10	298	114	—	—	270	11.9	332	9.6
15	264	94	—	—	240	11.4	300	9.5

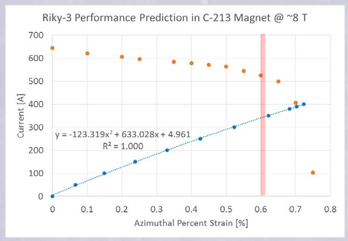
Test Coil Evaluation

Solenoid Measurement and Modelling

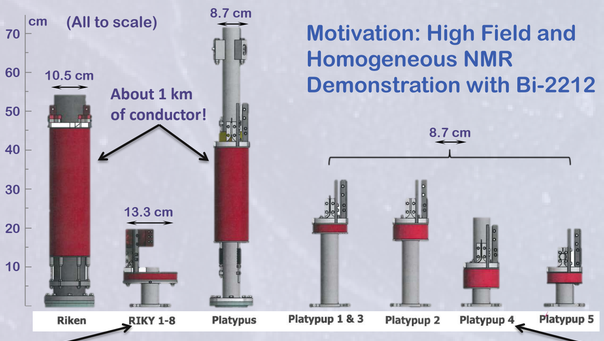
Riky-3 in 8 T Outsert



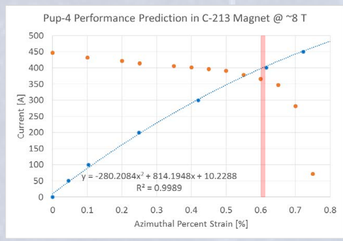
Coil Performance Predictions



Strain limited at predicted current

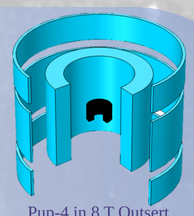


Motivation: High Field and Homogeneous NMR Demonstration with Bi-2212



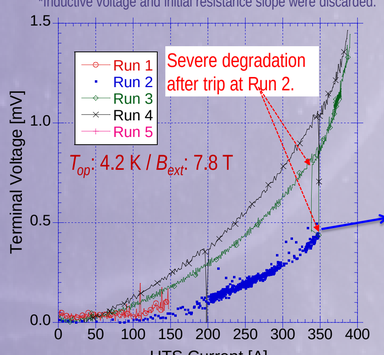
This coil is I_C limited

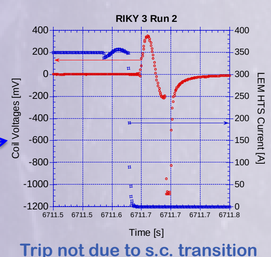
Central Current Lead



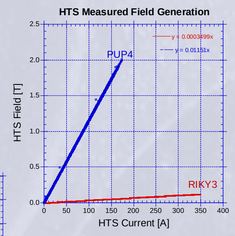
Pup-4 in 8 T Outsert

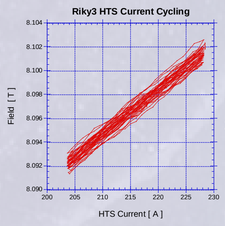
*Inductive voltage and initial resistance slope were discarded.



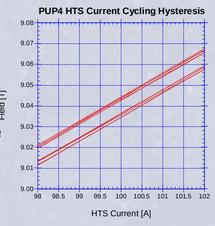


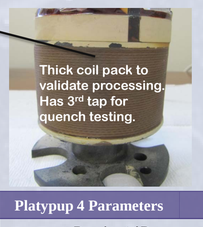
Trip not due to s.c. transition

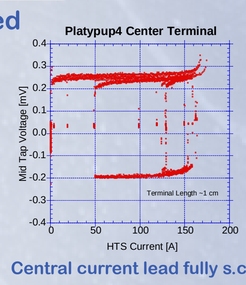




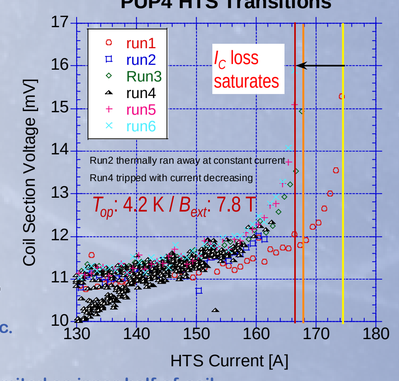
Screening currents are very small. (Hysteresis less than ±5 mT)







Central current lead fully s.c.



- Large Hoop Stress achieved due to13.3 cm OD
- Moderate reinforcement within windings
- FEM modelling prediction of strain
  - Critical strain value of ~0.6% observed in tensile testing and barrel measurements
  - 348 A predicted, damage after 350 A coil trip
- No signs of degradation from low-cycle fatigue

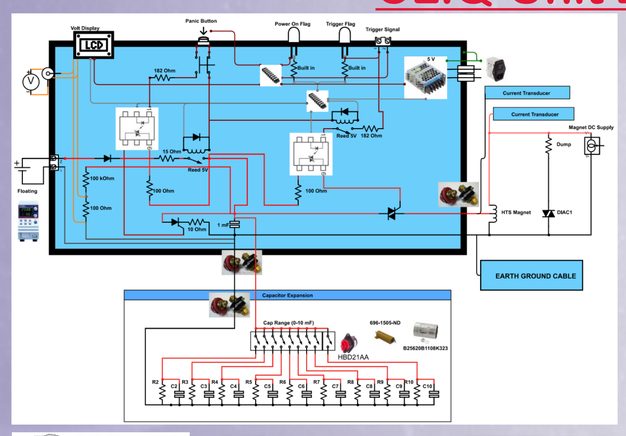
RIKY 3 Parameters		Value	Units
Wire	Product ID	pmm151103	
	Insulation	TiO_2 coating + Al_2SiO_5 braid	
	Wire Diam. Ø	1.0	mm
	ID, OD, h/2	122.8, 134.0, 8.2	mm
Turn (odd/even); Layer		10/9	4
Inductance		0.3	mH

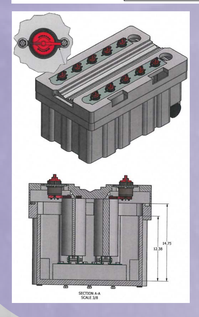
Platypup 4 Parameters		Value	Units
Wire	Product ID	PMM151103	
	Insulation	TiO_2 coating + Al_2SiO_5 braid	
	Wire Diam. Ø	1.3	mm
	ID, OD, h/2	44.5, 89.5, 25	mm
Turn; Layer		39	20
Inductance		25.0	mH

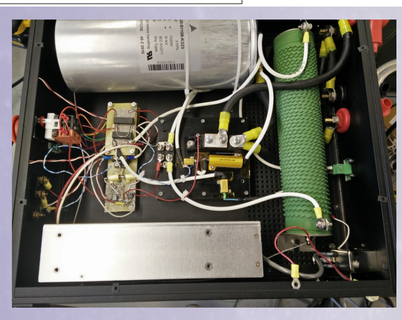
- I_C limited on inner half of coil
- Saturation of I_C loss of less than 10 A for progressive quench events
- No bubbles visible in epoxy
- No charging delay, indicating insulation integrity for TiO_2 coating with Al_2SiO_5 braid
- Reached 25% field of Platypus design (at 16% coil height)

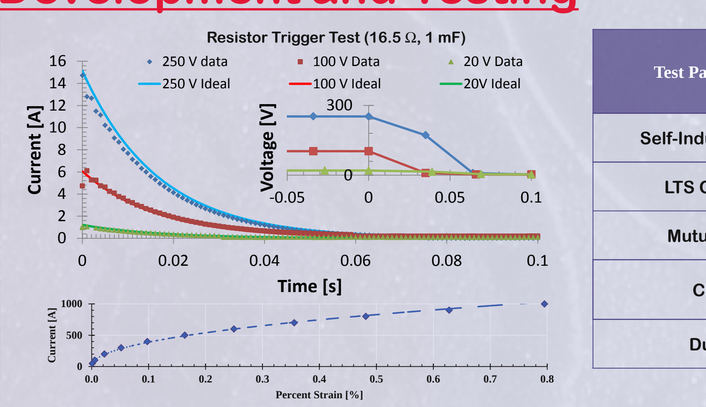
Quench Protection

CLIQ-Unit Development and Testing

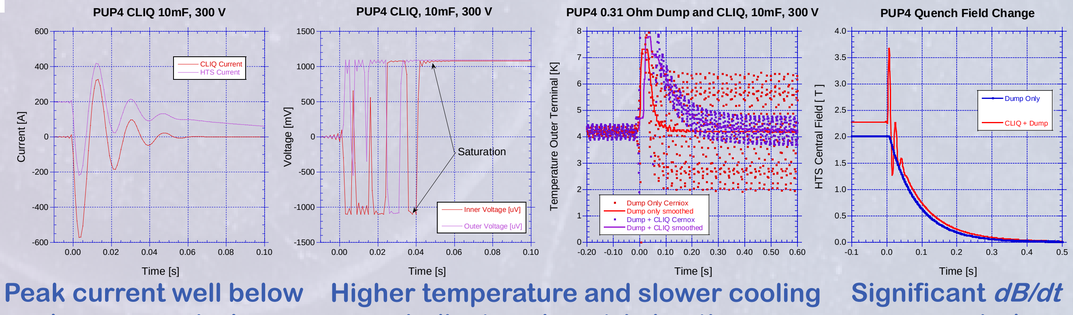








Test Parameters	Value	Units
Self-Inductance L	25.0	mH
LTS Outsert	254.3	H
Mutual Ind.	200	mH
CLIQ	10	mF
	300	V
Dump	0.31	Ω



Peak current well below dangerous strains

Higher temperature and slower cooling indicate volumetric heating

Significant *dB/dt* generated

Key Points

- Long length critical current distributions can now be factored into coil design
- Stress tolerances of over 330 MPa have been measured in barrels and magnets
- CLIQ Unit Assembled and Validated
  - Internal coil lead design has been demonstrated
- Bi-2212 magnet undamaged after more than 30 quenches including 20 low voltage CLIQ discharges

What's Next

- Bi-2212 Rutherford Cable Race Track Dipole
  - CLIQ simulations and measurements at LBNL with T. Shen & E. Ravaioli
- Quench Various Solenoids
  - Vary LTS field
  - Higher J_E and stored energy
  - Heater + thermocouple array
    - Observe t_{Detect} [s] , t_{Quench} [s], T_{peak} [K]
  - Multiple CLIQ leads
  - Frequency-Loss Induced Quench (FLIQ) of Bi-2212 solenoids with P. Noyes and K. Ijagbemi

Abstract: 3LP4-24
Session: Magnet Design and Quench

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