TESTS OF HTS INSERT COILS ABOVE 30 T

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Abstract

Recently HTS insert coils have been operated in background magnetic fields over 30 T, reaching record values for the central magnetic field. One YBCO double pancake coil generated 2.8 T in a 31 T background for a total of 33.8 T. A Bi-2212 layer wound coil generated 1.1 T in a 31 T background for a total of 32.1 T. Here we report on the test set-up and the obtained results.

Introduction

•Goal: demonstrate the suitability of HTS conductors > 30 T

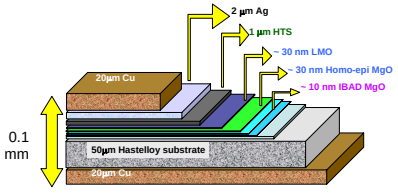
•Two insert coils are built and tested in a background magnetic field of 31 T.

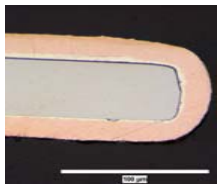
1) YBCO insert coil with commercial conductor from SuperPower Inc.

2) Bi-2212 coil using commercial ϕ 1 mm wire from Oxford Instruments, Superconducting Technology (OST).

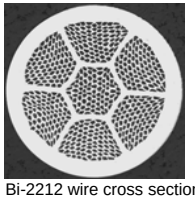
•Coils are wound and tested at the NHMFL in a 31 T resistive magnet with a 39 mm diameter cryostat.

•HTS coils were protected with a quench detection system, circuit breakers and a 0.5 Ohm dump resistor

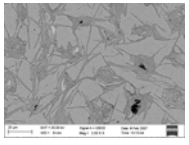




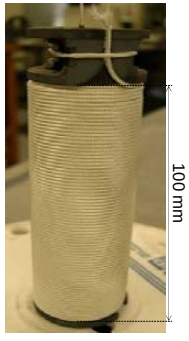
Sketch of YBCO conductor (left) and actual cross section (above)



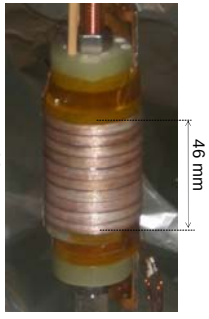
Bi-2212 wire cross section before heat treatment.



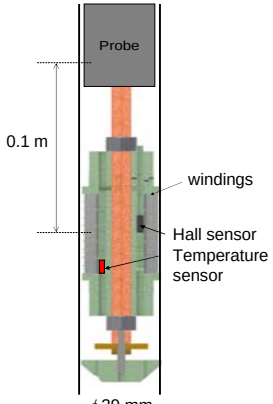
Detail of Bi2212 filaments after heat treatment



Picture of Bi-2212 coil after heat treatment

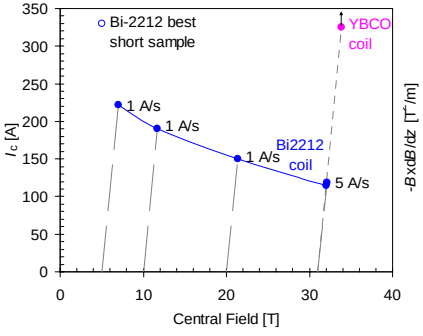


Picture of YBCO coil on winder

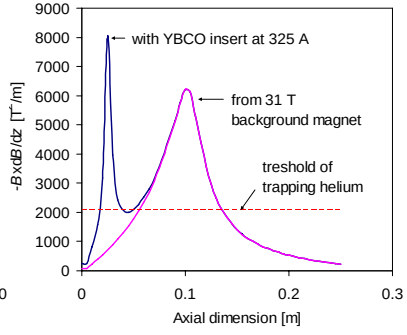


Schematic of YBCO coil

	units	YBCO coil	Bi-2212 coil
Conductor		4 by 0.1 mm tape	ϕ 1 mm wire
Typical I_c	A	120 A at 77 K, SF	330 A at 4.2 K, 5T
Insulation		varnish	ceramic braid
ID-OD	mm	25-36	15-37.5
Winding height	mm	46	100
Windings	-	5 double pancake units	10 layers, No joints
Impregnation		none	Epoxy VPI
# turns	-	380	750
Conductor length	m	36	66
Self-inductance	mH	1.9	2.6
Field constant	mT/A	8.7	9.1
I_c (31 T)	A	>325	120
J_{ave} (31 T)	A/mm^2	>459	80
J_{ave} (25 T)	A/mm^2	>459	92



Measured critical current of the Bi-2212 coil and quench current of the YBCO coil



Downward magnetic force of helium gas bubbles compared to buoyancy

Acknowledgements: The YBCO coil program benefited from many discussions and collaborations with Drew Hazelton and Venkat Selvamanickam of SuperPower and conductor tests by Jan Jaroszynski, Youri Viouchkov and Aixia Xu. The Bi-2212 program benefited from many discussions and collaborations with Seung Hong and Yibing Huang of OI-ST and from efforts within the NHMFL by David Myers, Michael LoSchiavo, Tengming Shen, Justin Schwartz and Eric Hellstrom

Results

Bi-2212 coil

•The onset of a resistive transition could be measured up to a ~ 5 mV, (~0.1 µV/cm) at which point the coil would quench.

•Repeated quenches did not degrade the coil performance.

•The shape of the $I_c(B)$ curve is similar to short samples.

•Coil I_c is ~ 70% of short sample I_c at 5T

YBCO coil

•Ohmic heating in the probe caused helium boil off. Magnetic forces (see left figure) traps the gas, resulting in a significant temperature rise while the coil is still superconducting.

•Coil is operating at estimated 60% of short sample I_c

•Coil degraded during run 5, before reaching I_c(4.2K), cause probably mechanical

Discussion

Bi-2212 coil

•Conductor has preferred wire geometry

•Coil performance is large fraction of short sample wire performance

•Heat treatment not fully optimized. Increased conductor and coil performance possible with further conductor development and heat treatment optimization.

•Current density suitable for 25 T magnets. (J_{ave} near 100 A/mm^2 at 25 T)

YBCO coil

•Central field of **33.8 T** is a **world record for a superconducting coil**

•Magnetic properties of helium combined with Ohmic heating in the probe caused unstable temperatures and limited coil performance.

•Current density is suitable for > 30 T magnets

•Probe and coil design need to be integrated to reduce heating

•Coil mechanical structure needs improvement

Summary

•A Bi-2212 wire wound solenoid and a YBCO double pancake coil were built and reacted at the NHMFL and operated in a 31 T background magnetic field.

• The Bi2212 coil reached 32.1 T at an average winding current density of 80 A/mm^2

•The YBCO coil reached 33.8 T at an average winding current density of 359 A/mm^2, which is a world record for HTS insert coils

•Both conductors are promising for HTS inserts

E.J. McNiff, B.Brandt, S.Foner, L.G. Rubin, R.J. Weggel, "Temperature anomalies observed in liquid ^{4}He columns in magnetic fields with field-field-gradient products > 21 T^2/cm," *Rev. Sci. Instrum.*, vol. 59, pp. 2474-2476, 1988.