Demonstrations of Operating Large REBCO Coils to High Fractions (>70 %) of Their Critical Current

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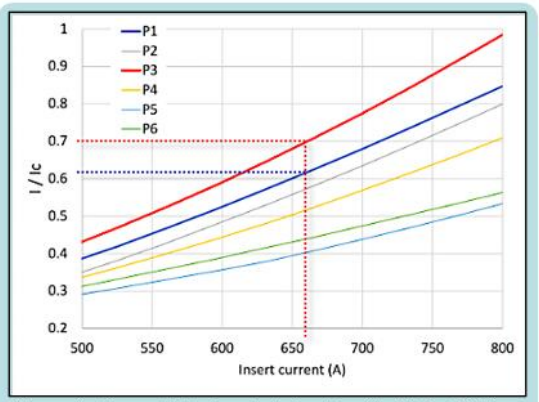
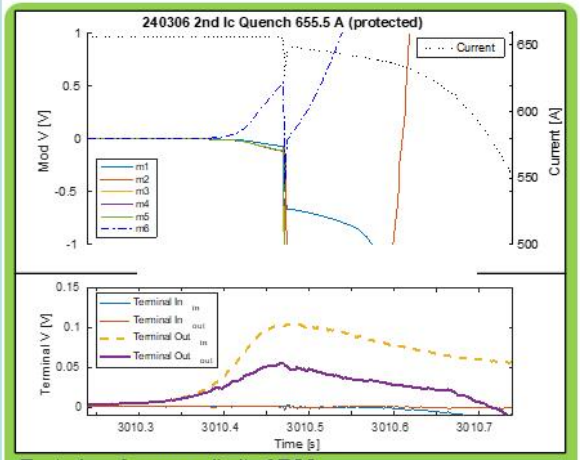
Within the Preliminary and Final Design of a 40T All-Superconducting Magnet project, several midscale test coils (comprised of ~1km of ReBCO) have been designed, constructed, and tested to their operational limits. ReBCO is a high-temperature superconductor (HTS) made in tape form, a few mm wide by ~0.1mm thick, of which only ~1 micron is the superconducting thin film. It is named for its chemical composition (Rare earth – Barium – Copper Oxide). The early midscale test coils provided invaluable technological advancements, but none successfully operated to 70% of their critical current (I_c). I_c is a conductor's ampacity above which it loses superconductivity and reverts to being normally resistive. A requirement for our 40T magnet design success is an operating current (I_{op}) near 70% I_c.

The latest test coil (TC2_c) was comprised of six, double-pancake modules (i.e. twelve disks) and generated 10.3T inside of the 11.4T background field from the 45T Hybrid Outsert magnet. The highlight is that the coil was operated with an operating current (I_{op}) ~70% of its I_c. Every tape used in this coil was extensively characterized to fully map the I_c as a function of both field and field angle. Moreover, the four middle (of the six-module TC2_c) were performance tested individually and were operated up to ~100% of each predicted I_c-fraction.

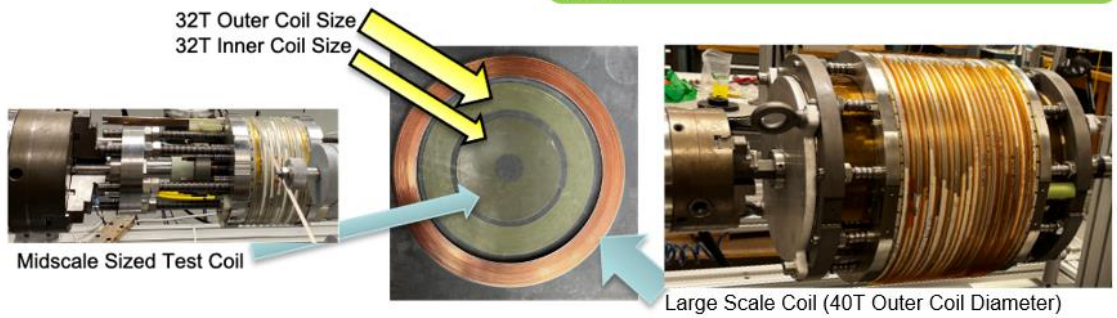
This achievement increases our confidence in the comprehensive methods used in designing and building ultra-high field ReBCO-wound solenoids. It validates our ability to sufficiently characterize individual tapes and later input those material properties into sophisticated numerical simulation tools required to design even larger full-scale magnet systems. The next and final experimental verification will be a test of a Large Scale (~3.5km of tape) Coil (LSC) which incorporates our technological development and scales the demonstration magnet up to the largest diameter coil pack of our present full 40T All-Superconducting Magnet Design. This test coil will be the first at the NHMFL of this diameter. For comparison, the 40T outer ReBCO coil fits around the outer ReBCO coil of the 32T Magnet.



Numerically predicted peak I_c-fraction (I_{op}/I_c) for TC2_c disks operating within an 11.4 T field generated by the 45T Hybrid Outsert magnet.
Disks 'P1' – 'P6' are the six disks in the three double-pancake modules in the top half of the coil, nominally symmetric to the bottom half of the coil.
Dotted lines highlight disks: P3 = 70% and P1 = 60% I_c-fractions, respectively, with an I_{op} = 655 A.



Tested performance limit of TC2_c.
Initially, Module 6 thought to be I_c-limited at 655 A. Later heating in the bottom terminal (attached to Module 6) was identified. Were it not for the terminal heating the coil is expected to have reached 100% I_c-fraction, limited in P3 at 800 A.



Facilities and instrumentation used: ASC/MST Materials Characterization Labs, HTS Winding Shop, DCF 45T Hybrid (outsert) Magnet