

Development of High Current CORC[®] Cables, CICC, and Low Resistance Demountable Joints for Fusion Magnet Applications

Danko van der Laan^{1,2}, Jeremy Weiss³, Sven Dönges¹, Kyle Radcliff¹, Yannik Dieudonné⁴, Julian Holt⁴, Peter Muscat⁴, Shailendra Chouhan⁴, Aurobindo Siddarth Swaminathan⁵, Chris Lamb⁵, ShailendraChouhan⁵, Gregg Schneider⁶, Zack Johnson⁶, Alexandre Torre⁷, Clément Nguyen⁷, and Reed Teyber⁸

¹ Advanced Conductor Technologies

² University of Colorado, Boulder, Colorado, USA

³ High Temperature Superconductors Inc., Santa Barbara, California, USA

⁴ United Kingdom Atomic Energy Authority, Oxfordshire, U.K.

⁵ United Kingdom Industrial Fusion Solutions, Oxfordshire, U.K

⁶ Type One Energy Group, Woburn, Massachusetts, U.S.A.

⁷ CEA Cadarache, F-13108 Saint-Paul-lez-Durance, France

⁸ Lawrence Berkeley National Laboratory, Berkeley, California, U.S.A.

E-mail: danko@advancedconductor.com

Abstract—It has been widely recognized that compact fusion machines that take advantage of high-temperature superconductors (HTS), which allow magnets to operate at relatively high magnetic fields and at temperatures that won't require liquid helium cooling, have the potential to significantly reduce the timeline towards net fusion energy production. HTS also may enable demountable toroidal field (TF) coils that would allow easy access to the fusion core and thus would significantly ease maintenance of the fusion device.

Advanced Conductor Technologies (ACT) is developing HTS Conductor on Round Core (CORC[®]) cables, wound from RE-Ba₂Cu₃O_{7- δ} (REBCO) coated conductors, Cable-in-Conduit-Conductors (CICC), formed by bundling several CORC[®] cables in parallel, and low-resistance demountable joints between CORC[®]-CICCs. An overview will be provided, outlining the status of CORC[®] cable, CICC and demountable joint development for fusion magnet applications.

Very-high current CORC[®] cables were developed specifically for the prototype Stellarator coil under development at Type One Energy Group. The single CORC[®] cable of 10 mm in thickness contained 96 REBCO tapes of 4 mm width from Fujikura, resulting in an expected critical current (I_c) of over 30 kA at 10 T at a temperature of 20 K, or at 20 T at 4.2 K. The CORC[®] cable was optimized to allow bending to a 125 mm radius without experiencing significant performance degradation, making it a highly attractive candidate for winding into the non-planar coils of Stellarator reactors.

Very-high current CORC® cables were also developed in collaboration with CEA Cadarache. A CORC® cable was developed containing 120 REBCO tapes from Shanghai Superconductor Technologies, to allow operation at 20 – 25 kA at 18 T at a temperature of 20 K. The tapes contained a thin layer of SnPb solder that will be melted after winding to provide the cable with a higher mechanical strength and better current sharing capabilities between tapes compared to a CORC® cable wound from REBCO tapes that don't contain a layer of solder. The performance of the CORC® will be tested within the SULTAN test facility in the near future. The results of the pair of CORC®-CICC samples that was developed in collaboration with the United Kingdom Atomic Energy Authority (UKAEA) and tested in the SULTAN facility will be discussed. Although the sample was operated to its expected I_c of 40 kA in a background magnetic field of 10.8 T at 20 K, the sample quenched before I_c was reached at temperatures below 20 K. Temperature gradients that may develop over the sample length, and especially between the parallel CORC® cables, could become the main driver behind the current distribution between cables within the CICC. Voltage measurements taken during the SULTAN test indicate that the thermoelectric voltages caused by the temperature gradient may cause reversal of the current in one or more CORC® cables within the CICC, significantly reducing its quench current.

The latest results of the development of remountable joints between CORC®-CICCs for fusion reactor magnets in collaboration with UKAEA will be outlined. Earlier tests performed at 4.2 K at a background magnetic field of up to 8 T demonstrated the feasibility of using CORC®-CICCs in demountable TF coils. A total loop resistance, including their terminations and joint, was about 4 nΩ at 4 K in self-field, with the contact resistance between the pressed copper joint surfaces being less than 1 nΩ at a high contact pressure of 50 MPa. Here we report on the latest results of the performance of demountable joints having different joint interfaces that would facilitate easier mounting and demounting at a reduced contact pressure of about 10 MPa. Loop resistances of 6 – 10 nΩ were measured at currents up to 5 kA at 25 K in self-field, with the contact resistance over the joint interface being as low as 0.5 nΩ, depending on the sample pair and joint surface preparation.

Keywords (Index Terms)—Cable in Conduit, Coated Conductors, Fusion, HTS cable