SuperPower® 2G HTS Wire Specifications

Second-Generation High Temperature Superconductor (2G HTS)

SuperPower has been developing (RE)BCO-based 2G HTS wire at its manufacturing plant in Schenectady, NY since 2000 and is now routinely producing long lengths of high performance wire that is being shipped to customers around the world for a wide range of applications.

SuperPower® 2G HTS Wire is produced in an automated, continuous process beginning with an inexpensive high strength metal alloy “tape” as the base substrate material and adding buffer layers, ceramic-based superconductor material and protective overlayers.

Once the wire has been slit into device-specific widths, Surround Copper Stabilizer (SCS) is applied to completely encase the wire. Overcurrent capability in SCS wire can be tailored to the specific application. The stabilizer protects the conductor and produces rounded edges that are beneficial for high-voltage applications. Further, the probability of failure in the device due to voltage breakdown is reduced in wire with SCS. SuperPower’s SCS has been successfully implemented and tested on continuous lengths of hundreds of meters of wire.
### SuperPower® 2G HTS Wire Specifications

<table>
<thead>
<tr>
<th>Spec SF = Stabilizer Free</th>
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<tbody>
<tr>
<td>SCS = Surround Copper Stabilizer</td>
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<tr>
<td><strong>SCS3050</strong></td>
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<tr>
<td>Minimum $I_c$</td>
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<tr>
<td>Widths</td>
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<tr>
<td>Total Wire Thickness</td>
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<tr>
<td>Standard Copper Stabilizer Thickness</td>
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<tr>
<td>Critical Tensile Stress</td>
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<tr>
<td>Critical Axial Tensile Strain</td>
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<tr>
<td>Critical Bend Diameter in Tension</td>
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<td>Critical Bend Diameter in Compression</td>
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### Wire Formulations

- **Cable Formulation (CF)** wire, utilizes standard wire chemistries that exhibit best performance at around 77K, the liquid nitrogen temperature regime, and in very low magnetic fields for cable and other similar applications.

- **Advanced Pinning (AP)** wire exhibits superior performance at a range of temperatures from 77K to as low as 4K and well suited for in-magnetic-field applications such as motors, generators and other high-field magnetics.

- **Fault Current Limiter (FCL)** wire utilizes the CF chemistry and begins with a thicker (100 micron), highly resistive Hastelloy® substrate suitable for these grid protection devices. This application, which does not call for any copper stabilizer, can also benefit from the option to vary the thickness of the silver cap layer.

### Copper Stabilizer

- **Silver Overlayer**
- **(RE)BCO - HTS (epitaxial)**
- **Buffer Stack**
- **Substrate**

**Substrate Thickness:**
- 50 µm Hastelloy® C-276 [or 100 µm for SF12100]
**Substrate Yield Strength:**
- 1200 MPa at 77 K

**Substrate Resistivity:**
- 125 µΩ-cm – higher resistivity leads to lower eddy current ac loss

**Magnetic Properties:**
- non-magnetic, leads to lower ferromagnetic ac loss

* not to scale; SCS4050
We are ready TODAY to discuss your SuperPower® 2G HTS Wire needs for your specific application.

- Standardized testing provided with all wire deliveries
- Hermeticity - 24 hrs, 10 bar, LN₂, no change in Ic & thickness
- Ic uniformity in long lengths of 2G HTS wire: STDEV less than 10%
- Insulated wire is available (see back page for details)
- Ic values range from 80-110 Amps and higher at 77 K in 4 mm widths
- Engineering Current Density (Je) = 21 – 29 kA/cm²

Other custom configurations are available. Please visit us at http://www.superpower-inc.com/content/request-quote, or by email at sales@superpower-inc.com, with your specifications, including:

- Wire length, width and thickness requirements
- Performance characteristics (critical current, stress, etc.)
- Silver overlayer and/or copper stabilizer preference
- Other physical or performance characteristics
- Delivery timeframe
- Application

SuperPower® 2G HTS Wire and coil application:

- 2011: A new world-record magnetic field of 35.4 T inside a superconducting coil has been reached using a single piece of about 100 m of REBCO conductor wound in layers and nested in a 31 Tesla background magnet.

- 2009: A high field magnet coil fabricated by SuperPower with its 2G HTS wire and tested at NHMFL again breaks world records when achieving a magnetic field of 27.4 Tesla at 4.2K in 19.89 Tesla background field

- 2008: Coil fabricated by NHMFL with SuperPower® 2G HTS Wire was tested at 4.2K in 31 Tesla background field at NHMFL and achieved a world record of 33.8 Tesla at an average winding current density of 459 A/mm²

- 2007: High field magnet coil fabricated with 2G HTS wire and tested at NHMFL achieved a record magnetic field of 26.8 Tesla in 19 Tesla background field at 4.2K

SuperPower has produced a number of prototype devices utilizing 2G HTS SCS Wire, including:

- The world’s first in-grid HTS Power Cables were fabricated by Sumitomo Electric Industries with SuperPower’s 4 mm wide 2G HTS wire

- Measured AC losses in a sample cable were 0.36 W/m at 1000A rms (I_quench/Ic ~ 65%, 60 Hz) over the entire cable structure

Other applications:

- 2G HTS wire type SF12100 with highly resistive substrate is suitable for fault current limiter (FCL) applications. First peak limitation demonstrated with fast response time, low quench current, and rapid recovery.

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### Table: SCS12050, SF12100 Properties

<table>
<thead>
<tr>
<th>SCS12050</th>
<th>SF12100</th>
<th>Unit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>200</td>
<td>amp</td>
<td>measured by continuous direct current</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>0.1</td>
<td>0.105</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>0.04</td>
<td>n/a</td>
<td>mm</td>
<td>surround stabilizer with rounded corners</td>
</tr>
<tr>
<td>&gt; 550</td>
<td></td>
<td>MPa</td>
<td>at 77K</td>
</tr>
<tr>
<td>0.45%</td>
<td>0.4%</td>
<td></td>
<td>at 77K</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>mm</td>
<td>at room temperature</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>mm</td>
<td>at room temperature</td>
</tr>
</tbody>
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SuperPower”TM” for superior performance.
Insulated 2G HTS Wire
SuperPower offers in-house insulation for a variety of applications. Available configurations include 4 mm and 12 mm wire widths.

Wire is insulated with 0.025 mm or 0.050 mm thick polyimide, both with a ~ 0.050 mm silicone adhesive. Wrapping styles are butt wrapped (no overlap) or an adjustable overlap of 0 to 50%.

After insulation, the wire is not accessible for transport current measurements at every 5 m in the reel-to-reel test system. Therefore, a non-contact I_{c} technique is used to re-confirm the wire quality after insulation.

High Quality Joints
SuperPower Inc. routinely holds the world record in long, splice-free lengths of 2G HTS wire. Despite these long lengths, however, it is often necessary to splice wire segments together. Our low resistance, high quality joints and splices have a minimal effect on the superior performance of our wire.

- Base tape thickness = 0.1 mm
- Thickness at joint or splice = 0.22 mm (about two times thinner than splices with 1G or other 2G wires!)
- Joint length = 2.5 to 10 cm, or per customer specifications
- Temperature limit on solder up to 250ºC (much higher than with other 2G HTS wires)

Joints between 2G HTS wires show excellent electrical and thermo-mechanical properties.
- No degradation in I_{c} (1 µV/cm) over the joint or splice
- No decrease in I_{c} and no increase in joint resistivity when bent over a diameter of 1 inch
- Minimum bend diameter at joint = 25 mm
- Typical joint resistance less than 20 nΩ, 100 mm over lap