Applied Superconductivity Center: HTS Coils Project

Antonio Goodman, Fernando Quiroz, Christopher Reis, Benjamin Walker

FAMU-FSU College of Engineering

Contents

Introduction

The Applied Superconductivity Center HTS Coils project is a design, fabrication, and testing project for a current lead that is to be used to power Hight Temperature Superconductor (HTS) coils. Due to the cost of liquid helium and the need to deliver more and more electrical current to these coils a new current lead needed to be designed and built. Team 501 designed a completely new type of current lead, unlike any other current lead. This current lead uses hexagonal tubes placed in a closed-pack configuration to maximize heat transfer efficiency and all for the necessary electrical current to pass to the test coils. This operation manual should always be used when using this scientific device and should be referenced for any troubleshooting needs. If the operations manual does not cover a particular incident for the use of the current lead, then the operation should be stopped until a safe use of the current lead is available. In the case of damage to the current lead, all use of the lead should be stopped until proper repairs have been made. In the case of fire or electrical short-circuiting stop, all use and contact emergency services.

Current Lead Parts

1. 0.220 Inch Deoxidized Phosphorous Copper (Cu122) Hexagonal Tubes (Qty:50)
    a. Used to transfer DC electrical current from exterior power source to the HTS coil. Tube design also allows for evaporative cooling of the current lead.
2. Copper (Cu101) Tube Clamps (Qty:4)
    a. Clamps tubes to ensure uniform electrical current distribution to all tubes and creates a connection point to attach to Current Lead Bus Bars.
3. Copper (Cu101) Current Lead Bus Bar (Qty: 4)

   a. Positive and negative terminals attach to Copper Tube Clamps by being screwed in. This part provides the terminal to attach both exterior power source cables (at the top) and test coil connections (at the bottom).
4. Halogen Free Garolite (G10) Nipple Insulator (Qty: 4)
   a. Presses Copper Tube Clamps into place within the lead Nipple of the current lead and the bottom of the current lead near test area. Acts as an electrical insulator for the current lead Nipple and cryostat
5. Halogen Free Garolite (G10) Insulative Shim: Tubes (Qty: 1)
   a. Placed in between the positive and negatively charged tubes to act as an electrical insulator to prevent electrical short-circuiting
6. Halogen Free Garolite (G10) Insulative Shim: Clamps (Qty: 2)
   a. Placed in between the positive and negative Copper Clamps and Garolite Nipple insulator to act as an electrical insulator to prevent electrical short-circuiting.
7. Stainless Steel Current Lead Nipple (Qty:1)
   a. Placed at the top portion of the current lead to enclosed electrical components and to capture evaporated helium gas for transfer to helium recovery lines. Sealed system with quick connect ports for connection to helium recovery lines, instrumentation access ports, and sealed ports to allow Current Lead Bus Bars to be exposed for connection to the exterior power source.
8. Ultrator Seals (Qty: 2)
   a. Used to seal the access ports of the Current Lead Bus Bars.

9. PTFE KF 70 Seal (Qty: 2)
    a. Used to seal the Current Lead Nipple to prevent helium gas loss.
10. KF 70 Flange Clamps
    a. Used to seal Current Lead Nipple KF 70 Flanges.
11. KF 70 Flanges (Qty: 4)
    a. Used to connect Current Lead Nipple to Garolite Tube Chassis
12. Halogen Free Garolite (G10) Tube Chassis (Qty: 1)
    a. Encases all Current Lead Tubes.
13. Screws (Qty: 28)
    a. Used to hold Nipple Insulators and Tube Clamps in place.
14. Epoxy Resin
    a. Used to seal all Garolite connections
15. Low-Temperature Solder
    a. Used to ensure electrical connection between all Copper tubes. Also seals all interstitial spaces between tubes to ensure that evaporated helium gas can only travel through insides of tubes.

Assembly

The correct assembly/reassembly of the current lead is extremely important to ensure correct and safe operation. The current lead is designed to be disassembled throughout its life for maintenance and modifications. The assembly/reassembly of the current lead should be completed as follows.

1. The Copper Current Tubes are to be stacked in a close-packed orientation using D-Ring assembly dies to ensure good electrical contact. Two D-Rings should be placed

4 inches apart, once in place, warm tubes bundle with a low heat butane torch and begin applying solder to a 1-inch wide area. (Note: A large amount of solder will be used and expect solder to drip from the bottom of the assembly.) Repeat this process every 12 inches along the bundle and repeat for the oppositely charged bundle. File off any excess solder. Ensure that enough solder has been used to completely bind and seal tube bundles.

2. With both Positive and Negative tube bundles well-soldered place Garolite Tube Shim in between bundles. Ensure that shim is straight, undamaged (very thin), and completely isolating Positive and negative bundles from each other.
3. With Positive and Negative tube bundles placed together with Garolite Shim in place, slide entire package into the Garolite Tube chassis until approximately 1.5-inches protrudes from one side leaving approximately 3 inches protruding from the other side. During this process be careful not to damage Tube Chassis or Insulative Shim as both are brittle materials.
4. With Tube Bundles inserted and protruding from Tube Chassis, pour epoxy resin into top and bottom of the tube. Make sure that no resin enters any copper tubes. Allow the resin to set and cure. Check to make sure that Tube Chassis in now sealed with Epoxy Resin at both ends.
5. With Epoxy Resin cured, slide bottom KF 70 Flange into place and then insert Garolite Nipple Insulator flush with KF 70 Flange. Place Nipple Insulator snuggly around top and bottom of Tube Chassis. Use Epoxy resin to form the connection between the Garolite pieces. Allow curing.

6. With Nipple Insulator Bonded to Tube Chassis, slide Copper Tube clamps into place and insert Copper Clamp Shim. Use all provided Hex Head screws and tighten to no more than 10 ft-lbs.
7. With Clamps in place, screw in Copper Lead Bus Bars (hand tighten only).
8. With Copper Lead Bus Bars inserted the bottom portion of the current lead is complete. For the top portion of the current lead, place PTFE seal onto bottom KF 70 Flange and then place Current Lead Nipple into place. Use KF 70 Flange Clamp to secure this connection.
9. With Nipple secured to current lead, place 2^{nd} PTFE KF 70 seal on top of the nipple. Then slide Nipple top KF 70 plate into place and use 2^{nd} KF 70 Clamp to ensure connection. (Note: KF 70 Nipple top should already have Ultrator seals in place before attaching to Nipple. Failure do to this will result in an unsealed system.)
10. The current lead is now completely assembled.

Caution: With current lead assembled the mass of the device will be quite high. When moving current lead endure firm grip and check surroundings. Close-toed shows should always be worn. Current lead chassis is also made of a strong but brittle material. Any forceful contact to the Chassis Tube could result in damage and make current lead inoperable.

Operation

The operation of the current lead can be broken down into very few steps.

1. Attached test coil to lower end terminal buses.
2. Place current lead into Outsert Magnet and ensure proper sealing to the top plate.

3. Connect all evaporative gas recovery lines to Nipple connections.
4. Connect all instrumentation wires to respective data ports.
5. Fill Cryostat with liquid nitrogen to cool cryostat and current lead to 77 Kelvin. Allow for 24 hours to ensure complete and stable cooling.
6. Pump all liquid nitrogen out of the cryostat.
7. Begin filling Cryostat with liquid helium until proper helium level reached. Allow the entire system to cool and stabilize (approx. 24hrs) to 4.2 Kelvin.
8. With system cooled and stable connect the current lead to the exterior power source by placing power source cables on both Negative and Positive Terminal buses. Ensure that connection is firm using nuts to secure cables.
9. With power source connected and all instrumentation receivers running electrical current can now be supplied to the current lead. Ensure area is safe and all personnel are aware of the beginning of the experiment.
10. Switch power on.
11. Monitor current lead and check for any irregularities.
12. Run entirety of experiment if possible.
13. Once experiment is complete turn off all power sources.
14. With area secured disconnect power source from the current lead.
15. Allow system to stabilize and once deemed safe remove current lead from Outsert magnet.

Troubleshooting

If power is supplied to the current lead but the superconducting magnet is not energized, then the experiment must be stopped. Once no current is passing, someone using insulated gloves will screw down the copper lead bus bars with more torque. With power applied again if the magnet is still not energized, check for any shortages in the lead. If this does not work, reapply solder in critical areas to ensure current is getting passed to the copper tubes.

If more than 4W of heat is being dissipated to the helium cryogen causing too much helium to boil off before the rated current is reached, stop the experiment and allow at least 24 hours for the current lead to cool down with liquid nitrogen.

If the Pressure loss through the current lead becomes too high, try looking for any tubes that may be constricting the flow of helium gas and unplug it.

If the voltage drop across the current lead becomes higher than what is normal, then check to see if any of the copper is burnt or melted. If so, replace that piece of copper with new copper.