Project Specifications

**EML 4551C – Senior Design – Fall 2011 Deliverable**

Team # 16

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**Introduction**

The purpose of this project is to design a probe that tests superconducting samples at very low temperatures while conserving as much of coolant (liquid helium) as possible. This will be done by identifying all of the major heat leaks in the system and eliminating or dampening them. Heat transfer will also be looked at, and ways to hinder the heat transfer from the high temperature of ambient air relative to the near absolute zero conditions at the site of the samples.

**Needs specification**

The customer has very specific design criteria for this particular probe.  An efficient probe which can effectively test 6-8 samples as well as a spiral sample and conserve helium must be produced. The probe must be able to withstand and deliver 1000 amps through the samples. This probe must also withstand several hours of extremely low temperatures without deformation as the samples must stay in the same location. In order to do this, the heat leaks must be minimized, materials must be analyzed, a stage for the samples must be designed, potential heat leaks may be insulated, and in depth analysis and modeling must be completed.

**Leads**

The leads are easily one of the main sources of heat leaks throughout the system. The leads are made out of a highly conductive material, normally copper, and are used to provide a current down to the superconductive wires used at the cryogenic temperatures. Two leads are needed for each sample, one for the current to enter and one for the current to exit the superconducting lead, and since such a high current is running through these leads (580 to 100 amps), heat is being given off from the resistance and therefore resulting in high temperatures. The main driving force of heat transfer is a high temperature gradient and since heat is being transferred from the extremely high temperature copper leads relative to the liquid helium through convection, any amount of heat generated by the leads due to current will play a substantial role.

There are anywhere from 6 to 8 superconducting samples at any given time while the probe is in use. This would mean that there could be up to 16 copper leads generating heat and boiling off the liquid helium at a substantial rate. An ideal way to reduce the amount of helium burn off would be to eliminate the number of copper rods in the new design while stills being able to provide testing to the same number of samples. This would reduce the total surface area and therefore reduce the convection rate and heat transfer to the liquid helium. Given the size constraint and how much current needs to be run through each superconducting material, the minimum number of leads that could be achieved would be 8. Assuming no extra current would be needed to run through the leads, this would mean as much as a %50 decrease in heat transfer would be achieved. The samples would have to be placed in parallel in order for the same amount of current to travel through each, along with two voltage meters to measure the voltage across each sample.

It will need to be determined, however, if a higher current will be needed to travel through the leads to provide the current to more than one sample. If this is the case, more heat will be generated by the leads and calculations will have to be done to see if the reduction in area of the leads will not be negated due to the temperature increase and therefore heat transfer increase by the existing leads.

**Superconducting Samples**

The samples are thin superconducting wires that are mounted on the sample holder and attached to two of the current leads. Due to the superconductivity of the wire from the cryogenic temperatures, these samples are able to pass large amounts of current without generating any heat. This is because at cryogenic temperatures the resistance is essentially zero and since power generation is directly related to the resistance, it too is also zero. Because of this, the project will not focus on the samples since they will not add to the heat being transferred to the liquid helium. However additional superconducting wires will be used in order to eliminate some of the copper and heat transfer of the system.

The way the probe is set up, the copper leads start at ambient temperature and travel down into the cryogenic liquid. Through extensive heat transfer and temperature calculations, the temperature point on the copper where a certain material reaches its superconductive properties can be located. This means that a superconductive material would be placed there in parallel with the copper leading the current through the path of least resistance, i.e. the superconducting wire. Since the remaining copper below this contact point would serve no purpose it would be eliminated and therefore reduce the amount of area and heat transferred by the system. This would make the probe more efficient and cheaper. There will, however, need to be a backup system that will allow the current to pass through an alternative source in case quenching, or the sudden loss of superconductivity, cause the wire to have resistance and therefore begin producing a large amount of power and heat loss.

**Sample holder**

During testing, the samples will be attached to the probe via a stage. The customer has specified 6-8 samples to be able to be tested during each test. A stage that holds 6-8 short samples and at least one spiral sample must be designed. This stage must be able to withstand the extremely low temperatures of liquid helium without corrosion or deformation.