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Conduction cooling test facility for superconducting model coils

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Abstract

A conduction cooling test facility to perform the characterization of superconducting model coils has been designed based on the use of a Gifford-McMahon cryocooler with a maximum of 1.8 Watt cooling capacity at 4.2 K. This facility will allow to test prototype coils as well as determine thermal properties of their components at a wide range of controllable temperatures. Such functionality is especially valuable when aiming to design and manufacture magnets at non-standard working conditions, for instance profiting from the temperature margins of the superconducting materials rather than their high critical fields, in which case, allowing to work at higher temperatures than those provided by cryogen bath based facilities is a necessity. A major challenge is presented when aiming to design and construct a test facility for cooling down and keeping temperature values stable and homogeneous while keeping the heat load below the cooling capacity of the cryocooler at the working temperature. The detailed design of the vacuum vessel, shields, current leads and cold mass supports are here presented.

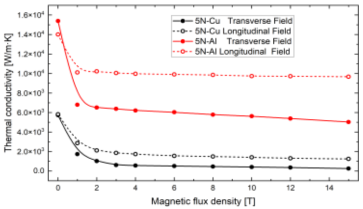
Introduction

- Conduction cooling test facility based on the use of cryocooler:
  - Sumitomo GMM RDE-418D4
  - 1st stage – 42W @ 50K
  - 2nd stage – 1.8W @ 4.2K
- Cooling strategy inspired in ILC SCQ package [1]:
  - Tubular heat sink
  - High purity Al for termal connection

Heat Sink

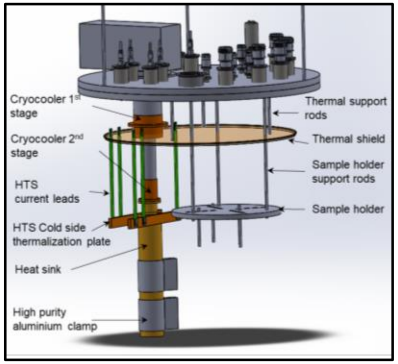
- Cilindrical heat sink simulating ILC cold pipe
- Two clamps are installed around heat sink to thermally connect the coils to the second stage of the cryocooler
- Additional Cu plate for CL Thermalization and mechanical support

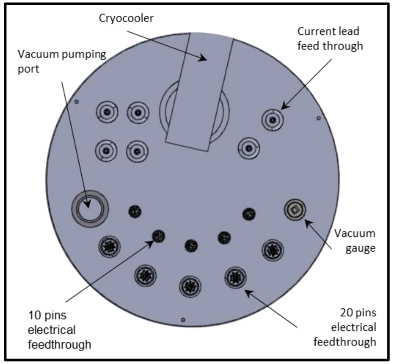
Thermal connection to coils



- Thermal connection carried out with high purity (5N) aluminum* foil.
- Improved termal conductivity performance w.r.t. Copper at 4.2 K and in presence of Magnetic field. [2]

*Thanks to Sumitomo® for providing High purity Al sample





Conduction Cooling Performance – Maximum size – Minimum achievable temperature

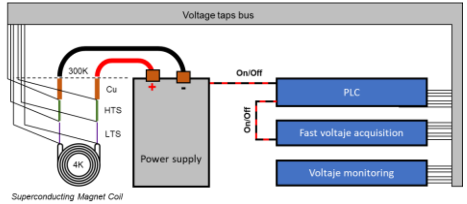
Temperature	HL Source	Component/Location	Heat Load [W]		CC capacity [W]
1st Stage 50K	Conduction	Cu Current lead to shield	2.2	29.29	42
		300K flange to first stage	0.66		
	Radiation	300K chamber to termal shield (10 layer MLI)	8.95		
	Joule	Cu Current lead to shield (150 A)	17.3		
2nd Stage 4.2K	Conduction	300K flange to sample holder	0.22	0.32	1.8
		HTS Current lead to second stage	0.078/0.089**		
	Radiation	50K termal shield to sample (10 layer MLI)	0.002		
	Joule	HTS current lead to 1st stage (150 A)	0.02		

***Using Kapton MT vs Traditional Kapton film*

- Maximum magnet size: Diameter 350mm, Length 500mm
- Maximum magnet weight (holding rods): 500 kg
- Cooling time – maximum magnet size – No Joule heat load: Fe ; 420kg ; 210 hours

Quench protection/Acquisition

- Voltage taps along the coil powering circuit
- Voltage monitoring by PLC and data logger
- When quench over voltage takes place, PLC triggers:
  - Power supply shutdown
  - Fast voltaje acquisition – 2 sec buffer – 1000 datapoints/second



Current leads

- Six current leads to allow energization of up to 3 magnet assemblies

Resistive

- KF vacuum leak tight electrical feedthrough
- Copper cable connected to warm side of superconducting current leads

Superconducting. Warm side

- REBCO and fiber glass
- Thermalization to 1st stage by means of Cu braid
- Thermalization to second stage by means of copper plate

Superconducting. Cold side

- Soldering of LTS (typically NbTi) by means of InBi soldering material

[1] "International Linear Collider Reference Design Report," http://www.linearcollider.org/cms/?pid=1000025. [2] Magnetoresistance of 5N, 6N, and 6N8 high purity aluminum H. Hoshikawa, et al. https://doi.org/10.1063/1.4712090