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Date: **9/2/11**

TECHNICAL NOTE

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MICE Spectrometer Solenoid:
Cryostat Heat Loads

1. Introduction

The following document summarizes the calculation results for the heat loads on the Spectrometer Solenoid radiation shield and on the cold mass. The resulting values are compared to those previously obtained by the magnet vendor Wang NMR. The heat conductivity integrals for AISI 304 stainless steel, as listed by NIST, are used both by Wang and in our calculations. The integrals for the glass-epoxy composite of the supports were those given by Wang in both cases. Our analysis of the MLI accounts for an expected level of imperfections, whereas Wang assumes no imperfections in the MLI.

2. Heat Load on 1st Stage Cu Plates and Shield (steady state)

The table on page 2 shows the comparison of heat load evaluations by Wang and by our calculations. The net results are not too different, apart from a few items that were not taken into account. The most notable omissions and differences are:

- We did not evaluate the current lead losses at full current, because the exact design of the Cu leads was not known. The values of Wang at full current are preferred.
- We did not calculate the heat load to the first stages due to the upper sections of the sleeve tubes; this is certainly not insignificant. Wang omits the load due to the single stage cooler sleeve in his calculations.
- Wang uses a measured value for the conduction through ideal MLI with 60 layers, whereas we have taken measured practical heat load values for 30 layers and added the expected imperfections that are based on the MLI geometry.

3. Heat Loads on Cold Mass (steady state)

The main differences are:

- Wang uses conduction through ideal MLI with no imperfections. We have also included an estimate for direct radiation from 300 K due to assumed gaps.
- For some reason Wang has a much higher value for the conduction through the cryocooler sleeves, whereas we used the measured value.
- Wang double-counts the contribution of the sleeve tubes, because he also subtracts their heat load from the cryocooler power.
- Wang puts the shield temperature at 80 K in his calculations, while we assumed 60 K. The latter is more realistic, if the heat loads to the Cu plates and shield sum up to no more than 150 W, which the second stages of the cryocoolers can absorb at well below 60 K. Similarly, we have assumed the heat sink points of the pipework and instrument wires to be at 60 K.

The table below lists and sums up our calculated heat loads and compares them to those of Wang. The calculations of the heat load into the cold mass (for the improved design) results in a total power of less than 4 watts, providing an adequate margin for a five cooler system (7.5 watts of cooling power at 4.2K). The thermal load on the radiation shield determines its temperature distribution during operation; if we take the higher value of each item in the table, the total heat load sums up to about 150 W, which is well within the total capacity of the first stages of the 5 two-stage cryocoolers + one single-stage cryocooler at less than 60 K. During the next cooldown of a Spectrometer Soleoid magnet, the temperature of the shield will be closely monitored in order to correlate its temperature to the heat load through the cold mass supports and into to the cold mass.

Heat Load Items	**Wang's result**	**LBNL result**	**Notes**
Shield and Cu plates			
	(W)	(W)	
Cu plates			
I-1 Cu leads	91.4	42.9	Wang: full current; LBNL: zero current
I-1. (i+ii) sleeves	17.7	0.0	Wang: single-stage sleeve missing; LBNL: not evaluated
Shield			
I-2. (i) Vent lines	3.7	1.5	Wang: shorter thermal length of vent lines
I-2. (ii) precool line	0.9	0.5	Wang: shorter thermal length
I-2. (iii) MLI	10.7	31.7	Wang: perfect MLI
I-2. (iv) shield supports	0.1	0.6	
I-2. (v) cold mass supports	6.4	6.4	
SUM (Shield + Cu plates)	**131.0**	**83.6**	
Cold mass at 4.2 K			
A) + B) HTS leads	0.800	0.870	at 6*300 A + 2*50 A, heat sink at 60K
C) 2 vent tubes	0.114	0.104	Heat sink at 60K
D) Precool line	0.046	0.097	TN: Heat sinked at 25 cm above LHe level, wall 0.5 mm
E) MLI	0.031	0.175	Wang: Ideal MLI, shield at 80K; LBNL: many imperfections, shield at 60K
Direct rad. from 300 K	0.000	0.500	Wang: not evaluated; LBNL: effective orifice area 10 cm^2
F) Instrument wires	0.036	0.050	
G) Cold mass suspension	0.308	0.188	Wang: heat sink at 80 K; LBNL: sink at 60K
H) Sleeve tubes (cryocoolers)	2.390	1.250	
SUM (Cold mass)	**3.725**	**3.234**	