Current-Leads Cooling for the Series-Connected Hybrid Magnets

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Introduction

Two Series-Connected Hybrid (SCH) magnets, one for the Helmholtz Zentrum Berlin (HZB) and one for the National High Magnetic Field Laboratory (NHMFL) are being developed at the NHMFL [1]. High temperature superconductor (HTS) current leads are to be used in both SCH magnets [2]. The heat load on the HTS section is thermally conducted to the cold end and is then removed by the supercritical helium at about 5 K. The cooling for the copper section of current leads is different for the two hybrid magnets. For the HZB SCH, the copper section is cooled with helium at 44 K and helium enters the current lead at the cold end of the Cu heat exchanger. For the NHMFL SCH, the copper section is cooled with liquid nitrogen (LN_2). Liquid nitrogen boils off in a self-demand mode at the LN_2 intercept section and cold nitrogen gas is then warmed up in the copper heat exchanger made of a pierced copper jelly roll. The LN_2 for the NHMFL SCH current leads is supplied to a buffer first, then it is supplied to cool the thermal intercepts of current leads. The level in the buffer is controlled by the LN_2 supply valve so that LN_2 level in the LN_2 interception is not less than 80% of the interception effective height. The pressure in the LN_2 bath is 1.1 bara and it corresponds to a temperature of 78.0 K. This configuration ensures the operation stability of the current leads, which is discussed below.

Results and Discussion

The LN_2 in the storage tank has a pressure of 3 bara and it is transferred to the LN_2 buffer through a throttling valve. The LN_2 buffer acts as a phase separator downstream of the throttling valve since there is a portion of 11% gas in the nitrogen due to the pressure drop. The level detector for the leads is installed in the buffer due to space constraints. The buffer and the LN_2 intercept are connected with two pipes: the “liquid pipe” connected to the bottom is for liquid nitrogen flow into the leads and the “gas pipe” connected to the top of the two vessels ensures that the level in the LN_2 intercept is the same as in the buffer. The gas flows out of the buffer through the “gas pipe”. The LN_2 buffer is installed very close to the leads in the same cryostat and the heat losses to the buffer and pipes are negligible compared with the heat loss at the thermal intercept and have no impact on the current leads operation. Figure 1 shows the calculated temperature profile of the heat exchanger section and LN_2 intercept. The case “No vapor” means that all the nitrogen flow in the heat exchanger originates in the boil off in the LN_2 intercept. The other case considered the 11% additional vapor portion in the nitrogen flow entering the intercept. The result shows the effect on the temperature profile is very minor. The LN_2 consumption for different vapor portions is also shown in the figure.

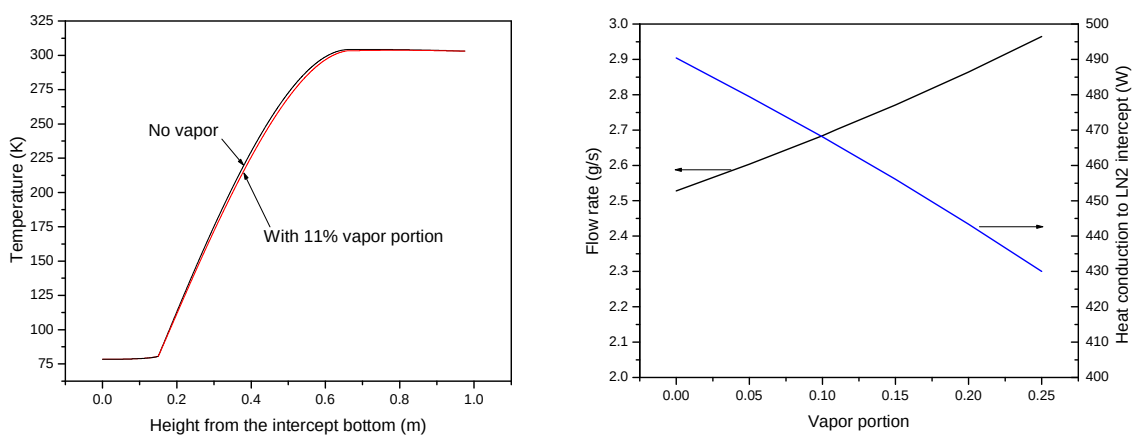

Figure 1. Temperature profile of the CLs (left) and LN_2 consumption for different vapor portion at full current (right).

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References

[1] Bird, M. D., *et al.*, *IEEE Trans. Appl. Supercond*. **19** (3), 1612-1616 (2009).
[2] Marshall, W. S., et al., *IEEE Trans. Appl. Supercond.* 23(3), 1051-8223 (2013).