Temperature distribution and heat flow at quench limit
Case of MB magnet immersed at helium bath at 4.5 K

The presented heat flow case in MB magnet coil (fig.1) is for a beam loss profile shown in figures 2 and 3. For this beam loss distribution ~50% of heat is loaded to the coil and ~50% to the cold bore. From the Network Model we obtain the temperatures, which are presented in fig. 1. In this case the temperature of the helium in the coil and in the channels is above the critical temperature of helium, hence helium is in the gaseous state. We suppose that the nucleate boiling is taking place only in free volume of the collars and yoke as well as between the laminations. We assume it is appropriate to put the heat reservoir in the model there.

In our models the volumes occupied by helium in the magnet coil are considered as narrow channels. Moreover these volumes should be considered as a semi-closed volumes, without "easy" direct link to the helium bath in the magnet cold mass.

The other important fact in the magnet design is related to the ground insulation in the helium channel around the cold bore. The ground insulation edges ("wings") are touching the cold bore insulation and are considered responsible for azimuthal segmentation of the channel around the cold bore. This effect reduces significantly convective heat flow.

In case of channels inside of the cable and μ-channels which are of the order of 0.2 mm and 0.07 mm respectively, a typical nucleate boiling flux becomes much lower than that for helium bath which is 10 000 W/m^2 [1]. The gaseous phase in the narrow channels is described by a constant heat transfer coefficient and is of the order of 70 W/m^2/K as extrapolated from [2]. The convective heat transfer in steady state mode is restricted to heat fluxes not greater than a few mW/cm^2 [3] as it is only relevant for large volumes. In case of helium inside the cable and in the μ-channels this mode is negligible. The nucleate boiling component is however valid for transient heat loads. The transient heat load case will be next step of model development and I would like to validate them with measurements as well.

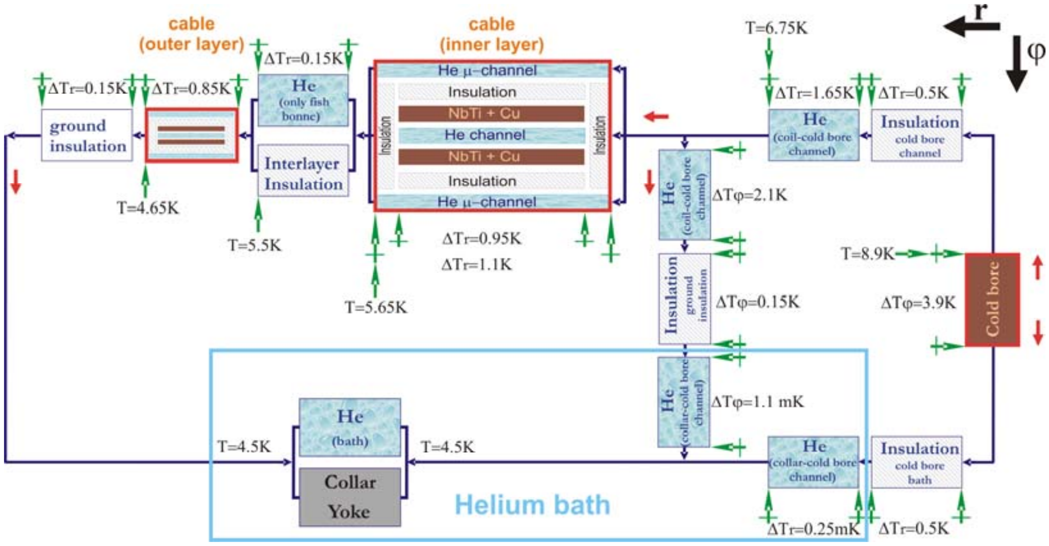

Fig. 1 MB magnet quench limit simulation – study case for heat transfer to liquid helium at 4.5 K.
Red boxes indicates heat load sources. Light blue box indicates the "nucleate boiling region"

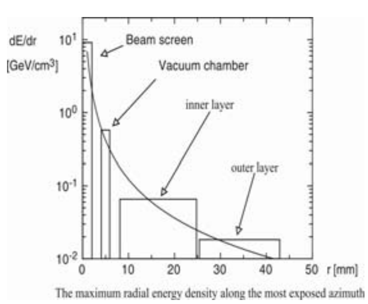

Fig. 2 Radial beam loss distribution

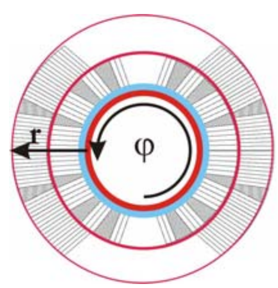

Fig. 3 Simulation of the radial beam loss distribution

[1] S.W. Van Sciver, Helium Cryogenics.

[2] M. Nishi et all., Boiling helium heat transfer characteristics in narrow cooling channel, IEEE TRANSACTIONS ON MAGNETICS, VOL. MAG-19, NO. 3, MAY 1983.

[3] C. Schmidt, Review of steady state and transient heat transfer in pool boiling helium I.