Advanced Hybrid Current Leads

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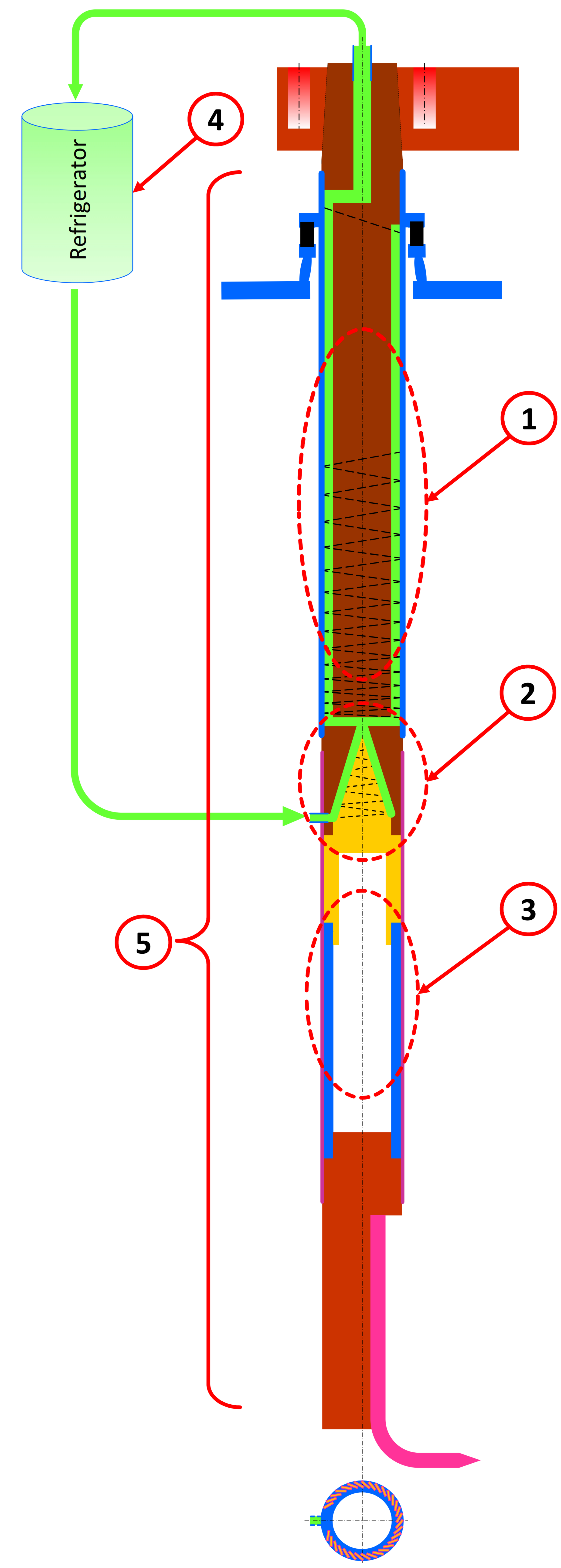
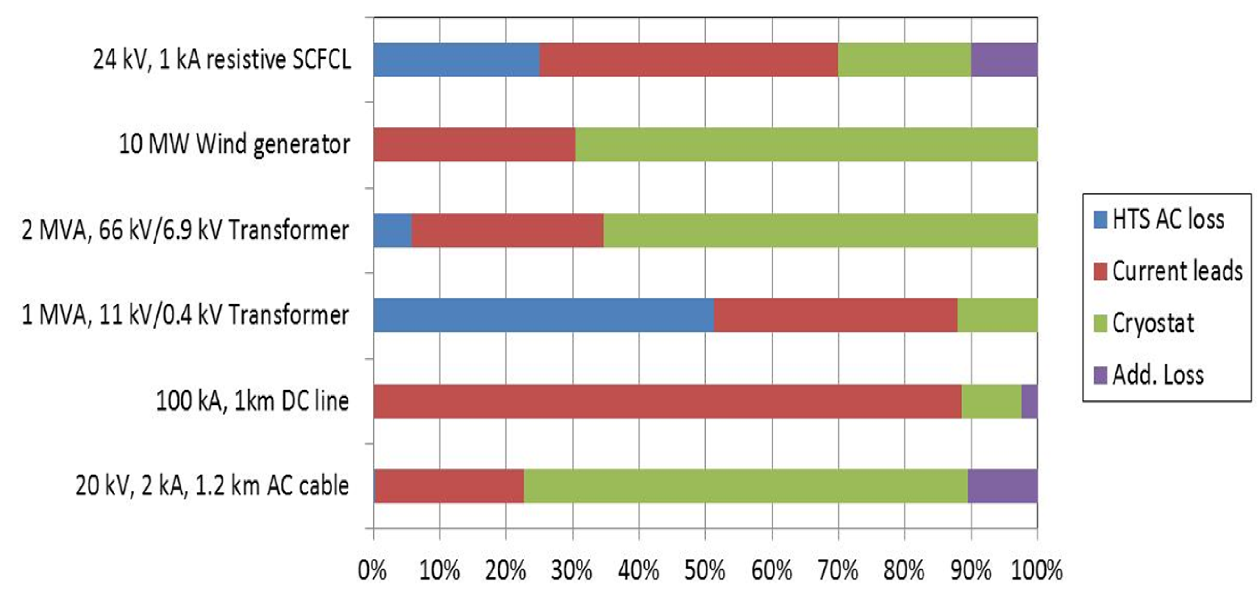
Introduction

Hybrid current leads consisting of a warm copper heat exchanger and a cold HTS sections have greatly reduced the refrigeration needs of many applications of superconductors. We have investigated whether it is possible to improve the presently used hybrid current leads. In our opinion improvements are possible by

1. Optimizing the geometry of the heat exchanger of the copper section to obtain a max. heat transfer with a min. of pressure drop of the coolant
2. Increasing the overlapping length between superconductor and copper for a more efficient use of the refrigerant
3. Using 2nd generation superconductors produced by thin film deposition
4. Using a coolant for the refrigerator, which is efficient in the region between 300 K and 70 K
5. Avoiding internal current transmitting joining surfaces by appropriate design and manufacturing technologies.



Importance of Cooling Cost of Current Leads



Besides the cryostat losses the current leads cooling are the largest „loss maker“. Thus there is a large motivation to further improve the technology of current leads.

Fundamental aspects of thermal load in HTS and Cryogenics
Prof. Dr.-Ing. Mathias Noe, Dr. Francesco Grilli
Institute for Technical Physics, Karlsruhe Institute of Technology
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1 Optimized Heat Exchanger

Best heat exchange is obtained, when the ratio NTU/NPH gets to a minimum. The main parameters influencing this is the geometry of the heat transfer surface and the Reynolds number of the flow. Optimal geometry forms a laminar flow between two parallel surfaces. Turbulence and separation of flow should be avoided; they cause pressure drop only w/o contributing to the heat transfer. So the proposed geometry is a helical grove with continuous increasing flow area machined into the copper rod. By adaptation of number of the parallel helical grooves, fin thickness and height and channel width the best possible heat exchanger will result.

2 Improved Transition Region

In the longer overlapping or transition region between copper and HTS the copper cross section is continuously reduced according to the decrease of the electric current. An additional cooling heat exchanger allows steadily lower temperatures in this transition region. This advanced design results in less Ohmic heat generation in a temperature region where cooling is most expensive. Model calculations based on a 10 kA current lead shows a potential reduction of the overall thermodynamic loss of more than 17 %. This is due to the smaller needed mass flow of the refrigerant which also may enter at a higher temperature.

3 2G HTS Superconductors

Until recently expensive 1st generation BSCCO HTS conductors were used. One had to save HTS material by choosing a lower temperature level in the current transition region between copper and HTS, typically 50 – 60 K. With the new and cheaper 2nd generation YBCO film deposited HTS conductors the transition temperature will rise to a higher level. Considering the specific characteristics of the 2nd generation HTS tapes which allows a current contacting from one side only, it is proposed to mill grooves under a certain angel into the copper—brass—stainless tube and solder two tapes back to back into these grooves.

4 Efficient Cooling

If one optimizes the current leads design for a minimum of coolant flow rate one should also optimise the production of the coolant. In most cases there will not be a specific refrigerator for the current leads only. One has to search for an efficient and cost effective production of 70 K refrigerant which is being warmed up to ambient temperature. Probably a Brayton refrigerator with several expansion stages between 300 K and 70 K may be the best choice. The side stream which is cooling the current lead copper section should not use the full pressure ratio of the refrigeration cycle. Therefore, a multi-stage compressor is of great value.

5 Avoiding Internal Section Joints

By introduction of appropriate design and manufacturing technologies combined with a sophisticated process sequence internal current carrying joining surfaces should reduced to a minimum. Further studies and prototype working will be needed for a proven stable manufacturing process.

Conclusions

Considering the proposed improvements, first estimations show a potential for remarkable reductions of the thermodynamic losses of more than 17 %. Also expected is a reduction of the costs due to the integrated design and less manufacturing steps.

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