WEKA Hybrid HTS Current Leads

Introduction

Superconducting magnets create very high magnetic fields for research projects in nuclear fusion as well as for accelerator systems. To establish such magnetic fields huge electrical currents are required. These currents are in the range of several 10,000 amperes and must be conducted from ambient temperature, at which they are generated, to the operating temperature of the magnets which is extremely low, typically around 4.4K. The connection between these two temperature levels is done with current leads. Together with EPFL CRPP, WEKA has developed hybrid current leads for fields of applications in the range of around 3 to 30kA.

Outstanding achievements

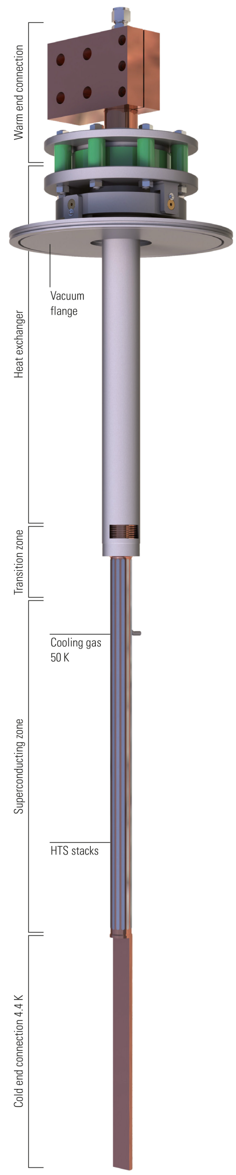
The focus of the development was set on optimizing the efficiency of the current leads to achieve a significant reduction of the refrigerant consumption. As a result, operating costs can be reduced by more than 10% compared to other solutions, while also having high functional reliability.

WEKA current leads are based on a hybrid design with a copper heat exchanger on the warm side and a High Temperature Superconductor (HTS) section on the cold side. The transition region is cooled by another upstream heat exchanger. Due to the ingenious design of these heat exchangers, highest heat transfer ratio can be achieved at lowest pressure drop. In contrast to metal-resistive structures, this design undergoes far less heat input and thus requires significantly less cooling power.

Key features

The upper resistive part of the current leads contains an integrated heat exchanger made out of copper, which is cooled by means of a cooling gas flow. While typically Helium at 50K input temperature is used, any other customer specific refrigerant in the range between 4 and 80K is possible as well. The heat exchanger is one of the core elements of a current lead. The geometry of the cooling channels must be designed so that a high degree of heat exchange is combined with a low pressure drop. This goal is achieved by geometry of parallel walls at low distance. In this way, deep and narrow channels are directly incorporated into the surface of the copper cylinder, which spiral around the solid core. The design principle allows for variation in depth and number of channels and wall width of the cooling ribs. The channel widths are continuously enlarged towards the warm end to reduce potential pressure drop. The heat exchanger may be extended from a single coil to a double or event triple helix to ensure higher volumetric flow into the warm part.

Special focus was put on the transition zone between the copper unit and the superconducting part of the current lead. Through the integration of another heat exchanger in a conical helix form, the contact temperature at the warm end of the HTS stack could be reduced with the temperature of the cooling fluid remaining unchanged.



With both the specific selection of the material and the sophisticated design of the two heat exchangers the required cooling flow can be reduced, which leads to a significant reduction of the operating cost.

The superconducting part consists of a stainless steel support with incorporated longitudinal grooves. HTS stacks of BSCCO2223 type are soldered into the grooves. This part of the current leads may be cooled either by heat conduction or also by means of a cooling gas flow. An adoption of the design for HTS 2nd generation can be implemented.

Performance Tests

The 10kA prototypes were tested by EPFL CRPP at PSI in Villingen, Switzerland both in standard and critical extreme situations. The expected performance could successfully be verified
In a follow-up project, WEKA customized, manufactured and delivered a pair of 25.7kA current leads to CEA Saclay, where they were installed in a JT-60SA test rig for magnet testing. Also these current leads fulfilled the specified performance parameters. The required cooling fluid between the 300K and the 50K level of 1.8g/s at 50K and 27.5kA could successfully be verified and the contact resistance between the current leads and the feeders at the cold end was not higher than the specified 7nΩ.

Conclusion

WEKA hybrid HTS current leads have an excellent performance compared to traditional designs. They offer a high degree of customization for each individual application and are industrially manufactured with stable processes and extensive testing. With the launch of current leads, WEKA will continue to be a competent partner in the market of cryogenic engineering and manufacturing of cryogenic components.

Product range

WEKA current leads consist of the following main components:

- warm end connection
- heat exchanger with vacuum flange
- transition zone
- superconducting zone
- cold end connection at 4.4K

The present design of WEKA current leads covers a range from 3 to 30kA. Typically it is cooled with Helium gas at 50K, but a customer specific adaptation to other refrigerants in the range of 4 to 80K is possible as well. The cooling fluid consumption as well as the transfer resistance at the cold end is very low and the warm and cold mechanical contact connections or the detailed design can be customized to the specific application. Several options like voltage and temperature measurement points, voltage breaker for the cooling gas connection or Paschen insulation are possible as well. The WEKA current lead design is especially lightweight and slim, but still very robust in sense of mechanical decoupling at the warm end connection.

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