§35. Development of Current Leads Combined with the Pulse-Tube Cryocooler

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In operating usual large superconducting magnets such as LHD coils, the high current of 10 kA class is supplied through current leads into the cryogenic region from a power supply located at room temperature. The heat leak from the current leads causes a large load of the refrigeration system. Therefore it is necessary to reduce the heat leak from the current leads with a minimum refrigeration load for a low cost and stable operation of the superconducting magnet system. Optimization methods have been studied for designing gas cooled current leads with copper conductor, and the heat leak into the liquid helium region is evaluated to be 1 W/kA for the optimum gas cooled current leads. Several types of high temperature superconducting (HTS) current leads were developed for further reduction of the heat leak. The HTS conductor is employed in the HTS current leads in the temperature region below ~ 50 K , while the copper conductor feeds the current from a room temperature to the HTS conductor. Although a large reduction in the heat leak has been demonstrated in the operation of the HTS current leads, large heat load to the refrigeration system is still generated in the conventional copper conductor part.

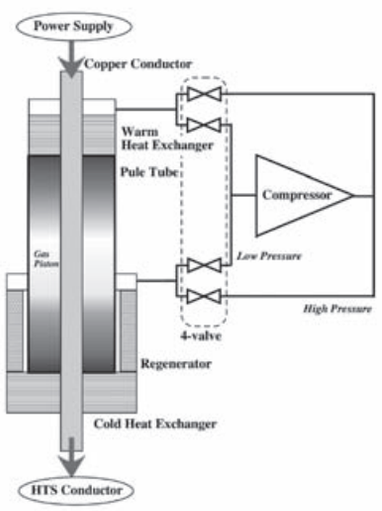

Fig. 1 Concept of the pulse tube current lead.

In this work, we apply advantageous characteristics of a pulse-tube cryocooler to the copper conductor region of the 3kA HTS lead system for a reduction of the refrigeration load caused by with a compact structure.

Since the thermoacoustic effect is utilized for operation, the pulse-tube cryocooler consists of a pulse tube, a regenerator and warm-and cold heat exchangers without moving element in the cryogenic region. Fig. 1 shows a schematic drawing of a pulse-tube current lead. The copper-rod conductor is concentrically inserted into the pulse tube. In Fig. 1, geometrical dimension of the copper conductor was optimized for supplying current of 3 kA to a temperature of 80 K in the adiabatic condition. The heat leak through the copper rod is estimated to be 200 W at the cold end of 80 K. In this work, the inner volume of the pulse tube is optimized to be 650 cm^3 by employing numerical analysis of the dynamics of a virtual gas piston in the pulse tube. The cooling power is estimated to be 196 W at 80 K.

A group of Maekawa developed a prototype of 2 kA pulse-tube current lead system. In this work, we carried out measurements of the temperature at the cold end of the conductor rod in the operating test of the prototype of the 2 kA pulse-tube current lead. For constructing a reliable numerical design code of the pulse tube current lead, temperature profiles along the conductor rod were estimated for several operation currents by solving a general heat conduction equation with using experimental data of the cold end temperatures.