§9. Estimation of Current Leads in Large Superconducting Systems

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Fusion energy is expected as a new clean energy without CO_2 emission. For the nuclear fusion, plasma should be confined by large superconducting magnets, for which large current is fed by huge bus lines. For such large current transmission, superconducting distribution systems seem to be effective. And also, future large energy generation by fusion systems would require highly effective transmission systems for actual use of electric power. Thus, we should develop high performance superconducting systems with low thermal loss. In this report, we discuss about the thermal performance of terminals in 200 m-class superconducting direct current (DC) transmission test device of CASER-2[1]. The temperature distribution and current dependence of the performance of the Peltier current lead (PCL) are then discussed.[2].

During the cooling operation, a large temperature difference between the ends of both thermoelectric elements in the PCL was observed as shown in Figs. 1 and 2. The temperature gradient on the Cu current lead in Fig. 1 corresponds to the heat leak at the low-temperature end. Fig. 2 is for n-type elements set in terminal A. For the case of no current (I = 0 A), the average temperature difference is 55 K; however, the data in Fig. 2 show a large scatter. When current is applied to the system, the temperature difference increases because of the Peltier effect, and a large temperature difference at I = 1.2 kA was obtained, corresponding to a small heat leak, where the temperature difference on the Cu current lead was relatively small. The situation was similar for p-type elements. A large temperature difference was observed during the experiment, which increased with increasing current. The typical scattering width (standard deviation) of the temperature difference is about 8.5 K for p-type elements.

A large temperature difference was also observed in the fourth cool-down. Fig. 3 shows the temperature difference at p-type elements set in terminal B, which is the improved version of the PCL. The average temperature difference is 58 K, and the scatter of the temperature difference was greatly reduced (standard deviation of temperature differences is 1.9 K). When energized, the temperature difference increased with current, improving thermal insulation. The stability during the operation was also greatly improved with the improved PCL. On the other hand, the temperature difference increases with increasing current in the measured range from 0 A to 720 A. The standard deviations of the temperature difference are also small. Of course, the temperature difference should decrease for a larger feeding current, as the current leads have optimum shape factors at the defined operating current. However, the scatter of the temperature difference may be small.

Thus, during the cool-down tests with current energization, large temperature differences were observed across both thermoelectric elements of the PCL. Therefore, we successfully insulated and reduced the heat leak at the current terminals. In the fourth cool-down, we improved PCL elements with a p-type at terminal B and compared the performance of terminals. Several improvements such as the balance of resistance of the PCLs can enhance the stability and performance of superconducting systems such as CASER-2. This approach contributes to the realization of applied superconducting systems ranging from small- to large-scale applications.

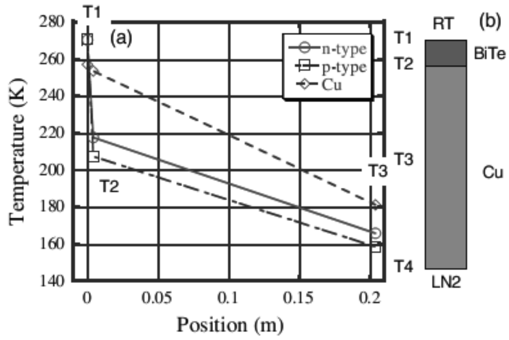

Fig. 1. (a) Temperature distribution along the current lead. Values for a PCL with n- and p-types, and also a copper current lead, are plotted. (b) Measurement positions; the position of the top of the current lead is set as zero.

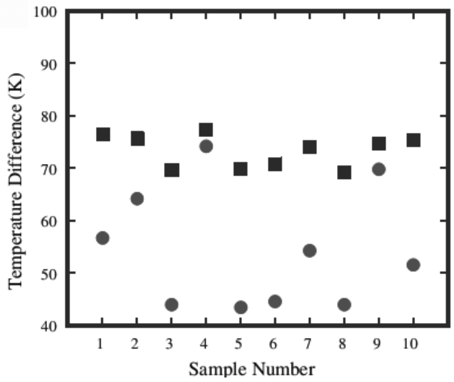

Fig. 2. Temperature difference across thermoelectric elements on the PCL. Filled circles are for a temperature difference without a current, and filled squares for that with a total current of 1.2 kA.

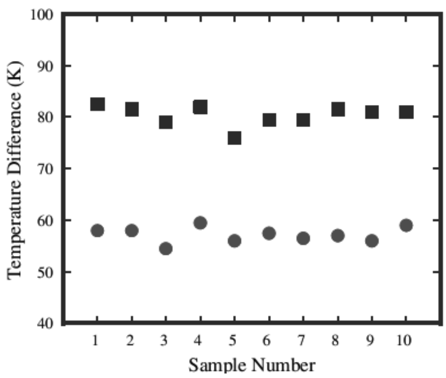

Fig. 3 Temperature difference across thermoelectric elements on the new PCL. Filled circles are for a temperature difference without a current, and filled squares for that with a total current of 720 A.

1) S. Yamaguchi *et al.*: AIP Conf. Proc. **1434** (2012) 1959.
2) T. Kawahara *et al.*: J. Electron. Mater. **42** (2013) 2337.