2K-GM/JT 冷凍機の開発 - 冷凍試験結果 -

Development of 2K-GM/JT Refrigerator - Testing -

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1. Introduction

A high field magnet needs a cooling temperature around 2 K to get higher critical current for superconducting wire. We have developed a 2K cryocooler with sufficient cooling capacities for magnet cooling.

2. System Design

A JT/GM cooling cycle was adopted for 2K cryocooler. The JT circuit is cooled at 60 K and 10 K by a two-stage GM cryocooler and three recuperative heat exchangers. After going through the third heat exchanger, the high-pressure helium gas expands to the low pressure at a JT valve. The low pressure for the JT circuit corresponds to a saturation pressure of a cooling temperature. To obtain 1.8 K with helium 4 a low pressure of 1.6 kPa is required.

The critical design of the cold head is the recuperative heat exchanger, which has a low pressure drop at low pressure path and a high thermal efficiency. A heat exchanger filled with small spheres in a low pressure path was developed [1]. All copper spheres and the copper tube were thermally bonded.

The low pressure path was exhausted by a Roots vacuum pump combined with a rotary vacuum pump in series. The exhaust port of the rotary pump was connected in series to a compressor. Input power for the GM/JT compressor, the Roots vacuum pump and the rotary vacuum pump were 5.1 kW, 1.5 kW and 2.2 kW respectively. Then, total input power for the 2K GM/JT cryocooler was 8.8 kW.

3. Experimental Results

Cooling capacities for the 2K GM/JT cryocooler were obtained by changing JT high pressure and mass flow rate for the JT circuit. Figure 1 shows cooling capacities with JT high pressure of 0.7, 0.9 and 1.0 MPa. The cooling capacity with 0.9 MPa JT high pressure shows the largest cooling capacity at every temperature. A cooling capacity of 0.6 W at 1.80 K or 1.85 W at 1.98 K was obtained.

Figure 2 shows cooling capacities at 1.81 K against JT high pressure. Mass flow rate for the JT circuit was almost constant as 4.56×10^{-2} g/sec. The maximum cooling capacity of 0.68 W was obtained with 0.7 MPa JT high pressure. The values of $W_{JTComp}/Q_{1.81K}$ were also plotted in Fig. 2. The optimized pressure is 0.7 MPa.

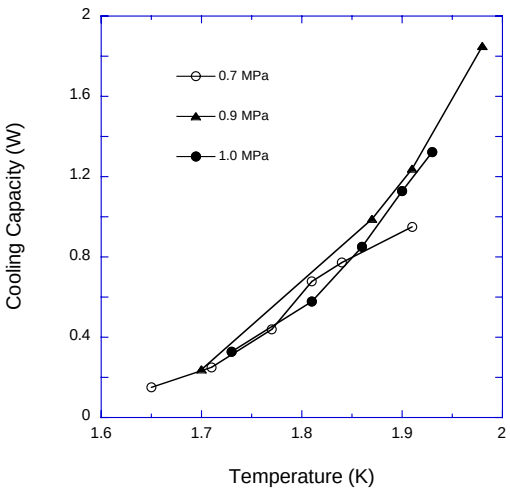

Fig. 1 Cooling Capacities for 2K Cryocooler.

The figure of merit (FOM) for this 2 K GM/JT cryocooler was plotted in Fig.3 to compare with the other cryocoolers. The efficiency for the 2K GM/JT cryocooler of this work is higher than those for 4K cryocoolers and 2K cryocoolers of previous works [2, 3].

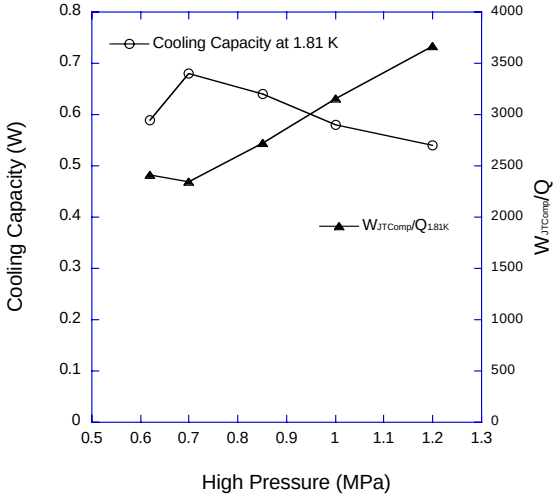

Fig. 2 Relation between Cooling Capacity and High Pressure in JT Circuit and Optimization of High Pressure.

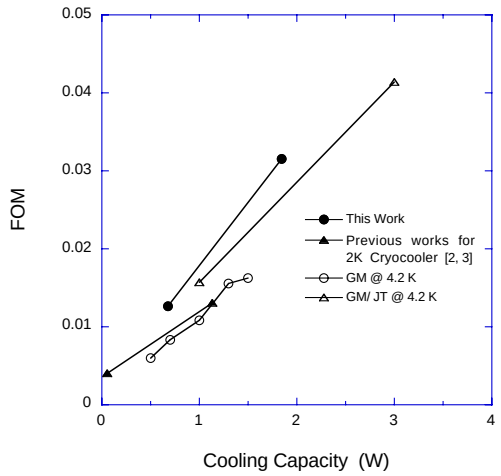

Fig. 3 FOM Values for 2K Cryocoolers and 4 K Cryocoolers.

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