# Development of a Cooling System for High-Temperature Superconducting Traction Transformer for Railway Rolling Stocks

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Research and development work is in hand for a high-capacity pulse-tube cryocooler that is at the heart of a cooling system of superconducting traction transformers that supports an overhead line voltage of 25 kV on the Shinkansen (bullet train) lines. The requirements in the specification of the cryocooler provide for a cooling capacity of 1 kW or more at a temperature of 65 K, percent Carnot of 18% or more (Th=300 K). The development challenge to meet this specification is to reduce the weight of Shinkansen vehicles, the weight reduction being achieved by applying superconductivity to the coils of traction transformers which are some of the heaviest items of equipment on the vehicle. Regarding normal oil-cooled traction transformers that are currently mounted on Shinkansen trains, those mounted on the N700 series since April 2008 are the lightest design to date, with a mass-to-capacity ratio of 0.69. If the mass-to-capacity ratio is even lower than this value, the advantages of applying superconductivity to the coils will be achieved.
In the design of superconducting traction transformers, we have studied electric currents that can be expected to pass through wires, and masses of iron cores. As a result, provided that the AC loss becomes 1 kW or less, assuming capacity to be 4 MVA, there is a prospect that superconducting traction transformers offer an advantage over normal traction transformers in terms of their mass-to-capacity ratio, even if the mass of the cooling equipment for generating subcooled liquid nitrogen to replace the oil-cooling is added. Thus, the development of a small high-capacity cryocooler has become necessary.
The reason for selecting a pulse tube cryocooler is the belief that it will be easy to re-use the system based on the fact that on a natural circulation cooling system that is in contact with the pin pole type heat exchanger at the cold head of the GM cryocooler, absorption of small-scale head loads has been verified.
Furthermore, a reduction in the weight of the cryocooler can be expected as there is no displacer made of Bakelite.
Figure 1 illustrates a schematic diagram of the cooling system using a simplified pulse-tube cryocooler.
A prototype pulse-tube cryocooler that used an active-buffer for phase control achieved a cooling capacity of 1.19 kW at a temperature of 65 K, and percent Carnot of about 8.6%. The on-off valves between the compressor and the cryocooler, between the cryocooler and the active-buffer are not dedicated rotary valves, but are replaced by several electromagnetic valves connected in parallel for the purpose of the performance evaluation test.
In subsequent improvements, as the result that we have performed change of regenerator material configuration meshes, improvement in gas conductance (increase in the Cv values of electromagnetic valves, increase in the quantity of electromagnetic valves) in the above-mentioned circuit, the addition of a manifold buffer tank to the compressor high/low pressure circuit,
In subsequent improvements, we changed the regenerator material configuration meshes, improved gas conductance (increased the Cv values of electromagnetic valves and increased the quantity of electromagnetic valves) in the above-mentioned circuit, and added a manifold buffer tank to the compressor high/low pressure circuit. As a result, we were able to raise the percent Carnot up to about 13.4% without deterioration in the cooling capacity.
Figure 2 shows the enhancement of the percent Carnot. Figure 3 is a real example of the pulse-tube cryocooler.
As a result of our work, we have confirmed that it is possible to meet fully the initial requirements specification by optimum design of the dedicated rotary valves.

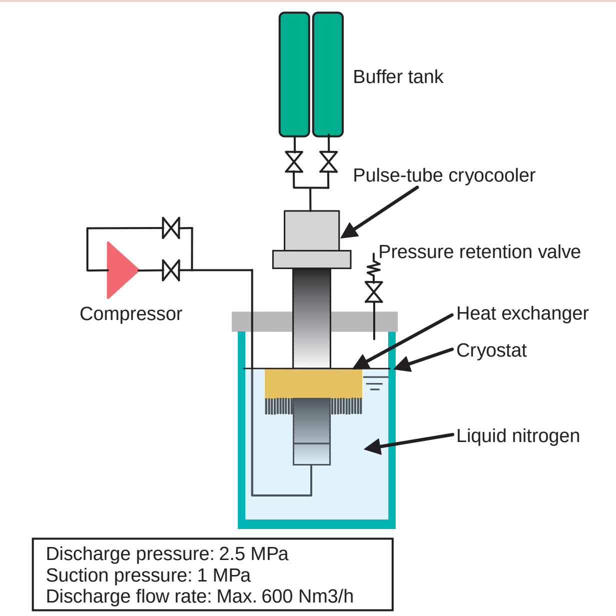


Fig. 1 Cooling system by pulse-tube cryocooler

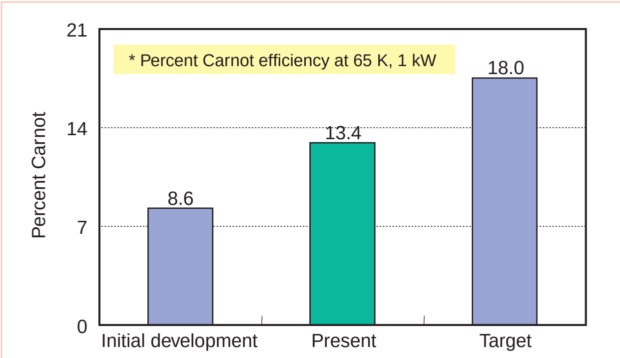


Fig. 2 Transition of percent Carnot

Fig. 3 Practical version of a pulse-tube cryocooler for a traction transformer