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Heat Balance of Supercritical Carbon Dioxide Power Cycles for Thermal Energy Storage System

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Introduction

· As the proportion of the new renewable energy increases, the intermittency and volatility of power generation increases, and in order to flexibly respond to such fluctuations, the necessity for the large-capacity energy storage capability of storing and supplying power are increasing.

· The thermal energy storage systems are considered a promising alternative due to their strength such as relatively few installation restrictions, eco-friendly, long-them energy storage, long life, and economical efficiency.

· The sodium as a working fluid has a wide operating temperature range, so it is highly usable. Also, the heat transfer coefficient is very large, therefore, the size of the heat exchange device can be minimized. In addition, there is an advantage of increasing the energy storage density by operating a large temperature difference between the hot tank and cold tank.

· Increasing temperature difference between the hot and cold tanks is very challenging to several sCO2 cycle options such as the recompression cycle, since the operating temperature of heater of the recompression cycle is limited by the outlet temperature of the recuperators.

In this study, the efficiency of the cascade cycle and the partial heating cycle was compared to find an option of a supercritical CO2 brayton cycle suitable for application to a large temperature range of a thermal energy storage device.

Cycle Design Conditions and Constraints

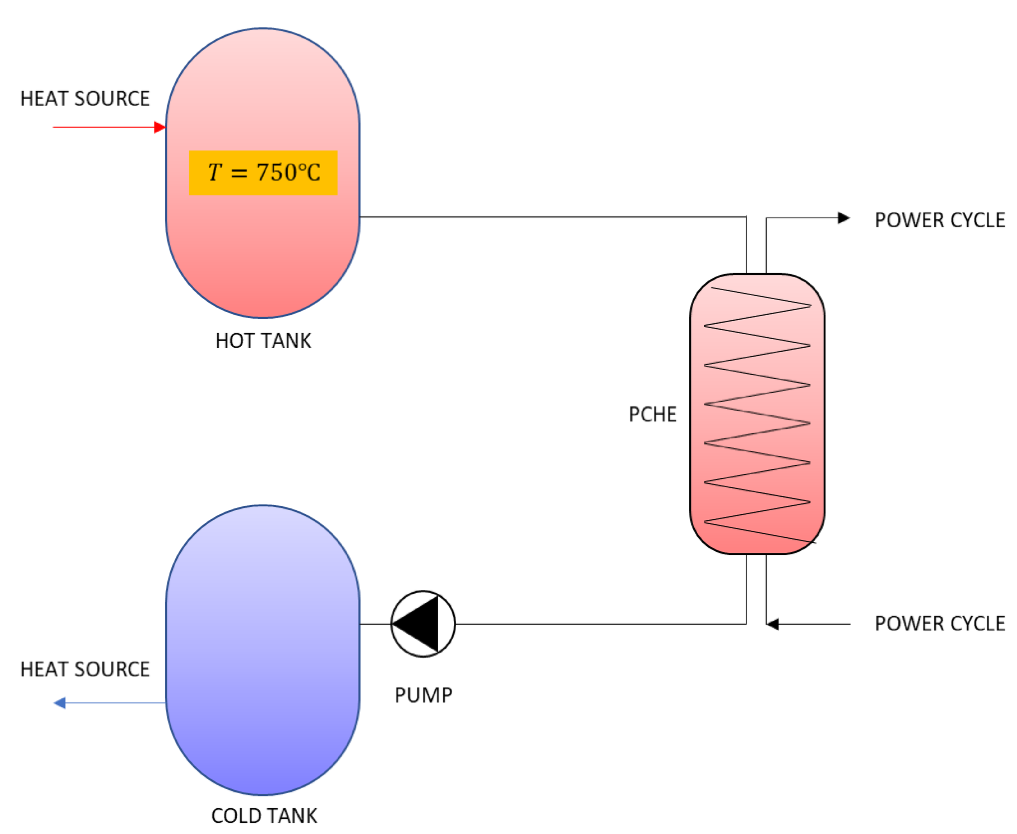

Fig. 1. The schematic diagram of two tank thermal energy storage system

Table I: Design constraints for supercritical CO2 brayton cycles

Compressor inlet condition	32℃, 7.6 MPa
Maximum pressure	30 MPa
Heat exchanger effectiveness	< 95%
Compressor efficiency	88%
Turbine efficiency	92%

- The heat storage capacity of the thermal energy storage system is 1 GWht and the rated output is 100 MWth

- The compressor inlet condition was assumed to be cooled to the critical point of 32℃ and 7.6 MPa in the cooler.

- The maximum pressure was set to 30 MPa or less.

- The effectiveness of the heat exchanger is more than 95%, the cost of the heat exchanger increases rapidly, so it was limited to less than 95%.

- Compressor and turbine efficiencies were assumed to be 88% and 92%, respectively, as typical efficiencies of commercial products.

- In thermal equilibrium, the effect of pressure change in other equipment other than the turbine and compressor was neglected.

Cascade Cycle

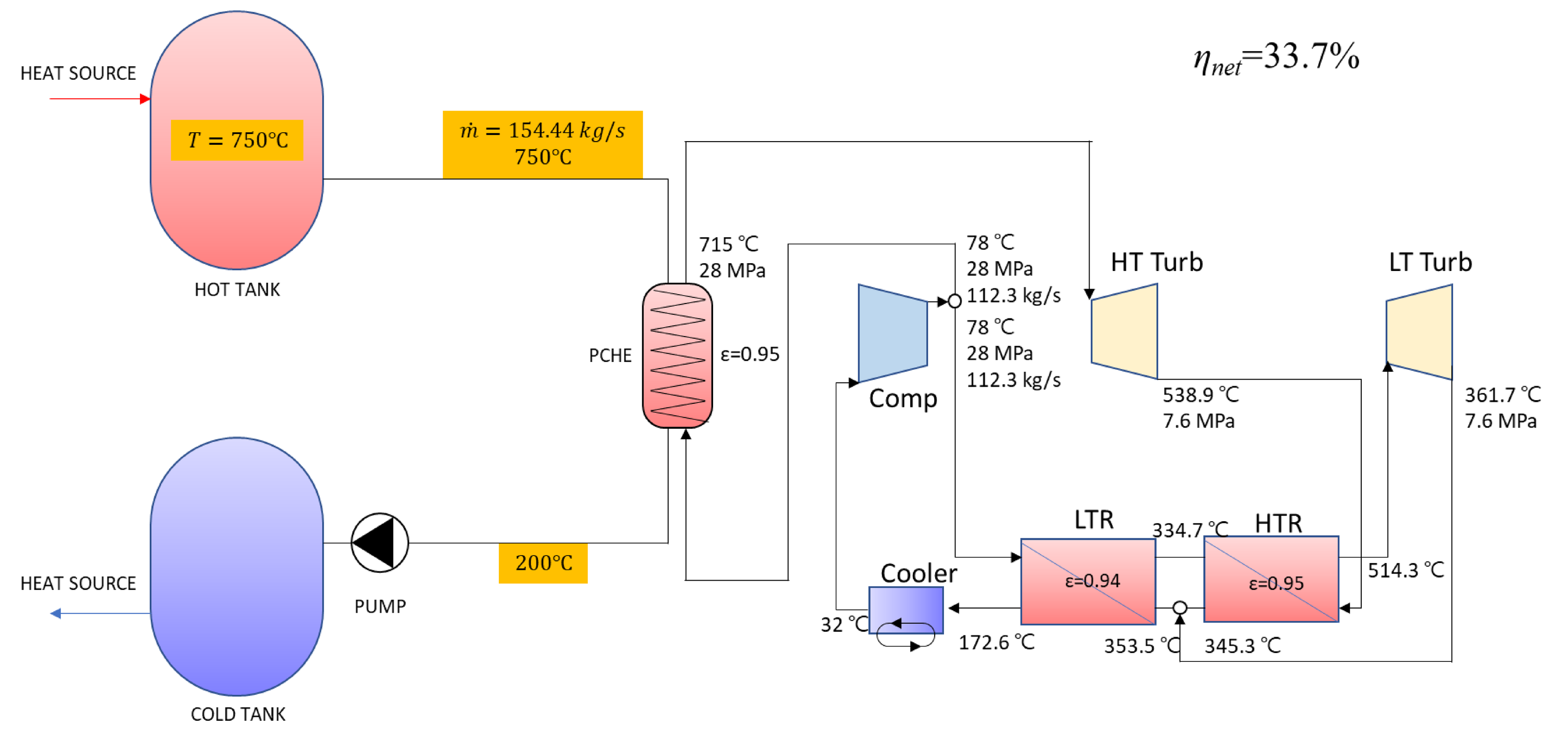

Fig. 2. Heat balance of Cascade cycle for thermal energy storage system

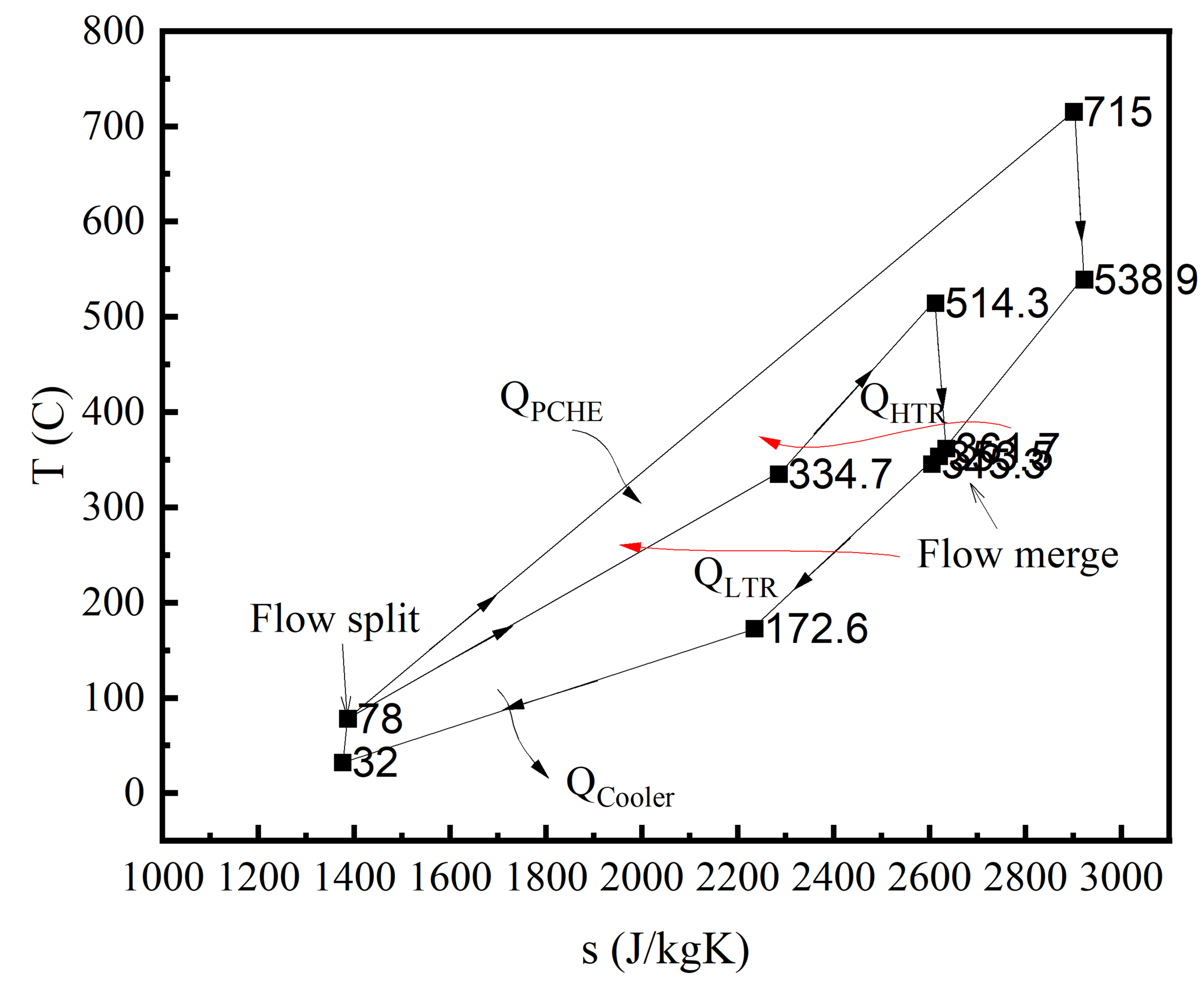

Fig. 3. T-s diagram of Cascade cycle for thermal energy storage system

Partial Heating Cycle

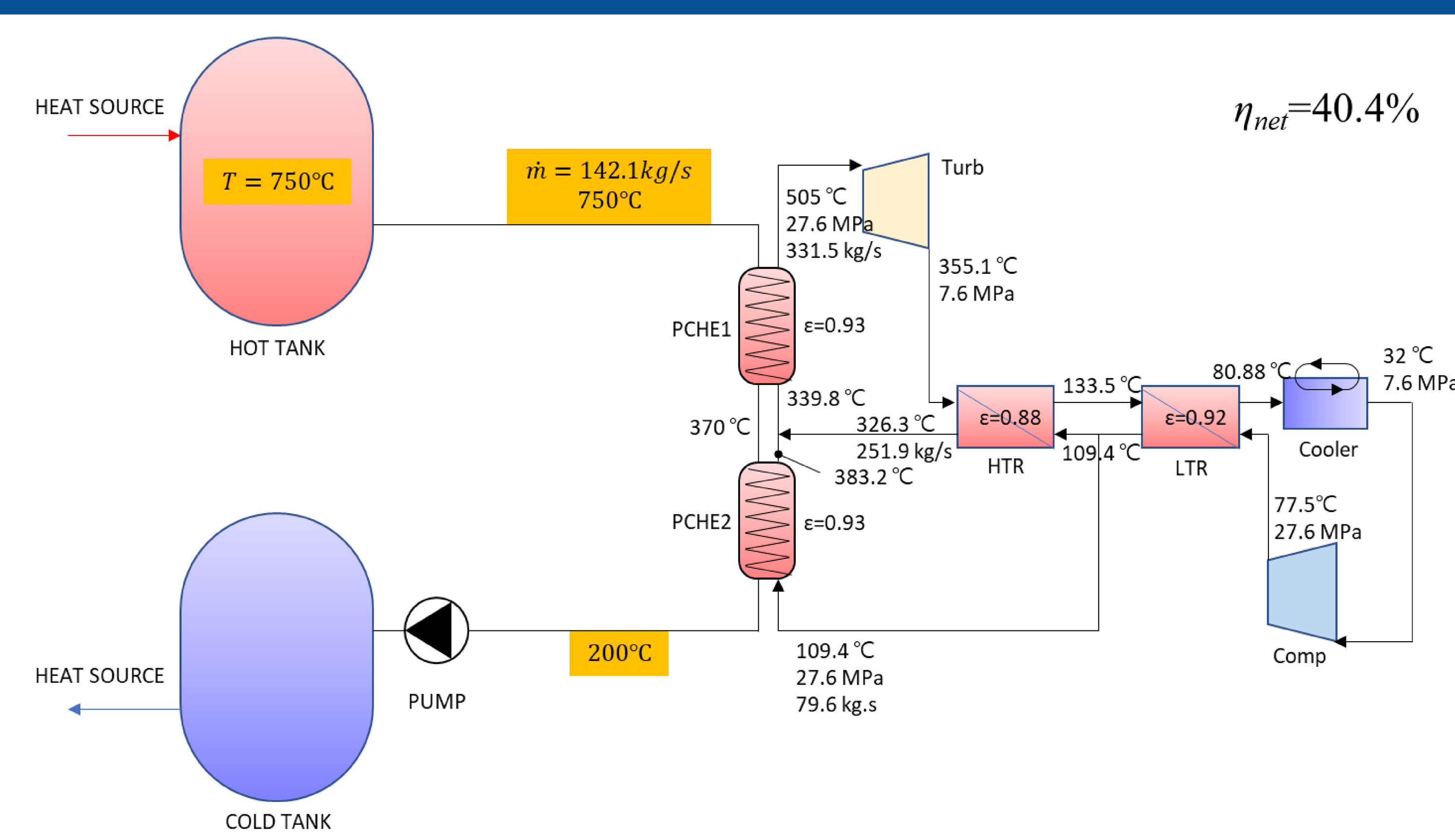

Fig. 4. Heat balance of Partial heating cycle for thermal energy storage system.

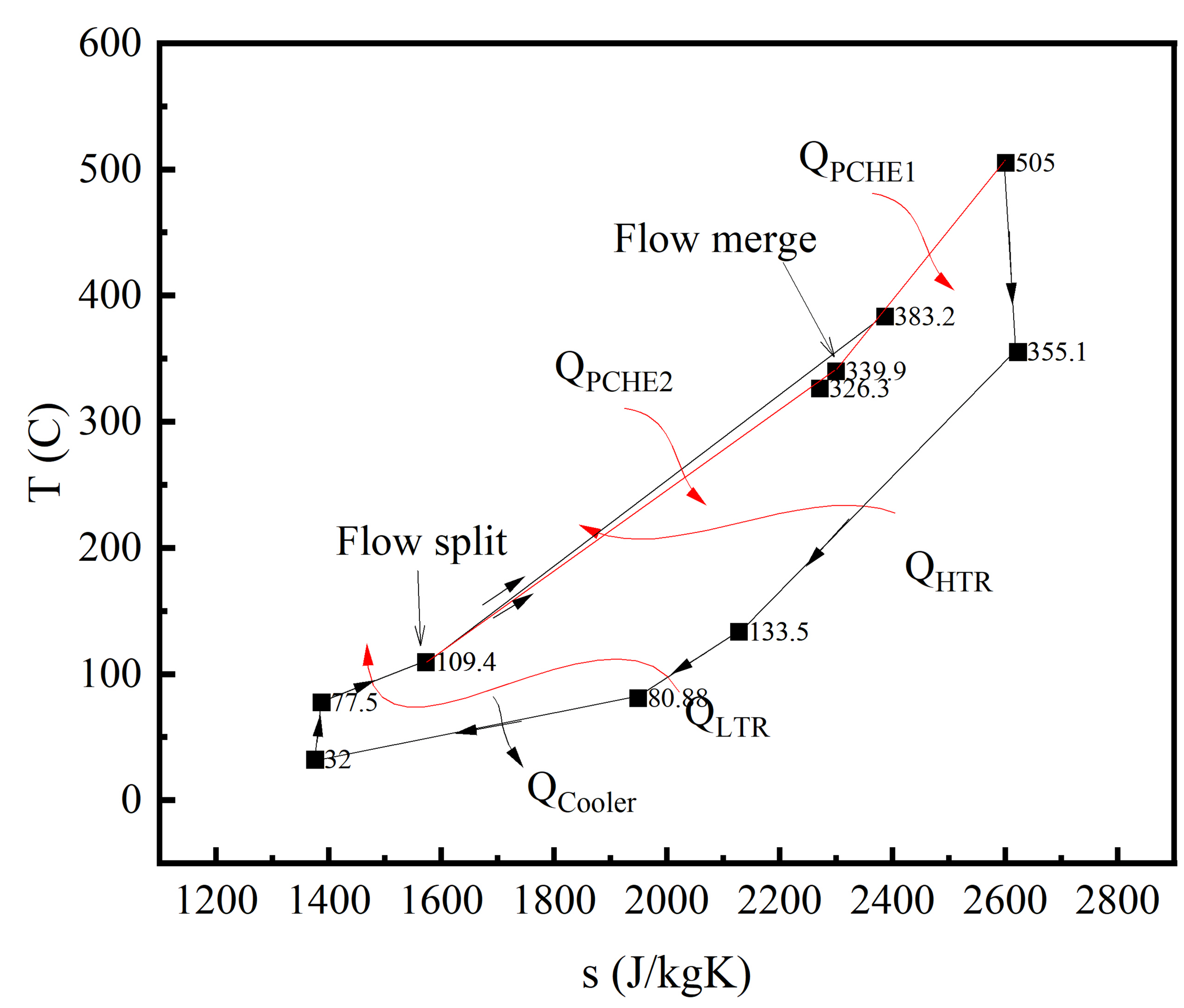

Fig. 5. T-s diagram of Partial heating cycle for thermal energy storage system.

Conclusions

· The efficiency of the cascade cycle and the partial heating cycle was compared to find an option of a supercritical CO2 brayton cycle suitable for application to a large temperature range of a thermal energy storage system

· As a result of the thermal equilibrium calculation, the efficiency of the partial heating cycle was 40.4%, which was higher than the efficiency of the cascade cycle, 33.7%.