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A Sensitivity Study of Compressed CO_2 Energy Storage with High Temperature TES

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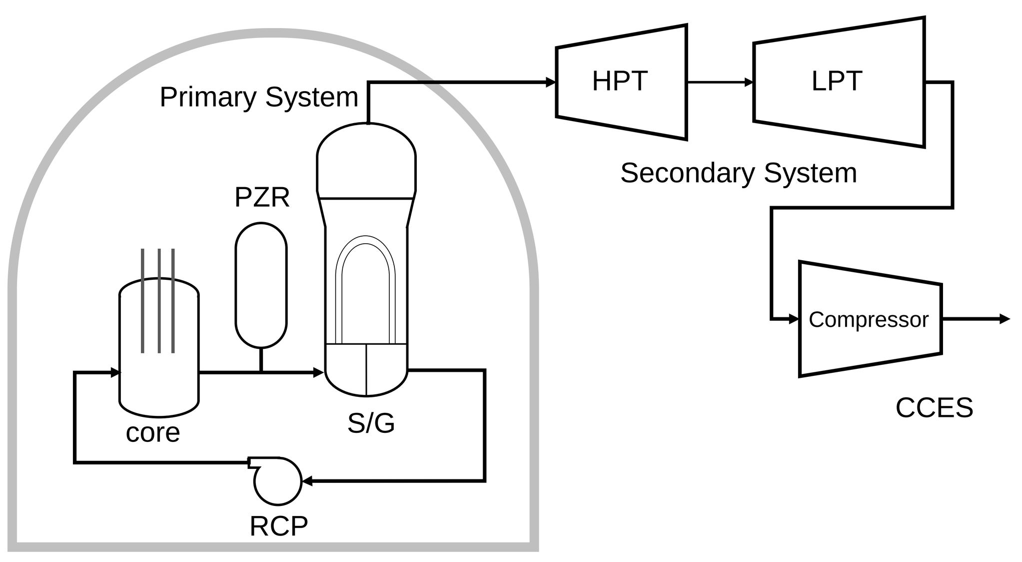
Introduction

- ✓ As the demand for electricity increases, the introduction of Energy Storage Systems (ESS) can alleviate these problems.
- ✓ Compressed CO_2 energy storage (CCES), which uses carbon dioxide as a working fluid and stores it in a pressure tank.
- ✓ Using Thermal Energy Storage (TES) in CCES enables CO_2 to be stored higher density. Therefore, the size of pressure tank can be reduced, which can reduce the overall size of CCES.
- ✓ It is expected that CCES could be applied to nuclear power plants as a large-capacity energy storage system.



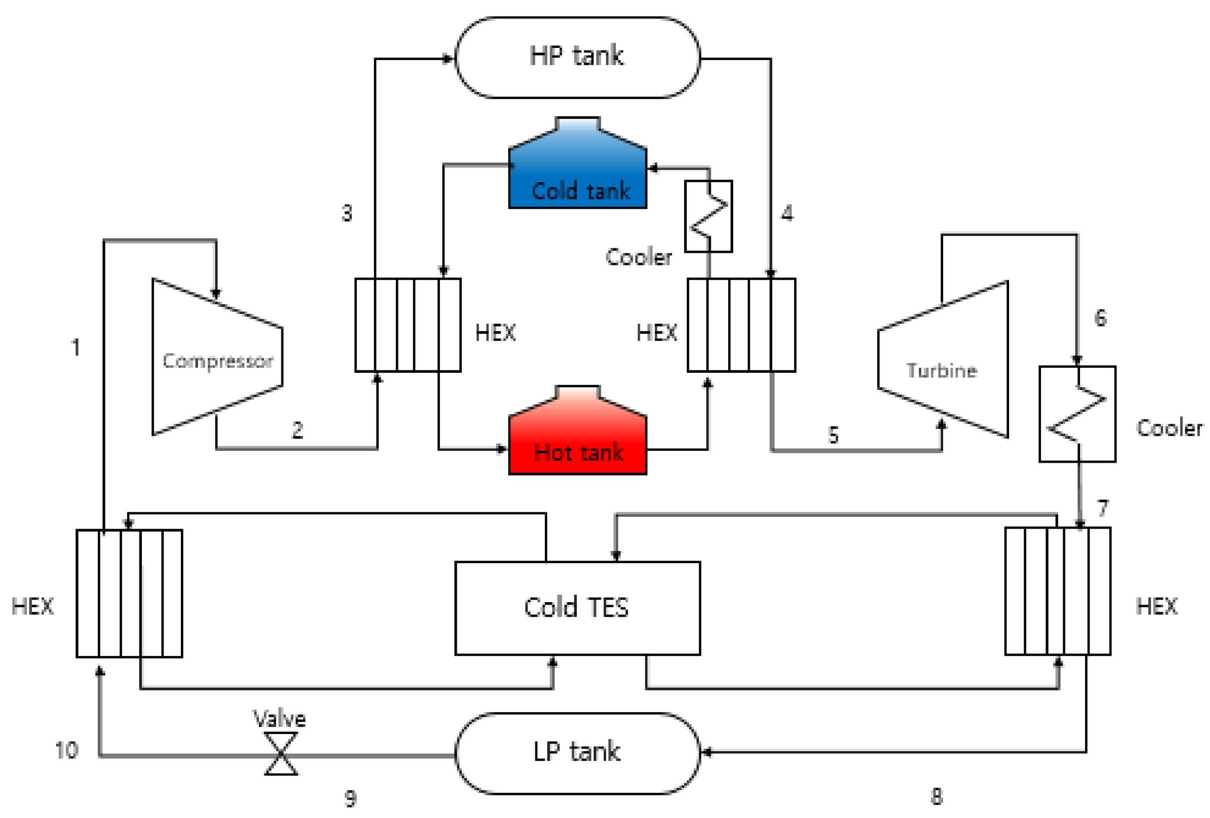
Schematic diagram of CCES integrated nuclear reactor

System Description

• Assumptions

1) The CO_2 tanks and the TES tanks have the same temperature, pressure, and properties at the inlet and outlet, respectively.
2) There is no pressure drop in the pipes, cooler and heat exchangers.
3) The turbine and compressor have constant isentropic efficiencies, respectively.

• Layout of CCES



Schematic of CCES

• TES

- ✓ Therminol 66 is used for the material of TES.
- ✓ The specific heat capacity of therminol 66 at 1bar

$$c_p = 3.313 \times 10^{-3}(T - 273.15) + 8.970785 \times 10^{-7}(T - 273.15)^2 + 1.496005 \; [kJ/kg \cdot K]$$

• Heat Exchanger

The effectiveness ε is defined, $\varepsilon = \frac{q}{q_{max}}$

q_{max} of counterflow heat exchanger

$$q_{max} = C_{min}(T_{hot,inlet} - T_{cold,inlet})$$

Result and Discussion

• System Parameters

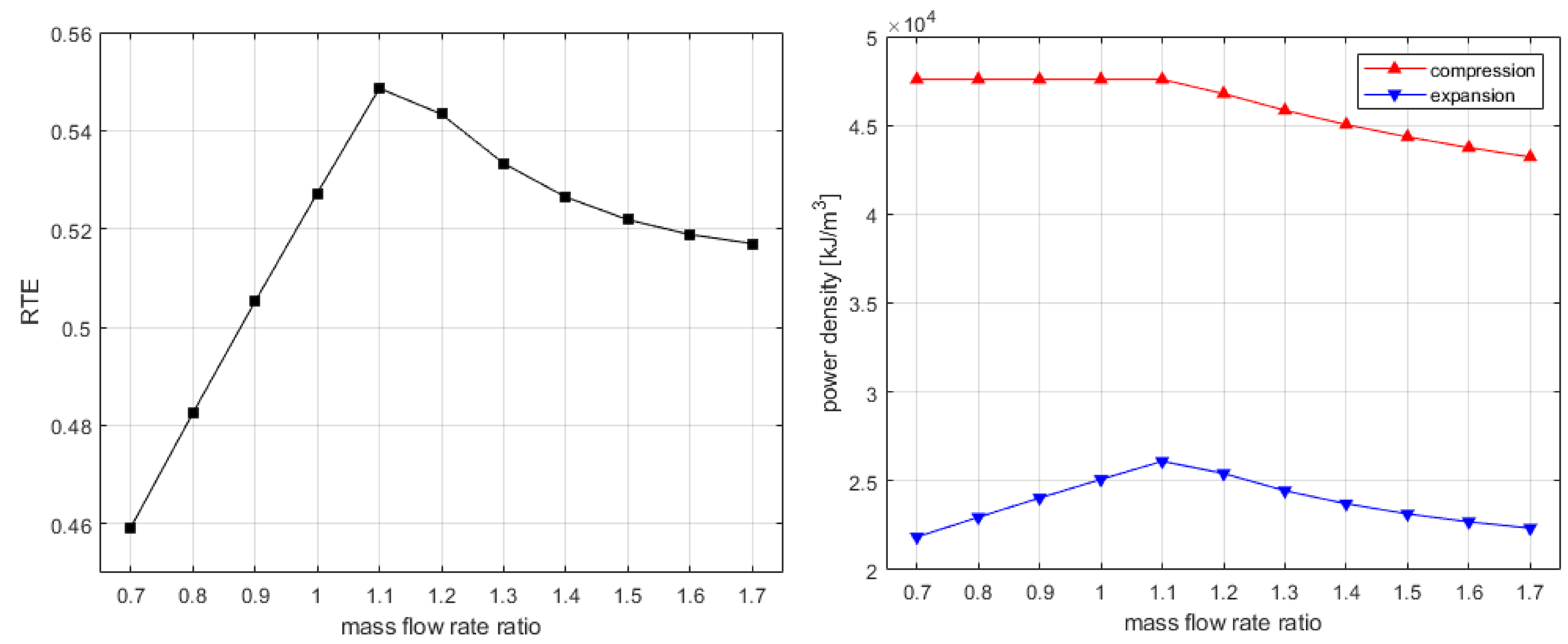
Parameters	Value
Compressor isentropic efficiency (%)	80
Turbine isentropic efficiency (%)	85
Inlet pressure of HPT (MPa)	30
Outlet pressure of LPT (MPa)	3.26
Outlet temperature of LPT (℃)	-2.5
Outlet pressure of turbine (MPa)	5.457
Minimum temperature approach in HEXs (℃)	5
Maximum effectiveness of heat exchanger	0.9
Outlet temperature of cooler (℃)	25
TES mass flow rate (kg/s)	1

• Definition of RTE and Power density

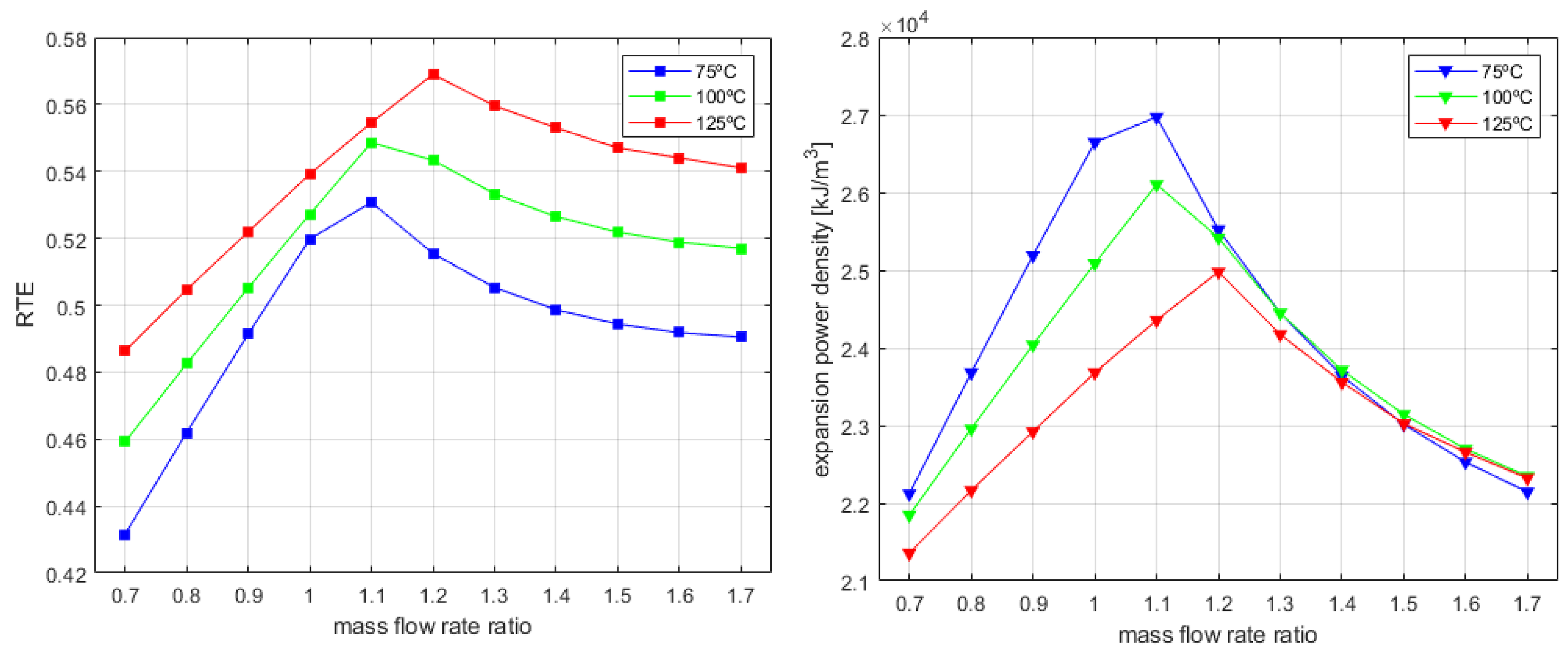
$$RTE = \frac{Expansion\ work}{Compression\ work}$$

$$Power\ density = \frac{Expansion\ or\ Compression\ work}{Volumes\ of\ HPT\ and\ LPT}$$

(CO_2 mass flow rate ratio) = $\dot{m}_{co2}$ / $\dot{m}_{tes}$



Effect of mass ratio on RTE and power density



Effect of cold tank temperature on RTE and expansion power density

- ✓ Both RTE and power density have maximum values at specific mass flow rate ratio. The higher temperature of the cold tank is, the higher the RTE but the lower the power density will be.

Summary and Future work

- ✓ RTE and power density have maximum values at specific mass flow rate ratio, and the cold tank has higher temperature, CCES has the higher RTE but the lower power density.

- ✓ For the future study, it is necessary to clarify the pressure tank modeling. If the maximum pressure of pressure tank is determined through modeling, CCES cycles can be optimized.