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Analysis of Waste Heat Transport System using Absorptive Cycle

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1. Introduction

At present, Korean depends upon nuclear power for ~40% of electric supply. By 2026, we are planning to construct 8 nuclear plants. Furthermore, additional 10 nuclear plants will be added by 2030 which mean nuclear energy will cover 59% of electricity consumption. For this reason, the necessity of a load following operation may be suggested in the future. However, in the case of load following operation, there is a shortage in the aspect of effective way to utilize uranium resource because the fuel once loaded cannot be saved. In this research, we suggest the method to utilize surplus energy by revising the configuration of a turbine cycle while maintaining the operating conditions of a primary system. Especially we suggest that surplus energy can be transported to a long distance by using an absorptive cycle. Also, we analyze the feasibility of this method in case of connecting an absorptive cycle and waste heat from condenser during a normal condition, which is applicable even if a load following operation does not work.

2. Methods and Results

2.1 Principle of Absorption Cycle

Different from conventional refrigerators, an absorption refrigerator does not use a compressor so it is of great use in the place where electricity is not available. Especially it can have high efficiency when waste heat is accessible. Absorption refrigerators make use of steam and hot water as heat source. Fig. 1 shows main components of an absorption refrigerator. An absorption refrigerator consists of absorber, generator, condenser, evaporator, and solution heat exchanger. Absorption refrigerator works as follow: the steam generated in an evaporator is absorbed to absorbent in an absorber, and the absorbent is changed from weak solution concentration to strong solution concentration. Strong solution in the absorber flows to a generator through a solution pump and the temperature of solution increases by the heat transfer from weak solution in a solution heat exchanger. The steam generated by the difference of boiling points of an absorbent and a refrigerant, can be used for making weak solution concentration. The absorbent of weak solution is returned back after cooling down in the solution heat exchanger. After being the liquid by exposing heat in the condenser, the absorbent steam absorbs the heat during evaporating in the generator. [2]

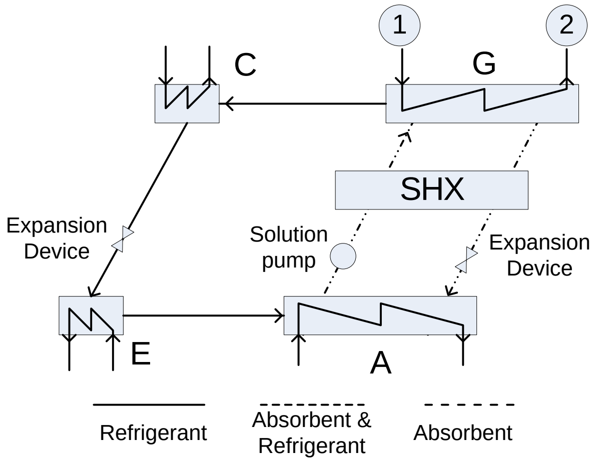
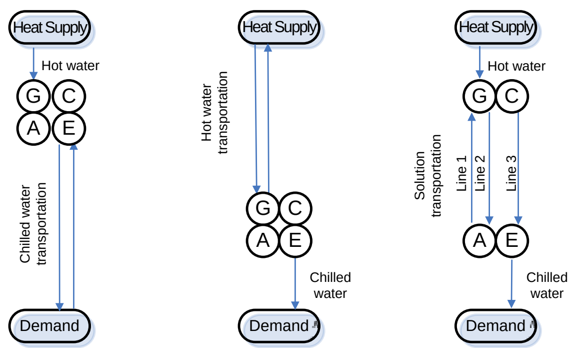


Fig. 1. Schematic diagram of a single effect absorption cycle

The absorption refrigerator is able to transfer energy which is produced by waste heat to a long distance. Fig. 2 shows the schematic diagrams of three different absorptive cycles for energy transportation. Generally, the main components of the systems are located together either at the supply side or at the demand side. In this case, the energy is transported by the sensible heat change of the hot or chilled water. In the proposed system, however, the energy is transported by the concentration difference of the absorption solution by locating the absorber and evaporator at the demand side and the condenser and generator at the supply side. This is called "solution transportation absorption system (STA)" which was conceptualized by Akisawa and Kashiwagi



a. Sensible heat transportation of chilled water
b. Sensible heat transportation of hot water
c. Solution heat transportation

Fig. 2. Concept of solution transportation absorption systems

The STA has four main advantages as follows:

1. Insulation of the pipelines is not required.
2. The size of pipelines can be significantly reduced.
3. Manufacturing and operating costs can be reduced.

4. The STA is possible for residential heating and cooling applications.

The STA has three main disadvantages:

1. Transportation of solution over a long distance is too expensive or is slightly toxic.
2. Special measures are required in the transportation of LiBr–H2O solution because it is a corrosive material.
3. Transportation of solution over a long distance may suffer from leakage. [1]

2.2 Turbine Cycle Simulation

The authors have experienced the analysis of turbine cycle efficiency using PEPSE (Performance Evaluation of Power System Efficiencies), and have the heat balance model of OPR1000. The accurate simulation of an absorptive cycle with PEPSE is not desirable, but the capability of PEPSE is enough to computer the efficiency which is associated with the turbine cycle of OPR1000 and an absorptive cycle. This study, therefore, attempted to perform a variety of feasibility analysis using PEPSE.

2.3 Combined Applications & Simulation

The developed model has following characteristic:

1. Fig. 3 suggested possible connections with an absorptive cycle in a turbine cycle.
2. We selected NH3-H2O as a working fluid of the absorptive cycle: Its advantages are crystallization, capacity, cost, transportability.
3. PEPSE equivalently simulate the thermal properties of NH3-H2O.
4. For a steady-state, heat source can be extracted from 1” (See Fig. 3). For a load following operation, heat source can be taken from 1 or 1’.
5. The pressure drop model in piping was applied to check transportability of the working fluid.
6. This model is able to calculate the efficiency of the combined cycle considering the efficiency of a turbine cycle and COP (Coefficient of Performance) of an absorptive cycle.

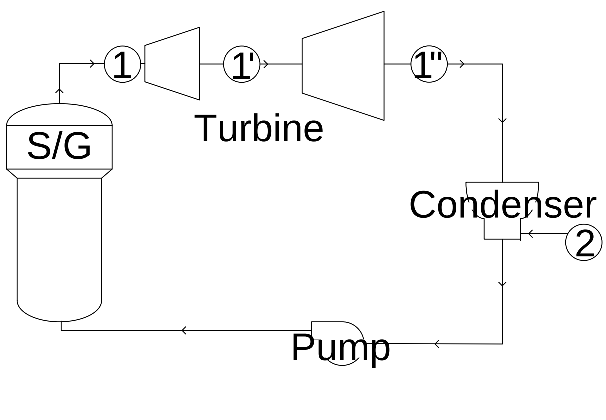


Fig. 3. Combined OPR 1000 Turbine cycle and an absorption refrigerator (See Fig. 1 to refer numbers)

Fig. 4 is the developed PEPSE model. The design parameters of the absorptive cycle were obtained from references [1] and the operating conditions of a turbine cycles were taken from those of OPR1000.

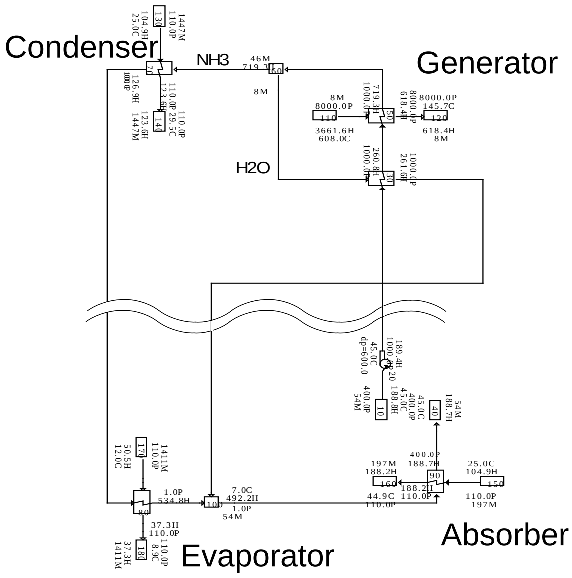


Fig. 4. PEPSE model of 1RT (Refrigeration Tons) capacity.

Until now, we have focused on developing a model of an absorptive cycle. We are going to perform sensitivity analysis according to the variety of design parameters and the configuration of the absorptive cycle so that it can be possible to decide the feasibility of the combine cycle.

3. Conclusion

We suggested the method to utilize surplus energy by revising the configuration of a turbine cycle while maintaining the operating conditions of a primary system, and attempted to analyze the feasibility of the turbine cycle with an absorptive cycle.

It is known that the energy transportability of the STA is more than several hundred kilometers. If we are successful to transport waste heat using the STA to the place where we need it, the value of nuclear power should be re-evaluated.

REFERENCES

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[2] D.W. Wu, R.Z. Wang. Combined cooling, heating and power: A review. 28 February 2006. P. 9 ~ 13