CHAPTER 1

Introduction

1.1 Background

Generally, energy transfers from a high temperature heat source to a lower temperature heat sink. If we want to reverse the direction of energy transfer, a heat pump is needed. Figure 1.1 shows a concept of a heat pump that an external power is needed to take heat from a low temperature source and the heat could be upgraded to a higher temperature level.

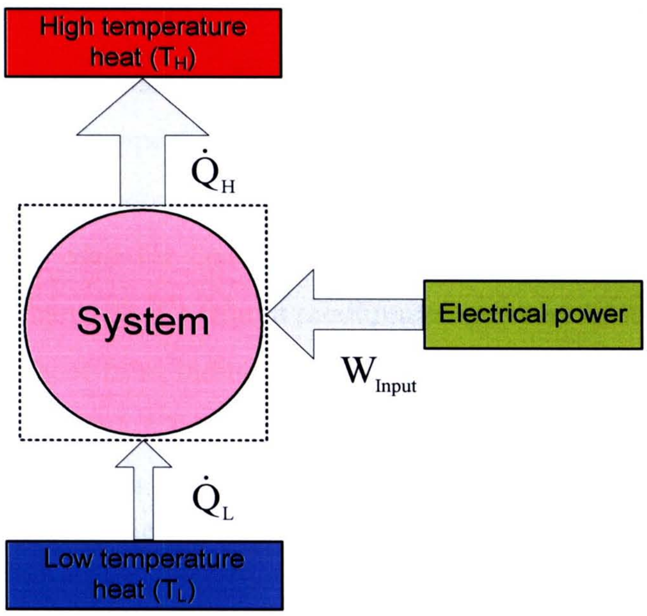
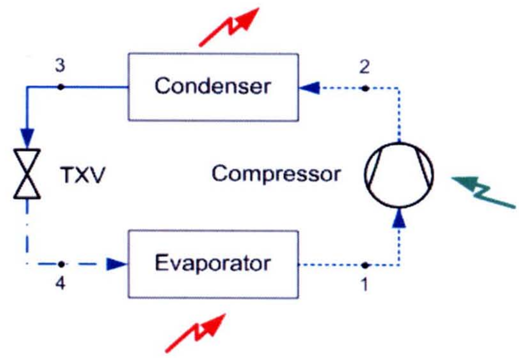
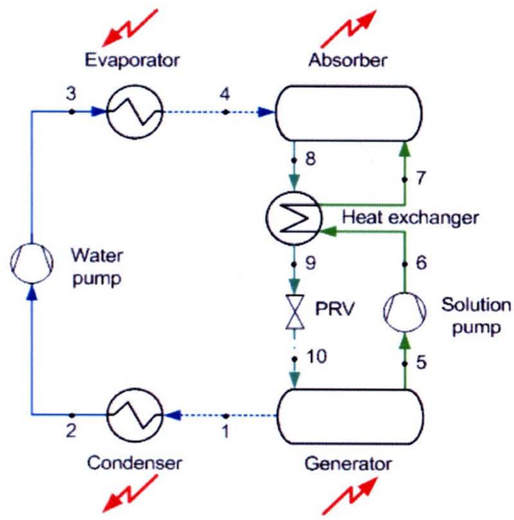


Figure 1.1 A concept of heat pump system.

The most common type of heat pump system is vapor compression (VCHP) due to high efficiency and easy to operate which the main components are compressor, condenser, evaporator and expansion valve as shown in Figure 1.2 (a). A stream of liquid at a low temperature level supplies heat to the evaporator of the VCHP, then the heat will be upgraded and generated at the condenser. This technique is commonly used to upgrade low temperature heat for generating hot water temperature around 60 $^{\circ}$C and uses electrical power as the main energy.





a) A vapor compression heat pump. b) An absorption heat pump.

Figure 1.2 A schematic diagram of heat pump system.

Absorption heat transformer is one type of heat pump technology. The system could be classified into 2 types, type I and type II. Absorption heat pump type I is normally used for cooling process. Absorption heat pump type II or absorption heat transformer (AHT) is used for heating process for generating hot water at a high temperature (higher than 100 $^{\circ}$C) from a medium temperature heat source (around 60-80 $^{\circ}$C) such as waste heat from industrial processes or solar. The concept of the AHT is shown in Figs 1.2 a and 1.3. A stream of liquid at a medium temperature level supplies heat to the generator and the evaporator, then the heat will be upgraded and generated at the absorber of the AHT. The cooling heat is rejected at the AHT condenser.

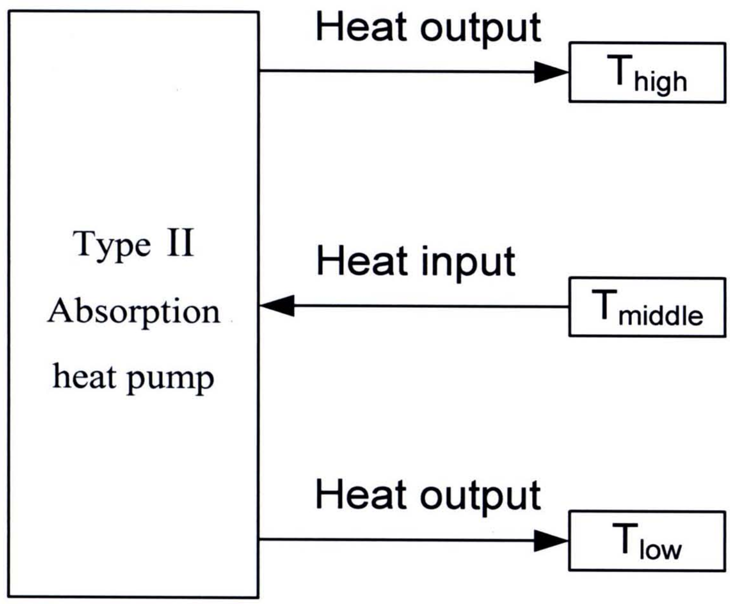


Figure 1.3 Heat driven of the absorption heat transformer (Keith et al., 1996).

The AHT technology has been known for many decades but it is not very attractive compared with the vapor compression type which is more compact and easy to be used and installed. However, due to the energy crisis and the environmental aspects related to the fossil fuel consumption, the AHT becomes an interesting topic since it consumes low external power and the energy input could come from low temperature heat source such as waste heat or solar heat.

However, the coefficient of performance (COP) of the conventional AHT is not over 0.5 (Kiatsiriroat et al., 1986 and Xuehu et al., 2002) because there is high heat loss rejected at the condenser.

In this study, a method to improve thermal efficiency and the appropriate working conditions of a single-stage H_2O-LiBr AHT by combining a VCHP to recover the heat rejected from the AHT condenser and supplied back at the AHT evaporator (CAHT) has been carried out. By this technique, the heat loss could be recovered and the overall COP could be improved.

In this study, a simulation on the CAHT performance has been performed to study the effects of related parameters on the system COP and the upgraded temperature of the heat at the AHT absorber. The heat source of the unit comes from a solar water heating system having a set of flat-plate solar collectors. The model verification could be done by comparing the simulated results with those of a 10 kW_{th} experimental unit. Moreover, a simplified model of the CAHT is presented to reduce the complication of the calculation steps. Finally, economic analysis of the solar-CAHT unit in term of exergy costing is also considered

1.2 Objectives

1. To study the parameters those affect thermal performance of an absorption heat transformer when there is a vapor compression heat pump recovering heat at the AHT condenser and supplying the heat back to the AHT evaporator. A suitable working fluid for the vapor compression heat pump is also considered.
2. To study the appropriate of operating conditions of the absorption heat transformer coupling with the vapor compression heat pump by considering the energy analysis, exergy analysis and economics analysis at various operating condition.

1.3 Scope of the Thesis

1. The working fluid of the absorption heat transformer is H_2O-LiBr solutions.
2. The heat source of this study is hot water at the temperature of 50-95 $^{\circ}C$.
3. The heating capacity of the absorption heat transformer is 10-350 kW_{th}.
4. For experimental study, a 10 kW_{th} H_2O-LiBr heat transformer is used. The unit has been assisted by a vapor compression heat pump.
5. For the parameters of this study, temperature, mass flow rate, pressure and concentration of working fluid of the absorption heat transformer and the vapor compression heat pump have been considered including temperature and mass flow rate of the heat source.

1.4 Expected Benefits

1. A new technique to improve performance of AHT.
2. The system could be used to upgrade low temperature heat such as waste heat or solar heat to a higher temperature level that could be implemented in industries.

1.5 Outline of the Thesis

For this thesis, the main topic is divided into 5 chapters. Chapter 1 introduces a concept and scope of this thesis. Chapter 2 shows method to improve thermal performance of the AHT by combining with the VCHP to recover heat at the AHT condenser which is supplied back to the AHT evaporator. The new design is called compression/absorption heat transformer (CAHT). For the VCHP, the suitable working fluid for supplying heat to the AHT is considered.

Chapter 3 presents simulated performance results of a H_2O-LiBr AHT having a VCHP to recover heat at the AHT condenser which is supplied back to the AHT evaporator. The unit of 10 kW_{th} AHT is used to upgrade heat from a solar hot water heater of which the heat is supplied by a set of flat-plate solar collectors each in parallel connection. The optimal units of solar collectors are also evaluated. The weather and the solar radiation data of Chiang Mai, Thailand are the input information for the calculation.

In Chapter 4, a prototype of R-123 single-stage VCHP and that of R-13A/R-123 two-stage VCHP each is integrated to a 10 kW_{th} H_2O-LiBr AHT. The experimental data are used to verify the simulated results. Moreover, a set of simplified models of the solar-AHT and the solar-CAHT are developed.

Chapter 5 presents exergy analysis and exergy costing of the solar-CAHT with R-134A/R-123 VCHP. The results are used to compare with those of the normal solar-AHT.

In Chapter 6, a set of performance curves of the CAHT at various capacities and operating conditions are constructed from the simplified models. With the prescribed temperatures of the hot water supplying at the generator and the working fluid at the absorber including their mass flow rates, the heat rate and the lift-up temperature of the working fluid at the absorber could be evaluated.

Chapter 7 shows the conclusions of this study.

1.6 Keywords

Absorption heat transformer; Vapor compression heat pump; Performance curve; Simplified model; Compression/Absorption heat transformer