Performance Testing of Air Source Heat Pump (ASHP) System

Introduction

Heat Pump is a thermodynamic system which can absorb heat from the outside environment and releases that heat to the indoor environment. Thus, Heat Pump can be used for space heating applications during cold weather. Heat Pump uses refrigerant to transfer heat from outdoor to the indoor environment. A compressor is used to compress the refrigerant at a high pressure where the refrigerant turns to a superheated vapor. This superheated vapor refrigerant enters into a Condenser. A Condenser is a heat exchanger where the refrigerant exchanges heat to its surroundings and turns to a saturated liquid. Then the saturated liquid refrigerant passes through an Expansion Valve and turns to a liquid-vapor mixture and finally this liquid-vapor mixture flows through another heat exchanger called Evaporator where the refrigerant absorbs heat from the surroundings and turns to saturated vapor. Then the saturated vapor enters into the compressor and this entire cycle repeats continuously. This cycle is called Vapor Compression Refrigeration Cycle. Figure 1 shows the major components of a vapor compression refrigeration cycle which include compressor, condenser, expansion valve and evaporator. So, a heat pump absorbs heat using an evaporator from the outside environment and releases that heat to the inside environment using a condenser. Power is consumed through a compressor which drives the refrigerant (heat transfer medium) throughout the cycle.

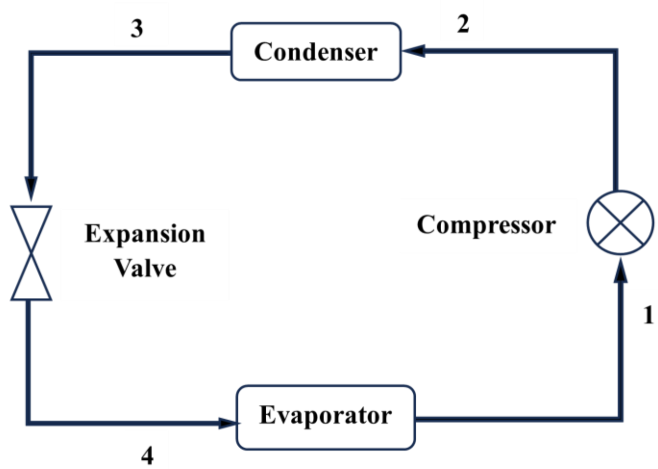

Figure 1: Major Components of Vapor Compression Refrigeration Cycle

There are two most popular types of heat pump available- air source heat pump and ground source heat pump. Air Source Heat Pump (ASHP) absorbs heat from air while Ground Source Heat Pump (GSHP) absorbs heat from the ground. In this experiment, we will study the ASHP system. The indoor unit (condenser) of the ASHP system can have different variations. The Condenser of ASHP system can release heat to either air or water which is termed as either Air-Air or Air-Water heat pump system. In this experiment, we will use the Air-Air heat pump system. There are various types of refrigerant used in the heat pump system such as R410A, R134A etc. In this study, we will experiment with the R410A heat pump system. The P-h diagram of R410A refrigerant has been shown in figure 2.

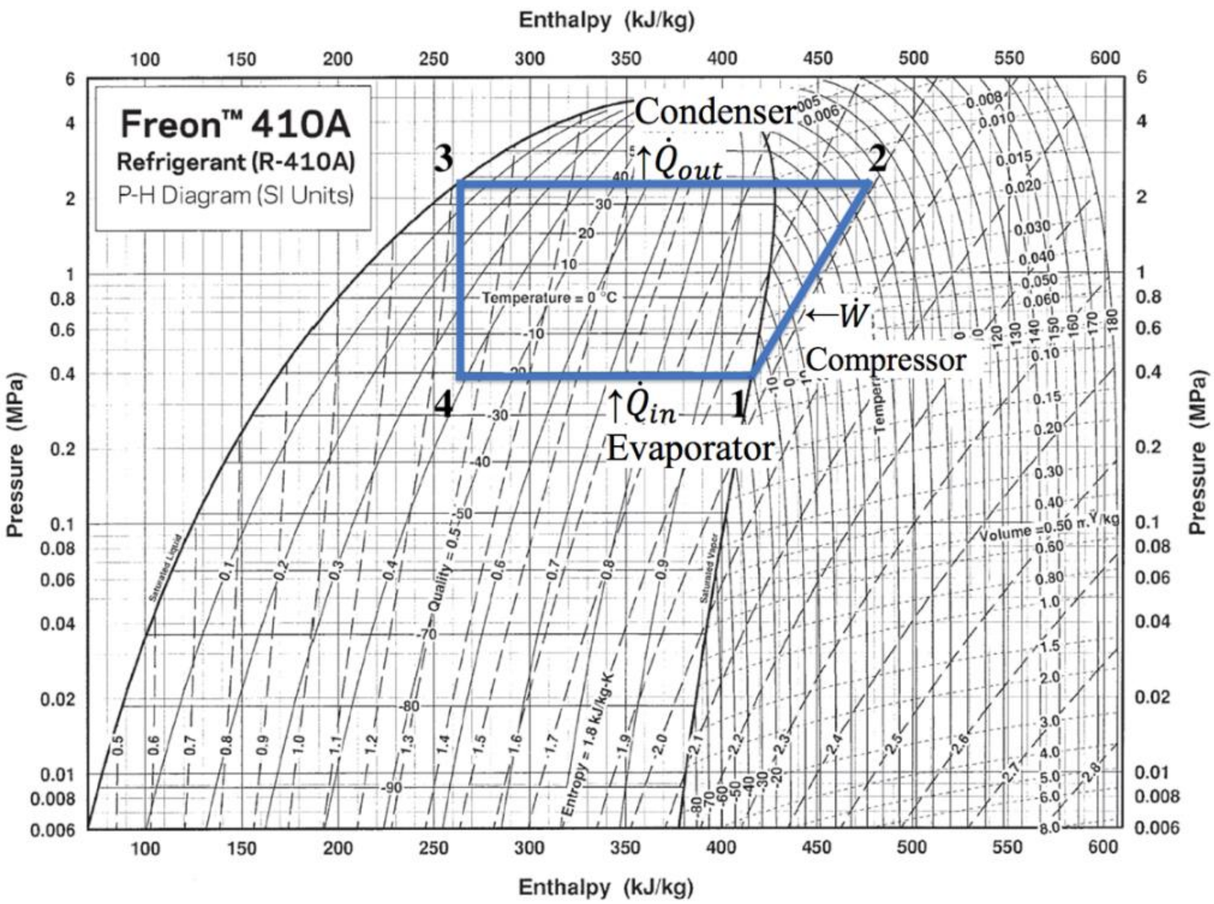

Figure: P-h diagram of R410A refrigerant

Air Source Heat Pump (ASHP) system works using the vapor compression refrigeration cycle. The overall efficiency of the ASHP depends on the efficient performance of the components such as compressor, condenser, and evaporator.

Objective

To investigate the Coefficient of Performance of ASHP system at different outdoor temperatures.

Background

We know that the efficiency of any system is defined as the ratio of the output to the input of the system. In Heat Pump system, there is power input to the compressor, and we get the heating output from the condenser. Heat is also absorbed by the evaporator. So, if we do an energy balance of the Heat Pump system we will get the following equation,

$$Q_{evap,in} + W_{c,in} = Q_{cond,out}$$

So, the efficiency of Heat Pump system is-

$$\eta = \frac{Output}{Input} = \frac{Q_{cond,out}}{W_{c,in}} = \frac{Q_{evap,in} + W_{c,in}}{W_{c,in}} = 1 + \frac{Q_{evap,in}}{W_{c,in}}$$

Here, we can see that the efficiency of a heat pump is always greater than 1, hence the efficiency of heat pump system is termed as the *Coefficient of Performance* or *COP*.

$$COP = \frac{Q_{cond,out}}{W_{c,in}}$$

Experimentation

In this experiment, the students will test the performance of R410A refrigerant based ASHP system inside the *Sustainable HVAC Technologies Laboratory* located in ST-B31A. An outdoor simulator has been built to simulate the outdoor winter conditions inside the laboratory. The experimentation will be conducted according to the following procedures:

1. The laboratory Assistants will assist the students to run the heat pump at different outdoor temperatures ranging from 32^{o}F-50^{o}F.
2. There is a data logging and monitoring system in the lab. The students will record the data for temperature and pressure at the inlet and outlet of condenser, the refrigerant flowrate, and the power consumption through the compressor.
3. The students will use the temperature and pressure data to find the refrigerant enthalpy at inlet and outlet of the condenser and get the heating output from the condenser, $Q_{cond,out}$. The heating output from condenser is also called the Heating Capacity, Q_h.
4. The students will get the compressor power input $W_{c,in}$ from the power meter.
5. Finally, the students will calculate the COP as shown in the Data Analysis section.
6. Each student group will record the data for at least three different outdoor temperatures and find the efficiencies.

Data Analysis

Heating Capacity: $Q_h = \dot{m}_r(h_{2,r} - h_{3,r})$

Coefficient of Performance (COP): $COP = \frac{\dot{m}_r(h_{2,r} - h_{3,r})}{W_{c,in}}$

Here,

$h_{2,r}$ = Refrigerant Enthalpy at Compressor Outlet/Condenser Inlet

$h_{3,r}$ = Refrigerant Enthalpy at Condenser Outlet

$W_{c,in}$ = Compressor Power Input

$\dot{m}_r$ = Refrigerant flowrate

Report

Plot the COP and Heating Capacity with the variation of outdoor temperatures and discuss the findings. Explain how the performance of ASHP system changes with the change of outdoor temperatures.

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