REFRIGERATION SYSTEM

Objective

The objective of the laboratory experiment is to familiarize the student with vapor-compression refrigeration cycle. The Armfield RA1 Refrigeration Unit is used to demonstrate the important features and operation of a vapor-compression refrigeration system, involving the combined processes of compression, condensation, expansion and evaporation (the vapor – compression thermodynamic cycle). In this experiment, the effect of adjusting the setting of the Expansion Valve to vary the operating point (evaporator superheat setting) for different load conditions will be investigated. This will be achieved by running the refrigeration system while making adjustments to the expansion valve using a flat bladed screwdriver. The results will be logged by the students, and they will compare multiple graphs to identify the optimum setting.

Figure 1. RA1 Refrigeration Unit.

Background

An expansion valve is precision device used to control the flow of liquid refrigerant entering the evaporator at a rate that matches the amount of refrigerant being boiled off in the evaporator, This is its main purpose but like all the other metering devices it also provides a pressure drop in the system, separating the high pressure side of the system from the low pressure side.

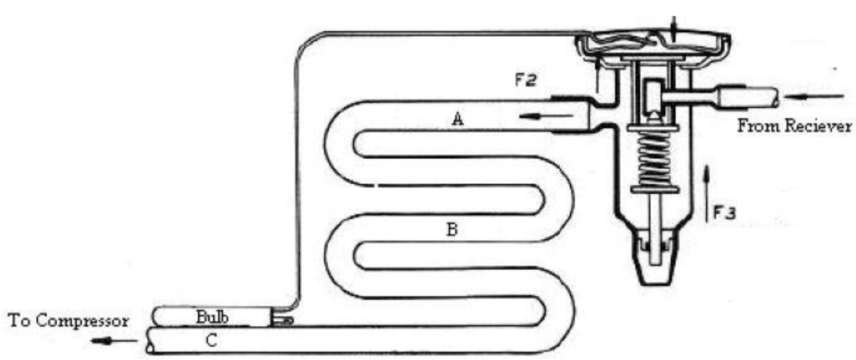

Figure 2: Forces on expansion valve.

The valve itself has 3 forces that act upon each other to accomplish this task. They are:

- Bulb Pressure F1
- Evaporator Pressure F2
- Spring Pressure F3

It can be noted in the diagram above that there are 2 closing forces (F2 & F3) and one opening force (F1). If the evaporator pressure was to increase while the bulb pressure stayed that same the valve would close. F2 + F3 would be greater than F1. If the bulb pressure was to increase to the larger amount, the valve would open. F1 is greater than F2+F3.

As the load across our evaporator increases the available refrigerant will boil off more rapidly. If it is completely evaporated prior to exiting the evaporator, the vapor itself will continue to absorb heat. This heat is referred to as super heat. Superheat is heat added to a substance above its saturation temperature. The bulb will sense this increase in temperature exiting the evaporator and increase the pressure on P1. Since P1 is now greater than P2+P3, the system will allow the valve to open, allowing more refrigerant to enter the evaporator. Now that more refrigerant is being introduced into the evaporator there is more availability to absorb heat. If there is insufficient heat to boil off the entire refrigerant prior to it exiting the evaporator, the temperature at the sensing bulb will decrease, reducing the pressure at P1 and causing the valve to close.

Manually changing the expansion valve will affect the energy entering the evaporator:

$$\boldsymbol{Heat_{in} = \dot{m} * (h_1 - h_4) * 1000}$$

Where,

$Heat_{in}$ = Heat absorbed by the refrigerant (Watts)
$\dot{m}$ = Mass flow rate of the refrigerant (Kg/s)
h_1 = Enthalpy of refrigerant at outlet of evaporator (KJ/Kg)
h_4 = Enthalpy of refrigerant at inlet of evaporator (KJ/Kg)

$$\boldsymbol{Q_{in} = \frac{F_2}{60} \times 4200 \times (T_9 - T_8)}$$

Where,
Q_{in} = Energy absorbed by the evaporator (Watts)
F_2 = Water flow rate through evaporator (l/min)
T_8 = Temperature of water at inlet of evaporator (K)
T_9 = Temperature of water at outlet of evaporator (K)

And ultimately this affects the efficiency of the evaporator:

$$\boldsymbol{Efficiency = \frac{Q_{in}}{Heat_{in}} \times 100}$$

Where,
Q_{in} = Energy absorbed from the evaporator (Watts)
$Heat_{in}$ = Heat absorbed by the refrigerant (Watts)

Equipment Required

- RA1 Refrigeration Unit
- Compatible PC with Armfield software
- Flat bladed screwdriver

Procedure

1) Check that the USB connection is made between the RA1 unit and the PC
2) Turning on and priming the unit:
    a. Check that the circuit breakers and RCD device at the rear left of the unit are in the on (up) position.
    b. Turn the unit on by pressing the **ON/OFF** switch on the unit, then click on the Power On switch on the RA1 software mimic diagram.
    c. Set both the condenser and evaporator water pump speeds to 90%.
    d. Check that there is a flow of water through both the condenser and evaporator indicated by FM1 and FM2 on the mimic diagram.
3) Experiment:
    a. Remove the cap from the adjusting screw on the expansion valve then turn the adjusting screw fully clockwise. Turn the screw ¼ way counter-clockwise.
    b. Turn the compressor motor on and set the speed to 65%.
    c. Check that refrigerant flows around the system indicated by the variable area flow-meter FM3 on the RA1. Record this value on the mimic diagram. This value changes for each adjustment made to the RA1, and should be continually monitored and recorded.
    d. Let the system run until the temperatures and pressures are reasonably stable.
    e. Configure the sample options as 'automatic', with a 5 second interval, and click the "**GO**" button once.
    f. Let the system run for 1 minute, and then turn the adjusting screw on the expansion valve ¼ turn counter-clockwise.
    g. Repeat the procedure of turning the adjusting screw in ¼ counter-clockwise turns every minute until the Coefficient of Performance remains constant.
    h. Stop recording data, and save on floppy drive.
    i. Repeat steps a – g, with compressor motor speed at 75% and 85%.
4) Before switching off the RA1 the expansion valve should be readjusted for normal operation as described at the end of this exercise.
    a. Set the compressor motor speed to 80%
    b. Set the condenser water pump speed to 50%
    c. Set the evaporator water pump speed to 70%
    d. Allow the system to stabilize then slowly adjust the expansion valve in small steps until the differential temperature across the evaporator (T3 – T7) is 4 to 6^oC.
    e. The equipment can be switched off in the knowledge that the expansion valve is correctly set.

Data Reduction

Graph and compare all your readings and analyze the importance of your numbers. Recommended graphs:

- Compressor work
- Coefficient of Performance (Vertical Box-and-Whisker Plot suggested)

Questions:

1) How does the temperature change as the expansion valve is adjusted? Explain.
2) How does the pressure vary across the expansion valve? Explain.
3) Use the equations provided to calculate the efficiency of the evaporator during each reading. Use Excel, and provide a graph for each compressor speed.
4) What happens to the system when the expansion valve is adjusted? Why?
5) Why does the expansion valve need to be adjusted?
6) Is there an optimum expansion valve position for greatest performance?
7) What happens to the system when the compressor speed is changed? Why?
8) Is there an optimum compressor speed for greatest performance?
9) What was the average range of values at each compressor speed?