MAAE 2400 L5

Thermodynamics

Laboratory 4: Carrier Air Conditioning System

Professor: Jean Duquette
Department of Mechanical & Aerospace Engineering
Carleton University

Lab Performed: March 27th, 2026

Submitted: April 3rd, 2026

Savage, Alexia, 101332163
alexiasavage@cmail.carleton.ca
Carleton University

Table of Contents:

Objective:

In Lab 4, this experiment investigated the processes of a Carrier Air Conditioning System. This particular system is commonly used in cooling homes and has both an indoor and outdoor component. Specifically, the condenser coil, the compressor, the condenser fan are a part of the outside system, and the evaporated and evaporator fan are parts of the inside system. Data is collected as further detailed in the procedure section, and then analyzed to quantify the vapour compress refrigeration cycle performance, referred to as COP(Coefficient of Performance, β).

Procedure:

After examining the equipment to become familiar, the system is turned on. The compressor is also powered on and the fan is set to the low setting. The throttle is then changed until it is set so that the refrigerant flow is 0.3 gallons per minute. The rest of the system (thermocouple and frequency counter) is turned on and the entire setup is left to run for twenty minutes to allow stabilisation of the instruments, this helps negate instrument error. Once steady state is reached data is recorded for all the temperatures and pressures. From here the data can be analysed.

Schematic:

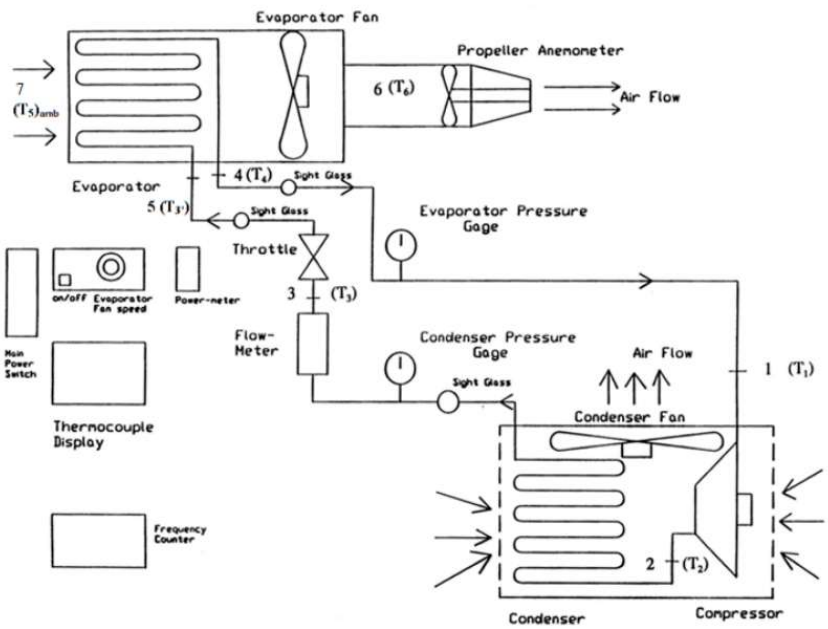

Figure 1 Schematic of Air Conditioning System as Provided in Lab Manual

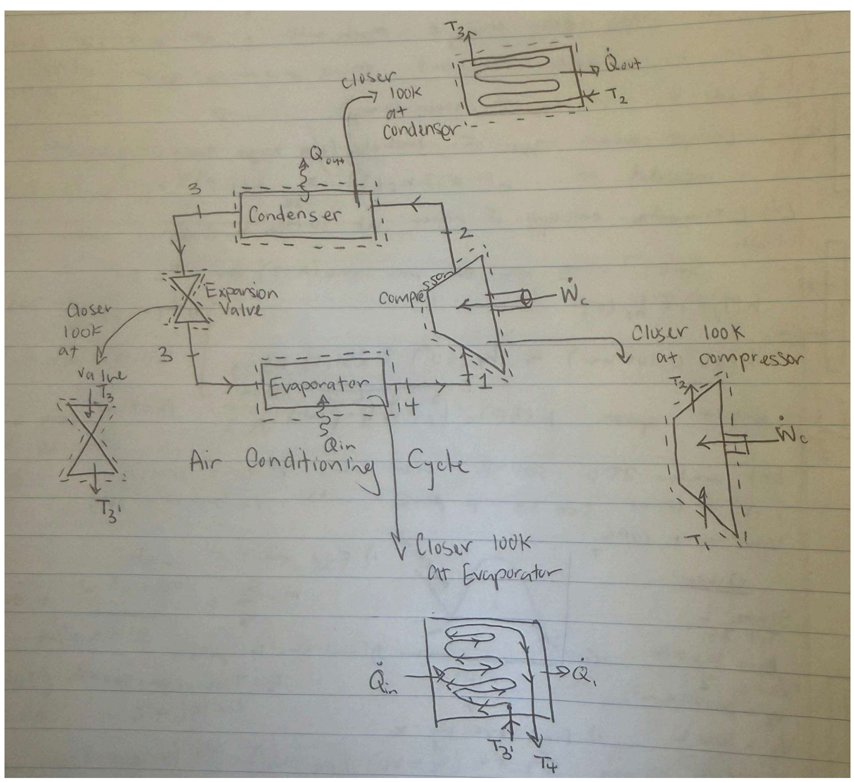

Figure 2 Drawn Schematic of Air Conditioning Process

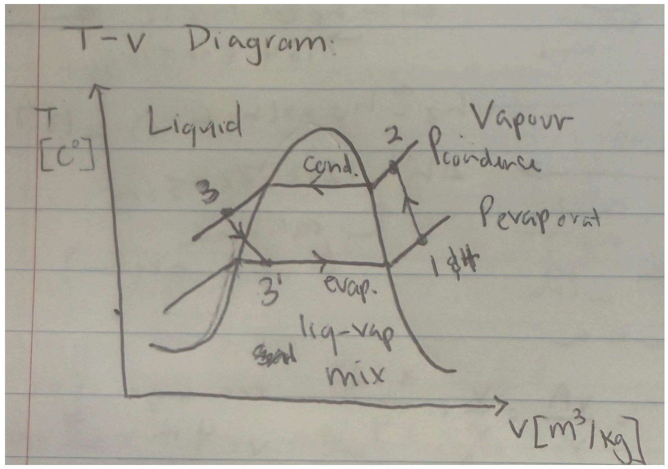

Figure 3 T-v Diagram

Data Tables:

Patm= 101,325kPa	Value	Unit
T1	19	C°
T2	84	C°
T3	23	C°
T3’	10	C°
T4	19	C°
T5	23.5	C°
T6	11.8	C°
P_{evap}	70	Psi
P_{cond}	260	Psi
V_{H20}	0.3	gal/min
Fan Speed setting	Low	
State of refrigerant upstream of compressor	Vapour	
State of refrigerant upstream of refrigerant flow meter	Liquid	
State of refrigerant upstream of evaporator	Vapour & Liquid Mixture	

Table 1: Values obtained during experiment

Results:

Convert Pressures from Data Table to MPa from psi:

P_{evap}= 70psi=> 482.63kPa+101.33kPa = 583.96 kPa = 0.584MPa

P_{cond}= 260psi=>1792.64kPa+101.33kPa = 1893.97kPa = 1.894MPa

Using Table A-8 Determine Saturation Temperature at P_{evap} and P_{cond}:

$T_{evap,sat}$ using 5.84 need to interpolate between 5.75 bar and 6 bar:

T_{evap}= 4.49+((5.85-4.49)/(6-5.85))*(5.84-5.75)= 4.98 C°

$T_{cond,sat}$ using 18.94 interpolate between 18 and 20 bar:

T_{cond}= 46.69+((51.26-46.69)/(20-18))*(18.94-18)= 48.84C°

Find state regions for Temperatures corrected based on sat temp:

$P_{1,4}$=0.584MPa, $T_{evap,sat}$=4.98C°

T_1=T_4=19C°

T_1>T_{sat}, meaning its superheated vapour

P_2= 1.894MPa, $T_{cond,sat}$=48.84C°

T_2= 84 C°

T_2>$T_{cond,sat}$, meaning its superheated vapour

P_3= 1.894MPa, $T_{cond,sat}$=48.84C°

T_3= 23 C°

T_3<$T_{cond,sat}$, meaning its supercooled liquid

T_4>$T_{evap,sat}$, meaning superheated vapour

Find h1, h2, h3, h4, and v3 using tables A-7,8,9
Sample Calc: h1

$h_{5.5bar}$=259.9+((263.57-259.9)/(20-15))*(19-15)=262.84kJ/kg

h_{6bar}=258.91+((262.65-258.91)/(20-15))*(19-15)=261.90kJ/kg

h_1= 262.84+((261.90-262.84)/(6-5.5)*(5.84-5.5)=262.20kJ/kg

h_2= 296.60kJ/kg

h_4=262.20kJ/kg

For h3 use sar-liq temp table A-7 to find enthalpy since it's more dependent on temperature.

h_3=$h_{3'}$= 72.80kJ/kg

v_3 from same table= 0.834 *10^-3 m^3/kg

Find the mass flow rate:

$$\dot{V}_{R22} = \left[(1.56 \cdot 10^3) \cdot v_{R22} - 0.556\right]^{\frac{1}{2}} \cdot \left[\dot{V}_{H_2O}\right] \cdot \left[6.31 \cdot 10^{-5}\right]$$

$$VR22 = [(1.56 \cdot 103) \cdot 0.834 - 0.556]^{1/2} \cdot [0.3] \cdot [6.31 \cdot 10^{-5}]$$

$V_{dot\ r\text{-}22}$=1.63*10^-5m/s^3

m_{dotR22}= Vdotr-22/ vr-22 = 1.63*10^-5/0.834*10-3= 0.01954 kg/s

Find enthalpy at P3' and use to determine quality at state 3':

P3'=Pevap=0.584MPa

From A-8

$h_{3'}$=72.80

h_f=51.21kJ/kg h_g=251.75kJ/kg

h3'=hf+x3'(hg-hf)

x3'=10.77%

Find heat input, heat output and work by compressor in kW:

$\dot{Q}_{in,evap} = \dot{m}R22(h1 – h3')$

=0.01954(262.20-72.80)=3.70kW

$\dot{Q}_{out,cond} = \dot{m}R22(h2 – h3)$

=0.01954(296.60-72.80)=4.37kW

$\dot{W}_{cond}=\dot{m}R22(h2 – h1)$

=0.01954(296.6-262.2)= 0.67kW

Calculate COP:

$\beta = \dot{Q}_{in,evap}/\dot{W}_{cond}$

β =3.70/0.67 = 5.52

Percent Error % is

5.52-3/3*100= 84%

Discussion:

1. Does the calculated COP agree with your expectations? Explain why or why not.

The calculated COP did not meet the expectations because ideally it would fall between the range of 2-4 and in the case of this lab our COP was calculated at 5.52 which gives a percent error of 84%. Likely the set up could be impacting this since normally this system as priorly mentioned has an indoor and outdoor section and this experiment was conducted in one spot with all systems mounted to the same wall.

2. Explain how the performance of the air conditioner might vary if it were installed in a real-life scenario rather than in the lab room (hint: did the lab room temperature go down as a result of this experiment?).

In the lab, the air conditioner does not cool the room because the evaporator and condenser are located in the same area. If this were set up in a real life air conditioner environment as intended the heat that would be removed would be removed outdoors though in the lab there is no other location so its COP is not an accurate indicator for how the system performs. Also, in the experiment the evaporator is cooling a small air stream inside a test bench and not the entire room which is why the COP can seem even higher and “more efficient” than the expected COP.

3. Is the calculated compressor work the total work required to run the system? Explain any other power requirements, and how they might change the COP if included in its calculation.

No, the compressor work is not the total work required to run the system, the compressor work only measures the power required to run the compressor. The other aspects of the system have to be taken into account as well for total work. The other components were not considered when doing the calculation for COP which could also be why performance was coming back much higher than anticipated.

4. Comment on the measured value of T3′ . Does it agree with the saturation temperature at P3′ ? Explain why this may be (this can relate to your sources of error section)

The T3’ value and saturation temperature at P3’ do not exactly match. This discrepancy coil be to to a variety of things in relation to the set up. Particularly, they are not recorded at the exact same position. The temperature and pressure gauges being apart means that heat transferring to other locations and pressure drops could lead to the values not being exactly aligned.

Error Analysis:

Several sources of error may have influenced the results of this experiment. First, instrument uncertainty in the thermocouples, pressure gauges, and flow meter introduces measurable deviations in temperature, pressure, and flow readings; because many calculated quantities depend on small temperature differences, even minor sensor inaccuracies can produce large errors in the energy balance and COP. Human error also contributes, particularly when reading analog gauges, recording values before the system is fully steady, or interpolating refrigerant properties from tables.

In addition to these measurement-related issues, the system itself introduces a significant non-instrumental source of error: heat gain and loss to the surrounding room. The refrigerant lines, evaporator, and condenser are not perfectly insulated, so the refrigerant temperature at state 3′ may not correspond exactly to the saturation temperature at the measured pressure. This environmental heat transfer alters the true thermodynamic state of the refrigerant and leads to discrepancies in calculated enthalpies and COP values. Together, these effects explain why the measured data may not perfectly match theoretical expectations.

Conclusion:

This laboratory experiment provided a practical demonstration of the vapor-compression refrigeration cycle and allowed for direct measurement of the thermodynamic properties that determine air-conditioning performance. By determining the refrigerant state points, calculating the heat absorbed in the evaporator, and evaluating the compressor work, the experiment was intended to estimate the system's coefficient of performance and compare it to theoretical expectations. Although the measured COP was higher than typical real-world values, this outcome reflects the controlled laboratory environment, the light cooling load, and the exclusion of other work power requirements such as fan motors. The comparison between measured temperatures and saturation values also highlighted the influence of heat transfer to the surroundings and non-ideal system behavior. Overall, the lab validated the relationship between pressure, temperature, phase, and energy transfer in a refrigeration cycle, while showing how environmental conditions and system losses affect actual air-conditioning performance.

References:

(1) Carleton University, Department of Mechanical and Aerospace Engineering. MAAE 2400 Winter 2026: Laboratory Instructions [PDF]. Carleton University.

(2) M. J. Moran, H. N. Shapiro, D. D. Boettner, and M. B. Bailey, Fundamentals of Engineering Thermodynamics, 9th ed. Hoboken, NJ: Wiley, 2018