California State University, Long Beach

College of Engineering
Department of Mechanical Engineering

EXPERIMENT 5: Refrigeration Cycle, the Analysis of Simple Air-Conditioning Unit

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Course: MAE 337-Thermal Engineering Lab

Section 9

Group 5
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Abstract:

The objective of this experiment is to have students investigate different air-conditioning processes including heating, cooling, humidification and dehumidification and to use the Psychrometric chart as applied to humidity measurement and control. The instrument used for this lab is the RA2 Air Conditioning Unit. There are several terms that help students get familiar with the lab. For instanceDry Bulb Temperature (DBT), Wet Bulb Temperature (WBT) or Saturation Temperature, Humidity, Relative Humidity, Specific Humidity, Dew Point, and Saturation Vapor Pressure. With the obtained data, The Psychrometric chart will act as a useful tool to determine humidity measurement and control.

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Objective

To investigate different air-conditioning processes including heating, cooling, humidification and dehumidification and to use the Psychrometric chart as applied to humidity measurement and control.

Introduction

With the popularity and importance of HVAC systems in any infrastructure, getting a fundamental understanding of the cycle is crucial for this lab. Refrigeration is a process that transfers heat from lower temperature regions to higher temperature ones to cool or maintain a space or body below its equilibrium temperature. According to the lab handout, the most widely used method for refrigeration is the vapor-compression cycle, which requires using a circulating liquid refrigerant to absorb and remove heat from the space to be cooled and subsequently reject that heat elsewhere. The refrigeration cycle has four components: a compressor, a condenser, a thermal expansion valve, and an evaporator. The idealized refrigeration cycle consists of four processes: isentropic compression, constant pressure heat rejection, isenthalpic expansion, and constant pressure heat absorption. Refrigeration is used in various applications such as air-conditioning of buildings, refrigerators, and commercial and industrial services.

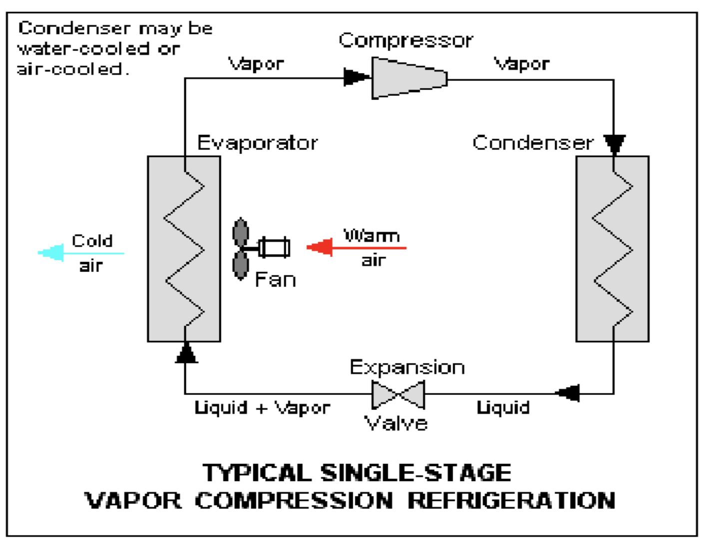

Figure 1: Vapor Compression Refrigeration

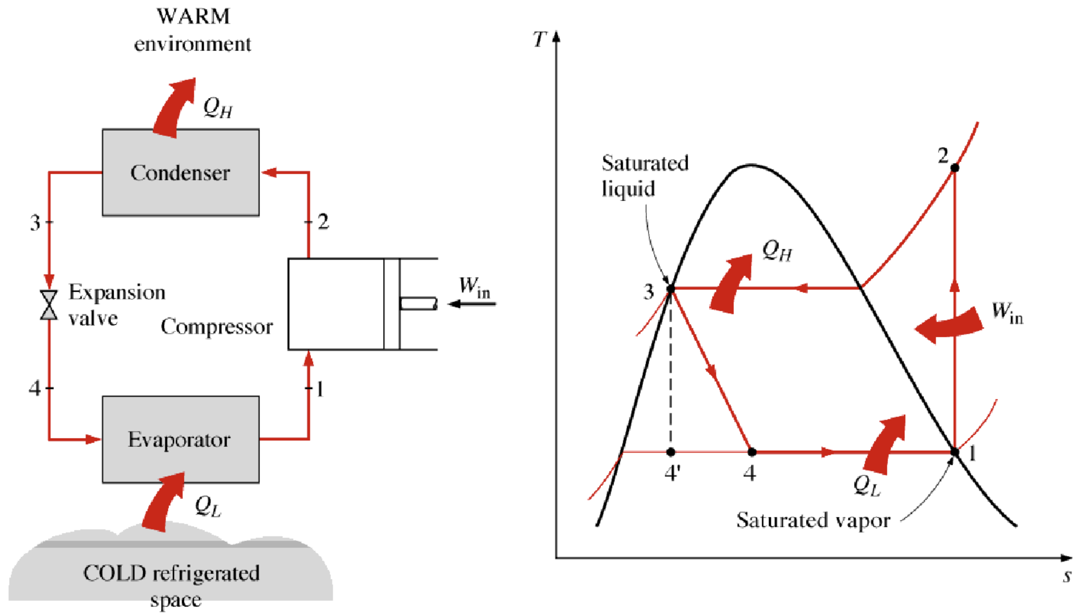

Figure 2: Schematic and T-s diagram for an ideal vapor-compression refrigeration cycle

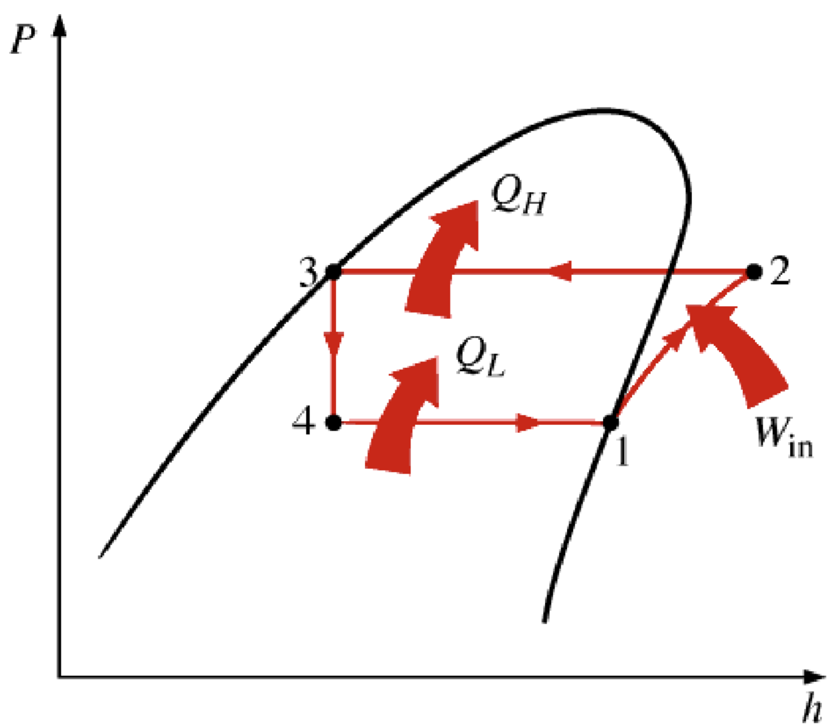

Figure 3: P-h Diagram

List of Apparatus

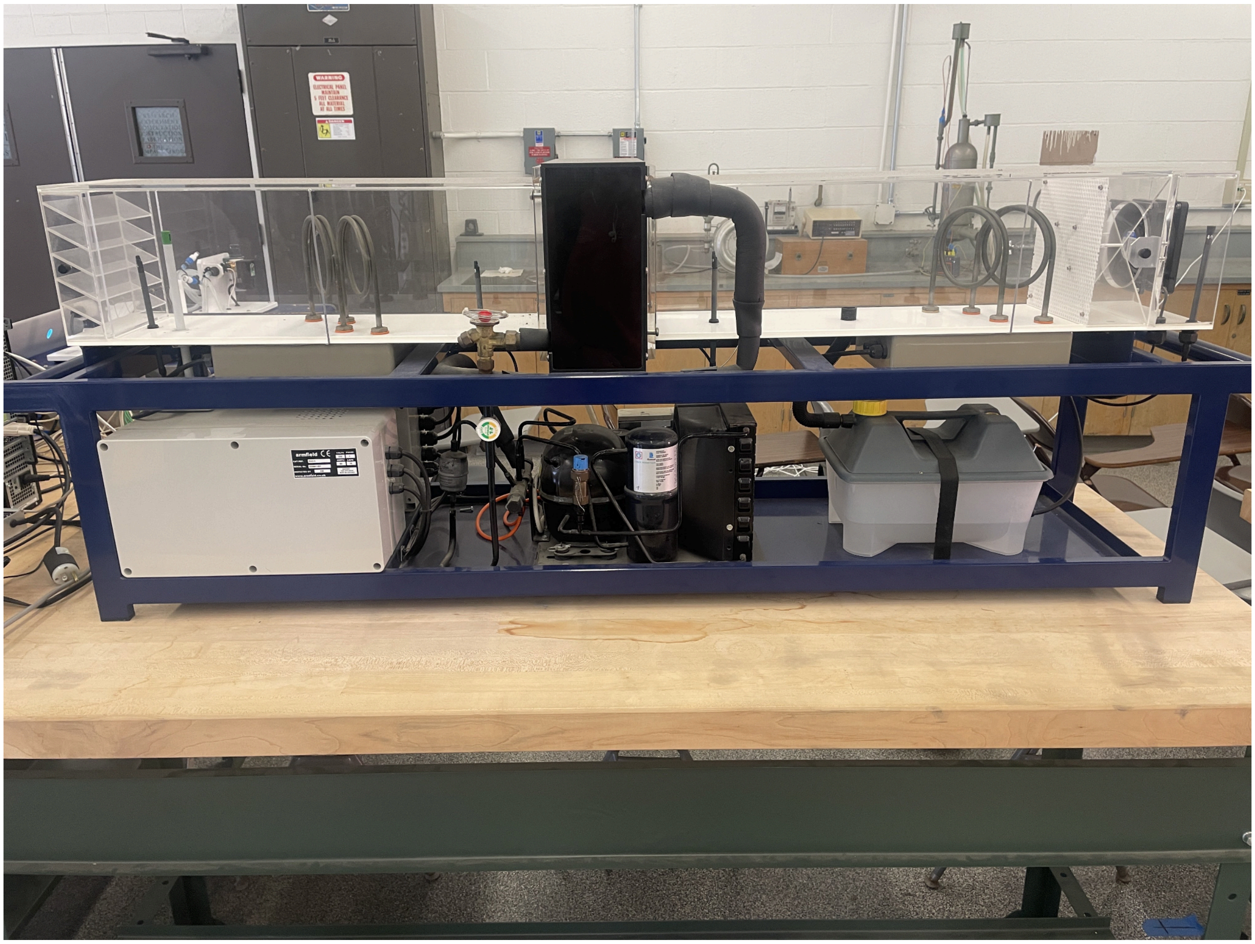

Figure 4: RA4 Air Conditioning Unit

Procedure

There are primarily 3 runs for this lab ranging from setting the fan to 60%, 50%, 70%. First, the lab instructor set up the Preheat control manual to 30%. After that, turn the cooling on and wait 5 mins for T3 to stabilize. Open the reheat control and set T4 at 2-3 degrees greater than T3. After a while, wait for the system to stabilize again. Once the system's stabilized select the “GO” icon to record data at an interval of 10 seconds for the duration of 1 minute. In the end, press the save button to save the gathered raw data in an excel file. In run 2, repeat the whole operation but run the fan at 50% instead. In run 3, repeat the whole operation but run the fan at 70% instead.

Table of Data and Results

Raw data Table

	RH1 (%)	T1 (C)	RH2 (%)	T2 (C)	RH3 (%)	T3 (C)	RH4 (%)	T4 (C)	u1 (m/s)	Win (hp)
Run 1 30% preheat	57.5	25.8	51.4	30.1	91	16.5	84.6	20	0.75	0.31
Run 2 50% preheat	39	24.3	32.4	31	62.7	15.3	52.4	20.1	0.7	0.278
Run 3 70% preheat	38.5	24.6	29.4	33.3	59.3	16.5	52.7	20	0.78	0.253
Average	45	24.9	37.73333	31.46667	71	16.1	63.23333	20.03333	0.743333	0.280333

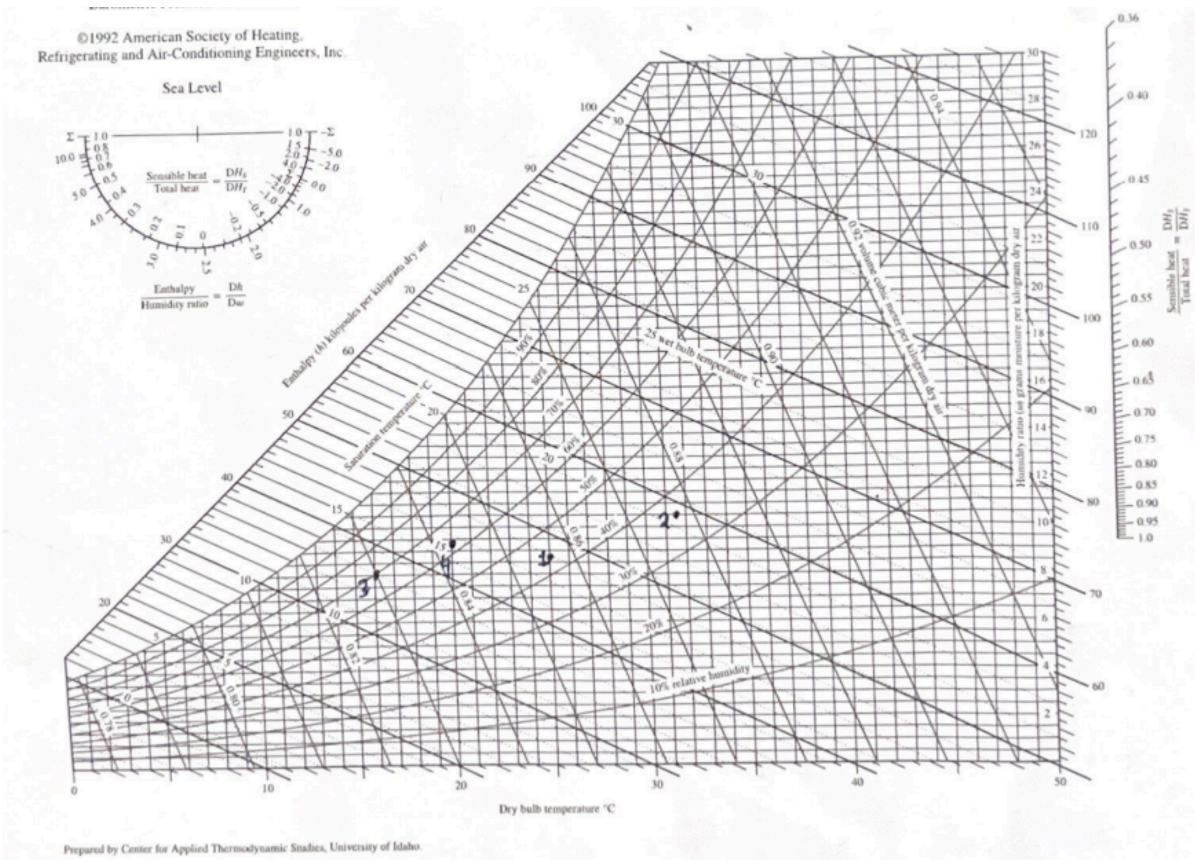

FIGURE A–31
Psychrometric chart at 1 atm total pressure.
Reprinted from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

	$T_{db}(^\circ C)$	RH (%)	$T_{wb}(^\circ C)$	SH(X) Grams moisture/ kg dry air	$h(kJ/kg)$	$T_{dp}(^\circ C)$	$v\ (m^3/kg)$
Point 1	25	45	17	9	48	12	0.855
Point 2	31.5	38	20.5	10.5	59	15	0.875
Point 3	16	70	13	8	38	10	0.83
Point 4	20	63	15.5	9	44	13	0.84

Sample Calculations

Air density at point 4

$$\rho = \frac{1}{v} = \frac{1}{0.84\frac{m^3}{kg}} = 1.19\frac{kg}{m^3}$$

Volumetric flow rate of air

$$V^{\circ} = V_{air} \times A_{duct} = 0.74\frac{m}{s} \times 0.0412m^2 = 0.03034\frac{m^3}{s}$$

Mass flow rate of air

$$m^{\circ}_{air} = V^{\circ} \times \rho = 0.03034\frac{m^3}{s} \times 1.19\frac{kg}{m^3} = 0.036\frac{kg}{s}$$

Energy analysis

$$Q^{\circ}_{1-2} = m^{\circ}_{air}(h_2 - h_1) = 0.036\frac{kg}{s}(59\frac{kJ}{kg} - 48\frac{kJ}{kg}) = 0.396\frac{kJ}{s}$$

$$Q^{\circ}_{2-3} = m^{\circ}_{air}(h_2 - h_3) = 0.036\frac{kg}{s}(59\frac{kJ}{kg} - 38\frac{kJ}{kg}) = 0.756\frac{kJ}{s}$$

$$Q^{\circ}_{3-4} = m^{\circ}_{air}(h_4 - h_3) = 0.036\frac{kg}{s}(44\frac{kJ}{kg} - 38\frac{kJ}{kg}) = 0.216\frac{kJ}{s}$$

Cooling load capacity

$$Q^{\circ}_{2-3} \times \frac{TON}{3.717kW} = 0.756\frac{kJ}{s} \times \frac{TON}{3.717kW} = 0.203$$

Coefficient of Performance

$$COP = \frac{Q^{\circ}_{removed}}{W^{\circ}_{in}} = \frac{0.756\frac{kJ}{s}}{0.209kW} = 3.62$$

Dehumidification

$$m^{\circ}_{moisture} = m^{\circ}_{air}(X_2 - X_3) = 0.036\frac{kg}{s}(10.5\frac{g}{kg} - 8\frac{g}{kg}) = 0.09\frac{g}{s}$$

Discussion and Analysis of Results

Process 1-2 is heating humidification, process 2-3 is cooling dehumidification, and process 3-4 is heating humidification. The processes seen during the experiment because there was no actual dehumidification. In order to dehumidify, the air must be cooled below the dew point temperature at point 2. The dew point temperature at point 2 was 15 ℃ and the temperature of air never got below 15.3 ℃, therefore the air was not dehumidified. In general, the relative humidity decreases as the temperature increases. The changes in relative humidity seen through the processes in this experiment are as expected since the hotter the temperature of the air was, the lower the relative humidity was measured.

Conclusion and Recommendations

This lab proved successful in allowing us to investigate different air-condition processes such as heating, cooling, humidification, and dehumidification. It also got us familiar with the Psychrometric chart and how to use it as applied to humidity measurement and control. We were able to calculate that our cooling load capacity for the process of 2-3 was 0.756 kJ/s. This yielded the air conditioner a coefficient of performance equal to 3.62. This is a pretty good COP, but it could be better. This rating tells us how effective it is at transferring heat versus the amount of power we put into it. This could be improved by decreasing the work that the compressor must do, or by increasing the refrigeration effect. Other types of coolants may be researched in order to achieve desired effects.

References

Çengel, Yunus A. Thermodynamics : an Engineering Approach. Boston :McGraw-Hill Higher Education, 2008.

Member’s Contribution

Hung Ngo: Abstract, Introduction, Procedures

Paul Yousefian: Data and results, Sample Calculations

Ricardo Jimenez: Discussion and Analysis of Results, Conclusion and Recommendations