MECH4880 Refrigeration and Air Conditioning

Assignment2

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Abstract

This report firstly simulates the cooling system and heating system of R22, then cooling system of R410a is also simulated. According to simulation result, EER of cooling system is smaller than COP of heating system. Some key factors can influence EER, like indoor coil area, outdoor coil area, indoor air flow rate and outdoor air flow rate. In experiment part, the functions of devices in system are illustrated, and analysis of failure of devices is made. Finally p-h diagram is used for calculating efficiency of cooling system.

Contents

Assumption & Justification

1 Modify indoor coil area from 7.32 ft^2 to 9.32 ft^2.

According to the result of simulation, larger indoor coil area can cause higher EER. So increase indoor coil area.

2 Modify outdoor coil area from 17.5 ft^2 to 22.5 ft^2

According to the result of simulation, larger outdoor coil area can cause higher EER. So increase indoor coil area.

3 Modify indoor air flow rate from 3600cfm to 4000cfm

According to the result of simulation, larger indoor air flow rate can cause higher EER. So increase indoor air flow rate.

4 Modify outdoor air flow rate from 6500cfm to 7000cfm

According to the result of simulation, larger outdoor air flow rate can cause higher EER. So increase outdoor air flow rate.

5 Keep indoor temperature at 27℃

According to the result of simulation higher indoor temperature can cause higher EER. But 27℃ is already a suitable indoor temperature, so it doesn't need to be changed.

6 There is no sub-cooling process in question2

Since only status of refrigerant in suction point and discharge point are assured during experiment. To complete the whole refrigerating process, assuming the status of refrigerant would be saturated after condensed.

1 Introduction

This report is composed of two parts which are system modelling and laboratory experiment. In part one, an air conditioning system is simulated by utilizing DOE/ORNL Heat Pump Design Model VII. R22 refrigerant would be firstly used in the system for heating and cooling. Then the refrigerant would be changed to R410a, meanwhile, the compressor would also be altered to be suitable for R410a.

In part two, the refrigeration demonstration system in lab would be used to observe the influences posed by changing coefficient.

2 Part1 (Simulation)

(All the input data are referenced from assignment requirement)

R22 refrigerant would be used in the cooling mode and heating mode, an R410a would be used in the cooling mode. The figures of cooling mode and heating mode are shown below.

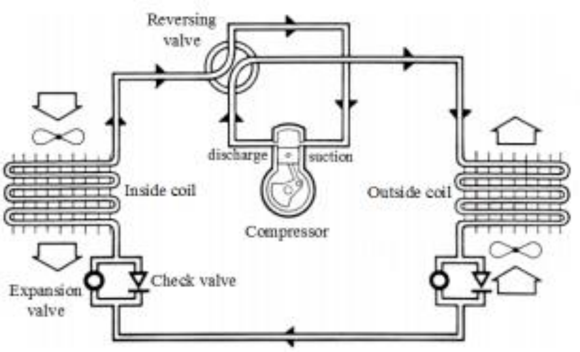


Figure1 cooling mode

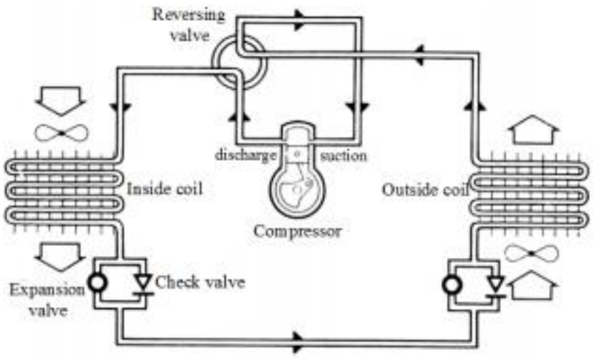


Figure2 heating mode

2.1 R22 Utilization

2.1.1 Cooling mode

The important steps of using DOE/ORNL Heat Pump Design Model VII for cooling simulation would be shown in the following figure.

(1) Requirement of Refrigerant

Choosing R22 as the refrigerant, and choosing heat pump as the cooling mode, the selection screen shot is shown in figure3

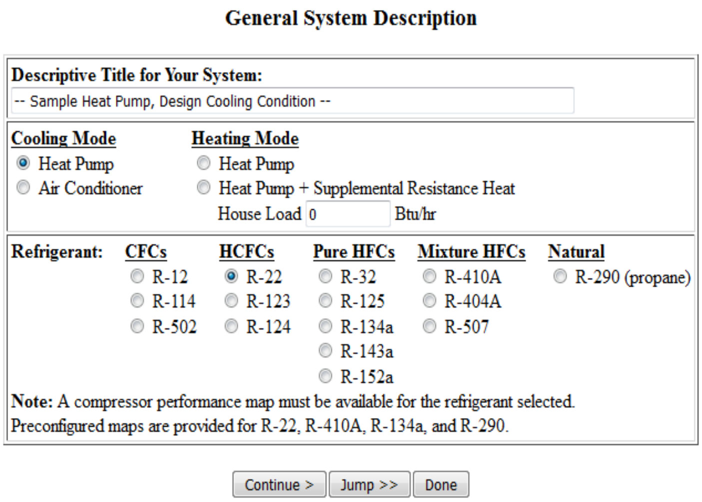


Figure3 General System Description

(2) Requirement of Compressor

According to assignment requirement, the compressor should be suitable to R22 refrigerant, and the type of the compressor should be Copeland Scroll, ZR28K1-PFV. The screen shot of selection of compressor is shown in the figure4 and figure5.

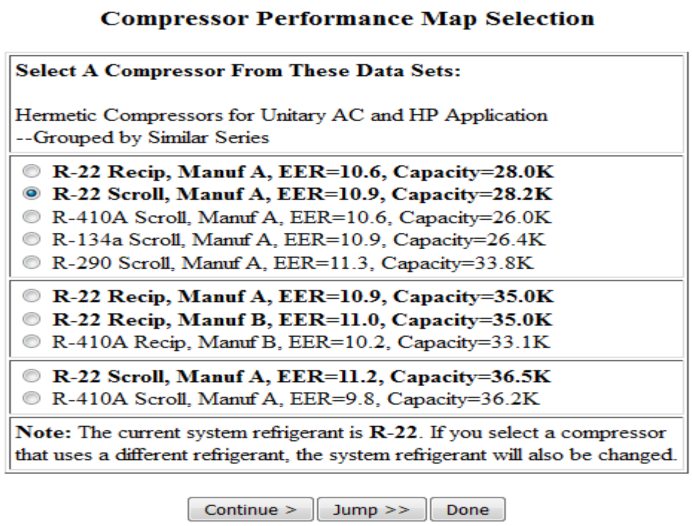


Figure4 Compressor selection

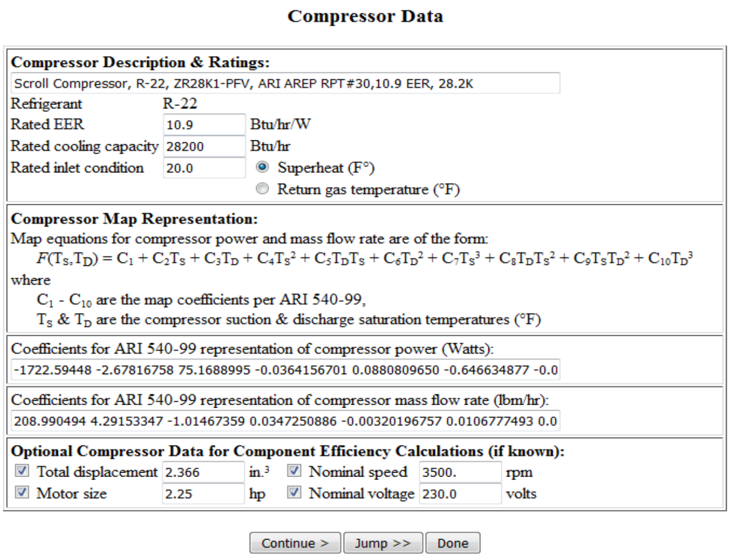


Figure5 Compressor Data

(3) Requirement of Indoor Unit

According to assignment requirement, the data of evaporator, indoor air state, and indoor fan characteristic should be inputted. The screen shot of indoor unit data is shown in the figure 6. Meanwhile, some data needed to be calculated from original data, are shown in table1.

Table1 Indoor Data

Indoor Data (cooling)	
Temperature DB,(°F)	80.6
Temperature: WB,(°F)	66.2
Thickness of tube wall(mils)	20

According to the data provided by assignment, the indoor temperature (DB) is 27°C, temperature (WB) is 19°C.

$$Dry\ Bulb\ Tempertaure(°\mathrm{F}) = 27 \times \frac{9}{5} + 32$$

$$= 80.6℃$$

$$Wet\ Bulb\ Tempertaure(°\mathrm{F}) = 19 \times \frac{9}{5} + 32$$

$$= 66.2℃$$

$$Thickness\ of\ tube = \frac{Outside\ diameter - Inside\ diameter}{2}$$

$$= \frac{0.42 - 0.38}{2} = 0.02(in) = 20(mils)$$

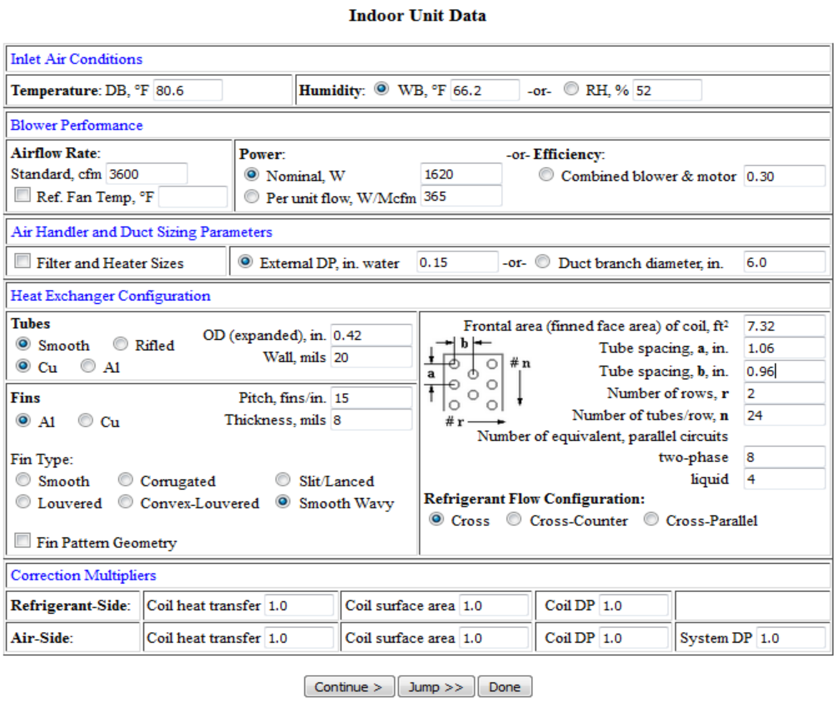


Figure6 Indoor unit data

(4)Requirement of Outdoor Unit

According to assignment requirement, the data of condenser, outdoor air state, and outdoor fan characteristic should be inputted. The screen shot of outdoor unit data is shown in the figure 7. Meanwhile, some data needed to be calculated from original data, are shown in table2.

Table2 Outdoor Data

Indoor Data (cooling)	
Temperature DB,(°F)	95
Temperature: WB,(°F)	75.2
Thickness of tube wall(mils)	20

According to the data provided by assignment, the indoor temperature (DB) is 35℃; temperature (WB) is 24℃.

$$Dry\ Bulb\ Tempertaure(°F) = 35 \times \frac{9}{5} + 32$$

$$= 95℃$$

$$Wet\ Bulb\ Tempertaure(°\text{F}) = 24 \times \frac{9}{5} + 32$$

$$= 75.2℃$$

$$Thickness\ of\ tube = \frac{Outside\ diameter - Inside\ diameter}{2}$$

$$= \frac{0.42 - 0.38}{2} = 0.02(in) = 20(mils)$$

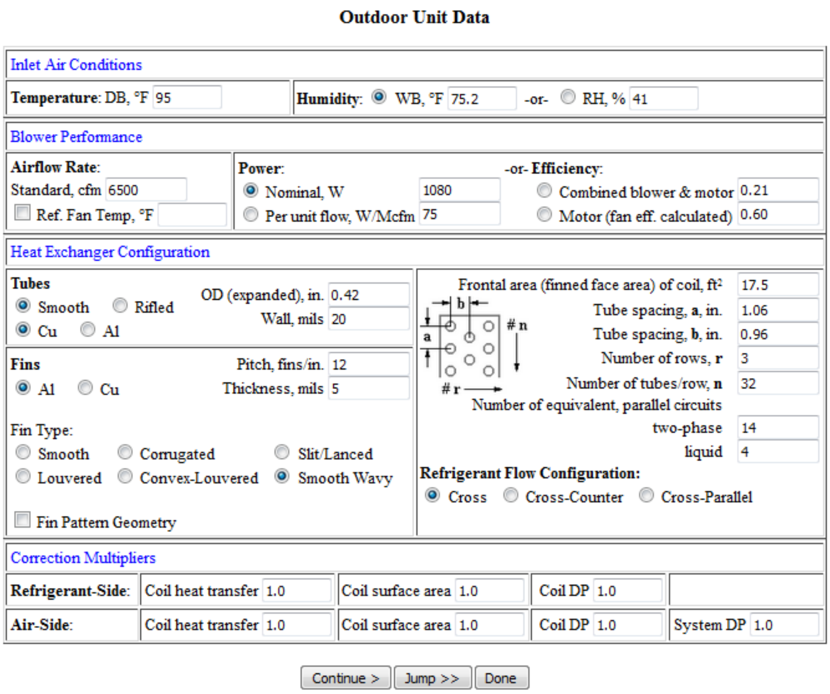


Figure7 Outdoor Unit Data

(5)Requirement of Refrigerant Lines

According to assignment requirement the data of refrigerant lines are inputted. The data of screenshot refrigerant lines are shown in the figure8.

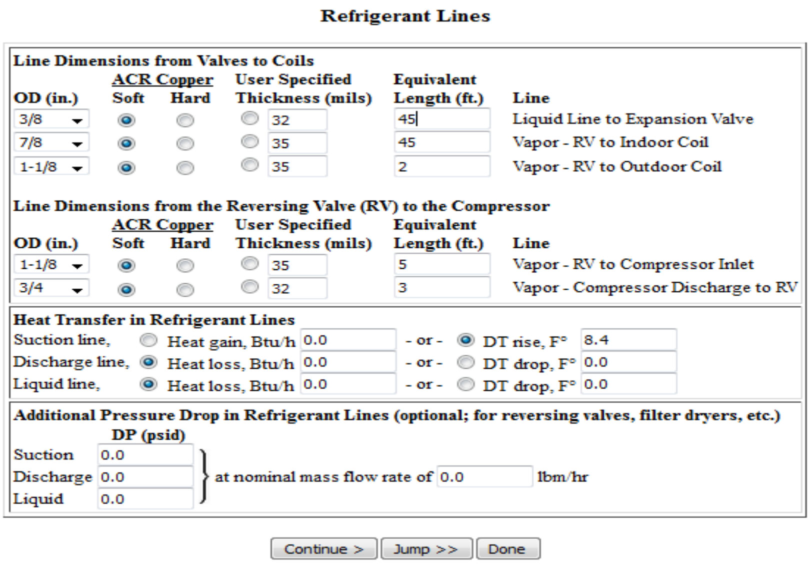


Figure8 Refrigerant Lines Data

(6)Result of simulation

After inputting all the data, DOE/ORNL Heat Pump Model VII would show the result automatically, the screenshots of the result are shown in figure9 and figure10.

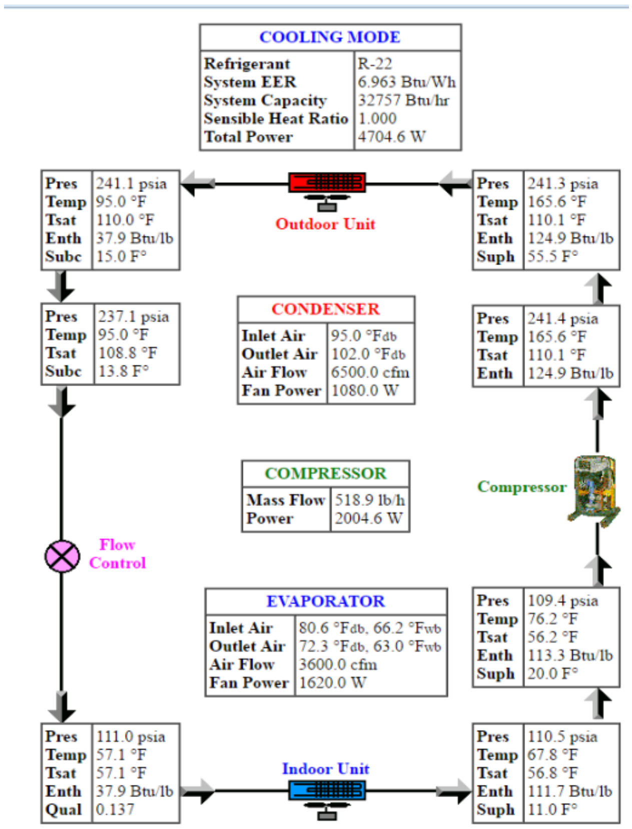


Figure9 Equipment Operation Conditions and Performance

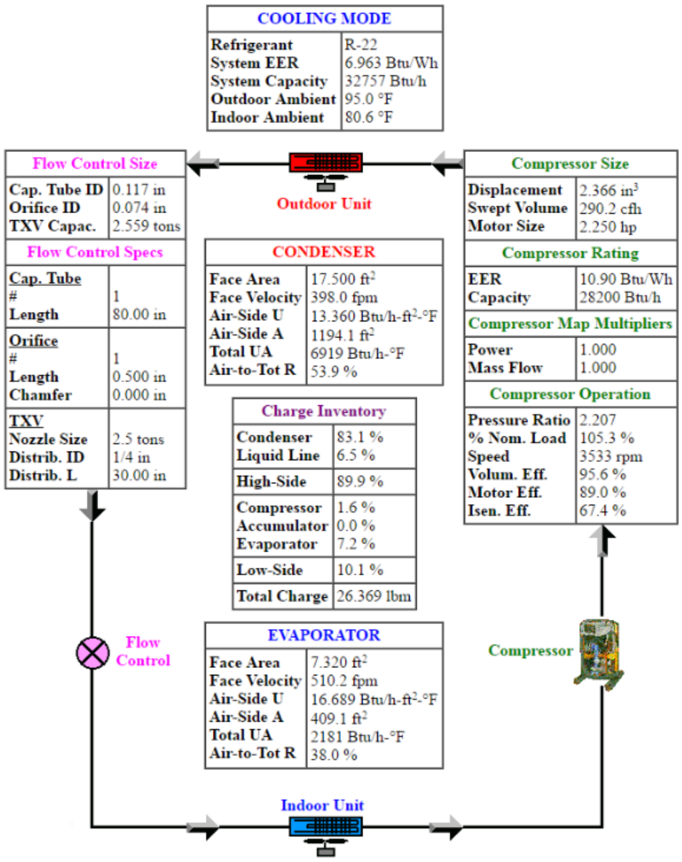


Figure10 Component Sizing, Charging, and Performance

According to figure9, figure10, the capacity, power input, and EER are shown in the Table3.

Table3 Result of Cooling Mode

Cooling Mode	Refrigerant	R-22
	System EER	6.963Btu/Wh
	System Capacity	32757Btu/hr
	Sensible Heat Ratio	1
	Total Power	4704.6W

2.1.2 Heating Load

The important steps of using DOE/ORNL Heat Pump Design Model VII for heating simulation would be shown in the following figures.

(1) Requirement of Refrigerant

Since the mode of air conditioning system is heating, and refrigerant is still R22, so choosing R22, and heat pump as the heating mode. The selection screen shot is shown in figure11.

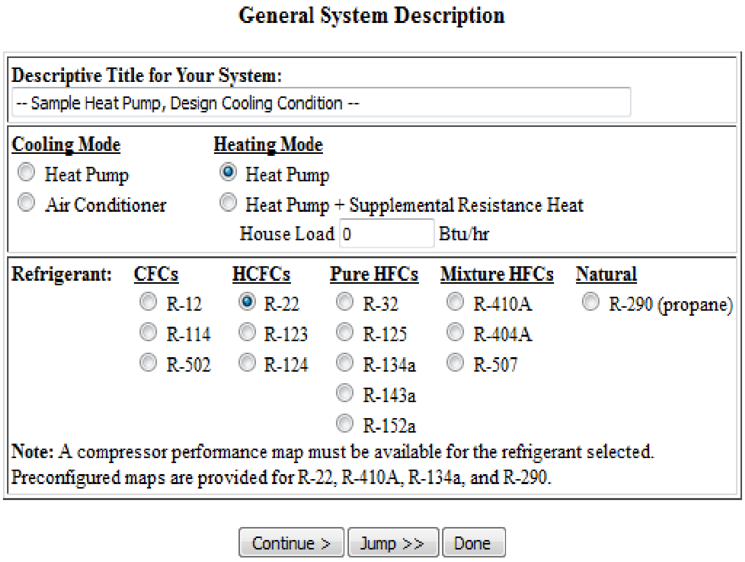


Figure11 General System Description

(2) Requirement of Compressor

Since the refrigerant is still R22, so the type of compressor doesn't change. The screen shot of selection of compressor is shown in the figure12 and figure13.

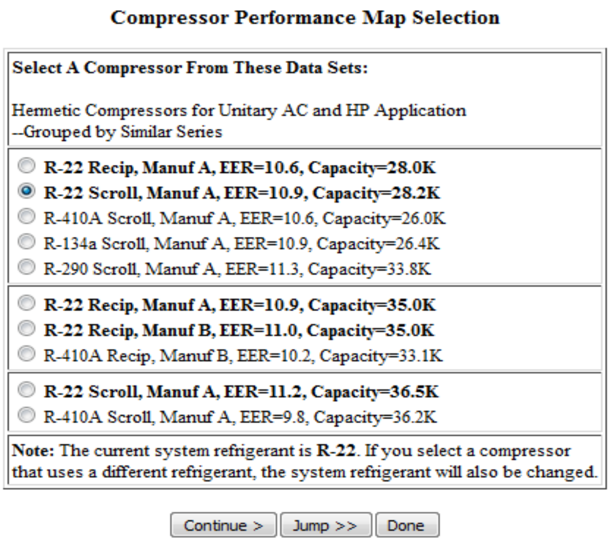


Figure12 selection of compressor

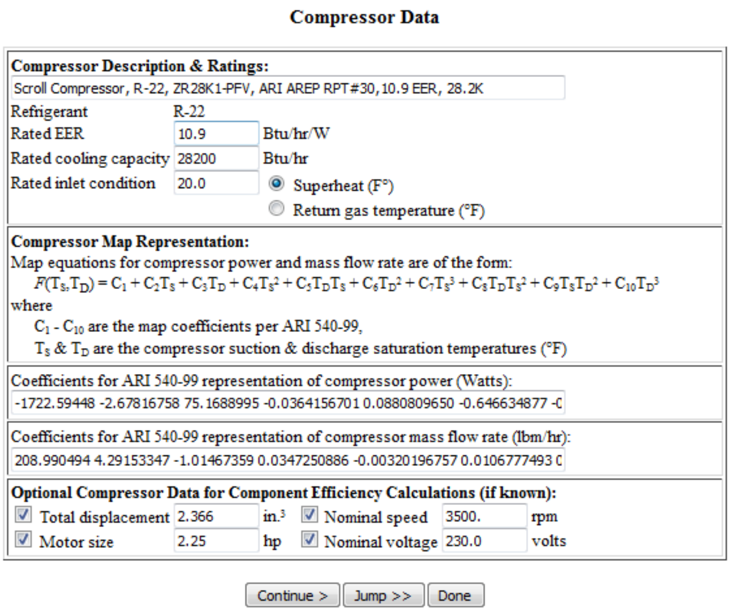


Figure13 Compressor Data

(3) Requirement of Indoor Unit

According to assignment requirement, the data of evaporator, indoor air state, and indoor fan characteristic should be inputted. The screen shot of indoor unit data is shown in the figure 14. Meanwhile, some data needed to be calculated from original data, are shown in table4.

Table4 Indoor Data

Indoor Data (heating)	
Temperature DB,(°F)	68
Temperature: WB,(°F)	59
Thickness of tube wall(mils)	20

According to the data provided by assignment, the indoor temperature (DB) is 20°C; temperature (WB) is 15°C.

$$Dry\ Bulb\ Tempertaure(°F) = 20 \times \frac{9}{5} + 32$$

$$= 68°C$$

$$Wet\ Bulb\ Tempertaure(°F) = 15 \times \frac{9}{5} + 32$$

$$= 59°C$$

$$Thickness\ of\ tube = \frac{Outside\ diameter - Inside\ diameter}{2}$$

$$= \frac{0.42 - 0.38}{2} = 0.02(in) = 20(mils)$$

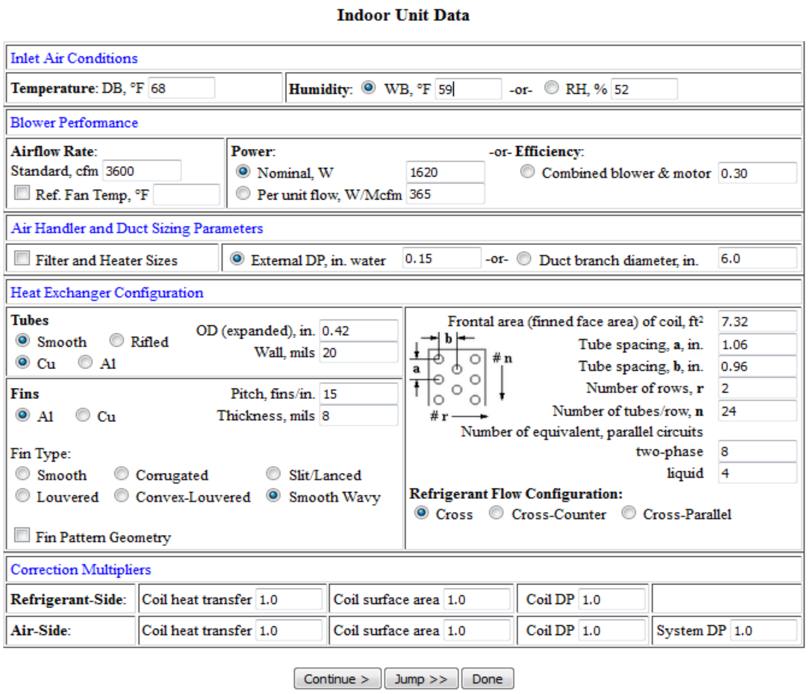


Figure14 Indoor Unit Data

(4)Requirement of Outdoor Unit

According to assignment requirement, the data of condenser, outdoor air state, and outdoor fan characteristic should be inputted. The screen shot of outdoor unit data is shown in the figure15. Meanwhile, some data needed to be calculated from original data, are shown in table5.

Table5 Outdoor Data

Indoor Data (heating)	
Temperature DB,(°F)	44.6
Temperature: WB,(°F)	42.8
Thickness of tube wall(mils)	20

According to the data provided by assignment, the indoor temperature (DB) is 35℃; temperature (WB) is 24℃.

$$Dry\ Bulb\ Tempertaure(°F) = 7 \times \frac{9}{5} + 32$$

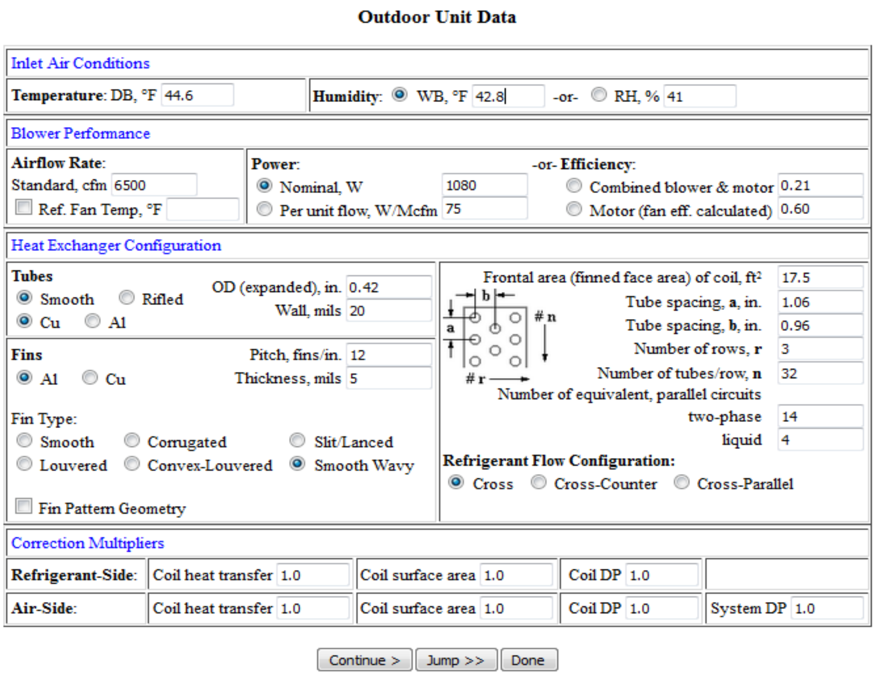
$$= 44.6$$

$$Wet\ Bulb\ Tempertaure(°F) = 24 \times \frac{9}{5} + 32$$

$$= 42.8$$

$$Thickness\ of\ tube = \frac{Outside\ diameter - Inside\ diameter}{2}$$

$$= \frac{0.42 - 0.38}{2} = 0.02(in) = 20(mils)$$


Outdoor Unit Data

Inlet Air Conditions

Temperature: DB, °F 44.6 | Humidity: WB, °F 42.8 -or- RH, % 41

Blower Performance

Airflow Rate: Standard, cfm 6500; Ref. Fan Temp, °F

Power: Nominal, W 1080; Per unit flow, W/Mcfm 75

-or- Efficiency: Combined blower & motor 0.21; Motor (fan eff. calculated) 0.60

Heat Exchanger Configuration

Tubes: Smooth, Rifled; Cu, Al; OD (expanded), in. 0.42; Wall, mils 20

Fins: Al, Cu; Pitch, fins/in. 12; Thickness, mils 5

Fin Type: Smooth, Corrugated, Slit/Lanced, Louvered, Convex-Louvered, Smooth Wavy

Fin Pattern Geometry

Frontal area (finned face area) of coil, ft² 17.5

Tube spacing, a, in. 1.06

Tube spacing, b, in. 0.96

Number of rows, r 3

Number of tubes/row, n 32

Number of equivalent, parallel circuits: two-phase 14; liquid 4

Refrigerant Flow Configuration: Cross, Cross-Counter, Cross-Parallel

Correction Multipliers

Refrigerant-Side:	Coil heat transfer 1.0	Coil surface area 1.0	Coil DP 1.0	
Air-Side:	Coil heat transfer 1.0	Coil surface area 1.0	Coil DP 1.0	System DP 1.0

Continue > Jump >> Done

Figure15 Outdoor Unit Data

(5)Requirement of Refrigerant Lines

According to assignment requirement the data of refrigerant lines are inputted. The data of screenshot refrigerant lines are shown in the figure16.

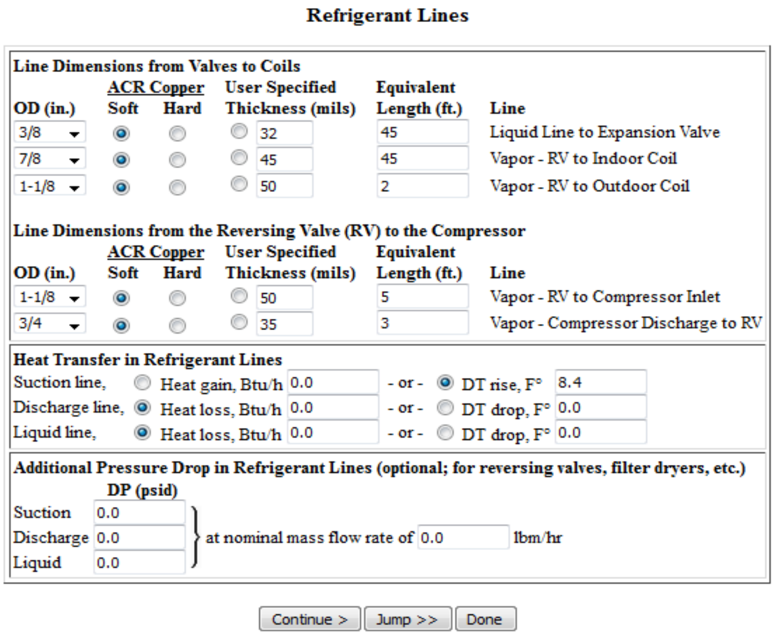


Figure16 Refrigerant Lines Data

(6)Result of simulation

After inputting all the data, DOE/ORNL Heat Pump Model VII would show the result automatically, the screenshots of the result are shown in figure17 and figure18.

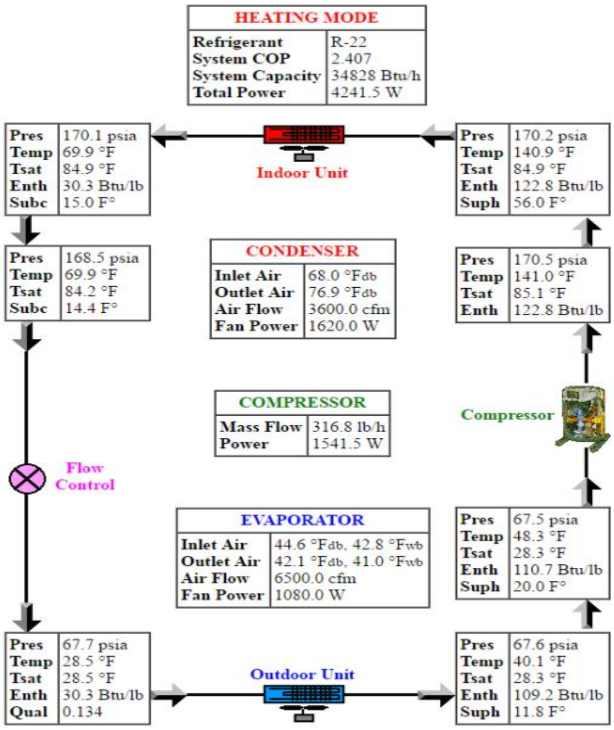


Figure17 Equipment Operation Conditions and Performance

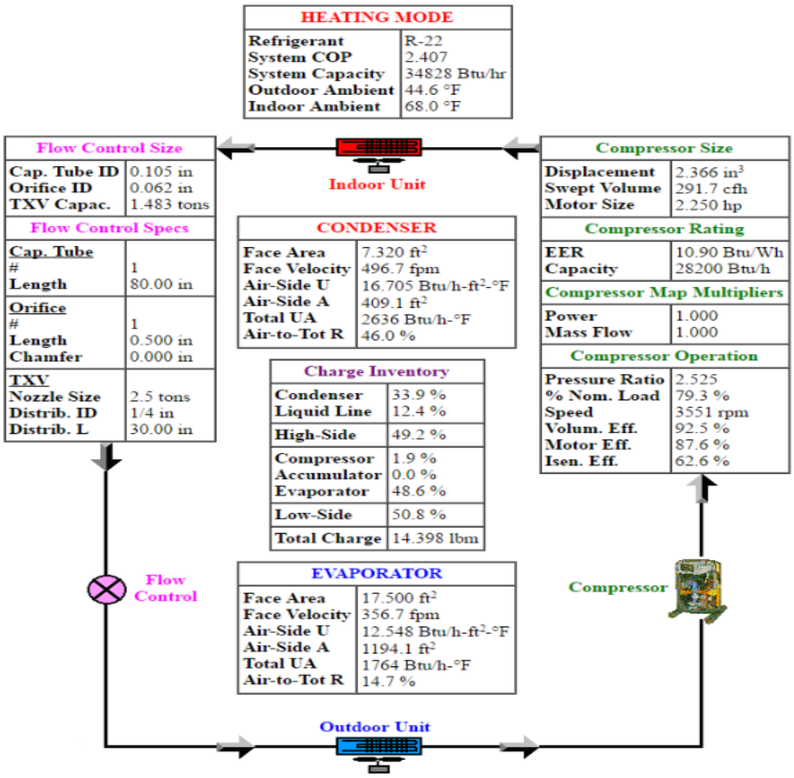


Figure18 Component Sizing, Charging, and Performance

According to figure17, figure18, the capacity, power input, and COP are shown in the Table6.

Table6 Result of Heating Mode

Heating Mode	Refrigerant	R-22
	COP	2.407
	System Capacity	34828Btu/hr
	Total Power	4241.5W

2.2 Comparison of cooling value and heating value

2.2.1 Comparison of System Capacity

According to Table3 and Table6, the system capacity of cooling mode and heating mode are 32757Btu/hr and 3482834828Btu/hr.

Hence

System capacity of heating mode > System capacity of cooling mode

2.2.2 Comparison of Total Power

According to Table3 and Table6, the total power of cooling mode and heating mode are 4704.6W and 4241.5W.

Hence Total power of cooling mode> Total power of heating mode

2.2.3 Comparison of Efficiency

According to table 3 and table6, the EER of cooling system and COP of heating system are 6.963Btu/Wh and 2.407 respectively.

Since

$$\frac{1Btu}{hr} = 0.293W$$

Hence

$$6.963\frac{Btu}{Wh} = 2.04$$

Hence

$$EER < COP$$

2.3 R410a Utilization

According to assignment requirement, the new unit should use the R410a to replace R22. The important steps of using DOE/ORNL Heat Pump Design Model VII for cooling simulation would be shown in the following figures.

(1) Requirement of Refrigerant

Choosing R410a as the refrigerant, and choosing heat pump as the cooling mode, the selection screen shot is shown in figure19.

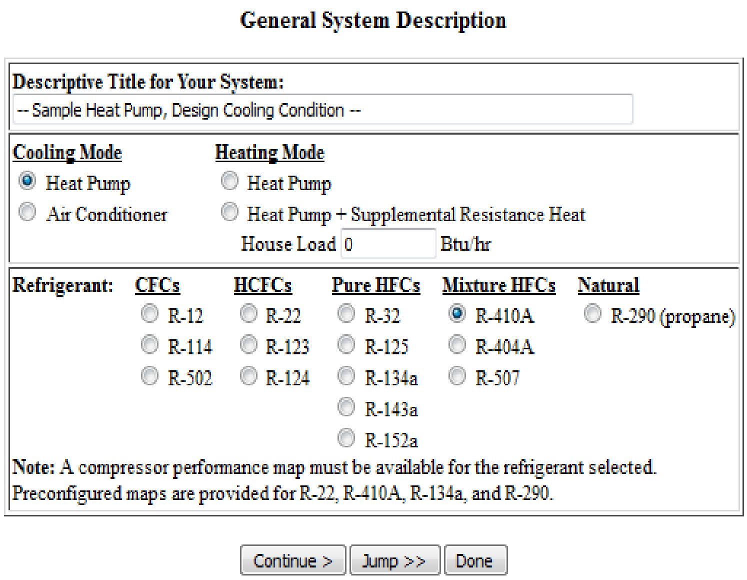


Figure19 General System Description

(2) Requirement of Compressor

According to assignment requirement, the compressor should be suitable to R410a refrigerant. The screen shot of selection of compressor is shown in the figure20 and figure21.

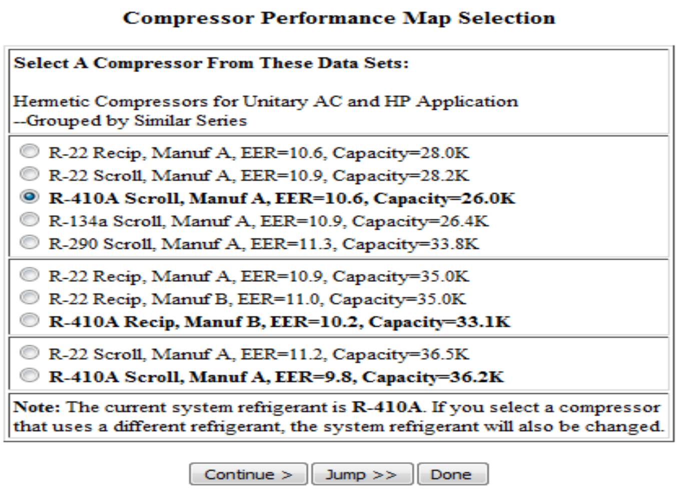


Figure20 Compressor selection

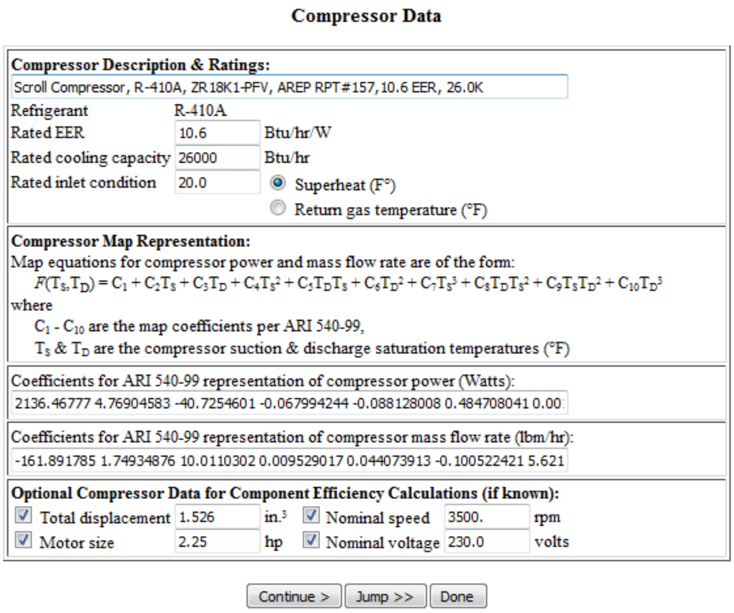


Figure21 Compressor Data

(3) Requirement of Indoor Unit

According to assignment requirement, the data of evaporator, indoor air state, and indoor fan characteristic should be inputted. The screen shot of indoor unit data is shown in the figure 22. Meanwhile, some data needed to be calculated from original data, are shown in table7.

Table7 Indoor Data

Indoor Data (cooling)	
Temperature DB,(°F)	80.6
Temperature: WB,(°F)	66.2
Thickness of tube wall(mils)	20

According to the data provided by assignment, the indoor temperature (DB) is 27°C, temperature (WB) is 19°C.

$$Dry\ Bulb\ Tempertaure(°\mathrm{F}) = 27 \times \frac{9}{5} + 32$$

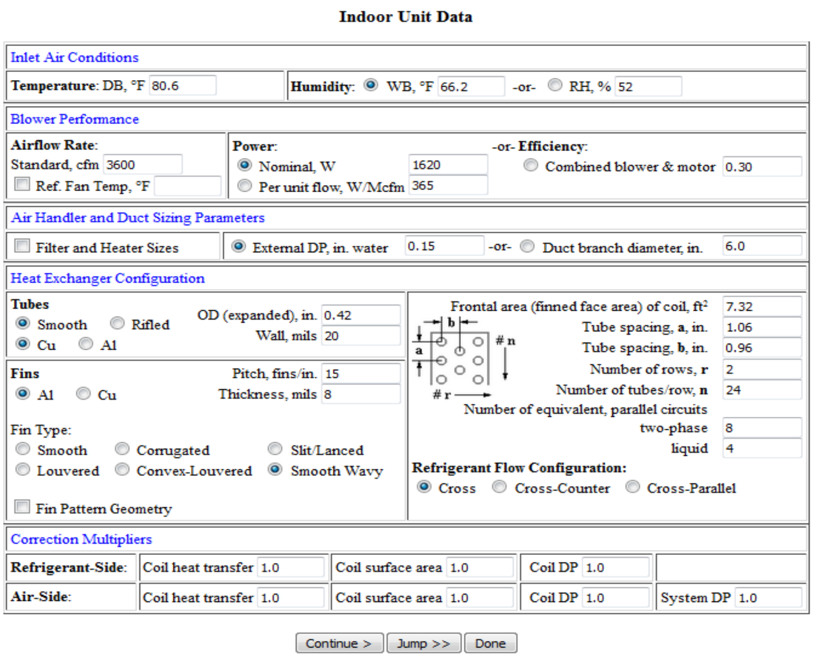
$$= 80.6\mathrm{°C}$$

$$Wet\ Bulb\ Tempertaure(°\mathrm{F}) = 19 \times \frac{9}{5} + 32$$

$$= 66.2\mathrm{°C}$$

$$Thickness\ of\ tube = \frac{Outside\ diameter - Inside\ diameter}{2}$$

$$= \frac{0.42 - 0.38}{2} = 0.02(in) = 20(mils)$$


Indoor Unit Data

Inlet Air Conditions
Temperature: DB, °F 80.6
Humidity: WB, °F 66.2 -or- RH, % 52

Blower Performance
Airflow Rate:
Standard, cfm 3600
Ref. Fan Temp, °F
Power:
Nominal, W 1620
Per unit flow, W/Mcfm 365
-or- Efficiency:
Combined blower & motor 0.30

Air Handler and Duct Sizing Parameters
Filter and Heater Sizes
External DP, in. water 0.15 -or- Duct branch diameter, in. 6.0

Heat Exchanger Configuration
Tubes
Smooth Rifled
Cu Al
OD (expanded), in. 0.42
Wall, mils 20
Fins
Al Cu
Pitch, fins/in. 15
Thickness, mils 8
Fin Type:
Smooth Corrugated Slit/Lanced
Louvered Convex-Louvered Smooth Wavy
Fin Pattern Geometry
Frontal area (finned face area) of coil, ft² 7.32
Tube spacing, a, in. 1.06
Tube spacing, b, in. 0.96
Number of rows, r 2
Number of tubes/row, n 24
Number of equivalent, parallel circuits
two-phase 8
liquid 4
Refrigerant Flow Configuration:
Cross Cross-Counter Cross-Parallel

Correction Multipliers
Refrigerant-Side: Coil heat transfer 1.0 Coil surface area 1.0 Coil DP 1.0
Air-Side: Coil heat transfer 1.0 Coil surface area 1.0 Coil DP 1.0 System DP 1.0

Continue > Jump >> Done

Figure22 Indoor Unit Data

(4)Requirement of Outdoor Unit

According to assignment requirement, the data of condenser, outdoor air state, and outdoor fan characteristic should be inputted. The screen shot of outdoor unit data is shown in the figure 23. Meanwhile, some data needed to be calculated from original data, are shown in table8.

Table8 Outdoor Data

Indoor Data (cooling)	
Temperature DB,(°F)	95
Temperature: WB,(°F)	75.2
Thickness of tube wall(mils)	20

According to the data provided by assignment, the indoor temperature (DB) is 35℃; temperature (WB) is 24℃.

$$Dry\ Bulb\ Tempertaure(°\mathrm{F}) = 35 \times \frac{9}{5} + 32$$

$$= 95℃$$

$$Wet\ Bulb\ Tempertaure(°\mathrm{F}) = 24 \times \frac{9}{5} + 32$$

$$= 75.2℃$$

$$Thickness\ of\ tube = \frac{Outside\ diameter - Inside\ diameter}{2}$$

$$= \frac{0.42 - 0.38}{2} = 0.02(in) = 20(mils)$$

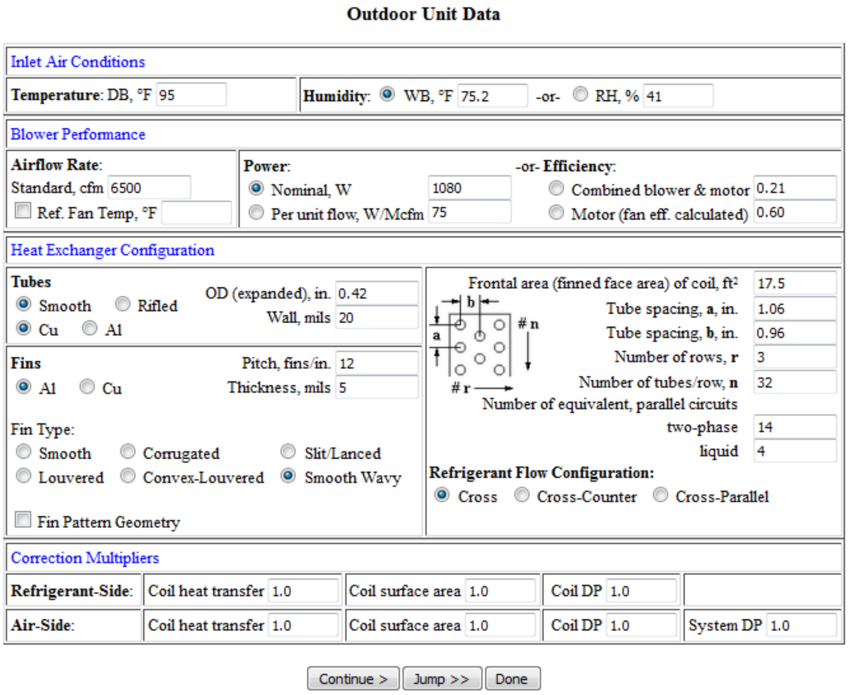


Figure23 Outdoor Unit Data

(5)Requirement of Refrigerant Lines

According to assignment requirement the data of refrigerant lines are inputted. The data of screenshot refrigerant lines are shown in the figure24.

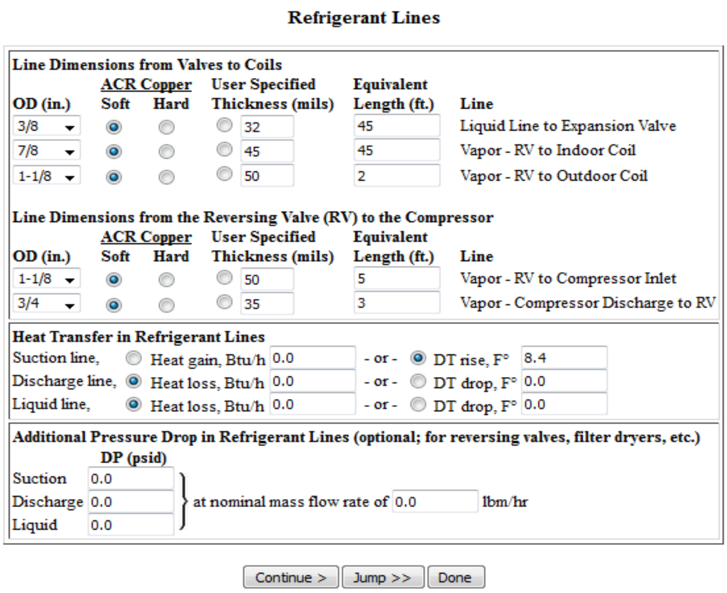


Figure24 Refrigerant Lines Data

(6)Result of simulation

After inputting all the data, DOE/ORNL Heat Pump Model VII would show the result automatically, the screenshots of the result are shown in figure25 and figure26.

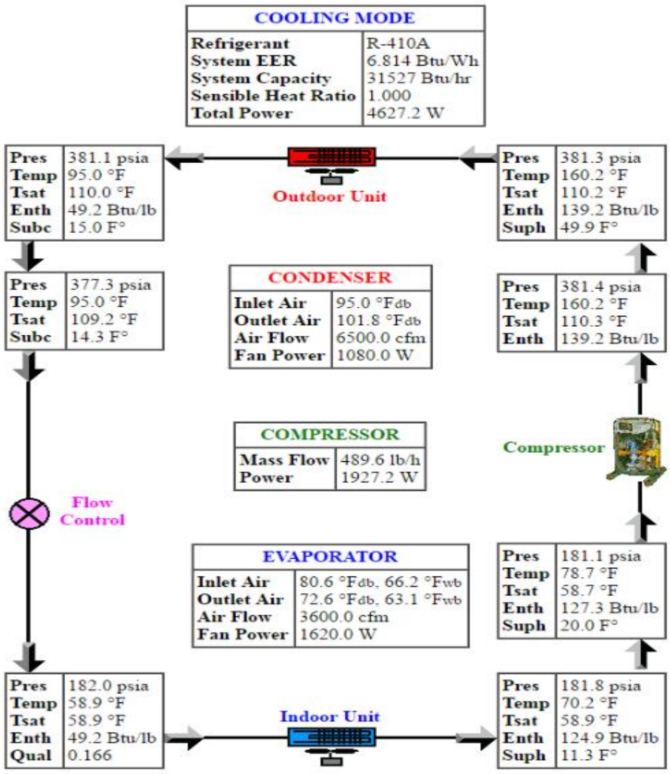


Figure25 Equipment Operation Conditions and Performance

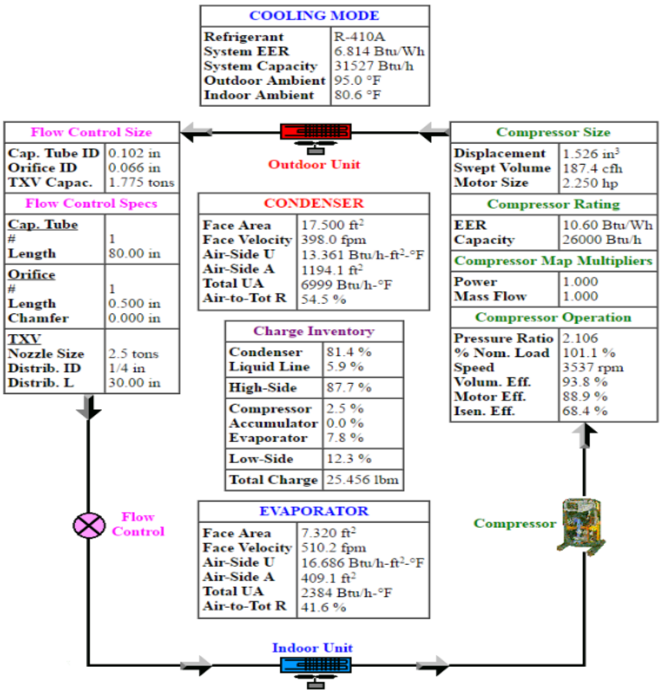


Figure26 Component Sizing, Charging, and Performance

According to figure25, figure26, the capacity, power input, and EER are shown in the Table9.

Table9 Result of Cooling Mode

Cooling Mode	Refrigerant	R-410a
	System EER	6.814Btu/Wh
	System Capacity	31527Btu/hr
	Sensible Heat Ratio	1
	Total Power	4627.2W

2.4Comparison of R22 and R410a

The comparison of the coefficient of system between using R22 and R410a is shown in table10.

Table10 Total Comparison between R22 and R410a

R410a	System EER	6.814Btu/Wh
	System Capacity	31527Btu/hr
	Sensible Heat Ratio	1
	Total Power	4627.2W
R22	System EER	6.963Btu/Wh
	System Capacity	32757Btu/hr
	Sensible Heat Ratio	1
	Total Power	4704.6W

2.4.1 Comparison of System Capacity

According to table10, the system capacity of R410a cooling mode and R22 cooling mode are 31527Btu/hr and 32757Btu/hr.

Hence

System capacity of R22 >System capacity of R410a

2.4.2 Comparison of Total Power

According to table10, the total power of R410a cooling mode and R22 cooling mode are 4627.2W and 4704.6W.

Hence

Total Power of R22 > Total Power of R410a

2.4.3Comparison of Efficiency

According to table10 the system EER of R410a and R22 are 6.814Btu/Wh and 6.963Btu/Wh.

Hence

$$EER_{R22} > ERR_{R410a}$$

3 Influences of Changing parameter

3.1 Influence of indoor coil area

According to figure6, the frontal area of indoor coil is 7.32ft^2, hence assuming the indoor area changes from 6.32ft^2 to 9.32 ft^2. Then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure27.

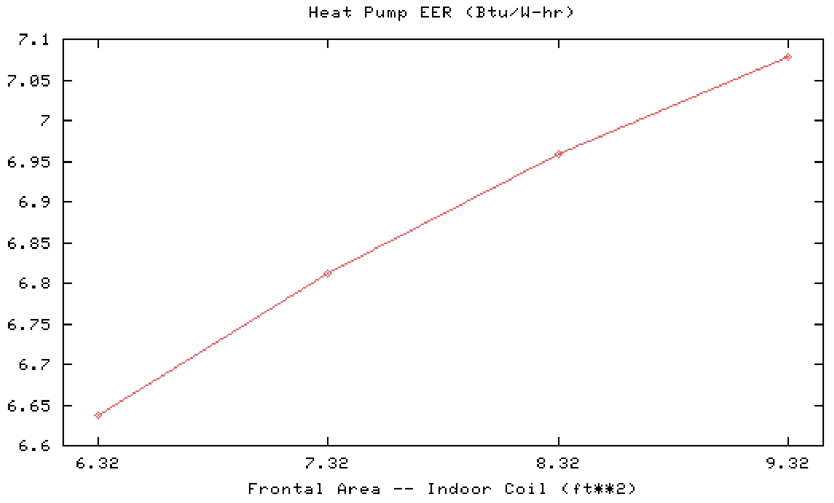


Figure27 EER curve

As can be seen in these curves, when indoor coil area changing from 6.32ft^2 to around9.32 ft^2, EER changes from 6.63Btu/W-hr to 7.06 Btu/W-hr.

3.2Influence outdoor coil area

According to figure7, the frontal area of outdoor coil is 17.5ft^2, hence assuming the outdoor area changes from 12.5ft^2 to 21.5ft^2. Then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure28.

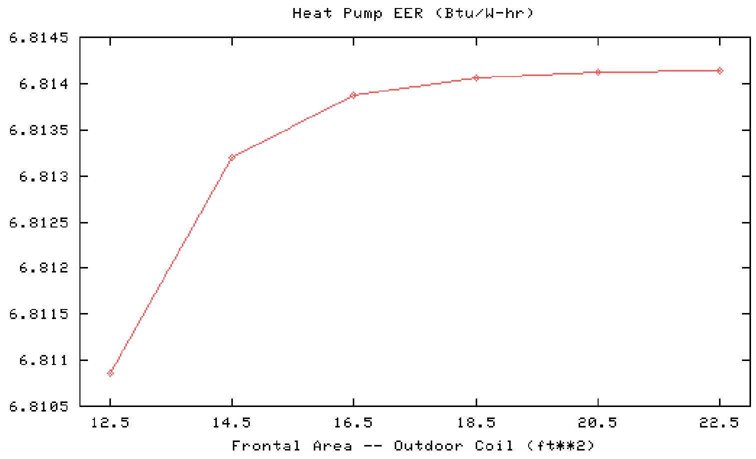


Figure28 EER curve

As can be seen from these figures, when the outdoor area changes from 12.5ft^2 to 21.5ft^2, the EER would increase firstly, but the increase tendency decreases, until the area changing to 21.5 ft^2, EER would keep 6.814Btu/W-hr.

3.3influen of indoor air flow rate

According to figure 6, the indoor air flow rate is 3600cfm, hence assuming the indoor air flowrate changes from 3000cfm to 4000cfm. Then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER, system capacity, and total power can be got. The curve is shown in figure29.

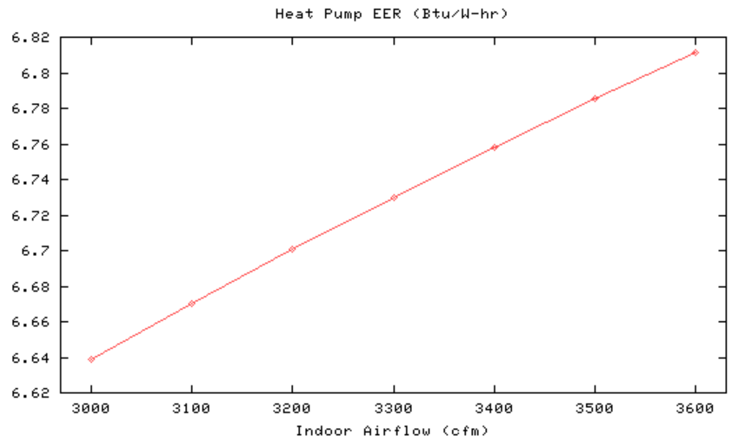


Figure29

As can be seen from these curves, when the indoor air flowrate changes from 3000cfm to 4000cfm, EER increases from 6.64 Btu/W-hr to 6.81 Btu/W-hr.

3.4 Influence of outdoor air flow rate

According to figure 7, the outdoor air flow rate is 6500cfm, hence assuming the outdoor air flowrate changes from 5500cfm to 7500cfm. Then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure30.

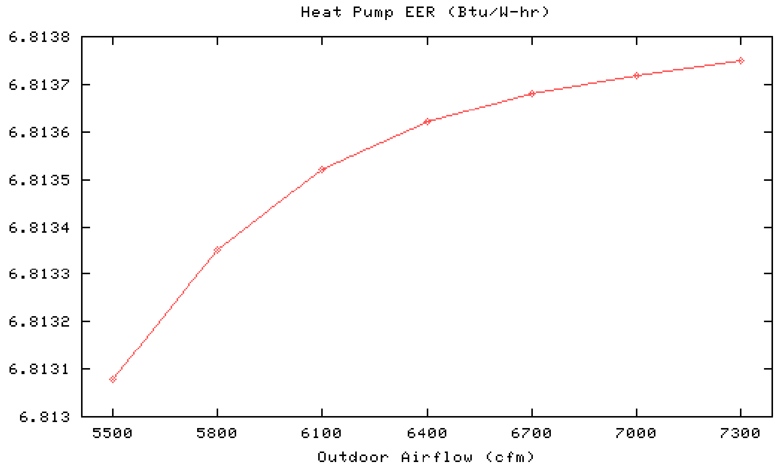


Figure30

As can be seen from these curves, when outdoor air flowrate changes from 5500cfm to 7500cfm, the EER would change from 6.81505Btu/W-hr to 6.81317Btu/W-hr, the increase tendency would keep decreasing.

3.5Influence of air –on conditions

Changing indoor coil area from 7.32 ft^2 to 9.32 ft^2, outdoor coil area from 17.5 ft^2 to 22.5 ft^2, indoor air flowrate from 3600cfm to 4000 cfm and outdoor air flow rate from 6500 cfm to 7500cfm.

According to the assignment requirement, the air on condition would change from 20°CDB, 40%RH to 25°CDB, 60%RH. then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure31.

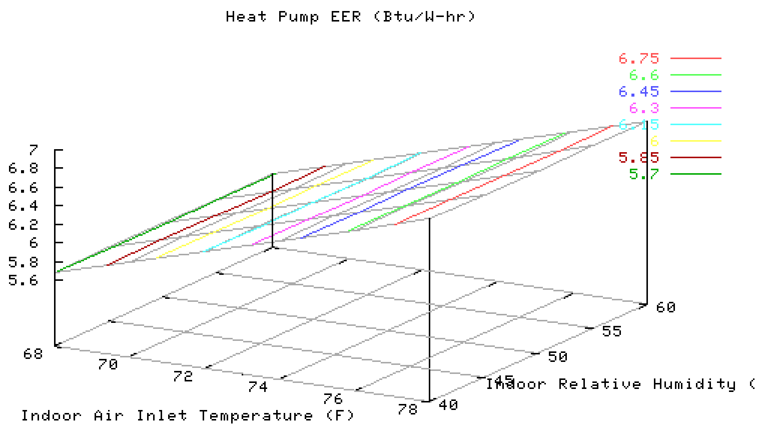


Figure31

As can be seen from these curves, when air on condition would change from 20°CDB, 40%RH to 25°CDB, 60%RH, EER would increase from 5.7 Btu/W-hr to 6.75Btu/W-hr, relevant humidity has no influences to EER.

3.6 Influence of outside conditions

According to assignment requirement, outside condition would change from 30°C, 28°CWB to 40°C DB, 35°CWB. then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure32.

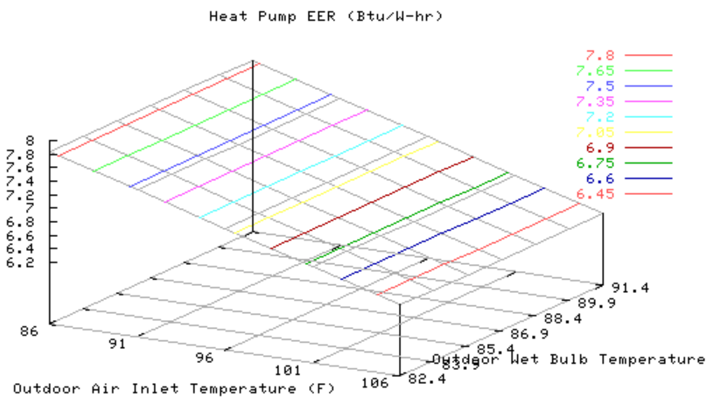


Figure32

As can be seen from these curves, when outside condition would change from 30 °C, 28°CWB to 40°C DB, 35°CWB , EER decreases from 7.8Btu/W-hr to 6.45Btu/W-hr; relevant humidity has no influences to EER.

3.7 Analysis of changing parameter.

To increase the EER of R410a cooling system, the indoor coil area should be increased, outdoor coil area should be increase d to 21.5ft, indoor air flow rate should be increase, outside air flow rate should be increased, and temperature of indoor air should be increased. Outside door condition can’t be controlled.

Hence, to increase EER, some parameter should be modified; the modification is shown in table 11. New EER is shown in figure 45

Table 11 Modification of Parameter

	Indoor coil area(ft^2)	Outdoor coil area(ft^2)	Indoor air flow rate(cfm)	Outdoor air flow rate(cfm)	Indoor temperature ℃	EER
Original	7.32	17.5	3600	6500	27	6.814
Modification	9.32	22.5	4000	7500	27	7.171

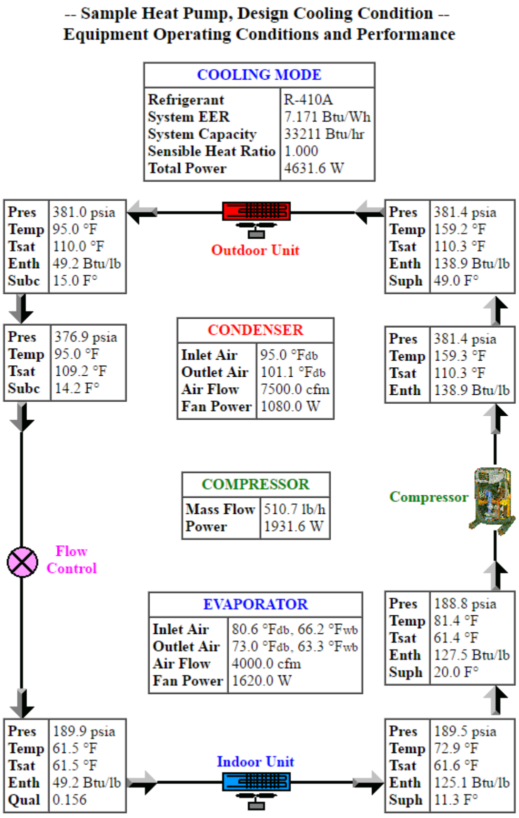


Figure33New result of R410a cooling system

4 Part2 (Lab Experiment)

4.1Objective

The part two is going to utilize refrigeration demonstration system to complete vapour compression process. Meanwhile some parameters would be changed, and the corresponding influences would be observed.

4.2Equipment

There are four main equipment in experiment, which are evaporator, compressor, condenser, and throttling.

Evaporator would first make the refrigerant evaporate to gas state, and then refrigerant would be sucked into the compressor, in which the pressure of refrigerant would be increased, then the refrigerant would be discharged out of the compressor, and then it would be transported to condenser in which the refrigerant would release heat and change to liquid. Finally, refrigerant would be go through throttling, the pressure of refrigerant can be decreased.

4.3Question 1

(a) As can be seen from figure 34; all the major components have been numbered. The identification of all the components is shown in table 12.

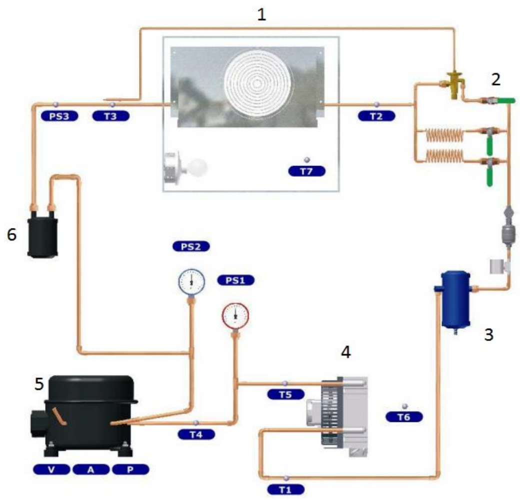


Figure34 Lab-Volt Refrigeration Demonstration System

Table12 components in Lab-Volt Refrigeration Demonstration System

Number	Component
1	Evaporator
2	Expansion Devices
3	Liquid Receiver
4	Condenser
5	Compressor
6	Accumulator

(b) The 4 main components of refrigeration system are shown in figure 35.

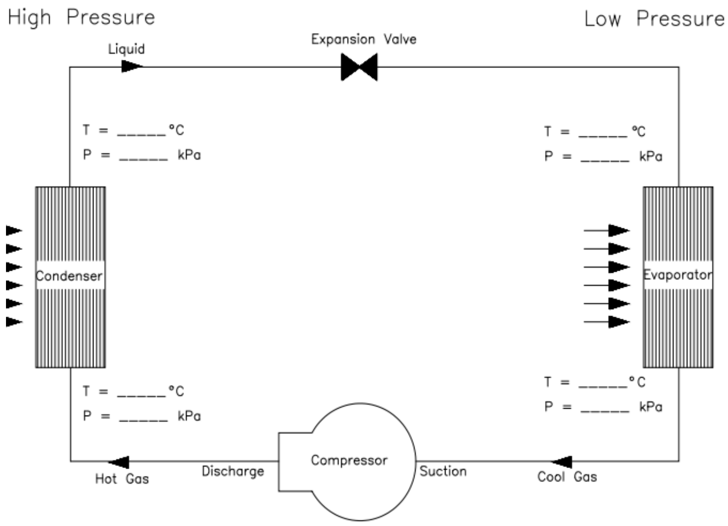


Figure35 Simplified Refrigeration System

Comparing figure35 and figure34, liquid receiver and accumulator are not shown in figure35. Liquid receiver is situated between condenser and throttling. When the statue of refrigerant changes from gas to liquid, to guarantee the entire refrigerant transported into throttling is liquid, liquid receiver can gather the refrigerant at a liquid state.

Accumulator is situated between evaporator and compressor; accumulator can store the liquid refrigerant, so that only refrigerant whose status is gas can be transported into compressor.

(c) From experiment observation, when pressure of refrigerant increases, p-h diagram would move to upside, conversely p-h diagram would move to down side. When enthalpy of refrigerant increase p-h diagram would move to right side, conversely, p-h diagram would move to left side

(d) The throttling devices consist of capillary tube and thermostatic expansion valve. The capillary would reduce the pressure of refrigerant coming from condenser, during the process; the temperature of refrigerant also decreases, some refrigerate can vaporize. So, pressure and temperature would change between the inlet and outlet of the capillary. There are two capillaries which have different length, longer capillary can cause larger pressure drop. They can control the degree of superheat.

Thermostatic expansion valve can control the flow rate of refrigerant, it can sense the temperature of refrigerant which is in outlet of evaporator, when sensed temperature is lower than setting temperature, and TEV would decrease the flow rant. On the contrary, if the sensed temperature is higher than setting temperature, TEV would increase flow rate.

(e) If there are bubbles occurring in liquid line, refrigerant is not totally condense into liquid in condenser, so condenser doesn't work in a full efficiency, meanwhile, the pressure of refrigerant in suction line would be low, which causes the low pressure in discharge line .

(f) According to data got from experiment, the p-h diagram is shown in figure36.

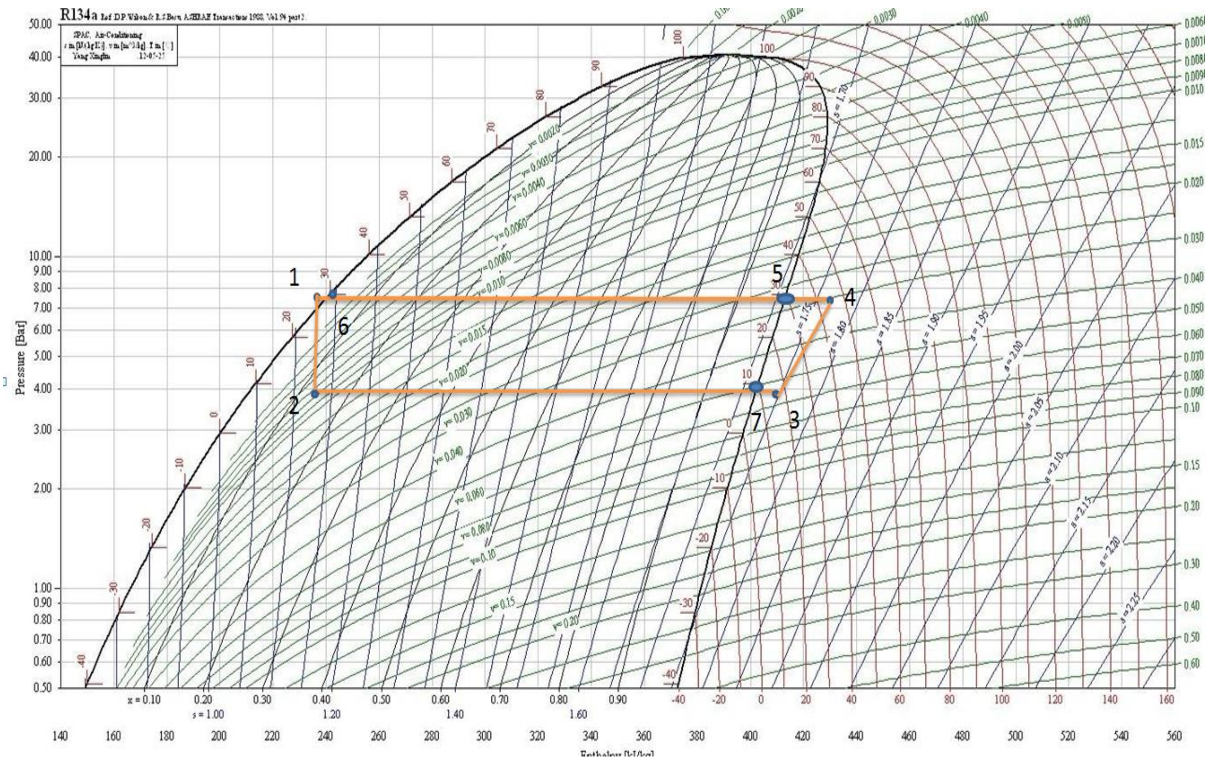


Figure36

As can be seen from figure36:

$$H_1 = 235\, {}^{kJ}/_{kg}$$

$$H_6 = 245\, {}^{kJ}/_{kg}$$

$$H_7 = 400\, {}^{kJ}/_{kg}$$

$$H_3 = 407\, {}^{kJ}/_{kg}$$

$$H_{subcooling} = H_6 - H_1$$

$$= 10\, {}^{kJ}/_{kg}$$

$$H_{superheat} = H_3 - H_4$$

$$= 7 \, {}^{kJ}/_{kg}$$

(g) When condenser fan fails, the heat of air surrounding the condenser cannot be released, so the temperature of refrigerant and pressure of refrigerant would increase, so enthalpy of refrigerant would increase.

(h) When evaporator fan fails, the cold air surrounding the evaporator cannot be blowed out, so temperature and pressure of refrigerant would decrease, so enthalpy of refrigerant would decrease.

(i) When capillary is blocked, p-h diagram would be narrow, because the pressure of refrigerant coming from condenser cannot be decreased. The evaporator can be starved, suction line cannot suck any refrigerant, so there is no refrigerant coming into condenser, so whole system is undercharged.

(j) When the system is overcharged, the pressure of refrigerant can be increased, so temperature of refrigerant can be increased which causes the cooling process cannot be as efficient as before. Meanwhile overcharged system can cause liquid moving into compressor which only allows gas to enter. So compressor can be destroyed.

4.4 Question2

(a) According to observation of experiment, the data are shown in table 13.

Table13 Experiment Data

	Pressure(Mpa)	Temperature(℃)
Suction	0.85	10.6
Discharge	1.95	48.6

According to table13, point3 and point4 can be drew on p-h diagram. Assuming there is no sub-cooling in system, and pressure of refrigerant in condenser would not change, so point 1 can be drew on p-h diagram. Since enthalpy of refrigerant in throttling would not change, and the pressure of refrigerant in evaporator would not change, so point 2 can be drew on p-h diagram. The p-h diagram is shown in figure 37.

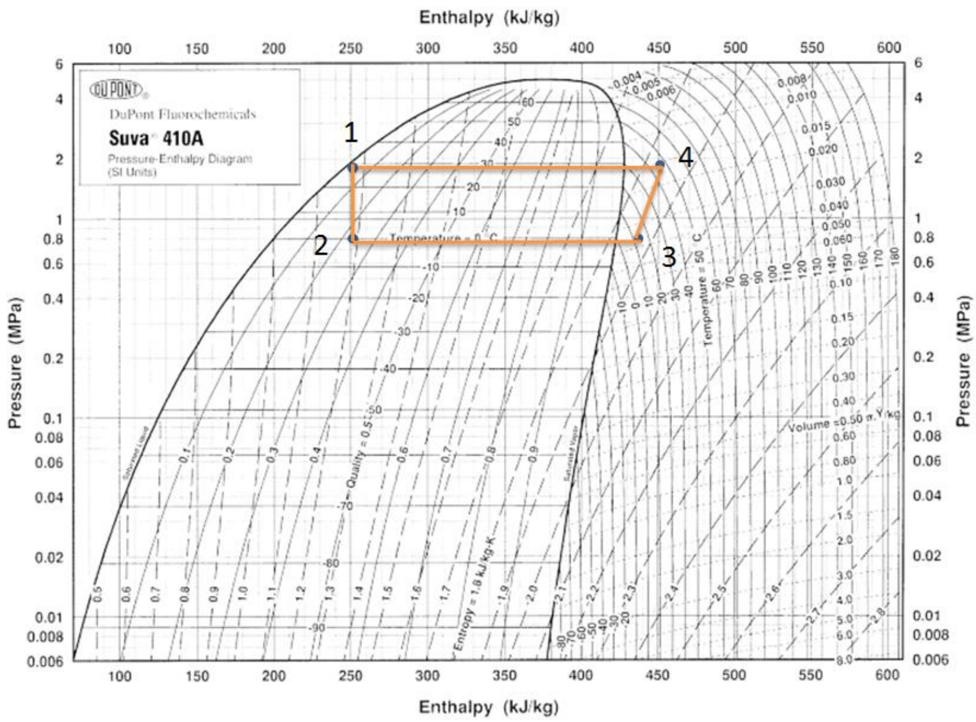


Figure37 p-h diagram of R410a

(b) The enthalpy change of refrigeration effect:

$$Q_{ref} = h_3 - h_2$$

$$h_3 = 430\ {}^{kJ}/_{kg}$$

$$h_2 = 250\ {}^{kJ}/_{kg}$$

$$Q_{ref} = 180\ {}^{kJ}/_{kg}$$

(c) Heat reject at condenser:

$$Q_{reject} = h_4 - h_1$$

$$h_4 = 450\ {}^{kJ}/_{kg}$$

$$h_1 = 250\ {}^{kJ}/_{kg}$$

$$Q_{reject} = 200\ {}^{kJ}/_{kg}$$

(d) Heat change during compression:

$$H_{change} = H_4 - H_3$$

$$H_4 = 450\ {}^{kJ}/_{kg}$$

$$H_3 = 430\ {}^{kJ}/_{kg}$$

$$H_{change} = 20\ {}^{kJ}/_{kg}$$

(e) EER

$$EER = \frac{Q_{ref}}{Q_{change}}$$

$$= \frac{180}{20}$$

$$= 9$$

Conclusion

EER of cooling system would be smaller than COP of heating system, since the enthalpy change of refrigerant in condenser is larger than that of in evaporator. Meanwhile, to increase EER of cooling system, indoor coil area, outdoor coil area, indoor air flow rate and outdoor air flow rate should be increased.

The basic refrigerating system should contain condenser, expansion valve, evaporator and compressor, at the same time, liquid receiver and accumulator can be installed to guarantee the high efficient of devices. The system cannot be undercharged or overcharged.

References

1 Mech4880 Refrigeration and air conditioning assignment2-Part1 (System modelling)

2 Mech4880 Refrigeration and air conditioning assignment2-Part2 (Laboratory2016)