



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.

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Assumption & Justification

1 Modify indoor coil area from 7.32 ft² to 9.32 ft².

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 ft² to 22.5 ft²

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°C

According to the result of simulation higher indoor temperature can cause higher EER. But 27°C 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.

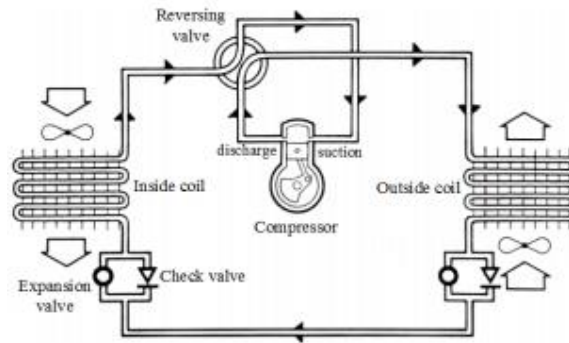


Figure1 cooling mode

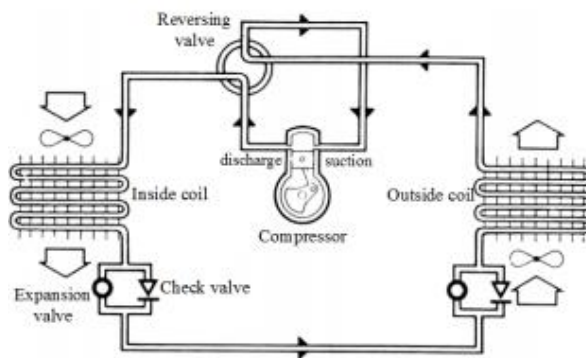


Figure2 heating mode

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

General System Description

Descriptive Title for Your System:				
-- Sample Heat Pump, Design Cooling Condition --				
Cooling Mode		Heating Mode		
<input checked="" type="radio"/> Heat Pump <input type="radio"/> Air Conditioner		<input type="radio"/> Heat Pump <input type="radio"/> Heat Pump + Supplemental Resistance Heat House Load 0 Btu/hr		
Refrigerant:	<u>CFCs</u>	<u>HCFCs</u>	<u>Pure HFCs</u>	<u>Mixture HFCs</u> <u>Natural</u>
	<input type="radio"/> R-12 <input type="radio"/> R-114 <input type="radio"/> R-502	<input checked="" type="radio"/> R-22 <input type="radio"/> R-123 <input type="radio"/> R-124	<input type="radio"/> R-32 <input type="radio"/> R-125 <input type="radio"/> R-134a <input type="radio"/> R-143a <input type="radio"/> R-152a	<input type="radio"/> R-410A <input type="radio"/> R-404A <input type="radio"/> R-507 <input type="radio"/> R-290 (propane)
Note: A compressor performance map must be available for the refrigerant selected. Preconfigured maps are provided for R-22, R-410A, R-134a, and R-290.				

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.

Compressor Performance Map Selection

Select A Compressor From These Data Sets:	
Hermetic Compressors for Unitary AC and HP Application --Grouped by Similar Series	
<input type="radio"/> R-22 Recip, Manuf A, EER=10.6, Capacity=28.0K <input checked="" type="radio"/> R-22 Scroll, Manuf A, EER=10.9, Capacity=28.2K <input type="radio"/> R-410A Scroll, Manuf A, EER=10.6, Capacity=26.0K <input type="radio"/> R-134a Scroll, Manuf A, EER=10.9, Capacity=26.4K <input type="radio"/> R-290 Scroll, Manuf A, EER=11.3, Capacity=33.8K	
<input type="radio"/> R-22 Recip, Manuf A, EER=10.9, Capacity=35.0K <input type="radio"/> R-22 Recip, Manuf B, EER=11.0, Capacity=35.0K <input type="radio"/> R-410A Recip, Manuf B, EER=10.2, Capacity=33.1K	
<input type="radio"/> R-22 Scroll, Manuf A, EER=11.2, Capacity=36.5K <input type="radio"/> R-410A Scroll, Manuf A, EER=9.8, Capacity=36.2K	
Note: The current system refrigerant is R-22. If you select a compressor that uses a different refrigerant, the system refrigerant will also be changed.	

Figure4 Compressor selection

Compressor Data

Compressor Description & Ratings:			
Scroll Compressor, R-22, ZR28K1-PFV, ARI AREP RPT #30,10.9 EER, 28.2K			
Refrigerant	R-22		
Rated EER	10.9	Btu/hr/W	
Rated cooling capacity	28200	Btu/hr	
Rated inlet condition	20.0	<input checked="" type="radio"/> Superheat (F°) <input type="radio"/> Return gas temperature (°F)	
Compressor Map Representation:			
Map equations for compressor power and mass flow rate are of the form: $F(T_s, T_D) = C_1 + C_2 T_s + C_3 T_D + C_4 T_s^2 + C_5 T_D T_s + C_6 T_D^2 + C_7 T_s^3 + C_8 T_D T_s^2 + C_9 T_s T_D^2 + C_{10} T_D^3$ where $C_1 - C_{10}$ are the map coefficients per ARI 540-99, T_s & T_D are the compressor suction & discharge saturation temperatures (°F)			
Coefficients for ARI 540-99 representation of compressor power (Watts): -1722.59448 -2.67816758 75.1688995 -0.0364156701 0.0880809650 -0.646634877 -0.0			
Coefficients for ARI 540-99 representation of compressor mass flow rate (lbm/hr): 208.990494 4.29153347 -1.01467359 0.0347250886 -0.00320196757 0.0106777493 0.0			
Optional Compressor Data for Component Efficiency Calculations (if known):			
<input checked="" type="checkbox"/> Total displacement	2.366	in. ³	<input checked="" type="checkbox"/> Nominal speed 3500. rpm
<input checked="" type="checkbox"/> Motor size	2.25	hp	<input checked="" type="checkbox"/> Nominal voltage 230.0 volts

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 table 1.

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.

$$\begin{aligned}
 \text{Dry Bulb Tempertaure}(\text{°F}) &= 27 \times \frac{9}{5} + 32 \\
 &= 80.6^\circ\text{C}
 \end{aligned}$$

$$\begin{aligned}
 \text{Wet Bulb Tempertaure}(\text{°F}) &= 19 \times \frac{9}{5} + 32 \\
 &= 66.2^\circ\text{C}
 \end{aligned}$$

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

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

Indoor Unit Data

Inlet Air Conditions			
Temperature: DB, °F 80.6		Humidity: <input checked="" type="radio"/> WB, °F 66.2 -or- <input type="radio"/> RH, % 52	
Blower Performance			
Airflow Rate: Standard, cfm 3600 <input type="checkbox"/> Ref. Fan Temp, °F		Power: <input checked="" type="radio"/> Nominal, W 1620 <input type="radio"/> Per unit flow, W/Mcfm 365 -or- Efficiency: <input type="radio"/> Combined blower & motor 0.30	
Air Handler and Duct Sizing Parameters			
<input type="checkbox"/> Filter and Heater Sizes		<input checked="" type="radio"/> External DP, in. water 0.15 -or- <input type="radio"/> Duct branch diameter, in. 6.0	
Heat Exchanger Configuration			
Tubes <input checked="" type="radio"/> Smooth <input type="radio"/> Rifled OD (expanded), in. 0.42 <input checked="" type="radio"/> Cu <input type="radio"/> Al Wall, mils 20		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	
Fins <input checked="" type="radio"/> Al <input type="radio"/> Cu Pitch, fins/in. 15 Thickness, mils 8		Refrigerant Flow Configuration: <input checked="" type="radio"/> Cross <input type="radio"/> Cross-Counter <input type="radio"/> Cross-Parallel	
Fin Type: <input type="radio"/> Smooth <input type="radio"/> Corrugated <input type="radio"/> Slit/Lanced <input type="radio"/> Louvered <input type="radio"/> Convex-Louvered <input checked="" type="radio"/> Smooth Wavy			
<input type="checkbox"/> Fin Pattern Geometry			
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

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°C; temperature (WB) is 24°C.

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

$$= 95^{\circ}C$$

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

$$= 75.2^{\circ}\text{C}$$

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

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

Outdoor Unit Data

Inlet Air Conditions			
Temperature: DB, °F 95		Humidity: <input checked="" type="radio"/> WB, °F 75.2 -or- <input type="radio"/> RH, % 41	
Blower Performance			
Airflow Rate:		Power:	
Standard, cfm 6500		<input checked="" type="radio"/> Nominal, W 1080	
<input type="checkbox"/> Ref. Fan Temp, °F		<input type="radio"/> Combined blower & motor 0.21	
		<input type="radio"/> Per unit flow, W/Mcfm 75	
		<input type="radio"/> Motor (fan eff. calculated) 0.60	
Heat Exchanger Configuration			
Tubes <input checked="" type="radio"/> Smooth <input type="radio"/> Rifled <input checked="" type="radio"/> Cu <input type="radio"/> Al		OD (expanded), in. 0.42 Wall, mils 20	
Fins <input checked="" type="radio"/> Al <input type="radio"/> Cu		Pitch, fins/in. 12 Thickness, mils 5	
Fin Type: <input type="radio"/> Smooth <input type="radio"/> Corrugated <input type="radio"/> Slit/Lanced <input type="radio"/> Louvered <input type="radio"/> Convex-Louvered <input checked="" type="radio"/> Smooth Wavy		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	
<input type="checkbox"/> Fin Pattern Geometry		Refrigerant Flow Configuration: <input checked="" type="radio"/> Cross <input type="radio"/> Cross-Counter <input type="radio"/> 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	

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.

Refrigerant Lines

Line Dimensions from Valves to Coils					
OD (in.)	ACR Copper		User Specified Thickness (mils)	Equivalent Length (ft.)	Line
3/8	<input checked="" type="radio"/> Soft	<input type="radio"/> Hard	<input type="radio"/> 32	45	Liquid Line to Expansion Valve
7/8	<input checked="" type="radio"/> Soft	<input type="radio"/> Hard	<input type="radio"/> 35	45	Vapor - RV to Indoor Coil
1-1/8	<input checked="" type="radio"/> Soft	<input type="radio"/> Hard	<input type="radio"/> 35	2	Vapor - RV to Outdoor Coil

Line Dimensions from the Reversing Valve (RV) to the Compressor					
OD (in.)	ACR Copper		User Specified Thickness (mils)	Equivalent Length (ft.)	Line
1-1/8	<input checked="" type="radio"/> Soft	<input type="radio"/> Hard	<input type="radio"/> 35	5	Vapor - RV to Compressor Inlet
3/4	<input checked="" type="radio"/> Soft	<input type="radio"/> Hard	<input type="radio"/> 32	3	Vapor - Compressor Discharge to RV

Heat Transfer in Refrigerant Lines					
Suction line,	<input type="radio"/> Heat gain, Btu/h	0.0	- or -	<input checked="" type="radio"/> DT rise, F°	8.4
Discharge line,	<input checked="" type="radio"/> Heat loss, Btu/h	0.0	- or -	<input type="radio"/> DT drop, F°	0.0
Liquid line,	<input checked="" type="radio"/> Heat loss, Btu/h	0.0	- or -	<input type="radio"/> DT drop, F°	0.0

Additional Pressure Drop in Refrigerant Lines (optional; for reversing valves, filter dryers, etc.)					
DP (psid)					
Suction	0.0	} at nominal mass flow rate of 0.0 lbm/hr			
Discharge	0.0				
Liquid	0.0				

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.

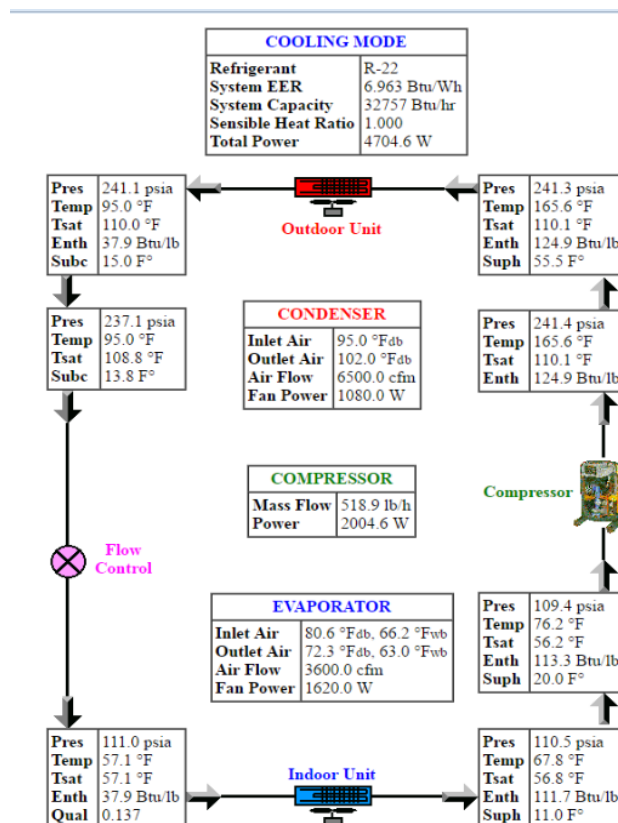


Figure9 Equipment Operation Conditions and Performance

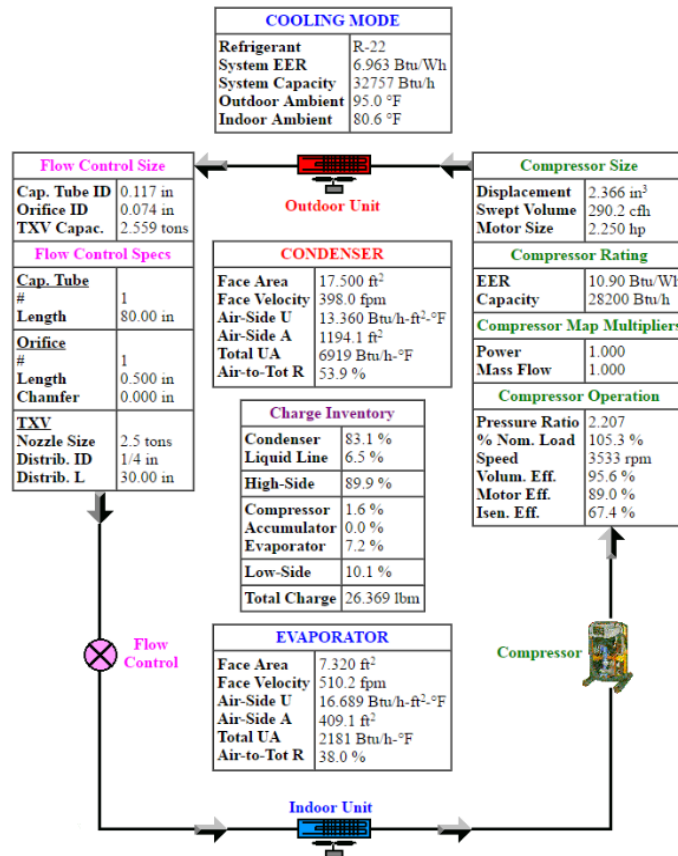


Figure10 Component Sizing, Charging, and Performance

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.

General System Description

Descriptive Title for Your System: -- Sample Heat Pump, Design Cooling Condition --	
Cooling Mode <input type="radio"/> Heat Pump <input type="radio"/> Air Conditioner	Heating Mode <input checked="" type="radio"/> Heat Pump <input type="radio"/> Heat Pump + Supplemental Resistance Heat House Load <input type="text" value="0"/> Btu/hr
Refrigerant: <u>CFCs</u> <u>HCFCs</u> <u>Pure HFCs</u> <u>Mixture HFCs</u> <u>Natural</u> <div style="display: flex; flex-wrap: wrap;"> <div style="width: 20%; text-align: center;"><input type="radio"/> R-12</div> <div style="width: 20%; text-align: center;"><input checked="" type="radio"/> R-22</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-32</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-410A</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-290 (propane)</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-114</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-123</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-125</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-404A</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-502</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-124</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-134a</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-507</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-143a</div> <div style="width: 20%; text-align: center;"><input type="radio"/> R-152a</div> </div>	
Note: A compressor performance map must be available for the refrigerant selected. Preconfigured maps are provided for R-22, R-410A, R-134a, and R-290.	

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.

Compressor Performance Map Selection

Select A Compressor From These Data Sets: Hermetic Compressors for Unitary AC and HP Application --Grouped by Similar Series
<input type="radio"/> R-22 Recip, Manuf A, EER=10.6, Capacity=28.0K <input checked="" type="radio"/> R-22 Scroll, Manuf A, EER=10.9, Capacity=28.2K <input type="radio"/> R-410A Scroll, Manuf A, EER=10.6, Capacity=26.0K <input type="radio"/> R-134a Scroll, Manuf A, EER=10.9, Capacity=26.4K <input type="radio"/> R-290 Scroll, Manuf A, EER=11.3, Capacity=33.8K
<input type="radio"/> R-22 Recip, Manuf A, EER=10.9, Capacity=35.0K <input type="radio"/> R-22 Recip, Manuf B, EER=11.0, Capacity=35.0K <input type="radio"/> R-410A Recip, Manuf B, EER=10.2, Capacity=33.1K
<input type="radio"/> R-22 Scroll, Manuf A, EER=11.2, Capacity=36.5K <input type="radio"/> R-410A Scroll, Manuf A, EER=9.8, Capacity=36.2K
Note: The current system refrigerant is R-22. If you select a compressor that uses a different refrigerant, the system refrigerant will also be changed.

Figure12 selection of compressor

Compressor Data

Compressor Description & Ratings:			
Scroll Compressor, R-22, ZR28K1-PFV, ARI AREP RPT#30, 10.9 EER, 28.2K			
Refrigerant	R-22		
Rated EER	10.9	Btu/hr/W	
Rated cooling capacity	28200	Btu/hr	
Rated inlet condition	20.0	<input checked="" type="radio"/> Superheat (°F) <input type="radio"/> Return gas temperature (°F)	
Compressor Map Representation:			
Map equations for compressor power and mass flow rate are of the form: $F(T_s, T_D) = C_1 + C_2 T_s + C_3 T_D + C_4 T_s^2 + C_5 T_D T_s + C_6 T_D^2 + C_7 T_s^3 + C_8 T_D T_s^2 + C_9 T_s T_D^2 + C_{10} T_D^3$ where $C_1 - C_{10}$ are the map coefficients per ARI 540-99, T_s & T_D are the compressor suction & discharge saturation temperatures (°F)			
Coefficients for ARI 540-99 representation of compressor power (Watts): -1722.59448 -2.67816758 75.1688995 -0.0364156701 0.0880809650 -0.646634877 -C			
Coefficients for ARI 540-99 representation of compressor mass flow rate (lbm/hr): 208.990494 4.29153347 -1.01467359 0.0347250886 -0.00320196757 0.0106777493 C			
Optional Compressor Data for Component Efficiency Calculations (if known):			
<input checked="" type="checkbox"/> Total displacement	2.366	in ³	<input checked="" type="checkbox"/> Nominal speed
<input checked="" type="checkbox"/> Motor size	2.25	hp	<input checked="" type="checkbox"/> Nominal voltage
			3500. rpm 230.0 volts

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.

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

$$= 68^{\circ}\text{C}$$

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

$$= 59^{\circ}\text{C}$$

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

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

Indoor Unit Data

Inlet Air Conditions			
Temperature: DB, °F 68		Humidity: <input checked="" type="radio"/> WB, °F 59 -or- <input type="radio"/> RH, % 52	
Blower Performance			
Airflow Rate: Standard, cfm 3600		Power: <input checked="" type="radio"/> Nominal, W 1620	-or- Efficiency: <input type="radio"/> Combined blower & motor 0.30
<input type="checkbox"/> Ref. Fan Temp, °F		<input type="radio"/> Per unit flow, W/Mcfm 365	
Air Handler and Duct Sizing Parameters			
<input type="checkbox"/> Filter and Heater Sizes		<input checked="" type="radio"/> External DP, in. water 0.15 -or- <input type="radio"/> Duct branch diameter, in. 6.0	
Heat Exchanger Configuration			
Tubes <input checked="" type="radio"/> Smooth <input type="radio"/> Rifled <input checked="" type="radio"/> Cu <input type="radio"/> Al		OD (expanded), in. 0.42 Wall, mils 20	
Fins <input checked="" type="radio"/> Al <input type="radio"/> Cu		Pitch, fins/in. 15 Thickness, mils 8	
Fin Type: <input type="radio"/> Smooth <input type="radio"/> Corrugated <input type="radio"/> Slit/Lanced <input type="radio"/> Louvered <input type="radio"/> Convex-Louvered <input checked="" type="radio"/> Smooth Wavy		<input type="checkbox"/> 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: <input checked="" type="radio"/> Cross <input type="radio"/> Cross-Counter <input type="radio"/> 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

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°C; temperature (WB) is 24°C.

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

$$= 44.6$$

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

$$= 42.8$$

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

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

Outdoor Unit Data

Inlet Air Conditions			
Temperature: DB, °F 44.6		Humidity: <input checked="" type="radio"/> WB, °F 42.8 <input type="radio"/> -or- <input type="radio"/> RH, % 41	
Blower Performance			
Airflow Rate:		Power: <input checked="" type="radio"/> Nominal, W 1080 <input type="radio"/> Combined blower & motor 0.21	
Standard, cfm 6500		<input type="radio"/> Per unit flow, W/Mcfm 75 <input type="radio"/> Motor (fan eff. calculated) 0.60	
<input type="checkbox"/> Ref. Fan Temp, °F			
Heat Exchanger Configuration			
Tubes <input checked="" type="radio"/> Smooth <input type="radio"/> Rifled OD (expanded), in. 0.42 <input checked="" type="radio"/> Cu <input type="radio"/> Al Wall, mils 20		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	
Fins <input checked="" type="radio"/> Al <input type="radio"/> Cu Pitch, fins/in. 12 Thickness, mils 5		two-phase 14 liquid 4	
Fin Type: <input type="radio"/> Smooth <input type="radio"/> Corrugated <input type="radio"/> Slit/Lanced <input type="radio"/> Louvered <input type="radio"/> Convex-Louvered <input checked="" type="radio"/> Smooth Wavy		Refrigerant Flow Configuration: <input checked="" type="radio"/> Cross <input type="radio"/> Cross-Counter <input type="radio"/> Cross-Parallel	
<input type="checkbox"/> Fin Pattern Geometry			
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	

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.

Refrigerant Lines

Line Dimensions from Valves to Coils					
OD (in.)	ACR Copper		User Specified	Equivalent Length (ft.)	Line
	Soft	Hard	Thickness (mils)		
3/8	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="32"/>	45	Liquid Line to Expansion Valve
7/8	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="45"/>	45	Vapor - RV to Indoor Coil
1-1/8	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="50"/>	2	Vapor - RV to Outdoor Coil

Line Dimensions from the Reversing Valve (RV) to the Compressor					
OD (in.)	ACR Copper		User Specified	Equivalent Length (ft.)	Line
	Soft	Hard	Thickness (mils)		
1-1/8	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="50"/>	5	Vapor - RV to Compressor Inlet
3/4	<input checked="" type="radio"/>	<input type="radio"/>	<input type="text" value="35"/>	3	Vapor - Compressor Discharge to RV

Heat Transfer in Refrigerant Lines					
Suction line,	<input type="radio"/> Heat gain, Btu/h	<input type="text" value="0.0"/>	- or -	<input checked="" type="radio"/> DT rise, F°	<input type="text" value="8.4"/>
Discharge line,	<input checked="" type="radio"/> Heat loss, Btu/h	<input type="text" value="0.0"/>	- or -	<input type="radio"/> DT drop, F°	<input type="text" value="0.0"/>
Liquid line,	<input checked="" type="radio"/> Heat loss, Btu/h	<input type="text" value="0.0"/>	- or -	<input type="radio"/> DT drop, F°	<input type="text" value="0.0"/>

Additional Pressure Drop in Refrigerant Lines (optional; for reversing valves, filter dryers, etc.)					
DP (psid)					
Suction	<input type="text" value="0.0"/>	} at nominal mass flow rate of <input type="text" value="0.0"/> lbm/hr			
Discharge	<input type="text" value="0.0"/>				
Liquid	<input type="text" value="0.0"/>				

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.

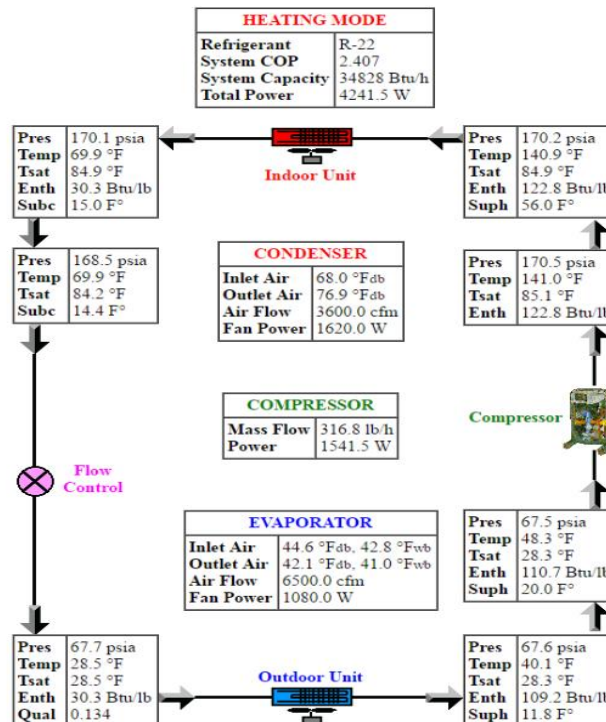


Figure17 Equipment Operation Conditions and Performance

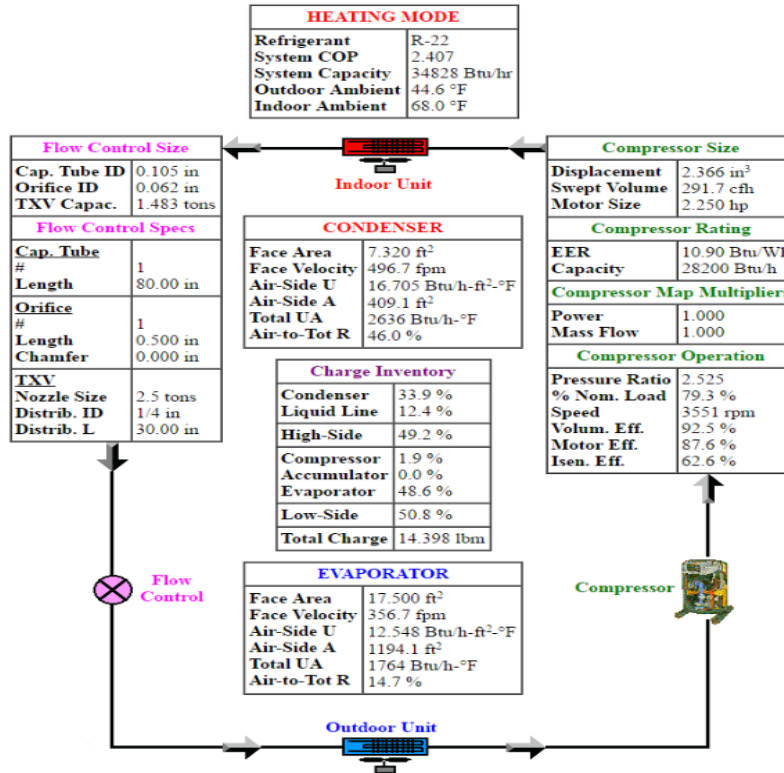


Figure18 Component Sizing, Charging, and Performance

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 table 6, the EER of cooling system and COP of heating system are 6.963 Btu/Wh and 2.407 respectively.

Since

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

Hence

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

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 figure 19.

General System Description

Descriptive Title for Your System:
 -- Sample Heat Pump, Design Cooling Condition --

Cooling Mode	Heating Mode
<input checked="" type="radio"/> Heat Pump	<input type="radio"/> Heat Pump
<input type="radio"/> Air Conditioner	<input type="radio"/> Heat Pump + Supplemental Resistance Heat
House Load 0 Btu/hr	

Refrigerant:	CFCs	HCFCs	Pure HFCs	Mixture HFCs	Natural
	<input type="radio"/> R-12	<input type="radio"/> R-22	<input type="radio"/> R-32	<input checked="" type="radio"/> R-410A	<input type="radio"/> R-290 (propane)
	<input type="radio"/> R-114	<input type="radio"/> R-123	<input type="radio"/> R-125	<input type="radio"/> R-404A	
	<input type="radio"/> R-502	<input type="radio"/> R-124	<input type="radio"/> R-134a	<input type="radio"/> R-507	
			<input type="radio"/> R-143a		
			<input type="radio"/> R-152a		

Note: A compressor performance map must be available for the refrigerant selected. Preconfigured maps are provided for R-22, R-410A, R-134a, and R-290.

Figure 19 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.

Compressor Performance Map Selection

Select A Compressor From These Data Sets:	
Hermetic Compressors for Unitary AC and HP Application —Grouped by Similar Series	
<input type="radio"/>	R-22 Recip, Manuf A, EER=10.6, Capacity=28.0K
<input type="radio"/>	R-22 Scroll, Manuf A, EER=10.9, Capacity=28.2K
<input checked="" type="radio"/>	R-410A Scroll, Manuf A, EER=10.6, Capacity=26.0K
<input type="radio"/>	R-134a Scroll, Manuf A, EER=10.9, Capacity=26.4K
<input type="radio"/>	R-290 Scroll, Manuf A, EER=11.3, Capacity=33.8K
<input type="radio"/>	R-22 Recip, Manuf A, EER=10.9, Capacity=35.0K
<input type="radio"/>	R-22 Recip, Manuf B, EER=11.0, Capacity=35.0K
<input type="radio"/>	R-410A Recip, Manuf B, EER=10.2, Capacity=33.1K
<input type="radio"/>	R-22 Scroll, Manuf A, EER=11.2, Capacity=36.5K
<input type="radio"/>	R-410A Scroll, Manuf A, EER=9.8, Capacity=36.2K
Note: The current system refrigerant is R-410A . If you select a compressor that uses a different refrigerant, the system refrigerant will also be changed.	

Figure20 Compressor selection

Compressor Data

Compressor Description & Ratings:	
Scroll Compressor, R-410A, ZR18K1-PFV, AREP RPT#157, 10.6 EER, 26.0K	
Refrigerant	R-410A
Rated EER	10.6 Btu/hr/W
Rated cooling capacity	26000 Btu/hr
Rated inlet condition	20.0 <input checked="" type="radio"/> Superheat (°F) <input type="radio"/> Return gas temperature (°F)
Compressor Map Representation:	
Map equations for compressor power and mass flow rate are of the form: $F(T_s, T_D) = C_1 + C_2 T_s + C_3 T_D + C_4 T_s^2 + C_5 T_D T_s + C_6 T_D^2 + C_7 T_s^3 + C_8 T_D T_s^2 + C_9 T_s T_D^2 + C_{10} T_D^3$ where $C_1 - C_{10}$ are the map coefficients per ARI 540-99, T_s & T_D are the compressor suction & discharge saturation temperatures (°F)	
Coefficients for ARI 540-99 representation of compressor power (Watts): 2136.46777 4.76904583 -40.7254601 -0.067994244 -0.088128008 0.484708041 0.00:	
Coefficients for ARI 540-99 representation of compressor mass flow rate (lbm/hr): -161.891785 1.74934876 10.0110302 0.009529017 0.044073913 -0.100522421 5.621	
Optional Compressor Data for Component Efficiency Calculations (if known):	
<input checked="" type="checkbox"/> Total displacement	1.526 in. ³ <input checked="" type="checkbox"/> Nominal speed 3500. rpm
<input checked="" type="checkbox"/> Motor size	2.25 hp <input checked="" type="checkbox"/> Nominal voltage 230.0 volts

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.

$$\begin{aligned} \text{Dry Bulb Tempertaure}(\text{°F}) &= 27 \times \frac{9}{5} + 32 \\ &= 80.6^{\circ}\text{C} \end{aligned}$$

$$\begin{aligned} \text{Wet Bulb Tempertaure}(\text{°F}) &= 19 \times \frac{9}{5} + 32 \\ &= 66.2^{\circ}\text{C} \end{aligned}$$

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

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

Indoor Unit Data

Inlet Air Conditions			
Temperature: DB, °F 80.6		Humidity: <input checked="" type="radio"/> WB, °F 66.2 -or- <input type="radio"/> RH, % 52	
Blower Performance			
Airflow Rate: Standard, cfm 3600		Power: <input checked="" type="radio"/> Nominal, W 1620 -or- Efficiency: <input type="radio"/> Combined blower & motor 0.30	
<input type="checkbox"/> Ref. Fan Temp, °F		<input type="radio"/> Per unit flow, W/Mcfm 365	
Air Handler and Duct Sizing Parameters			
<input type="checkbox"/> Filter and Heater Sizes		<input checked="" type="radio"/> External DP, in. water 0.15 -or- <input type="radio"/> Duct branch diameter, in. 6.0	
Heat Exchanger Configuration			
Tubes <input checked="" type="radio"/> Smooth <input type="radio"/> Rifled OD (expanded), in. 0.42 <input checked="" type="radio"/> Cu <input type="radio"/> Al Wall, mils 20		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	
Fins <input checked="" type="radio"/> Al <input type="radio"/> Cu Pitch, fins/in. 15 Thickness, mils 8		Refrigerant Flow Configuration: <input checked="" type="radio"/> Cross <input type="radio"/> Cross-Counter <input type="radio"/> Cross-Parallel	
Fin Type: <input type="radio"/> Smooth <input type="radio"/> Corrugated <input type="radio"/> Slit/Lanced <input type="radio"/> Louvered <input type="radio"/> Convex-Louvered <input checked="" type="radio"/> Smooth Wavy			
<input type="checkbox"/> Fin Pattern Geometry			
Correction Multipliers			
Refrigerant-Side:			
Coil heat transfer	1.0	Coil surface area	1.0
Coil DP	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

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°C;
temperature (WB) is 24°C.

$$\begin{aligned} \text{Dry Bulb Tempertaure}(\text{°F}) &= 35 \times \frac{9}{5} + 32 \\ &= 95\text{°C} \end{aligned}$$

$$\begin{aligned} \text{Wet Bulb Tempertaure}(\text{°F}) &= 24 \times \frac{9}{5} + 32 \\ &= 75.2\text{°C} \end{aligned}$$

$$\begin{aligned} \text{Thickness of tube} &= \frac{\text{Outside diameter} - \text{Inside diameter}}{2} \\ &= \frac{0.42 - 0.38}{2} = 0.02(\text{in}) = 20(\text{mils}) \end{aligned}$$

Outdoor Unit Data

Inlet Air Conditions

Temperature: DB, °F 95 Humidity: ☒ WB, °F 75.2 -or- ☐ RH, % 41

Blower Performance

Airflow Rate: Standard, cfm 6500 Power: ☒ Nominal, W 1080 -or- Efficiency: ☐ Combined blower & motor 0.21
☐ Ref. Fan Temp, °F ☐ Per unit flow, W/Mcfm 75 ☐ Motor (fan eff. calculated) 0.60

Heat Exchanger Configuration

Tubes
☒ Smooth ☐ Rifled OD (expanded), in. 0.42
☒ Cu ☐ Al 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

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.

Refrigerant Lines

Line Dimensions from Valves to Coils

OD (in.)	ACR Copper		User Specified Thickness (mils)	Equivalent Length (ft.)	Line
	Soft	Hard			
3/8	<input checked="" type="radio"/>	<input type="radio"/>	32	45	Liquid Line to Expansion Valve
7/8	<input checked="" type="radio"/>	<input type="radio"/>	45	45	Vapor - RV to Indoor Coil
1-1/8	<input checked="" type="radio"/>	<input type="radio"/>	50	2	Vapor - RV to Outdoor Coil

Line Dimensions from the Reversing Valve (RV) to the Compressor

OD (in.)	ACR Copper		User Specified Thickness (mils)	Equivalent Length (ft.)	Line
	Soft	Hard			
1-1/8	<input checked="" type="radio"/>	<input type="radio"/>	50	5	Vapor - RV to Compressor Inlet
3/4	<input checked="" type="radio"/>	<input type="radio"/>	35	3	Vapor - Compressor Discharge to RV

Heat Transfer in Refrigerant Lines

Suction line,	<input type="radio"/> Heat gain, Btu/h 0.0	- or -	<input checked="" type="radio"/> DT rise, F° 8.4
Discharge line,	<input checked="" type="radio"/> Heat loss, Btu/h 0.0	- or -	<input type="radio"/> DT drop, F° 0.0
Liquid line,	<input checked="" type="radio"/> Heat loss, Btu/h 0.0	- or -	<input type="radio"/> DT drop, F° 0.0

Additional Pressure Drop in Refrigerant Lines (optional; for reversing valves, filter dryers, etc.)

DP (psid)		} at nominal mass flow rate of 0.0 lbm/hr
Suction	0.0	
Discharge	0.0	
Liquid	0.0	

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.

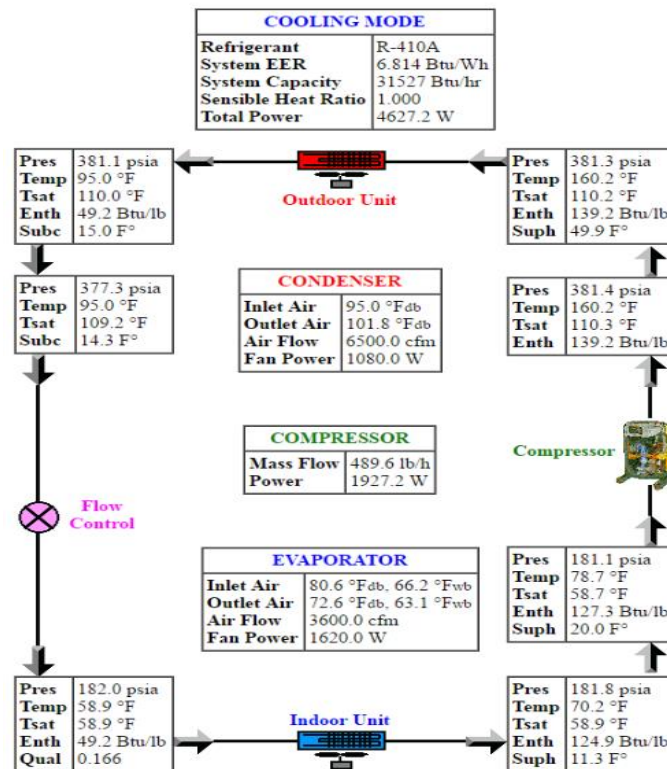


Figure25 Equipment Operation Conditions and Performance

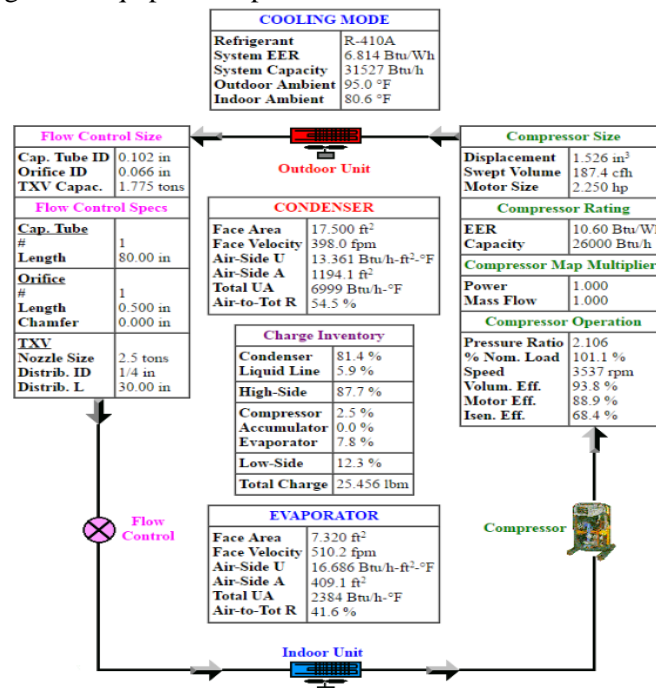


Figure26 Component Sizing, Charging, and Performance

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

$$\text{System capacity of R22} > \text{System capacity of R410a}$$

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

$$\text{Total Power of R22} > \text{Total Power of R410a}$$

2.4.3 Comparison of Efficiency

According to table 10 the system EER of R410a and R22 are 6.814 Btu/Wh and 6.963 Btu/Wh.

Hence

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

3 Influences of Changing parameter

3.1 Influence of indoor coil area

According to figure 6, the frontal area of indoor coil is 7.32 ft², hence assuming the indoor area changes from 6.32 ft² to 9.32 ft². Then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure 27.

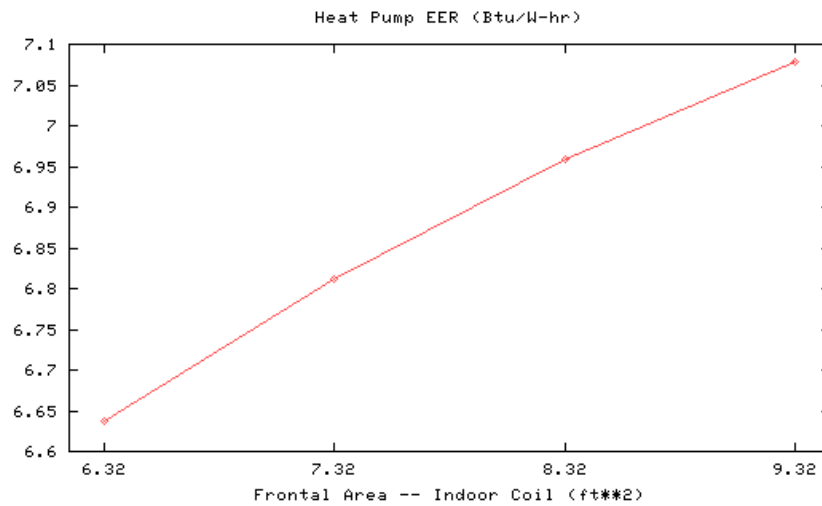


Figure 27 EER curve

As can be seen in these curves, when indoor coil area changing from 6.32 ft² to around 9.32 ft², EER changes from 6.63 Btu/W-hr to 7.06 Btu/W-hr.

3.2 Influence outdoor coil area

According to figure 7, the frontal area of outdoor coil is 17.5 ft², hence assuming the outdoor area changes from 12.5 ft² to 21.5 ft². Then utilizing DOE/ORNL Heat Pump Design Model VII, the performance curve of system EER can be got. The curve is shown in figure 28.

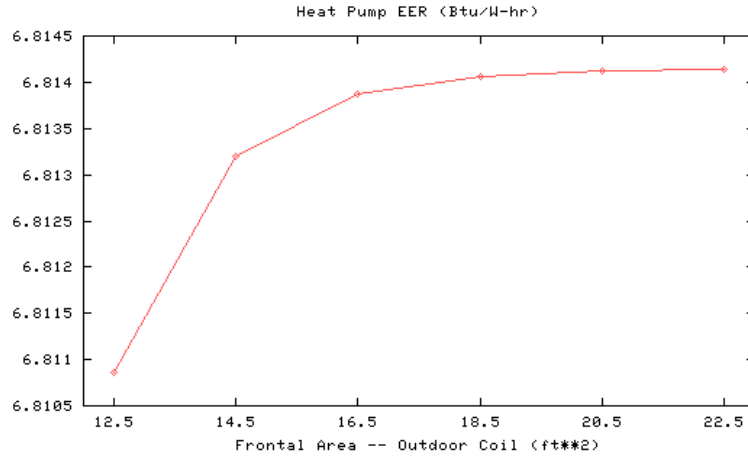


Figure28 EER curve

As can be seen from these figures, when the outdoor area changes from 12.5ft² to 21.5ft², the EER would increase firstly, but the increase tendency decreases, until the area changing to 21.5 ft², 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.

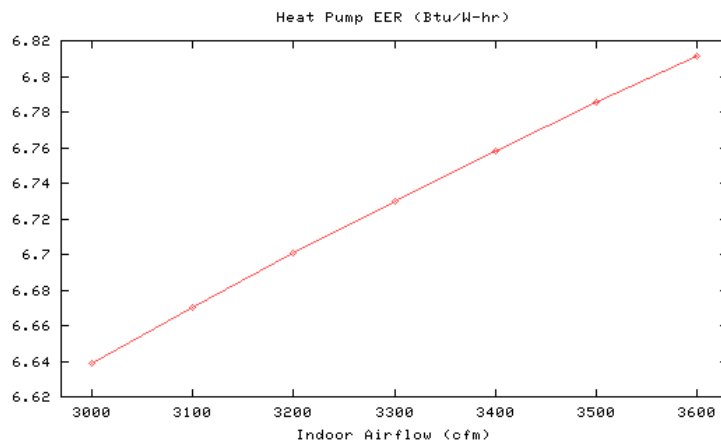


Figure29

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.

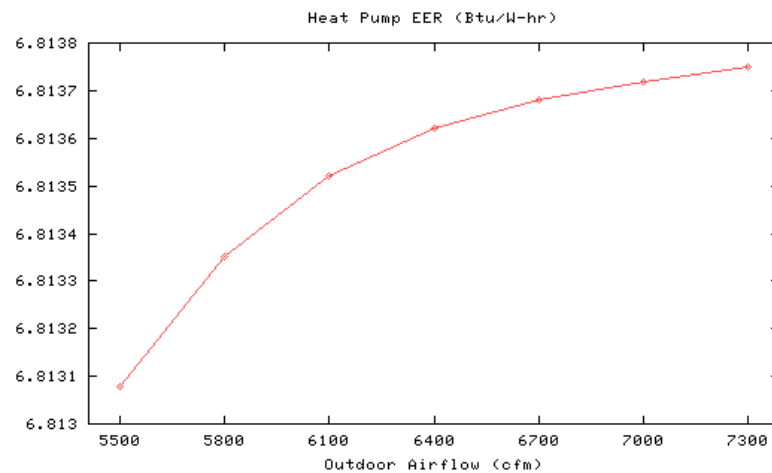


Figure30

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 ft² to 9.32 ft², outdoor coil area from 17.5 ft² to 22.5 ft², 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.

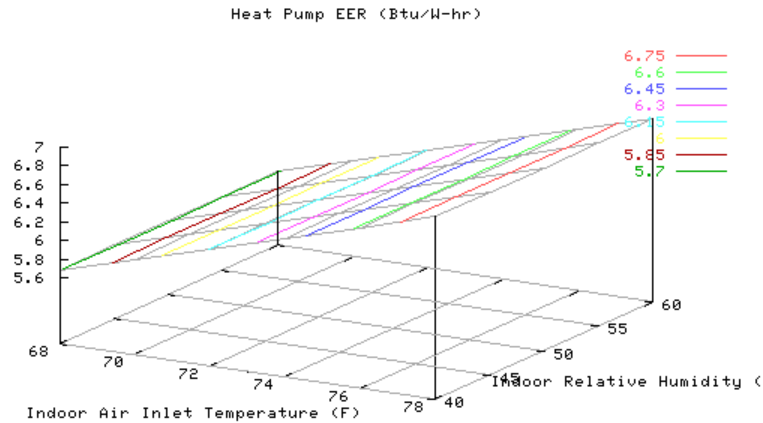


Figure31

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.

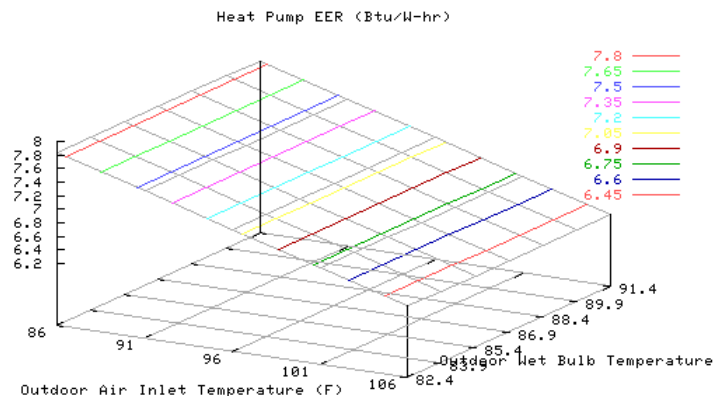


Figure32

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 °C	EER
Original	7.32	17.5	3600	6500	27	6.814
Modification	9.32	22.5	4000	7500	27	7.171

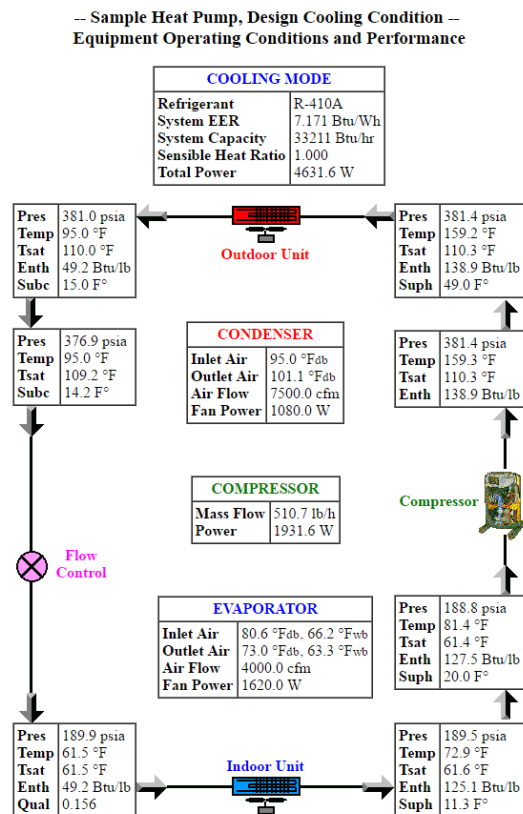


Figure33New result of R410a cooling system

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.

4.2 Equipment

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.

4.3 Question 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.

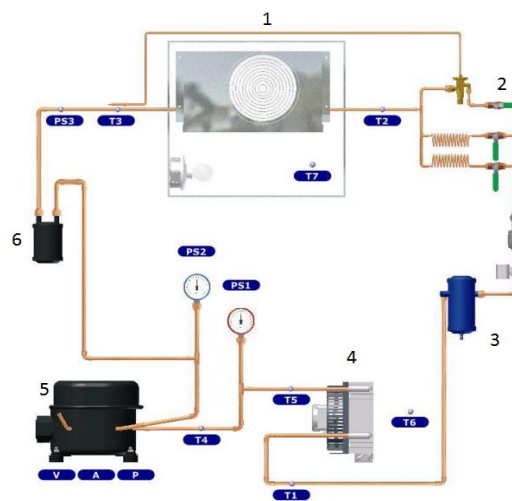


Figure34 Lab-Volt Refrigeration Demonstration System

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.

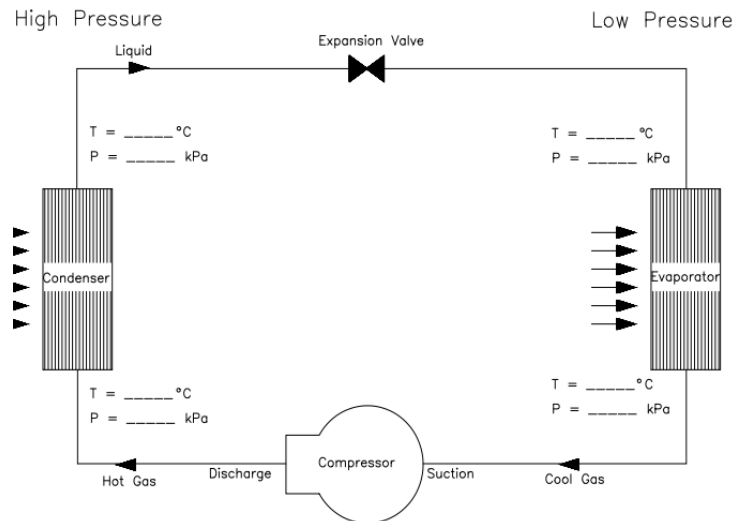


Figure35 Simplified Refrigeration System

Comparing figure35 and figure34, liquid receiver and accumulator are not shown in figure35.

Liquid receiver is situated between condenser and throttling. When the status 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.

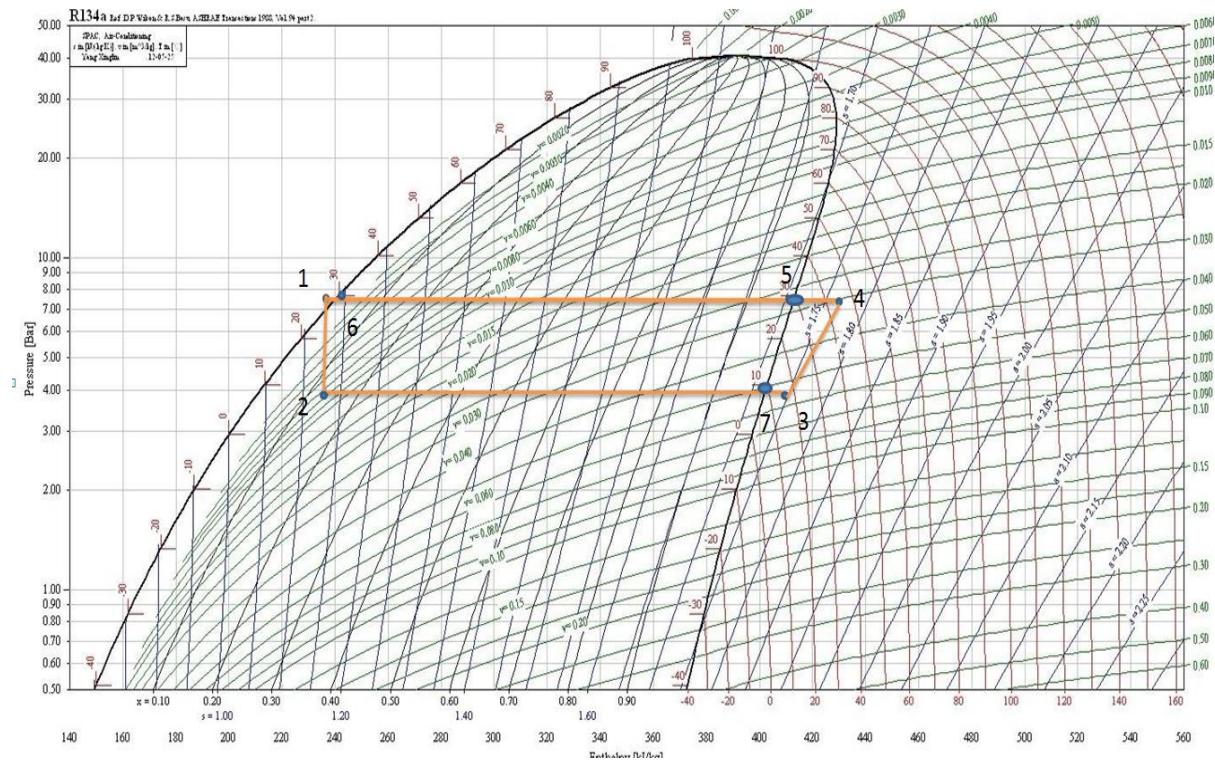


Figure36

As can be seen from figure36:

$$H_1 = 235 \text{ kJ/kg}$$

$$H_6 = 245 \text{ kJ/kg}$$

$$H_7 = 400 \text{ kJ/kg}$$

$$H_3 = 407 \text{ kJ/kg}$$

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

$$= 10 \text{ kJ/kg}$$

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

$$= 7 \text{ kJ/kg}$$

(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 blown 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(°C)
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.

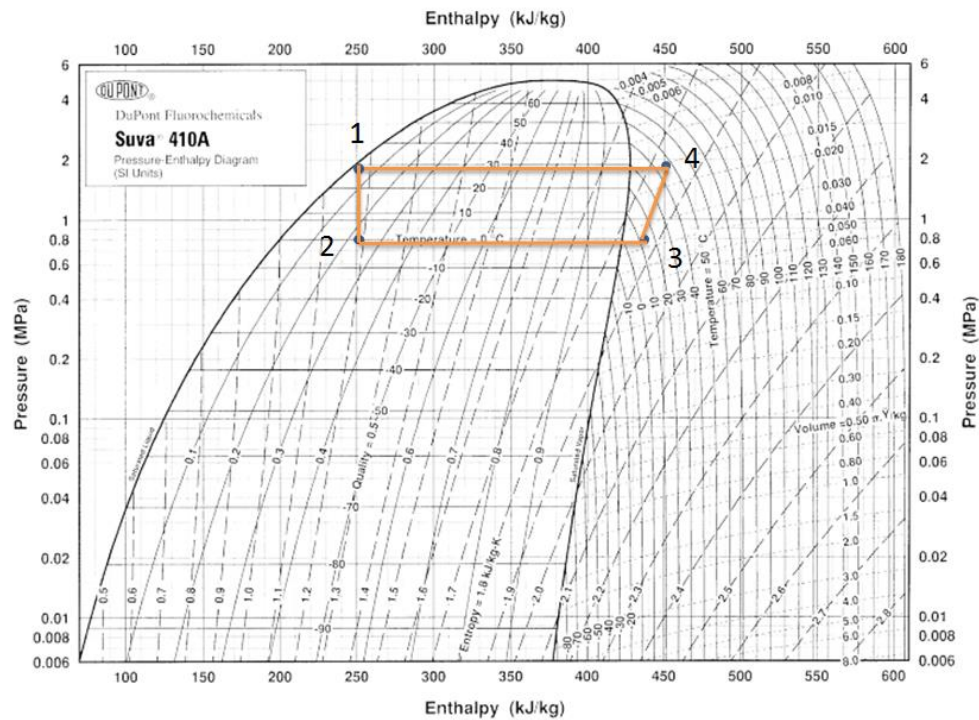


Figure 37 p-h diagram of R410a

(b) The enthalpy change of refrigeration effect:

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

$$h_3 = 430 \text{ kJ/kg}$$

$$h_2 = 250 \text{ kJ/kg}$$

$$Q_{ref} = 180 \text{ kJ/kg}$$

(c) Heat reject at condenser:

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

$$h_4 = 450 \text{ kJ/kg}$$

$$h_1 = 250 \text{ kJ/kg}$$

$$Q_{reject} = 200 \text{ kJ/kg}$$

(d) Heat change during compression:

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

$$H_4 = 450 \text{ kJ/kg}$$

$$H_3 = 430 \text{ kJ/kg}$$

$$H_{change} = 20 \text{ kJ/kg}$$

(e) EER

$$\begin{aligned} EER &= \frac{Q_{ref}}{Q_{change}} \\ &= \frac{180}{20} \\ &= 9 \end{aligned}$$

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)