Design Homework 1 – Compressor Selection
DUE DATE: Thursday, Feb. 16, 2023

Climate change due to the effects of global warming and the increase in energy costs due to changes in the international situation have led to a significant increase in commercial and residential cooling costs. Also, the recent massive inflation has led to an increase in living costs, causing economic difficulties for many people.

As a student studying thermal fluid engineering, you want to contribute to reducing the living costs for your family. While you were thinking about how you could utilize the knowledge and insights you learned in the related courses, you found the air conditioning system in your house was old and outdated, and it seemed like it was not going to work well and be energy efficient. Therefore, you are planning to first analyze current vapor compression cycle of the AC system to find if the system was well designed for the cooling capacity corresponding to your own house size, then, you are going to optimize it to improve comfort conditions and energy costs.

Based on a little research, you figured out the operating conditions of the current AC system as follows.

Table 1 Typical operating conditions for the current AC system

Refrigerant	R-410A
Mass flowrate of refrigerant at typical operating condition	62.99 g/s
Typical power at typical operating condition	2403 W
High-side operating pressure	2420 kPa
Evaporator temperature	5°C
Superheat	15°C
Subcooling	10°C

Due to the fact that the compressor is relatively easy to replace in the AC system, you decided to find a way to improve the system with an alternative compressor. Based on the investigation on the operating conditions of the current AC system you have determined that the compressor should satisfy the following constraints:

Table 2 Design Constraints

Compressor Info.	Manufacturer	Copeland
	Refrigerant	R-410A
	Electrical power supply	60Hz, single phase, 208/230 V
	Maximum size	10" L x 10" W x 20" H
Typical Operating Conditions	Condenser operating pressure	2420 kPa
	Evaporator temperature	5°C
	Superheat	15°C
	Subcooling	10°C
	Capacity	TBD based on your house size

For this homework assignment, you will identify at least 2 suitable compressors. You will model the compressors using the standardized AHRI compressor map and validate your compressor models against the manufacturer supplied performance data. You will, then, use your models to calculate performance metrics at the typical operating conditions given. Finally, you will compare the compressors, select a compressor to purchase and a supplier to purchase the compressor from, and explain the factors that influenced your selection.

Deliverables:

You will submit this assignment as a well-organized report with a **title page and page numbers** containing the following numbered sections. The title page must include your **name, course number and course name, assignment title and submission date**.

1. **Evaluation of current AC system performance based on the existing compressor performance** – Using EES, perform a real vapor compression cycle analysis of the system for the operating conditions given in Table 1 to find overall isentropic efficiency, COP, cooling capacity and energy cost of the existing compressor. Assume 8 hours of AC operation per day. **It is also required** to find the cooling capacity required for your own house size, and find if the existing AC system was overdesigned or not. **The house size for your design is assigned in the table in Appendix.** Although there are many factors to be considered in calculating cooling loads such as climate conditions in your area, the volume of space in your house, insulation type, the number of people, heating sources and

windows in the space, etc., you could calculate an approximate cooling capacity required for your home size using the equation following:

$$AC\ capacity\ (Btu/h) = \ Area\ of\ cooling\ space\ (ft^2)\ \times 25$$

If you want more detailed calculations to find the right AC cooling capacity for your house, refer to the section "HOW TO CALCULATE AC TONNAGE OF A ROOM: STEPWISE GUIDE" in the article "AC Tonnage Calculator to Determine the exact AC Capacity Needed?" (https://top10gears.com/ac-tonnage-calculator/)

This section must include a table like the table below**. It must also include a printout of the EES code and EES results** for COP, overall isentropic efficiency, and energy cost, and capacity of the existing system, and the target capacity for your house size calculations.

Overall isentropic efficiency	
COP	
Energy cost ($/hour)	
Energy cost ($/month)	
Capacity of the existing AC system (W)	
Your house size (ft^2)	
Capacity required for your house (W)	

2. **Identification of Compressor Alternatives** – This section must have a **paragraph** that states the goals of your design and includes your target capacity, and the manufacturer and model numbers for at least 2 suitable Copeland compressors from the Emerson website (https://climate.emerson.com/en-us/brands/copeland > Tools & Resources > Copeland Online Product Information > Copeland Online Product Information > Compressors), and states that they meet all of the constraints listed on page 2 of this assignment. **It must also include a table** with the following information:

	1st alternative	2nd alternative	Units
Manufacturer	Copeland	Copeland	
Model number			
Refrigerant			
Motor frequency			Hz
Motor phase (1 or 3)			
Motor voltage			V
Performance @7°C/54°C rating conditions			
Capacity			W
Power			W
EER			Btu/h-W
Other specifications			
Overall length			in
Overall width			in
Overall height			in
RPM			RPM

Also include copies of the manufacturer's summary data sheet, performance data sheet and rating coefficients data sheet for each of the 2 compressor alternatives in an Appendix.

3. **Evaluations of Compressor Alternatives** – This section must include a paragraph stating that mathematical models of the compressor alternatives were created in EES using the rating coefficients provided by the manufacturer, that the models were validated by comparing model calculated values with the manufacturer's published values, and that the models were used to predict the compressors' performance at the condenser pressure of 2420 kPa and evaporator temperature of 5 °C as the typical operating conditions. **It must also contain the following for each of the 2 compressor alternatives**:
   a. **Mathematical Model of Compressor Capacity and Power** – Using the ratings coefficients provided by the manufacturer for the standardized AHRI compressor map, create mathematical models in EES of the compressor capacity (W) and power (W) as functions of the condenser and evaporator temperatures. **This section must**

include a table like the table below, containing the ratings coefficients for both the capacity and power models. **It must also include a printout of the EES code** containing the ratings coefficients and model equations.

Copeland Compressor Model #:			
Coefficient #	Capacity Coefficients (W)	Power Coefficients (W)	Mass Flowrate Coefficients (g/s)
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			

b. **Model Validation** – Using EES and the models that you created in Section 3a, calculate the capacity, power, and mass flowrate of the compressor at an evaporator temperature of 7°C and a condenser temperature of 54°C. Compare the calculated values to the values listed in the compressor summary data sheet. Calculated values must be within 1% of the values on the data sheet. Repeat the calculations and comparisons for the 2nd evaporator and condenser temperature on the compressor summary data sheet. **This section must include a table** like the table below containing the calculated and published values with units and the % error between the calculated values and published values for both rating conditions. **It must also include a printout of the EES code and EES results** for the validation calculations.

	At 7°C/54°C			At °C/ °C		
	Manufacturer's value	Calculated Value	% Error	Manufacturer's value	Calculated Value	% Error
Capacity (W)						
Power (W)						
Mass flowrate (g/s)						

c. **Prediction of Compressor Performance at Typical Operating Conditions** – Using EES, and the typical operating conditions shown in Table 2, find the typical operating temperatures and pressures for the evaporator and condenser. Assume ambient pressure is 101.3 kPa. Then assuming 15°C of superheat, 10 of subcooling, and 0.75 of correction factor, calculate the capacity, power and mass flowrate at the condenser and evaporator temperatures using the mathematical models you created in Section 3a. Then, perform a cycle analysis to find COP, actual capacity and overall isentropic efficiency at the typical operating conditions. **This section must include a paragraph** which compares the calculated actual capacity to your target capacity value. **This section must also include a table** like the table below of the typical operating pressures and temperatures and all calculated compressor performance parameters with units, and **a printout of all EES code and EES results** for predicting compressor performance at typical operating conditions.

	Pressure (kPa)	Temperature (°C)
Evaporator operating conditions		
Condenser operating conditions		
Performance parameters at operating conditions		
Actual capacity (W)		
COP		
Power (W)		
Mass flowrate (g/s)		
Overall isentropic efficiency (%)		
Energy cost ($/month)		

Organize this section with parts a-c for the first alternative, followed by parts a-c for the second alternative.

4. **Final Compressor Selection and Supplier Information – This section must have a paragraph** that states the manufacturer and model number of your final selected compressor. The paragraph must also explain the factors and tradeoffs that influenced your selection. **It must clearly state** whether or not the selected compressor meets all requirements and identify and assess all risks anticipated with the selection**. It must also state** how much your AC system with the selected compressor can improve the comfort conditions and energy costs for your family. **You must include a table** with the following information for the selected compressor, and EES T-s and P-h plots of the cycle analysis at the typical operation conditions given for the selected compressor.

Manufacturer	Copeland	
Model number		
Refrigerant		
Motor frequency		Hz
Motor phases (1 or 3)		
Motor voltage		V
Overall length, width & height		in
Performance @typical operating conditions (P_{cond}=2420 kPa and T_{evap}=5°C)		
Your target capacity for your house		W
Actual capacity from the cooling cycle		W
Power		W
Isentropic efficiency		%
Mass flowrate		g/s
COP		
Expected energy cost		$/month