Exercise 1: Own Cooling Problem By: Rajnesh Kumar

Problem Statement: The owner of a building in Terrassa, Spain wants to cool down the entire floor of the building to achieve a comfortable temperature of 22.5°C. Considering the ambient temperature of around 35°C, the vapor compression system must be designed to achieve a peak cooling load of around 63 kW.

The modelling of the system was carried out in Python. Two Python files have been created. One of the files contains functions related cycle modelling and property plots (P-h & T-s). In the second file, these functions are called, and results are obtained corresponding to the given input data.

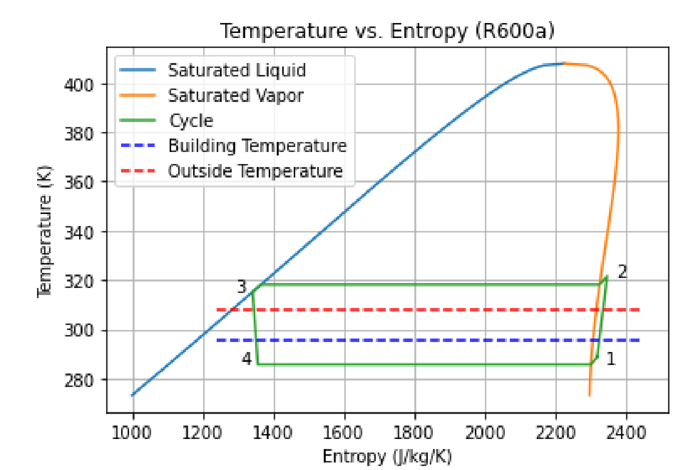
For this report, the following input data was used to determine cycle's remaining parameters.

Input Parameter	*Value*	*Description*
Ref	R600a	Refrigerant
DT_eva	10°C	The difference between building's comfortable temperature and evaporator's temperature.
DT_cond	10°C	The difference between condenser saturated temperature and ambient temperature.
T_sc	3°C	Degree of subcooling at condenser exit.
T_sh	3°C	Degree of superheating at evaporator outlet
Eta_is_comp	0.8	Compressor isentropic efficiency
Eta_electric	0.95	Compressor electrical efficiency

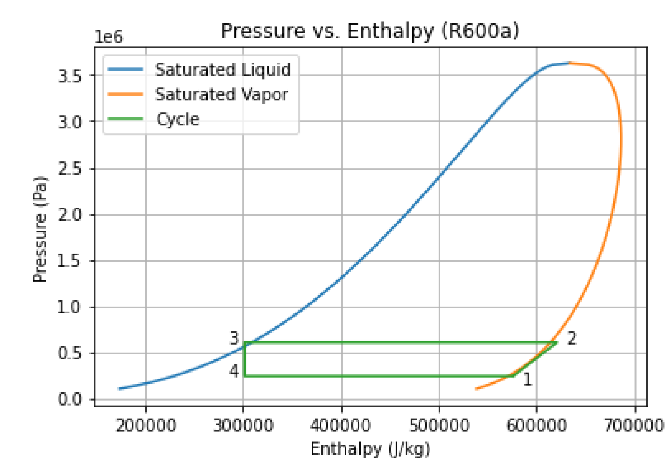
Using these input values inside the program, the functions first calculated state properties at inlet, outlet and saturated points of each equipment. These intermediate results were further used to obtain output parameters.

Output	*Value*	*Description*
m_cycle	0.229 kg/s	Mass flowrate of the vapor compression cycle to achieve this cooling demand.
W_comp	10.273 kW	The compressor required by the cycle.
W_electric	10.814 kW	The electric power required by the compressor
COP_cycle	6.13	Coefficient of the performance of cycle
COP_customer	5.82	Coefficient of the performance from customer's perspective

T-s Diagram



P-h Diagram



The T-s and P-h diagrams above illustrate the thermodynamic cycle of our refrigeration system, showcasing how the temperature, pressure, entropy and enthalpy vary from one component to another.

- During process (1-2), the refrigerant undergoes compression, resulting in an increase in pressure, temperature, and enthalpy. Due to the non-isentropic nature of the process, entropy also increases.
- In process (2-3), the condenser rejects heat to the environment at constant pressure, reducing the refrigerant's enthalpy and preparing it for reuse in the evaporator.

- The expansion valve causes a significant temperature to drop in the refrigerant during process (3-4). This prepares the refrigerant to absorb heat from the building.
- Finally, the process (4-1) involves the evaporator absorbing heat from the building at constant pressure, fulfilling our cooling demand of 63 kW.

MAIN RESULTS

Impact of cooling capacity on m_cycle, W_comp, W_electric, COP_cycle and COP_customer.

Q_cooling_peak (kW)	*m_cycle (kg/s)*	*W_comp (kW)*	*W_electric (kW)*	*COP_cycle*	*COP_customer*
63	0.229	10.273	10.814	6.13	5.82
73	0.265	11.904	12.530	6.13	5.82
83	0.302	13.534	14.247	6.13	5.82

To analyze the impact of cooling capacity, it was changed from 63 to 83 kW. It is observed that while the mass flowrate of the cycle and compressor change, there is no impact on the COPs of the system. The results indicate that varying cooling demand can easily be managed by adjusting the mass flow rate of refrigerant. Although it will impact the compressor work, it will not affect the performance of the system. Mathematically, COP = Q_cooling_peak/W_comp. Since both the cooling capacity and compressor work are dependent on refrigerant's mass flowrate, they effectively cancel each other out in the COP calculation, making it independent of refrigerant's mass flow rate.

Impact of DT_eva on m_cycle, W_comp, W_electric, COP_cycle and COP_customer.

DT_eva (°C)	*m_cycle (kg/s)*	*W_comp (kW)*	*W_electric (kW)*	*COP_cycle*	*COP_customer*
10	0.229	10.273	10.814	6.13	5.82
7	0.225	9.104	9.583	6.91	6.57
4	0.222	7.987	8.408	7.88	7.49

The above table shows the impact of DT_eva on output parameters and following key observations are made for decrease in DT_eva:

- When DT_eva decreases, the evaporator operating pressure rises, reducing the pressure difference across the compressor. This results in decreased compressor work followed by a lower COP which is inversely proportional to compressor work.
- Decrease in DT_eva has no significant impact on mass flow rate. A slight decrease can be observed due to increase in thickness of dome which means relatively more energy can be absorbed during evaporation, therefore, the same cooling capacity is being achieved with relatively lower refrigerant flow.

Impact of DT_cond on m_cycle, W_comp, W_electric, COP_cycle and COP_customer.

DT_cond (°C)	*m_cycle (kg/s)*	*W_comp (kW)*	*W_electric (kW)*	*COP_cycle*	*COP_customer*
10	0.229	10.273	10.814	6.13	5.82
7	0.223	9.165	9.648	6.873	6.53
4	0.217	8.099	8.526	7.777	7.389

- A decrease in compressor work and COP of the system is observed with the decrease in DT_cond is due to the same reasons as explained in case of DT_eva. Apart from that, these results explain the reason why the vapor compression system works well in colder environments. As cooling capacity is independent of the compressor outlet conditions, therefore in colder environments, lower condenser temperatures can also be used to provide the same cooling capacity. Consequently, better COP can be achieved.
- Again, there is only a slight decrease in m_cycle due to shift in condenser outlet which results in increased dome thickness. Consequently, a relatively lower mass flow rate is sufficient to provide the same cooling capacity.

Exercise 1: Own Cooling Problem By: Rajnesh Kumar

CONCLUSIONS

In this report, a design of cooling system for a building located in Terrassa, Spain was considered. The system was required to provide the cooling capacity of 63 kW and maintain our cooling space at comfortable temperature of 22.5°C. System was modelled using Python programming language and corresponding to the input parameters, the mass flowrate of cycle, compressor works and COPs were obtained. The impact of cooling capacity, DT_eva and DT_cond was also analyzed output parameters and following conclusions were drawn:

- R600a is a high-performance working fluid, offering a COP of approximately 6 and even higher in some cases.
- COP of the system is independent of the refrigerant mass flow rate. Therefore, varying cooling demand can be managed without losing the performance by adjusting mass flow rate.
- Both DT_eva and DT_cond have a huge impact on the performance of the system. The lower the pressure difference across the compressor, the higher the performance of the system. That is mainly the reason why in colder environment higher COP can be achieved compared to the hotter environment.

LEARNINGS

- By modelling the system in Python, not only did I improve my programming skills but also gained robust understanding of the physics of the system.
- I improved my coding practices by organizing functions in a separate file and using a main function to call them, resulting in cleaner code.
- I realized that developing a code is an efficient method to analyze the system compared to solving it manually. Because it provides more flexibility to change the fluid or parameters and observe the change by visualizing the results.
- Overall, this problem was a great learning opportunity which allowed me to improve my concepts and programming skills.