



VAPOUR-COMPRESSSION REFRIGERATION SYSTEM

This case study demonstrates the modeling of a vapour compression refrigeration system using R22 as refrigerant. Both a steady-state and a transient simulation will be considered.

HVAC

CHALLENGE:

The primary objective of the simulation is to determine the steady-state performance of the system given the design of all the components together with appropriate boundary conditions.

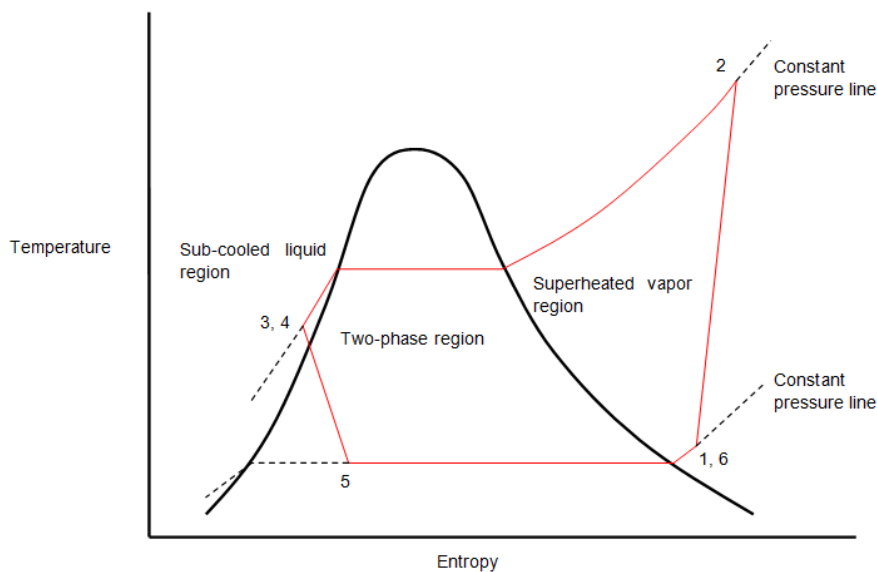
The secondary objective is to investigate the dynamic performance of the system under varying operating condition.

BENEFITS:

This case study demonstrates the modeling of a vapour compression refrigeration system using R22 as refrigerant. Both a steady-state and a transient simulation will be considered.

SOLUTION:

Flownex was used to simulate a vapour compression refrigeration system using R22 as refrigerant. First a steady-state simulation was done and the results of this simulation were used as initial conditions for a transient simulation.



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INTRODUCTION

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SYSTEM DESCRIPTION

The lay-out of the system is shown in Figure 1.

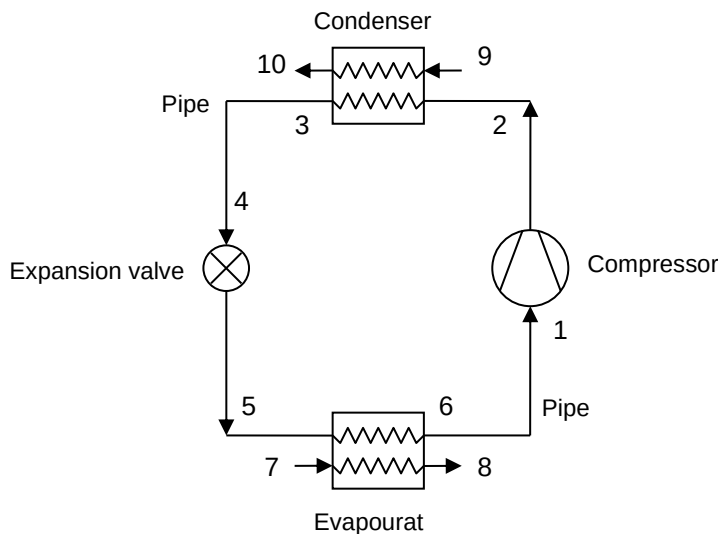


Figure 1: Layout of the R22 vapour-compression refrigeration system.

Refrigerant (R22) vapour enters a positive displacement compressor at a slightly superheated state (1) and is then compressed to state 2. From 2 the high pressure high temperature vapour is first sensibly cooled to saturation, then condensed and ultimately sub-cooled to state 3. From 3 to 4 the liquid refrigerant flows through a tube to the inlet of the expansion valve in an adiabatic process. The expansion valve is a restrictor that causes a large pressure drop with an accompanying adiabatic temperature drop. From 5 to 6 all the liquid is evaporated in the evaporator and then slightly superheated to state 6. From there the vapour refrigerant flows through a tube to the inlet of the compressor (1) to close the cycle.

Figure 2 shows the process on a temperature entropy diagram.

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OBJECTIVE OF SIMULATION

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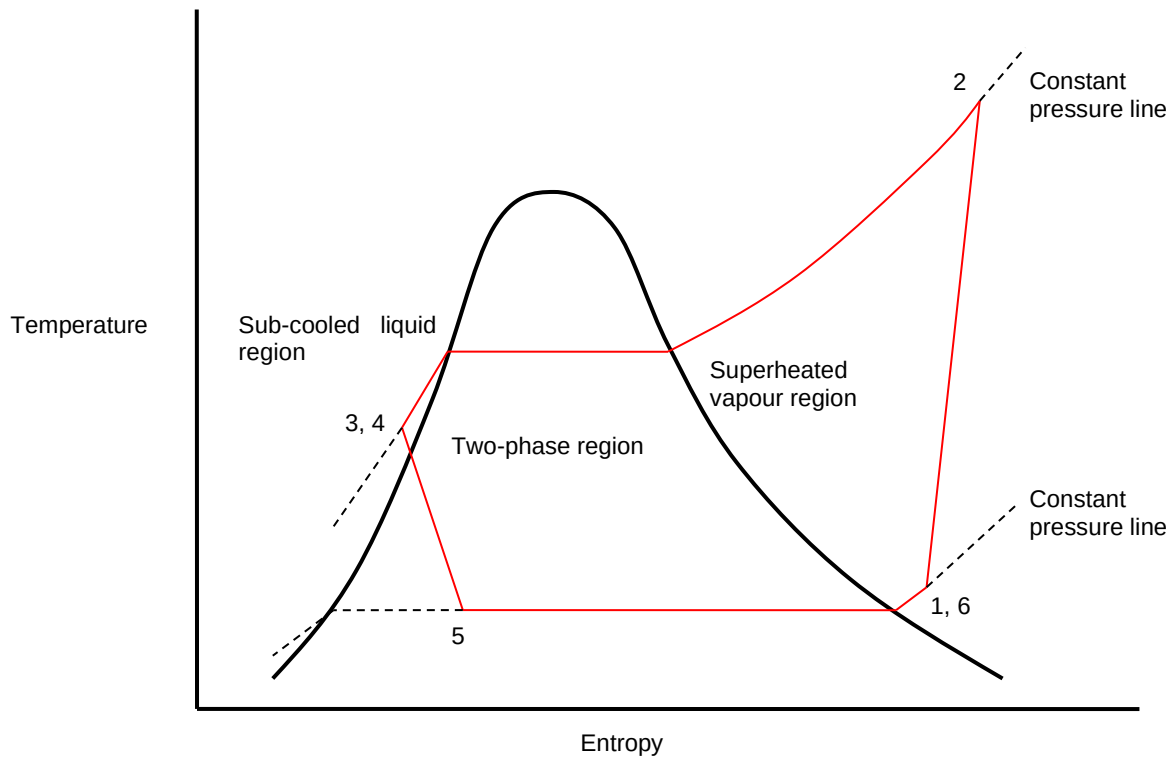


Figure 2: Vapour compression cycle on a T-s diagram.

DESCRIPTION OF SIMULATION

The Flownex model of the system is shown in Figure 3. The compressor is modeled with Flownex's Positive Displacement Compressor (PDC) element while the evaporator and condenser is modeled with Flownex's discretized parallel or counter flow heat exchanger element. Each heat exchanger element is subdivided in 20 increments. Flownex's Restrictor with Discharge (RD) element is used to model the expansion valve. This type of element use accurate relationships to model choking.

Two simulations are done. The first is a steady-state simulation and the second is the transient simulation that uses the steady-state results of the first case as initial conditions. The condition that is varied in the transient simulation is the temperature at node 9.

The following boundary conditions are specified for the steady-state case:

Node number	Boundary condition
4	Quality = -0.03 (to make sure that the refrigerant is in the sub-cooled liquid region)
6	Quality = 1.03 (to make sure that the refrigerant is in the superheated vapour region)
7	P = 100 kPa, T = 15 °C
8	Mass flow = 3.09 kg/s
9	P = 100 kPa, T = 30 °C
10	Mass flow = 1.7 kg/s

Flownex's Designer capability is used to determine the diameter of the restrictor (element 8) as well as the pressures at nodes 1 and 4 so as to ensure that the quality conditions at nodes 4 and 5 is satisfied as well as continuity at node 4.

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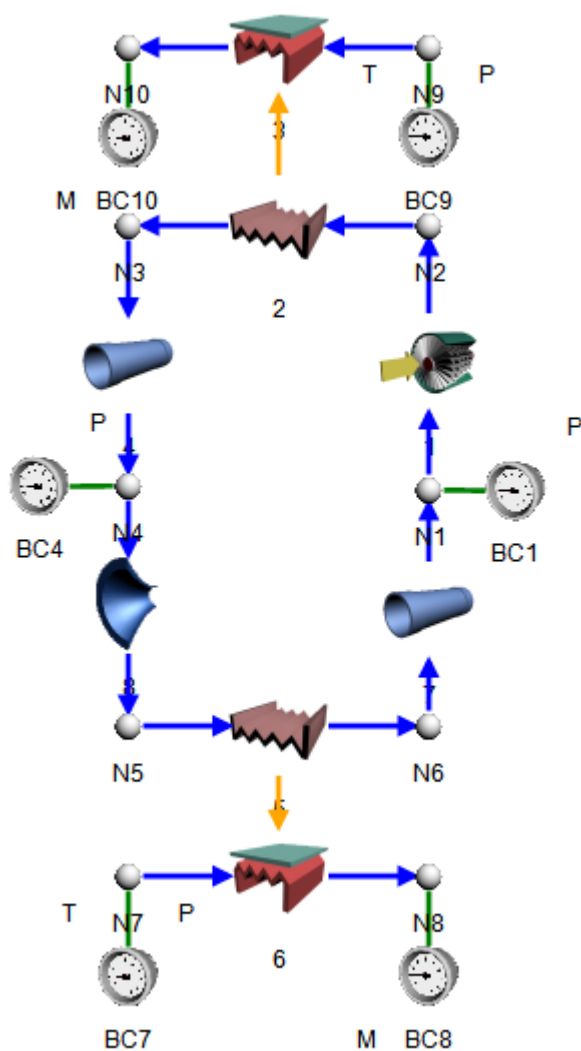


Figure 3: Flownex network of the vapour compression refrigeration system.

In the transient case the temperature at node 9 is reduced from 30 °C to 20 °C during a 10 second period. At the start of the transient simulation the boundary conditions are set such that the total mass of refrigerant in the system is kept constant. The time increment for the transient simulation is 50 ms.

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RESULTS: STEADY-STATE CASE

Some important results of the steady-state case are summarized in the following table.

Parameter	Value
Condenser heat transfer	118.13 [kW]
Evapourator heat transfer	94.04 [kW]
Compressor power	24.12 [kW]
Refrigerant mass flow	0.616 [kg/s]
Pressure at node 1	512 [kPa]
Pressure at node 2	1959 [kPa]
Temperature at node 2	84.4 [°C]

RESULTS: TRANSIENT CASE

Figure 4 to Figure 7 show some results for the transient case. From Figure 4 it can be seen that the mass flow increases during the transient. This is due to the decrease in compressor discharge pressure. Both compressor power and quality to the inlet of the compressor also decrease during the transient.

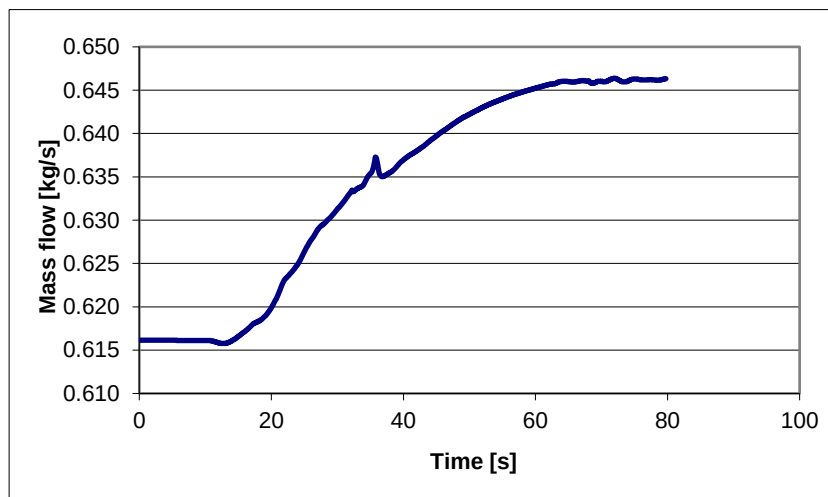


Figure 4: Refrigerant mass flow.

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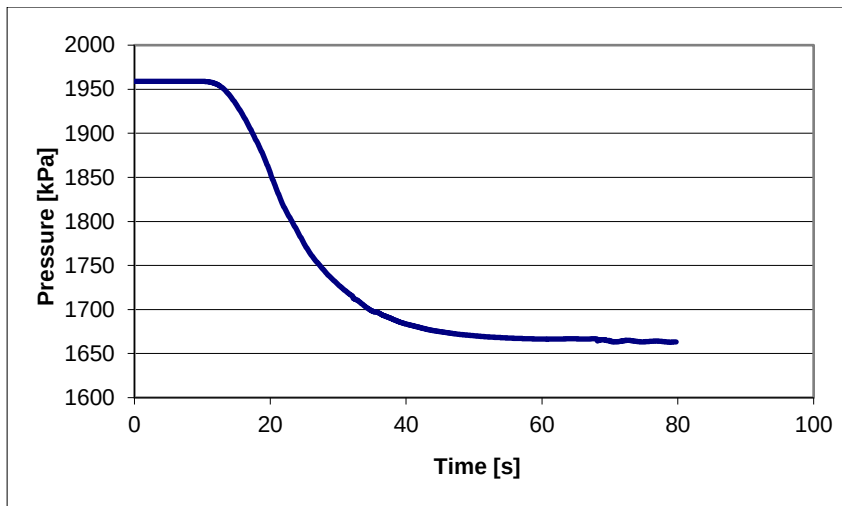


Figure 5: Compressor discharge pressure.

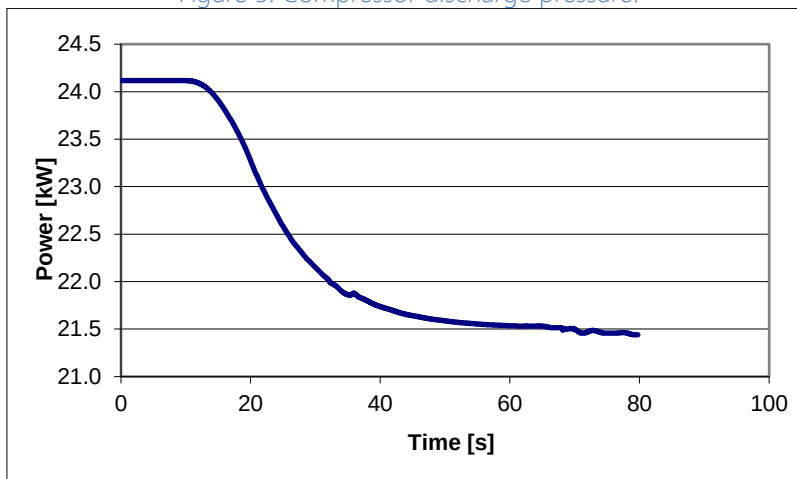


Figure 6: Compressor power.

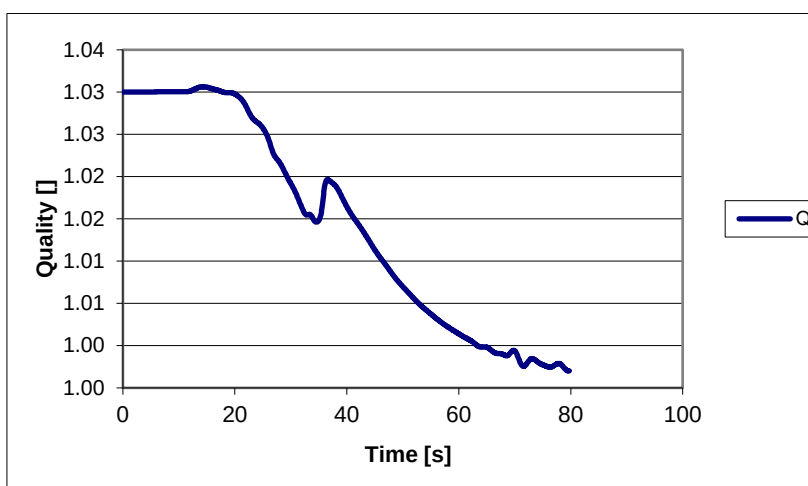


Figure 7: Quality at inlet to compressor.

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CONCLUSION

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