## 15.1.5.3. Problem-3: Refrigeration System

## **Problem Statement**

The refrigerator show in below figure uses R-134a as the working fluid. The mass flow through each component is 0.1 kg/sec, and the power input to the compressor 5 kW. The heat lost to the compressor is 0.21 kW. Following state data are known, using the state notation (shown as numbers within circles) given in the figure below:

P<sub>1</sub>=100 kPa, T<sub>1</sub>=-20 °C P<sub>2</sub> = 800kPa,  $x_3$ =0.0(Vapor Fraction) T<sub>4</sub>= -25 °C

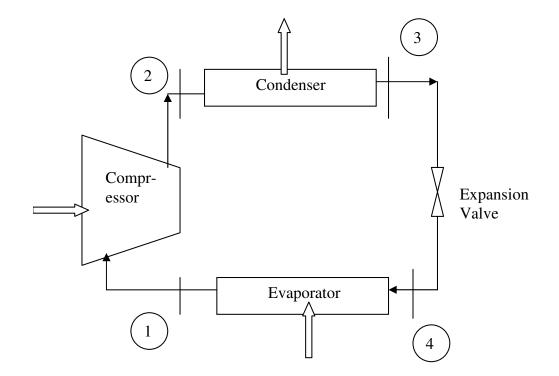


Fig. 15.4. Refrigeration System.

State 1: Cold Vapor

State 2: Warm Vapor

State 3: Warm Liquid

State 4: Cold liquid + vapor

Determine the following:

- 1. Quality at the evaporator inlet.
- 2. Rate of heat transfer to the evaporator.
- 3. Mass flow rate of cold water in the condenser and the evaporator if temperature differences are from 10→15 °C and 85→ 45 °C.
- 4. Pressure and temperature at the all four states.

- 1. Click on the shortcut of the Hysys 3.1.
- 2. Give the command ALT+F or open new case from menu. Following window would be opened.

🗼 Simulation Basis Manag	er					_ 🗆 🗵
Component Lists						
Master Component List	⊻iew					
	Add					
	Delete	1				
	Сору					
	Import					
	Export					
	<u>R</u> efresh	[				
Components Fluid Pkg	Bypotheticals	Oil Manager	Reactions	Component Maps	UserProperty	
				Enter Simulation En	vironment	

3. Press the Add button and select the component R-134a and water as shown below.

🕴 Component List View					_ 🗆 ×
Aug component	Selected Components R134a H2O	<add pure<br="">&lt;-Substitute-&gt; Remove&gt; Sort List ⊻iew Component</add>	Components Availa <u>Match</u> Sim Name Naphthalene Methanol Methanol	able in the Component Library C Full Name / Synonym White_Tar Wood_Alcohol Wood_Naphtha	View Filters C Formula C10H8 CH40 CH40 CH40
			🔽 Show Synonyr	ns 🗖 Cluster	
Selected Componer	it by Type	2			
Delete		Name Master C	omponent List		

 Now close the above window. In the window of simulation basis manager press the tab Fluid Pkgs. In the opened window of Fluid Package select the package of Peng Robinson as shown below.

Fluid Package: Basis-1	
Property Package Selection         NRTL         OLL Electrolyte         PRSV         Sour PR         Sour SRK         SRK         UNIQUAC         Van Laar         Wilson	EOS Enthalpy Method Specification © Eguation of State © Lee-Kesler Peng Robinson Options © HYSYS © Standard Use EOS Density
Zudkevitch Joffee     Image: Component List Selection       Component List - 1     Image: View       Set Up     Parameters     Binary Coeffs     StabTest     Phase	Smooth Liquid Density     Advanced Thermodynamics     COMThermo Regression     Export     Export e Order Rxns Tabular Notes
Delete Name Basis-1 Property Pkg	Peng Robinson Edit Properties

- 5. Now close the window of Fluid Package: Basis1.
- In the window of simulation basis manager, press the key of Enter the Simulation Environment. The new window named PFD-Case (Main) would be opened along with Case (Main) window.
- 7. From the Case (Main) window select the compressor and double click on it. You would get following window.

🕨 K-100		_ 🗆 ×
Design Connections Parameters Links User Variables Notes	Name K-100	
Design Rating	Worksheet Performance Dynamics	
Delete	Requires a feed stream	Ignored

- In the window of the K-100, enter the inlet, outlet and energy stream as Cold Vapor, Warm Vapor, and Work respectively.
- 9. Click the worksheet tab and fill the data of cold vapor, warm vapor and work as follows.

Worksheet	Name	Cold Vapor	Warm Vapor	Work
e re	Vapour	1.0000	1.0000	<empty></empty>
Conditions	Temperature [C]	-20.00	<empty></empty>	<empty></empty>
Properties	Pressure [kPa]	100.0	800.0	<empty></empty>
Composition	Molar Flow [kgmole/h]	<empty></empty>	<empty></empty>	<empty></empty>
	Mass Flow [kg/h]	360.0	360.0	<empty></empty>
PF Specs	LiqVol Flow [m3/h]	<empty></empty>	<empty></empty>	<empty></empty>
	Molar Enthalpy [kJ/kgmole]	<empty></empty>	<empty></empty>	<empty></empty>
	Molar Entropy [kJ/kgmole-C]	<empty></empty>	<empty></empty>	<empty></empty>
	Heat Flow [kJ/h]	<empty></empty>	<empty></empty>	1.724e+004
Design Rating	Worksheet Performance Dyna	amics		

Worksheet		Cold Vapor	Warm Vapor	
	R134a	1.0000	1.0000	
Conditions	H20	0.0000	0.0000	
Properties				
Composition				
PF Specs				
Design Rating	Worksheet Performance	Dynamics		

10. Click the composition and fill the data as shown below.

- 11. As can be seen, the compressor (K-100) is solved and the outlet warm vapor temperature is found out to be 48.26 °C.
- 12. Select the next component heat exchanger by double clicking on it and fill the data as follows. Here vapors are getting condensed and hence one has to choose heat exchanger only. If we select cooler, then solver would automatically take it for granted that no phase change occurs during cooling, which is not the case in the present problem.

🗩 E-100		
Design Connections Parameters	Iube Side Inlet Name E-100 Warm Vapor ▼	Shell Side Inlet
Specs User Variables Notes	Tube Side Shell Side Shell Side I Shellside Flowsheet Shellside Flowsheet Case (Main)	wisheet
	Tube Side Outlet Warm Liquid Tube Side Fluid <u>Pkg</u> Basis-1	Shell Si <u>d</u> e Outlet CWout ▼ Shell Side Fluid P <u>kg</u> Basis-1 ▼
Design Rating	Worksheet Performance Dynamics HTFS - TASC	
Delete	Unknown Delta P	🗖 Ignored

13. Click on the parameter and enter the value of the  $\Delta P$  as 0 kPa. Click on the Worksheet Tab and press the composition. Enter the fraction 1.00 for H<sub>2</sub>O and make the composition of Cw<sub>in</sub> and Cw<sub>out</sub> as 100% H<sub>2</sub>O.

14. Now press the condition and enter the vapor fraction 0 for warm liquid. Then enter the CW<sub>in</sub> and CW<sub>out</sub> temperatures and its vapor fraction. Solver would calculate the mass flow rate as shown in the window below.

Vapour Temperature [C] Pressure [kPa] Molar Flow [kgmole/h] Mass Flow [kg/h] Std Ideal Liq Vol Flow [m3/h] Molar Enthalpy [kJ/kgmole] Molar Entropy [kJ/kgmole-C] Heat Flow [kJ/h]	Warm Vapor 1.0000 48.26 800.0 3.528 360.0 0.2899 -8.948e+005 187.0 -3.157e+006	Warm Liquid 0,0000 31.31 800.0 3.528 360.0 0.2899 -9.144e+005 122.9 -3.226e+006	0.0000 10.00 414.2 96.02 9797 7.890 -9.175e+005 112.2 -8.810e+007	0.0000 15.00 488.0 96.02 9797 7.890 -3.168e+005 114.7 -8.803e+007
Pressure (kPa) Molar Flow (kgmole/h) Mass Flow (kg/h) Std Ideal Liq Vol Flow (m3/h) Molar Enthalpy (kJ/kgmole) Molar Entropy (kJ/kgmole-C)	800.0 3.528 360.0 0.2899 -8.948e+005 187.0	800.0 3.528 360.0 0.2899 -9.144e+005 122.9	414.2 96.02 9797 7.890 -9.175e+005 112.2	488.0 96.02 9797 7.890 -9.168e+005 114.7
Molar Flow (kgmole/h) Mass Flow (kg/h) Std Ideal Liq Vol Flow (m3/h) Molar Enthalpy (kJ/kgmole) Molar Entropy (kJ/kgmole-C)	3.528 360.0 0.2899 -8.948e+005 187.0	3.528 360.0 0.2899 -9.144e+005 122.9	96.02 9797 7.890 -9.175e+005 112.2	96.02 9797 7.890 -9.168e+005 114.7
Mass Flow (kg/h) Std Ideal Liq Vol Flow (m3/h) Molar Enthalpy (kJ/kgmole) Molar Entropy (kJ/kgmole-C)	360.0 0.2899 -8.948e+005 187.0	360.0 0.2899 -9.144e+005 122.9	9797 7.890 -9.175e+005 112.2	9797 7.890 -9.168e+005 114.7
Std Ideal Liq Vol Flow (m3/h) Molar Enthalpy (kJ/kgmole) Molar Entropy (kJ/kgmole-C)	0.2899 -8.948e+005 187.0	0.2899 -9.144e+005 122.9	7.890 -9.175e+005 112.2	7.890 -9.168e+005 114.7
Molar Enthalpy [kJ/kgmole] Molar Entropy [kJ/kgmole-C]	-8.948e+005 187.0	-9.144e+005 122.9	-9.175e+005 112.2	-9.168e+005 114.7
Molar Entropy [kJ/kgmole-C]	187.0	122.9	112.2	114.7
Heat Flow [kJ/h]	-3.157e+006	-3.226e+006	-8.810e+007	-8.803e+007
		1	I	
Vorksheet Performance Dyna	amics HTFS - TASC			
	f <b>orksheet</b> Performance Dyn	forksheet Performance Dynamics HTFS - TASC		

## 15. Condenser has been solved and the main window of PFD-case would look as follows:

© PFD - Case (Main)	
田園習 田園 PA2 📲	🧐 Default Colour Scheme 💌
CWin E-100 Cold Vapor Vapor Vapor K-100	▲ Warm Liquid
	<u> </u>
PFD 1	

16. Now select the expander by double clicking on it. And enter the stream names as shown below. Actually we require expansion valve (Joule-Thompson) in this problem, but this is not included as one of the symbols in the Case (Main) window of this software (HYSYS). However, it is possible to take care of such problems in this software. Though all the components required for various problems are not directly available, with some approximations and assumptions, equivalent components could be found. In the present problem, the expander with no work and no heat loss could be approximated to Joule-Thompson expansion valve, which is available in the Case (Main) list.

<ul> <li>K-101</li> </ul>		_ 🗆 ×
Design	<u>N</u> ame K-101	
Connections	Inlet Warm Liquid	
Parameters Links User Variables	Fluid Package	
Notes		
	O <u>u</u> tlet cold mixture	
Design Rating	Worksheet Performance Dynamics	
Delete	Liquid in inlet stream	Ignored

17. Press the worksheet tab and enter the data of cold mixture temperature and zero work. One can see that rest all the quantities have been solved. Still warning is there for liquid inlet in expander but we are using expander as a Joule Thompson valve with no work and no heat transfer. 18. Select the heat exchanger and double click on it, which would work as evaporator and fill the stream names as following.

🛡 E-101		
Design Connections Parameters	Iube Side Inlet     Name       Cold mixture	Shell Side Inlet
Specs User Variables Notes	Tube Side     Shell Side       Tubeside Flowsheet     Shellside Flowshe       Case (Main)     Case (Main)	
	Tube Side Fluid Pkg	Shell Sige Outlet
	Basis-1	Basis-1
Design Rating	Worksheet Performance Dynamics HTFS - TASC	
Delete	Unknown Delta P	Ignored

19. Press the worksheet tab and enter the data of coldwater inlet and outlet temperatures and give its composition. The problem is solved and the results are displayed.

Worksheet	Name	cold mixture	Cold Vapor	CWEin	CWEout
	Vapour	0.3555	1.0000	0.0000	0.0000
Conditions	Temperature [C]	-25.00	-20.00	85.00	45.00
Properties	Pressure [kPa]	106.8	100.0	57.81	9.494
	Molar Flow [kgmole/h]	3.528	3.528	16.56	16.56
Composition	Mass Flow [kg/h]	360.0	360.0	298.4	298.4
PF Specs	Std Ideal Lig Vol Flow [m3/h]	0.2899	0.2899	0.2990	0.2990
	Molar Enthalpy [kJ/kgmole]	-9.144e+005	-8.997e+005	-2.807e+005	-2.839e+005
	Molar Entropy [kJ/kgmole-C]	126.3	186.0	68.00	58.75
	Heat Flow [kJ/h]	-3.226e+006	-3.174e+006	-4.649e+006	-4.701e+006
100 C					

20. Finally the PFD case window would be looks as following.

