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_1=100 kPa, T_1=-20 °C

P_2 = 800kPa, x_3=0.0(Vapor Fraction)

T_4= -25 °C

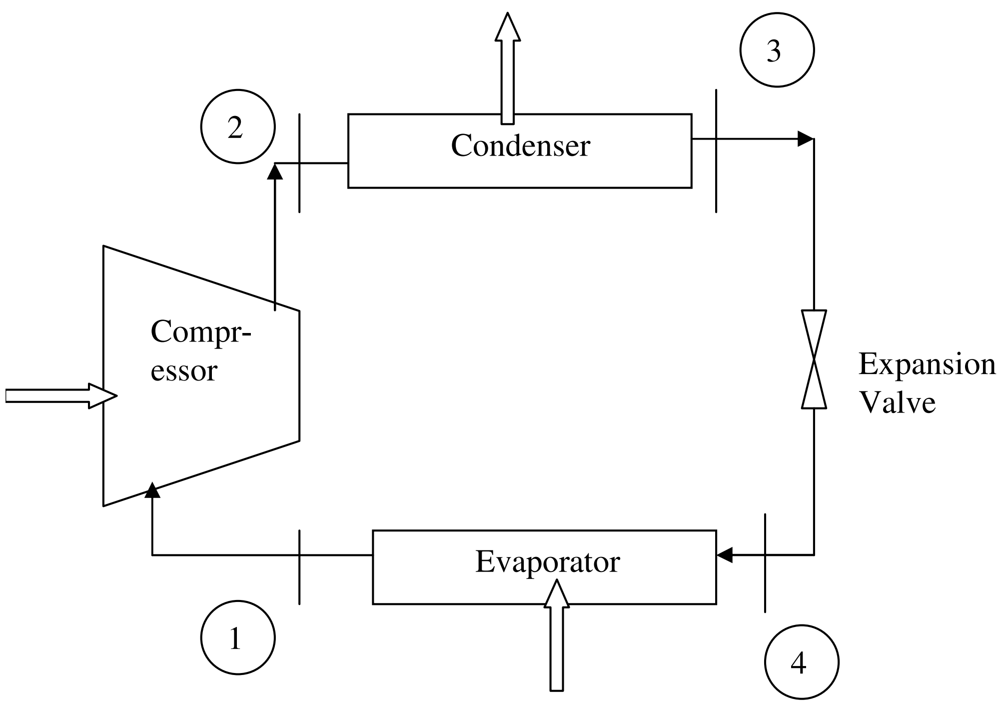


Fig. 15.4. Refrigeration System.

State 1: Cold Vapor

State 2: Warm Vapor

State 3: Warm Liquid

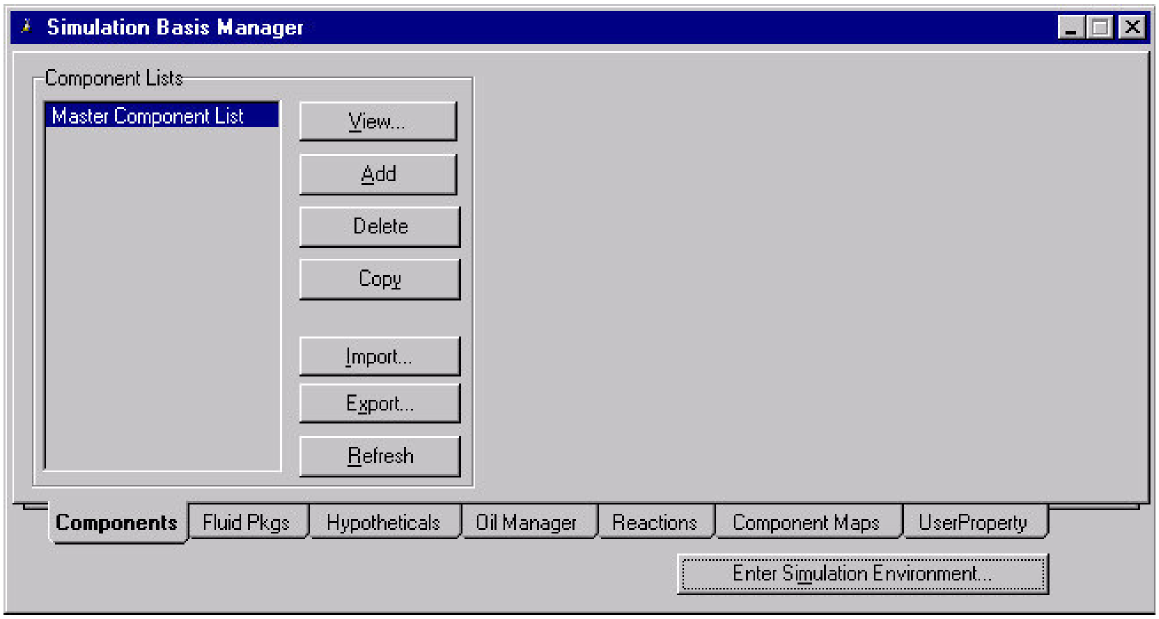
State 4: Cold liquid + vapor

Determine the following:

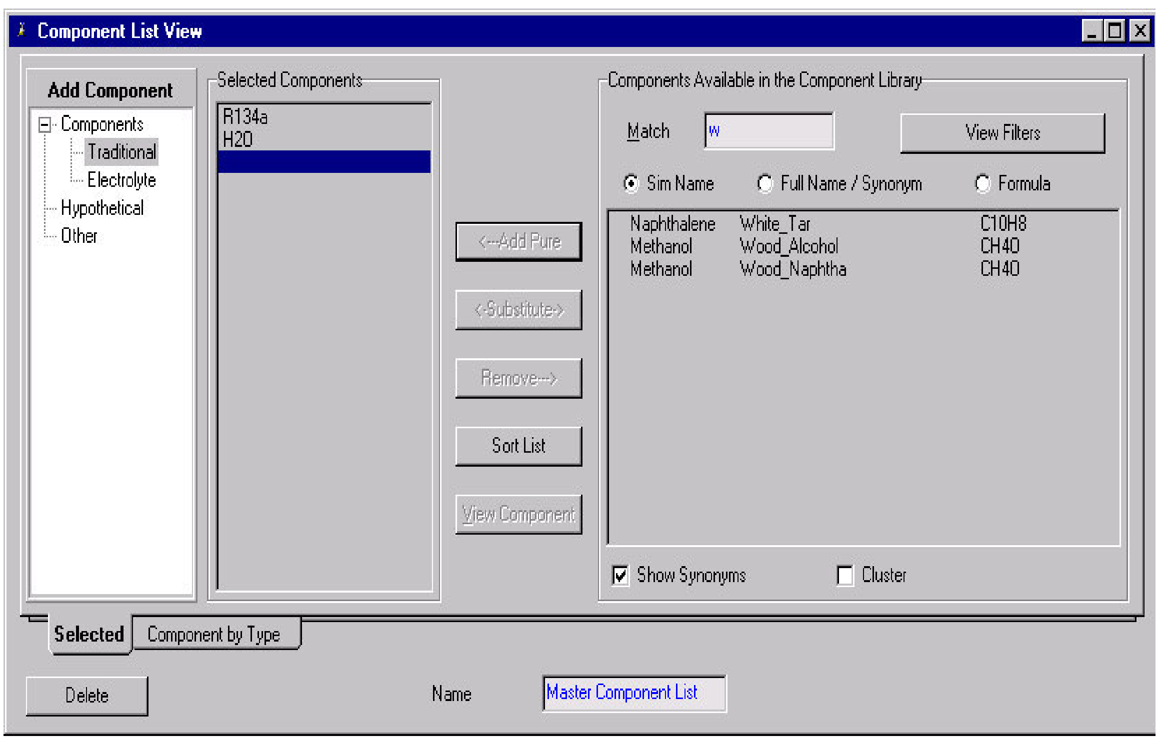
1. Quality at the evaporator inlet.
2. Rate of heat transfer to the evaporator.
3. Mass flow rate of cold water in the condenser and the evaporator if temperature differences are from 10→15 °C and 85→ 45 °C**.**
4. Pressure and temperature at the all four states.

1. Click on the shortcut of the Hysys 3.1.

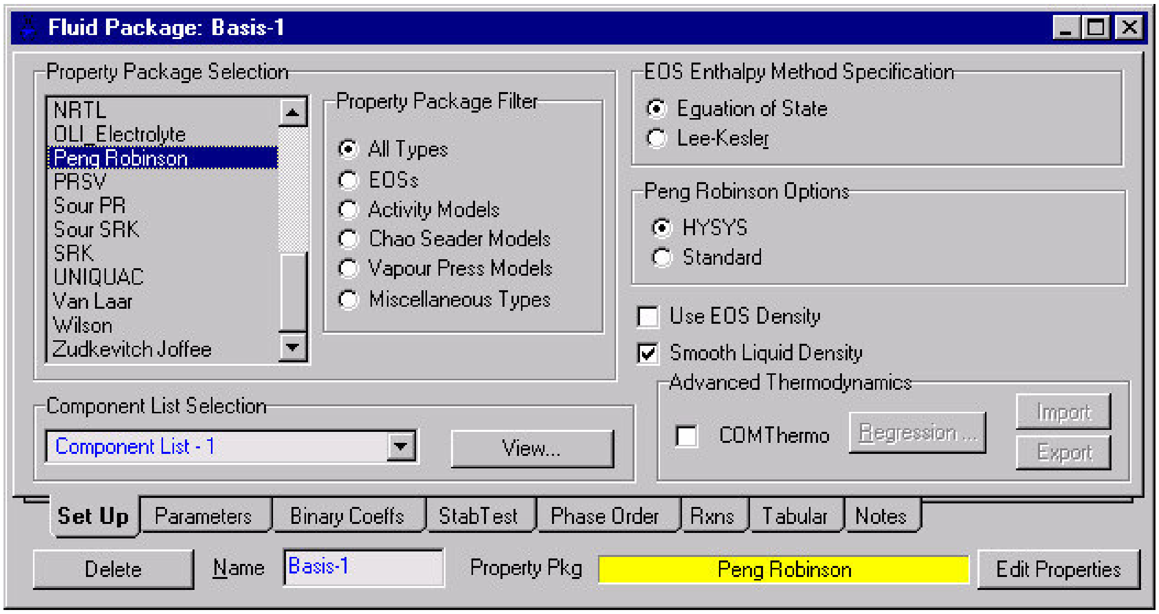
2. Give the command ALT+F or open new case from menu. Following window would be opened.



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



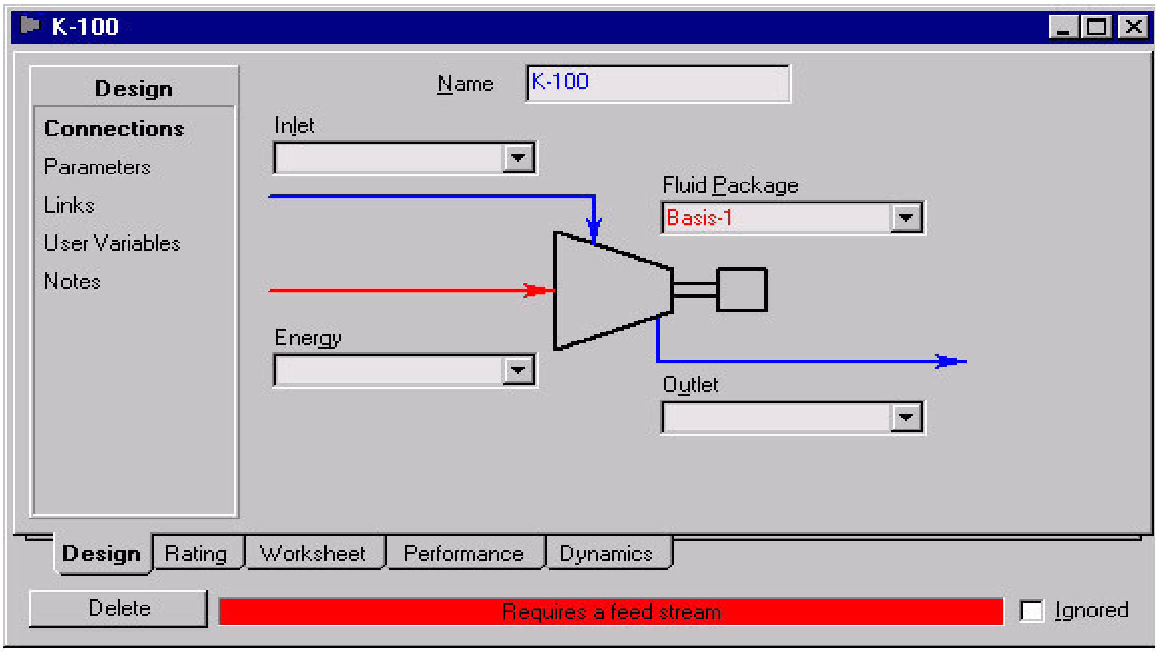
4. Now close the above window. In the window of simulation basis manager press the tab Fluid Pkgs. In the opened window of Fluid Package select the package of Peng Robinson as shown below.



5. Now close the window of Fluid Package: Basis1.

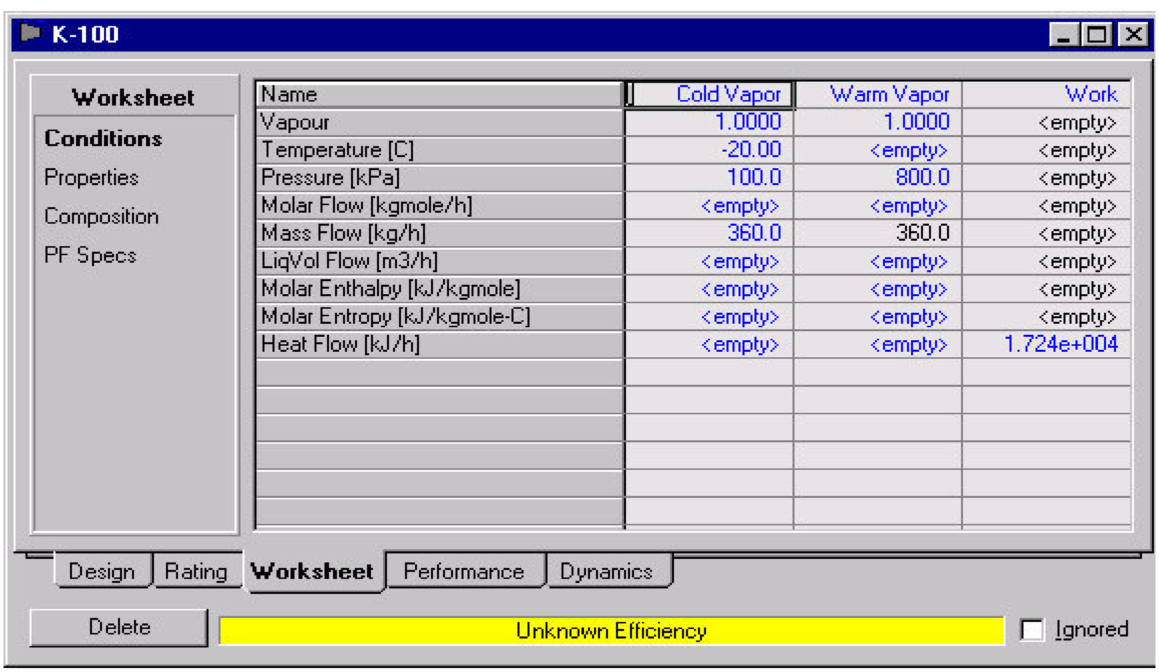
6. In the window of simulation basis manager, press the key of Enter the Simulation Environment. The new window named PFD-Case (Main) would be opened along with Case (Main) window.

7. From the Case (Main) window select the compressor and double click on it. You would get following window.



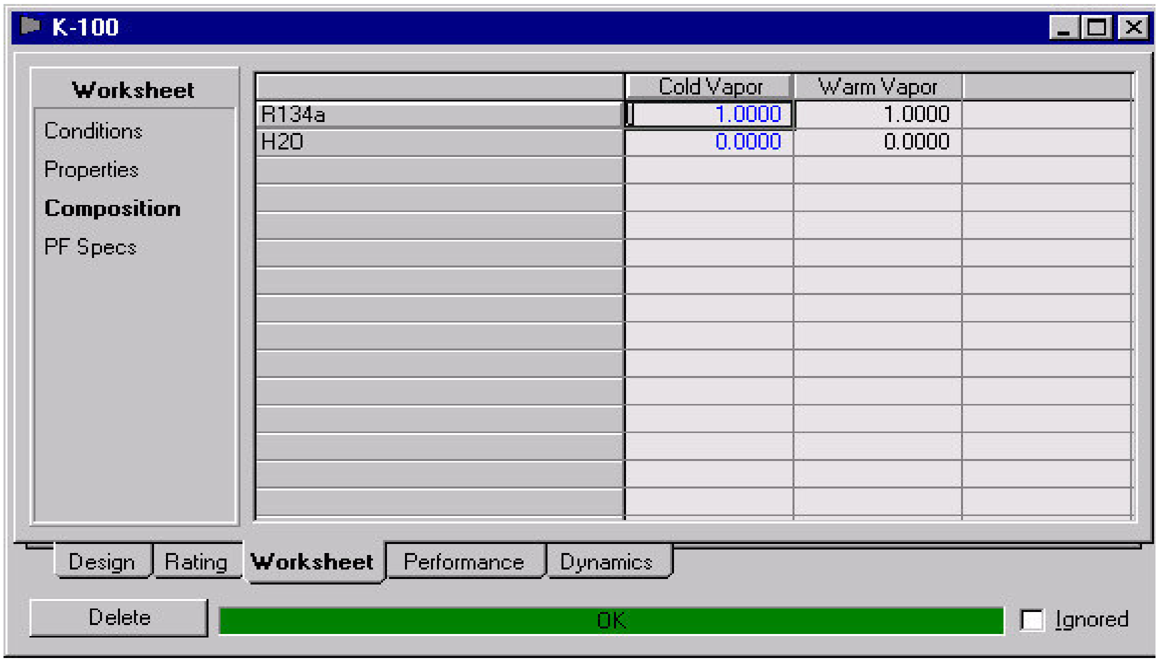
8. In the window of the K-100, enter the inlet, outlet and energy stream as Cold Vapor, Warm Vapor, and Work respectively.

9. Click the worksheet tab and fill the data of cold vapor, warm vapor and work as follows.



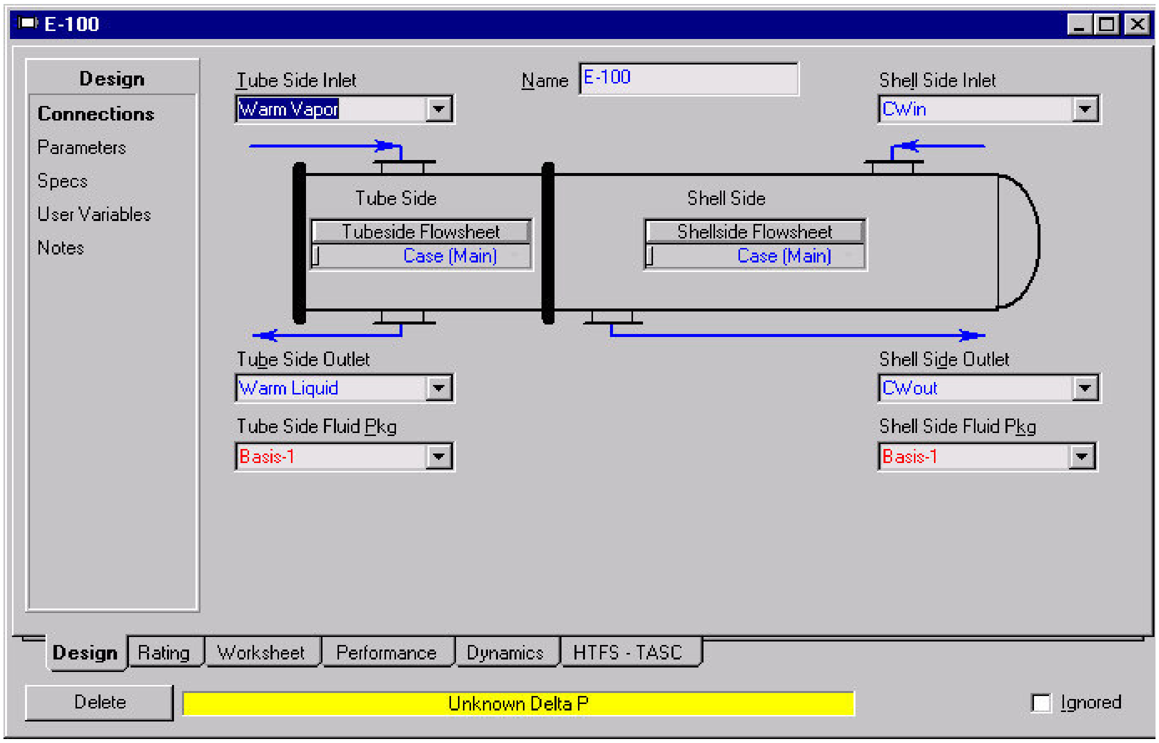
Name	Cold Vapor	Warm Vapor	Work
Vapour	1.0000	1.0000	<empty>
Temperature [C]	-20.00	<empty>	<empty>
Pressure [kPa]	100.0	800.0	<empty>
Molar Flow [kgmole/h]	<empty>	<empty>	<empty>
Mass Flow [kg/h]	360.0	360.0	<empty>
LiqVol Flow [m3/h]	<empty>	<empty>	<empty>
Molar Enthalpy [kJ/kgmole]	<empty>	<empty>	<empty>
Molar Entropy [kJ/kgmole-C]	<empty>	<empty>	<empty>
Heat Flow [kJ/h]	<empty>	<empty>	1.724e+004

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



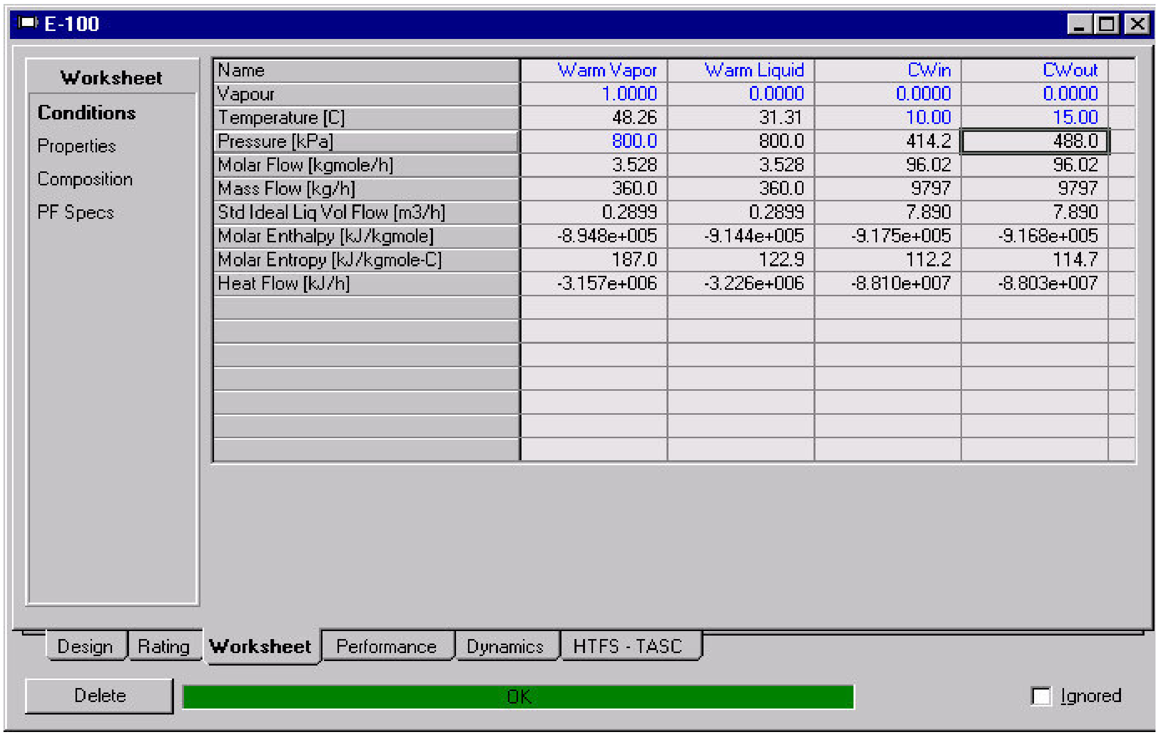
11. As can be seen, the compressor (K-100) is solved and the outlet warm vapor temperature is found out to be 48.26 °C.

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.



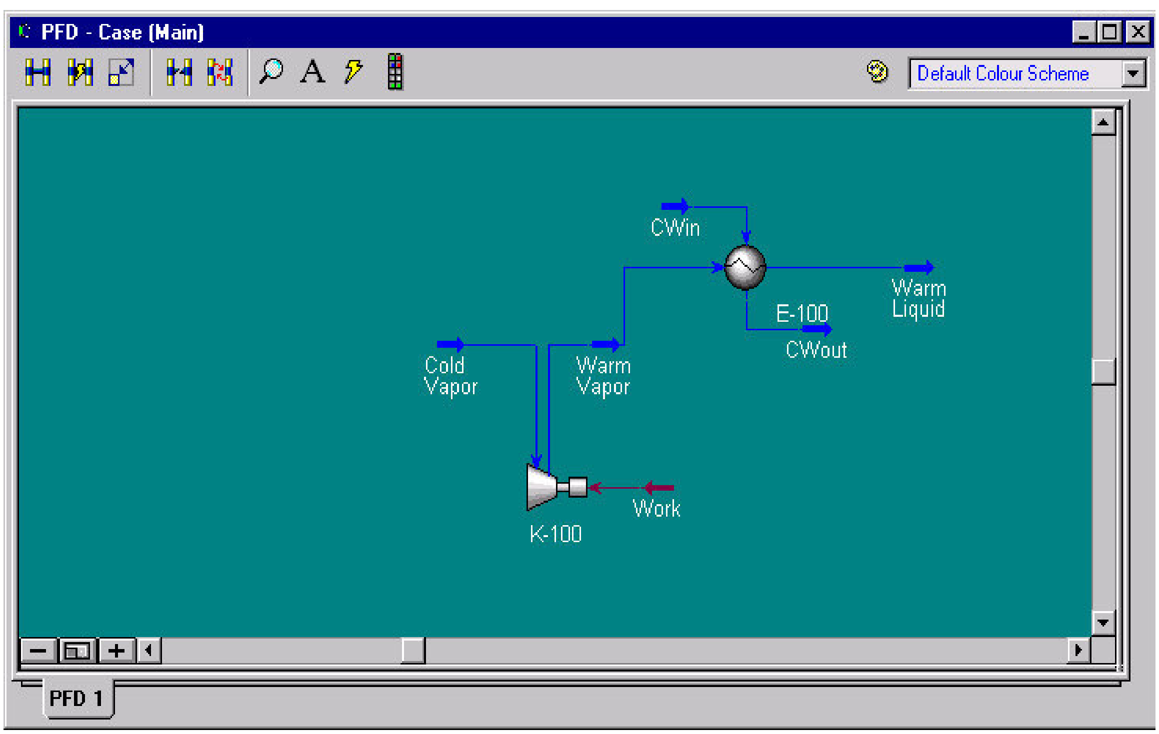
13. Click on the parameter and enter the value of the ΔP as 0 kPa. Click on the Worksheet Tab and press the composition. Enter the fraction 1.00 for H_2O and make the composition of Cw_{in} and Cw_{out} as 100% H_2O.

14. Now press the condition and enter the vapor fraction 0 for warm liquid. Then enter the CW_{in} and CW_{out} temperatures and its vapor fraction. Solver would calculate the mass flow rate as shown in the window below.

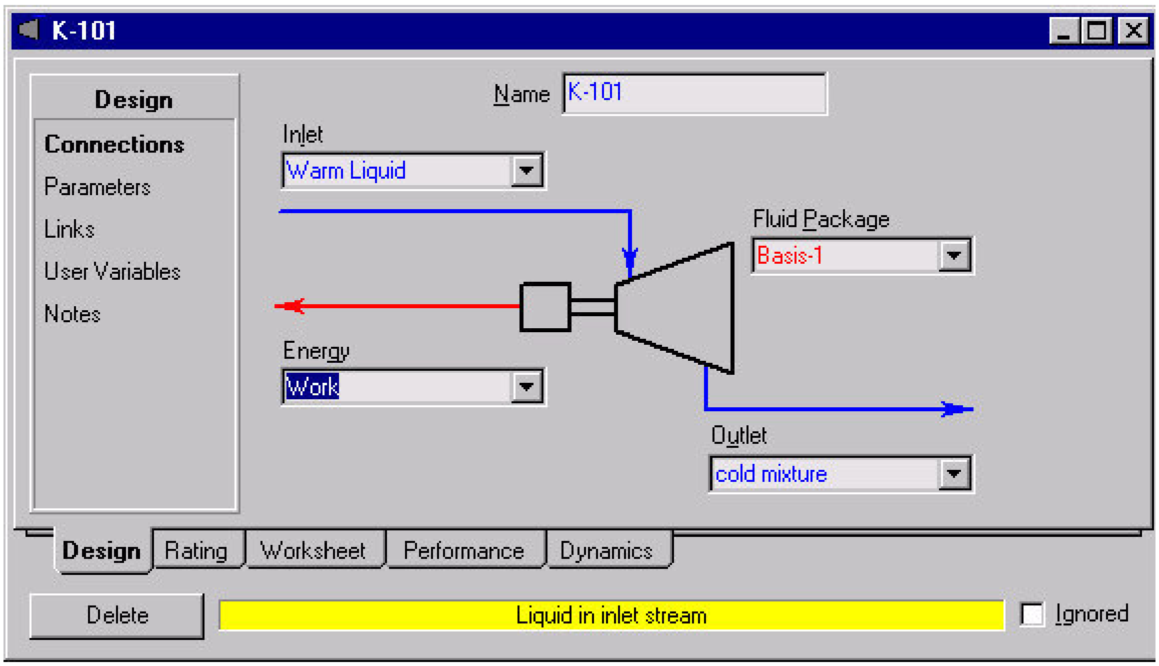


Name	Warm Vapor	Warm Liquid	CWin	CWout
Vapour	1.0000	0.0000	0.0000	0.0000
Temperature [C]	48.26	31.31	10.00	15.00
Pressure [kPa]	800.0	800.0	414.2	488.0
Molar Flow [kgmole/h]	3.528	3.528	96.02	96.02
Mass Flow [kg/h]	360.0	360.0	9797	9797
Std Ideal Liq Vol Flow [m3/h]	0.2899	0.2899	7.890	7.890
Molar Enthalpy [kJ/kgmole]	-8.948e+005	-9.144e+005	-9.175e+005	-9.168e+005
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

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

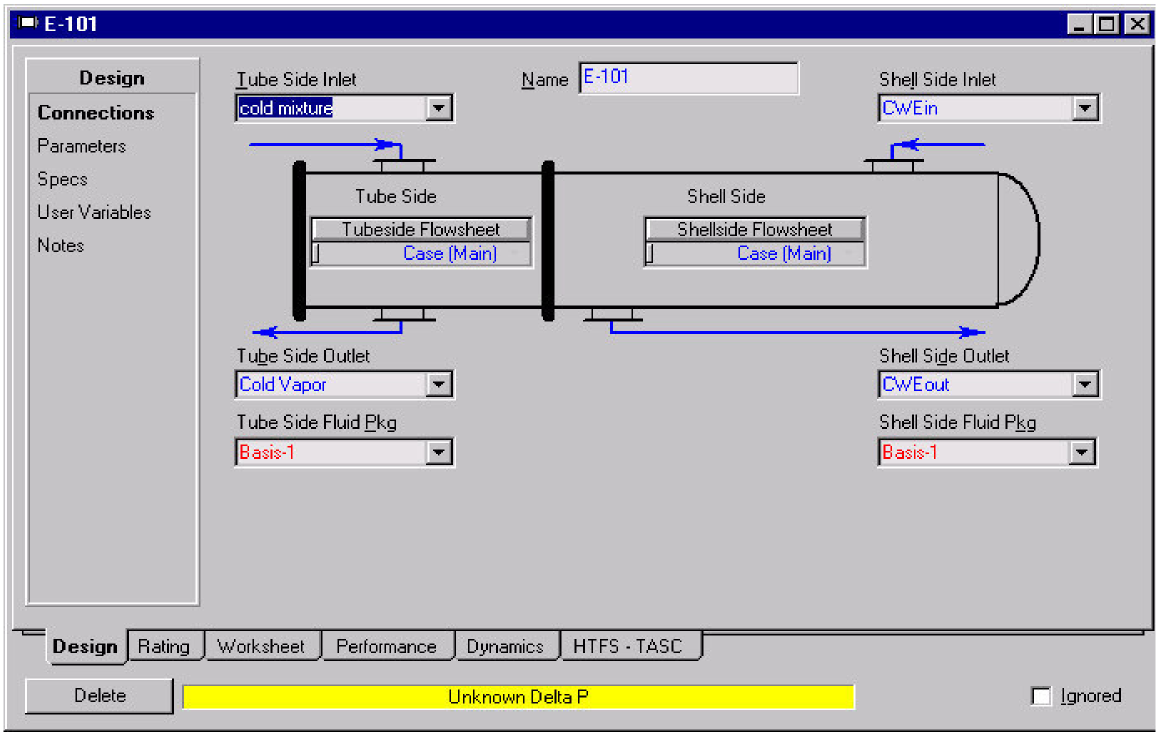


16. Now select the expander by double clicking on it. And enter the stream names as shown below. Actually we require expansion valve (Joule-Thompson) in this problem, but this is not included as one of the symbols in the Case (Main) window of this software (HYSYS). However, it is possible to take care 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.

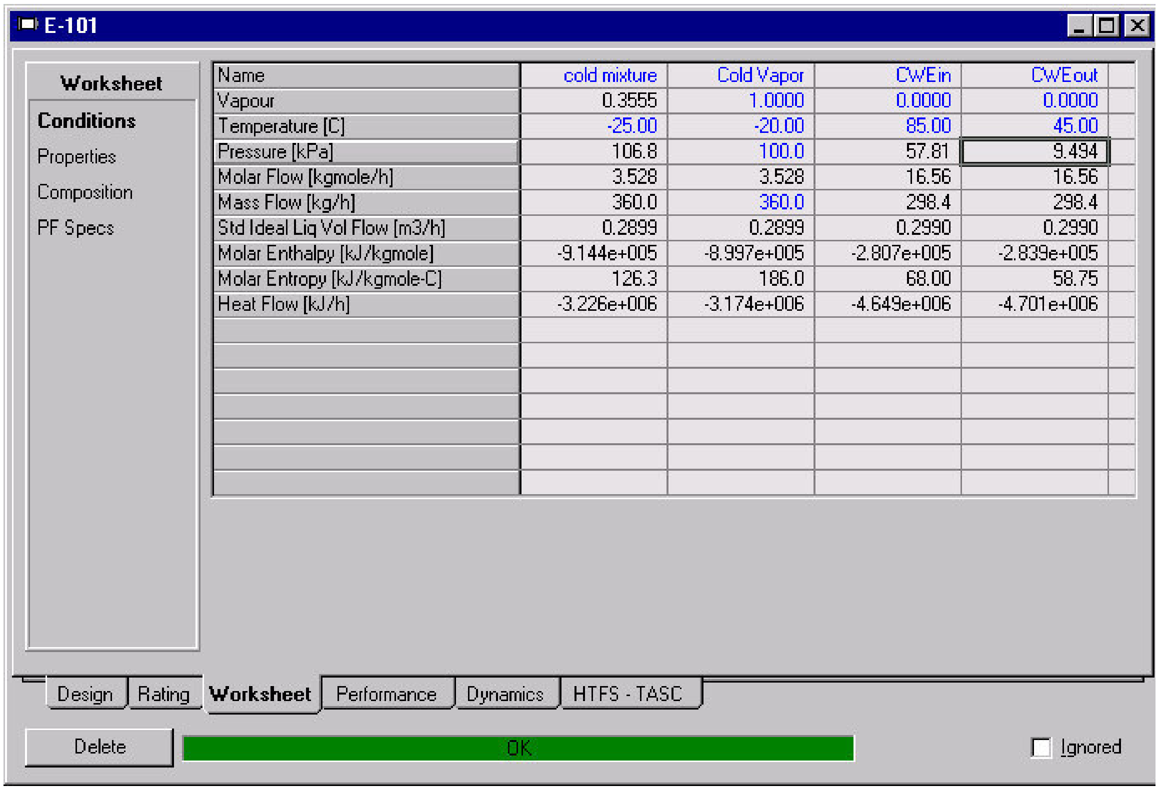


17. Press the worksheet tab and enter the data of cold mixture temperature and zero work. One can see that rest all the quantities have been solved. Still warning is there for liquid inlet in expander but we are using expander as a Joule Thompson valve with no work and no heat transfer.

18. Select the heat exchanger and double click on it, which would work as evaporator and fill the stream names as following.



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.



Name	cold mixture	Cold Vapor	CWEin	CWEout
Vapour	0.3555	1.0000	0.0000	0.0000
Temperature [C]	-25.00	-20.00	85.00	45.00
Pressure [kPa]	106.8	100.0	57.81	9.494
Molar Flow [kgmole/h]	3.528	3.528	16.56	16.56
Mass Flow [kg/h]	360.0	360.0	298.4	298.4
Std Ideal Liq 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

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