Ideal Vapor-Compression Refrigeration System Program

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MET 3501

(Engineering Computations using Matlab)

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The function "Vapor Compression Refrigeration Cycle":

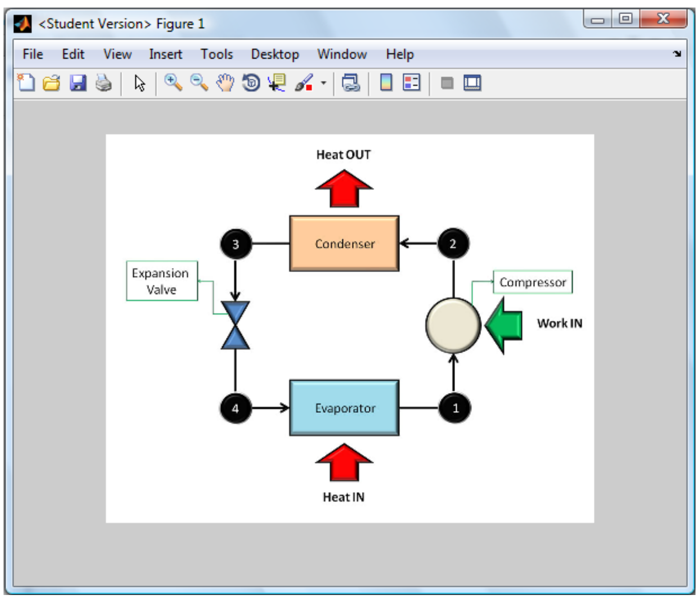
```
function [Refrig_Cap,Heat_Cap,COP] = Vap_Comp_Refrig_Cycle
%This function calculates the refrigeration capacity, heat capacity
%and refrigeration coefficient of performance for the ideal vapor
%compression refrigeration cycle.
%Written by Brian Poag

clc
clear all

fprintf('This program calculates the refrigeration capacity,\n')
fprintf('heat capacity, and refrigeration coefficient of\n')
fprintf('performance for the ideal vapor compression refrigeration cycle\n')
fprintf('with Refrigerant 134a as the working fluid.\n')
fprintf('This program assumes that the user knows either the maximum and\n')
fprintf('minimum pressures of the cycle or the temperatures at states 1,
2,\n')
fprintf('and 3, the mass flow rate of the cycle and power to
compressor.\n\n')

fprintf('Refer to the given figure.\n\n')
imshow('Diagram_of_Cycle.bmp','InitialMagnification',100)
load LiqVapTempTble

mdot=input('Enter the mass flow rate of the cycle in kg/s: ');
Comp_Power=input('Enter the power to the compressor in kW : ');
disp('Do you know the pressures of the cycle or the temperatures?')
casenum1=input('(1)=pressures (2)=temperatures: ');
if casenum1==1
    pmin=input('Enter the minimum pressure of the cycle in kPa: ');
    if pmin<51.64
        fprintf('\n')
        disp('This pressure exceeds the table''s limits.')
        disp('Table''s lowest pressure is 51.64 kPa.')
        disp('Enter a pressure higher than or equal to this.')
        disp('Rerunning program')
        pause(5)
        run Vap_Comp_Refrig_Cycle
    end
    p1=pmin;
    pmax=input('Enter the maximum pressure of the cycle in kPa: ');
    if pmax>3974.2
        fprintf('\n')
        disp('This pressure exceeds the table''s limits.')
        disp('Table''s highest pressure is 3974.2 kPa.')
        disp('Enter a pressure lesser than or equal to this.')
        disp('Rerunning program')
        pause(5)
        run Vap_Comp_Refrig_Cycle
    end
    p2=pmax;
    p3=p2;
    if pmax<pmin
        fprintf('\n')
        disp('Minimum pressure can''t exceed maximum pressure!')
```

```
        disp('Rerunning Program')
        pause(5)
        run Vap_Comp_Refrig_Cycle
    end
    h1=interp1(LiqVapTempTble(:,2),LiqVapTempTble(:,6),p1);
    %Units for all enthalpy values is kJ/kg.
    h3=interp1(LiqVapTempTble(:,2),LiqVapTempTble(:,5),p3);
    h4=h3;

elseif casenum1==2
    Tmin=input('Enter the minimum temperature of the cycle in deg Celsius:
');
    if Tmin<-40
        fprintf('\n')
        disp('Table''s lowest temperature is -40 deg Celsius.')
        disp('Enter a temperature higher than or equal to this.')
        disp('Rerunning program')
        pause(5)
        run Vap_Comp_Refrig_Cycle
    end
    T1=Tmin;
    T3=input('Enter the temperature of the fluid after leaving condenser: ');
    if T3<Tmin || T3>100
        fprintf('\n')
        disp('Minimum temperature can''t exceed State 3 temperature')
        disp('nor can it exceed the table''s limit of 100 degrees Celsius.')
        disp('Rerunning Program')
        pause(5)
        run Vap_Comp_Refrig_Cycle
    end
    h1=interp1(LiqVapTempTble(:,1),LiqVapTempTble(:,6),T1);
    h3=interp1(LiqVapTempTble(:,1),LiqVapTempTble(:,5),T3);
    h4=h3;

else
    disp('Either pressures or temperatures must be known for this program')
    disp('to work. Rerunning program.')
    pause(5)
    run Vap_Comp_Refrig_Cycle

end

    h2=(Comp_Power/mdot)+h1;
    RefrigCapInkW=abs(mdot*(h1-h4));        %In kW or kJ/s
    Refrig_Cap=abs((RefrigCapInkW)*60/211);  %Converts from kJ/s to tons.
    Heat_Cap=abs(mdot*(h2-h3));
    COP=RefrigCapInkW/Comp_Power;
    fprintf('\nRefrigeration capacity is %4.2f tons\n',Refrig_Cap)
    fprintf('Heat capacity is %4.2f kW\n',Heat_Cap)
    fprintf('Refrigeration coefficient of performance is %4.2f\n',COP)

end
```

Program Results from User Entering 'Pressure' Values:

(User first enters: >>[Refrig_Cap,Heat_Cap,COP] = Vap_Comp_Refrig_Cycle;])

```
This program calculates the refrigeration capacity,
heat capacity, and refrigeration coefficient of
performance for the ideal vapor compression refrigeration cycle
with Refrigerant 134a as the working fluid.
This program assumes that the user knows either the maximum and
minimum pressures of the cycle or the temperatures at states 1, 2,
and 3, the mass flow rate of the cycle and power to compressor.
Refer to the given figure.
```




```
Enter the mass flow rate of the cycle in kg/s: .117
Enter the power to the compressor in kW : 3.34
Do you know the pressures of the cycle or the temperatures?
(1)=pressures (2)=temperatures: 1
Enter the minimum pressure of the cycle in kPa: 200
Enter the maximum pressure of the cycle in kPa: 800
Refrigeration capacity is 4.92 tons
Heat capacity is 20.64 kW
Refrigeration coefficient of performance is 5.18
```

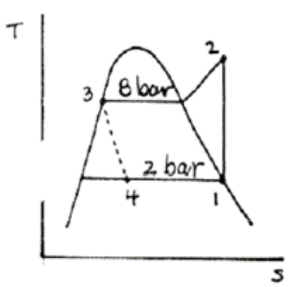
*Notice that this problem is correct by checking problem "10.6" and its solution shown below.

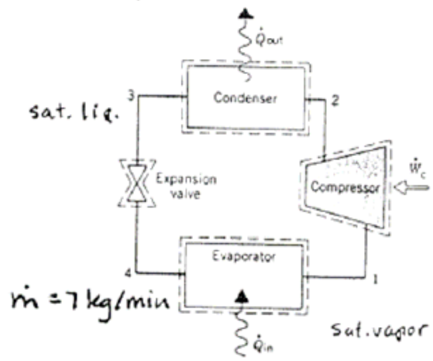
PROBLEM 10.6

KNOWN: Refrigerant 134a is the working fluid in an ideal vapor-compression refrigaration cycle. Operating data are known.

FIND: Determine (a) the compressor power, (b) the refrigerating capacity, and (c) the coefficient of performance.

SCHEMATIC & GIVEN DATA:





ENGINEERING MODEL: (1) Each component is analyzed as a control volume at steady state. (2) The expansion through the valve is a throttling process. All other processes are internally reversible. (3) The compressor and valve operate adiabatically. (4) Kinetic and potential energy effects are negligible.

ANALYSIS: First, fix each of the principal states.

State 1 $p_1 = 2$ bar, sat. vapor $\Rightarrow h_1 = 241.30$ kJ/kg, $s_1 = 0.9253 \frac{kJ}{kg \cdot K}$

State 2 $p_2 = 8$ bar, $s_2 = s_1 \Rightarrow h_2 = 269.92$ kJ/kg

State 3 $p_3 = 8$ bar, sat. liquid $\Rightarrow h_3 = 93.42$ kJ/kg

State 4 Throttling process $\Rightarrow h_4 = h_3 = 93.42$ kJ/kg

(a) The compressor power is

$$\dot{W}_c = \dot{m}(h_2 - h_1) = \left(7 \frac{kg}{min}\right)(269.92 - 241.30)\frac{kJ}{kg}\left|\frac{1\ min}{60\ s}\right|\left|\frac{1\ kW}{1\ kJ/s}\right|$$
$$= 3.34\ kW \leftarrow \dot{W}_c$$

(b) The refrigerating capacity is

$$\dot{Q}_{in} = \dot{m}(h_1 - h_4) = \left(7 \frac{kg}{min}\right)(241.30 - 93.42)\frac{kJ}{kg}\left|\frac{1\ ton}{211\ kJ/min}\right|$$
$$= 4.91\ tons \leftarrow \dot{Q}_{in}$$

(c) The coefficient of performance is

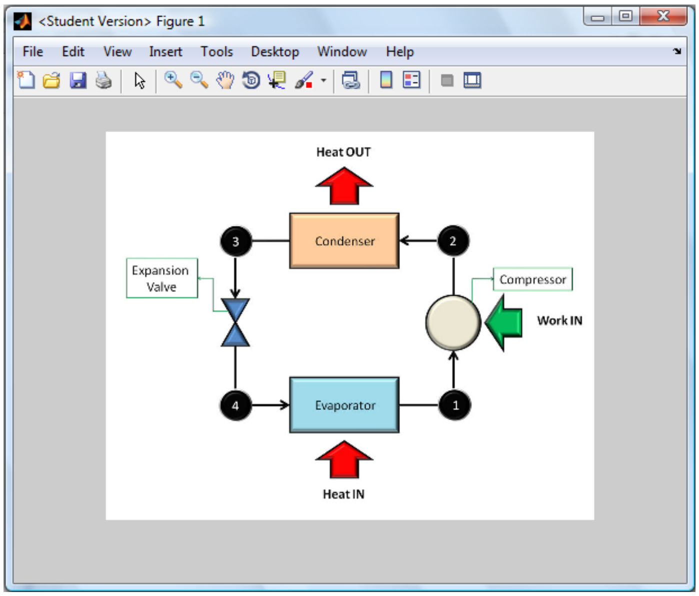
$$\beta = \frac{(h_1 - h_4)}{(h_2 - h_1)} = \frac{(241.30 - 93.42)}{(269.92 - 241.30)} = 5.17 \leftarrow \beta$$

Program Results from User Entering 'Temperature' Values:

(User first enters: `>>[Refrig_Cap,Heat_Cap,COP] = Vap_Comp_Refrig_Cycle;]`)

```
This program calculates the refrigeration capacity,
heat capacity, and refrigeration coefficient of
```

```
performance for the ideal vapor compression refrigeration cycle
with Refrigerant 134a as the working fluid.
This program assumes that the user knows either the maximum and
minimum pressures of the cycle or the temperatures at states 1, 2,
and 3, the mass flow rate of the cycle and power to compressor.
Refer to the given figure.
```




```
Enter the mass flow rate of the cycle in kg/s: .117
Enter the power to the compressor in kW : 4.65
Do you know the pressures of the cycle or the temperatures?
(1)=pressures (2)=temperatures: 2
Enter the minimum temperature of the cycle in deg Celsius: -12
Enter the temperature of the fluid after leaving condenser: 32
Refrigeration capacity is 4.85 tons
Heat capacity is 21.70 kW
Refrigeration coefficient of performance is 3.67
```

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*Notice that this problem is correct by checking problem “10.8” and its solution shown below:

10.8] Refrigerant 134a is the working fluid in an ideal vapor compression refrigeration cycle operating at steady state. Refrigerant enters the compressor at 1.4 bar, -12°C, and the condenser pressure is 9 bar. Liquid enters the compressor at 32°C. The mass flow rate of the refrigerent is 7 kg/min (.117 kg/s). Find:

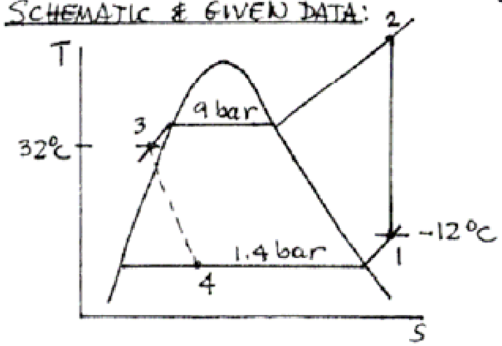
a. Compressor power, in kW.
b. Refrigeration capacity, in tons.
c. Coefficient of performance.

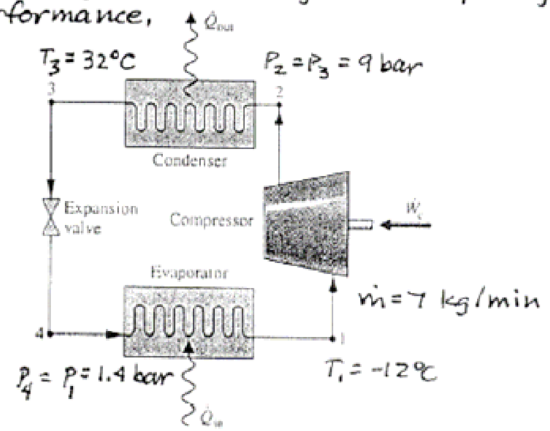
PROBLEM 10.8

KNOWN: R-134a is the working fluid in an ideal vapor compression refrigeration cycle. Operating data are known, and the refrigerant mass flow rate is given.

FIND: Determine (a) the compressor power, (b) the refrigeration capacity, and (c) the coefficient of performance.

SCHEMATIC & GIVEN DATA:





ENGINEERING MODEL: See Example 10.1, items 1–4.

ANALYSIS: First, fix each of the principal states.

State 1: $P_1 = 1.4$ bar, $T_1 = -12°C \Rightarrow h_1 = 241.73$ kJ/kg, $s_1 = 0.95415$ kJ/kg·K

State 2: $P_2 = 9$ bar, $s_2 = s_1 \Rightarrow h_2 = 281.56$ kJ/kg

State 3: $P_3 = 9$ bar, $T_3 = 32°C \Rightarrow$ sub-cooled liquid. Thus, $h_3 \approx h_{f@T_3} = 94.39 \frac{kJ}{kg}$

State 4: Throttling process $\Rightarrow h_4 = h_3 = 94.39$ kJ/kg

(a) For the compressor

$$\dot{W}_c = \dot{m}(h_2 - h_1) = \left(7 \frac{kg}{min}\right)(281.56 - 241.73)\frac{kJ}{kg}\left|\frac{1\ min}{60\ s}\right|\left|\frac{1\ kW}{1\ kJ/s}\right|$$

$$= 4.65\ kW \quad \leftarrow \dot{W}_c$$

(b) For the evaporator

$$\dot{Q}_{in} = \dot{m}(h_1 - h_4) = \left(7 \frac{kg}{min}\right)(241.73 - 94.39)\frac{kJ}{kg}\left|\frac{1\ ton}{211\ kJ/min}\right|$$

$$= 4.89\ tons \quad \leftarrow \dot{Q}_{in}$$

(c) The coefficient of performance is

$$\beta = \frac{\dot{Q}_{in}/\dot{m}}{\dot{W}_c/\dot{m}} = \frac{(h_1 - h_4)}{(h_2 - h_1)} = \frac{(241.73 - 94.39)}{(281.56 - 241.73)} = 3.70 \quad \leftarrow \beta$$