APPROVED SOLUTION

CADET ____________________ SECTION ______TIME OF DEPARTURE ________

DEPARTMENT OF CHEMISTRY & LIFE SCIENCE

CH402, AY2023-2024
WRITTEN PARTIAL REVIEW I
55 Minutes, C-Hour
9 February 2024

TEXT: Peters, Timmerhaus & West
SCOPE: CHAPTERS: 12, 14

References Permitted: Open note and open book; Mathematica; Excel; CHEMCAD.

INSTRUCTIONS

1. You will have 55 minutes for the exam.
2. Do not mark this exam or open it until “begin work” is given.
3. Solve the problems in the space provided. Show all work to receive full credit.
4. There are 3 problems on 4 pages in this exam (not including the cover page).
5. Write your name on the top of each sheet.
6. Save all work and save it frequently.
7. Final CHEMCAD file must be saved in Canvas to receive partial credit.

(TOTAL WEIGHT: 200 POINTS)

DO NOT WRITE IN THIS SPACE

PROBLEM	VALUE	CUT
A	80	
B	60	
C	60	
TOTAL CUT		
GRADE	200	

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THE FOLLOWING INFORMATION IS REQUIRED FOR QUESTIONS A, B, & C

Air used in a catalytic oxidation process is to be heated from 15 to 470 °C before entering the process. The heating is accomplished with the use of product gases, which cool from 480 to 200 °C.

A one-pass shell-and-tube TEMA type AEL exchanger with single-segmental baffles has been proposed. The tubes are type 316 stainless-steel, with type A-240-316 stainless steel used for the tube sheet, shell, channel material, and baffles.

The properties of the hot gases can be considered identical to those of air.

Both streams enter the exchanger at 1020 kPa.

The hot gasses are sent through the tubes at a flow rate of 5.6 kg/s.

The air is sent through the shell.

The shell-side and tube-side fouling factors are zero.

The inside and outside diameters for the tubes are 0.0191 and 0.0254 m, respectively. The tubes will be arranged in line with a square pitch of 0.0381 m with fixed tube sheets. The tubesheet thickness is equal to the outside diameter of the tubes.

Baffles are single segmental.

The exchanger operates for 8000 h/yr.

Installation costs are 15% of purchased cost, and annual fixed charges including maintenance are 20% of the installed cost.

The energy cost is \$0.16/kWh.

No utility fluid is used so the annual cost of utility fluid may be ignored.

Design Constraints: The upper limit on the tube length is 20 m and the upper limit on the shell diameter is 6 m.

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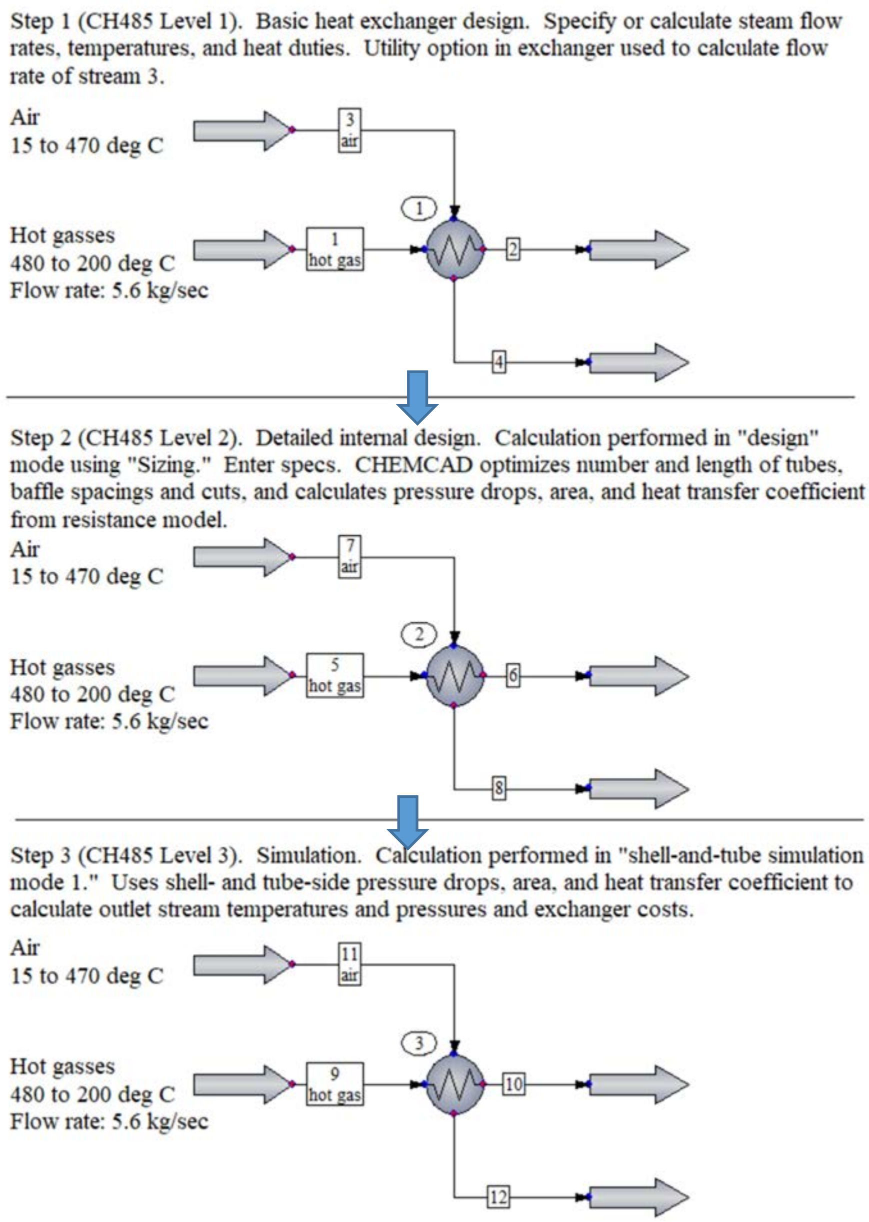
Problem: Weight:
A 80

Use CHEMCAD to perform a 3-step *design* analysis on the proposed heat exchanger and answer the following questions: (1) Determine the number and length of tubes, the inside diameter of the shell, and the required area of the exchanger. (2) Determine the largest resistance to heat transfer in the exchanger. (3) Determine the February 2024 total installed cost of the heat exchanger.

SOLUTION:

Blue arrows indicate the 1-2-3 heat exchanger design process.



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TABLATED ANALYSIS - DESIGN (LEVEL 2)

```
Overall Data:
 Area Total          m2       286.32  % Excess                      -4.60
 Area Required       m2       291.96  U Calc.    W/m2-K              94.35
 Area Effective      m2       278.53  U Service  W/m2-K              98.90
 Area Per Shell      m2       278.53  Heat Duty  J/sec            1.65E+06
 Weight LMTD C    59.98   LMTD CORR Factor  1.0000    CORR LMTD C    59.98

Shell-side Data:
 Crossflow Vel. m/sec  4.7E+00  EndZone Vel. 4.7E+00  Window Vel. 3.1E+00
 Film Coef.  W/m2-K           205.67  Reynolds No.                  32721
 Allow Press. Drop   kPa       34.47  Calc. Press. Drop       kPa     42.00
 Inlet Nozzle Size   m          0.15  Press. Drop/In Nozzle   kPa      3.06
 Outlet Nozzle Size  m          0.13  Press. Drop/Out Nozzle  kPa      3.06
                                      Mean Temperature        C      242.50
 Rho V2 IN  kg/m-sec2        2841.99  Press. Drop (Dirty)     kPa     71.40

Stream Analysis:
 SA Factors:    A 12.78     B 75.38     C  2.53     E  9.31     F  0.00
 Ideal Cross Vel.  m/sec      6.20  Ideal Window Vel. m/sec      3.94

Tube-side Data:
 Film Coef.  W/m2-K           240.38  Reynolds No.                  37203
 Allow Press. Drop   kPa       34.47  Calc. Press. Drop       kPa     15.38
 Inlet Nozzle Size   m          0.20  Press. Drop/In Nozzle   kPa      2.88
 Outlet Nozzle Size  m          0.15  Press. Drop/Out Nozzle  kPa      2.45
 Interm. Nozzle Size m          0.00  Mean Temperature        C      340.00
 Velocity            m/sec     10.16  Mean Metal Temperature  C      287.11

Clearance Data:
 Baffle to shell   m          0.0063  Bundle diameter     m          0.8202
 Tube hole clear.  m          0.0008  Outer tube clear.   m          0.0180
 Bundle top space  m          0.0000  In-line pass clear. m          0.0000
 Bundle btm space  m          0.0000  Pass clearance      m          0.0159

Baffle Parameters:
 Number of Baffles                                  38
 Baffle Type                          Single Segmental
 Baffle space def.                    Edge-Edge
 Inlet Space              m                      0.403
 Center Space             m                      0.267
 Outlet Space             m                      0.403
 Baffle Cut, % Diameter                          19.000
 Baffle Overlap           m                      0.000
 Baffle Cut Direction                       Horizontal
 Number of Int. Baffles                              0
 Baffle Thickness         m                      0.006

Shell:
 Shell O.D.        m             0.86    Orientation                     H
 Shell I.D.        m             0.84    Shell in Series                 1
 Bonnet I.D.       m             0.84    Shell in Parallel               1
 Type                            AEL    Max. Heat Flux Btu/ft2-hr     0.00
 Imping. Plate      Impingement Plate    Sealing Strip                   5

Tubes:
```

Number		327	Tube Type		Bare
Length	m	10.97	Free Int. Fl Area	m2	0.00
Tube O.D.	m	0.025	Fin Efficiency		0.000
Tube I.D.	m	0.019	Tube Pattern		SQUAR
Tube Wall Thk.	m	0.003	Tube Pitch	m	0.038
No. Tube Pass		1			
Inner Roughness	m	0.0000016			
Number of tubesheets		2	Tubesheet thickness, m		0.025

Resistances:

Shell-side Film	m2-K/W	0.00486
Shell-side Fouling	m2-K/W	0.00000
Tube Wall	m2-K/W	0.00020
Tube-side Fouling	m2-K/W	0.00000
Tube-side Film	m2-K/W	0.00416
Reference Factor (Total outside area/inside area based on tube ID)		1.330

Pressure Drop Distribution:

Tube Side			Shell Side		
Inlet Nozzle	kPa	2.8773	Inlet Nozzle	kPa	3.0568
Tube Entrance	kPa	0.1441	Impingement	kPa	1.8473
Tube	kPa	3.9437	Bundle	kPa	23.3859
Tube Exit	kPa	0.2386	Outlet Nozzle	kPa	3.0647
End	kPa	0.0000	Total Fric.	kPa	29.5074
Outlet Nozzle	kPa	2.4548	Total Grav.	kPa	-0.0638
Total Fric.	kPa	9.6585	Total Mome.	kPa	12.5575
Total Grav.	kPa	0.0593	Total	kPa	42.0010
Total Mome.	kPa	5.6606			
Total	kPa	15.3783			

The completed CHEMCAD flowsheet is shown on page 2 and the detailed tabulated results on pages 3-4, with answers to questions (1) and (2) are highlighted in yellow.

Number of tubes: 327 //ANS
Length of the tubes: 10.97 m //ANS
Inside diameter of the shell: 0.84 m //ANS
Required area of the exchanger: 291.96 m^2 //ANS
Largest resistance to heat transfer in the exchanger: 0.00486 m^2K/W Shell-side //ANS

The installed cost is determined by activating the "costing report" in the Cost Estimations tab in the Level 3 heat exchanger.

February 2024 total installed cost: $263,008 //ANS

Cadet: APPROVED SOLUTION

Problem: Weight:
B 60

Use equation 14-91 to determine the total annual operating costs for the shell-and-tube exchanger as designed in Problem A assuming utility costs are zero. Do not optimize.

SOLUTION:

Equation 14-91 is found in the PTW textbook on page 739, and the stream properties are shown in the stream box from CHEMCAD:

$$C_T = A_0 \cdot K_F \cdot C_{A_0} + \cancelto{0}{m_u \cdot H_y \cdot C_u} + A_0 \cdot E_i \cdot H_y \cdot C_i + A_0 \cdot E_0 \cdot H_y \cdot C_0$$

C_T Total annual costs, dollars/yr

A_0 Outside tube area, m^2
K_F Annual fixed charges factor (maintenance, etc) as a fraction of installed cost, dimensionless
C_{A_0} Installed cost of the heat exchanger per unit outside tube area, dollars/m^2

m_u Mass flow rate of utility fluid, kg/hr
H_y Hours of operation per year
C_u Cost of utility fluid, dollars/kg

E_i Power loss due to fluid flow inside heat exchanger tubes per unit outside tube area, $N \cdot m/s$ per m^2
C_i Cost of supplying 1 $N \cdot m$ to pump fluid through the inside of the tubes, dollars/$N \cdot m$

E_0 Power loss experienced on the shell side per unit outside tube area, $N \cdot m/s$ per m^2
C_0 Cost of supplying 1 $N \cdot m$ to pump fluid through the shell side, dollars/$N \cdot m$

Stream No.	9	10	11	12
Name	hot gas		air	
- - Overall - -				
Temp C	480.0000	200.9785	15.0000	468.5166
Pres kPa	1020.0000	1004.3643	1020.0000	977.6427
Mass flow kg/sec	5.6000	5.6000	3.4950	3.4950
Actual dens kg/m3	4.6984	7.3505	12.3721	4.5736

Tube-side pressure drop = 1020 – 1004.3643 = 15.6357 kPa = 15,635.7 Pa
Tube-side average density = (4.6984 + 7.3505)/2 = 6.02445 kg/m^3
Tube-side mass flow rate = 5.6000 kg/s

Shell-side pressure drop = 1020 – 977.6427 = 42.3573 kPa = 42,357.3 Pa
Shell-side average density = (12.3721 + 4.5736)/2 = 8.47285 kg/m^3
Shell-side mass flow rate = 3.4950 kg/s

$$A_0 = \pi \cdot D_O \cdot L \cdot N_P = \pi \cdot 0.0254\,\text{m} \cdot 10.97\,\text{m} \cdot 327 = 286.245\,\text{m}^2$$

$$C_{A_0} = \$263{,}008 / 286.245\,\text{m}^2 = \$918.821 / \text{m}^2$$

$$K_F = 0.2$$

$$C_u = 0$$

$$H_y = 8{,}000\,\text{hrs}$$

$$C_i = \$0.16 / \text{kWh}$$

$$E_i = \frac{15{,}635.7\,\frac{\text{N}}{\text{m}^2} \cdot 5.6000\,\frac{\text{kg}}{\text{s}} \cdot \frac{1\,\text{m}^3}{6.02445\,\text{kg}}}{286.245\,\text{m}^2} = 50.7750\,\frac{\text{W}}{\text{m}^2} = 0.0507750\,\frac{\text{kW}}{\text{m}^2}$$

$$E_0 = \frac{42{,}357.3\,\frac{\text{N}}{\text{m}^2} \cdot 3.4950\,\frac{\text{kg}}{\text{s}} \cdot \frac{1\,\text{m}^3}{8.47285\,\text{kg}}}{286.245\,\text{m}^2} = 61.0391\,\frac{\text{W}}{\text{m}^2} = 0.0610391\,\frac{\text{kW}}{\text{m}^2}$$

$$C_T = 286.245\,\text{m}^2 \cdot 0.2 \cdot \frac{\$918.821}{\text{m}^2}$$
$$+ 286.245\,\text{m}^2 \cdot 0.05077750\,\frac{\text{kW}}{\text{m}^2} \cdot 8{,}000\,\text{h} \cdot \frac{\$0.16}{\text{kWh}}$$
$$+ 286.245\,\text{m}^2 \cdot 0.0610391\,\frac{\text{kW}}{\text{m}^2} \cdot 8{,}000\,\text{h} \cdot \frac{\$0.16}{\text{kWh}}$$
$$= \underline{\underline{\$93{,}570}}\ \text{ans}$$

Cadet: APPROVED SOLUTION

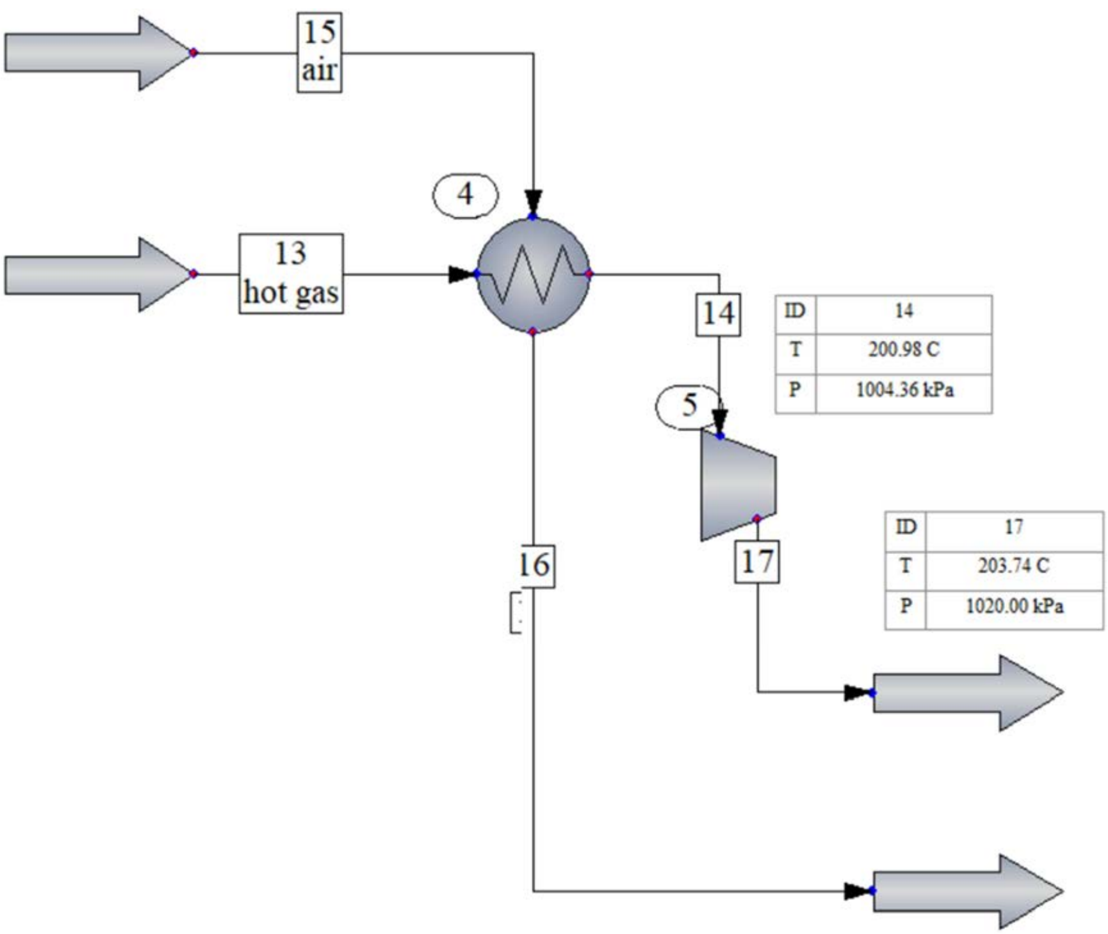
Problem: C   Weight: 60

(1) Determine the total purchased cost in February 2024 of a compressor designed to increase the tube-side hot gasses from the outlet pressure at the exchanger back to 1020 kPa. The compressor is centrifugal with an open drip-proof 1200 RPM motor and a variable speed drive coupling.

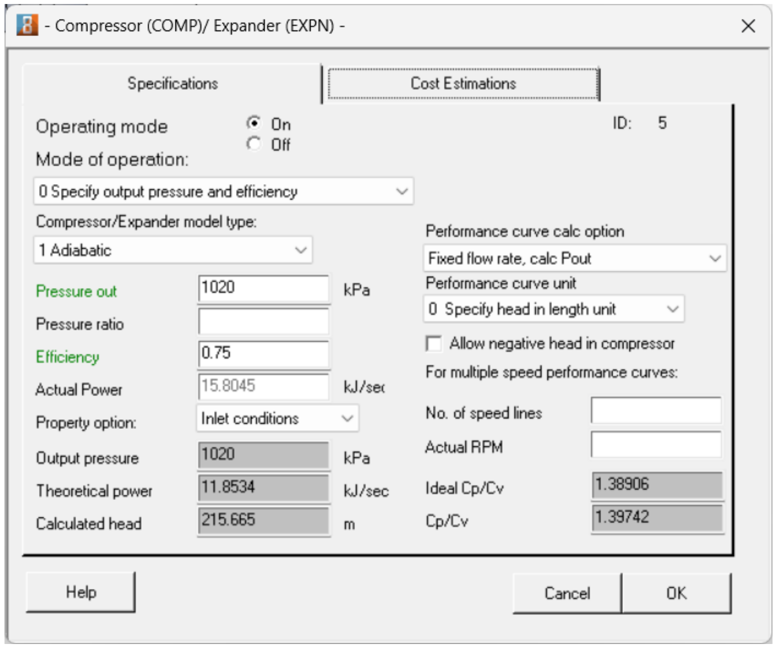
(2) If the air temperature must be within 0.5 degrees of 200 ºC at the outlet of the compressor, how does the addition of the compressor impact the design of the heat exchanger? (No simulation, explain only.)

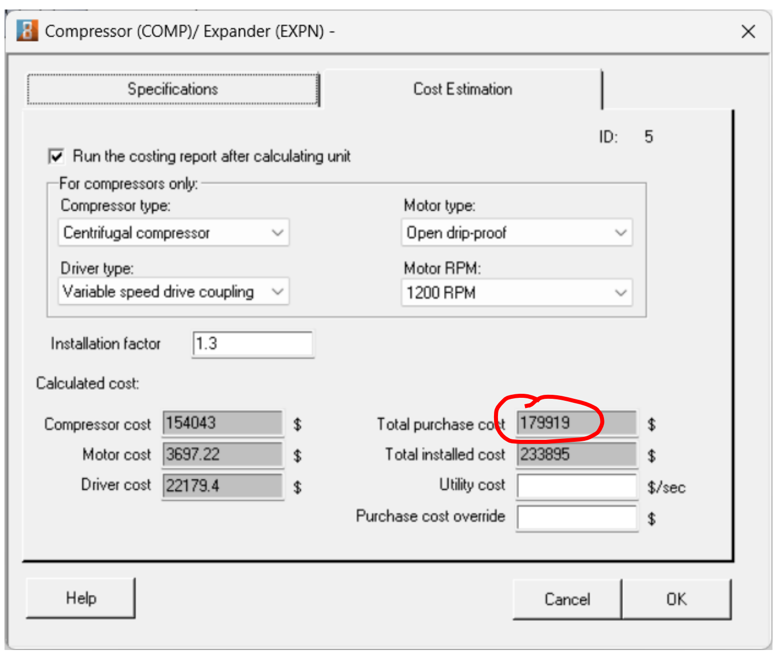
SOLUTION:

The CHEMCAD flowsheet is shown below with temperatures and pressures indicated in the TP boxes. The unit op cost specifications and cost estimation windows follow on the next page. The total purchase cost is $179,919 in February 2024.



Cadet: **APPROVED SOLUTION**





A screenshot of the pump cost estimation window is shown above. The purchased cost is obtained after cadets check the button "Run the costing report after calculating the unit." Cadets must also update the pump/compressor cost index to 1505.0 for February 2024.

(1) The purchased cost in February 2024 is $179,919 and is circled in red. **//ANS**

(2) The compressor heats the hot gas ~2 degrees, so more heat must be removed from the hot gas to compensate. Either the area of the heat exchanger or the flow rate in stream 15 could be increased. **//ANS**

APPROVED SOLUTION

CADET ____________________ SECTION ______TIME OF DEPARTURE ________

DEPARTMENT OF CHEMISTRY & LIFE SCIENCE

CH402, AY2023-2024
WRITTEN PARTIAL REVIEW I
55 Minutes, D-Hour
9 February 2024

TEXT: Peters, Timmerhaus & West
SCOPE: CHAPTERS: 12, 14

References Permitted: Open note and open book; Mathematica; Excel; CHEMCAD.

INSTRUCTIONS

1. You will have 55 minutes for the exam.
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3. Solve the problems in the space provided. Show all work to receive full credit.
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5. Write your name on the top of each sheet.
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7. Final CHEMCAD file must be saved in Canvas to receive partial credit.

(TOTAL WEIGHT: 200 POINTS)

DO NOT WRITE IN THIS SPACE

PROBLEM	VALUE	CUT
A	80	
B	60	
C	60	
TOTAL CUT		
GRADE	200	

Cadet: APPROVED SOLUTION

THE FOLLOWING INFORMATION IS REQUIRED FOR QUESTIONS A, B, & C

Air used in a catalytic oxidation process is to be heated from 15 to 270 °C before entering the process. The heating is accomplished with the use of product gases, which cool from 480 to 20 °C.

A one-pass shell-and-tube TEMA type AEL exchanger with single-segmental baffles has been proposed. The tubes are type 316 stainless-steel, with type A-240-316 stainless steel used for the tube sheet, shell, channel material, and baffles.

The properties of the hot gases can be considered identical to those of air.

Both streams enter the exchanger at 1020 kPa.

The hot gasses are sent through the tubes at a flow rate of 5.6 kg/s.

The air is sent through the shell.

The shell-side and tube-side fouling factors are zero.

The inside and outside diameters for the tubes are 0.0191 and 0.0254 m, respectively. The tubes will be arranged in line with a square pitch of 0.0381 m with fixed tube sheets. The tubesheet thickness is equal to the outside diameter of the tubes.

Baffles are single segmental.

The exchanger operates for 8000 h/yr.

Installation costs are 15% of purchased cost, and annual fixed charges including maintenance are 20% of the installed cost.

The energy cost is $0.16/kWh.

No utility fluid is used so the annual cost of utility fluid may be ignored.

Design Constraints: The upper limit on the tube length is 20 m and the upper limit on the shell diameter is 6 m.

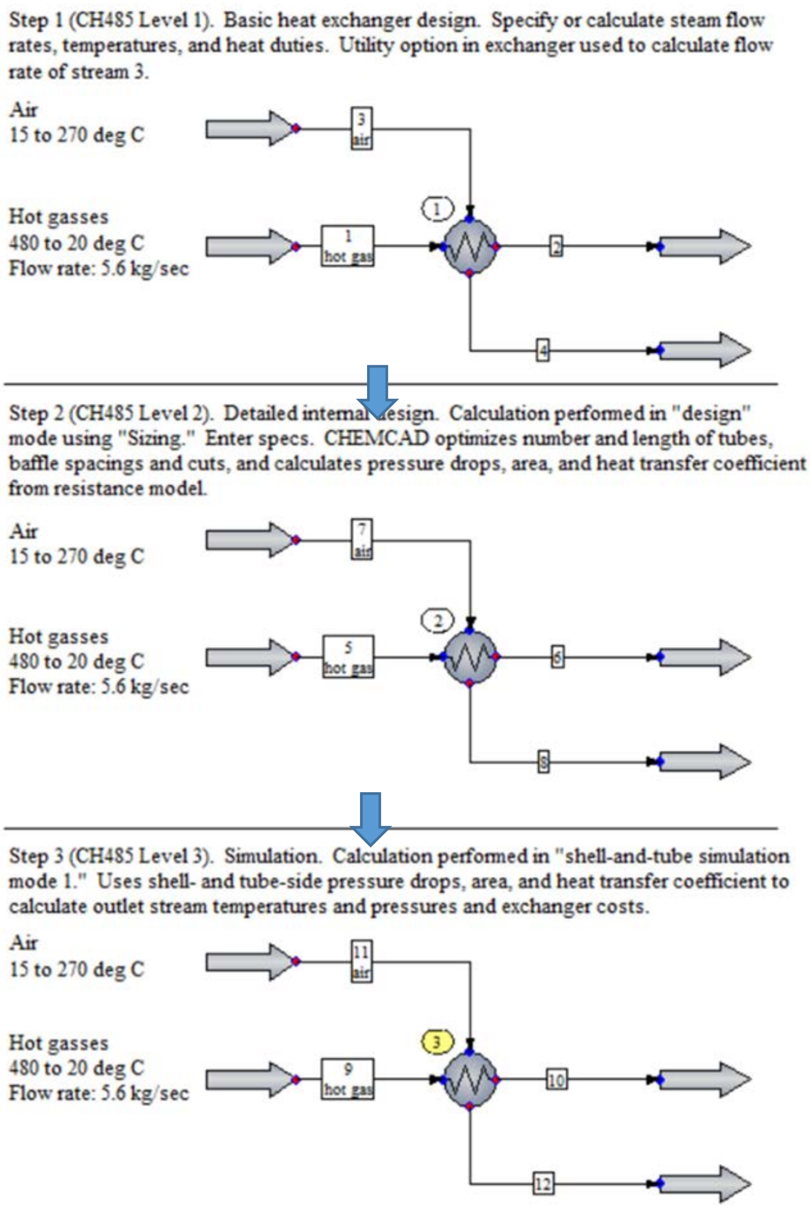
Cadet: **APPROVED SOLUTION**

Problem:	Weight:
A	80

Use CHEMCAD to perform a 3-step *design* analysis on the proposed heat exchanger and answer the following questions: (1) Determine the number and length of tubes, the inside diameter of the shell, and the required area of the exchanger. (2) Determine the largest resistance to heat transfer in the exchanger. (3) Determine the February 2024 total installed cost of the heat exchanger.

SOLUTION:

Blue arrows indicate the 1-2-3 heat exchanger design process.



Cadet: APPROVED SOLUTION

TABULATED ANALYSIS - DESIGN (LEVEL 2)

```
Overall Data:
 Area Total          m2       663.50  % Excess                      1.41
 Area Required       m2       643.73  U Calc.    W/m2-K            75.89
 Area Effective      m2       652.82  U Service  W/m2-K            74.83
 Area Per Shell      m2       652.82  Heat Duty  J/sec           2.68E+06
 Weight LMTD C    54.85   LMTD CORR Factor  1.0000   CORR LMTD C   54.85

Shell-side Data:
 Crossflow Vel. m/sec  5.2E+00  EndZone Vel. 3.5E+00  Window Vel. 3.8E+00
 Film Coef.  W/m2-K          228.11  Reynolds No.                   50223
 Allow Press. Drop   kPa      34.47  Calc. Press. Drop       kPa    42.22
 Inlet Nozzle Size   m         0.25  Press. Drop/In Nozzle   kPa     3.61
 Outlet Nozzle Size  m         0.20  Press. Drop/Out Nozzle  kPa     3.14
                                     Mean Temperature        C     142.50
 Rho V2 IN  kg/m-sec2       3297.71  Press. Drop (Dirty)     kPa    71.77

Stream Analysis:
 SA Factors:    A 10.77     B 81.71     C  1.97     E  5.55     F  0.00
 Ideal Cross Vel.  m/sec      6.39  Ideal Window Vel. m/sec      4.57

Tube-side Data:
 Film Coef.  W/m2-K          155.23  Reynolds No.                   22002
 Allow Press. Drop   kPa      34.47  Calc. Press. Drop       kPa    16.70
 Inlet Nozzle Size   m         0.20  Press. Drop/In Nozzle   kPa     3.04
 Outlet Nozzle Size  m         0.13  Press. Drop/Out Nozzle  kPa     3.21
 Interm. Nozzle Size m         0.00  Mean Temperature        C     250.00
 Velocity            m/sec     4.29  Mean Metal Temperature  C     177.95

Clearance Data:
 Baffle to shell   m         0.0063  Bundle diameter     m         1.1250
 Tube hole clear.  m         0.0008  Outer tube clear.   m         0.0180
 Bundle top space  m         0.0000  In-line pass clear. m         0.0000
 Bundle btm space  m         0.0000  Pass clearance      m         0.0159

Baffle Parameters:
 Number of Baffles                               26
 Baffle Type                        Single Segmental
 Baffle space def.                  Edge-Edge
 Inlet Space               m                  0.710
 Center Space              m                  0.471
 Outlet Space              m                  0.710
 Baffle Cut, % Diameter                       27.000
 Baffle Overlap            m                  0.000
 Baffle Cut Direction                    Horizontal
 Number of Int. Baffles                           0
 Baffle Thickness          m                  0.006

Shell:
 Shell O.D.        m              1.17    Orientation                     H
 Shell I.D.        m              1.14    Shell in Series                 1
 Bonnet I.D.       m              1.14    Shell in Parallel               1
 Type                             AEL   Max. Heat Flux Btu/ft2-hr      0.00
 Imping. Plate     Impingement Plate    Sealing Strip                   5

Tubes:
```

Number		620	Tube Type		Bare
Length	m	13.41	Free Int. Fl Area	m2	0.00
Tube O.D.	m	0.025	Fin Efficiency		0.000
Tube I.D.	m	0.019	Tube Pattern		SQUAR
Tube Wall Thk.	m	0.003	Tube Pitch	m	0.038
No. Tube Pass		1			
Inner Roughness	m	0.0000016			
Number of tubesheets		2	Tubesheet thickness, m		0.025

Resistances:

Shell-side Film	m2-K/W	0.00438
Shell-side Fouling	m2-K/W	0.00000
Tube Wall	m2-K/W	0.00023
Tube-side Fouling	m2-K/W	0.00000
Tube-side Film	m2-K/W	0.00644
Reference Factor (Total outside area/inside area based on tube ID)		1.330

Pressure Drop Distribution:

Tube Side			Shell Side		
Inlet Nozzle	kPa	3.0427	Inlet Nozzle	kPa	3.6082
Tube Entrance	kPa	0.0433	Impingement	kPa	2.1435
Tube	kPa	1.2097	Bundle	kPa	23.3191
Tube Exit	kPa	0.0409	Outlet Nozzle	kPa	3.1424
End	kPa	0.0000	Total Fric.	kPa	30.0696
Outlet Nozzle	kPa	3.2101	Total Grav.	kPa	-0.1168
Total Fric.	kPa	7.5467	Total Mome.	kPa	12.2643
Total Grav.	kPa	0.0773	Total	kPa	42.2171
Total Mome.	kPa	9.0803			
Total	kPa	16.7044			

The completed CHEMCAD flowsheet is shown on page 2 and the detailed tabulated results on pages 3-4, with answers to questions (1) and (2) are highlighted in yellow.

Number of tubes: 620 //ANS
Length of the tubes: 13.41 m //ANS
Inside diameter of the shell: 1.14 m //ANS
Required area of the exchanger: 643.73 m^2 //ANS
Largest resistance to heat transfer in the exchanger: 0.00644 m^2K/W Tube-side //ANS

The installed cost is determined by activating the “costing report” in the Cost Estimations tab in the Level 3 heat exchanger.

February 2024 total installed cost: $645,337 //ANS

Cadet: APPROVED SOLUTION

Problem: B

Weight: 60

Use equation 14-91 to determine the total annual operating costs for the shell-and-tube exchanger as designed in Problem A assuming utility costs are zero. Do not optimize.

SOLUTION:

Equation 14-91 is found in the PTW textbook on page 739, and the stream properties are shown in the stream box from CHEMCAD:

$$C_T = A_0 \cdot K_F \cdot C_{A_0} + \overset{0}{\cancel{m_u \cdot H_y \cdot C_u}} + A_0 \cdot E_i \cdot H_y \cdot C_i + A_0 \cdot E_0 \cdot H_y \cdot C_0$$

C_T Total annual costs, dollars/yr

A_0 Outside tube area, m^2

K_F Annual fixed charges factor (maintenance, etc) as a fraction of installed cost, dimensionless

C_{A_0} Installed cost of the heat exchanger per unit outside tube area, dollars/m^2

m_u Mass flow rate of utility fluid, kg/hr

H_y Hours of operation per year

C_u Cost of utility fluid, dollars/kg

E_i Power loss due to fluid flow inside heat exchanger tubes per unit outside tube area, $N \cdot m/s$ per m^2

C_i Cost of supplying 1 $N \cdot m$ to pump fluid through the inside of the tubes, dollars/$N \cdot m$

E_0 Power loss experienced on the shell side per unit outside tube area, $N \cdot m/s$ per m^2

C_0 Cost of supplying 1 $N \cdot m$ to pump fluid through the shell side, dollars/$N \cdot m$

Stream No.	9	10	11	12
Name	hot gas		air	
- - Overall - -				
Temp C	480.0000	19.7409	15.0000	270.1087
Pres kPa	1020.0000	1002.9738	1020.0000	976.5488
Mass flow kg/sec	5.6000	5.6000	10.2759	10.2759
Actual dens kg/m3	4.6984	11.9621	12.3721	6.2360

Tube-side pressure drop = 1020 – 1002.9738 = 17.0262 kPa = 17,026.2 Pa
Tube-side average density = (4.6984 + 11.9621)/2 = 8.33025 kg/m^3
Tube-side mass flow rate = 5.6000 kg/s

Shell-side pressure drop = 1020 – 976.5488 = 43.4512 kPa = 43,451.2 Pa
Shell-side average density = (12.3721 + 6.2360)/2 = 9.30405 kg/m^3
Tube-side mass flow rate = 10.2759 kg/s

$$A_0 = \pi \cdot D_O \cdot L \cdot N_P = \pi \cdot 0.0254\,m \cdot 13.41\,m \cdot 620 = 663.444\,m^2$$

$$C_{A_0} = \$645,337 / 663.444\,m^2 = \$972.708 / m^2$$

$$K_F = 0.2$$

$$C_u = 0$$

$$H_y = 8,000\,hrs$$

$$C_i = \$0.16 / kWh$$

$$E_i = \frac{17,026.2\frac{N}{m^2} \cdot 5.6000\frac{kg}{s} \cdot \frac{1m^3}{8.33025\,kg}}{663.444\,m^2} = 17.2522\,\frac{W}{m^2} = 0.0172522\,\frac{kW}{m^2}$$

$$E_0 = \frac{43,451.2\frac{N}{m^2} \cdot 10.2759\frac{kg}{s} \cdot \frac{1m^3}{9.30405\,kg}}{663.444\,m^2} = 72.3345\,\frac{W}{m^2} = 0.0723345\,\frac{kW}{m^2}$$

$$\begin{aligned} C_T = {} & 663.444\,m^2 \cdot 0.2 \cdot \frac{\$972.708}{m^2} \\ & + 663.444\,m^2 \cdot 0.0172522\frac{kW}{m^2} \cdot 8,000\,h \cdot \frac{\$0.16}{kWh} \\ & + 663.444\,m^2 \cdot 0.0723345\frac{kW}{m^2} \cdot 8,000\,h \cdot \frac{\$0.16}{kWh} \end{aligned}$$

$$= \underline{\underline{\$205,145}}$$

ans

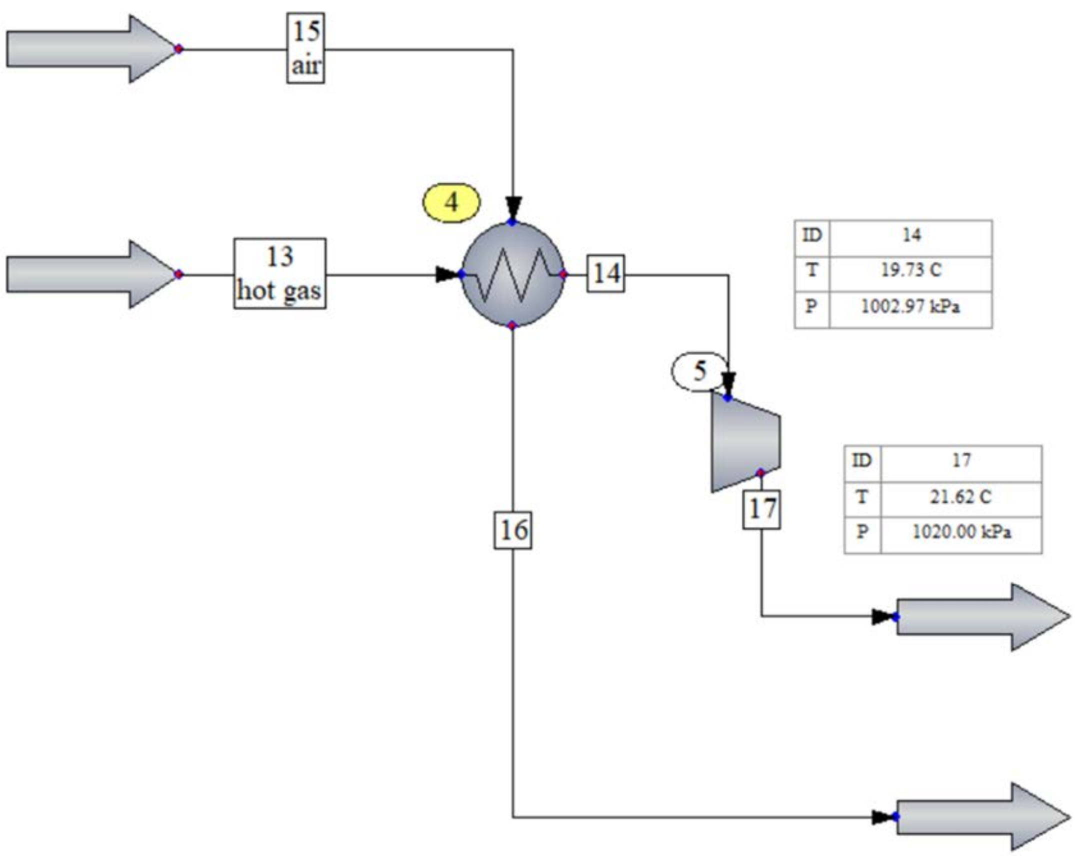
<u>Problem:</u> <u>Weight:</u>
C 60

(1) Determine the total purchased cost of a compressor designed to increase the tube-side hot gasses from the outlet pressure at the exchanger back to 1020 kPa. The compressor is centrifugal with an explosion-proof 1800 RPM motor and a chain-drive coupling. Determine the cost must be in February 2024.

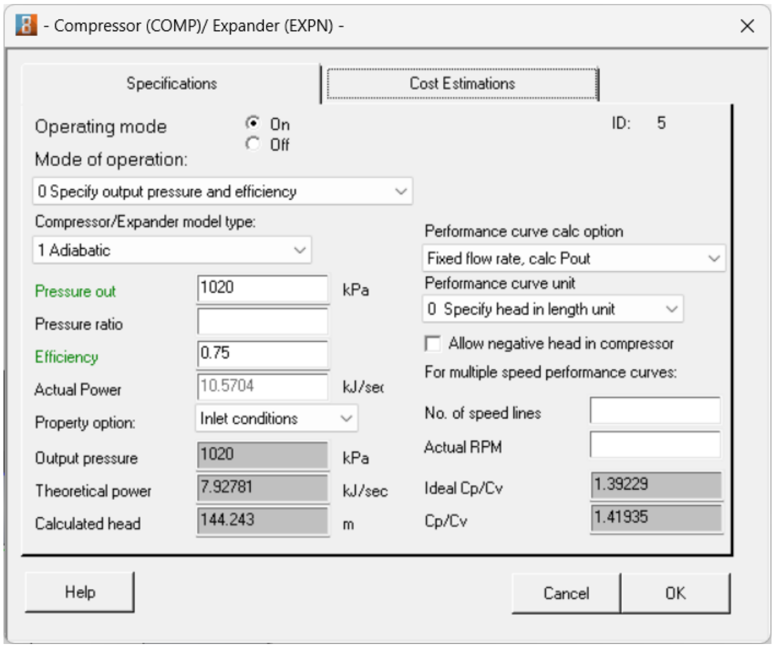
(2) If the air temperature must be within 0.5 degrees of 20 ºC at the outlet of the compressor, how does the addition of the compressor impact the design of the heat exchanger? (No simulation, explain only.)

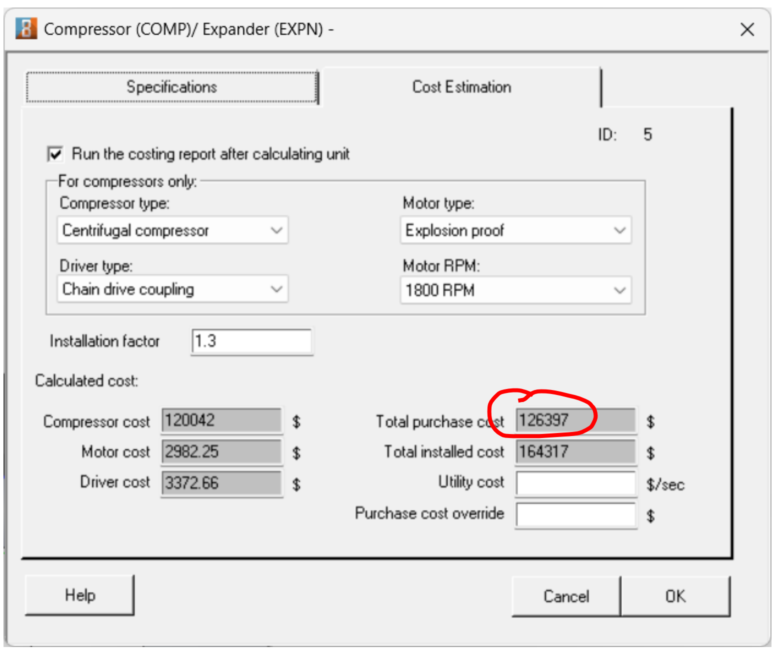
SOLUTION:

The CHEMCAD flowsheet is shown below with temperatures and pressures indicated in the TP boxes. The unit op cost specifications and cost estimation windows follow on the next page. The total purchase cost is $126,397 in February 2024.



Cadet: APPROVED SOLUTION





A screenshot of the pump cost estimation window is shown above. The purchased cost is obtained <u>after</u> cadets check the button "Run the costing report after calculating the unit." Cadets must also update the pump/compressor cost index to 1505.0 for February 2024.

(1) The purchased cost in February 2024 is $126,397 and is circled in red. **//ANS**

(2) The compressor heats the hot gas ~2 degrees, so more heat must be removed from the hot gas to compensate. Either the area of the heat exchanger or the flow rate in stream 15 could be increased. **//ANS**