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B. JOSEPH **CHE 477** **FALL 1996**

TEST #2

Time: 55 minutes
Open: Text
1 - 2 points bonus for neatness, clarity, and organization.

PROBLEM 1 (10 points)

A heat exchanger is to be constructed by forming copper tubing into a coil and placing it inside an insulated steel shell. If the following data apply, what should be the length of the coil?

a) Water will flow inside the tubing, and a hydrocarbon vapor will condense on the outside of the tubing.
b) ID of tubing = 0.5 in.
c) OD of tubing = 0.6 in.
d) Condensate rate = 1000 lb/h.
e) Temperature of condensation = 190°F.
f) Heat of vaporization of hydrocarbon at 190°F = 144 Btu/lb.
g) Overall heat-transfer coefficient for condensing vapor = 250 Btu/(h) (ft^2) (°F) (based on inside area).
h) Inlet water temperature = 50°F.
i) Outlet water temperature = 90°F.
j) Heat losses from the shell may be neglected.

PROBLEM 2 (10 points)

The sales income from a project is $1.1 million/year. The operating expenses (excluding depreciation) is $0.82 million/yr. The total capital investment in the project is $1.5 million out of which 20% is for working capital and 80% is for fixed capital investment. Part of the fixed capital is land costing $0.1 million. The estimated life of the plant is 10 years at which time the plant is estimated to have a salvage value of $0.2 million. The income tax rate is 40%. Compute the cash flow in $/year resulting from the plant operation. Assume straight-line depreciation.

PROBLEM 3 (10 points)

You win the Missouri Lotto Jackpot worth 20 million. You are given two choices

a) $20 million paid in 20 installments of $1 million each year. The first payment is immediate and then on the anniversary date for every year thereafter.

b) $6 million in cash right now as one lump sum payment.

Assume income tax rate is 37%. Your investments can be expected to give a return of 10% per year after taxes (effective annual interest rate on your savings).

Which option would you select if you want to maximize your present worth. Neglect inflation.

PROBLEM 4 (10 points)

(Based on Aspen project work)

It is desired to design a separation column using DSTWU model with the following stream as feed.

Flow of cyclohexanol, A	10 lbmoles/hr
Flow of cyclohexanone, B	10 lbmoles/hr
Flow of High Boiler, C	0.01 lbmoles/hr

We would like to separate a product consisting of 95 mole% B and 5% A. The recycle stream is 99% mole% A, the remainder being C and A. You may assume that 1% of B entering the feed leaves with the recycle stream. Aspen DSTWU block requires the following specifications: Answer these questions.

a) What is the light key component?
b) What is the heavy key component?
c) What is recovery of light key component in distillate?
d) What is recovery of heavy key in distillate?
e) Either actual reflux ratio or the reflux ratio as multiple of the minimum reflux ratio. Which one will you enter. What is a recommended value? Why?

f) After completing this run, the student includes a small amount of H_2 dissolved in the feed and Aspen fails to complete normally, reporting a problem with DSTWU calculations. Why would adding a trace amount of H_2 cause a problem? Will this change your column design significantly? How?

Solution To Test 2

Problem 1

1. Conductivity of copper is high. Neglect wall resistance to heat transfer

$$q = UA(\Delta T)_{lm}$$

$$\Delta T_1 = 190 - 50 = 140°F$$

$$\Delta T_2 = 190 - 90 = 100°F$$

$$(\overline{\Delta T})_{lm} = 1 \Big/ \frac{\ln(\Delta T_1/\Delta T_2)}{(\Delta T)_1 - (\Delta T)_2} = 118.8°$$

$$q = (m c_p \Delta T)_w = (\lambda \cdot m)_{vapor} = 144 \frac{Btu}{lb} \times 1000 \frac{lb}{hr} = 144000 \frac{Btu}{hr}$$

$$= UA\Delta T$$

$$A = (\pi D)L = \frac{\pi (0.5)}{12} ft \times L$$

$$\therefore L = \frac{144{,}000\ Btu/hr\ ft}{250 \frac{Btu}{hr\ ft^2\ °F} \times 118.8°F \times \frac{\pi(.5)}{12} ft^2} = 37.\ ft$$

Problem 2

Sales Income = ~~$11~~ \$1100 k/yr
Op. Exp = \$820 k/yr
TCI = ~~$15~~ \$1500 k
FCI = \$1200 k
WCI = 300 k
land = 100 k
n = 10 years
Salv = \$200k
tax = 0.40

depreciation = (FCI − land − Salvage Value)/n

$$= \frac{\$1200 - \$100k - \$200k}{10\ \text{yrs}}$$

= \$90 k/yr

Gross profit = ~~$820 k~~ \$1100 k − \$820k
GP = \$280 k

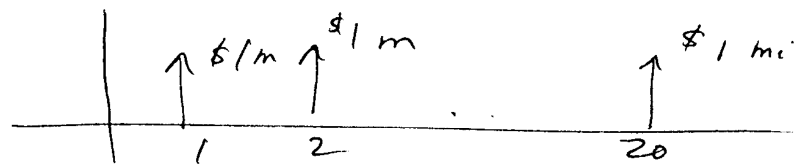
Net Profit = GP − deprec.
= \$280 k − \$90k = \$190k /yr

Tax = NP × tax = \$190 × .40 = \$76.00/yr
Net Profit After Tax = \$114 k/yr

Net Cash Flow = \$114k + \$dep
= \$114k + \$90k
= **\$204 k/yr**

Problem 3

(a) 2 choices



20 payments of \$1 million each

If you collect \$ ~~15~~ 6 million now, after tax you will have

$= \sout{15}\ 6\,(1 - .37) = \$\ \sout{9.45}\ 3.78$ million

~~The present worth of~~

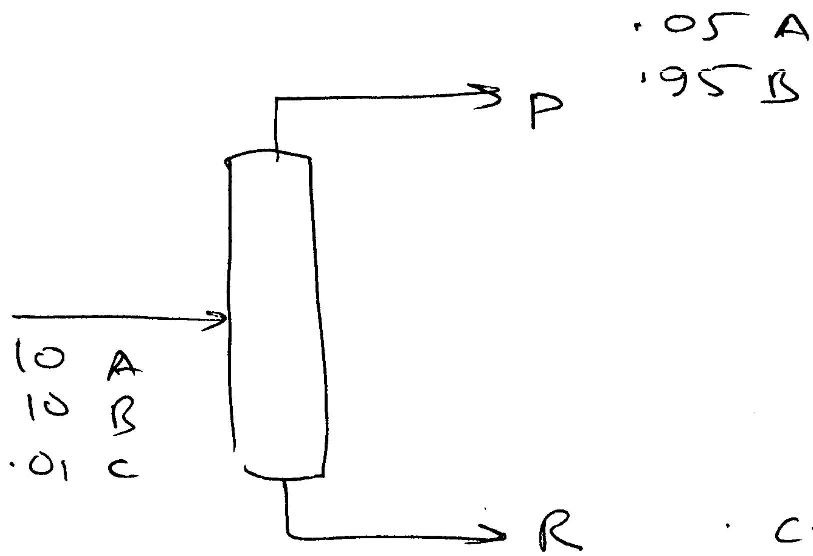
If you took the annuity option, you will get $= \$1 \text{ mil} \times (1 - .37) = .63 \text{ mil/yr}$

$$PW \text{ of annuity} = R \, \frac{(1+i)^n - 1}{(1+i)^n i}$$

$$= .63 \times \frac{(1+.1)^{20} - 1}{(1.1)^{20} (0.1)}$$

$$= \$3.30 \text{ million}$$

Take the 6 million.



C = .01
B = .1
A = ? x

we have

<u>Total</u>

$$10 + 10 + .01 = P + .01 + .1 + x$$

$$20.01 = P + x + .11$$

$$P + x = 19.9$$

<u>B.alance on B</u>

$$10 = .95P + .1$$

$$P = 10.42$$

$$x = 9.48$$

<u>Check</u> Balance on A

$$10 = 10.42 \times .05 + x$$

$$= 10.001 \quad \underline{ok}$$

(a) Light key is ~~A~~ B
(b) Heavy key is A
(c) Recovery of HK in Dist $= \frac{.05 \times P}{10} = \underline{\underline{.0521}}$
(d) " LK " Dist $\frac{.95 \times P}{10} = .9899$
(e) ~~Act~~ Use 1.2 times min Reflux Ratio

f) Because H_2 cannot be condensed easily at the top. DSTWU assumes distillate is all liquid. With H_2 you need to specify a vapor distillate product as well.

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TEST 2

- Open Text, Bound volume of Lecture Notes
- Time = 1 hour
- 3% for neatness and clarity of presentation

PROBLEM 1 (35 points)

The following questions are based on the cyclohexanol process we worked on, on Friday workshop session. See attached flowsheet and stream summary.

a) The stream summary shows that the waste stream contains about 19 mole% cyclohexanol. While it is a small amount, its annual value is in thousands of dollars. Suggest ways to reduce this loss by changing the current design and/or the processing conditions. Explain your answer. You should consider costs involved in suggesting the solution.

b) An economic potential sensitivity was done on the reactor alone in an earlier workshop. It was found that the economic potential decreased monotonically as the reactor operating temperature was increased. It would seem to suggest that the EP is maximized by operating the reactor at as a low temperature as possible. Is this a right conclusion? Explain.

c) In the design of the A/B separator, we found that the relative volatility improves at lower pressures. A pressure of 3 psia was used in the design. Under vacuum distillation, air is likely to leak into the system. How can this air be removed?

d) In sizing/costing the process, the block F1 was not sized or costed. Why not? Explain.

e) In the design of the A/B separator, the product is withdrawn as a vapor. Is it possible to design this column so that the product is withdrawn as a liquid distillate? Why or why not? Explain. (Hint: look at the feed composition)

PROBLEM 2 (40 points)

Air is to be compressed from 1 atm and 80°F for delivery at 9 atm and 100°F. The flow rate is 80 lbmoles/hr.

a) Would you use a single stage or multistage compressor?

b) Estimate the installed cost in 1995 ($) for the compressor.

c) Estimate operating costs (1995 cost) in $/year (Assume 8000 hrs/year of operation).

Data: $C_p/C_v = 1.40$

Assume air is ideal gas at 1 atm.

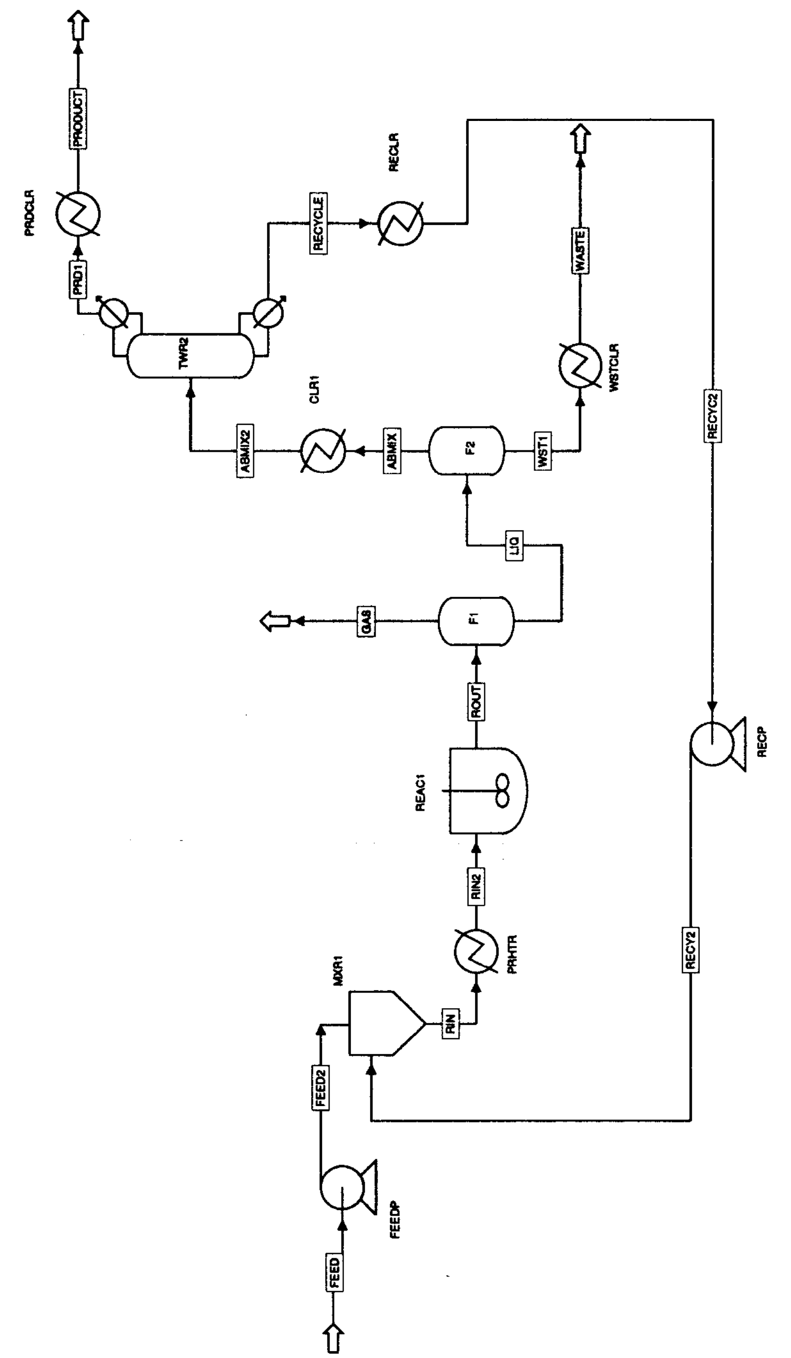
$$PV = n\,RT \quad R = .7302\ atm\ ft^3/lbmol\,^{\circ}R$$

CE Cost index = 382 in 1995.
Cost of utilities are given in P&T
Cost of compressors are also in P&T.

50

PROBLEM 3 (22 points)

A spherical carbon-steel storage tank has an inside diameter of 30 ft. All joints are double butt-welded (spot-examined). If the tank is used at a working pressure of 30 psig and a temperature of 80°F, estimate the necessary wall thickness. No corrosion allowance is necessary.



FEED
FEEDP
FEED2
MXR1
RIN
PRHTR
RIN2
REAC1
ROUT
F1
GAS
LIQ
F2
ABMIX
CLR1
ABMIX2
TWR2
PRD1
PRDCLR
PRODUCT
RECYCLE
RECLR
WST1
WSTCLR
WASTE
RECYC2
RECP
RECY2

DP41 Reactor design																
Stream ID		ABMIX	FEED	FEED2	GAS	LIQ	PRD1	PRODUCT	RECY2	RECYC2	RECYCLE	RIN	RIN2	ROUT	WASTE	WST1
Temperature	F	410.0	70.0	73.9	200.0	200.0	217.8	120.0	154.0	150.0	239.2	121.6	200.0	200.0	120.0	410.0
Pressure	PSI	14.7	14.7	324.7	300.0	300.0	3.0	20.0	340.0	20.0	3.0	324.7	324.7	300.0	20.0	14.7
Vapor Frac		1.000	0.000	0.000	1.000	0.000	1.000	< 0.001	0.000	0.000	0.000	0.000	0.000	0.279	0.000	0.000
Mole Flow	LBMOL/HR	29.880	12.483	12.483	11.585	29.909	12.025	12.025	17.655	17.655	17.655	30.138	30.138	41.493	0.229	0.229
Mass Flow	LB/HR	2951.400	1250.000	1250.000	29.733	2990.297	1181.374	1181.374	1770.030	1770.030	1770.030	3020.030	3020.030	3020.030	38.897	38.897
Volume Flow	CUFT/HR	18475.752	18.795	18.834	276.294	50.287	28905.682	20.191	27.926	27.862	29.444	46.745	48.967	326.581	0.383	0.441
Enthalpy	MMBTU/HR	-2.972	-1.670	-1.866	0.003	-3.908	-1.134	-1.401	-2.546	-2.552	-2.448	-4.412	-4.263	-3.905	-0.053	-0.048
Mole Flow	LBMOL/HR															
A		17.858	12.355	12.355	0.028	17.700	0.601	0.601	17.055	17.055	17.055	29.410	29.410	17.727	0.044	0.044
B		11.996	0.127	0.127	0.038	12.017	11.423	11.423	0.572	0.572	0.572	0.699	0.699	12.055	0.022	0.022
C		0.029			trace	0.192	trace	trace	0.029	0.029	0.029	0.029	0.029	0.192	0.163	0.163
H2		< 0.001			11.519	< 0.001	< 0.001	< 0.001	trace	trace	trace	trace	trace	11.519		
Mole Frac																
A		0.595	0.990	0.990	0.002	0.592	0.050	0.050	0.966	0.966	0.966	0.976	0.976	0.427	0.192	0.192
B		0.404	0.010	0.010	0.003	0.402	0.950	0.950	0.032	0.032	0.032	0.023	0.023	0.291	0.094	0.094
C		976 PPM			trace	0.006	trace	trace	0.002	0.002	0.002	962 PPM	962 PPM	0.005	0.713	0.713
H2		1 PPM			0.994	1 PPM	3 PPM	3 PPM	trace	trace	trace	trace	trace	0.278		

Test 2 Solution

Problem 1

(a) One possible way is to send the waste stream to another distillation column where ~~A & B~~ A & B are removed at the top and nearly pure ~~B~~ C is removed at the bottom.

Another alternative is to replace the existing flash with a stripper column.

(b) No, the conclusion is wrong. At low temp conversion is low. Hence recycle costs will increase (a fact not taken into account in ~~at~~ the EP calculation).

At optimum temperature the recycle costs will be balanced by the ~~cost~~ reduction in loss of A as waste product.

(c) Air will not condense at the top of the distillation column. Hence it can be removed as uncondensed vapor in the distillate product using a vaccuum pump.

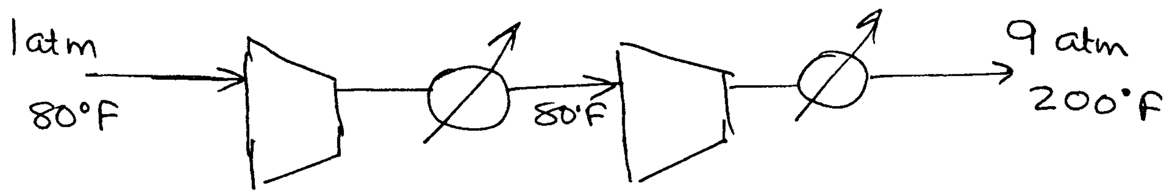
(d) Block F-1 was used because RCSTR will not allow ~~a u~~ two product streams. In actual implementation, the H_2 will be withdrawn directly from the reactor as a gas stream.

(e) Not completely. The feed contains ~~a~~ hydrogen which will not condense. If only a liquid distilate is provided at the top, ~~as well~~ aspen will try to condense the hydrogen also and this will require extraordinarily low temperature in the condenser. This will not be acceptable due to the high cost.

Use a partial condenser to condense and remove product as liquid.

Problem 2

Since delivery pressure/intake pressure is 9:1, use a multistage (two-stage) compressor, with interstage cooling



$$\text{Power} = 3.03 \times 10^{-5}\, k N_s P_1 q_{fm1} \left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k N_s}} - 1 \right]$$

k = ratio = C_p/C_v = 1.40 for air

$N_s = 2$

P_1 = intake press $\frac{lbf}{ft^2}$ = $14.7 \frac{lbf}{in^2} \times 144 \frac{in^2}{ft^2}$

$$\frac{P_2}{P_1} = \left(\frac{9}{1}\right)$$

q_{fm1} = $\frac{\text{cubic ft at intake conditions}}{\text{min}}$

Assume ideal gas at 1atm.

$$PV = nRT$$

$$V = \frac{nRT}{P} = 80 \frac{\text{lbmoles}}{hr} \times \frac{1\ hr}{60\ min} \times \frac{.7302\ atm \cdot ft^3}{1\ lbmol \cdot R} \times \frac{(459+80)\ °R}{1\ atm}$$

q_{fm1} = 524.7 ft^3/min

$$\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{kN_s}} - 1 = \left[9^{\frac{1.40-1}{(1.40)2}} - 1\right]$$

$$= ~~2.50~~ \; 1.368$$

$$\therefore hp = 3.03\times10^{-5} \times 1.40 \times 2 \times 14.7 \times 144 \times 524.7 \times 1.368$$

$$= \underline{\underline{127.53 \; (~~99.23~~) \; hp}}$$

$$T_2 = T_1\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{kN_s}} = 540 \; (~~80~~) \left(\frac{9}{1}\right)^{\frac{1.4-1}{1.4\times2}}$$

~~= 109.5~~

$$T_2 = \underline{\underline{279.1\,°F}}$$

• Compresser Efficiency ≃ 80 %

$$\text{Brake } hp = \frac{127.53}{.80} = 159.4 \; hp$$

~~Co~~ Purchased Cost (Fig 14-48, p. 530 (~~529~~))

= ~~$9.5 x 10^4~~ $60,000

~~= $95,000.~~ 1990 cost

Installation Charge 30-60 % for compressors

Table 6, p. 171, text.

Use 45%

∴ Installed Cost = ~~$137,750~~ 1990

= [illegible]

c. operating costs

Electricity needed

$= 159.4 \text{ hp} \times \frac{\cancel{30}\ 2.93 \times 10^{-4} \text{ kWhr}}{3.93 \times 10^{-4} \text{ hp-hr}}$

$= 118.7$ kw-hr/hr

Cost = 7 ¢/kwhr   Table 23, p. 200

Cost of Electricity

$= 118.7 \frac{\text{kWhr}}{\text{hr}} \times \frac{\$ .07}{\text{kWhr}}$

= $8.31 /hr   1989 costs

@ 8000 hr/yr   = $66,508. /year

Cooling water needed

1st stage. To cool gas from ~~109.5~~ 279 to 80°F

$q \approx m C_p \Delta T$

$= 80 \frac{\text{lbmoles}}{\text{hr}} \times .25 \frac{\text{Btu}}{\text{lb} \cdot \text{F}} \times \frac{28.8 \text{ lb}}{\text{lbmo}}$

$\times (\cancel{109}\,279.5 - 80)$

$= 16{,}992 \frac{\text{Btu}}{\text{hr}}$

Cooling water needed assume (@ inlet = 70°F, outlet = 120°F
$C_p \approx 1$ Btu/lb·F)

Water needed $= \frac{16{,}992 \text{ Btu lb}}{50 \text{ hr} \times}$

$= 339.8$ lb/hr

Water needed in stage 2 to cool from 109.5 to 100°F

$$= 339.8 \times \frac{(109.5-100)}{(109.5-80)}$$

$$= 109.4 \text{ lb/hr}$$

Total $= 339.8 + 109.4$
$= 449.2$ lb/hr

Cost of Cooling water = 10 ¢/~~gal~~ 1000 gal

~~cost = 449.2 lb/hr × 62.5 lb/ft³ × 7.48 gal/ft³ × ft³/7.48 gal × 1~~

$$\text{Cost} = 449.2 \frac{lb}{hr} \times \frac{1\ ft^3}{62.5\ lb} \times \frac{7.48\ gal}{ft^3} \times \frac{\$.10}{1000\ gal} \times 8000\ hr/yr$$

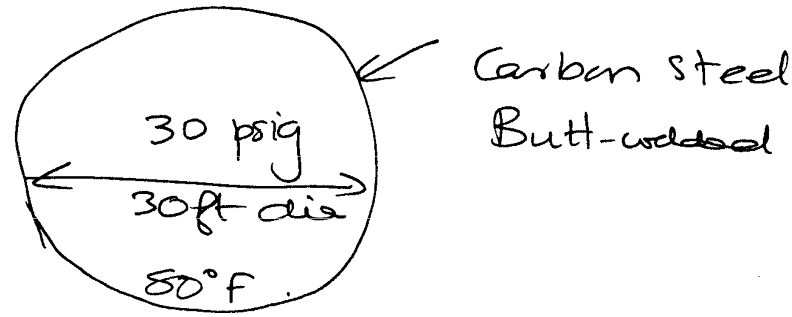
$= \$5.37$ /year, 1989 cn

CEP Plant cost Index = 355 1989
356 1990
382 1995

∴ Installed cost = $137,750 \times \frac{382}{356}$
= \$147,810 in 1995

Operating Cost = \$66,508 × $\frac{382}{355}$
= \$71,566 /yr in 1995

Problem 3



Use Table-4, p. 538 for pressure vessel design.

$$t = \frac{P r_i}{2 S E_J - .2P} + C_c$$

$C_c = 0$ from problem

$S = 13,700$ psi for C-S 0-650°C

$E =$ ~~0.60~~ 0.85

$P = 30$ psig

$r_i = 15$ ft × 12 in/ft

$$\left\{ \begin{matrix} P < .665 S E_J \\ t < .356 r_i \end{matrix} \right\}$$

$$t = \frac{30 \text{ psig} \times 15 \text{ ft} \times 12 \text{ in/ft}}{2 \times 13,700 \times .85 - .2 \times 30}$$

$= .25$ in

Conditions are satisfied

For safety allow Design Pressure = 30 + 15 + 25 (Working, Max, margin of safety)
≈ 70 psi

$t \approx .58$ in

60

B. Joseph | ChE 477 | Test 2 | Fall 1994

1. Open text and lecture notes..
2. 5% bonus for neatness & clarity.
3. Return question sheets with your solution.

NAME ____________________

Problem 1 (10 pts)

250 gal/min of water at 60 °F is to be transported via a pipe over a distance of 1000 ft. What nominal size (diameter) pipe should be used? Justify your answer with calculations.

Density of water = 62.5 lb/ft^3
Viscosity = 1.1 cp

Any other data correlation you need can be found in text (P & T). State any assumption you make.

Problem 2 (15 pts)

A pump is to be used to pump 250 gal/min of water. The pressure increase in the pump is 30 psi.

a. Should you use a centrifugal pump or positive displacement pump?

b. What is the estimated cost in 1990 dollars? (pump and motor)

c. What horsepower motor is required?

Problem 3 (10 points)

Estimate the annual operating labor cost for a large, highly automated, fluid processing plant of capacity 10 million lb/yr. The plant consists of three processing steps: reaction, separation and purification. Use data and correlations from text (P & T). Assume 300 days/yr of operation.

Problem 4 (5%)

Indicate whether the following cost items associated with a project is fixed-capital, working capital or manufacturing cost.

ITEM	FIXED CAPITAL	WORKING CAPITAL	MANUFACTURING COST
Patent and Royalties			
Depreciation			
Insurance			
Site Preparation			
Power Plant			
Laboratory Supplies			
Start-up Expense			
Accounts Receivable			
Contingency			
Make-up Catalyst			

Problem 5 (10 pts.)

See attached output from an Aspen run. Debug the input using the errors and warnings reported. List the corrections below.

```
;
;Input file created by ModelManager Rel. 3.3-3 on Tue Oct 18 16:05:31 1994
;Directory /auto/home/cec/faculty/che/joseph/che477/design  Runid DES4
;
;
;Input file created by ModelManager Rel. 3.3-3 on Sun Sep 25 17:33:29 1994
;Directory /auto/home/cec/faculty/che/joseph/che477/design  Runid SEPERN
;

TITLE  " CYCLOHEXANONE PROCESS WITH RECYCLE  JOSEPH "

;SIMULATE INTERACTIVE=YES

DATABANKS ASPENPCD

COMPONENTS
    CHL C6H12O-1 CHL /
    CHN C6H10O CHN /
    H2 H2 H2 /
    HB * HB

FLOWSHEET
    BLOCK R1 IN=RFEED OUT=ROUT
    BLOCK GASSEP IN=ROUT OUT=RGAS RLIQD
    BLOCK MIX IN=FEED RECYCLE  OUT=RFEED
    BLOCK SEPRTR IN=FEED2D OUT=PROD RECYCLE
    BLOCK B1 IN=RLIQD OUT=FEED2D WASTE

PROPERTIES SYSOP3

ESTIMATE ALL

STRUCTURES
    STRUCTURES HB O1 C2 S / C2 C7 CYC6 / C4 C8 S / C8  &
        C13 CYC6 / C10 O14 S

STREAM FEED
    SUBSTREAM MIXED TEMP=77 PRES=14.7 MASS-FLOW=1250
    MASS-FRAC CHL .99 / CHN .01

STREAM RFEED
   SUBSTREAM MIXED TEMP=225 PRES=14.7 MASS-FLOW=2500
   MASS-Flow CHL .99 / CHN .01

BLOCK MIX MIXER

BLOCK GASSEP FLASH2
    PARAM TEMP=225 PRES=300.0

BLOCK B1 RADFRAC
    PARAM NSTAGE=3
    FEEDS RLIQD 1
    PRODUCTS FEED2D 1 V / WASTE 3 L
    P-SPEC 1 14.7 / 2 14.7
    COL-SPECS B:F=.02 Q1=0 MOLE-RDV=1
    SPEC 1 MOLE-FRAC .5 COMPS=HB STREAMS=WASTE
    VARY 1 B:F .001 .2
    SIZE-DATA COND=0 REB=1 LIGHT-KEY=CHL HEAVY-KEY=HB
BLOCK SEPRTR RADFRAC
    PARAM NSTAGE=55
    FEEDS FEED2D 26
    PRODUCTS PROD 1 V / RECYCLE 55 L
    P-SPEC 1 14.7 / 2 14.7
    COL-SPECS D:F=.5 MOLE-RDV=1 MOLE-RR=18
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```
      T-EST 1 310 / 55 320
      SPEC 1 MOLE-FRAC .95 COMPS=CHN STREAMS=PROD
      SPEC 2 MOLE-FRAC .95 COMPS=CHL STREAMS=RECYCLE
      VARY 1 MOLE-RR .01 25
      VARY 2 D:F .1 1.5
      SIZE-DATA  COND=1 REB=1 LIGHT-KEY=CHN HEAVY-KEY=CHL
  BLOCK R1 RCSTR
      PARAM VOL=100 TEMP=225 PRES=300.0 NPHASE=2 PHASE=L
      STOIC 1 MIXED CHL -1.0 / CHN 1.0 / H2 1.0
      STOIC 2 MIXED CHL -1.0 / CHN 1.0 / HB 1.0
      RATE-CON 1 63.116 .33172E8 <J/KMOL>
      RATE-CON 2 1.13E13 .1362E9 <J/KMOL>
      POWLAW-EXP 1 CHL 1.0
      POWLAW-EXP 2 CHL 1.0 / CHN 1.0
  ;
  CBLOCK  T101  TANK
     REFERENCE  INLET STREAM=FEED
     SIZING-DATA RETEN-TIME=7 [DAYs]

  CBLOCK T102 TANK
     REFERENCE  INLET STREAM= WASTE
     SIZING-DATA  RETEN-TIME=7 [DAY]

  CBLOCK P101 PUMP
    REFERENCE  INLET  STREAM=FEED
    SIZING-DATA PRISE=300
    UTILITY  ELEC=ELEC220
    COSTING-DATA NSTANDBY=1

  CBLOCK P102 PUMP
    REFERENCE INLET STREAM=RECYCLE
    SIZING-DATA PRISE=300
    UTILITY ELEC=ELEC220
    COSTING-DATA NSTANDBY=1

  CBLOCK P103 PUMP
    REFERENCE INLET  STREAM=  WASTE
    SIZING-DATA PRISE=10
    UTILITY ELEC=ELEC220
    COSTING-DATA NSTANDBY=1

  CBLOCK P104 PUMP
    REFERENCE BLOCK=SEPRTR  STAGE=1
    SIZING-DATA PRISE=60
    UTILITY ELEC=ELEC220
    COSTING-DATA NSTANDBY=1

  UTILITY ELEC220 ELECTRICITY
    COST PRICE=0.08 [$/kwhr]

  CBLOCK HX101 HEATX
    REFERENCE SHELL UTILITY=LPSTEAM
    REFERENCE TUBE  BLOCK =R1
    SIZING-DATA U=100 [BTU/HR-SQFT-R]

  UTILITY LPSTEAM STEAM
    PARAM HEATING-VALUE =850 [BTU/LB]
    PARAM TIN=300  TOUT=300  PRES=30
    COST  PRICE=0.002 [$/LB]


  UTILITY CWATER WATER
    PARAM COOLING-VALUE=72 [BTU/LB] TIN=70 TOUT=140
    COST PRICE= 1.2E-4 [$/LB]

  CBLOCK HX103 HEATX
    REFERENCE TUBE BLOCK=B1 STAGE=3
```

```
   REFERENCE SHELL UTILITY=lPSTEAM
   SIZING-DATA U=100

 UTILITY HPSTEAM STEAM
   PARAM HEATING-VALUE=850
   PARAM TIN=450 TOUT=450 PRES =400
   COST PRICE= 0.004

 CBLOCK HX104 HEATX
   REFERENCE TUBE BLOCK=SEPRTR STAGE =1
   REFERENCE SHELL UTILITY=CWATER
   SIZING-DATA U=100

 CBLOCK HX105 HEATX
   REFERENCE TUBE BLOCK=SEPRTR STAGE=55
   REFERENCE SHELL UTILITY=HPSTEAM
   SIZING-DATA U=100

 CBLOCK D101 TRAY-TOWER
   REFERENCE BLOCK=B1
   SIZING-DATA TRAY-EFF=.50
   COSTING-DATA TRAY=SIEVE

 CBLOCK D102 TRAY-TOWER
   REFERENCE BLOCK=SEPRTR
   SIZING-DATA TRAY-EFF=.50
   COSTING-DATA TRAY=SIEVE

 CBLOCK V101 V-VESSEL
   REFERENCE BLOCK=R1
   SIZING-DATA VOL=100

 CBLOCK V102 H-VESSEL
   REFERENCE BLOCK=SEPRTR STAGE=1
   SIZING-DATA RETEN-TIME =5  [MIN]

;
;
; Capital and operating cost cost expenses

unit storage
  blocks t101 t102
unit process
  blocks p101 p102 p103 p107 hx101 hx103 hx104 hx105 d101 d102 v101 v102

product hexanone
  reference stream=prod
  revenue price= .85 [$/lb] month =december year = 1994

by-product fuelgas
  reference stream = rgas
  revenue price= .0085 [$/lb] year =1994

raw-material hexanol
  reference stream=feed
  cost price= .59 [$/lb] month= december  year = 1994

project-dates
  start december 1994

cost-index
  equipment current-index = 345 index-month =october index-year = 1994

labor-costs
  wages  rate= 23  month=march year= 1989

operating-costs
```

```
202    operating-labor  noper=2  rate=17  month=march year=1989
203
204   costing-options  profit
205
206   profitability
207     analysis mode=irr
208     economic-life year=10
209     corporate-costs sales=.03  admin=0.09
210     depreciation  method=irs  life=10  salv=0.07
211     tax rate=.40
212
```

```
*** INPUT TRANSLATOR MESSAGES ***

 *   WARNING IN PHYSICAL PROPERTY SYSTEM WHILE RETRIEVING AND CHECKING
     PARAMETER VALUES                                                (LCLIMS.4)
     PARAMETER DHVLWT/ELEMENT  5 (DATA SET 1)
     UPPER BOUND VIOLATED FOR COMPONENT HB
     VALUE =    688.08     , UPPER BOUND =    500.00

 *   WARNING IN THE "STREAM" PARAGRAPH WHICH BEGINS ON LINE 44
     STREAM NAME: RFEED                                              (STSTRM.30)
     COMPONENT MASS FLOWS OF SUBSTREAM: "MIXED"
     ARE NORMALIZED TO THE TOTAL MASS FLOW VALUE.

 *   WARNING IN THE "BLOCK" PARAGRAPH WHICH BEGINS ON LINE 74
     BLOCK NAME: R1     MODEL NAME: RCSTR                            (ZURE03.15)
     REACTION NUMBER "2" DOES NOT SATISFY ATOM BALANCE.
     CHECK STOICHIOMETRY.


 **  ERROR IN THE "CBLOCK" PARAGRAPH WHICH BEGINS ON LINE 83
     COST BLOCK ID: T101     MODEL: TANK      SKW: SIZING-DATA     TKW:
     RETEN-TIME                                                      (UCONV2.23)
     SYMBOL ENTERED AS UNITS SPECIFICATION: DAYS
     IS NOT VALID.  UNITS CONVERSION NOT PERFORMED.

 **  ERROR IN THE "UNIT" PARAGRAPH WHICH BEGINS ON LINE 177
     FIRST ID: PROCESS                                               (CSSMPR.2)
     COST BLOCK P107      ASSIGNED TO UNIT PROCESS IS INVALID
     COST BLOCK IGNORED

 *   WARNING WHILE PROCESSING DEFAULTS FOR THE PRIMARY KEYWORD: UNIT-END
                                                                     (CSSEND.4)
     COST BLOCK P104      IS NOT ASSIGNED TO A UNIT
     IT WILL BE ASSIGNED TO UNIT $UNIT
```

Solution to Test 2

Problem 1

Using equation 15, p. 496

Assume Turbulent Flow:

$$D_{i,opt} = 3.9\, q_{f}^{.45}\, \rho^{0.13}$$

~~= 3.9~~

$$q_f = 250 \frac{gal}{min} \times \frac{1\ min}{60\ sec} \times \frac{1\ ft^3}{7.48\ gal}$$

$$= 0.557\ ft^3/sec$$

$$\therefore D_i = 3.9 \times (.557)^{.45} (62.5)^{0.13}$$

$$= 5.13\ in$$

From p. 888, Table 13

Choose 6" nominal size ID = 6.06"
OD = 6.625"

This is closest.

Verify turbulent flow

$$D = 6.06/12 = 0.5\ ft$$

$$V = \frac{.557\ ft^3/sec}{\pi R^2} = 2.83\ ft/sec$$

$$\rho = 62.5\ lb/ft$$

$$\mu = 1.1\ cp = (1.1)\ cp \left(\frac{.000672}{cp} \frac{lb}{s.\ ft.} \right)$$

$$N_{Re} = Dv\rho/\mu$$

$$= \frac{(.5\ ft)(2.83\ ft/sec)(62.5\ lb/ft^3)}{.000739\ lb/s.ft}$$

$$= 119{,}671$$

which is turbulent.

Problem 2

$$\Delta p = 30 \text{ psi}$$
$$q = 250 \text{ gal/min}$$

(a) Use of a centrifugal pump is suggested for this range of flow and Δp by the rules of thumb. Positive displacement pumps are used for high pressure, low flow applications

(b) Cost of pump & motor

See Fig 14-41, p. 499 text

Capacity factor = flow rate × Δp

$$= 250 \text{ gpm} \times 30 \text{ psi}$$
$$= 7500 \text{ (gpm} \cdot \text{psi)}$$

Cost ≈ \$2000 from correlation

(c) Horse power required

Work = flow × Δp

$$\text{Flow} = 250 \frac{\text{gal}}{\text{min}}$$
$$= 0.557 \frac{\text{ft}^3}{\text{sec}}$$

$\therefore$ work $= 0.557 \frac{ft^3}{sec} \times 30 \frac{lbf}{in^2} \times \frac{144 \ in^2}{ft^2}$

$= 2406$ ft. lbf/sec $\times \frac{60 \ sec}{min} \times$

$\times \frac{3.03 \times 10^{-5} \ thp}{1. \ ft.lb/min}$

$= \underline{\underline{4.374 \ thp}}$
(Theoretical horse power)

Assume 70% Efficiency
Actual horse power

$= \frac{4.374}{.7} = \underline{\underline{6.24 \ hp}}$

Problem 3

Use Fig 6-8, p. 198, Text

Capacity $= 10 \times 10^6 \frac{lb}{yr} \times \frac{1 \ yr}{300 \ days} \times \frac{1 \ ton}{2000 \ lb}$
$= 16.6$ tons/day

operating labor $=$ 21 hrs/day/step $\times$ ~~3~~
3 steps ~~/~~

$\therefore$ Net operating labor $= 21 \frac{hrs}{day.step} \times$ ~~x~~ 3 steps

$= 66$ hrs/day

Assume 365 days of work required

Total O.L. hrs $= 66 \frac{hrs}{day} \times 365 \frac{day}{yr} = 24,090 \frac{hrs}{yr}$

labor cost = \$21/hr (Table 23, p.2[illegible])

$$\therefore \text{D.L. cost} = 24{,}090\ \frac{\text{hr}}{\text{yr}} \times \frac{\$21}{\text{hr}}$$

$$= \text{~~58~~}\ \$505{,}890\ /\text{yr}$$

Errors

1. Line 44. stream para

   Mass-flow ⟶ Mass_Frac

2. Line 74 Reaction 2

   CHL -1 / CHN -1.0 / HB 1

   Coefficient of CHN is should be -1.0

3. Unit of Reten-time = 7 [day]

   not [days]

4. P107 is not defined anywhere

5. P.104 is not listed in the units paragraph.

   Replace P107 with P104.