7 1

B. Joseph | ChE 477 | Test 2

Open Textbook and Bound Volume of lecture notes
Time: 53 minutes
Neatness, Clarity, organization:(5 points)

Problem 1 **(40 points)**

Calculate the horse power of a pump required to transport water at 77° F over a distance of 1000 ft at a rate of 100 gallons per minute. The elevation and pressure at inlet and exit are the same. Density of water = 62.5 lb/ft^3. Viscosity of water = 0.000739 lb/(ft.s)
1 ft^3 = 7.48 gal. (Hint: Size the pipe first)

Must give complete references for data/correlations used for full credit.

Problem 2 **(25 points)**

Estimate the number of operating labor hours/yr required for a large, highly automated, fluid processing plant of capacity 10 million lb/year. The plant consists of three processing steps: reaction, separation and purification. What will be the annual operating labor cost in $/year? (1989 costs). What is operating labor cost in $/lb of product?

Must give sources of data.

Problem 3 **(30 points)**

The sales income from a project is $1.1 million/year. The operating costs excluding depreciation) are $0.82 million/yr. The Fixed Capital Investment (all depreciable) for the plant is $1.2 million. Depreciation is done using the straight-line method with a salvage value of $0.2 million and an estimated life of 10 years. Compute the net cash flow ($/year) from the project if the income tax rate is 40%. Also compute gross profit, income tax and net profit after taxes.

Solution to Test 2

Problem 1

First we size the pipe to transport the liquid.

$$D_{i,opt} = 3.9\, q_f^{.45} \rho^{0.13} \quad \text{(Eqn 15, p. 496)}$$

$$q_f = 100 \text{ gpm} \times \frac{1 \text{ min}}{60 \text{ sec}} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal}} =$$

$$= 0.223 \text{ ft}^3/\text{sec}$$

$$D_i = 3.9(.223)^{.45}(62.5)^{0.13}$$

$$= 3.39 \text{ in}$$

See p. 588, Table 13

Use 4" nominal size Sch. 40 pipe

ID = 4.0 in

OD = 4.5 in

A_c = 12.7 in²

$$N_{Re} = \frac{Dv\rho}{\mu} = \frac{(4.0/12)\text{ ft} \times \frac{.223 \text{ ft}^3}{\text{sec}(12.7/144 \text{ ft}^2)} \times 62.5 \frac{\text{lb}}{\text{ft}^3}}{0.000739 \frac{\text{lb}}{\text{s.ft}}}$$

$$= \underline{71281}$$

Problem 2

capacity $= 10 \times 10^6$ lb/yr

Assume 90% on-stream time $= 365 \times .90$

$= 329$ days/yr

$\therefore$ Capacity $= 10\times10^6 \frac{lb}{yr} \times \frac{1\ yr}{329\ day} \times \frac{1\ ton}{2000\ lb}$

$= 15.19$ tons/day

From Fig 6-8, p. 198,

Operating labor reqd = 22 hrs/day/step

For three steps,

Op. Labor = 66 hrs/day

$\therefore$ Yearly op. labor reqd $= 66 \times 365$

$= 24{,}090$ hrs/yr

At a rate of \$21.00/hr (p. 200, Table 23)

= \$ 505,890 /yr

= **\$ 0.0506**/ lb of product

Pressure drop

Using the mechanical energy balance

$$\delta W = \frac{g}{g_c}\Delta z + v\Delta p + \Sigma F$$

$\Delta z = 0$, $\Delta p = 0$ ∴

$\delta W = \Sigma F$ (friction losses)

From Fig 14-1, p. 482 at $N_{Re} = 71281$

$f = 0.006$

$$\Delta F = \frac{2 f v^2 (L)}{g_c D} \qquad v = \frac{.223}{(12.7/144)} = 2.52 \frac{ft}{sec}$$

$$= \frac{2 \times 0.006 \times (2.52)^2 (1000\ ft)}{(32.7)(4/12\ ft)}$$

$= 6.935$ ft. lbf/lbm

$\delta W = 6.935$ ft. lbf/lbm

Total Work by pump = (δW) (flow rate)

$$= 6.935 \frac{ft.lbf}{lbm} \times \frac{.223\ ft^3}{sec} \times \frac{62.5\ lb}{ft^3}$$

$$= 96.65\ ft.lbf/sec \times \frac{1\ hp}{550\ ft.lbf/sec}$$

Theoretical horse power $= 0.175$ hp //

Problem 3

Sales Income = \$1.1 million/yr

Operating costs = \$0.82 mil/yr

Gross Profit = 1.1 − 0.82
= \$0.28 million/yr

Depreciation = (\$1.2 million − 0.2)/10
= \$0.1 million/yr

Net Profit before tax = \$0.28 − 0.1
= \$0.18 million/yr

Taxes = \$0.18 × 0.40 = \$0.072 mil/y

Net Profit After Tax
= \$0.108 million/yr

Net Cash Flow = NPAT + Dep
= \$0.108 + 0.1
= \$.208 million/yr

B. Joseph

ChE 477 - Test 2

Open Text and Lecture Notes Only

Fall 1984

Time: ~~85~~ min

Problem ~~1~~ 20 (30%)

A process plant making 2000 tons/year of a product selling for \$.80 per lb has annual total production costs of \$2.7 million at 100 percent capacity out of which fixed costs including depreciation are \$700,000. Depreciation costs are \$500,000/year. What is the total production cost per lb at break-even point? If selling price of the product increases by 10%, what is the dollar increase in cash flow at full capacity if the income tax rate is 48% of net profit? variable costs are proportional to the production capacity.

Problem ~~2~~ 21 (35%)

A heat exchanger has been designed for use in a chemical process. A standard type of heat exchanger with a negligible scrap value cost \$4,000 and will have a useful life of 6 years. Another proposed heat exchanger of equivalent design capacity costs \$6,800 but will have a useful life of 10 years and a scrap value of \$800. The company is earning 8% return after taxes on its other investments. The tax rate is 50%. Which heat exchanger should be selected to minimize uniform annual costs? Straight line depreciation is used.

Problem ~~3~~ 22 (35%)

The facilities of an existing company must be increased if the company is to continue in operation. There are two alternatives. One of the alternatives is to expand the present plant. If this is done, the expansion would cost \$130,000. Additional labor costs would be \$150,000 per year, while additional costs for overhead, depreciation, local taxes, and insurance will be \$60,000 per year. Depreciation is \$15,000 per year.

A second alternative requires construction and operation of new facilities at a location about 50 miles from the present plant. This alternative is attractive because cheaper labor is available at this location. The new facilities would cost \$200,000. Labor costs would be \$120,000/year. Overhead costs would be \$70,000/year. Annual insurance and local taxes would amount to 2 percent of the initial cost. All other costs except depreciation would be the same at each location. Depreciation would be \$20,000 per year. If the minimum return on any acceptable investment is 9 percent after taxes, which alternative should be selected using the incremental return on investment analysis? Federal income tax rate is 48%.

Repeat using the venture profit method of analysis.

Joseph

84

Fall 19?

ChE 477 Test 2, Solution

Problem 1

(a) Break-even point is point at which production costs equal sales income.

Let $x \frac{lb}{yr}$ be the production rate at the breakeven point.

Then sales income = $\frac{\$0.80}{lb} \times x \frac{lb}{yr} = \$.80x/yr$

Fixed costs = $700,000 /yr

Variable cost at 100% capacity = $2700 k$/yr − 700 k$/yr

= 2000 k$/yr

Production at 100% capacity = 2000 ton/yr

= $2000 \frac{ton}{yr} \times 2000 \frac{lb}{ton}$

= 4000 klb/yr

Variable costs/lb = $\frac{\$2000\ k\$/yr}{4000\ klb/yr}$

= $0.5 \frac{\$}{lb}$

Variable costs at $x \frac{lb}{yr}$ capacity

= $0.5x \frac{\$}{yr}$

At breakeven sales income = fixed costs + variable costs

85

$$0.80\,x\ \$/yr = 0.5\ x\ \frac{\$}{yr} + 700{,}000\ \$/yr$$

$$\therefore\ .30\,x = 700{,}000$$

$$x = \underline{\underline{2333{,}333}}\ lb/yr$$

$$\text{Total product cost} = .5x + 700{,}000$$

$$= \underline{\underline{\$1.866}}\ \text{Million}$$

(b) Selling price goes up 10%.

(i) at 100% capacity and old price

$$\text{Sales income} = 2000\ \frac{tons}{yr} \times 2000\ \frac{lb}{ton} \times 0.80\ \frac{\$}{lb}$$

$$= 3200\ k\$/yr$$

$$\text{Production Cost (inc. dep)} = 2700\ k\$/yr$$

$$\therefore\ \text{Net Profit} = (3200 - 2700)$$

$$= 500\ k\$/yr$$

$$\text{Net Profit After Tax} = 500\,(1 - .48)$$

$$= 260\ k\$/yr$$

$$\text{Dep} = 500\ k\$/yr$$

$$\text{Net Cash Flow} = \$760\ k\$/yr$$

(ii) at new price

$$\text{Sales income} = 3520\ k\$/yr$$

$$\text{Production Cost} = 2700\ k\$/yr$$

$$\text{Net Profit} = 820\ k\$/yr$$

(86)

Net Profit After Taxes = ~~800~~ 820×(1−.48) k$/y
= 426.4 k$/yr

Depreciation = 500 k$/yr

Cash Flow = 926.4 k$/yr

Increase in cash flow = 926.4 − 760.0
= 166.4 k$/yr

% increase = 21.89 %

87

Problem 2

Let value of service provided by heat exchanger be S \$/yr

Then for (i) standard type heat exchanger

annualized cost of capital (\$4000)

$$= \$4000 \times \left[\frac{(1+i)^n \cdot i}{(1+i)^n - 1} \right] \qquad i = 0.08, \; n = 6$$

$$= \$865.2 \,/\text{yr}$$

Depreciation = \$666.66 \$/yr

~~Savings due~~ Cash Flow after ~~to~~ depreciation $= (S-d)(1-t)+d$

$= S(1-t) + dt$

savings due to dep $= dt$ \$/yr

$= 666.66 \times .5$

$= \$333.33$ /yr

~~Net~~ Total annualized costs $= 865.20 - 333.33$

$= \$531.87$/yr

(ii) For the second heat exchanger

Annualized cost due to capital expenditure

$$= \$6800 \cdot \left[\frac{(1+i)^n \cdot i}{(1+i)^n - 1} \right] \qquad i = .08, \; n = 10$$

$$= \$1013 \,/\text{yr}$$

Depreciation $= (6800 - 800)/10 = \$600/\text{yr}$

Tax savings due to depreciation $= \$300/\text{yr}$

Resale value $= \$800$

PW of resale value $= 800/(1+.08)^{10} = 370.55$

Annualized value of resale income $= \$55.2/\text{yr}$

Net annualized cost $= 1013 - 300 - 55.2$

$= \$657.8$

First heat exchanger is cheaper.

Problem 3

Incremental Return = $\dfrac{\text{Incremental profit after taxes}}{\text{Incremental investment}}$

Incremental investment = 200,000 − 130,000
= **70 k$/**

Incremental savings before taxes
= (150 k$/yr + 60 k$/yr + ~~15 k$/yr~~)
— (120 k$/yr + 70 k$/yr + 4 k$/yr
+ 20 k$/yr)

= −4 k$/yr

∴ Hence ~~no~~ incremental return is negative;
do not ~~go to the~~ go to new facilities

Venture ~~Worth~~ Profit

(i) Venture Profit from expansion of present facilities:

let S = ~~sales~~ income from the expansion k$/yr
x = expenses other than labor, ov, dep, tax & ins

~~Gross~~ Net Profit = (S − 150 − 60 − x) k$/yr

Net Profit After taxes = (S − x − 210)(1 − .48) k$/yr

Venture Profit = (S − x − 210) .52 − .09 × 130
= (S − x) .52 − 120.9 k$/yr

(40)

(ii) Venture Profit by going to new facilities

Net Profit = (S − 120 − 70 − 4 − 20 − x)

= (S − x − 214) k$/yr

Net Profit After taxes (S − x − 214)(.52)

Venture Profit = (S − x)·.52 − 111.28 k$/yr

− 200 × .09

= (S − x).52 − 129.28

Comparing Venture Profits, Present Facilities should be expanded.

ChE 477 **Test 2** **Fall 1998**
B. Joseph

1. Closed Book
2. Time – 55 minutes
3. One 8 ½ x 11 sheet allowed
4. Neatness, clarity and organization will carry up to 3 bonus points

Problem 1 (15 points)

In a design, you have the choice of purchasing either of the following pieces of equipment:

Equipment	A	B
Material of Construction	CS	SS
Installed Cost	$6,000	$12,000
Equipment Life	4 years	6 years
Yearly maintenance cost	$2,200	$1,300

If the interest rate for such comparisons is set at 10% per annum, which of the two alternatives is the least costly? Justify your answer with appropriate calculations.

Neglect effect of inflation and taxation.

Problem 2 (15 points)

The cyclohexanol reactor is operated under the following conditions:

T = 195°F
Volume = 50 ft^3
Pressure = 300 psi

At these conditions, 80 mole % of the cyclohexanol fed to the reactor is converted.

The stoichiometry is given as

$$A \rightarrow B + H_2$$
$$2A \rightarrow C + H_2$$

where $A =$ cyclohexanol
$B =$ cyclohexanone
C = high boiler

90% of the A converted yields the desired product while the remaining goes to produce the byproduct C.

Basis: 100 lb moles/hr of raw material.

Feed raw material is a mixture of 95% A, 5% B (by mole).

Assume product is 100% pure B.

a. Given the costs below, what is the economic potential in $/lb mole of raw material entering the process?

Product = $120/lb mole
Feed = $59 / lb mole of mixture
C = no value
H_2 = no value

b. How much of A is recycled for each lb mole/hr of fresh feed to the process? Assume recycle is 100% pure A.

Problem 3 (15 points)

Attached you will find excerpts from an Aspen Report file on the simulation of a distillation column to separate Monchlorohexane. Using the Table of Experienced Based Rules (also attached), estimate

(a) the diameter of the column

(b) the height of the column

(c) the height and diameter of the reflux drum (accumulator) needed.

You may assume the vapor phase behaves like an ideal gas. One lb mole of ideal gas occupies 359 ft^3 at 32°F, 1 atm.

Table 9.13 Heuristics for Towers (Distillation and Gas Absorption) (Adapted from Walas, S. M., *Chemical Process Equipment: Selection and Design*, Butterworths, Stoneham, MA, 1988, copyright © 1988 by Butterworth Publishers, adapted by permission of Butterworth Publishers, Stoneham, MA, all rights reserved)

1. Distillation is usually the most economical method for separating liquids, superior to extraction, absorption crystallization, or others.
2. For ideal mixtures, relative volatility is the ratio of vapor pressures $\alpha_{12} = P_1^*/P_2^*$.
3. Tower operating pressure is most often determined by the temperature of the condensing media, 38–50°C (100–120°F) if cooling water is used; or by the maximum allowable reboiler temperature to avoid chemical decomposition/degradation.
4. Sequencing of columns for separating multi-component mixtures:[a]
    a. Perform the easiest separation first, that is, the one least demanding of trays and reflux, and leave the most difficult to the last
    b. When neither relative volatility nor feed composition vary widely, remove components one by one as overhead products
    c. When the adjacent ordered components in the feed vary widely in relative volatility, sequence the splits in order of decreasing volatility
    d. When the concentrations in the feed vary widely but the relative volatilities do not, remove the components in order of decreasing concentration.
5. Economical optimum reflux ratio is in the range of 1.2–1.5 times the minimum reflux ratio, R_{min}.
6. The economically optimum number of theoretical trays is near twice the minimum value N_{min}.
7. The minimum number of trays is found with the Fenske-Underwood equation
   $N_{min} = \ln\{[x/(1-x)]_{ovhd}/[x/(1-x)]_{btms}\}/\ln \alpha$.
8. Minimum reflux for binary or pseudobinary mixtures is given by the following when separation is essentially complete ($x_D \approx 1$) and D/F is the ratio of overhead product to feed rate:
   $R_{min}D/F = 1/(\alpha-1)$, when feed is at the bubble point
   $(R_{min}+1)\,D/F = \alpha/(\alpha-1)$, when feed is at the dew point.
9. A safety factor of 10% of the number of trays calculated by the best means is advisable.
10. Reflux pumps are made at least 10% oversize.
11. The optimum value of the Kremser absorption factor $A = (L/mV)$ is in the range of 1.25 to 2.0.
12. Reflux drums usually are horizontal, with a liquid holdup of 5 min half full. A take-off pot for a second liquid phase, such as water in hydrocarbon systems, is sized for a linear velocity of that phase of 1.3 m/s (0.5 ft/sec), minimum diameter is 0.4 m (16 in).
13. For towers about 0.9 m (3 ft dia), add 1.2 m (4 ft) at the top for vapor disengagement and 1.8 m (6 ft) at bottom for liquid level and reboiler return.
14. Limit the tower height to about 53 m (175 ft) max. because of wind load and foundation considerations. An additional criterion is that L/D be less than 30 ($20 < L/D < 30$ often will require special design)

[a]Additional information on sequencing is given in Table 17.2

Table 9.14 Heuristics for Tray Towers (Distillation and Gas Absorption) (Adapted from Walas, S. M., *Chemical Process Equipment: Selection and Design*, Butterworths, Stoneham, MA, 1988, copyright © 1988 by Butterworth Publishers, adapted by permission of Butterworth Publishers, Stoneham, MA, all rights reserved)

1. For reasons of accessibility, tray spacings are made 0.5–0.6 m (20–24 in).
2. Peak efficiency of trays is at values of the vapor factor $F_s = u\rho^{0.5}$ in the range of 1.2–1.5 m/s $\{kg/m^3\}^{0.5}$ [1–1.2 ft/s $\{lb/ft^3\}^{0.5}$]. This range of F_s establishes the diameter of the tower. Roughly, linear velocities are 0.6 m/s (2 ft/sec) at moderate pressures and 1.8 m/s (6 ft/sec) in vacuum.
3. Pressure drop per tray is on the order of 7.6 cm (3 in) of water or 0.007 bar (0.1 psi).
4. Tray efficiencies for distillation of light hydrocarbons and aqueous solutions are 60–90%; for gas absorption and stripping, 10–20%.
5. Sieve trays have holes 0.6–0.7 cm (0.25–0.5 in) dia., area being 10% of the active cross section.
6. Valve trays have holes 3.8 cm (1.5 in) dia. each provided with a liftable cap, 130–150 caps/m^2 (12–14 caps/ft^2) of active cross section. Valve trays are usually cheaper than sieve trays.
7. Bubblecap trays are used only when a liquid level must be maintained at low turndown ratio; they can be designed for lower pressure drop than either sieve or valve trays.
8. Weir heights are 5 cm (2 in), weir lengths are about 75% of tray diameter, liquid rate—a maximum of 1.2 m^3/min m of weir (8 gpm/in of weir); multi-pass arrangements are used at higher liquid rates.

Table 9.6 Heuristics for Process Vessels (Drums) (Adapted from Walas S. M., *Chemical Process Equipment: Selection and Design*, Butterworths, Stoneham, MA, 1988, copyright © 1988 by Butterworth Publishers, adapted by permission of Butterworth Publishers, Stoneham, MA, all rights reserved)

1. Drums are relatively small vessels that provide surge capacity or separation of entrained phases.
2. Liquid drums are usually horizontal.
3. Gas/liquid phase separators are usually vertical.
4. Optimum length/diameter = 3, but the range 2.5 to 5 is common.
5. Holdup time is 5 min for half-full reflux drums and gas/liquid separators, 5-10 min for a product feeding another tower.
6. In drums feeding a furnace, 30 min for half-full drum is allowed.
7. Knockout drums placed ahead of compressors should hold no less than 10 times the liquid volume passing per minute.
8. Liquid/liquid separations are designed for settling velocity of 0.085–0.127 cm/s (2–3 in/min)
9. Gas velocity in gas/liquid separators, $u = k\sqrt{\rho_l/\rho_v - 1}$ m/s (ft/sec) k = 0.11 (0.35) for systems with mesh deentrainer and k = 0.0305 (0.1) without mesh deentrainer.
10. Entrainment removal of 99% is attained with 10.2–30.5 cm (4–12 in) mesh pad thickness; 15.25 cm (6 in) thickness is popular.
11. For vertical pads, the value of the coefficient in Step 9 is reduced by a factor of 2/3.
12. Good performance can be expected at velocities of 30–100% of those calculated with the given k; 75% is popular.
13. Disengaging spaces of 15.2–45.7 cm (6–18 in) ahead of the pad and 30.5 cm (12 in) above the pad are suitable.
14. Cyclone separators can be designed for 95% collection at 5 μm particles, but usually only droplets greater than 50 μm need be removed.

BLOCK: B1 MODEL: RADFRAC

****
**** INPUT DATA ****
****

**** INPUT PARAMETERS ****

NUMBER OF STAGES	22
ALGORITHM OPTION	STANDARD
ABSORBER OPTION	NO
INITIALIZATION OPTION	STANDARD
HYDRAULIC PARAMETER CALCULATIONS	NO
INSIDE LOOP CONVERGENCE METHOD	BROYDEN
DESIGN SPECIFICATION METHOD	NESTED
MAXIMUM NO. OF OUTSIDE LOOP ITERATIONS	25
MAXIMUM NO. OF INSIDE LOOP ITERATIONS	10
MAXIMUM NUMBER OF FLASH ITERATIONS	50
FLASH TOLERANCE	0.000100000
OUTSIDE LOOP CONVERGENCE TOLERANCE	0.000100000

**** COL-SPECS ****

MOLAR VAPOR DIST / TOTAL DIST		0.0
MOLAR REFLUX RATIO		8.00000
MOLAR DISTILLATE RATE	LBMOL/HR	200.000

☐

****

☐

**** RESULTS ****

☐

****

☐

☐

☐

*** COMPONENT SPLIT FRACTIONS ***

☐

☐

OUTLET STREAMS

COMPONENT:	3	4
TOLUENE	.26058E-01	.97394
PHENOL	.21849E-03	.99978
MCH	.97263	.27369E-01

*** SUMMARY OF KEY RESULTS ***

TOP STAGE TEMPERATURE	F	218.829
BOTTOM STAGE TEMPERATURE	F	325.307
TOP STAGE LIQUID FLOW	LBMOL/HR	1,600.00
BOTTOM STAGE LIQUID FLOW	LBMOL/HR	1,400.00
TOP STAGE VAPOR FLOW	LBMOL/HR	0.0
BOTTOM STAGE VAPOR FLOW	LBMOL/HR	1,601.35
MOLAR REFLUX RATIO		8.00000
MOLAR BOILUP RATIO		1.14382
CONDENSER DUTY (W/O SUBCOOL)	BTU/HR	- 0.241734+08
REBOILER DUTY	BTU/HR	0.315583+08

STAGE	TEMPERATURE F	PRESSURE PSI	ENTHALPY BTU/LBMOL LIQUID	ENTHALPY BTU/LBMOL VAPOR	HEAT DUTY BTU/HR
1	218.83	16.000	-72547.	-59167.	-.24173+08
2	219.69	16.200	-72474.	-59117.	
6	225.04	17.000	-70994.	-58386.	
7	235.93	17.200	-64773.	-56993.	
8	236.89	17.400	-63796.	-55885.	
13	243.50	18.400	-51746.	-41682.	
14	243.53	18.600	-46877.	-36067.	
15	245.41	18.800	-43631.	-32019.	
16	247.92	19.000	-39399.	-26381.	
21	280.54	20.000	-30209.	10547.	
22	325.31	20.200	-44783.	2239.4	.31558+08

STAGE	FLOW RATE LBMOL/HR LIQUID	FLOW RATE LBMOL/HR VAPOR	FEED RATE LBMOL/HR LIQUID	FEED RATE LBMOL/HR VAPOR	FEED RATE LBMOL/HR MIXED	PRODUCT RATE LBMOL/HR LIQUID	PRODUCT RATE LBMOL/HR VAPOR
1	1600.	0.				200.0000	
2	1600.	1800.					
6	1504.	1781.					
7	2888.	1704.	1200.0000				
8	2890.	1888.					
13	2901.	1888.					
14	3327.	1901.	400.0000				
15	3323.	1927.					
16	3318.	1923.					
21	3001.	1839.					
22	1400.	1601.				1400.0000	

**** MASS FLOW PROFILES ****

STAGE	FLOW RATE LB/HR LIQUID	FLOW RATE LB/HR VAPOR	FEED RATE LB/HR LIQUID	FEED RATE LB/HR VAPOR	FEED RATE LB/HR MIXED	PRODUCT RATE LB/HR LIQUID	PRODUCT RATE LB/HR VAPOR
1	0.1568E+06	0.				.19605+05	
2	0.1568E+06	0.1764E+06					
6	0.1471E+06	0.1744E+06					

```
  7 0.2778E+06 0.1667E+06  .11294+06
  8 0.2778E+06 0.1844E+06
```

STREAM SECTION

1 2 3 4

STREAM ID	1	2	3	4
FROM :	----	----	B1	B1
TO :	B1	B1	----	----
SUBSTREAM: MIXED				
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID
COMPONENTS: LBMOL/HR				
TOLUENE	200.0000	0.0	5.2115	194.7884
PHENOL	0.0	1200.0000	0.2621	1199.7378
MCH	200.0000	0.0	194.5262	5.4737
COMPONENTS: MOLE FRAC				
TOLUENE	0.5000	0.0	2.6058-02	0.1391
PHENOL	0.0	1.0000	1.3109-03	0.8569
MCH	0.5000	0.0	0.9726	3.9098-03
TOTAL FLOW:				
LBMOL/HR	400.0000	1200.0000	200.0000	1400.0000
LB/HR	3.8066+04	1.1294+05	1.9605+04	1.3140+05
CUFT/HR	827.4465	1793.7186	449.9977	2314.3895
STATE VARIABLES:				
TEMP F	220.0000	221.0000	218.8286	325.3069
PRES PSI	20.0000	20.0000	16.0000	20.2000
VFRAC	0.0	0.0	0.0	0.0
LFRAC	1.0000	1.0000	1.0000	1.0000
SFRAC	0.0	0.0	0.0	0.0
ENTHALPY:				
BTU/LBMOL	-3.1754+04	-5.9907+04	-7.2547+04	-4.4783+04
BTU/LB	-333.6805	-636.5394	-740.0851	-477.1481
BTU/HR	-1.2702+07	-7.1888+07	-1.4509+07	-6.2696+07
ENTROPY:				
BTU/LBMOL-R	-113.2566	-72.1558	-154.6975	-64.5733
BTU/LB-R	-1.1901	-0.7666	-1.5781	-0.6880
DENSITY:				
LBMOL/CUFT	0.4834	0.6690	0.4444	0.6049
LB/CUFT	46.0038	62.9617	43.5669	56.7736
AVG MW	95.1643	94.1130	98.0252	93.8545

MIXED SUBSTREAM PROPERTIES:

*** VAPOR PHASE ***					
RHOMX	LB/CUFT	MISSING	MISSING	MISSING	MISSING
MUMX	CP	MISSING	MISSING	MISSING	MISSING
*** LIQUID PHASE ***					
RHOMX	LB/CUFT	46.0038	62.9617	43.5669	56.7736
MUMX	CP	0.2882	1.0115	0.3229	0.4429
SIGMAMX	DYNE/CM	16.8047	31.9342	14.9495	23.8045

Solution To Test 2

Problem 1

Since projected lives are different:
Compute and Compare on the basis of Uniform ~~Yearly~~ Annual Costs [EAOC Method]

For **Carbon Steel**

Total ~~Y~~EAOC = \$2,200 + Capital Inv. $(A/P, i, n_{eq})$

$= \$2200 + 6000\,[A/P, .10, 4]$

$= 2200 + 6000\,\dfrac{(.10)(1.10)^4}{(1.10)^4 - 1} = \boxed{4092.83}$ /yr

For **Stainless Steel**

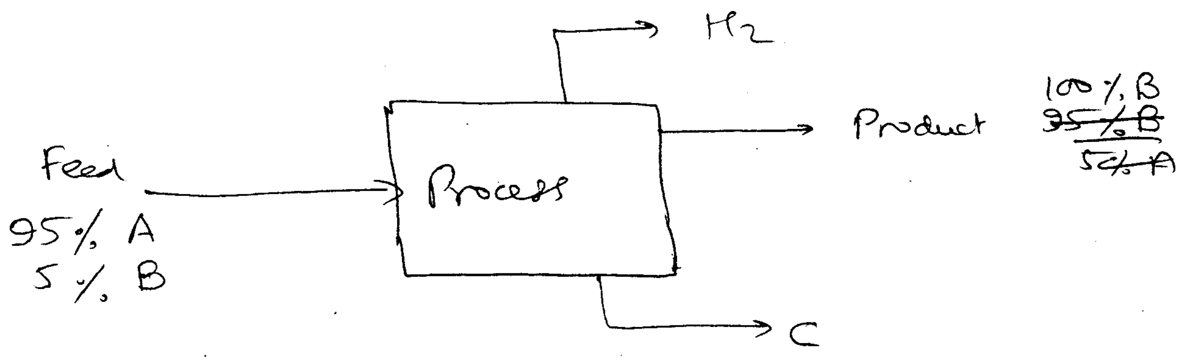
Total EAOC $= \$\,1300 + 12{,}000\,\dfrac{(.10)(1.10)^6}{(1.10)^6 - 1}$

$= \boxed{4055.29}$

The S.S. tank is slightly ~~more~~ less expensive.

Choose S.S. ~~Equipment~~.

Problem 2



Basis: 100 lbmole/hr of fresh feed

= 95 lbmole/hr of A
5 " B

90% of A ~~et~~ is converted to B
$\Rightarrow$ 95 × .90 = 85.5 lbmole of A goes to make B + H_2

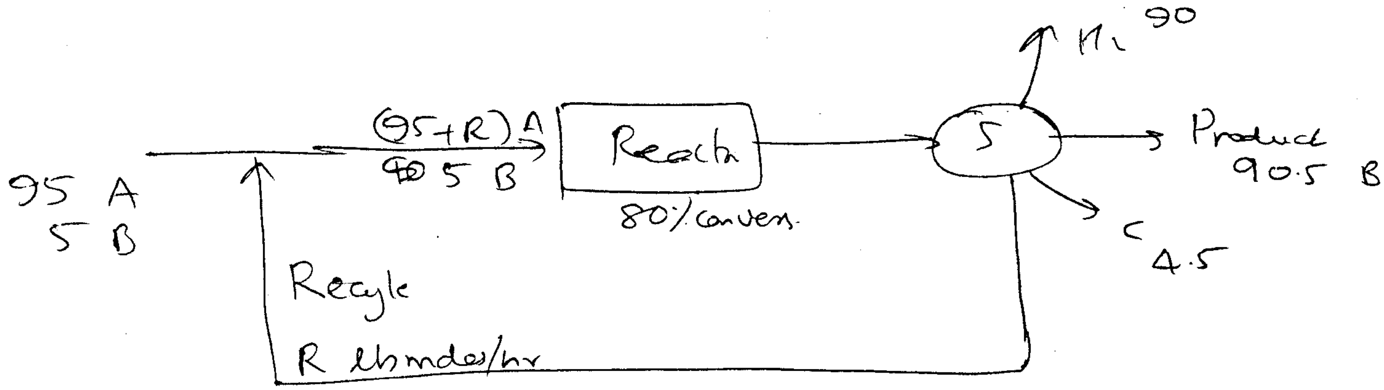
$\Rightarrow$ 85.5 lbmole/hr of B produced +
85.5 " H_2 "

10 % of A is converted to C = 9 moles/hr of A
$\Rightarrow$ 4.5 moles of C produced
4.5 " H_2 "

Also feed contains 5 mole of B.

Total B in product = 85.5 + 5 = 90.5
H_2 " = 85.5 + 4.5 = 90
C " = 4.5

Economic Potential = \$120 × 90.5 − \$59 × 100 = \$4960/hr = **\$49.60/lbmole of feed**



Let R = lbmole/hr of Recycle

A entering reactor = (95 + R)

~~A leaving reactor~~ =

A converted in reactor = (95+R)·80

A leaving the " = (95+R)(·20)

A in product ? =

Product contains ~~95~~ 100 % B. But B in product

~~= 90.5 lbmoles/hr~~

B in feed + B produced in reactor

= 5 lbmole/hr + ·80(95+R) * ·90

= 5 + ·72(95+R)

= 90.5 from previous calculat

~~∴ A in product =~~

Also ∴ A in recycle = unconverted A in reactor product

= ·20(95+R)

= R

∴ ·20 * 95 = .80 R ⇒ R = 23.75 lbmol/hr

Recycle/Feed = ·2375 Ans

Size a Tray column

1. Height, Diameter ?
2. Reboiler area ?

1. Diameter is fixed by vapor velocity

Use Rule 2, Table 9.14

Linear velocities are 2 ft/sec at moderate pressures

$$\therefore \text{Area} = \frac{\text{Gas flow } (ft^3/sec)}{\text{gas velocity } (ft/sec)}$$

max Gas flow = 1923 lbmoles/hr

Ideal gas density = 359 ft^3/lbmole @ 32°F, 14.7 psi

$= 359 \times \left(\frac{14.7}{18}\right)\left(\frac{700}{490}\right) = 418 \ \frac{ft^3}{lbmole}$

$$\text{Area} = \frac{1923 \times 418 \ ft^3/hr \times \frac{1 \ hr}{3600 \ sec}}{2 \ ft/sec}$$

$= 95.88 \ ft^2$

$\pi D^2/4 = 95.88 \ ft^2$

D = 11.0 ft

Tray Efficiency 60-90%, Rule 4, 9.14

Use 75% efficiency

$\therefore$ No of Stages = 22. (1 is for Reboiler)

No of Trays = (22-1)/0.75 = **28**

Height required = 22 in / tray
(Rule 1, 9.14)

Height of Column = $28 \times \frac{22 \text{ in}}{12 \text{ in/ft}}$

= **51.3 ft**

Allow 3 ft for vapor disengagement
6 ft at bottom for ~~liq.~~ reboiler
return (Rule 13, p 252)

Total height = **60 ft**

Reflux Drum

Holdup = 5 min liq / halfful
Rule 12, Table 9.13

Condensate flow rate = **1800 lbmole/hr**

Condensate density = 43 lb/ft^3
= .444 lbmol/ft^3

Reflux Drum Volume = $\frac{1800}{.44} \frac{ft^3}{hr} \times 5 \text{ min} \times 2 \times \left(\frac{1 \text{ hr}}{60 \text{ min}}\right)$

= **682 ft^3**

H/D ≃ 3 ∴ $\frac{\pi D^2}{4} \cdot H = \frac{\pi D^2}{4} \cdot (3D) = \frac{3\pi}{4} D^3 = 682$

∴ **D = 6.6 ft**
H = 19.8 ft

(100)

B. Joseph **ChE 477** **Test 3**
1 hour

Open Text and Lecture Notes
(5% Bonus for Neatness and Clarity of the Solution)

Problem 1 (15%)

A company wants to purchase a building worth $900,000. The company makes a down payment of $100,000 and borrows the rest at 10% nominal interest rate. Interest is compounded monthly. Loan period is 10 years.

1. What will be the loan payment per period if the loan is paid off in equal monthly installments (i.e. period = 1 month)?
2. What will be the payment per period if the loan is paid off in equal semi-annual installments (i.e. period = 6 months)?
3. Is there any advantage to choosing method 1 or 2 above? Explain your answer.

Problem 2 (20%)

A company must purchase a reactor. Two choices are available:

	Reactor 1	**Reactor 2**
Total capital investment	$10,000	$20,000
Operating Expenses (Not including depreciation)	$3,000/yr	$2,000/yr
Salvage value	0	0
Expected life	10 years	10 years
Interest rate = 15% **Tax rate = 50%**		

Both reactors provide same service.

a. Which reactor should be chosen based on a venture profit analysis?

b. Which reactor is recommended based on a net present worth analysis?

(100)

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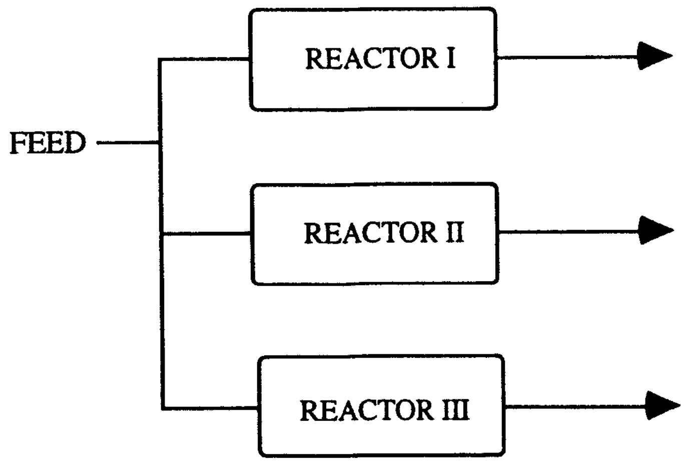
Problem 3 (15%)

A process has three reactors operating in parallel as shown:



The Reactions taking place are $A \rightarrow P_1$ and $A \rightarrow P_2$. The capacity of each reactor and the product yields are given below:

	REACTOR 1	REACTOR 2	REACTOR 3
Maximum Feed Capacity (lbs/day)	5,000	5,000	5,000
Yield of P_1 (lb of P_1 produced/lb A consumed)	.40	.30	.50
Yield of P_2 (lb P_2/lb A)	.60	.70	.50

Note: All A is consumed in the reactors.

10,000 lbs/day of total feed is available. All of this must be processed.

The prices of feed and products are:

Feed	\$0.40/lb
Product, P_1	\$0.60/lb
Product, P_2	\$0.30/lb

Maximum demand for P_1 is 4,000 lb/day and maximum demand for P_2 is 7,000 lb/day. Lesser amounts may be produced but all feed available must be processed.

Formulate an optimization problem which will maximize the profit. Neglect operating costs. The only cost involved is the cost of raw material.

a. Define variables
b. Show objective function
c. Show all equality constraints, inequality constraints and variable bounds.

A solution to the optimization problem is not needed.

Solution To Test 3

Problem 1

Amount borrowed = \$900 K − \$100 K

= \$800 K.

Interest rate = 10 %/yr nominal compounded monthly

$i = 0.1$, $k = 12$

$i_p = i/k$

$= \frac{10\ \%}{12}$ per month

$= 0.008333$ /month

$= i_p$

number of payments $= n =$ 10 years × 12

$= 120$

Using the Annuity Formula

$$P = R \cdot \frac{(1+i_p)^n - 1}{i_p(1+i_p)^n}$$

$$= R \frac{[1 + i/k]^n - 1}{\frac{i}{k}(1 + i/k)^n}$$

$$\$800{,}000 = R \cdot \left\{ \frac{[1 + .10/12]^{120} - 1}{(1 + .10/12)^{120} \cdot (\frac{.10}{12})} \right\} = 75.67\ R$$

$$\boxed{R = \$10{,}571 / \text{month}}$$

Total payments = \$1.268 million

Problem 1, part 2

First calculate the interest per period

Let ~~ip = interest~~ i_6 = interest per six month period

i_1 = " " month = $.10/12$

Then

$$1 + i_6 = (1 + i_1)^6$$

$$= (1 + .10/12)^6$$

$$= 1.05105$$

or $i_6 = .05105$

$= 5.1\%$ per 6 months.

No of payments = 10 years × 2 times/yr

= 20 = n

R_6 = payment per period (6 months)

$$\therefore P = R_6 \frac{(1+i_6)^n - 1}{(1+i_6)^n \cdot i}$$

$$800{,}000 = R_6 \frac{(1+.05105)^{20} - 1}{(1+.05105)^{20} \cdot (.05105)}$$

$$= R_6 \cdot (12.352)$$

or $R_6 = \$64{,}764$

Total payments = $1.2952 million

Problem 1, part 3

If company makes 10% return/yr on its investments then ~~a~~ both forms of payments are equivalent.

If company earns less than 10% return then it is better to use the monthly payment. Otherwise use ~~6 month~~ semiannual payments.

Solution to Problem 2

(a) Venture Profit Analysis.

Let x be the sales income.

Then

		Reactor I	Reactor II
1.	Op. Income, \$/yr	x	x
2.	Op. Exp., \$/yr	3,000	2,000
3.	Gross Profit \$/yr (1-2)	$x - 3000$	$x - 2000$
4.	Depreciation, "	1000	2000
5.	Net Profit before Tax (3-4)	$x - 4000$	$x - 4000$
6.	Net Profit After Tax .5 (3-4)	$.5x - 2000$	$.5x - 2000$
7.	Net Cash Flow (6+4)	$.5x - 1000$	$.5x$
8.	Net Interest Charge .15 × I	1,500	3,000
9.	Venture Profit (6) − (8)	$.5x - 3500$	$.5x - 5000$

∴ Reactor I is better by \$1,500/yr

(b) Present Worth Analysis

<u>Net Present Worth using Reactor I</u>

Cash flows : $-10,000$ year 0

$+(.5x-1000)$/yr for 10 years

Applying annuity formula (15% interest) to

$$NPW_I = -10,000 + (.5x-1000)\left[\frac{(1.15)^{10}-1}{(1.15)^{10}(0.15)}\right]$$

$$= 2.51x - 15000$$

<u>NPW for Reactor II</u>

$$NPW_{II} = -20,000 + (.5x)\left[\frac{1.15^{10}-1}{(1.15)^{10}(.15)}\right]$$

$$= -20,000 + 2.51x$$

∴ Again Reactor I increases NPW by \$5000

R-I is better choice

Solution to Problem 3

Let F_1 = feed of A lbs/~~hr~~day to R1
F_2 = ,, ,, R2
F_3 = ,, ,, R3

Then

Processing Requirement ① $F_1 + F_2 + F_3 = 10000$ lbs (equality)

Reactor Capacity limit

② $0 \le F_1 \le 5000$ ~~$F_1 \ge 0$ 10,000~~ Variable bound

③ $0 \le F_2 \le 5000$ ~~10,000~~ ,,

④ $0 \le F_3 \le 5000$,,

Demand Constraint on Product P_1 ⑤ $0.4F_1 + .3F_2 + .5F_3 \le 4000$ (Inequality)

" " P_2 ⑥ $.6F_1 + .7F_2 + .5F_3 \le 7000$ (Inequality)

Objective Function

~~Profit = 0~~

Amount of P_1 produced $= .4F_1 + .3F_2 + .5F_3$

,, P_2 ,, $= .6F_1 + .7F_2 + .5F_3$

$\text{Max}\{\text{Profit}\} = (\$.6/lb)(.4F_1 + .3F_2 + .5F_3) +$