Key

Mid Term Exam **ChE 473 K** **Fall 1997**

<u>Problem No. 1 (20 pts)</u>

As a process engineer, you determine the following data for one of your projects:

- Land cost - $ 100,000 two years before start-up
- Construction costs - $100,000 per year spread evenly over the two years before start-up.
- A lump sum payment for a patent made one year before start-up of $500,000 is required.
- After tax cash flow (including depreciation) - $ 1,000,000 / yr for the first five years of project and $ 600,000 for the sixth year (final) of the project.

Determine: The present worth of the project at 20 % continuous interest.

<u>Problem No. 2 (80 pts)</u>

You are assigned the following project to dispose of a stream of waste acid sludge. You determine the following information and data.

- The stream amounts to 150 tons / day of 15 wt % H2SO4. The other 85 wt % is mostly water, but there is sufficient "gunk" to make the stream highly viscous at ambient temperatures. The specific gravity of this stream is 1.1 and its heat capacity is 1.08 BTU/lb F.

- Caustic will be used to neutralize the acid stream.

- A stirred-tank reactor will be used for neutralization. Because of the "gunky" nature of the acid waste, additional agitation will be required. Laboratory tests have indicated a 10 Hp, carbon steel dual-impeller, 50 RPM turbine mixer will be required for each 300 gallons of reactor volume. These agitators are in addition to the normal agitation system which comes with the stirred-tank reactor.

  The reactor should be sized to provide a 30 minute retention time based on <u>total</u> feed to the reactor.

- The caustic will be delivered to the project as a 40 % NaOH solution (Sp. Gr = 1.43) in 5,000 gallon tank trucks. Delivery is 8:00 to 5:00 weekdays only, with no night, weekend, or holiday delivery. The caustic is to be off-loaded into a large holding tank.

- The caustic is to be transferred to a reactor feed tank where it is diluted to 20 % NaOH (Sp. Gr. = 1.23) by continuous dilution with water. The dilution tank should provided 1 hour retention and be agitated.

- Laboratory tests have indicated the neutralization reaction will occur more readily if the "gunky" waste acid sludge is heated from its production temperature of 70 F to 120 F before neutralization. Waste steam at 220 F is available, and tests on the material have indicated a heat transfer coefficient of no more than 50 BTU/hr ft2 F. The waste acid is at a pressure sufficient to get it through the exchanger and to the reactor without a pump.

- From the reactor the effluent is to be pumped to the waste treatment area of the plant. The treatment area is at the same elevation as the neutralization unit, but is roughly three miles away.

- For the transfer of 40 % caustic from the storage to the dilution tank there are two diaphragm pumps in storage. These are available to the project at no cost.

- The reactor caustic feed pump(s) for feeding the 20 % caustic to the reactor should be diaphragm pump(s) and must be purchased.

- The process must operate round-the-clock, 330 days per year.

- This neutralization unit will be an "add-on" to the existing unit and will not require site preparation, control house, etc.

- Assume carbon steel for all pieces of equipment.

Solution:

1. Generate a flow sheet for the process showing all equipment items with names and numbers.

2. Determine the mass balance for the process showing for each stream the component flows and total flows in lb /hr.

3. Determine the project FCI in late 1998 dollars.

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Problem No 1

Given: Land $100,000 (-2 yrs)

Construction $200,000 (-2 to 0 yrs)

Patent $500,000 (-1 yr)

Cash Flow $1,000,000/yr (0-5 yrs)

$600,000/yr (6 yr)

Find: PW @ 20%

Land	-100,000	(1.492)	=	-$149,200
Cost	-100,000	(2) (1.23)	=	-$246,000
Patent	-500,000	(1.221)	=	-$610,500
CF (1-5)	1,000,000 (5)	(0.632)	=	$3,160,000
CF (6)	600,000	(0.3334)	=	$200,040

NPV => **$2,354,400**

Problem No. 2

Given: Waste Acid 150 Ton/Day @ 15% H_2SO_4

$Sp\ gr = 1.1$, $C_p = 1.08\ \frac{BTU}{lb\,°F}$

Neutralize in stirred tank reactor
Add. Agitation 1 10Hp 50 RPM / 300 gal

Reactor – 30 minute residence time

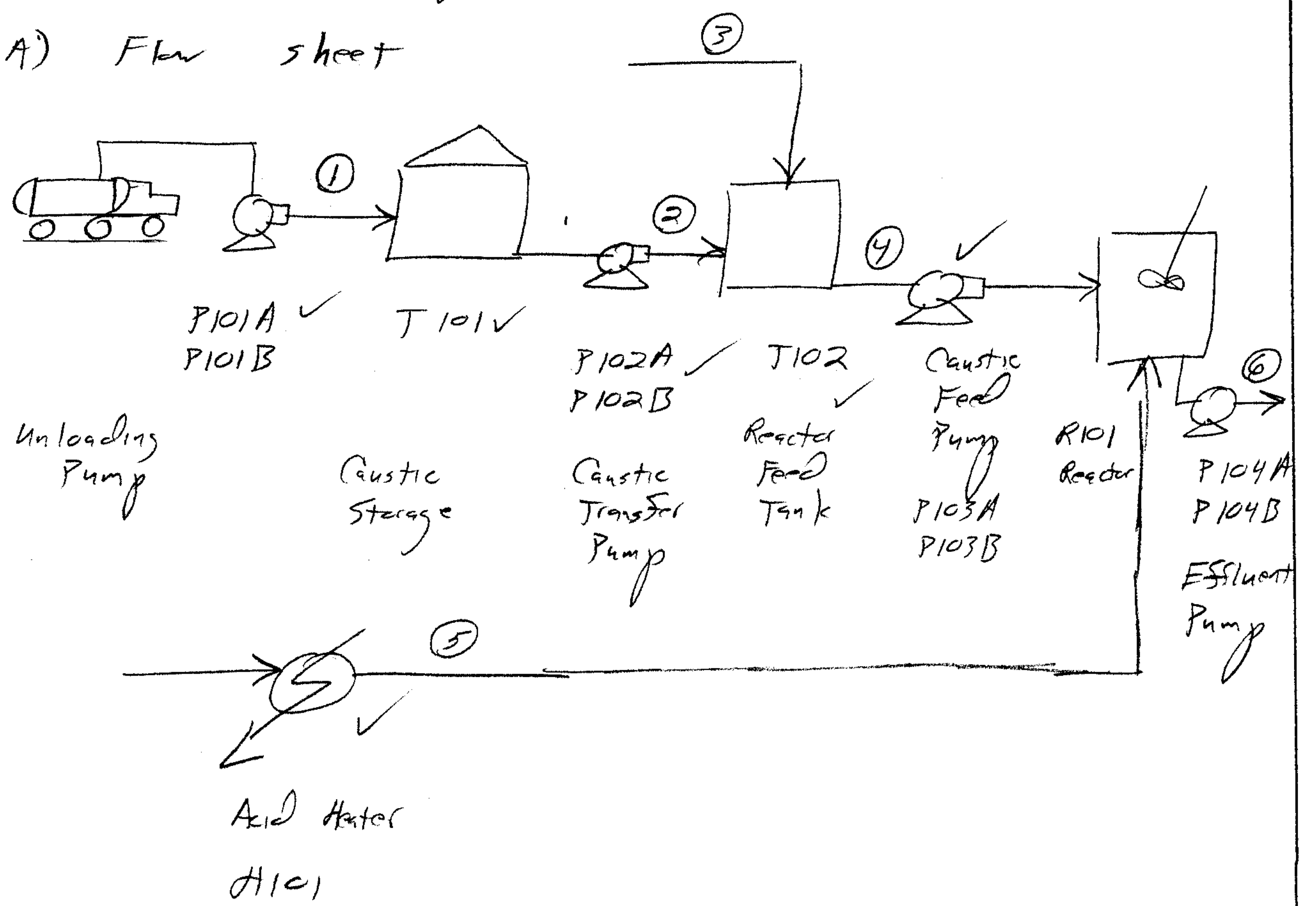
Caustic delivered @ 40% NaOH $Sp\ gr = 1.43$
in 5000 gal trucks

Caustic diluted to 20% $Sp\ gr = 1.23$

Heat waste acid from 70°F → 120°F
with 220°F waste steam. $U = 50\ \frac{BTU}{lb\,°F\,ft^2}$

Effluent pumped 3 miles

A) Flow sheet



B) Material Balance

Waste acid stream (5)

$150 \frac{Ton}{Day} \left(2000 \frac{lb}{Ton}\right)\left(\frac{1 D}{24 hr}\right) = 12,500 \ lb/hr$

Acid in stream = 12,500 lb/hr (0.15) = 1875 lb/hr

Waste Acid [Gunk + H_2O]

12,500 (0.85) = 10625 lb/hr

$$\underset{(40)}{2 NaOH} + \underset{(98)}{H_2SO_4} \rightarrow \underset{(142)}{Na_2SO_4} + \underset{(18)}{2 H_2O}$$

NaOH Req'd

$1875 \ lb/hr \left(\frac{80}{98}\right) = 1530 \ lb/hr$

Na_2SO_4 Produced $1875 \left(\frac{142}{98}\right) = 2720 \ lb/hr$

H_2O Produced = $1875 \left(\frac{36}{98}\right) = 690 \ lb/hr$

Caustic req'd (40%) $1530 \left(\frac{1}{0.40}\right) = 3825 \ lb/hr$

- Dilution H_2O -

0.20 (Dilute sol'n) = 1530 lb/hr

$\frac{1530}{0.20} = 7650 \ lb/hr$

Dilute H_2O Added = 7650 - 3825 = 3825 lb/hr

Tank Trucks

Gap 3 pm Friday to 10 AM Tuesday (Holiday on Monday)

⇒ 91 HRS

Caustic req'd @ 40%

$\frac{3825 (91)}{8.33 (1.43)} = 29,200$ gals say 30,000 gals

TOPS 35500

Unload Truck in 50 minutes

$$Flow = \frac{5000}{50} = 100 \text{ GPM}$$

Reactor Discharge H_2O

3825 (0.60) + 3825 + 10625 + 690 = **17,435 lbs**

From Dilution tank to reactor 20% Caustic

NaOH = 1530

$$Total = \frac{1530}{0.20} = 7650$$

H_2O = 2295 + 3825 = 6120

Equipment

P 101 A / 101 B — Caustic unloading pump — $ 1550 / 300 — $ 1550 / 300

100 GPM @ 60 ft Head

Fig 14-40 pg 526
Fig 14-54 pg 523

T101 — Caustic Storage — $ 40,000

30,000 gal Fig 14-56 pg 539

P102 A / 102 B — Caustic Transfer — Available

T102 — Reactor Feed tank (Dilution Tank) — $ 10,000

$$5.4 \text{ GPM} + \frac{3825}{8.33(60)} = 13 \text{ GPM}$$

13 GPM (60 min) = 780 gal

say 800 gal

Fig 14-56 p 539

TOPS 35500

P 103 A
103 B

Caustic Feed pump

13 GPM Diaphragm

Fig 14-43 pg 528

$3000

$3000

H101, Acid Heater

$$Q = 12{,}500 \frac{lb}{hr}\left(1.08 \frac{BTU}{lb\ °F}\right)(120-70) = 675{,}000 \frac{BTU}{hr}$$

$$\Delta T_{Lm} = \frac{(220-120)-(220-70)}{\ln\left(\frac{100}{150}\right)} = 123\ F$$

$$A = \frac{675{,}000 \frac{BTU}{hr}}{123\ F\left(50 \frac{BTU}{hr\ ft^2\ °F}\right)} = 110\ ft^2$$

Fig 15-13 pg 616

$4500

P104 A
104 B

Effluent Pumps

$$Flow = 13\,GPM + \frac{12500}{8.33(1.1)60}$$

$$13 + 22.7 = 35.7\ GPM$$

$$Head = \frac{5280\ ft}{mi}(3\ mi)\left(\frac{0.5\ ft\ Head}{100\ ft\ Run}\right) \cong 80\ ft$$

Fig 14-40 pg 526

3HP Fig 14-54 pg 533

$1600
$200

$1600
$200

TOPS 35500

R 101 Reactor

Volume 35.7 GPM (30 min) = 1071 gal — **$ 10,500**

Agitators $\frac{1071}{300}$ = 3.57 = 4.0

Purchase 5 need 4

Fig 14-57 pg 540

10 Hp $9500 (5) => **$ 47,500**

Total Equipment **$ 125,800**

Lang Factor

	Deliver	Install	1998/1990	Costing	Lang
125,800	(1.1)	(1.05)	(1.28)	(1.20)	(4.74)

= $1.06 mm