Key

Mid-term Exam **ChE 473 K** **Fall 1996**

Problem No. 1 (50 points)

A sketch of a system for neutralization of 100 TPD of 15 percent sulfuric acid (specific gravity = 1.1) is attached. The acid is to be neutralized by lime slurry, 40 percent $Ca(OH)_2$, which is received by 5000 gallon tank truck. Specific gravity of the 40 percent slurry is 1.34. The lime company will make deliveries daily except weekends.

The 40 percent slurry is diluted to 20 percent (specific gravity = 1.15) in the dilution tank by adding process water. Transfer of the slurry from the storage tank to the dilution tank is made once per day during the day shift.

The neutralization tank is a stainless steel-lined agitated tank providing 30 minutes retention time. The filter is a continuous vacuum drum of stainless steel construction and of 100 ft^2 area. The solids leaving the filter contain 50 percent moisture in addition to the combined water.

Estimate the fixed capital investment (FCI) for the system in 1998 dollars by the Lang method.

Problem No. 2 (50 points)

Your company has the opportunity to purchase 10,000 B/CD of hydrocarbon liquids from a nearby producer for $ 21 / bbl. The stream is composed of 50 % gasoline components and 50 % heating oil components. Because all of your distillation towers are at capacity, a new column and auxiliaries will have to be constructed at a cost of $ 5,000,000. A simulation of the tower operation reveals that adequate separation can be achieved at a reflux ratio of 1.0 with a corresponding condenser duty of 25 mm BTU/hr and a reboiler duty of 40 mm BTU / hr. Labor for the new column will amount to $ 400,000 per year and maintenance costs are estimated to be $ 500,000 per year.

The spread between gasoline and heating oil is estimated at 2 cents per gallon for the next five years (i.e. gasoline will sell for 2 cents per gallon more than heating oil). For the project life of five years, straight line depreciation, and a tax rate of 50 %, determine the required selling price (i.e. the internal transfer price to the marketing department) for the heating oil and the gasoline in order for the project to realize a 25 % IRR.

Assume 365 days per year operation and a construction period of one year.

Cost information:	Cooling water	$ 0.06 / 1000 gal
	Steam	$ 4.50 / mm BTU

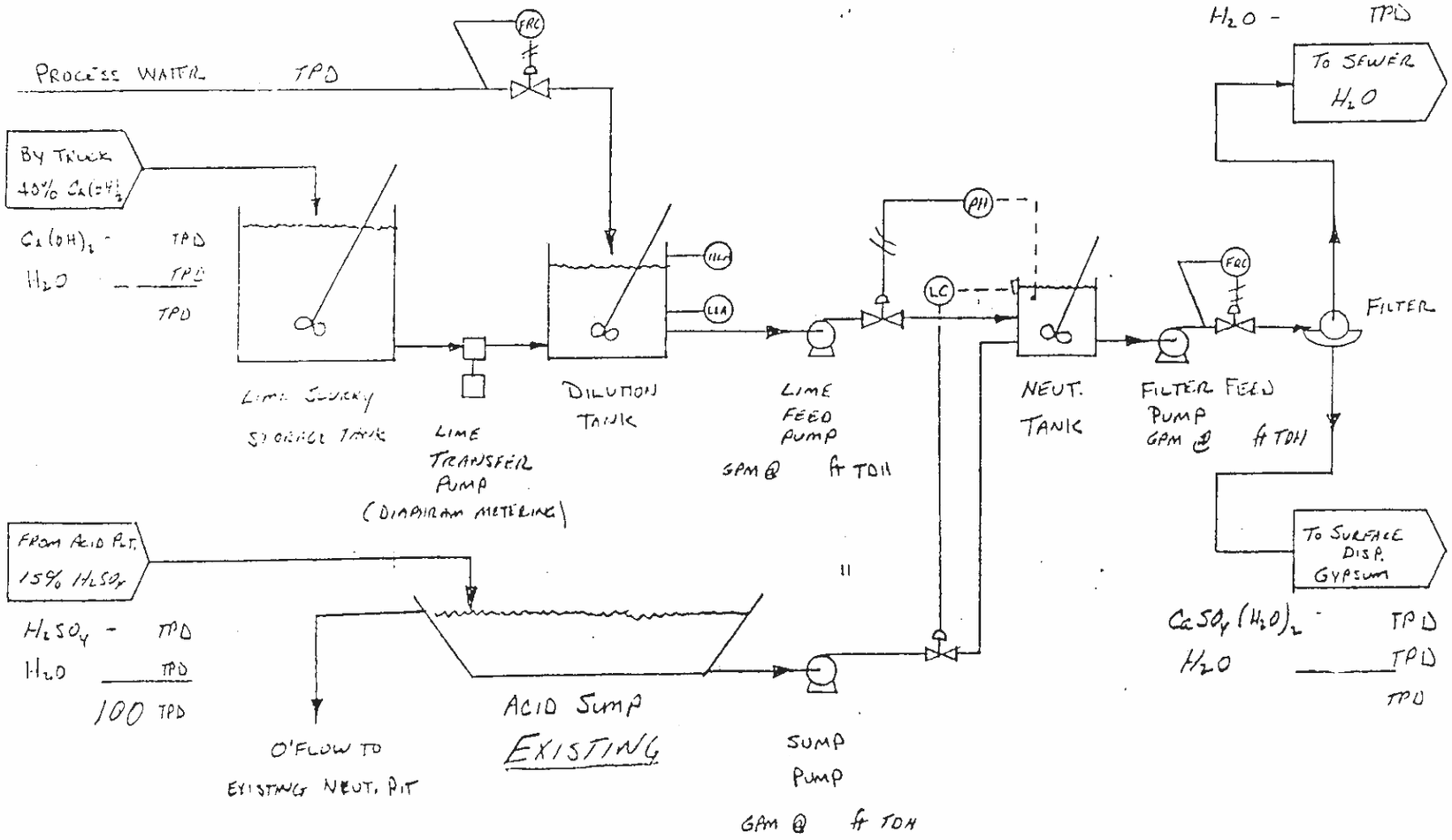

FIGURE 1 - LIME SLURRY NEUTRALIZATION SYSTEM

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OF

Exam #1 Mid-Term
Fall 1996

RBE

Problem #1

Solution

RxN

(98) (74) (172)
$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4(2H_2O)$

Amt of $Ca(OH)_2$

$$100 \frac{ton}{day}\left(\frac{0.15\ ton\ H_2SO_4}{1\ ton\ soln}\right)\left(\frac{2000\ lb}{1\ ton}\right)\left(\frac{1\ lbmol}{98\ lb}\right)\left(\frac{1\ lbmol\ Ca(OH)_2}{1\ lbmol\ H_2SO_4}\right)$$
$$\left(\frac{74\ lbs\ Ca(OH)_2}{1\ lbmol\ Ca(OH)_2}\right) = 22{,}650 \frac{lb\ Ca(OH)_2}{day}$$

As 40% slurry $\frac{22{,}650\ lb\ Ca(OH)_2}{day}\left(\frac{1}{0.40}\right) = 56{,}630 \frac{lb\ soln}{day}$

Lime slurry

22,650	lb/day	$Ca(OH)_2$
33,980	lb/day	H_2O
56630	lb/day	Total

Slurry storage tank 3 days

$$56630 \frac{lb}{day}\left(3\ day\right)\left(\frac{1\ gal}{8.33(1.34\ lb)}\right) = 15{,}200\ gal$$

Lime Transfer pump (Transfer once per day)

$$\frac{Volume}{time} = 5073 \frac{gal}{day}\left(\frac{1\ day}{480\ min}\right) = 10.6 \frac{Gal}{min}$$

All transfer done during 8 hr shift

Dilution tank (1 day residence time)

Holds Slurry + water

$$5073 \text{ gal} + \frac{56630 \text{ lb}}{8.33 \text{ lb/gal}} = 11870 \text{ gal}$$

Water flowrate = 14.2 gal/min

Acid flowrate

$$\frac{100 \text{ TPD}\ (2000)}{8.33\ (1.1)(1440)} = 15.2 \text{ GPM}$$

Lime Sludge pump (continuous operation)

Slurry $5073 \frac{\text{gal}}{\text{day}} \left(\frac{1 \text{ day}}{1440 \text{ min}}\right) + \frac{56630 \text{ lb}}{8.33 \text{ lb}} \frac{\text{gal}}{\text{day}} \left(\frac{1 \text{ day}}{1440 \text{ min}}\right)$

Lime pump = $3.5 \frac{\text{gal}}{\text{min}} + 4.7 \frac{\text{gal}}{\text{min}} = 8.3 \frac{\text{gal}}{\text{min}}$

Neutralization tank (Acid + Base) 30 min RT

15.2 + 8.3 = 23.5 gal/min

Volume = $23.5 \frac{\text{gal}}{\text{min}} (30 \text{ min}) = 705 \text{ gal}$

Say 750 gal

Filter Seed pump

Flowrate = 23.5 gal/min

Filter 100 ft² Area

Acid Pump

	Item	Size	R.S	1990 Cost (#2196 CE)
①	Acid Pump	15 GPM 50' Head (55)	14-40	~~1220 (1.80)~~ CE
		Motor = 1Hp	14-54	250 CE
②	Slurry tank	15,200 gal	14-56	25,000 CE
③	Lime trans pump (Diaphram)	10.6 GPM, 50' Head	14-40	2500 CE
④	Dilution tank	12,000 gal	14-56	22,000 CE
⑤	Lime Seed pump	8.3 GPM, 50' Head	14-40	1220 CE
		Motor 1 Hp	14-54	250 CE
⑥	Neut tank	750 gal (55)	14-56	15000 CE
⑦	Filter Seed pump	23.5 GPM	14-40	#1220 CE
		motor 1Hp	14-54	650 CE
⑧	Filter	100 ft²		#100,000 CE
	Total Equipment			#169,886 CE

FCI

169,886 (1.10) (390/358) (4.74) (1.15) = $1.10 mm

Delivered 1990-1995 Long Cent

Problem #2

Costs: Raw Material

$$10{,}000 \frac{BBL}{D}\left(365 \frac{D}{yr}\right)\left(\$21/BBL\right) = \$\ 76{,}650{,}000$$

Cooling Water

$$\$ = 25 \times 10^6 \frac{BTU}{hr}\left(365 \frac{Day}{yr}\right)\left(\frac{24\,hr}{Day}\right)\left(\frac{1\,lb\,of}{1\,BTU}\right)\left(\frac{1}{30\,F}\right)\left(\frac{lb\,al}{8.33\,lb}\right)\left(\frac{\$0.06}{1000\,gal}\right)$$

$$\$ = 52{,}580 / yr$$

Steam $\quad 40 \times 10^6 \frac{BTU}{hr}\left(365 \frac{day}{yr}\right)\left(24 \frac{hr}{day}\right)\left(\$4.50/10^6 BTU\right)$

$$\$ = 1{,}577{,}000$$

Labor = \$ 400,000

Maintenance \$ 500,000

Op Expense = \$ 79,180,000

X = Heating oil sales price

$X + 0.02$ = gasoline sales price

Revenue $\quad X(5000)(42)(365) + (X+0.02)(42)(365)(5000)$

$$= 153{,}300{,}000\,X + 1{,}533{,}000$$

Dep ↓ Cash Flow ↙

$CF = 0.50\,(1{,}000{,}000) + 0.5\,[153{,}300{,}000X + 1{,}533{,}000 - 79{,}180{,}000] =$

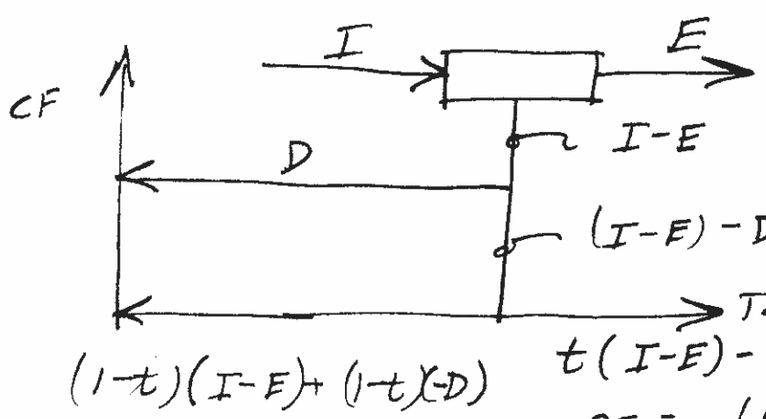
Cash Position

Year	Item		Uniform	25% Factor	
-1 to 0	FCI				$-5{,}000{,}000\ (1.136) = -5{,}680{,}000$
0 to 5	Cash flow	$5(76{,}500{,}000X - 38{,}323{,}500)\ (0.571)$			
		$= 218407500X - 109413593$			
		$\Sigma = 0$			

$-5{,}680{,}000 + 218407500X - 109413593 = 0$

$X = 0.527$ 52.7 ¢/gal Heating oil

54.7 ¢/gal Gasoline



$CF = (1-t)(I-E) + tD$