PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Midterm Examination : Semester II — Academic Year : 2004

Date : 22 December 2004 — Time : 09.00 – 12.00

Subject : 230 - 432 Chemical Engineering Plant Design — Room : A 401

Student Name: ..... Code : .....

Number of questions : 4

Time : 3 hours

Total marks : 120

Books and notes are not allowed

Calculators and writing in pencil are allowed.

Question	Full Marks	Marks Received
1	30	
2	40	
3	20	
4	30	
Total	120	

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

1) a) Please provide design steps for the development of a design project for a chemical plant.

(10 marks)

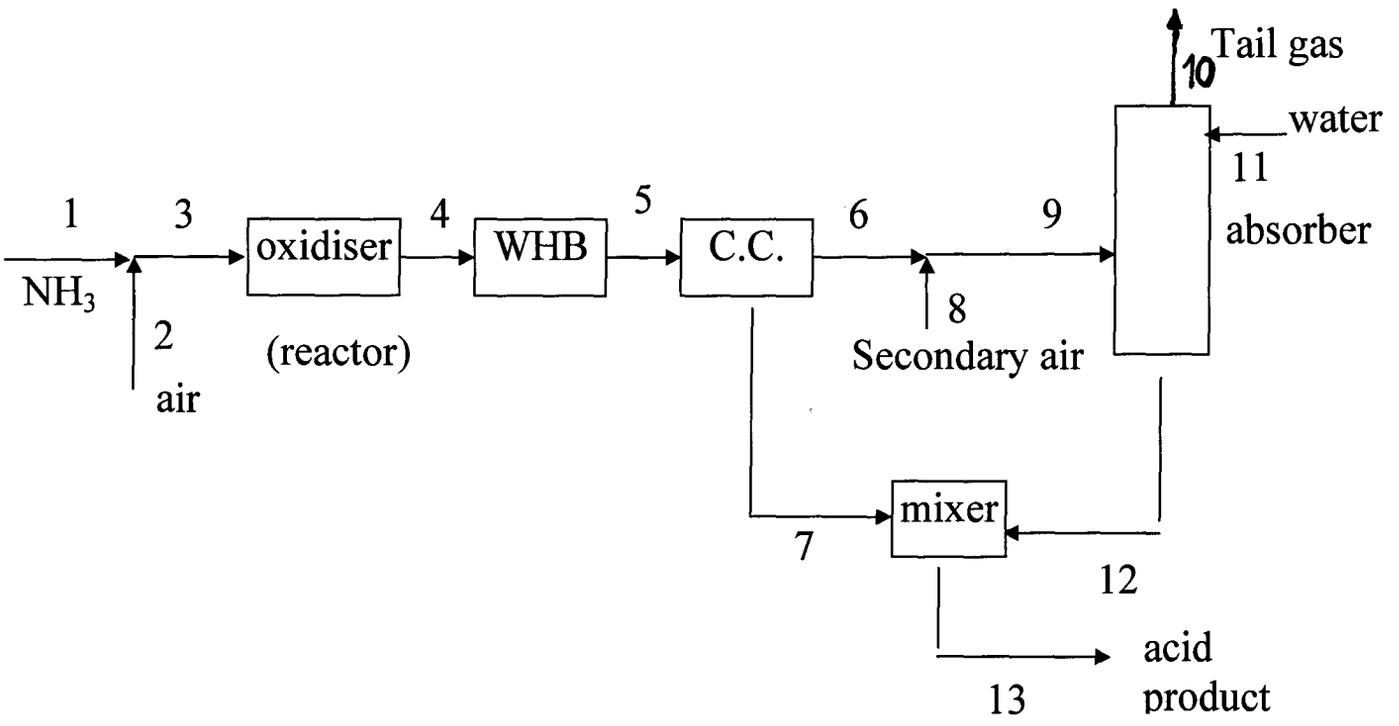
b) Please provide factors that should be considered in choosing a process from different process alternatives.

(10 marks)

c) Please provide factors that should be considered in selecting a plant site or location.

(10 marks)

2) a) Nitric acid process using oxidation of ammonia at 8 bar is described below.



Principal Reactions:

Reaction 1

$$NH_3(g) + \frac{5}{4} O_{2(g)} \text{ ----> } NO(g) + \frac{3}{2} H_2O(g) \quad \Delta H_r^0 = -226{,}334 \text{ kJ/kmol}$$

Reaction 2

$$NH_3(g) + \frac{3}{4} O_2(g) \text{ ----> } \frac{1}{2} N_2(g) + \frac{3}{2} H_2O(g) \quad \Delta H_r^0 = -316{,}776 \text{ kJ/kmol}$$

Reaction 3

$$NH_3 + \frac{3}{2} NO(g) \text{ ----> } \frac{5}{4} N_2(g) + \frac{3}{2} H_2O(g) \quad \Delta H_r^0 = -452{,}435 \text{ kJ/kmol}$$

Reaction 4

$$NO(g) + \frac{1}{2} O_2(g) \text{ ----> } NO_2(g) \qquad \Delta H_r^0 = -57{,}120 \text{ kJ/kmol}$$

Reaction 5

$$3\ NO_2(g) + H_2O\ (l) \text{ ----> } 2\ HNO_3(l) + NO(g) \qquad \Delta H_r^0 = \text{not known}$$

Reaction 6

$$2\ NO_2(g) + H_2O(l) + \frac{1}{2} O_2\ (g) \text{ ----> } 2\ HNO_3(l) \qquad \Delta H_r^\circ = -127.28 \times 10^3 \text{ kJ/kmol}$$

	Stream 4
Component	kmol/h
O_2	43.8
N_2	464.4
NO	61.95
H_2O	96.75

Temp, T_4 = 1180 K, T_5 = 507 K

At the WHB 10% of NO is oxidised to NO_2. The heat content of stream 4 and 5 are 19.05 and 29.17 GJ/h respectively. The feed water temperature to the WHB is 293 K with enthalpy 84 kJ/kg. The plant steam produced is saturated steam at 11 bar, 457 K with enthalpy 2781 kJ/kg.

a.1) Calculate the amount of steam produced in kg/h.

a.2) What are the factors that can affect the amount of steam produced?

a.3) What are the safety factors that should be included in making this process design?

a.4) If you are asked to design the absorber for this process what are the details you should specify for the fabrication or construction of the column?

(25 marks)

2) b) Synthesis of methanol from carbon monoxide and hydrogen by the reaction

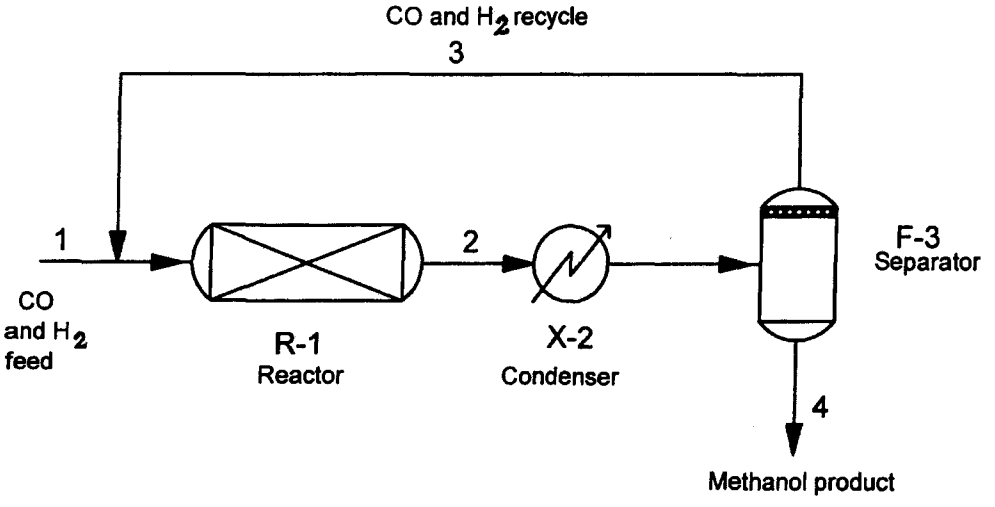
$$CO + 2H_2 \rightarrow CH_3OH$$

Carbon monoxide feed rate = 100 mol/h

Reactor conversion per pass is 0.4

The separator gives perfect separation between reactants and products.

There is no purge.



Write a spread sheet program by filling in cells in a provided spreadsheet to estimate the flow rates of CO and CH_3OH in streams 2, 3 and 4. Explain criteria used for performing iterations.

(15 marks)

3) Three raw materials, ethylene (C_2H_4), oxygen (O_2), and acetic acid (HAc) react and are converted into the vinyl acetate (VAc) product. An inert component ethane (C_2H_6) enters with the fresh ethylene feed stream. The two following exothermic reactions occur.

$C_2H_4 + CH_3COOH + ½\ O_2$ -----> $CH_2{=}CHOCOCH_3 + H_2O$ ------- (1)

ethylene acetic acid vinyl acetate

$C_2H_4 + 3O_2$ -----> $2CO_2 + 2H_2O$ ------- (2)

The ethylene and oxygen feed streams come from supply headers. Acetic acid comes from a storage tank. The reactor contains tubes packed with metal catalyst on silica support. Heat is removed from the reactor by generating steam on the shell side of the tubes. Boiler-feed-water (BFW) is supplied as make-up water. The steam leaves the steam drum as saturated vapor.

The reactor effluent flows through a process-to-process heat exchanger called the feed-effluent heat exchanger, where the cold stream is the recycle gas. The reactor effluent is then cooled with cooling water and the vapor (oxygen, ethylene, carbon dioxide, ethane) and liquid (vinyl acetate, water, acetic acid) are separated. The vapor stream from the separator goes to the compressor and the liquid stream from the separator becomes a part of the feed to the azeotropic distillation column. The gas from the compressor enters the bottom of an absorber, where the remaining vinyl acetate is recovered. A liquid stream from the base is recirculated through a cooler and fed to the middle of the absorber. Liquid bottoms product from the absorber combines with the liquid from the separator as the feed stream to the distillation column.

Part of the overhead gas exiting the absorber enters the carbon dioxide removal system. This could be one of the several standard industrial CO_2 removal processes. The gas stream which has been removed for carbon dioxide is split, with part going to the purge for removal of the inert ethane from the process. The rest combines with the large recycle stream and goes to the feed-effluent heat exchanger. The fresh ethylene feed stream is added. The recycle gas stream, the fresh acetic acid

feed, and the recycle liquid acetic acid stream enter the vaporizer, where steam is used to vaporize the liquid. The gas stream from the vaporizer is further heated to the desired reactor inlet temperature in a trim heater using steam. Fresh oxygen is added to the gas stream from the vaporizer just prior to the reactor to keep the oxygen composition in the gas recycle loop outside the explosivity region.

The azeotropic distillation column separates the vinyl acetate and water from the unconverted acetic acid. The overhead product is condensed with cooling water and the liquid goes to a decanter, where the vinyl acetate and water phases separate. The organic product contains 95 mol% of vinyl acetate while the aqueous product contains 95 mol% of water. The organic and aqueous products are sent for further refining to another distillation section. The bottom product from the distillation column contains acetic acid, which recycles back to the vaporizer along with fresh make-up acetic acid. Part of this bottoms stream is the wash acid used in the absorber after being cooled.

The carbon dioxide is released to the atmosphere. The gas purge stream is sent to a thermal converter. The vinyl acetate and water products from the decanter are fed to other distillation columns in the refining train.

If you are one of the members of the process design team, draw a flowsheet diagram for the above process. The process description has been obtained from literature survey. The chief project engineer will need it for his meeting with the company board of directors next week.

(20 marks)

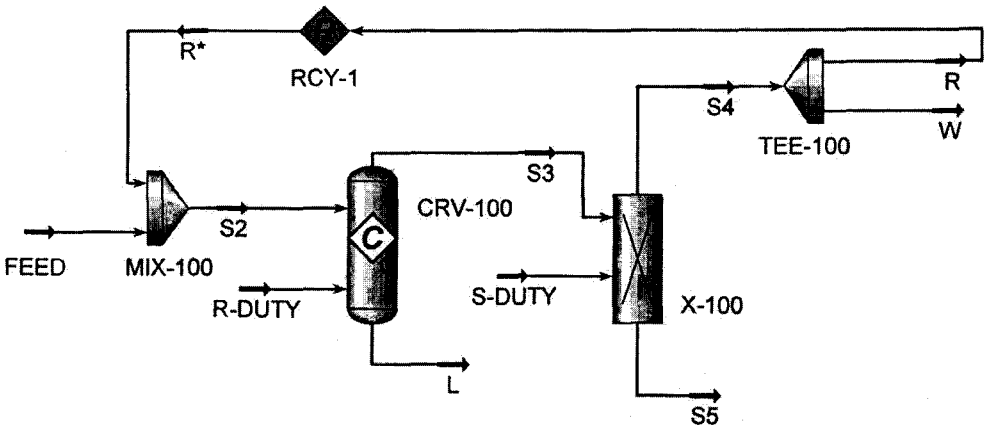
4) a) What are the basic environments that work in HYSYS? What are the information included in the Fluid Package in HYSYS?

(5 marks)

b) Ethyl chloride is produced by the gas-phase reaction of HCl with ethylene over a cooper chloride catalyst supported on silica at 25°C, 1 atm.

$$C_2H_4 + HCl \rightarrow C_2H_5Cl \text{ ethyl chloride}$$

In this process ethylene contains nitrogen impurity.



Material Streams — Fluid Pkg: All

Name	FEED	R*	S2	S3	L
Vapour Fraction	1.0000	1.0000	1.0000	1.0000	0.0000
Temperature (C)	25.00 *	25.00 *	25.00	25.00 *	25.00
Pressure (kPa)	101.3 *	101.3 *	101.3	101.3	101.3
Molar Flow (kgmole/h)	100.0 *	0.9630 *	101.0	57.46	0.0000
Mass Flow (kg/h)	3226	31.06	3257	3257	0.0000
Liquid Volume Flow (m3/h)	5.678	4.972e-002	5.728	3.830	0.0000
Heat Flow (kJ/h)	-2.110e+006	-2.706e+004	-2.137e+006	-5.262e+006	0.0000

Name	S4	S5	W	R
Vapour Fraction	1.0000	1.0000	1.0000	1.0000
Temperature (C)	25.00 *	25.00 *	25.00	25.00
Pressure (kPa)	101.3 *	101.3 *	101.3	101.3
Molar Flow (kgmole/h)	13.96	43.50	13.00 *	0.9630
Mass Flow (kg/h)	450.3	2806	419.3	31.06
Liquid Volume Flow (m3/h)	0.7209	3.109	0.6712	4.972e-002
Heat Flow (kJ/h)	-3.924e+005	-4.870e+006	-3.653e+005	-2.706e+004

Compositions — Fluid Pkg: All

Name	FEED	R*	S2	S3	L
Comp Mole Frac (HCl)	0.5000 *	0.5000 *	0.5000	0.1215	0.0074
Comp Mole Frac (Ethylene)	0.4800 *	0.3462 *	0.4787	0.0841	0.0031
Comp Mole Frac (CIC2)	0.0000 *	0.0000 *	0.0000	0.7570	0.9894
Comp Mole Frac (Nitrogen)	0.0200 *	0.1538 *	0.0213	0.0374	0.0001

Name	S4	S5	W	R
Comp Mole Frac (HCl)	0.5000	0.0000	0.5000	0.5000
Comp Mole Frac (Ethylene)	0.3462	0.0000	0.3462	0.3462
Comp Mole Frac (CIC2)	0.0000	1.0000	0.0000	0.0000
Comp Mole Frac (Nitrogen)	0.1538	0.0000	0.1538	0.1538

Energy Streams — Fluid Pkg: All

Student Name: ..... Code : .....

Operation type:	MIX-100	Mixer
	CRV-100	Conversion reactor
	X-100	Component splitter
	TEE-100	Tee (purge)
	RCY-1	Recycle (operator for HYSYS)

(b.1) Describe the procedure for drawing and simulation of this process flow diagram by HYSYS simulation program.

(b.2) Determine the % conversion of the reactor and the % purge at the component splitter.

(b.3) Calculate the heat flow of energy stream S-DUTY in kJ/h.

(25 marks)

Answer to Q4.