B. Joseph **ChE 477** **Fall 2000**

Test 1

Closed Book, 55 minutes.

Up to 3 points given as bonus for neatness, clarity and organization of solution.

Problem 1 (10 points)

A 100 million lbs./year ammonia plant constructed in 1994 at a total cost of $20 million. What is your best estimate of a 200 million lbs./year ammonia plant to be built in May 2000? Use attached page of cost indices taken from Chemical Engineering Magazine.

Problem 2 (10 points)

Consider the benzene separation process (see attached PID). Using attached table, determine the yearly operating labor cost for this unit in 2000.

(Average Operator's Salary = $42,000/yr in 1996)

Equipment Type	Operators/Equipment/Shift
Evaporators	.3
Vaporizers	.05
Furnaces	.5
Fans	.05
Blowers and Compressors	.15
Heat Exchangers	.1
Towers	.35
Vessels	.0
Pumps	.0
Reactors	.5

For equipment such as pumps just count equipment plus spare as one item.

Problem 3 (10 points)

In the final design stage of a project, the question has arisen as to whether to use a water-cooled exchanger or an air-cooled exchanger in the overhead condenser loop of a distillation tower. The information available on the two pieces of equipment are provided below:

	Initial Investment	Yearly Operating Cost
air-cooled	$23,000	$1,200
water-cooled	$12,000	$3,300

Both pieces of equipment have service lives of 12 years. For an internal rate of return of *8%* p.a., which piece of equipment represents the better choice?

<u>Problem 4</u> (10 points)

See attached PID for benzene distillation. Answer the following questions:

a. How is the level in the reflux stream V-102 controlled? (i.e., which valve (which flow) is adjusted to maintain the level constant)

b. How is the level in the bottom of the column controlled?

c. What is the purpose of stream 7, vent to flare?

d. What is the purpose of stream 5 attached to pump P-102A?

e. What utility is used in the exchanger E-104?

Problem 5 (10 points)

The PFD and stream summary for the cyclohexanone process is attached.

The following costs are given:

A,	cyclohexanol	$59/lb mole
B,	cyclohexanone	$125/lb mole
C,	high boiler	$0/lb mole
	Hydrogen	$0/lb mole

a. What is the economic potential for this process expressed in $/hr? (i.e., income from product sold – cost of raw materials)?

b. How much money is lost in the gas leaving the reactor? Would it be worthwhile to put in a recovery system to recover the A, B in this stream?

c. How much money is lost in the A,B leaving with the waste stream?

d. What is the maximum economic potential achievable?

e. Suggest changes in the process that will improve the economic potential.

Washington University
St. Louis, MO 63130

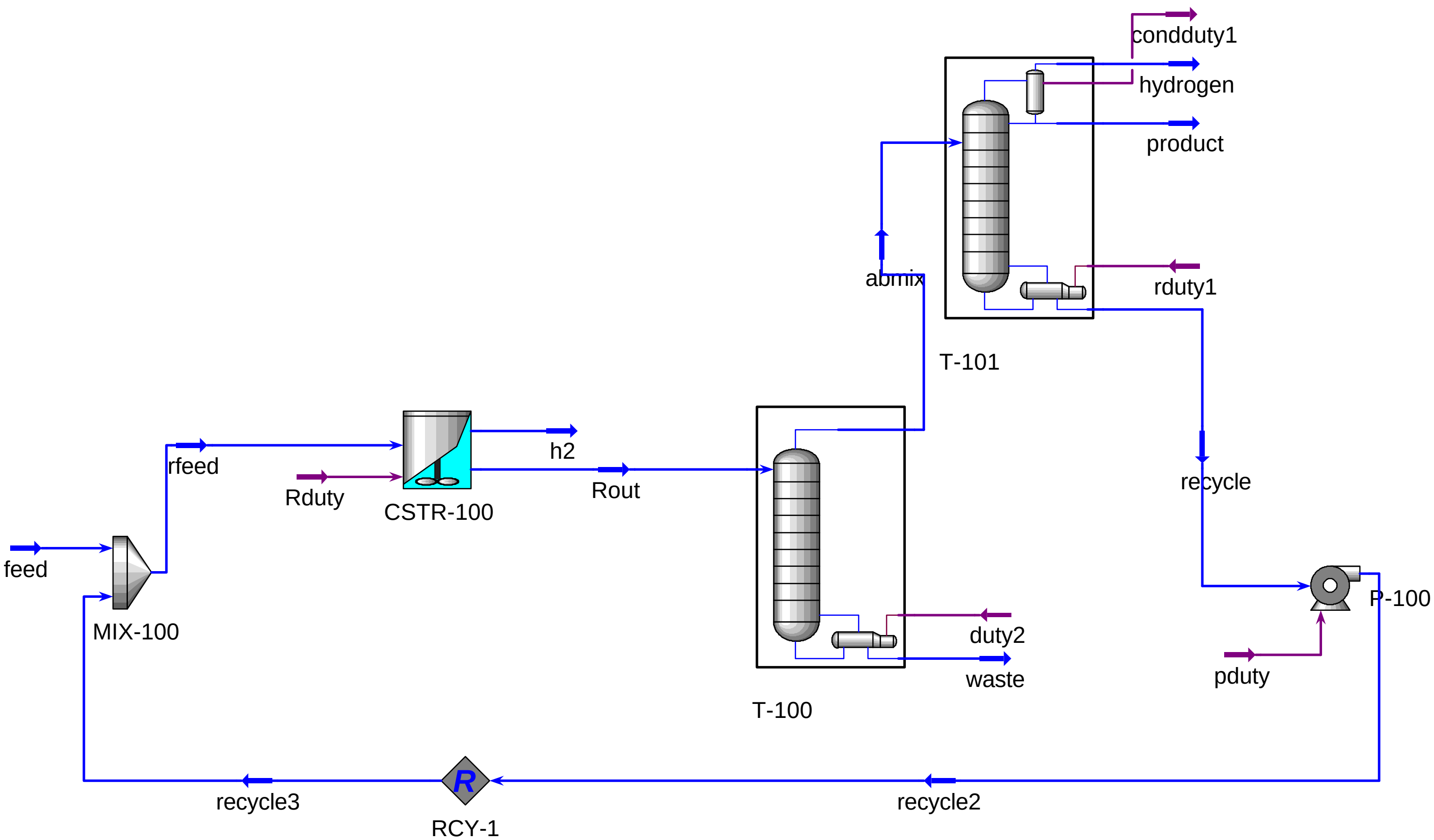
Case Name:	E:\COURSES\CHE477\DESIGN\hysys\dp6bj.HSC
Unit Set:	Field
Date/Time:	Mon Oct 09 12:04:23 2000

Workbook: Case (Main)

Material Streams

Name		feed	h2	Rout	abmix	waste
Vapour Fraction		0.0000	1.0000	0.0000	1.0000	0.0000
Temperature	(F)	200.0 *	200.0	200.0 *	313.5	339.4
Pressure	(psia)	300.0 *	300.0	300.0 *	14.70	14.70
Molar Flow	(lbmole/hr)	9.984	9.167	10.99	10.19	0.7913
Mass Flow	(lb/hr)	1000 *	23.81	1099	996.9	101.9
Liquid Volume Flow	(barrel/day)	71.18	18.40	79.69	71.85	7.834
Heat Flow	(Btu/hr)	-1.444e+06	2328	-1.310e+06	-9.686e+05	-9.719e+04
Molar Enthalpy	(Btu/lbmole)	-1.446e+05	254.0	-1.192e+05	-9.502e+04	-1.228e+05
Comp Molar Flow (Hydrogen)	(lbmole/hr)	0.0000 *	9.1117	0.0806	0.0806	0.0000
Comp Molar Flow (cycHexanol)	(lbmole/hr)	9.9840 *	0.0062	1.7523	1.6460	0.1064
Comp Molar Flow (CC6one)	(lbmole/hr)	0.0000 *	0.0491	8.9038	8.4586	0.4452
Comp Molar Flow (Highboiler*)	(lbmole/hr)	0.0000 *	0.0000	0.2485	0.0088	0.2397
Name		product	recycle	hydrogen	rfeed	recycle2
Vapour Fraction		0.0000	0.0000	1.0000	0.0000	0.0000
Temperature	(F)	214.7	240.6	214.7	204.8	242.9
Pressure	(psia)	3.000	3.000	3.000	300.0	300.0
Molar Flow	(lbmole/hr)	8.478	1.216	0.5000	11.20	1.216
Mass Flow	(lb/hr)	832.9	122.6	41.37	1123	122.6
Liquid Volume Flow	(barrel/day)	59.98	8.749	3.127	79.93	8.749
Heat Flow	(Btu/hr)	-9.743e+05	-1.730e+05	-4.015e+04	-1.617e+06	-1.729e+05
Molar Enthalpy	(Btu/lbmole)	-1.149e+05	-1.423e+05	-8.030e+04	-1.444e+05	-1.422e+05
Comp Molar Flow (Hydrogen)	(lbmole/hr)	0.0001	0.0000	0.0804	0.0000	0.0000
Comp Molar Flow (cycHexanol)	(lbmole/hr)	0.4242	1.2067	0.0151	11.1906	1.2067
Comp Molar Flow (CC6one)	(lbmole/hr)	8.0539	0.0003	0.4044	0.0003	0.0003
Comp Molar Flow (Highboiler*)	(lbmole/hr)	0.0000	0.0088	0.0000	0.0088	0.0088
Name		recycle3				
Vapour Fraction		0.0000				
Temperature	(F)	242.9 *				
Pressure	(psia)	300.0 *				
Molar Flow	(lbmole/hr)	1.216 *				
Mass Flow	(lb/hr)	122.6				
Liquid Volume Flow	(barrel/day)	8.748				
Heat Flow	(Btu/hr)	-1.729e+05				
Molar Enthalpy	(Btu/lbmole)	-1.422e+05				
Comp Molar Flow (Hydrogen)	(lbmole/hr)	0.0000 *				
Comp Molar Flow (cycHexanol)	(lbmole/hr)	1.2066 *				
Comp Molar Flow (CC6one)	(lbmole/hr)	0.0003 *				
Comp Molar Flow (Highboiler*)	(lbmole/hr)	0.0088 *				

* Specified by user.


condduty1
hydrogen
product
abmix
rduty1
T-101
h2
rfeed
Rduty
CSTR-100
Rout
recycle
feed
MIX-100
duty2
waste
P-100
pduty
T-100
recycle3
RCY-1
recycle2

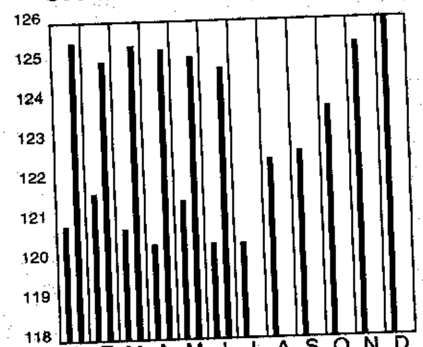
1999 2000

CURRENT BUSINESS INDICATORS

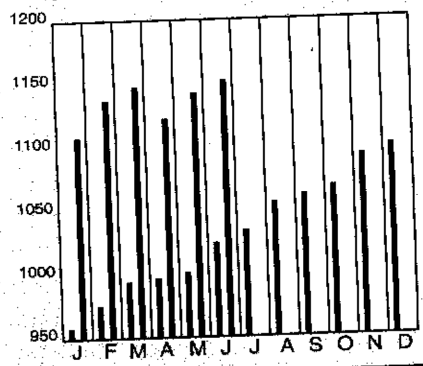
	LATEST	PREVIOUS		YEAR AGO
CPI output index (1992 = 100)*	June '00 = 124.8	May '00 = 124.6	April '00 = 125.1	Jun '99 = 121.2
CPI value of output, $ billions	June '00 = 1,151.4	May '00 = 1,142.9	April '00 = 1,121.9	Jun '99 = 1,024.2
CPI operating rate, %	July '00 = 83.1	June '00 = 82.8	May '00 = 82.8	July '99 = 81.8
Construction cost index (1967 = 100)	Aug. '00 = 580.2	July '00 = 579.5	June '00 = 580.7	Aug. '99 = 567.0
Producer prices, industrial chemicals (1982 = 100)	July '00 = 133.2	June '00 = 129.9	May '00 = 128.7	July '99 = 118.1
Index of industrial activity (1992 = 100)	July 29, '00 = 176.1	July 22, '00 = 175.3	July 15, '00 = 174.4	July 31, '99 = 153.2
Hourly earnings index, chemical & allied products (1992†† = 100)	July '00 = 124.3	June '00 = 123.2	May '00 = 122.7	July '99 = 119.9
Productivity index, chemicals & allied products (1987 = 100)**	July '00 = 118.6	June '00 = 118.4	May '00 = 117.8	July '99 = 112.8

††See article CE, April, 1999, p. 58

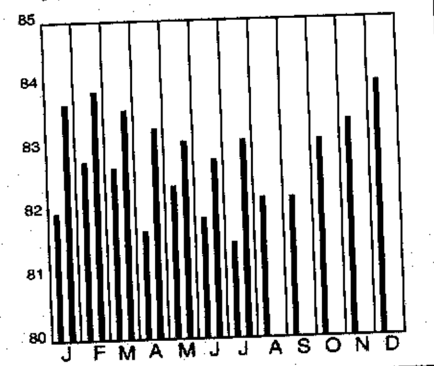
CPI OUTPUT INDEX (1987 = 100)



CPI OUTPUT VALUE ($ Billions)



CPI OPERATING RATE (%)



*To convert to 1987 = 100 base, divide by 91.302 and multiply by 100. †Revised as of Jan. 1987 -- multiply values from Jan. 1982 to Jan. 1987 by 0.9586 to convert to values starting with Jan. 1987.
**To convert to 1977 = 100 base, multiply by 1.478; P = Preliminary; R = Revised. For an explanation and additional information, call: 212-621-4678. Data provided by DRI, Lexington, Mass.

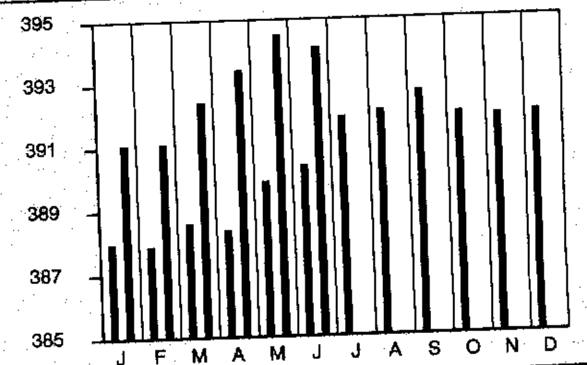
CHEMICAL ENGINEERING PLANT COST INDEX

(1957-59 = 100)

	June '00 Prelim.	May '00 Final	June '99 Final
CE INDEX	394.1	394.5	390.4
Equipment	438.5	439.0	434.9
Heat exchangers & tanks	372.5	372.8	370.6
Process machinery	438.8	438.9	431.8
Pipe, valves & fittings	546.2	547.2	540.4
Process instruments	666.6	666.6	657.9
Pumps & compressors	339.7	339.9	335.8
Electrical equipment	405.5	407.4	410.9
Structural supports & misc	297.9	297.9	292.6
Construction labor	385.2	386.4	381.9
Buildings	340.8	340.7	339.8
Engineering & supervision			

Annual Index

1993 = 359.2
1994 = 368.1
1995 = 381.1
1996 = 381.7
1997 = 386.5
1998 = 389.5
1999 = 390.6



VATAVUK AIR POLLUTION CONTROL COST INDEXES (VAPCCI)

(1st Quarter 1994 = 100.0)[1]

[1]Index values have been rounded to the nearest tenth.

CONTROL DEVICE	1997 (Avg.)[2]	1998 (Avg.)[2]	3rd Q '99	4th Q '99	1st Q '00[3]	2nd Q '00[3]
Carbon adsorbers	104.7	103.6	100.3	101.4	104.7	108.8
Catalytic incinerators	107.7	106.5	100.5	105.7	109.7	112.3
Electrostatic precipitators	108.8	109.2	100.5	99.6	100.9	101.2
Fabric filters[4]	106.2	109.5	111.6	112.2	112.3	112.3
Flares	105.8	103.6	98.9	100.0	102.3	105.3
Gas absorbers	107.6	109.7	110.7	111.7	112.5	113.3
Mechanical collectors[4]	103.9	111.0	121.4	121.5	121.7	121.8
Refrigeration systems	106.1	107.6	105.5	105.3	106.3	106.5
Regenerative thermal oxidizers	107.9	108.9	107.8	107.8	108.4	108.8
Thermal incinerators	109.4	110.5	107.6	107.2	107.8	107.9
Wet scrubbers	109.0	109.7	108.5	109.0	111.6	115.3

[2] Each annual average is the arithmetic mean of the quarterly indexes for that year.

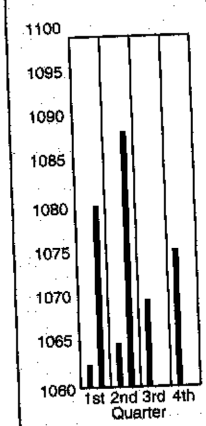
[3] All first quarter 2000 indexes are **preliminary**.

[4] For fabric filters and mechanical collectors, each quarterly value shown is the average of the Producer Price Indexes (PPIs) for the three months in question, divided by the average of the PPIs for January, February, and March 1994 (i.e., first quarter 1994).

Note: For a detailed explanation of the development and use of the VAPCCI, see *Chem. Eng.*, December 1995, pp. 88-95.

MARSHALL & SWIFT EQUIPMENT COST INDEX

(1926 = 100)



	2ndQ 2000	1stQ 2000	2ndQ 1999
M & S INDEX	1,089.0	1,080.6	1,065.0
Process industries, average	1,102.2	1,093.5	1,080.7
Cement	1,092.0	1,083.5	1,070.3
Chemical	1,084.7	1,076.2	1,063.7
Clay products	1,088.1	1,079.5	1,067.2
Glass	1,014.3	1,006.2	991.4
Paint	1,107.1	1,097.5	1,082.0
Paper	1,055.2	1,047.1	1,029.9
Petroleum products	1,147.7	1,138.8	1,127.7
Rubber	1,176.3	1,167.3	1,155.8
Related industries			
Electrical power	989.5	979.4	963.3
Mining, milling	1,125.5	1,116.9	1,102.7
Refrigerating	1,299.2	1,288.8	1,268.9
Steam power	1,059.6	1,050.2	1,038.3

Annual Index

1994 = 993.4
1995 = 1,027.5
1996 = 1,039.1
1997 = 1,056.8
1998 = 1,061.9
1999 = 1,068.3

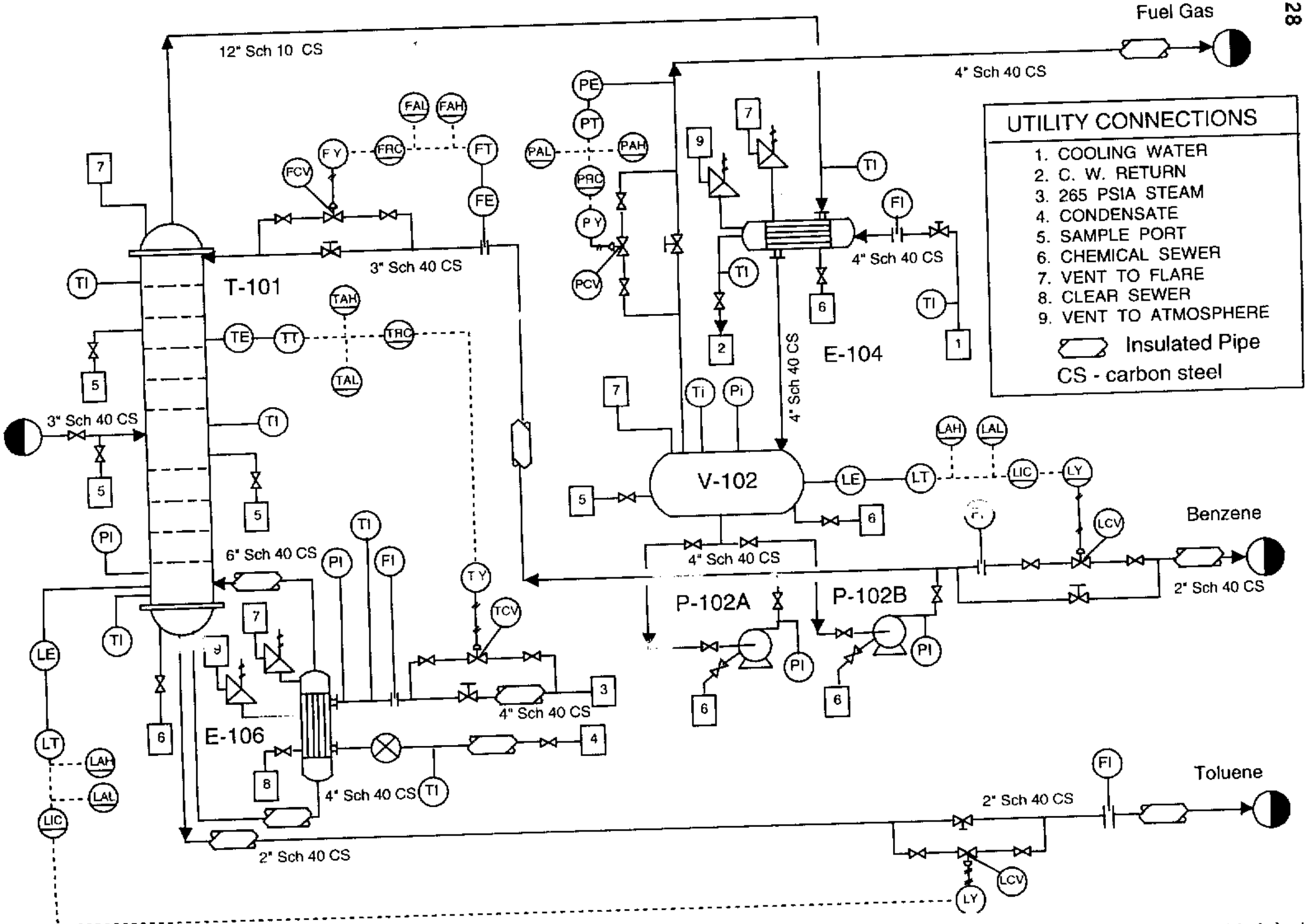


Figure 1.7 Preliminary piping and instrumentation diagram for benzene distillation. (Adapted from Kauffman, D., *Flow Sheets and Diagrams*, AIChE Modular Instruction, Series G: Design of Equipment, series editor J. Beckman, AIChE, New York, 1986, vol 1, Chapter G.1.5, AIChE copyright, © 1986 AIChE, all rights reserved)