Major No. 1 – A Problem at the Dimethyl Ether Facility

Background

You have recently joined a Process Engineering and Production Company called Drift Engineering. This company produces a variety of solvent chemicals for specialized uses. The process unit to which you have been assigned produces dimethyl ether (DME) and is designated Unit 200. This unit is currently not operating but undergoing a yearly maintenance check. The unit is scheduled to start-up in 10 days (i.e., it will start back up on the day following your oral presentation).

This plant has been operating for over 7 years at design capacity and experiences few problems in the day-to-day operation. However, a major problem has recently occurred at this facility. Over the last couple of months, the system by which raw materials are ordered has been "upgraded" to a fully automated e-commerce system. However, there have been some teething problems with the new system, and one of these has caused a major problem at the DME facility. The order clerk, the person in charge of ordering raw materials, accidentally sent an order for a shipment of ethanol (EtOH) to be sent to your plant instead of the normal order for methanol. This error was only discovered after a portion of a tank car was emptied into one of the methanol storage tanks. The result is that the methanol in this tank now contains a significant concentration of ethanol.

A sample from the tank indicates that the contents now contain 5 mol% ethanol and 0.9 mol% water, with the balance being methanol. The capacity of the storage tank (shown shaded on Figure 1) is 500,000 gallons, and it is currently 80% full. With this concentration of ethanol in the feed, there are several potential problems. First is that ethanol will react to form diethyl ether (DEE), methyl ethyl ether (MEE), and ethylene in R-201. The catalyst that we use is quite specific to the production of symmetric molecules, and it is believed that the formation of MEE will be negligible. However, significant conversion of ethanol to DEE and direct dehydration to give ethylene are expected. Moreover, the additional chemical species passing through Unit 200 must still be separated, and DME purity (99.5 wt%) cannot be compromised. A further constraint is that any wastewater sent to the treatment facility cannot contain in excess of 1 wt% organics at any time. The catalyst is not affected adversely by small concentrations of ether in the feed. Thus, any ether (DME or DEE) that might be recycled to R-201 will act as an inert. Ethanol is used elsewhere in our plant, as indicated by the EtOH storage tanks shown in Figure 1. However, the purity of this ethanol must be very high and must contain less than 100 ppm of ethers and less that 100 ppm of methanol. Water content is not critical but must be less than 30 wt%. A column used previously for organic solvent separation (T-1104) and its associated reboiler, condenser, overhead condensate drum, and reflux pumps (E-1106, E-1105, V-1107, and P-1107A/B) were decommissioned several years ago. It has been suggested that this column and associated equipment could be used to provide additional separation capacity to help with the current problem. The column system has been "inerted" with nitrogen, and all feed-line and product-line connections have been removed and these nozzles are currently blind flanged. If this column is to be used, new pipe must be run from Unit 200 (or storage) to T-1104 and back to Unit 200 or elsewhere depending on the intended use of the column. The operations manager believes that her crew can repipe the column using the existing

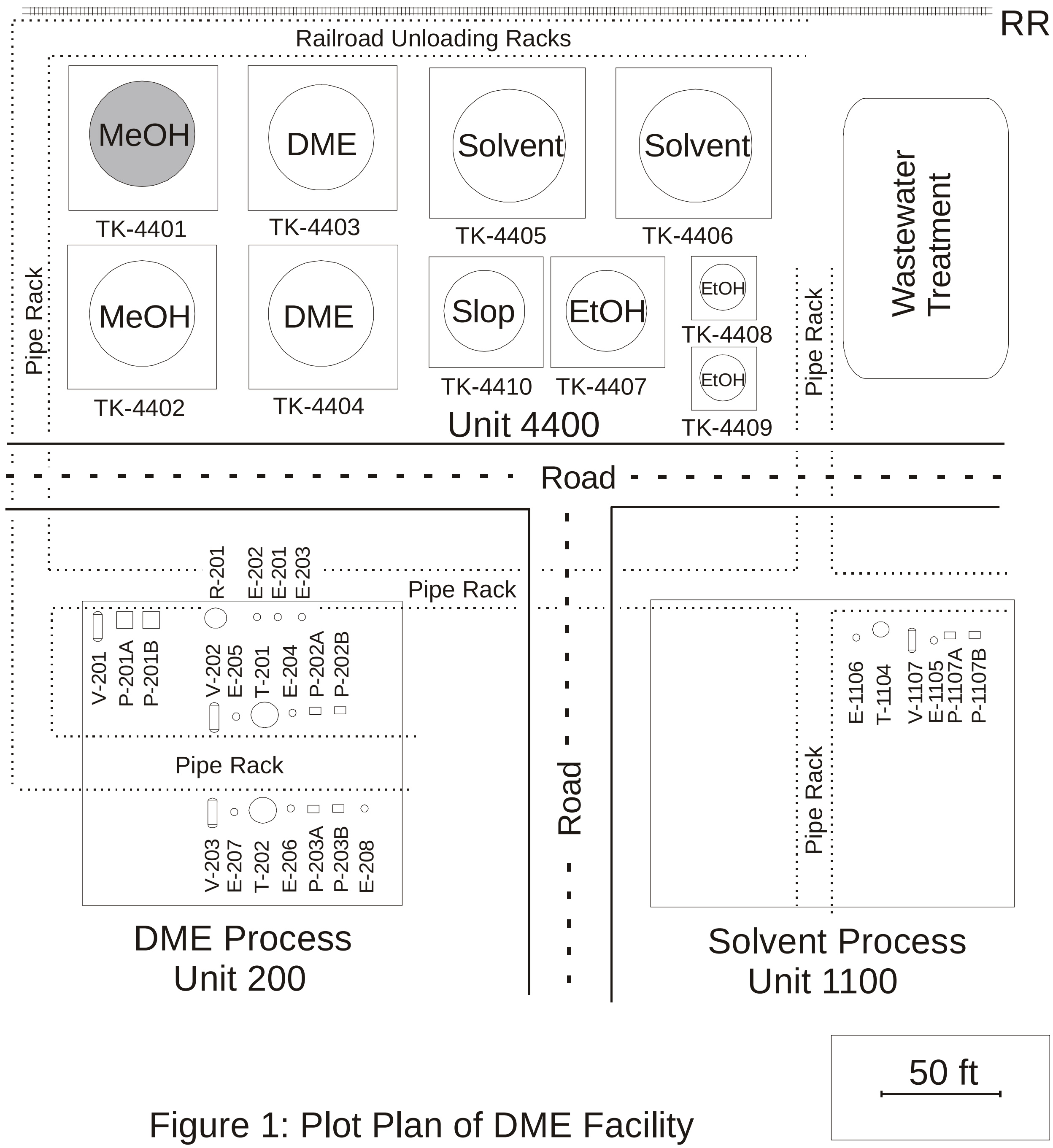
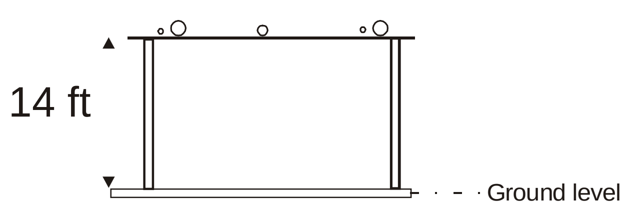


Figure 1: Plot Plan of DME Facility



Pipe Rack Elevation

pipe racks in a period of about 2 days from obtaining a design from engineering (this design will be part of the recommendations from your report). She has broken down the labor cost at the rate shown below and this can be used for estimating purposes. If column T-1104 is used, then it is expected to take approximately 36 hours to "come on line", i.e., it takes 36 h to start it up and to reach steady state.

As shown in Figure 1, there is a slop tank (capacity 100,000 gal) that is used to hold off-spec product. Upon consultation with the operations manager, it has been agreed that this tank can be made available to Unit 200 for a period of no longer than 1 month in order to deal with the current problem.

Fortunately, the other storage tank is approximately 80% full with on-spec. methanol (99.05 mol% MeOH and 0.95 mol% water). This can be used to feed the process for the current time. It should be noted that the time to refill one of the storage tanks from rail tank-cars is approximately 18 hours, and, during this time, material cannot be fed from the tank to the process.

One alternative is to ship the off-spec methanol to a "toller" who will charge us $0.05 per lb (this includes a transportation charge) to purify it. Alternatively, we may use the off-spec feed material and avoid these tolling charges. Your assignment is to generate and to evaluate as many different "solutions" to the problem and recommend the most economically beneficial alternative.

<u>Economic Data</u>

You may use the following labor costs for repiping the column and any other repiping work:

Overtime for Maintenance - $ 35 per hour
Estimated total time for piping = 1 hour per 10 ft of installed pipe.

For material costs use the following

Pipe costs:	6" diameter, use $25 per foot for installed piping – this includes flanges, insulation, shut of valves, pipe supports, etc.
	4" diameter, use $22 per foot for installed piping – this includes flanges, insulation, shut of valves, pipe supports, etc.
	3" diameter, use $20 per foot for installed piping – this includes flanges, insulation, shut of valves, pipe supports, etc.
	2" diameter, use $18 per foot for installed piping – this includes flanges, insulation, shut of valves, pipe supports, etc.
	1.5" diameter, use $17 per foot for installed piping – this includes flanges, insulation, shut of valves, pipe supports, etc.
	1" diameter, use $16 per foot for installed piping – this includes flanges, insulation, shut of valves, pipe supports, etc.
Pump Costs:	For new pumps, use the cost curves in Figure A.8 in your textbook and multiply this cost by 2.5 to get the installed cost. Delivery times for pumps are usually a few days.

Heat Exchanger Costs: Use the capital costs for exchangers from Figure A.1 in your textbook and multiply this cost by 3.5 to get the installed cost. Note: delivery times for heat exchangers are generally several weeks.

Assignment

Your assignment is to prepare a written and oral report summarizing your findings and recommendations. The written report is due by 9:00 am, Monday September 25, 2000. The oral reports will follow during the week of September 25 - 29. You should read carefully the guidelines for written and oral reports and Chapters 22 and 23 in the your textbook “Analysis, Synthesis, and Design of Chemical Processes.” These chapters cover the required guidelines for written and oral presentations. The written report should not exceed 10 pages of double-spaced text, plus figures and tables. All relevant calculations should be included in a well-indexed appendix. These calculations should be neat and legible but may be hand written. The form of the report should be an executive summary (same organization as a long report but without section headings), which clearly and succinctly presents your major findings, explanations, conclusions, and recommendations. The following information must appear in the main body of the report:

a. A computer-generated process flow diagram (PFD) showing the configuration of equipment for your optimal case.
b. A list of all the cases considered and a ranking of their cost.
c. A flow summary table showing the amounts and conditions of the streams shown in the PFD.
d. A list of all new equipment with installed costs and material and labor costs for new piping.
e. A detailed summary of the piping arrangement for T-1104 and associated exchangers, pumps, vessels, etc., if this equipment is used.
f. A signed copy of the confidentiality statement. This should be the very last page of the written report.

Please provide the written report in a 3-ring, spiral or riveted binder (not oversized). You must bring a hard copy of your slides to leave behind after the oral presentation; these should be distributed to your audience prior to the start of your presentation.

Late Written Reports

Late written reports are unacceptable. The following severe penalties will apply:

- Late reports on the due date before noon (September 25, 2000): one letter grade.
- Late reports after noon on the due date (September 25, 2000): two letter grades.
- Late report one day late (September 26, 2000): three letter grades.
- More than one day late (after September 26, 2000): one additional letter grade for every day after the 26th of September.

Additional Information

Information about the reactions of ethanol is given in Appendix 1.

Details of tower T-1104 and associated equipment are given in Appendix 2.

Details of the Tank Farm, Unit 4400, are given in Appendix 3.

Details of the design of the DME facility, as it has been operating prior to the upset, are included in Appendix 4.

Appendix 1: Reaction of Ethanol to Form Diethyl Ether and Ethylene

<u>Diethyl Ether Reaction</u>

As mentioned previously the catalytic dehydration reaction of ethanol to produce diethyl ether (DEE) and the direct dehydration to form ethylene can take place in the present reactor at the current conditions. Since these reactions have typically not been studied in the past no reaction kinetic data are available. Specifically, the activation energies for these reactions are not known. However, some work was done several years ago in our laboratories, and the results indicated that the selectivities of these reactions, at the design operating conditions, are as follows:

$$\begin{array}{l} 2C_2H_5OH \rightarrow (C_2H_5)_2O + H_2O \\ \quad ethanol \qquad\qquad DEE \end{array}$$

$$S_1 = \frac{rate\ of\ \ formation\ of\ \ DME}{rate\ of\ \ formation\ of\ \ DEE} = 5\frac{C_{MeOH}}{C_{EtOH}}$$

$$\begin{array}{l} C_2H_5OH \rightarrow C_2H_4 + H_2O \\ ethanol \quad\ ethylene \end{array}$$

$$S_2 = \frac{rate\ of\ \ formation\ of\ \ DEE}{rate\ of\ \ formation\ of\ \ ethylene} = 2$$

These results were obtained from a pilot plant operating at approximately the same conditions used in the current design (adiabatic packed bed reactor, T_{in} = 250°C and T_{out} =364°C).

Appendix 2: Details of Tower T-1104 and Associated Equipment

Equipment Specifications for Solvent Separation System – T-1104, E-1105, E-1106, V-1107, P-1107A/B

Design details for the solvent column, T-1104, and associated equipment are given below. The specifications are for the as-built unit and are believed to be correct. Because of the need for a quick solution to the current problem, you should use this information as given. It may further be assumed that the materials of construction, including gaskets, seals, etc., are suitable for any and all chemicals used in the DME process including DEE, ethanol, and ethylene.

Column T-1104

Maximum operating pressure = 10 bar
Maximum operating temperature = 500°C at 10 bar
Diameter = 2.2 m
Height = 43.1 m (grade to top of overhead vapor nozzle)
Number of trays = 59
Feed tray location = 26
Type of tray = Sieve
% Active Area = 75%

Tray efficiency = 60-70%
You should assume a constant tray efficiency of 65% for any of the separations that this column will be used for in the current problem.

Overhead Condenser - Exchanger E-1105

Tube side - Cooling water
Max cooling water flow = 250 kg/s (250 lit/s)
Max exit temperature for cw = 45°C

Shell Side – Condensing vapor
Maximum operating pressure for shell side = 10 bar
Minimum operating pressure for shell side =0.5 bar

Orientation = horizontal

Heat Transfer surface area = 320 m^2

Configuration – 1 shell pass, 2 tube passes

From previous operation at a cw rate of 200 kg/s the heat transfer coefficients were 1800 W/m^2K for cooling water and 1200 W/m^2K for condensing organic.

Reboiler - Exchanger E-1106

Tube side – condensing steam
Maximum tube side pressure = 225 psia (16.9 bar)

Shell side – boiling process stream
Maximum operating pressure for shell side = 10 bar
Minimum operating pressure for shell side =0.5 bar

Type = Horizontal Kettle Reboiler with liquid overfow

Heat Transfer surface area = 300 m^2

From previous operation the heat transfer coefficients were 3000 W/m^2K for condensing steam and 1750 W/m^2K for boiling organic.

Configuration – 1 shell pass, 1 tube pass – tubes slanted for gravity flow of condensate
Overflow weir on shell side for disengagement of vapor and liquid, operate with all tubes covered by process liquid as shown in Figure A.2.1

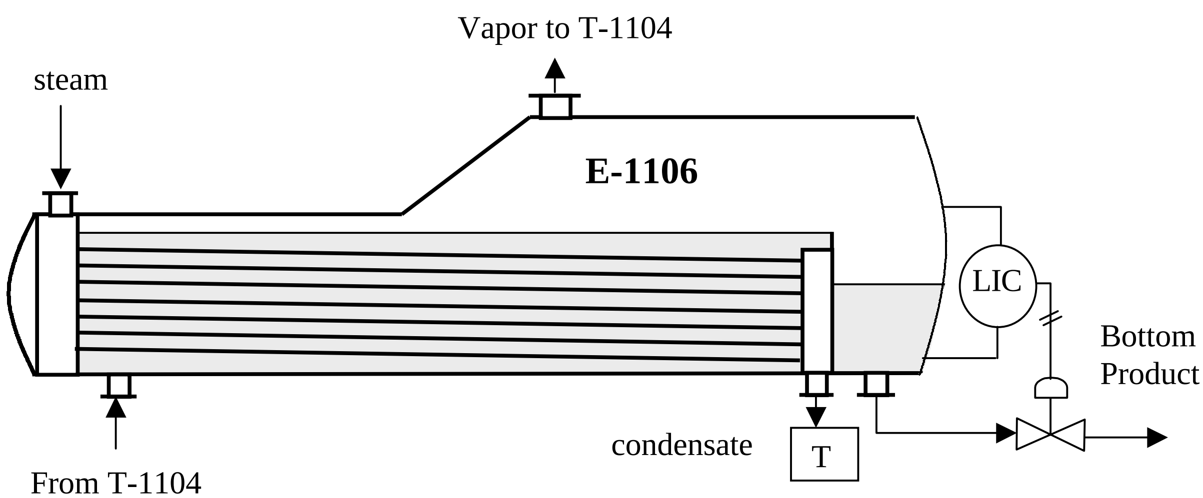


Figure A.2.1: Equipment Sketch of E-1106

Overhead Reflux Drum - V-1107

Orientation = horizontal
Diameter = 1.33 m
Length = 4.0 m

Reflux pumps - P-1107A/B piped in parallel

Design flow = 9.4 L/s at a developed head of 325 kPa
Power = 4.3 kW
Efficiency = 70%

See pump curves in Figure A.2.2

A sketch of the tower configuration is given below in Figure A.2.3.

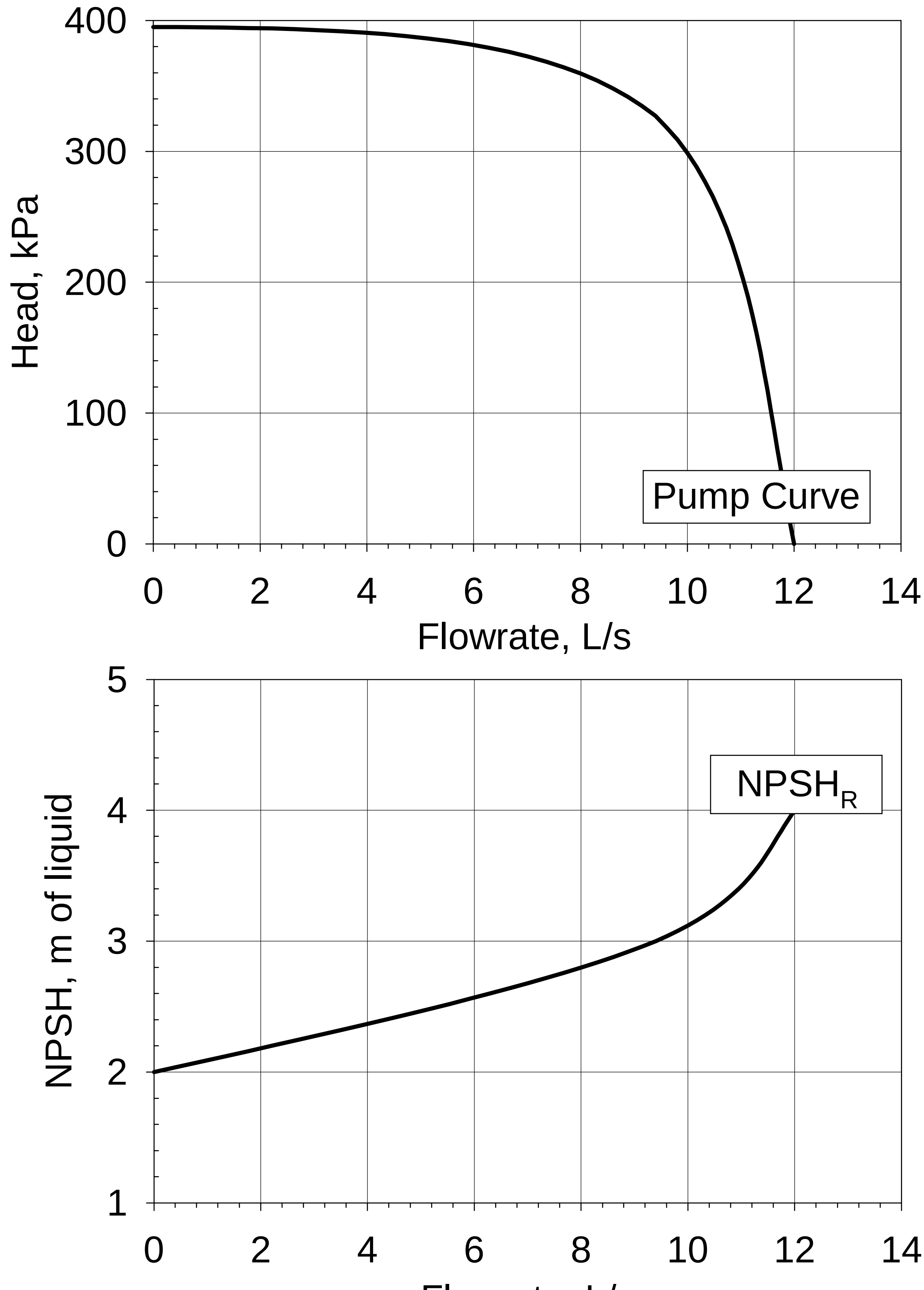


Figure A.2.2: Pump and NPSH Curves for Pumps P-1107 A/B

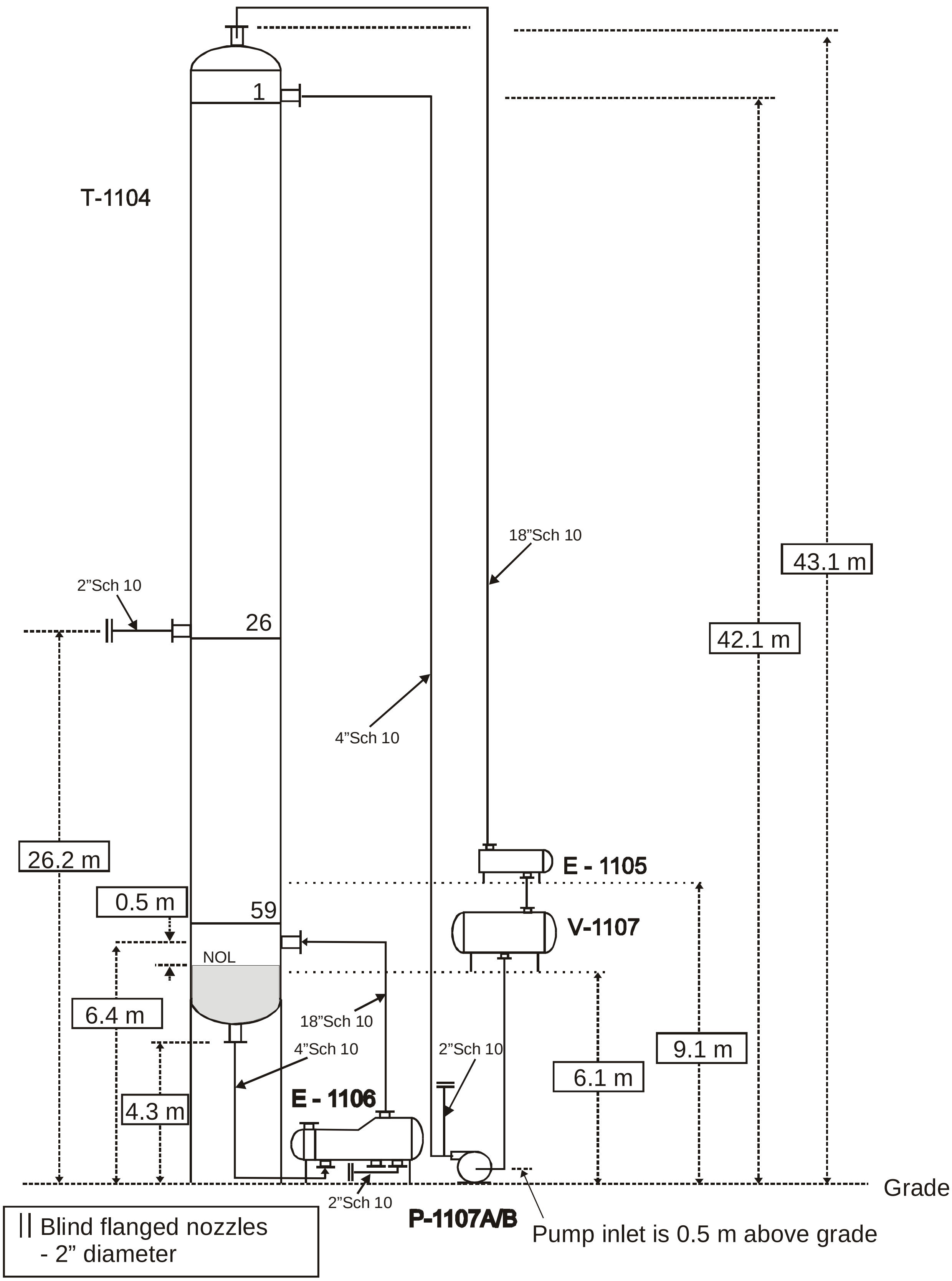


Figure A.2.3: Vessel Sketch for T-1104 and Associated Equipment

Hints on Simulating Separations

If you choose to use ChemCad to simulate any of the additional separations then you should use a rigorous algorithm such as Tower or SCDS with the Uniquac K-value option. Alternatively, you may use a McCabe-Thiele analysis for the key components. You can generate the XY diagrams using the Plot TPXY function on ChemCad. Several sets of data for different component pairs are included here for your benefit, see Figures A.2.4 - 6. Note that these XY diagrams are plotted for a given (constant) pressure. If you wish to run a column at a different pressure then you must get the data from ChemCad at that pressure.

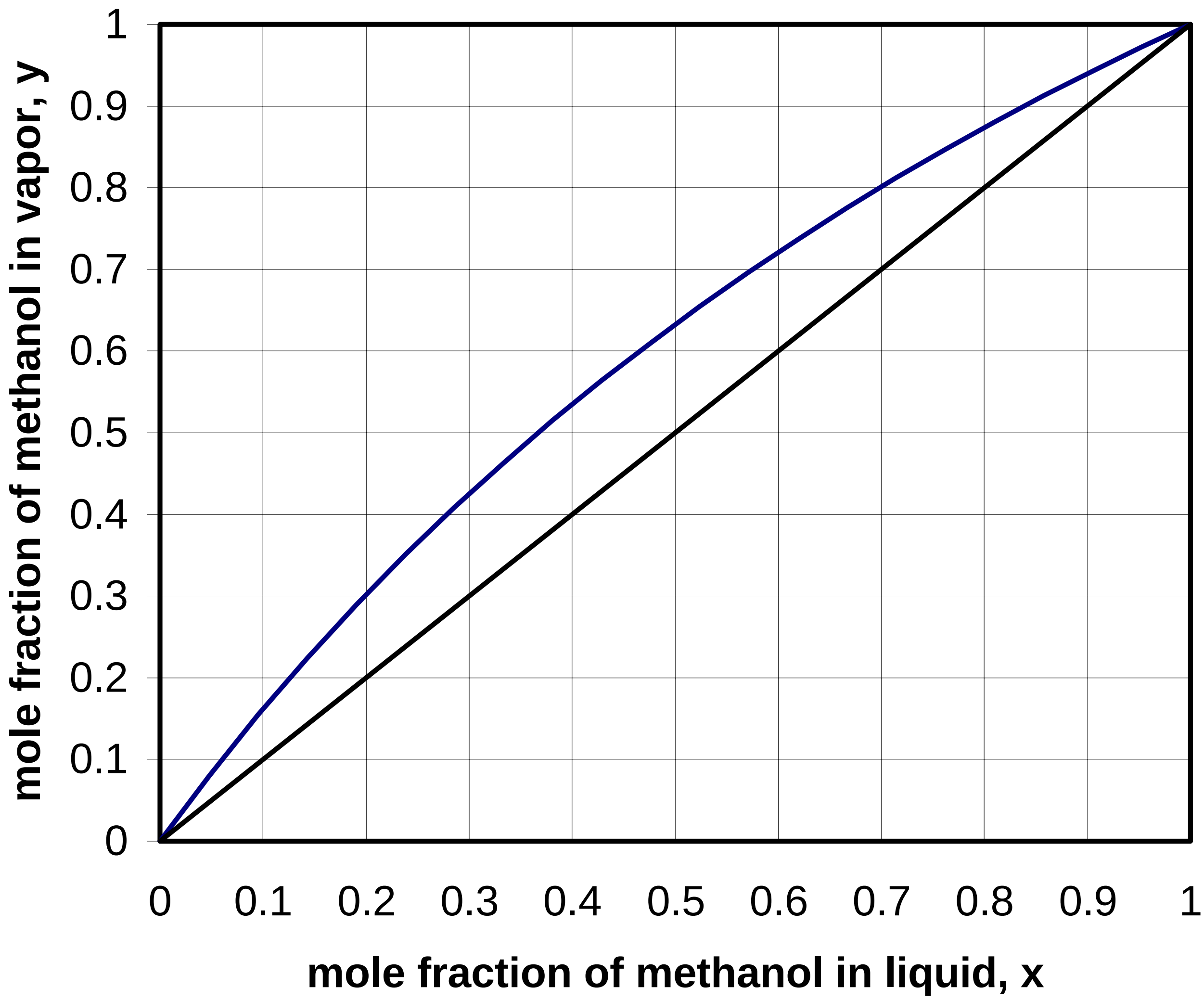


Figure A.2.4: Methanol-Ethanol XY Diagram

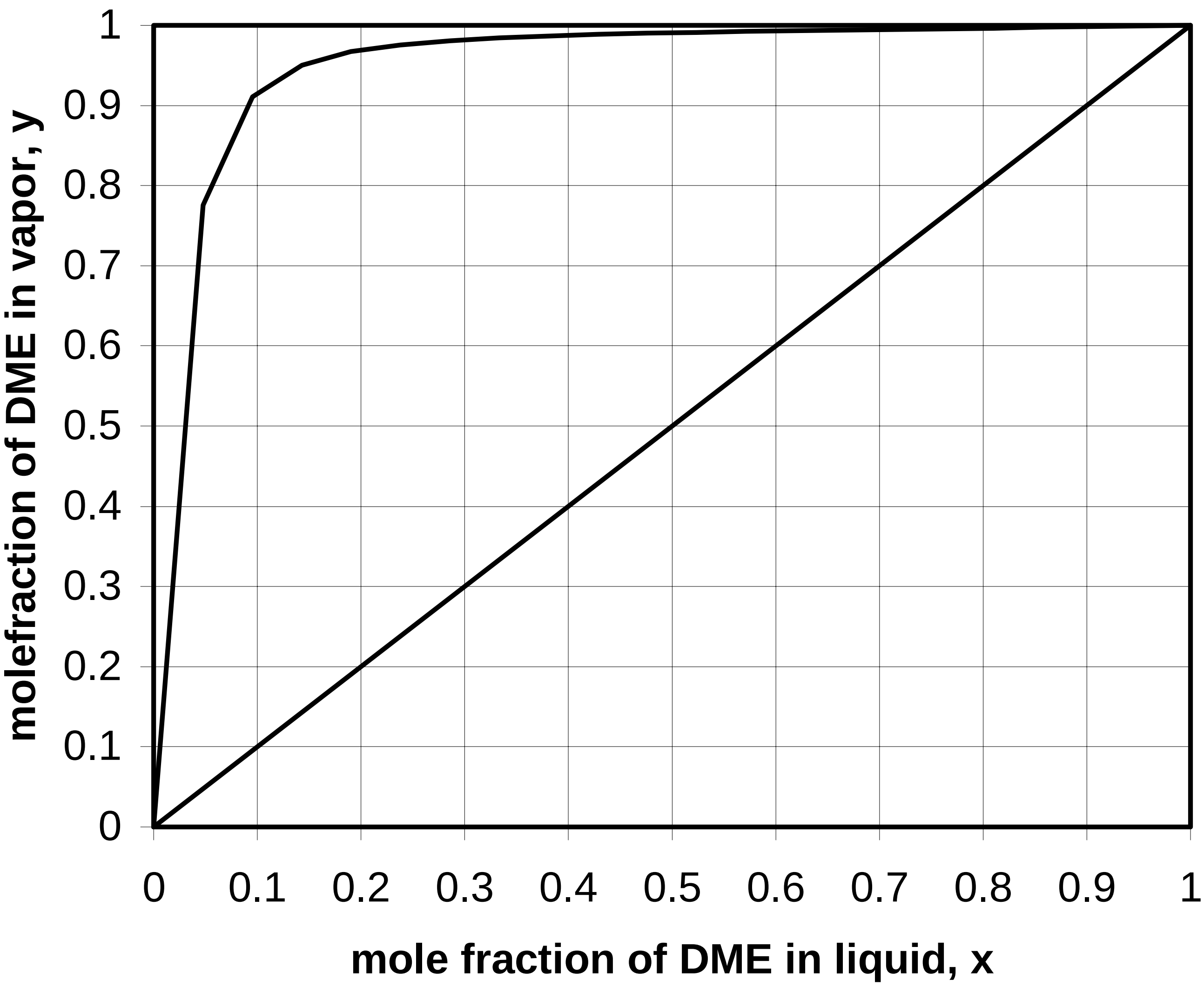


Figure A.2.5: Diethyl Ether – Methanol XY Diagram

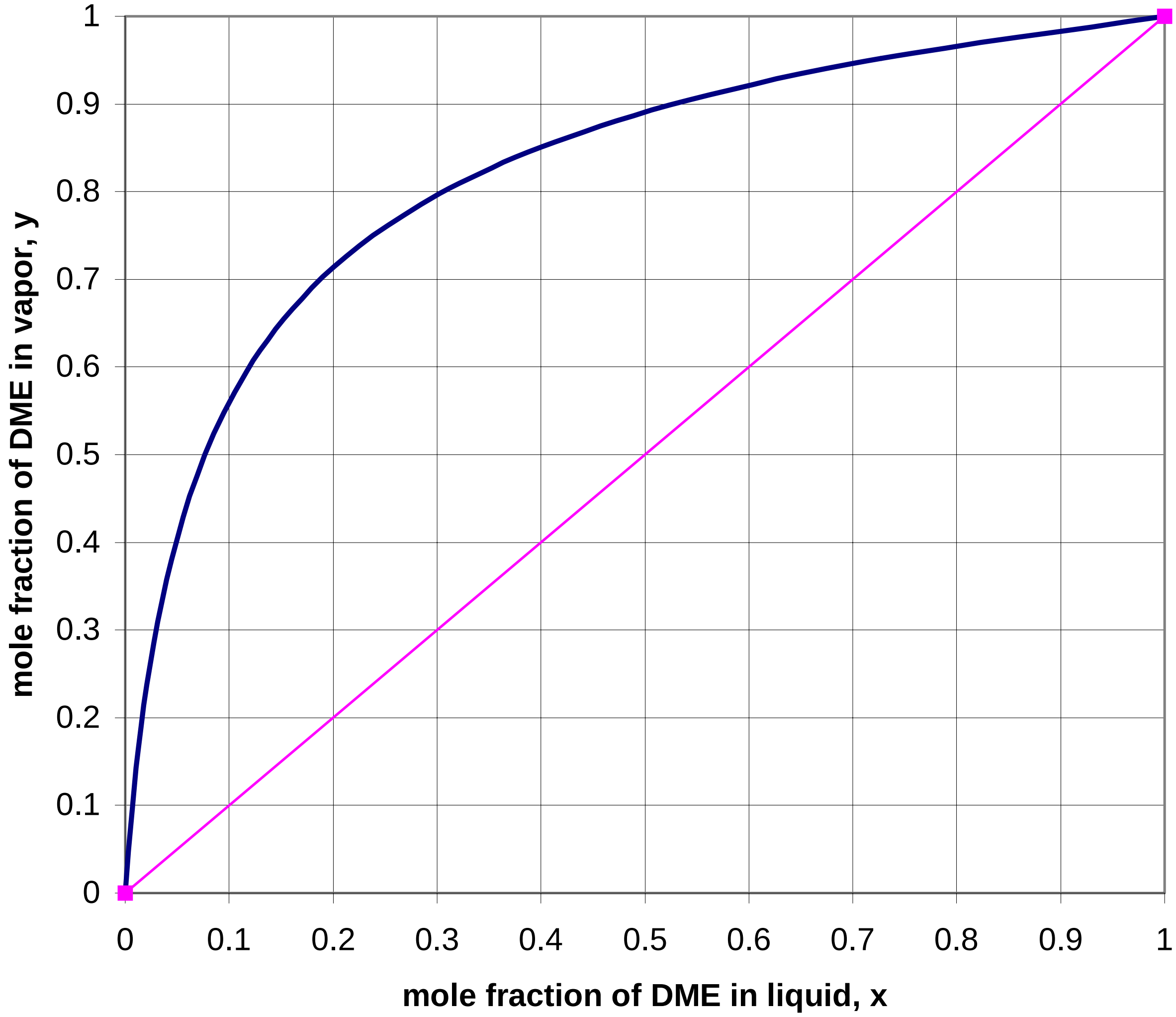


Figure A.2.6: Dimethyl Ether – Diethyl Ether XY Diagram

Appendix 3: Information on the Tank Farm and Storage Tanks

Tank Farm (Unit 4400) Information – for tanks shown in Figure 1

Tank Capacities

Methanol Tanks (TK-4401 and 2) have a nominal capacity of 500,000 gallons each
DME (TK-4403 and 4) Tanks have a nominal capacity of 500,000 gallons each
Solvent Tanks (TK-4405 and 6) have a nominal capacity of 500,000 gallons each
Ethanol Tanks have a nominal capacity of 100,000 gallons (large, TK-4407) and 25,000 gallons (small, TK-4408 and 9) each
Slop Tank (TK-4410) has a nominal capacity of 100,000 gallons

Methanol Feed System

The methanol feed is fed from either of the storage tanks via one of two pumps, P-4403A/B, to the Feed storage tank, V-201. The set-up is illustrated in Figure A.3.1. The design calculations for this pump are shown below.

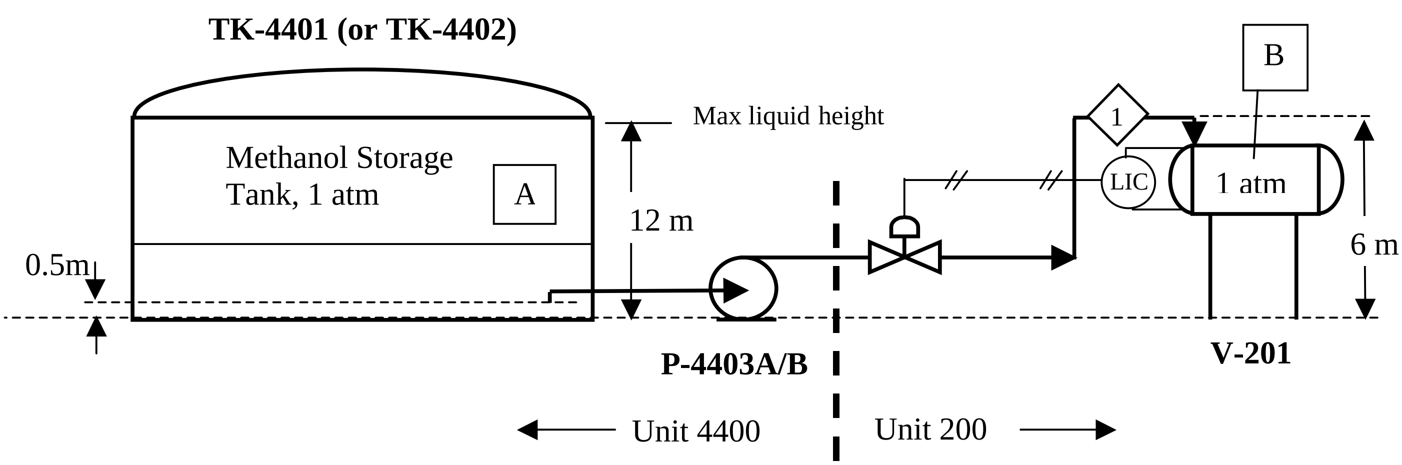


Figure A.3.1: Equipment Sketch of Methanol Feed System

At the limiting design condition, the liquid level is 0.5 m above ground level. This is the distance of the pipe from the bottom of the tank.

Suction piping length = 50 ft equivalent
Discharge piping length = 300 ft equivalent
Total piping = 350 ft equivalent

At design conditions flow = 8370 kg/h
Density = 790 kg/m^3
Volumetric flow = 2.94 L/s

Use Schedule 10 piping

Diameter inches	vel m/s	Re	e/d	f	$\Delta P_f/L$		
2.157	1.25	92,800	0.00084	0.0054	243	Pa/m	← discharge
3.260	0.55	40,600	0.00056	0.0058	33	Pa/m	← suction
4.260	0.32	23,800	0.00043	0.0062	9.3	Pa/m	

$\Delta P_{total,\ friction}$ = (243)[Pa/m](300)[ft](0.3048)[m/ft] + (33)[Pa/m](50)[ft](0.3048)[m/ft] = 22.7 kPa
ΔP_{CV} = 5 psi = 34.5 kPa
$\Delta P_{AB} = 0$
$\rho g\ \Delta z_{AB}$ = (6-0.5)[m](790)[kg/m^3](9.81)[m/s^2]= 42.6 kPa

System curve

Flow [L/s]	ΔP [kPa]
0	42.6
1	$42.6+(1/2.94)^2(22.7) = 45.3$
2	$42.6+(2/2.94)^2(22.7) = 53.1$
2.94	$42.6+(2.94/2.94)^2(22.7) = 65.3$
4	$42.6+(4/2.94)^2(22.7) = 84.6$
5	$42.6+(5/2.94)^2(22.7) = 108.3$

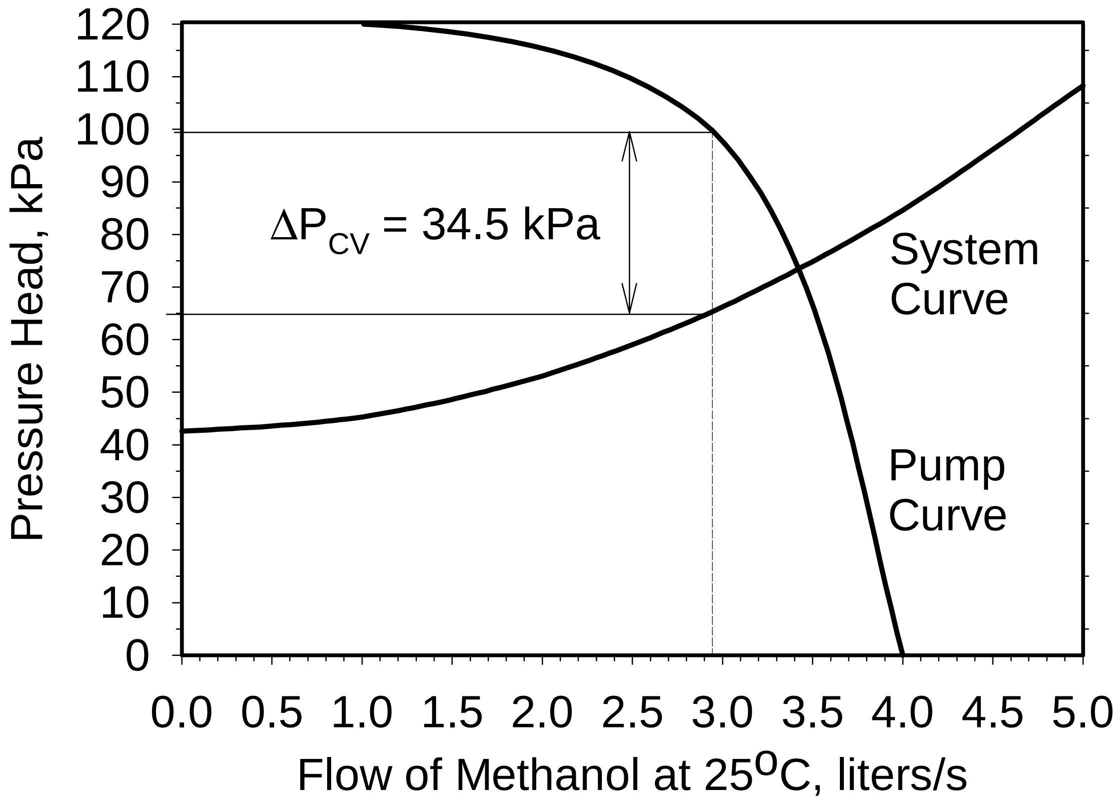
These are plotted against the system curve in Figure A.3.2.

At the design flow, the pump head = $\Delta P_{total,\ friction} + \rho g\ \Delta z_{AB} + \Delta P_{CV}$ = (22.7+42.6+34.5)= 99.8 kPa

NSPH available

P_{supply} = 1 atm = 101 kPa ⇒ (101300)[Pa]/(790)[kg/m^3]/(9.81)[m/s^2] = 13.07 m
hρg (lowest liquid level in tank - pump suction) =0.5 – 0.5 = 0 m
ΔP_f = (33)[Pa/m](50)[ft](0.3048)[m/ft] = 503 Pa ⇒ (503)[Pa]/(790)kg/m^3]/(9.81)[m/s^2] = 0.06 m
vapor pressure of methanol =$P^*_{methanol}$ (at 25°C) =16.8 kPa = 2.15 m

$NPSH_A$=13.07 + 0 - 0.06 - 2.15 = 10.86m ⇒ cavitation is not a problem for P-4403 A/B



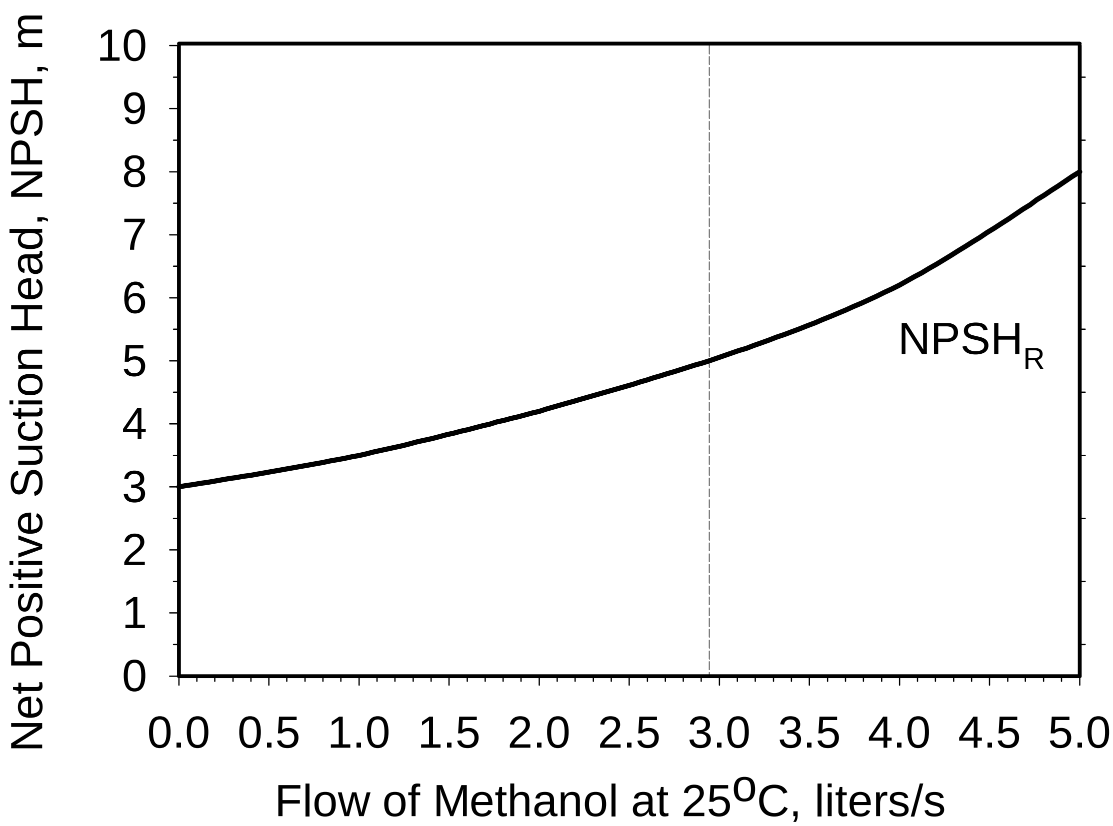


Figure A.3.2: Methanol Tank Farm Feed Pumps P-4403A/B

Appendix 4: Process Information for DME Process – Design Case

The following information is provided for the DME process operating at design conditions. This represents the operation of the plant prior to the current problem with feedstock contamination. The PFD for the process is given as Figure A.4.1, the equipment summary table and stream table are attached as Tables A.4.1 and 2, respectively.

<u>Process Notes</u>

Dimethyl ether (DME) is used primarily as a propellant. DME is miscible with most organic solvents, it has a high solubility in water and is completely miscible in water and 6% ethanol [1]. Recently, the use of DME as a fuel additive for diesel engines has been investigated due to its high volatility (desirable for cold starting) and high cetane number. The production of DME is via the catalytic dehydration of methanol over an acid zeolite catalyst. The main reaction is as follows:

$$\underset{\text{methanol}}{2\,CH_3OH} \rightarrow \underset{\text{DME}}{(CH_3)_2O} + H_2O$$

In the temperature range of normal operation, there are no significant side reactions.

A preliminary process flow diagram for a DME process is shown in Figure A.4.1 in which 50,000 metric tons per year of 99.5 wt% purity DME product is produced. The process has a stream factor of 0.95 (8375 h/yr).

Process Description

Fresh methanol, Stream 1, is combined with recycled reactant, Stream 14, and vaporized prior to being sent to a fixed bed reactor operating between 250°C and 368°C. The single pass conversion of methanol in the reactor is 80%. The reactor effluent, Stream 7, is then cooled prior to being sent to the first of two distillation columns, T-201 and T-202. DME product is taken overhead from the first column. The second column separates the water from the unused methanol. The methanol is recycled back to the front end of the process, while the water is sent to waste water treatment to remove trace amounts of organic compounds.

Reaction Kinetics and Reactor Configuration

The reaction taking place is mildly exothermic with a standard heat of reaction, $\Delta H_{reac}(25°C)$ = -11,770 kJ/kmol. The equilibrium constant for this reaction at three different temperatures is given below:

T	K_p
473 K (200°C)	34.1
573 K (300°C)	12.4
673 K (400°C)	6.21

The corresponding equilibrium conversions for pure methanol feed over the above temperature range are greater than 83%. This reaction is kinetically controlled at the conditions used in this process.

The reaction takes place on an amorphous alumina catalyst treated with 10.2% silica. There are no significant side reactions below 400°C. Above 250°C the rate equation is given by Bondiera and Naccache [2] as:

$$-r_{methanol} = k_0 \exp\left[\frac{-E_a}{RT}\right] p_{methanol}$$

where $k_0 = 1.21\times10^6$ kmol/(m^3 reactor h kPa) , E_a = 80.48 kJ/mol, and $p_{methanol}$ = partial pressure of methanol (kPa).

Significant catalyst deactivation occurs at temperatures above 400°C and the reactor is designed so that this temperature is not exceeded anywhere in the reactor. The design given in Figure A.4.1 uses a single packed bed of catalyst, which operates adiabatically. The temperature exotherm of 118°C, occurring in the reactor, is high and gives an exit temperature of 364°C. However, the single pass conversion is quite high (80%), and the low reactant concentration at the exit of the reactor tends to limit the possibility of a run away.

References

1. "DuPont Talks About its DME Propellant," *Aerosol Age*, May and June, (1982)
2. Bondiera, J. and C. Naccache, "Kinetics of Methanol Dehydration in Dealuminated H-Mordenite: Model with Acid and Basic Active Centres," *Applied Catalysis*, **69**, 139-148 (1991)

Table A.4.1: Equipment Summary Table for DME Process

Equipment	P-201A/B*	P-202A/B*	P-203A/B*	V-202	V-202	V-203	T-201	T-202	R-201
MOC	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Power (kW)	7.2	1.0	5.2	-	-	-	-	-	-
Efficiency	60%	40%	40%	-	-	-	-	-	-
Type/Drive	Recip / Electric	Centrifugal/ Electric	Centrifugal/ Electric	-	-	-	-	-	-
Temperature (°C)	25	46	121	-	-	-	-	-	-
Pressure In (bar)	1.0	10.3	7.3	-	-	-	-	-	-
Pressure Out (bar)	15.5	11.4	16.0	-	-	-	-	-	-
Diameter (m)	-	-	-	1.0	0.96	0.85	0.79	0.87	0.72
Height/length (m)	-	-	-	3.0	2.89	2.53	15.8	14.9	10.0
Orientation	-	-	-	Horizontal	Horizontal	Horizontal	Vertical	Vertical	Vertical
Internals	-	-	-	-	-	-	+21 SS Trays 24inch spacing	+26 SS Trays 18inch spacing	Packed bed section 7.2 m high filled with catalyst
Pressure (barg)	-	-	-	0.0	9.3	6.3	9.6	6.3	13.7

*For all pumps except P-201A/B assume that maximum head is 15% greater than design head, and that zero head occurs at 150% of design flow. For P-201A/B (a positive displacement pump) you may assume that the maximum head is twice the design head, and zero head occurs at 105% of design flow. +Assume a tray efficiency of 70% and a tray spacing of 2ft and a weir height of 2”.

Table A.4.1: Equipment Summary Table for DME Process (cont'd)

Equipment	E-201	E-202	E-203	E-204	E-205	E-206	E-207	E-208
Type	Float. Head Vaporizer	Float. Head	Float. Head Partial Cond.	Float. Head Reboiler	Fixed TS Condenser	Float. Head Reboiler	Float. Head Condenser	Float. Head
Duty (MJ/h)	14,400	2,030	12,420	2,730	3,140	5,790	5,960	1,200
Area (m^2)	99.4	171.0	101.8	22.0	100.6	83.0	22.7	22.8
Shell Side								
Max Temp(^oC)	154	250	280	153	46	167	121	167
Pressure (barg)	14.2	14.1	12.8	9.5	9.3	6.6	6.3	6.6
MOC	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Phase	Boiling Liq.	V	Cond. Vapor	Boiling Liq.	Cond. Vapor	Boiling Liq.	Cond. Vapor	L
Tube Side								
Max Temp. (^oC)	184	368	40	184	40	184	40	40
Pressure (barg)	10.0	12.9	4.0	10.0	4.0	10.0	4.0	4.0
MOC	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Phase	Cond. Steam	V	L	Cond. Steam	L	Cond. Steam	L	L
%Heat transfer resistance for process side	35%	50%	50%	35%	40%	35%	40%	30%

Table A.4.2: Flow Summary Table for DME Process in Figure A.4.1

Stream No.	1	2	3	4	5	6	7	8
Temperature (°C)	25	25	45	154	250	364	278	100
Pressure (bar)	1.0	15.5	15.2	15.1	14.7	13.9	13.8	13.4
Vapor Fraction (molar)	0.0	0.0	0.0	1.0	1.0	1.0	1.0	0.0798
Mass Flow (tonne/h)	8.37	8.37	10.49	10.49	10.49	10.49	10.49	10.49
Mole Flow (kmol/h)	262.2	262.2	328.3	328.3	328.3	328.3	328.3	328.3
Component Mole Flow (kmol/h)								
Dimethyl ether	0.0	0.0	1.5	1.5	1.5	130.5	130.5	130.5
Methanol	259.7	259.7	323.0	323.0	323.0	64.9	64.9	64.9
Water	2.5	2.5	3.8	3.8	3.8	132.9	132.9	132.9

Table A.4.2: Flow Summary Table for DME Process in Figure A.4.1 (cont'd)

Stream No.	9	10	11	12	13	14	15	16	17
Temperature (^oC)	89	46	153	139	121	167	50	46	121
Pressure (bar)	10.4	11.4	10.5	7.4	15.5	7.6	1.2	11.4	7.3
Vapor Fraction (molar)	0.148	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0
Mass Flow (tonne/h)	10.49	5.97	4.52	4.52	2.13	2.39	2.39	2.17	3.62
Mole Flow (kmol/h)	328.3	129.7	198.6	198.6	66.3	132.3	132.3	47.1	113.0
Component Mole Flow (kmol/h)									
Dimethyl ether	130.5	129.1	1.4	1.4	1.4	0.0	0.0	46.9	2.4
Methanol	64.9	0.6	64.3	64.3	63.6	0.7	0.7	0.2	108.4
Water	132.9	0.0	132.9	132.9	1.3	131.6	131.6	0.0	2.2

Utility	mps	cw	mps	cw	mps	cw	cw
Equipment	E-201	E-203	E-204	E-205	E-206	E-207	E-208
Temperature In (°C)	184	30	184	30	184	30	30
Temperature Out (°C)	184	40	184	40	184	40	40
Flow (tonne/h)	7.22	297.1	1.37	78.47	3.29	160.1	28.70

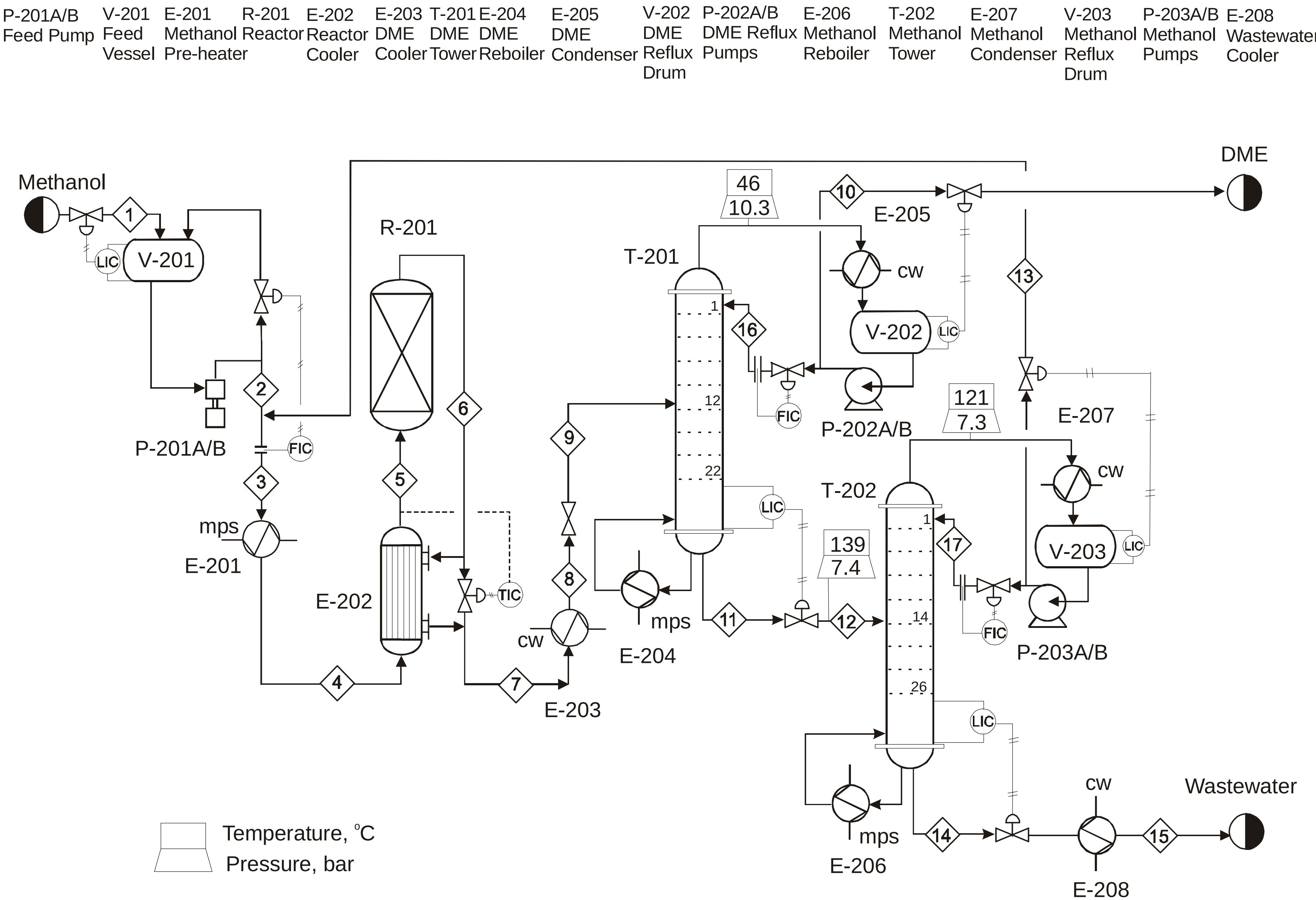


Figure A.4.1: Process Flow Diagram for the Production of Dimethyl Ether (Unit 200)