CHEN 425 ASPEN Simulation Report

Title: Use of the ASPEN RADFRAC Design Spec

Workshop: #4

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Prepared by: Mark Levchenko

To: Professor Mahmoud El-Halwagi

1 Summary of Results

1.1 Part A

In order to meet the required distillate and bottoms specifications, the reflux ratio was 1.2037 and the distillate rate was 56504.8 lb/hr. In order to meet these rates, the condenser duty was $5.8383 \cdot 10^7$ Btu/hr and the reboiler duty was $6.10364 \cdot 10^7$ Btu/hr.

1.2 Part B

In order to meet the required distillate and bottoms specifications with the 65% efficient trays, the reflux ratio was 1.58658 and the distillate rate was 56504.8 lb/hr. In order to meet these rates, the condenser duty was $6.85269 \cdot 10^7$ Btu/hr and the reboiler duty was $7.11795 \cdot 10^7$ Btu/hr.

1.3 Part C

1. The single section column with sieve trays requires a diameter of 9.86464 ft.

2. In the two-section column, the diameter of the section below the feed tray is 9.26729 ft, and the diameter of the section above the feed tray is 9.86485 ft. The smaller diameter of the lower section will allow the column to be built for less money. The multi-section design should be selected if savings in capital costs are desired.

3. The multi-section column allows for one section to be smaller. With a smaller diameter, less material is needed for the shell and smaller trays are required. The need for less material decreases the capital costs of the column. However, the smaller diameter of the lower section may decrease the structural integrity of the column.

1.4 Part D

The packed column is half the height of the column with trays, but its diameter is much larger. The diameter of the packed column is 14.3397 ft. The column itself will be much cheaper; however, packing is much more expensive than trays. The trays may also require less maintenance.

2 Discussion of Simulation Results

2.1 Part A

The distillate flow rate combined with the purity of the distillate means that almost all of the Methanol is being recovered in the distillate stream. The condenser and reboiler duties seem reasonably achievable in an industrial setting. The operation of the column can probably be achieved economically provided that the price of methanol is high enough.

2.2 Part B

Clearly the efficiency of the stages has a major impact on the operation of the column. The reflux ratio had to be increased significantly in order to meet the required purity in the distillate. The flow rate of the distillate is almost identical as a result of the methanol and water specifications. Furthermore, notice that the reboiler and condenser duties increased significantly. As a result, the efficiency of the stages will have a major impact on the operating costs of the column.

2.3 Part C

The height of the single section and the two-section column are the same. The diameter of the lower section of the two-section column is less than the diameter of the single section column. The smaller diameter of the lower section of the two-section column will lead to a lower capital cost of the column and the trays as smaller trays are required.

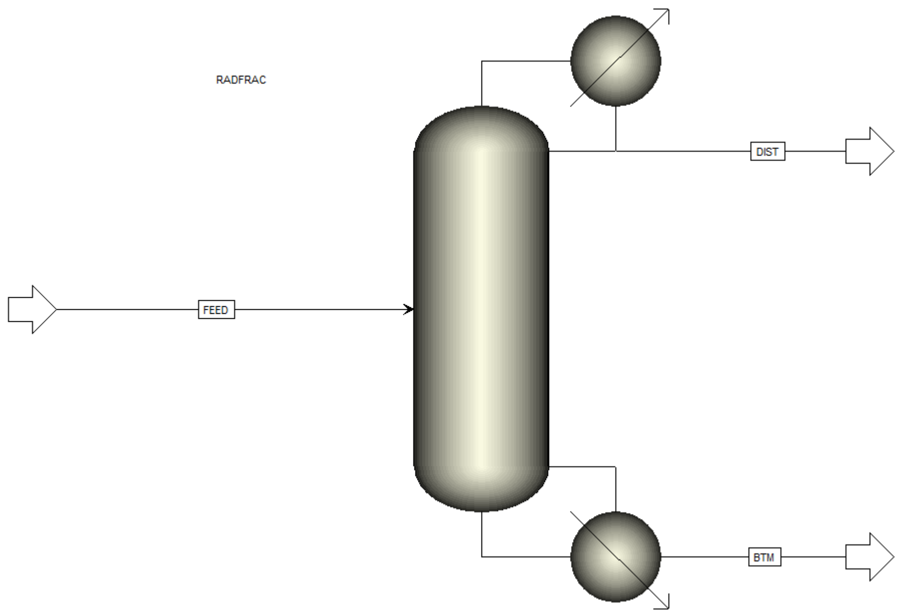
2.4 Part D

The height of the packed column is much smaller which will result in a lower capital cost of the column shell. However, in packed columns, almost the entire inside of the column needs to be filled with material as opposed to columns with trays which only need sheet metal spaced every few feet. The higher material costs combined with the added complexity of packing result in a much higher overall capital cost of installing a packed column. Packed columns also require more work during installation and additional structures inside the column to support the packing and ensure even distribution of the fluid into the packing. However, packing generally is more efficient than trays are, and the increased efficiency can offset the capital costs by lowering operating costs. In the right situation, using packing inside a distillation column can have tremendous benefits.

The condenser and reboiler duties for the packed column and both columns with trays are the same. In every design, the same amount of fluid is heated and cooled, and so the amount of heat tranfer required is identical. However, it is possible for the packing to be much more efficient than the trays. If the higher efficiency is accounted for, the packed column would require less heat tranfer overall as it would be more efficient than the column with trays.

3 Simulation Screenshots

Main flowsheet:



Part A Reflux ratio design spec results:

Type	MASS REFLUX RATIO	
Lower bound	0.8	
Upper bound	2	
Final value	1.2037	

Part A Distillate rate design spec results:

Type	MASS DISTILLATE RATE	
Lower bound	25000	lb/hr
Upper bound	85000	lb/hr
Final value	56504.8	lb/hr

Part B Reflux ratio design spec results:

Type	MASS REFLUX RATIO	
Lower bound	0.8	
Upper bound	2	
Final value	1.58658	

Part B Distillate rate design spec results:

Type	MASS DISTILLATE RATE	
Lower bound	25000	lb/hr
Upper bound	85000	lb/hr
Final value	56504.8	lb/hr

Stream results showing specification mass fractions:

	Units	BTM	DIST	FEED
Molar Vapor Fraction		0	0	0
Molar Liquid Fraction		1	1	1
Molar Solid Fraction		0	0	0
Mass Vapor Fraction		0	0	0
Mass Liquid Fraction		1	1	1
Mass Solid Fraction		0	0	0
Molar Enthalpy	Btu/lbmol	-119950	-100593	-115026
Mass Enthalpy	Btu/lb	-6655.3	-3140.6	-5255.7
Molar Entropy	Btu/lbmol-R	-34.2457	-54.1608	-39.4504
Mass Entropy	Btu/lb-R	-1.90009	-1.69096	-1.80254
Molar Density	lbmol/cuft	3.13363	1.43658	2.35415
Mass Density	lb/cuft	56.478	46.0132	51.5228
Enthalpy Flow	Btu/hr	-5.55686e+08	-1.77459e+08	-7.35798e+08
Average MW		18.0232	32.0297	21.8859
+ Mole Flows	**lbmol/hr**	**4632.66**	**1764.14**	**6396.8**
+ Mole Fractions				
+ Mass Flows	**lb/hr**	**83495.2**	**56504.8**	**140000**
− Mass Fractions				
WATER		0.999	0.000500043	0.596
MEOH		0.00100003	0.9995	0.404
Volume Flow	cuft/hr	1478.37	1228.01	2717.25
+ Liquid Phase				

Part A RADFRAC block results:

Condenser / Top stage performance

Name	Value	Units
Temperature	157.892	F
Subcooled temperature		
Heat duty	-5.83838e+07	Btu/hr
Subcooled duty		
Distillate rate	1764.14	lbmol/hr
Reflux rate	2123.49	lbmol/hr
Reflux ratio	1.2037	
Free water distillate rate		
Free water reflux ratio		

Reboiler / Bottom stage performance

Name	Value	Units
Temperature	234.399	F
Heat duty	6.10364e+07	Btu/hr
Bottoms rate	4632.66	lbmol/hr
Boilup rate	3537.08	lbmol/hr
Boilup ratio	0.76351	
Bottoms to feed ratio		

Part B RADFRAC block results:

Condenser / Top stage performance

Name	Value	Units
Temperature	157.892	F
Subcooled temperature		
Heat duty	-6.85269e+07	Btu/hr
Subcooled duty		
Distillate rate	1764.14	lbmol/hr
Reflux rate	2798.94	lbmol/hr
Reflux ratio	1.58658	
Free water distillate rate		
Free water reflux ratio		

Reboiler / Bottom stage performance

Name	Value	Units
Temperature	234.399	F
Heat duty	7.11795e+07	Btu/hr
Bottoms rate	4632.66	lbmol/hr
Boilup rate	4125.09	lbmol/hr
Boilup ratio	0.890437	
Bottoms to feed ratio		

Part C Sieve tray results for a uniform diameter:

Property	Value	Units
Tray type	SIEVE	
Diameter	9.86464	ft
Tray spacing	2	ft
Number of passes	1	
Hole diameter	0.0416667	ft
Hole area / Active area	0.1	
Deck gauge thickness	10 GAUGE	
Deck gauge thickness value	0.133858	in
Cross-sectional area	76.428	sqft
Active area	61.1424	sqft
Net area	68.7852	sqft

Downcomer geometry

Property	Side	Units
Downcomer clearance	0.125	ft
Downcomer width top	18.5229	in
Downcomer width bottom	18.5229	in
Downcomer area top	7.6428	sqft
Downcomer area bottom	7.6428	sqft

Weir geometry

Property	Side	Units
Weir height	0.166667	ft
Weir length	7.16776	ft

Panels

Property	A	Units
Flow path length	6.77749	ft
Bubbling area	61.1424	sqft

	Property	Value	Units
	Section starting stage	2	
	Section ending stage	45	
	Calculation Mode	Sizing	
	Tray type	SIEVE	
	Number of passes	1	
	Tray spacing	2	ft
	Section diameter	9.86485	ft
	Section height	88	ft
	Section pressure drop	5.01223	psi
	Section head loss (Hot liquid height)	177.307	in
	Trays with weeping	None	
	Section residence time	0.0669895	hr

Limiting conditions

	Property	Value	Units	Tray	Location
	Maximum % jet flood	80.0003		2	
	Maximum % downcomer backup (aerated)	38.9411		26	
	Maximum downcomer loading	64.3602	gpm/sqft	29	Side
	Maximum % downcomer choke flood	25.744		29	Side
	Maximum weir loading	68.6263	gpm/ft	29	Side
	Maximum aerated height over weir	0.417183	ft	26	
	Maximum % approach to system limit	51.727		2	
	Maximum Cs based on bubbling area	0.327166	ft/sec	2	

Part C Sieve tray results for a two-section column:

Upper section of the column:

	Property	Value	Units
	Tray type	SIEVE	
	Diameter	9.86485	ft
	Tray spacing	2	ft
	Number of passes	1	
	Hole diameter	0.0416667	ft
	Hole area / Active area	0.1	
	Deck gauge thickness	10 GAUGE	
	Deck gauge thickness value	0.133858	in
	Cross-sectional area	76.4313	sqft
	Active area	61.145	sqft
	Net area	68.7881	sqft

Downcomer geometry

	Property	Side	Units
	Downcomer clearance	0.125	ft
	Downcomer width top	18.5233	in
	Downcomer width bottom	18.5233	in
	Downcomer area top	7.64313	sqft
	Downcomer area bottom	7.64313	sqft

Weir geometry

	Property	Side	Units
	Weir height	0.166667	ft
	Weir length	7.16791	ft

Panels

	Property	A	Units
	Flow path length	6.77764	ft
	Bubbling area	61.145	sqft

Property	Value	Units
Section starting stage	2	
Section ending stage	26	
Calculation Mode	Sizing	
Tray type	SIEVE	
Number of passes	1	
Tray spacing	2	ft
Section diameter	9.86485	ft
Section height	50	ft
Section pressure drop	2.94723	psi
Section head loss (Hot liquid height)	109.238	in
Trays with weeping	None	
Section residence time	0.04751	hr

Limiting conditions

Property	Value	Units	Tray	Location
Maximum % jet flood	80.0003		2	
Maximum % downcomer backup (aerated)	38.9411		26	
Maximum downcomer loading	64.3158	gpm/sqft	26	Side
Maximum % downcomer choke flood	25.7262		26	Side
Maximum weir loading	68.5789	gpm/ft	26	Side
Maximum aerated height over weir	0.417183	ft	26	
Maximum % approach to system limit	51.727		2	
Maximum Cs based on bubbling area	0.327166	ft/sec	2	

Lower section of the column:

Property	Value	Units
Tray type	SIEVE	
Diameter	9.26729	ft
Tray spacing	2	ft
Number of passes	1	
Hole diameter	0.0416667	ft
Hole area / Active area	0.1	
Deck gauge thickness	10 GAUGE	
Deck gauge thickness value	0.133858	in
Cross-sectional area	67.4521	sqft
Active area	53.9617	sqft
Net area	60.7069	sqft

Downcomer geometry

Property	Side	Units
Downcomer clearance	0.125	ft
Downcomer width top	17.4013	in
Downcomer width bottom	17.4013	in
Downcomer area top	6.74521	sqft
Downcomer area bottom	6.74521	sqft

Weir geometry

Property	Side	Units
Weir height	0.166667	ft
Weir length	6.73372	ft

Panels

Property	A	Units
Flow path length	6.36708	ft
Bubbling area	53.9617	sqft

Property	Value	Units
Section starting stage	27	
Section ending stage	45	
Calculation Mode	Sizing	
Tray type	SIEVE	
Number of passes	1	
Tray spacing	2	ft
Section diameter	9.26729	ft
Section height	38	ft
Section pressure drop	2.32575	psi
Section head loss (Hot liquid height)	76.7159	in
Trays with weeping	None	
Section residence time	0.0185723	hr

Limiting conditions

Property	Value	Units	Tray	Location
Maximum % jet flood	80.0005		27	
Maximum % downcomer backup (aerated)	42.7338		27	
Maximum downcomer loading	72.9279	gpm/sqft	29	Side
Maximum % downcomer choke flood	29.171		29	Side
Maximum weir loading	73.0514	gpm/ft	29	Side
Maximum aerated height over weir	0.464558	ft	27	
Maximum % approach to system limit	37.7583		27	
Maximum Cs based on bubbling area	0.293834	ft/sec	27	

Part D Packed column results:

Property	Value	Units
Section starting stage	2	
Section ending stage	45	
Calculation Mode	Sizing	
Column diameter	14.3397	ft
Packed height per stage	1	ft
Section height	44	ft
Maximum % capacity (constant L/V)	80	
Maximum % capacity (constant L)	75.8122	
Maximum capacity factor (Cs)	0.123873	ft/sec
Section pressure drop	0.654531	psi
Average pressure drop / Height	0.411758	in-water/ft
Average pressure drop / Height (Frictional)	0.395642	in-water/ft
Maximum stage liquid holdup	6.03799	cuft
Maximum liquid superficial velocity	3.046	gpm/sqft
Maximum Fs	0.839355	ft/s-sqrt(lb/cuft)
Maximum % approach to system limit	22.0084	

4 Conclusions

The reflux ratio, reboiler duty, and condenser duty seem practically achievable. Given that the rest of the process for producing methanol is profitable, this distillation column can be economically viable.

The efficiency of the stages in the column could negate any econmic viability. Part B illustrated that a much larger amount of reflux is necessary to maintain the purity specification. The higher reflux leads to more fluid in the column which requires more heat tranfer. Higher heat tranfer increases the operating cost of the column. If the stages are too inefficient, the column may become unprofitable.

Depending on the type of column internals, the geometry of the column will change.

The packed column requires a larger diameter but is shorter compared to the column with trays. In Part C, a column was designed in two sections. The upper section of the column had approximately the same diameter as the single section column, the lower section had a smaller diameter. Splitting the column into sections allowed for a part of the column to be smaller requiring less material. Generally, buying a smaller column will cost less, decreasing the capital cost of the column. However, one consideration is that packing can be more expensive than trays. It is necessary to obtain an accurate estimate of the cost of the necessary trays compared to the cost of packing in order to determine whether the increased cost of packing outweighs the decreased cost of the shell. If maximum efficiency and the smallest column are desired, the packed column should be selected. If a column with trays is sufficient, then the multisection column is the better, more cost effective option.