CHEN 425 ASPEN Simulation Report

Title: Simulation of a Distillation Column Using the RADFRAC Model

Workshop: #3

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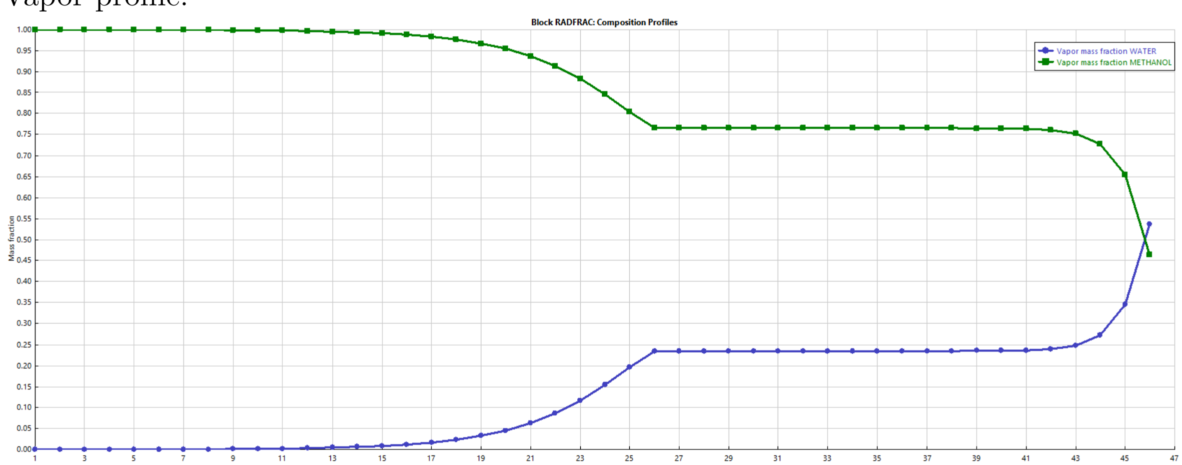
1 Summary of Results

1.1 Part 1

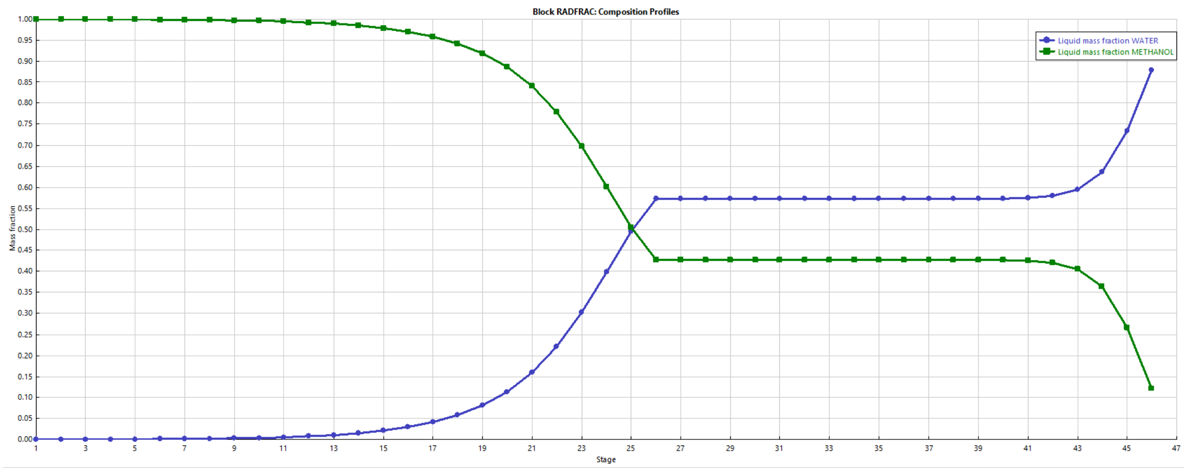
The operating cost of the column based on the cost of heating and cooling the column is \$4,049,989/yr.

1.2 Part 2

Vapor profile:



Liquid profile:



1.3 Part 3

The number of stages was reduced to 30, the feed stage was changed to 20, and the reflux ratio was reduced to 1.2.

Summary of column duties between base case and the case after changes were made to decrease operating costs:

Simulation	Heating duty (kW)	Cooling Duty (kW)
Base column	15262.3	14833.4
With changes	13938.2	13627.6

2 Discussion of Simulation Results

2.1 Part 1

The operating cost was calculated by finding the amount of steam and cooling water needed to heat and cool the column respectively. Heating and cooling duties were taken from the ASPEN simulation. Heating was achieved with the condensation of 683.56 kPa saturated steam. Cooling was achieved with liquid water with a heat capacity of 4.184 kJ/kg/°C decreasing in temperature 20°C.

Table 2.14 in the textbook contains costs for various utilities. From this table, a steam cost of \$15/ton and a cooling water cost of \$0.10/m^3 were used in the operating cost calculations. Conservatively, the highest prices of each range were taken as the basis for the operating cost calculations.

Operating cost calculation:

$$Q_{\text{cooling}} = 14833.4 \text{ kW}$$
$$C_P = 4.184\text{kJ/kg/°C}$$
$$\Delta T = 20\text{°C}$$

Cost of cooling water is \$0.10/m^3

Operate 31536000 s/yr

$$\text{Cooling cost} = \frac{14833.4 \text{ kW}}{4.184\text{kJ/kg/°C} \cdot 20\text{°C}} \cdot \frac{1 \text{ m}^3}{1000 \text{ kg}} \cdot 31536000 \text{ s/yr} \cdot \$0.10/\text{m}^3$$
$$\text{Cooling cost} = \$559017/\text{yr}$$
$$Q_{\text{heating}} = 15262.3 \text{ kW}$$
$$\Delta h_v = 2068.1\text{kJ/kg}$$

Take the cost of 683.56 kPa steam as \$15/ton

$$\text{Heating cost} = \frac{15262.3 \text{ kW}}{2068.1\text{kJ/kg}} \cdot \frac{1 \text{ ton}}{1000 \text{ kg}} \cdot 31536000 \text{ s/yr} \cdot \$15/\text{ton}$$
$$\text{Heating cost} = \$3490971/\text{yr}$$
$$\text{OPEX} = \$4,049,989/\text{yr}$$

2.2 Part 2

From stage 27 to stage 42, the vapor and liquid compositions do not change. The lack of change suggests that these stages may not be necessary to achieve a sufficient purity of products.

2.3 Part 3

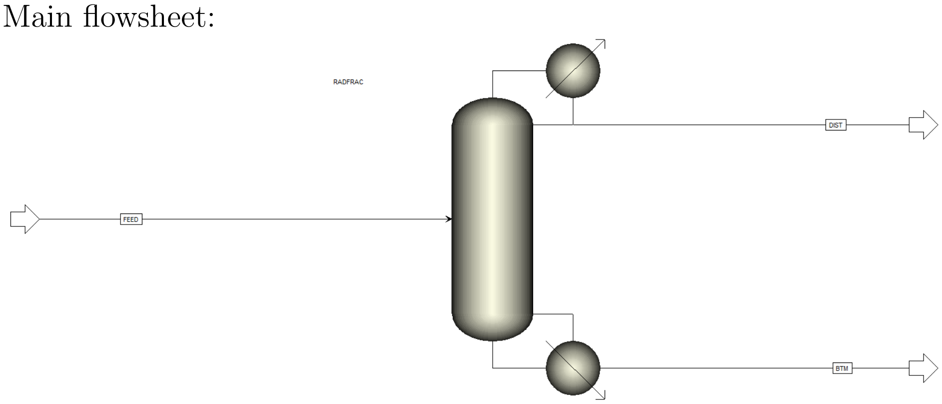
The Total duty decreased approximately 8.4%. The decrease will result in approximate savings of $340,000/yr.

From Part 2, there is a section of the column where the vapor and liquid compositions do not change. Removing these stages has little effect on the product purity because these stages were not doing anything to begin with. Removing them will decrease the capital and installation costs due to the smaller column size.

Lowering the reflux ratio lowers the amount of liquid in the column which reduces the amount of heat necessary to vaporize the liquid in the column. Lowering the reflux ratio had the biggest impact on column operating costs because it directly decreases the amount of heating and cooling necessary.

3 Simulation Screenshots

Main flowsheet:



3.1 Part 1

RADFRAC results for part 1:

Condenser / Top stage performance

Name	Value	Units
Temperature	69.9275	C
Subcooled temperature		
Heat duty	-14833.4	kW
Subcooled duty		
Distillate rate	0.176959	kmol/sec
Reflux rate	0.247742	kmol/sec
Reflux ratio	1.4	
Free water distillate rate		
Free water reflux ratio		

Reboiler / Bottom stage performance

Name	Value	Units
Temperature	102.843	C
Heat duty	15262.3	kW
Bottoms rate	0.629024	kmol/sec
Boilup rate	0.3833	kmol/sec
Boilup ratio	0.609357	
Bottoms to feed ratio		

3.2 Part 2

Profile plots are in the summary of results section for part 2.

3.3 Part 3

RADFRAC results with reduced reflux ratio and stages:

Condenser / Top stage performance

Name	Value	Units
Temperature	69.9844	C
Subcooled temperature		
Heat duty	-13627.6	kW
Subcooled duty		
Distillate rate	0.17724	kmol/sec
Reflux rate	0.212687	kmol/sec
Reflux ratio	1.2	
Free water distillate rate		
Free water reflux ratio		

Reboiler / Bottom stage performance

Name	Value	Units
Temperature	100.628	C
Heat duty	13938.2	kW
Bottoms rate	0.628743	kmol/sec
Boilup rate	0.348743	kmol/sec
Boilup ratio	0.554667	
Bottoms to feed ratio		

Purity of distillate is still 99%.

	Units	FEED	BTM	DIST
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	-115026	-118867	-100648
Mass Enthalpy	Btu/lb	-5255.7	-6243.76	-3146.23
Molar Entropy	Btu/lbmol-R	-39.4504	-35.7413	-54.074
Mass Entropy	Btu/lb-R	-1.80254	-1.8774	-1.69033
Molar Density	lbmol/cuft	2.35415	2.89507	1.43868
Mass Density	lb/cuft	51.5228	55.1153	46.0234
Enthalpy Flow	Btu/hr	-7.35798e+08	-5.93157e+08	-1.4158e+08
Average MW		21.8859	19.0376	31.9901
+ Mole Flows	**lbmol/hr**	**6396.8**	**4990.11**	**1406.69**
− Mole Fractions				
WATER		0.724053	0.927114	0.00371179
METHANOL		0.275947	0.0728861	0.996288
+ Mass Flows	**lb/hr**	**140000**	**95000**	**45000**
+ Mass Fractions				
Volume Flow	cuft/hr	2717.25	1723.66	977.765
+ Liquid Phase				
<add properties>				

4 Conclusions

The cost of cooling and heating a distillation column is significant. $4,000,000 per year in operating costs outweighs any capital costs or any other costs associated with the operation of the column like electricity.

The initial design of the column included too many stages. The composition profiles demonstrated that the additional stages of the initial design were not doing anything to improve the separation. To reduce the capital costs, these stages were removed, and the purity of methanol did not decrease significantly. Furthermore, the operating cost of the column could be decreased by more than 8% by decreasing the reflux ratio to 1.2.