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Influence of Operating Parameters on the Efficiency of a Multi-Components Flash Distillation Operation

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Abstract: This research aims to study by numerical simulation the influence of various parameters on the efficiency of a flash distillation. The main characteristic of this system is that it feed a binary or a multi-components distillation column, such as a debutaniser column, by providing this last one by both a liquid and a gas stream. The study of the flash distillation is carried out in order to emphasis the influence of operating parameters on the gas vaporized fraction (δ). The studied parameters are: temperature and pressure inside the flash tank, feed flow rate, and the feed composition. The obtained results showed that for an ideal mixture, the vaporized fraction is sensitive to the pressure, temperature and feed composition and is non- sensitive to the feed flowrate.

Keywords: flash distillation; vaporized fraction; operating parameters; column

1. Introduction

This research focuses on the study of a multi-components flash distillation because it is very used in the petroleum industrial practice as a unit feeding a binary or multi-component distillation column for the production of various and important chemical products [1]. The flash distillation is a single –stage separation technique in which a feed mixture is partially vaporized in order to get a vapor enriched with more volatile component and a liquid enriched in the less volatile components. The vapor and liquid streams leaving the tank or drum are in equilibrium. The flash distillation tank provides the distillation column by both a liquid and gas stream. Generally, there are two kinds of flash distillation operations namely: isotherm flash and adiabatic flash [1,2] The run of flash distillation unit presents many challenges, such as a strong variation of products concentrations at the exit of the flash unit versus the operating parameters. This variation of concentrations is due mainly to the complex phenomenon of vaporization occurring inside the flash tank.[2]. These considerations motivate the need for investigate the effect of the operating parameters on the efficiency of a flash operation because the parametric sensivity can give important information on the run of a given process [3–5]. For this purpose, the mathematical model of a multi-components flash distillation was set and solved using the data related to a nominal operating point. Afterwards, the influence on the vaporized fraction and outlet concentrations of the main operative variables was evidenced.

2. The Flash Distillation Unit

A flowsheet of flash distillation operation is presented in Figure 1 [8]. This unit consists of a tank supplying a distillation column. The feed entering the flash tank is entirely liquid and it consist generally of a hydrocarbon mixture called stabilized naphtha which will be partially vaporized . At the exit of the flash tank, the vapor and liquid streams will be headed towards the inlet of a multi-components distillation column (debutanizer). Table 1 gives additional parameter values related to the studied process.

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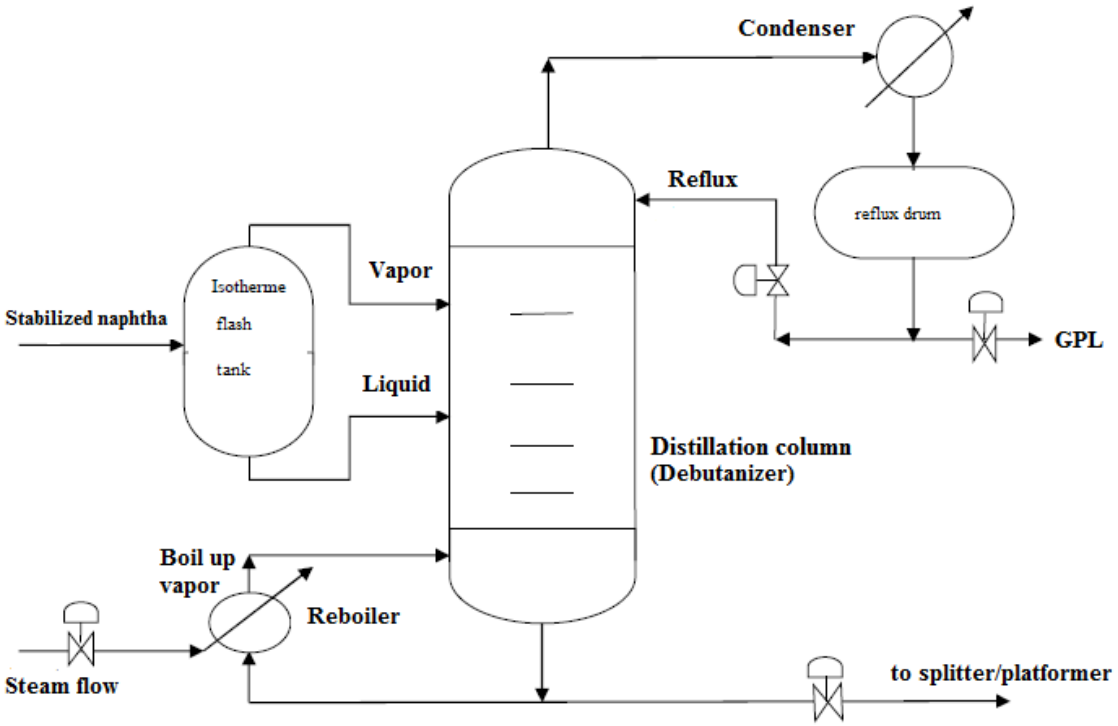

Figure 1. Flowsheet of the location of flash distillation tank in debutanization unit [6].

Table 1. Parameters values for the flash distillation operation [6].

Parameter	Signification	Value
Tf	temperature feed	180 °F
P	flash pressure	110 Psi
F	feed flowrate	880.56 lbmol/h
Nc	number of components in the mixture at the inlet of flash tank	8
Tcf (1)	critical temperature of ethane (i =1)	90.32 °F
Tcf(2)	critical temperature of propane (i =2)	206.24 °F
tcf(3)	critical temperature of iso-butane (i =3)	274.9 °F
tcf(4)	critical temperature of n-butane (i =4)	305.6 °F
tcf(5)	critical temperature of iso-pentane (i =5)	369.32 °F
tcf(6)	critical temperature of n-pentane (i =6)	385.88 °F
tcf(7)	critical temperature of n-hexane (i =7)	453.92 °F
tcf(8)	critical temperature of n-octane (i =8)	564.44 °F
$z_F(1)$	molar fraction of ethane in the flash distillation tank feed	0.00120174
$z_F(2)$	molar fraction of propane in the flash distillation tank feed	0.00675980
$z_F(3)$	molar fraction of iso-butane in the flash distillation tank feed	0.24079915
$z_F(4)$	molar fraction of n-butane in the flash distillation tank feed	0.31515700
$z_F(5)$	molar fraction of iso-pentane in the flash distillation tank feed	0.12167645
z_F (6)	molar fraction of n-pentane in the flash distillation tank feed	0.10244855
z_F (7)	molar fraction of n-hexane in the flash distillation tank feed	0.13159080
$z_F(8)$	molar fraction of n-octane in the flash distillation tank feed	0.08036650
tolerance	value used in the iterative procedure to solve the model	0.00000001

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3. Model Assumptions

The main model assumptions are listed below:

- isothermal operation (isothermal flash);
- steady state mathematical model;
- ideal behavior of the mixture.

4. Mathematical Model and Method of Resolution

The mathematical model of flash distillation operation can be resumed essentially to the following steps:

1. Compute the saturated pressure P_i^S for each component i (i=1,.. Nc), by using Lee-Kesler equation :

$$P_i^s = P_{ci}\exp(\ln\pi_{1i} + w_i \ln\pi_{2i})$$

$$\ln\pi_{1i} = 5.92714 - (6.09648/T_{ri}) - 1.28862\ln T_{ri} + 0.169347T_{ri}^6$$

$$\ln\pi_{2i} = 15.2518 - (15.6875/T_{ri}) - 13.4721\ln T_{ri} + 0.43577T_{ri}^6$$

2. Compute the liquid-vapor equilibrium coefficient $k_{Fi} = P_i^S/P$ (i=1,.. Nc)
3. Assume a starting value for δ (δ = 0.1 for example)
4. Compute V_F according to the following equation $V_F = \delta.F$
5. Compute L_F according to the following equation $L_F = F - V_F$
6. Compute molar fractions in liquid phase $x_{Fi} = z_{Fi}/(1- \delta.(1-k_{Fi}))$ (i=1,.. Nc)
7. Compute molar fractions in vapor phase $y_{Fci} = -k_{Fi}.\, x_{Fi}$ (i=1,.. Nc)
8. If $|\ (\Sigma\, y_{Fci}) - 1\ | \leq$ tolerance then $y_{Fi} = y_{Fci}$ and stop the computing.
   Otherwise compute normalized molar fractions in vapor phase
   $y_{Fi} = y_{Fci}/\Sigma y_{Fci}$ (i=1,.. Nc) and go to the next step
9. Compute $k_{Fi} = y_{Fi}/x_{Fi}$ for all components (in our case, i=1,..8) according to

$x_{Fi} = z_{Fi}/(1- \delta.(1-k_{Fi}))$ (i=1,..Nc) (from step 6)
$y_{Fi} = y_{Fci}/\Sigma y_{Fci}$ (i=1,..Nc) (from step 8)
Update δ by using the Newton-Raphson convergence technique:
$\delta_{new} = \delta_{old} - F(\delta)/F'(\delta)$
$F(\delta) = \Sigma\, z_{Fi}/(1- \delta.(1-k_{Fi}))$ (i=1,..Nc)
$F'(\delta) = \Sigma\, z_{Fi}\,(1-k_{Fi})/(1- \delta.(1-k_{Fi}))^2$ (i=1,..Nc)
Go to step 4

5. Results and Discussion

5.1. Influence of Temperature on the Vaporized Fraction

Figure 2 show the effect of varying the temperature inside flash tank on the vaporized fraction for different values of the pressure. It can be seen that the vaporized fraction is very sensitive to the operating temperature; this effect can be explained by the fact that the increase of the temperature accelerate the vaporization. For a fixed value of the pressure inside the flash drum, the vaporized fraction increases as the operating temperatures becomes higher. This last effect is very pronounced at low pressure relatively to high pressures values because the curves have tendency to be separated from one another. Indeed, the vaporized fraction value becomes approximately constant especially at high values of the pressure. Furthermore, for a fixed value of the operating temperature, the

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vaporized fraction becomes higher if the operating pressure decreases, and this effect is pronounced for low pressure values.

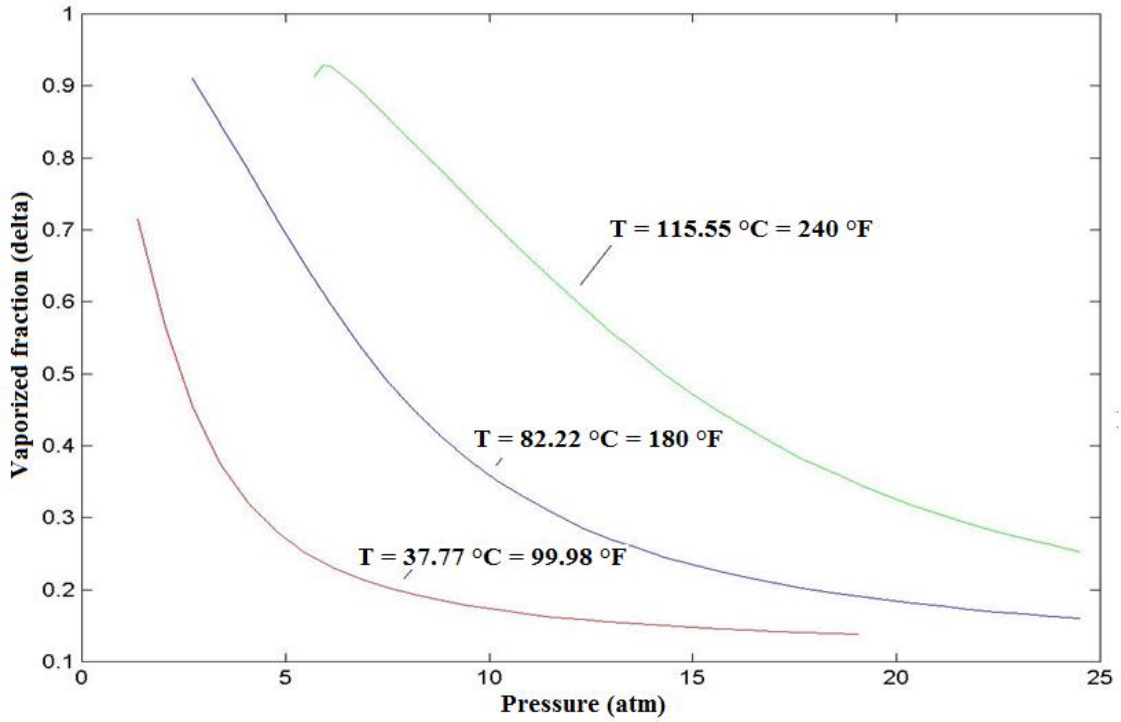

Figure 2. vaporized fraction (δ) versus pressure for different values of the operating temperature.

5.2. Influence of Feed Composition on the Vaporized Fraction

Table 1 shows the effect of varying the feed composition on the vaporized fraction. It can be seen that the vaporized fraction is very sensitive to the feed composition. This last effect can be explained by the difference in volatility from a component to another.

Table 1. influence of feed composition on the vaporized fraction (δ).

x(1)	**0.001**	**0.101**	**0.301**	**0.101**	**0.501**	**0.001**
x(2)	**0.006**	**0.101**	**0.006**	**0.006**	**0.306**	**0.006**
x(3)	**0.240**	**0.040**	**0.140**	**0.140**	**0.040**	**0.040**
x(4)	**0.315**	**0.015**	**0.215**	**0.015**	**0.015**	**0.015**
x(5)	**0.121**	**0.221**	**0.021**	**0.221**	**0.021**	**0.021**
x(6)	**0.102**	**0.201**	**0.002**	**0.202**	**0.002**	**0.002**
x(7)	**0.131**	**0.231**	**0.031**	**0.231**	**0.031**	**0.431**
x(8)	**0.080**	**0.080**	**0.280**	**0.080**	**0.080**	**0.480**
δ	**0.491**	**0.428**	**0.611**	**0.396**	**0.911**	**0.188**

5.3. Influence of Feed Flowrate on the Vaporized Fraction

Table 2 show the influence of feed flowrate on the vaporized fraction (δ) for different values of the pressure (T=180 °F). It can be seen that the vaporized fraction is non sensitive to the feed composition value. Table 3 show the influence of feed flowrate on the vaporized fraction (δ) for different values of the temperature (P=110 psi). As noticed previously for the pressure, it can also be seen that the vaporized fraction is non sensitive to the feed composition value.

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Table 2. influence of feed flowrate on the vaporized fraction (δ) for different values of the pressure (T=180 °F).

P = 180 pis	**δ**	**0.292**	**0.292**	**0.292**	**0.292**
	F (Ibmol/h)	**580.56**	**680.56**	**880.56**	**1880.56**
P = 110 pis	**δ**	**0.371**	**0.371**	**0.371**	**0.371**
	F (Ibmol/h	**580.56**	**680.56**	**880.56**	**1880.56**
P = 80 pis	**δ**	**0.434**	**0.434**	**0.434**	**0.434**
	F (Ibmol/h	**580.56**	**680.56**	**880.56**	**1880.56**

Table 3. influence of feed flowrate on the vaporized fraction (δ) for different values of the temperature **(**P = 110 pis).

T=180 °F	**δ**	**0.371**	**0.371**	**0.371**	**0.371**
	F (Ibmol/h)	**580.56**	**680.56**	**880.56**	**1880.56**
T = 240 °F	**δ**	**0.527**	**0.527**	**0.527**	**0.527**
	F (Ibmol/h	**580.56**	**680.56**	**880.56**	**1880.56**
T = 80 °F	**δ**	**0.230**	**0.230**	**0.230**	**0.230**
	F (Ibmol/h	**580.56**	**680.56**	**880.56**	**1880.56**

6. Conclusions

This research highlighted the effects of operating parameters on the vaporized fraction value of a flash distillation operation. Four operating parameters were studied, namely: temperature pressure, feed flowrate and the feed composition The obtained results showed that for a given pressure in the flash drum, the vaporized fraction is very sensitive to the operating temperature, and it increase as the temperature increases.. The vaporized fraction is very sensitive to the feed composition. This last effect can be explained by the difference of the volatility from a component to another in the mixture feed. Furthermore, it was found that the vaporized fraction is non sensitive to the feed composition value. Finally, in a future study, the effects of operating parameters on the vaporized fraction value for a non ideal mixture will be investigated.

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