Study of Material and Heat Balances of Rectification Processes

Askarov Xasanjon Abduqaxorovich and Karimov Ikromali Tojimatovich
Department Structural Engineering, Insti Andijan Institute of Economics and Construction, Fergana Polytechnic Institute, Uzbekistan

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Abstract: In the article fractionation in a rectification column in a laboratory device separation methods are studied. Separator rectification using steam the construction of the column, the principle of operation is given. Rectification column allowing separation of acetic acid without losses in continuous operation plate constructions are studied.

1 INTRODUCTION

The distillation or rectification process is widely used in the chemical and oil refining industries (Yusufbekov et al., 2015; Askarov & Isomiddinov, 2021; Askarov & Mukhammadsodiqov, 2021; Askarov & Axunboev, 2021; Xidirberdiyevich et al., 2020). In the implementation of this process, it is intended to conduct a theoretical study of the material and heat balances of the rectification column apparatus using large-scale plate columns (Abdullah et al., 2023; Uralovich et al., 2023; Rakhmankulovna & Makhmudovich, 2020; Mirmakhmutovich et al., 2019; Rahimov et al., 2024; Askarov et al., 2024; Rakhimov et al., 2024; Makhmudov et al., 2024; Makhmudov & Abduraimova, 2020). The scheme of the experimental device of the rectification process is shown in Figure 1, and a brief classification of the device is as follows. The steam leaving the column cube 1 is transferred to the rectification column 2 and, colliding on the contact surface plates 3, the two-component phases are separated and fall into the residue cube 4. In this process, the liquid is separated into two components, namely, reflux F and distillate.

It is possible to write the material balance according to the given process scheme (Fig. 1) as follows:

$$G_f = G_d + G_w \quad (1)$$

As for the light volatile component, it is as follows:

$$G_f \cdot x_f = G_d \cdot x_d + G_w \cdot x_w \quad (2)$$

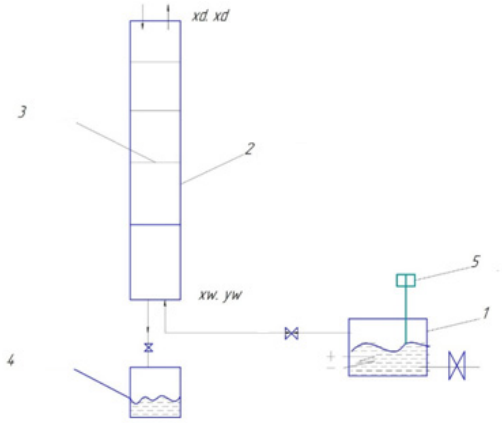

Figure 1: Technological scheme of the experimental device of the rectification process.

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2 METHODS

Here G_f, G_d, G_w- initial solution distillate and cubic residue masses; kmol. Concentrations of the light volatile component in the initial solution distillate and cubic residue. Wealth shares. From equations (1) and (2), the masses of distillate and cube residue are determined:

$$G_d = G_f \frac{x_f - x_w}{x_d - x_w} \quad (2)$$

We determine the ratios of the initial solution cubic residue and phlegm to 1 kmol of distillate as follows:

$$\frac{G_f}{G_d} = F;\ \frac{G_w}{G_d} = W;\ \frac{\Phi}{G_d} = R \quad (3)$$

The ratio of the reflux ratio to the reflux ratio is called the reflux ratio R. The supply plate of the rectification column divides it into 2 upper and lower parts. Based on the general equation, we construct the material balance equations for the upper and lower parts of the column:

$$G \cdot dy = L \cdot (-dx) \quad (4)$$

Here. $L = R \cdot G_d$ - the amount of liquid flowing at the top of the column.

The amount of steam rising up the column is determined as follows:

$$G = G_d + \Phi = G_d + RG_d = G_d(1+R) \quad (5)$$

For the top of the column:

$$(R+1) \cdot dy = R \cdot (-dx) \quad (6)$$

Concentrations ***x,y*** desired cross-section and concentrations of the upper part of the column x_d, y_d The equation for the upper part of the column can be written as follows:

$$(R+1) \cdot dy = (F+R) \cdot (x_d - y) = R \cdot (x_d - x) \quad (7)$$

Or:

$$y = \frac{R}{R+1} x + \frac{x_d}{R+1} \quad (9)$$

For the lower part:

$$(R+1) \cdot dy = (F+R) \cdot (-dx) \quad (10)$$

Concentration ***x,y*** and concentrations of the bottom of the column x_w, y_w for any cross section of a cube that is, $x_w = y_w$ Taking into account, we write the following equation:

$$(R+1) \cdot (y - y_w) = (R+1) \cdot (y - x_w) = (F+R) \cdot (x - x_w)$$

Or:

$$y = \frac{R+F}{R+1} x + \frac{F-1}{R+1} x_w \quad (11)$$

It can be seen that equations (10) and (11) represent the straight line in Figure 2. Thus, equations (10) and (11) represent the operating line of the upper and lower parts of the rectification column. The operating line is distinguished by its smooth and uneven state.

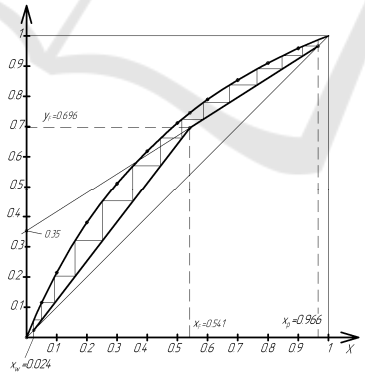

Figure 2: Classification of the working line of the rectification process.

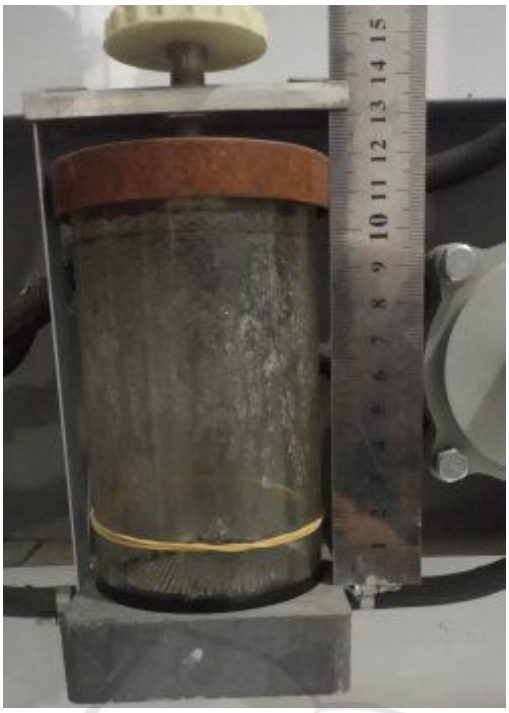

Figure 3: Recommended laboratory setup.

Table 1: Optimal coefficients for the Rectification process in the column and apparatus.

Installation	Column	Print, MPa	Acceptable number of phlegm	Number of plates
Atmospheric-vacuum distillation	Topping	0,4-0,5	2-4	20-30
	Atmospheric	0,15-0,20	1,5-2,5	45-55
	Each section is separate	-	-	8-12
	Acceptable	0,16-0,,18	-	6-8
	Vacuum	$(5\text{-}8),10^{-3}$	2-3	14-26
	Stabilized	0,8-1,4	3-6	35-60
Catalytic process	Stabilized	0,8-1,4	2-3	40-60
Hydraulics (for diesel fuels)	Ordinary	0,15-0,4	1,5-2	20-40
Catalytic process	Rectification cleaning	0,15-0,20	4-5	30
	Stabilization	0,8-1,4	6-8	40-60
Separation of gases	Ethan	1,3-1,5	1,5-3	30-40
	Propane	1,6-1,8	2-4	40-60
	Isobutane	1,8-0,85	8-12	80-100
	Isobutane	0,3-035	15-20	80-120

The recommended laboratory setup (Figure 1-3) shows that the advantages of the plate-based atmospheric-vacuum distillation process over the old processes are that it does not require complex technological processes and has a robust and simple design. Theoretical calculations show that the new plate surface improves heat transfer, and an increase in acetic acid regeneration in atmospheric-vacuum distillation by 19% is achieved.

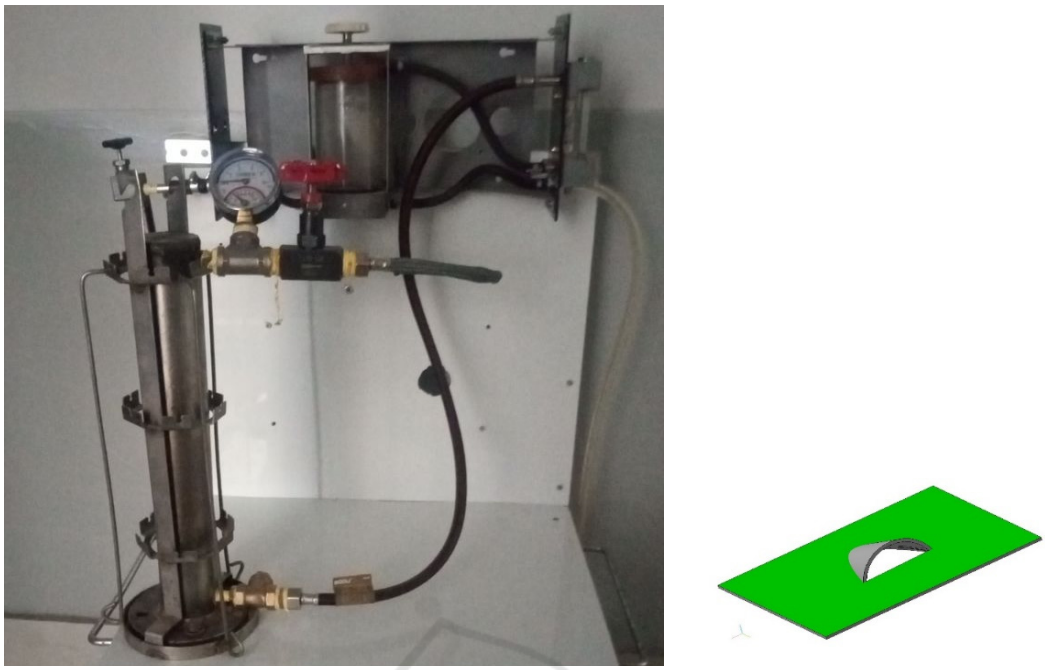

Figure 4: Plate construction.

Such a plate construction can be used not only in the chemical industry, but also in the rectification column apparatus of the primary oil refining processes in the oil refining industry.

3 CONCLUSION

This study focuses on the separation methods used in a laboratory-scale rectification column, particularly examining the process of fractionation using steam. The construction and operational principles of the rectification column are discussed in detail. The research highlights that the rectification column facilitates the effective separation of acetic acid with minimal losses during continuous operation, specifically utilizing plate constructions for improved efficiency. These findings contribute to the understanding and optimization of separation processes in industrial applications.

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