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ASPECTS REGARDING EFFICIENCY OF TWO EXPERIMENTAL FRACTIONATING COLUMNS

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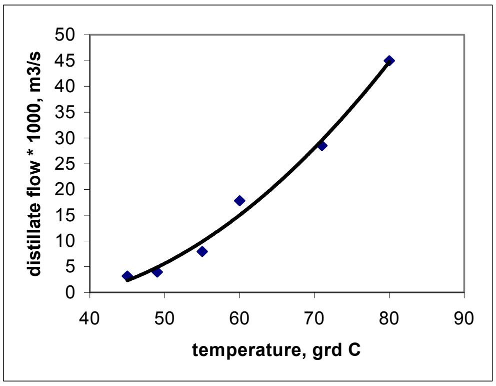
Fractionation is today the most widely used unit operation for separation of liquid mixtures in the chemical and petroleum industries. There are a number of factors that influence the performance of the columns such as: feed concentration, flow rate, temperature, working pressure, pressure losses through the column. Columns used in distillation processes may be bubble-cap plate columns or columns with packing material inside, both being efficient equipment for achieving the distillation of mixtures of close volatilities. The variation of the temperature in the jacket may influence the performance of the column. It has been studied the separation efficiency determined by the jacket temperature and have been established the temperature regimes that resulted in an increase of efficiency.



INTRODUCTION

Fractionation is one of the most used operations in the chemical industry in order to separate mixtures into individual components. The factors that influence the performance of the columns are as follows: feed concentration, flow rate, temperature, working pressure, pressure losses through the column, flooding, liquid phase diffusivity, the density of the liquid and of the vapor phases, the viscosity of the liquid and of the vapor phases, the surface tension, column diameter, surface velocity of the vapor, reflux ratio, height of column, the distributors used for the liquid and vapor.[1-4]

Although fractionation is by far the most widely applied separation technology, its major drawback is the inevitable degradation of energy associated to the temperature difference between the reboiler and condenser – which leads to a low overall thermodynamic efficiency of a distillation column. Heat integrated distillation column (HIDiC) could help to expand the applications window for heat pump assisted distillation. HIDiC maximizes the energy efficiency of a heat pump design by making use of internal heat-integration. Random and structured packing materials are frequently used to improve fractionating performances of columns. Column efficiencies are expressed in terms of the number of theoretical plates to which they are equivalent. Thermodynamic optimization of distillation columns as well as pressure drop of internals for packed columns were also investigated by several authors.[5-13]

The literature lacks data referring to the influence of the jacket temperature upon column efficiency. For this matter, the authors present in this paper the results of the research carried out

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concerning the manner and the effect of the jacket temperature on the separation efficiency of two experimental fractionation columns: a bubble-cap plate column and a packed column. As known, the bubble-cap plate columns are efficient apparatus for achieving the separation of chemical mixtures. Therefore the columns have been provided with a jacket through which air, supplied by the blower and heated by the heating device, is circulated. The temperatures of the air inlet and outlet are measured with thermocouples.[14]

RESULTS AND DISCUSSION

The variation of the concentration at the head of the column versus the jacket temperature for benzene – diclor-ethane mixture is presented in Fig. 1 and the variation of the distillate flow with the jacket temperature for the same mixture in Fig. 2:

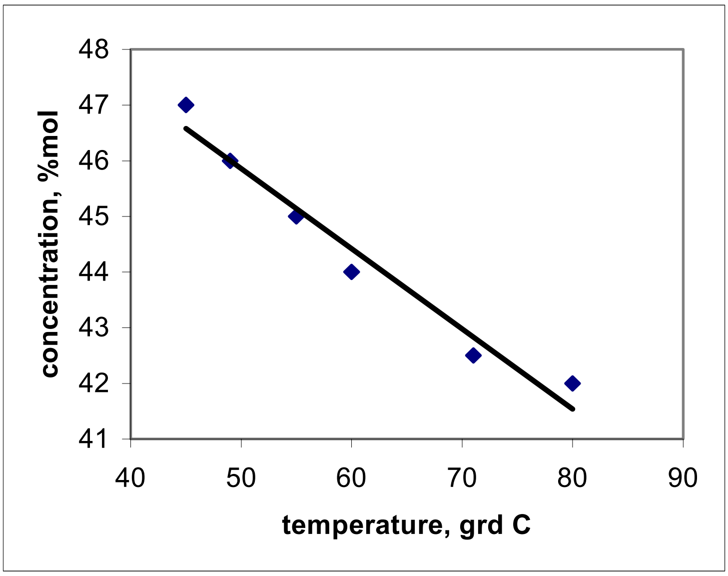

Fig. 1 – Variation of concentration at the head of the bubble-cap plate column versus jacket temperature for benzene – dichlor-ethane mixture.

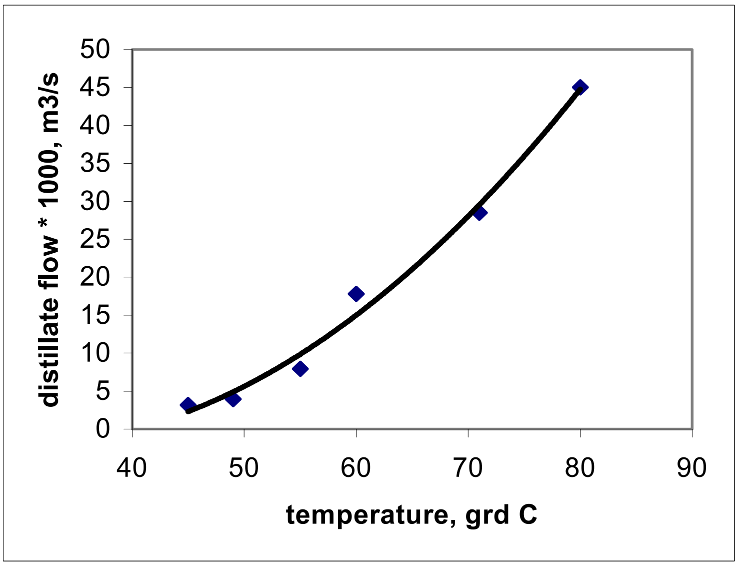

Fig. 2 – Variation of the distillate flow with the jacket temperature in the bubble-cap plate column for benzene – dichlor-ethane mixture.

In order to determine the column efficiency there have been used:

– diagram t-x-y for the mixture benzene – diclor-ethane, obtained from the literature data

– following relations: – that of Fenske:[15]

$$y^* = \frac{\alpha_r \cdot x}{1 + (\alpha_r - 1) \cdot x} \quad (1)$$

where: x – mole fraction of the more volatile component in the liquid phase

y^* – molar fraction of the more volatile component in the vapor phase in equilibrium with the liquid phase

α_r – coefficient of relative volatility

– relation for the determination of the minimum number of theoretical plates:

$$N = \frac{\lg\left(\frac{x_D}{1 - x_D} \cdot \frac{1 - x_W}{x_W}\right)}{\lg(\alpha_{med})} - 1 \quad (2)$$

where: N – the minimum number of theoretical plates

x_D, x_W – mole fraction of the more volatile component in the distillate, respectively in the still pot

α_{med} – average volatility, calculated with the relation:

$$\alpha_{med} = \sqrt{\alpha_D \cdot \alpha_W} \quad (3)$$

where: α_D, α_W – relative volatilities in the distillate, respectively in the still pot

– relation for the determination of the plate efficiency:

$$\varepsilon_t = \frac{N}{N_{real}} \quad (4)$$

Based on the equations (1 - 4) the efficiency of the bubble-cap plate column has been determined. Thus it has been obtained an efficiency increase from 64.7% to 86% by increasing the temperature in the heating jacket.

Further on has been studied the influence of the temperature variation in the jacket on the separation efficiency in the bubble-cap plate column of a mixture of alcohols: methanol and ethanol.

When no air was circulated through the jacket – that means that the column works only with the heat provided by the boiler and the temperature of the jacket of the column has no influence upon the process – using the equations (1 – 4) has been determined an efficiency of 60%.

For this mixture, as the temperature was increased in the jacket from 47°C to 62°C, it influenced the distillate flow, which was increased, but not very much (from 2.44ml/min to 2.7ml/min), but the concentration at the head of the column did not change. The efficiency increased to 75%.

Carrying out the separation with a mixture of water and acetic acid, and applying the same calculation method, it has been found an efficiency increase from 64.5% to 80%.

The degree of the efficiency increases due to the temperature increase in the heating jacket for the three systems studied is presented in Table 1.

It has been also carried out the separation of the mixture methanol - ethanol in a packed column at total reflux. The temperature in the heating jacket of the distillation column influences the process performance, determining a higher or lower liquid reflux. Thus it has been found that by increasing the jacket temperature, the concentration at the head of the column was lowered. The results obtained are presented in Figs. 3 and 4.

According to equations (1–3) the number of theoretical plates (NTP) and the height equivalent to a theoretical plate (HETP) have been determined. The results are presented in Table 2.

Table 1

The degree of the separation efficiency by increasing the jacket temperature for the bubble-cap plate column

Studied system	Degree of efficiency increase , %
benzene – dichlor-ethane	23.6
methanol – ethanol	20
water – acetic acid	23.6

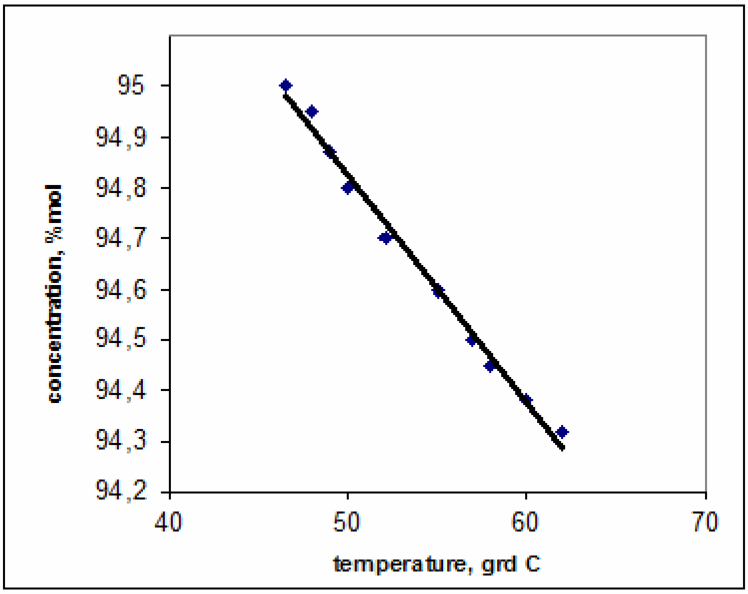

Fig. 3 – Variation of the concentration at the head of the packed column versus the jacket temperature for methanol – ethanol mixture.

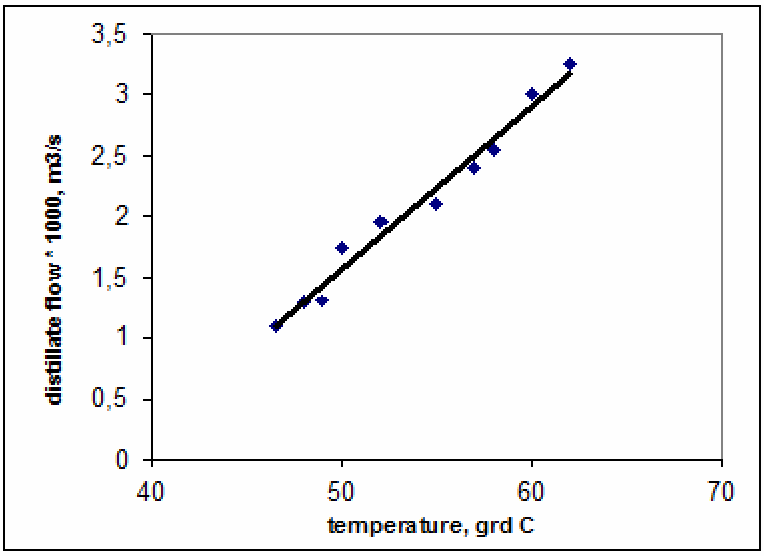

Fig. 4 – Variation distillate flow versus the jacket temperature in the packed column for methanol – ethanol mixture.

Table 2

Separation efficiency in the packed column by increasing the jacket temperature

Temperature, grd C	NTP	HETP, cm
47	4	7.5
62	5	6

EXPERIMENTAL

Experiments were carried out in two types of columns:

– A bubble-cap plate glass laboratory column having 17 plates, with the following dimensions: height of 0.7 m, and diameter of 0.08 m. The mixture to be separated is placed in the flask, which is the still pot of the column, heated through a sand bath by an electric resistance. The vapor passes through the distillation column and is condensed by the condenser. Still and column head temperatures are measured with thermocouples. An important characteristic of the bubble-cap plate columns is the dependence of their efficiency on insulation, in order to avoid heat losses.

– The other glass column, with the following dimensions: height of 0.4 m, and diameter of 0.05 m, was packed with glass Raschig rings (σ_u = 776 m^2/m^3; V_f = 0.71 m^3/m^3) having a height H_u = 0.3 m, and worked at total reflux. The mixture to be separated is placed in the flask, which is the still pot of the column, heated through a sand bath by an electric resistance. The temperatures are measured with thermocouples.

Experiments were carried out with different mixtures: benzene – dichlor-ethane, methanol – ethanol and water – acetic acid. For each mixture, all experiments were conducted at the same temperature in the boiler, which did not influence the efficiency of the studied processes.

The columns have been provided with jackets through which air, supplied by the blower and heated by the heating device, is circulated, having the role of heating the columns during experiments. The temperatures of the air inlet and outlet are measured with thermocouples.

CONCLUSIONS

It has been studied the separation efficiency by mass transfer in a laboratory bubble-cap plate column determining the influence of the jacket temperature on the process performance.

Similar studies have been carried out with a laboratory glass packed column.

It has been concluded that the increase of the jacket temperature resulted in an increase of the separation efficiency.

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