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PROPYLENE-PROPANE RECTIFICATION COLUMN'S EXAMINATION

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ABSTRACT

In this study a propylene-propane column was examined. Due to the energy-intensive feature of this petrochemical procedure the goal of this study was to find a modified alternative solution with less energy consumption and low investment costs. For that, firstly the influence of the feed stage's location was investigated. This parameter has effect to the mass flow and purification of the distillate stream, furthermore to the condenser's and reboiler's heat flow. In this case the temperature profile of the original and modified systems were analysed. The overhead product's purification was also examined, which has influence on the reflux ratio and the heat exchanger's power too.

1. INTRODUCTION

Propylene is one of the most used raw material for producing petrochemical products, for example polypropylene, cumene, propylene oxide, isopropyl-alcohol. Nowadays, because of this widespread usage of the propylene, there is a great demand about this product in the last few years and probably in the near future [1]. Propane can be used as refrigerant in the system [2] or after quenching it can be used in lower carbon-content procedure. This method is frequently used in the industry to save energy and other costs.

Distillation columns are one of the most widely used separation units in petrochemical industries, however these have enormous energy consumption [3]. Viewpoint of the column's operation and energy consumption, it is essential to use the suitable heat exchangers [4] during the rectification procedure. Therefore, this study deals with the examination of the heat exchanger's power too.

Propylene-propane separation is a highly energy-intensive procedure due to the close volatilities of these two compounds (there is only 5.6 °C difference between them boiling points). Besides that, the processing has become more difficult by the purity specifications of the propylene (minimum 90 mole%) [1]. During the conventional propylene-propane separation in the rectification column it is necessary to use more than 100 trays, high pressure and high reflux ratio, which leads to high investment and operational costs. In the industry because of the height of this equipment, generally it is made from two columns, however both of them mean the same equipment [5].

During the simulation, it is essential to use high-precision equation of state to get nearly same values like in the real system. In this case the most convenient ones are the Soave-Redlich-Kwong [6] (SRK) and the Peng-Robinson [7] (PR) equation of state [8].

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2. PARAMETERS OF THE RECTIFICATION COLUMN

During this study ChemCAD [9] process simulation software were used to make the rectification column's model with SRK equation of state. The column's parameters are summarized in the Table 1.

Table 1
Parameters of the rectification column

Number of theoretical trays	140
*Place of the feed**	90.
Reflux ratio	16
Pressure of the tower [bar]	8.5

*: Trays are numbered from top to down.

Table 2 contains the feed stream's parameters and the results of the products with ChemCAD software. In the simulated model a total condenser [10] was used to condensate the vapour which leave the first tray. The degrees of freedom was 2, the reflux ratio (R = 16) and the propylene's mole fraction of the bottom product (x = 0.00016) were specified.

Table 2
Parameters of the feed stream and results of the distillate and bottom product

	Feed	**Distillate**	**Bottom product**
Temperature [°C]	16.0	13.0	20.2
Pressure [bar]	8.5	8.5	8.5
Molar flow [kg/hr]	1000	527	473
Composition [n/n%]			
Propylene	50	92.89	0.016
Propane	50	7.11	99.984

In Table 3 the column's heat exchangers' energy consumption was summarized, these data supports that it is a really energy-intensive procedure.

Table 3
Energy consumption of the heat exchangers

Condenser's heat flow [kW]	**Reboiler's heat flow [kW]**
901.147	802.544

3. COLUMN’S EXAMINATION

This study deals with cases when some parameters in the column are modified. During the simulation the goal was to examine the energy consumption of the column with little alterations and make an offer to an alternative system, what has lower energy consumption and does not require significant investment.

3.1. Modifying the feed stream’s location

Firstly, the influence of the feed stream’s location on the distillate’s propylene composition was examined. The location of the feed tray was modified from the 20th to the 108th tray (when the trays are numbered from the top to down). In each case the energy consumption, the distillate’s purification and the mass flow of the products were examined.

Fig 1. shows the connection between feed location and the examined parameters. In case of, when the feed tray is between the 63rd and the 82nd tray (in Fig. 1 the area between the green vertical dashed lines), the propylene contents of the overhead product is the highest (between 99.1 and 99.26 mole%). Furthermore, in this interval the energy consumption of the condenser and reboiler is the lowest (approx. 844 kW in the condenser and approx. 745 kW in the reboiler).

Fig.1 shows also that there is an obvious connection between the mass flow of the distillate and the heat exchangers’ power. The more overhead product results the more energy consumption, because the condenser and the reboiler has to condensate and boil more mass.

It is unequivocal too, that lower purification in the distillate causes higher mass flow in the same stream, because it means that the overhead product will contain more propane

Fig. 2 shows temperature profiles, width different feed stages: 90th (original), 65th and 80th. These last two stages were chosen, because these are in the previously specified interval, when the features of the energy consumption and purity are the most convenient. It seems that the two modified column’s temperature profile’s shape is better than in the original system, because in this case the temperature distribution is more consistent. Some phenomena, like the temperature profile is not consistent or there is a sharp shift between the values, cause malfunctions in the system (if the temperature profile does not consistent the pressure profile will not be consistent, therefore it can result corrosion problems, tray malfunctions).

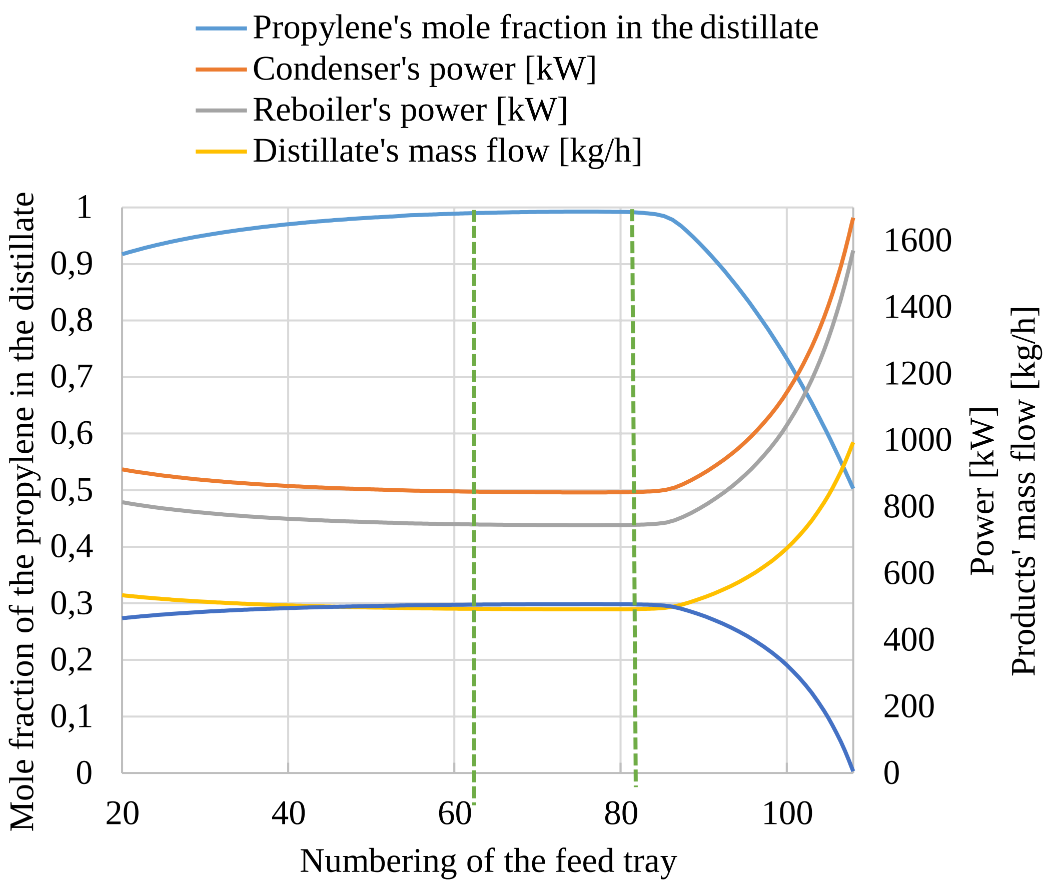

Fig. 1
Feed location's influences

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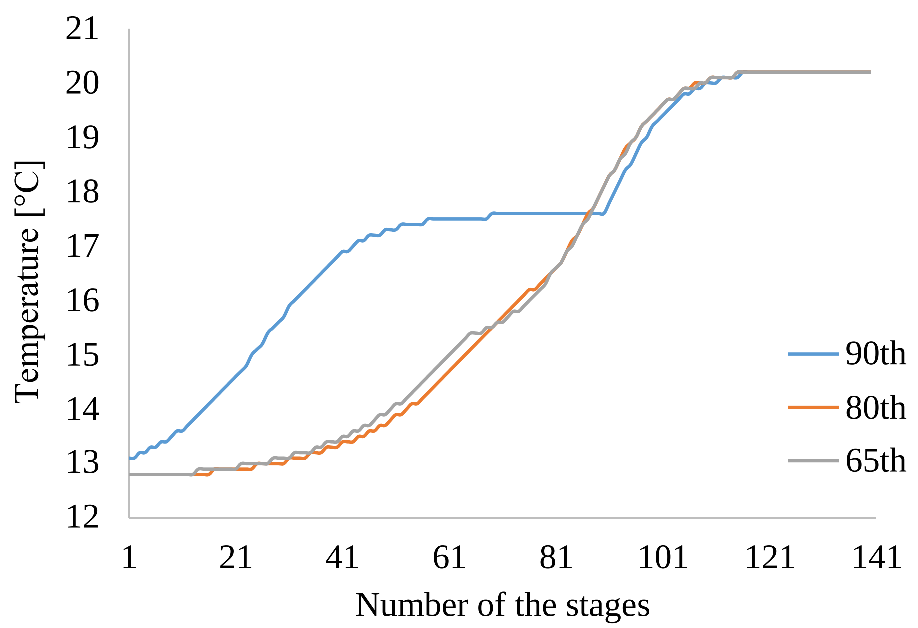

Fig 2.
The temperature profile in the column if the feed's stage is different

3.2. Changing the purification of the distillate

It was also examined what will happen when the purification of the overhead product is gradually increased. It has also essential influence on the column's operation.
In this case during the simulations one of the degrees of freedom changed. The propylene's mole fraction (0.00016) is unchanged, while instead of the given reflux ratio value, the propylene's mole fraction in the overhead product was given.
Higher purification in the overhead product needs higher reflux ratio and naturally higher energy consumption. Between the quantity of the distillate and the purity of the distillate there is an inverse relationship.
Among the 0.9 and 0.9995 purity values there is a relatively slow increasing in the examined parameter's values. However, 0.9999 purity value means an extremely great increasing. It means that the almost purified distillate makes the process extraordinarily energy- and cost-intensive.

Table 4
Influence of the distillate's purity in propylene

Distillate's purity in propylene	**Reflux ratio**	**Distillate's mass flow [kg/h]**	**Bottom product's mass flow [kg/h]**	**Condenser's power [kW]**	**Reboiler's power [kW]**
0.9000	15.058	545.0471	454.9529	878.442	779.835
0.9500	16.687	515.1856	484.8144	916.792	818.197
0.9900	18.261	493.3559	506.6441	957.992	859.392
0.9950	19.069	490.7994	509.2006	993.265	894.667
0.9990	24.084	488.7588	511.2412	1236.540	1137.940
0.9995	27.771	488.5245	511.4755	1407.700	1319.110
0.9999	59.575	488.2704	511.7296	2983.290	2884.700

Modifying the purity of the overhead product is very uneconomical after a certain point. When the distillate's purity increased from 0.9995 to 0.9999 causes twice as much energy consumption in the column (Fig.3).

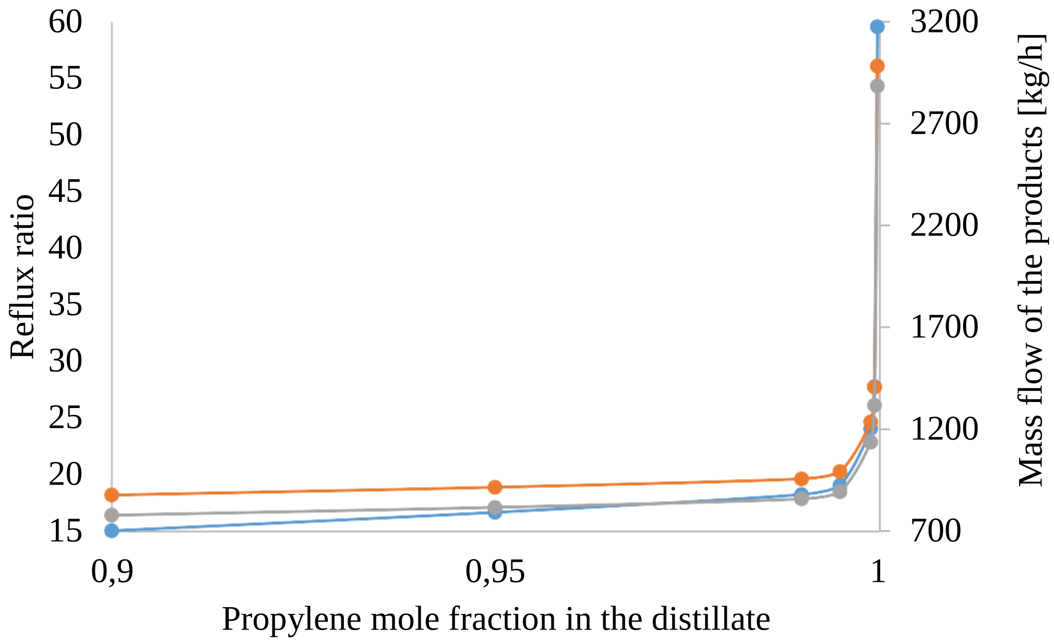

Fig. 3
Connection between the overhead product's purity and reflux ratio

4. CONCLUSION

This study shows that in the investigated system the feed's location should be changed to a value, that is in the previously specified interval, because in this case higher purity and less energy consumption can reach. Beside that, the temperature profiles in case of modified feed's location also supported the previous statements. We pointed out that increasing the purity of the overhead causes high energy consumption.

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