Original Article: Re-Boiler Simulation of Separation Tower of Methanol to Propylene Conversion Unit

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ABSTRACT

Heat exchangers are used as the most important equipment to transfer the energy of materials to each other, to increase or decrease the energy level of material flows. The purpose of this research is to optimize and estimate costs for re-boiler, one of the leading units of National Petrochemical Industries Company. This heat exchanger is in the form of a plate, which is used as a re-boiler for tower 511. In this research, ASPEN PLUS and ASPEN EXCHANGER DESIGN & RATING software were used to design and estimate costs. This design is based on the conditions required to set up tower 511 of methanol to propylene conversion unit. Based on the designs, the required area for the converter was 2.6 square meters, which compared to the previous converter, we had an increase of about 8% in the area for heat exchange.

Introduction

Heat exchangers are devices that transfer heat between two fluids. There are many heat exchangers such as shell and tube heat exchanger, plate heat exchanger, double tube heat exchanger, etc. Shell and tube heat exchangers and plate heat exchangers are used in various industries such as energy production [1-5]. Shell and tube exchangers are often made as cross-flow and layered exchangers as counter-flow. ASPEN PLUS and Aspen EDR are comprehensive tools for process models that are used in

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industries to optimize and simulate processes [6-9]. Aspen EDR is a software that includes a comprehensive range of heat exchanger designs. Aspen PLUS also has the ability to calculate the rate of hot and cold flows passing through the heat exchanger in different conditions. In this software, heat exchangers are flexible from the point of view that they can solve the problems caused by temperature, pressure, heat flows and material flows.

The heat exchanger model can also be selected for the purpose of analysis in Aspen PLUS. It can simulate and operate a heat exchanger and the model of the heat transfer process that occurs inside the heat exchanger. Aspen Exchanger Design and Rating (EDR) is a software that provides heat exchanger designs and dimensional measurements. With the cooperation of users, the costs of designed equipment can be reduced by 10 to 30 percent by performing an effective design in Aspen EDR. The software is able to provide the optimal design cost by giving suitable physical data. The details of the heat exchanger are also displayed on the specification page.

The counter flow heat exchanger (Figure 1) is commonly used in oleo chemical plants, which is capable of passing high viscosity fluids. This converter has a high heat transfer coefficient, which is due to the grooves on the plate, which are also the cause of confusing current. This converter also has low sedimentation in this converter.

To get the required level, we use the following equation:

(1)

$$A = \int_0^Q \frac{dQ}{U_0 \Delta T}$$

where U_0 is the overall heat transfer coefficient and ΔT is the temperature difference between cold and hot streams at a given point. The driving force in the heat exchanger can be written and described as the logarithmic mean temperature difference (LMTD), and in heat exchangers that are countercurrent, the LMTD is written as follows:

(2)

$$T_{lm} = \frac{(t_1' - t_2'') - (t_2' - t_1'')}{\ln\left(\frac{t_1' - t_2''}{t_2' - t_1''}\right)}$$

which $(t_1' - t_2'')$ is the temperature difference at one end of the heat exchanger and $(t_2' - t_1'')$ is the temperature difference at the other end of the heat exchanger. U_0 is highly dependent on the fluids in the heat exchanger. In practice, it is appropriate to calculate LMTD as the temperature at which the heat exchanger is in steady state and the overall heat transfer coefficient is constant.

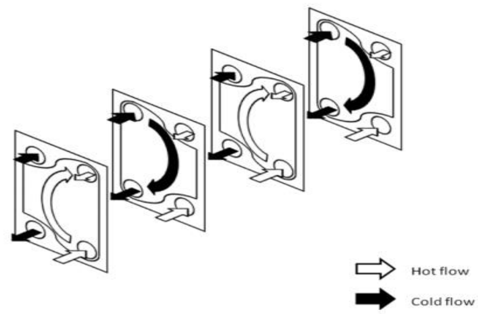

Figure 1. Fluid flow in a common single-pass countercurrent plate heat exchanger

Description of the article

The problem started from the fact that, according to the instructions of the designer company, the operating temperature that heavy C5+ compounds must be completely vaporized at a temperature of 179 degrees Celsius with the mentioned steam conditions (Steam-MP), and of course, the issue of being in equilibrium or being in equilibrium of the re-boiler was not taken into account. Due to the fact that the unit had encountered problems, we decided to redesign this converter, which first required a detailed knowledge of the input and output materials of the converter. The most important point in this design is the accurate knowledge of the material, which was obtained by using C5+ flow analysis.

Table (1): Input and output materials

chemical formula	Mass percentage
C5H12	**0.32**
C5H10	**0.28**
C6H14	**0.16**
C6H12	**0.12**
C7H16	**0.03**
C7H14	**0.03**
C8H18	**0.04**
C8H16	**0.02**
Total	**1**

After this work, important properties such as mixture density, enthalpy, thermal conductivity coefficient, surface tension, molecular mass, etc. related to this mixture should be calculated in order to have a more accurate design of the plate heat exchanger. Aspen PLUS software was used to achieve these specifications [10]. The specifications related to this flow are also given in table No. 2.

Table (2). Flow specifications

TEMP	LIQUID MA	VAPOR MA	LIQUID MU	VAPOR MU	LIQUID CP	VAPOR CP	LIQUID KM	VAPOR KM	LIQUID SIG	LIQUID MW	VAPOR MW	LIQUID MA	VAPOR MA	TOTAL MASSVFRA
C	kg/cum	kg/cum	cP	cP	kJ/kg-K	kJ/kg-K	Watt/m-K	Watt/m-K	dyne/cm			kJ/kg	kJ/kg	
150	493.1		0.098542		3.0859		0.078739		4.54528	77.8615		-1314.68		0
153.158	487.907		0.096391		3.13074		0.077936		4.28339	77.8615		-1304.86		0
156.316	482.576		0.094289		3.17931		0.077154		4.02447	77.8615		-1294.9		0
159.474	477.094		0.092232		3.23237		0.076395		3.76866	77.8615		-1284.78		0
162.632	471.446		0.090223		3.29093		0.07566		3.51608	77.8615		-1274.48		0
165.79	465.617		0.088259		3.35633		0.074953		3.26687	77.8615		-1263.98		0
168.947	459.587		0.086339		3.43044		0.074276		3.02119	77.8615		-1253.27		0
172.105	453.331		0.084463		3.51588		0.073635		2.77922	77.8615		-1242.31		0
175.263	446.821		0.082627		3.61653		0.073009		2.54116	77.8615		-1231.05		0
178.421	440.023		0.080832		3.7384		0.072383		2.30723	77.8615		-1219.44		0
181.579	432.894		0.079076		3.89143		0.071757		2.07769	77.8615		-1207.41		0
184.737	425.38		0.077359		4.09347		0.071131		1.85283	77.8615		-1194.81		0
187.895	422.736	77.9766	0.076249	0.012832	4.17416	3.12626	0.070725	0.031354	1.77337	78.6287	76.1961	-1195.57	-994.23	0.308633
191.053	422.982	78.209	0.075531	0.012863	4.15931	3.1301	0.070474	0.031587	1.80927	79.8375	77.0288	-1201.36	-1000.16	0.696014
194.211	423.236	78.4189	0.074861	0.012892	4.14425	3.13303	0.070435	0.03182	1.98398	81.0648	77.8615	-1205.3	-1003.66	0.999995
197.368		75.7391		0.012877		3.04481		0.0322			77.8615		-993.918	1
200.526		73.4083		0.012871		2.98102		0.032582			77.8615		-984.409	1
203.684		71.3435		0.012873		2.9333		0.032966			77.8615		-975.074	1
206.842		69.4891		0.01288		2.89676		0.033352			77.8615		-965.871	1
210		67.8055		0.012892		2.86835		0.033739			77.8615		-956.77	1

As you can see in table No. 2, the characteristics of each two-phase vapor and liquid have been extracted so that VLE can also be considered. Now, we have to calculate the changes of heat capacity and density with temperature. To achieve this, Span Plus software is used. As you know, melting point and specific heat capacity are very important in calculations related to heat transfer in heat exchangers, especially since they determine the minimum fluid of these two [11].

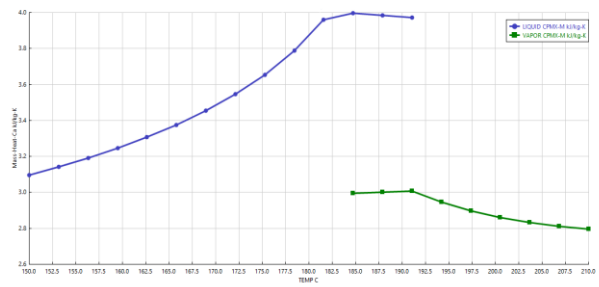

Chart 1. calculations related to heat transfer in heat exchangers, especially since they determine the minimum fluid of these two

As you can see in chart No. 1, firstly, in the liquid state, the specific heat capacity of the mixture increases with the increase in temperature, the reason for which is the increase in the energy accepted by the solution with the increase in temperature, vibrations and rotation, etc. of the molecules. Against vibration and... it becomes more important that this increases the heat capacity of the mixture, only of course in the liquid phase and in the vapor phase due to the increase of collisions and... we see that the heat capacity decreases with the increase in temperature. That is, by giving the minimum energy to the system, the temperature increases. In the inter-phase transition, as can be seen from the above, it is clear that it will decrease with temperature [12-14].

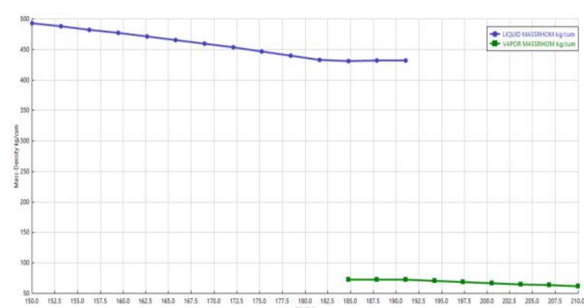

Chart 2. the required level by changing the input steam flow and its economic estimation, which will be explained in the diagrams below.

In chart No. 2, it can be seen that the density decreases with the increase in temperature, which is a reason for the increase in the volume of liquid and vapor during the increase in the temperature of the system, which is again related to intermolecular forces and collision energy between them. It can be mentioned above. We decided to design a converter with the required level by changing the input steam flow and its economic estimation, which will be explained in the diagrams below [15-17].

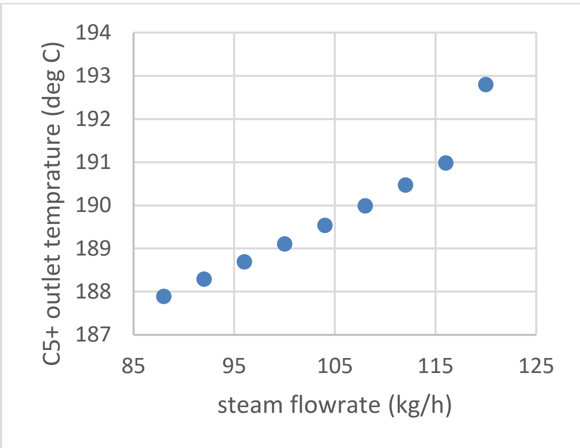

Chart 3. The temperature of the cold fluid output in terms of the steam flow entering the converter, as can be seen the temperature of the cold fluid increases with the increase of the flow rate of the hot flow until it is observed

Chart No. 3 shows the temperature of the cold fluid output in terms of the steam flow entering the converter, as can be seen the temperature of the cold fluid increases with the increase of the flow rate of the hot flow until it is observed that the temperature of about 193 is different from other. There are many points that this point according to the explanations given and the specifications obtained from the software and the laboratory is the point where all our cold fluid turns into steam and this increase in temperature is due to the change in the characteristics of the fluid.

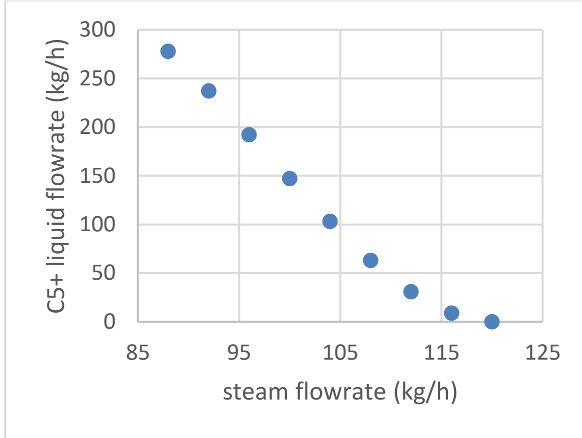

Chart 4. The flow of C5+ output per steam flow entering the converter. As a rule, with the increase in the steam input flow, the amount of steam energy will increase and will increase the steam and decrease the amount of liquid in the cold part of the converter.

Chart No. 4 shows the flow of C5+ output per steam flow entering the converter. As a rule, with the increase in the steam input flow, the amount of steam energy will increase and will increase the steam and decrease the amount of liquid in the cold part of the converter. This is due to the rise of mC_pfluid [18].

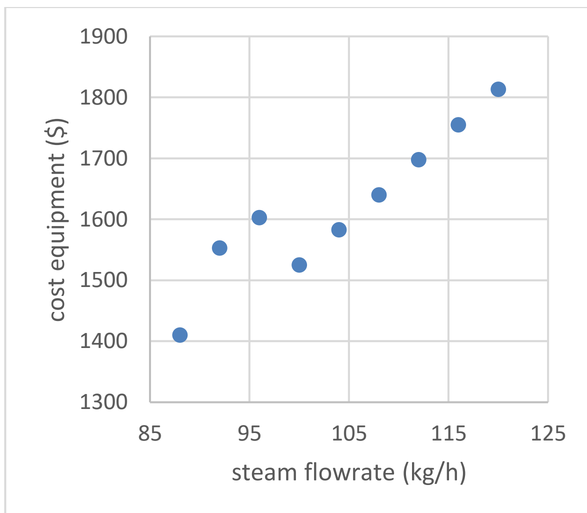

Chart 5. The cost required for the construction of the heat exchanger in terms of the required flow, and this cost reaches its lowest value at a flow rate of 100 kg/h based on the design, and that is due to the optimization of the paths and the reduction of the heat exchange level

Chart No. 5 shows the cost required for the construction of the heat exchanger in terms of the required flow, and this cost reaches its lowest value at a flow rate of 100 kg/h based on the design, and that is due to the optimization of the paths and the reduction of the heat exchange level. It was evaluated in the design phase [19].

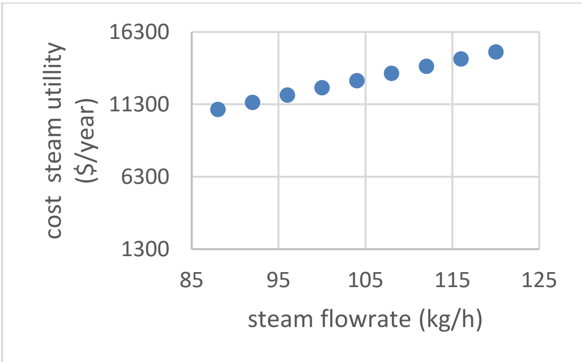

Chart 6. The cost of utility steam according to the flow of this steam, which increases completely linearly.

Chart No. 6 shows the cost of utility steam according to the flow of this steam, which increases completely linearly.

Conclusion

The designed converter has a surface equal to 2.6 square meters, which is to achieve the required and normal conditions of tower 511 of MTP unit of Research and Technology Company of Mahshahr unit and satisfies the requirements of tower 541 feed. To supply the required energy for this equipment, we need a steam flow rate in the range of 96 to 104 kg/hour of steam, which is the best flow rate based on the design of 100 kg/hour, in which the output temperature is within the desired temperature range and the conditions is provided for material separation and the designed heat exchanger is also economically optimal. In the previous converter, the outlet temperature of the cold part finally reached 181 degrees Celsius under the same conditions, which did not have the ability to produce steam at all, but in the new design, we have reached higher temperatures that produce steam to the full extent.

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