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Increasing the efficiency of heat exchange by changing the construction of a shell-and-tube heat exchanger

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Abstract. To date, various methods of intensifying convective heat transfer have been proposed and studied. This article focuses on solutions to increase the heat exchange efficiency and maintenance time of the shell-and-tube heat exchanger by preventing the formation of liquid vapors in the internal pipes and distribution chamber of the device when the liquid flow moves through the internal pipes.

1 Introduction

In our country, scientific research works aimed at raising production to a new level, modernizing and diversifying production, introducing innovative technologies, increasing the volume and quality of manufactured products, and expanding their types [1].

In the chemical and oil and gas industry, the process of processing products under the influence of heat is widely used. The process of heat exchange is carried out for the following purposes:

1) maintaining the process temperature at the given level;
2) heating the product or cooling the hot product;
3) steam condensation;
4) condensation of solutions, etc.

These processes are carried out in separate heat exchange devices or in the technology device itself [2].

Industrial heat exchangers have a very wide nomenclature of types, sizes, parameters and materials. For this reason, it is possible to choose a device that is optimal in terms of all its parameters for each specific condition. It is advisable to follow the following general rules when choosing heat exchange devices [3].

1. If the pressure of heat transfer agents is high, pipe heat exchangers should be used; in such conditions, a heat-carrying agent with a higher pressure is sent inside the pipes, because the diameter of the pipes is small compared to the diameter of the device shell, so it can withstand a slightly higher pressure [4];

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2. The corrosive heat transfer agent is supplied through the pipes of the tubular heat exchanger, because the shell of the device is not changed when the pipes are destroyed by corrosion [4].

3. When using corrosive heat transfer agents, heat exchangers made of corrosion-resistant polymer materials (for example, fluoroplast and its copolymers) should be used [4].

4. If one of the heat transfer agents is dirty or has the property of giving the surface of the device, it is necessary to send such a heat transfer agent to the side of the heat exchange surface that is easy to clean (for example, the inner surface of the tubes in shell-and-tube devices, and the outer surface of the tubes in coiled devices) [4].

5. The improvement of heat exchange conditions does not always depend on the speed of the heat carrier (for example, the rate of condensation of steam depends on the correct organization of condensate transfer from the heat exchange surface), for this reason, any specific it is necessary to choose a device with an appropriate design for the conditions [4].

In the technology of primary and deep chemical processing of oil and gas, gasses and electricity generated from the combustion of fuels are often used as a direct heat source. In technological processes, heat exchange devices are mainly used as a heating agent for the temperature of water, water vapor, and liquid or gaseous products coming out of the technological process [5].

2 Materials and methods

When heating raw materials in shell-and-tube heat exchangers, when liquid raw materials move from the internal pipes of the device, partial evaporation of raw materials (depending on the evaporation temperature of the raw materials) occurs in the internal pipes. As a result, the following situations occur [6].

1. As a result of the evaporation of the heated liquid raw materials, a gas mass is formed in the internal pipes and distribution chamber of the device. It resists the movement of raw materials through internal pipes and causes pressure loss [7].

2. Heat exchange efficiency is estimated by temperature difference. One of the factors that greatly affect the efficiency of heat exchange is the heat exchange surface, the heat transfer coefficients of the agent and the product, and the heat transfer coefficient of the heat exchange surface. As we know, the coefficients of heat transfer and transfer of substances in the state of liquid aggregates are much higher than substances in the state of gaseous aggregates. So, when raw materials are heated, when the shell moves through the internal pipes of the tubular heat exchanger, partial evaporation of the raw materials will have a negative effect on the heat exchange efficiency [8, 9].

3. The formation of a gas mass in the internal pipes of the device affects the internal pipes of the device and the surface of the distribution chamber with excessive pressure. This causes a reduction in the time between repairs of the device [10, 11].

Above, the conditions that adversely affect the heat exchange efficiency of the device during the heating of liquid raw materials moving in the internal pipes of the shell-and-tube heat exchanger to a high temperature have been listed. In the condensate stabilization device, the hot condensate coming out of the stabilization column before entering the column cools the shell-tube heat exchanger device used for heating the unstable condensate by moving through the inter-tube space.

3 Results and discussion

This article presents the research results and their analysis in the laboratory device of the shell-and-tube heat exchanger used in this condensate stabilization technology. In this case, the heated raw material is an unstable condensate at 30 ℃, and the heating agent is stable at 120 ℃, moving from the inter-pipe space. The technological scheme of the shell-and-tube heat exchanger device, in which the nozzle for steaming condensate is placed in the distribution chamber, is presented (Figure 1).

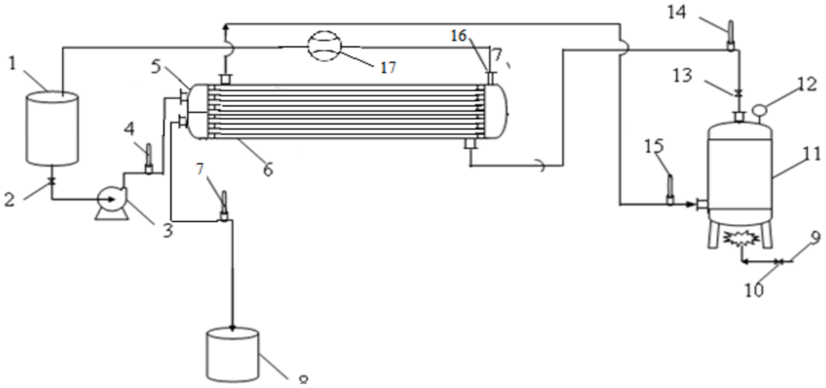

Fig. 1. The technological scheme of the shell-and-tube heat exchanger in which the gas mass generator is placed in the distribution chamber: 1 - container for raw materials; 2 - raw material consumption control valve; 3 -centrifugal pump; 4, 7 - temperature of raw material at the entrance and exit to the heat exchanger; 5 - centrifugal movement camera; 6 - shell tube heat exchanger; 8 - vessel; 9 - natural gas; 10 - gas tap; 11 - generator for heating agent; 12 - manometer for measuring atmospheric pressure; 13 - faucet for adjusting heat carrier consumption; 14, 15 - thermometers for measuring the temperatures at the inlet and outlet of the heat exchanger of the shell and tube; 16 - gas release valve (air heater); 17 - separated gas consumption measuring device.

The experimental device works in the following sequence. A heating agent is poured into the tank 1 for raw materials, the raw materials are fed to the centrifugal pump 3 through the faucet 2, and the raw materials are pumped to the shell-and-tube heat exchanger using the pump 5 the raw material collected in the heat exchanger is heated to 7 in this process, the initial and final temperatures of raw materials are monitored using 4 and 6 thermometers. Its volume consumption is determined by the volume of raw materials that have entered the collecting tank over time. The heating agent, that is, the stable condensate is poured into the heating boiler 10, and the fire is lit in the pipe 8 using the tap 9, the heating agent is heated, and the tap 12 is opened, and it is transferred to the shell part of the shell-and-tube heat exchanger 5, and the condensed heat carrier is heated pot is returned to 10. The initial and final temperatures of the heating agent are measured using thermometers 13 and 14, and the pressure of the process is measured using a monometer 11. A steam release valve is installed on 16 pipes, and the evaporated condensate separated from it is condensed and fed to the raw material collection tank.

Experiments were carried out in a two-way heat exchanger and a shell-and-tube heat exchanger with a gas mass generator in the distribution chamber. The obtained results are presented in Tables 1 and 2.

Table 1. Dependence of flow temperature on raw material consumption in a two-way shell-and-tube heat exchanger.

Consumption of raw materials V l/min	**Temperature of heated raw material, °C**		**Heating agent temperature, °C**	
	t_1	**t_2**	**t_3**	**t_4**
1	30	102	120	106
2	30	98	120	109

3	30	95	120	111
4	30	91	120	113
5	30	89	120	114

Table 2. Dependence of the flow temperature on the raw material consumption in the shell-and-tube heat exchanger with a gas mass generator in the distribution chamber.

Consumption of raw materials V l/min	Temperature of heated raw material, °C		Heating agent temperature, °C	
	t_1	t_2	t_3	t_4
1	30	110	120	90
2	30	107	120	97
3	30	103	120	101
4	30	101	120	105
5	30	100	120	108

From the results obtained above, it can be seen that increasing the consumption of raw materials from 1 l/min to 5 l/min leads to a decrease in the temperature of the heated agent. However, the total volume of heated raw materials increases 5 times.

It can be seen in the tables with the experimental results that the dependence of the temperature of the flows in the two-way shell-and-tube heat exchanger on the raw material consumption is given, where the temperature of the heating agent is 120 °C and the raw material is 106°C when the agent consumption is 1 l/min. it was possible to heat up to temperature. This experiment was carried out in a shell-and-tube heat exchanger with a gas mass generator in the distribution chamber, and the temperature of the heating agent was 120 °C and the raw material was heated to 90 °C at an agent flow rate of 1 l/min. The temperature difference between the experiment carried out in the shell-and-tube heat exchanger with the gas mass generator in the distribution chamber and the experiment conducted in the ordinary two-way heat exchanger was equal to 18 °C.

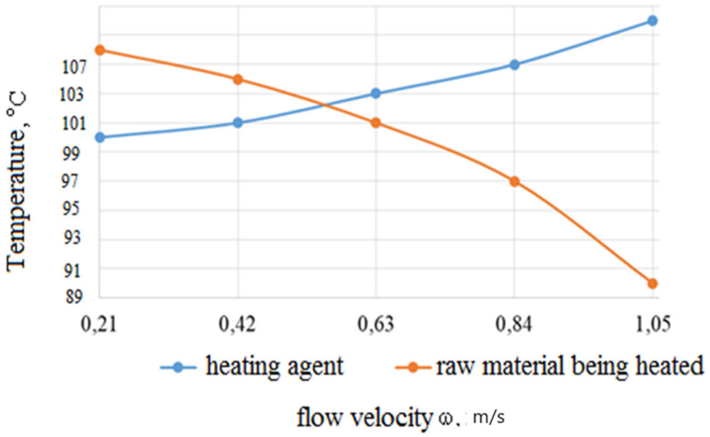

Fig. 2. Dependence of the temperature of the heat carriers in the heat exchanger on the speed of the flows.

From the results obtained above, it can be seen that increasing the consumption of raw materials from 1 l/min to 5 l/min causes the temperature of the heated agent to decrease to 18 °C. However, the total volume of heated raw materials increases 5 times. From the curve graph presented in the figure, it can be seen that if the temperature of the heated raw material in the pipe is increased from 20 to 109 ºC at a flow rate of 0.21 m/s, the increase in the raw material speed leads to an increase in consumption and, as a result, the heating efficiency of the raw material decreases.

According to it, if we take into account that the temperature of raw material entering the pipe is constant 30 ºC, when we increase the speed by 2 times, the temperature rises to 104 ºC, when we increase it by 3 times to 101 ºC, when we increase it 4 times to 97 ºC, and when we increase it by 5 times (1.06 m/s), it is 90 ºC it was determined as a result of experiments. According to the given speeds, the temperature of the heating agent (the raw material to be cooled) was also found to increase to 90, 97, 101, 104 and 109 ºC.

The results of the experiment show that the heat exchanger with an improved design, when moving through the internal pipes, the heated condensate evaporates due to heating in the internal pipes and in the distribution chamber. Evaporated condensate heated in the internal pipes of the heat exchanger leads to a decrease in heat exchange efficiency due to the lower coefficient of heat transfer from the surface of the heat exchanger than liquid condensate. In a heat exchanger with an improved design, condensate vapors formed in the distribution chamber are discharged through a steam release valve. Separated condensate is collected in a steam collection tank.

4 Conclusion

Thus, as a result of the research, a shell-and-tube heat exchanger with a gas mass generator in the distribution chamber was developed. The change in raw material consumption depending on the temperature in a shell-and-tube heat exchanger and a two-pass shell-and-tube heat exchanger in the distribution chamber was studied. In the distribution chamber, the gas was discharged into a shell-and-tube heat exchanger and a two-pass shell-and-tube heat exchanger. It has been shown that the improved heat exchanger design significantly improves heat transfer efficiency. Note that in the developed device the number of internal pipes of the shell-and-tube heat exchanger is reduced. This became possible because in the heat exchanger the gas mass generation nozzle is located in the distribution chamber. This also led to a reduction in the formation of water hammer generated in the device due to the release of the gas mass formed in the distribution chamber. As a result, the time between device repairs increases.

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