MAIN UNITS OF HEAT EXCHANGERS

Tojibaev Makhmudjon Mukhammad ugli
PhD student,
Namangan Institute of Engineering and Technology
Namangan, Republic of Uzbekistan
E-mail: mahmudtojibaev@gmail.com
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ABSTRACT
In this article, you will learn about the main units and features of heat exchangers. In addition, depending on the problem, you can get information about the most important quantities, such as construction design methods, flow types, logarithmic values, heat transfer coefficient, heat transfer surface.
Key words: heat exchanger, flow rate, temperature difference, temperature change, flow types, fouling.

The heat exchanger design process requires the following steps [1,2,3]:

1. Problem definition: Design features
2. Determining the type of construction
3. Thermo-hydraulic calculation
4. Mechanical design
5. Production, cost and process optimization issues.

Choosing a heat exchanger, its design and construction is carried out according to the following block scheme figure 1. In most cases, this block scheme is the basis. However, in some cases, additions and changes to this block scheme are not excluded [2,3]. The size and structure of heat exchangers depends on many factors. Currently, the dimensions of devices are calculated by computer. But before designing devices, the following units and sizes should be taken into account [4].

- Product flow rate
- Physical properties of liquids
- Temperature chart
- Fixed pressure
- Heat exchanger design
- Cleanliness requirements
- Required time

The required heat transfer surface area of the heat exchanger is calculated by the following general formula [5].

$$A = \frac{V * \rho * C_p * \Delta t}{\Delta t_m * k} \qquad (1)$$

Here, *A- required heat transfer surface, V- product flow rate,* ρ *- product density,* C_p*- specific heat of the product,* Δt *- temperature difference,* Δt_m*- average temperature difference, k - general heat transfer coefficient*

Product flow rate. Product flow rate V is determined depending on the planned size of the milk processing plant. A larger flow rate requires a larger heat exchanger.

For example, if the flow rate of the enterprise is changed from 10,000 liters/hour to 20,000 liters/hour, the heat exchanger will be doubled. The remaining sizes are also doubled.

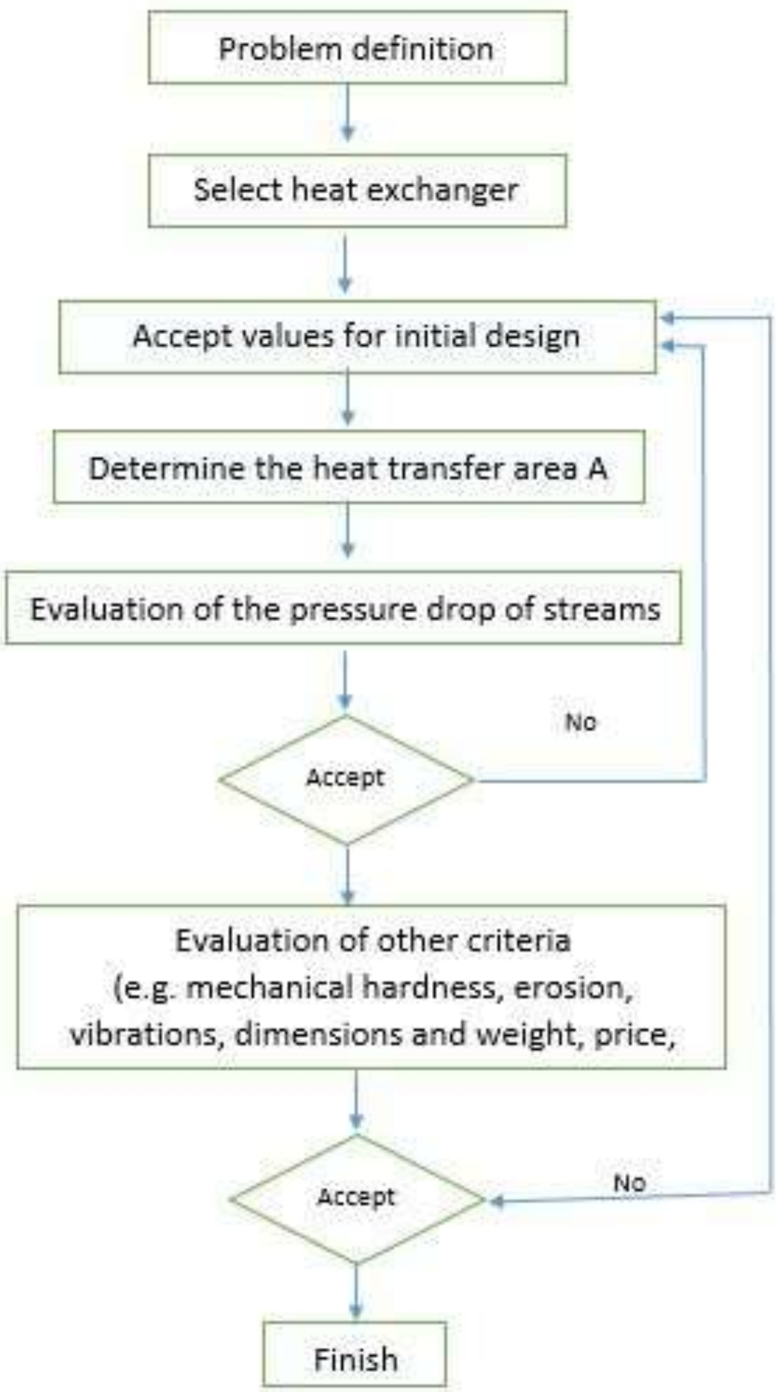

Figure 1. Block scheme of the heat exchanger design process [2,3].

Physical properties of liquids. Product density ρ is a physical unit. The specific heat value of the product is also a physical unit. It is the heat used to increase the product by 1 °C. Viscosity is also one of the main physical parameters of the product.

Temperature diagram. Let's see the temperature diagram in the example of milk. In a word, we use hot water as a heat transfer agent, so as a result of hot water transferring its heat to cold milk, temperatures change inversely proportionally, that is, as the temperature of water decreases, that of milk increases. When the temperature equalizes, the heat transfer process stops.

Temperature change. In the process, the difference between the incoming and outgoing temperatures of the product and heat transfer agents represents the temperature change. The quantity representing the temperature difference is Dt, its general equation is expressed as follows:

$\Delta t = t_{out1} - t_{in1}$ (2)

Heat and energy balances of the process are calculated through temperature changes. In modern heat exchangers, the loss of energy to the environment is almost not taken into account, because it is very small and does not affect the process. So, the heat transferred by the heat transfer agent hot water is equal to the amount of heat received by the heated product cold milk, this can be called energy balance and it can be expressed by the following formula [4]:

$V_1 * \rho_1 * C_{p1} * \Delta t_1 = V_2 * \rho_2 * C_{p2} * \Delta t_2$ (3)

Average temperature difference. As we mentioned above, there must be a temperature difference between two surfaces for heat transfer. Average temperature difference is the driving force of the process. The higher the temperature difference, the more heat transfer occurs and the smaller the heat exchanger is required. The average temperature can be changed through a heat exchanger. The average temperature difference is expressed by the magnitude Δt_m

$$\Delta t_m = \frac{(t_{in2} - t_{out1}) - (t_{out2} - t_{in1})}{ln\frac{(t_{in2} - t_{out1})}{(t_{out2} - t_{in1})}} \quad (4)$$

Another important parameter in determining the average temperature difference is the direction of liquid flow. Liquid flow can be of two types: opposite flow or parallel flow.

Opposite flow. A high result is achieved in the use of heat transfer when the flow of liquids is directed in the opposite direction during heat exchange, Figure 2. In this case, the cold product collides with the previously cold surface, and gradually freezes over time. As the process continues, cold and hot liquids collide with the surface of the plate through the channel and the product heats up to the desired temperature.

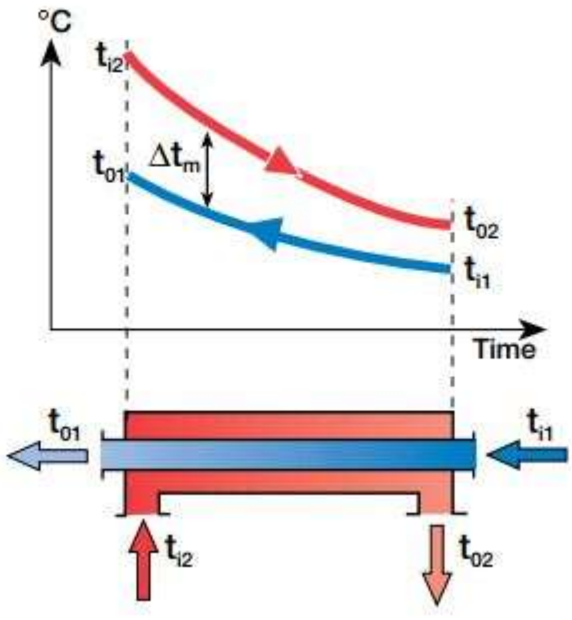

Figure 2. Temperature change in opposite flow

Parallel flow. In the parallel direction, the flow of liquids is transmitted in a parallel direction. In this case, the liquid or

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product to be heated does not heat up to a temperature nearly equal to that of the heating agent. It is used to heat up to 3-4 °C. We can see the parallel flow process in Figure 3

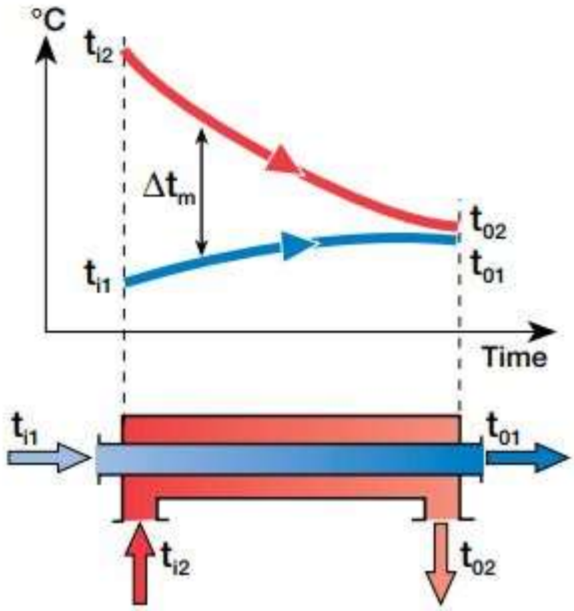

Figure 3. Temperature change in parallel flow

Overall heat transfer coefficient. This factor K, is a measure of how efficient heat transfer is. This quantity is a unit that indicates how much heat is released to change the temperature of 1 m^2 surface by 1 °C. This size depends on the following factors:

- Permissible fluid pressure
- Viscosity of liquids
- the shape and thickness of the surface (part).
- material of the surface (partition).
- the presence of impurities

Pressure drop. It is possible to increase the overall heat transfer coefficient K, reduce the size of the product flow channels to increase the heat transfer. In turn, this causes an increase in the flow rate of liquids in the channels. In this case, two different outcomes occur:

- *the speed of the flow in the channels increases*

-flow turbulence increases

The higher the product pressure, the faster the heat exchange and the smaller the heat exchanger required. Products that are sensitive to mechanical changes (milk fat) can change their properties if forced pressure is applied. Therefore, the permissible pressure of liquids is checked. If it is suitable for the required pressure, the product must be pressurized before entering the heat exchanger. For example, in most cases, liquids are introduced into the heat exchanger using pumps.

Viscosity. The viscosity of products and liquids affects the dimensions and properties of the heat exchanger. Fluids with high viscosity achieve less turbulence than fluids with low viscosity when moving through the channels of a heat exchanger. This in turn requires a larger heat exchanger. For example, cream requires a larger heat exchanger than milk. Because the viscosity of cream is higher than milk.

Shape and thickness of surfaces (parts). Plates are usually corrugated to increase turbulence. The thickness of the plates is a very important quantity that affects the efficiency of heat transfer. However, when choosing the thickness of the plate, it is necessary to pay special attention to the pressure of the product and liquid. In addition, the properties of liquids can cause the plate to crumble if it is thin. Figure 4 below shows several types of flow plates.

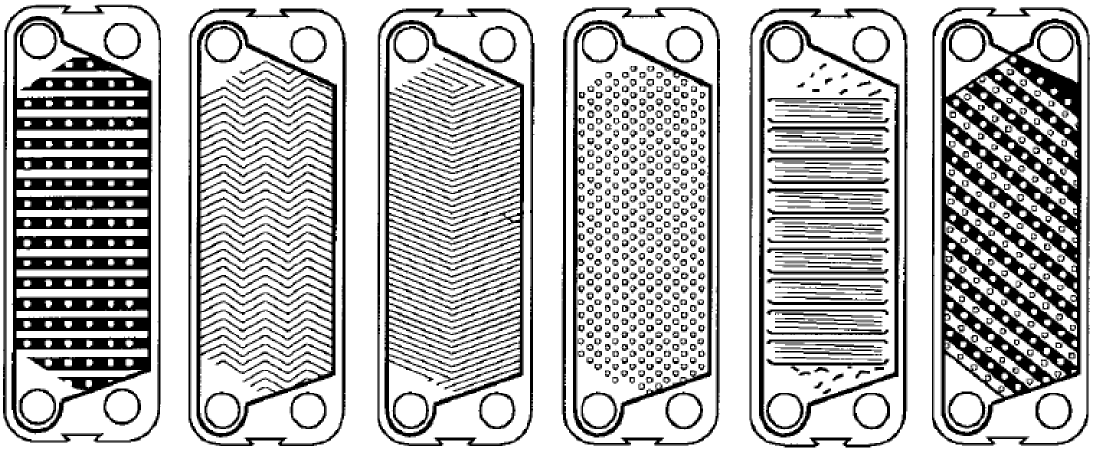

Figure 4. Types of partition (plates)

The material of the plates. In industry, stainless steel is always used in food production and heat exchange devices. Only, depending on the purpose and properties, stainless steel is selected from different types. A special material is used when choosing a material for the device [6], in general, the following 4 types of special materials can be used [7]:

1. Stainless steel and its following alloys: 304, 316, 316Ti, 254SMO, 904L, 317, 317LN, 6-XN
2. Nickel alloys: C-276, C-22, C-2000, G-30, D-205, 59, 31, 28, 3033, 825, 686, 625, 400, Nickel 200/201
3. Titanium and titanium alloys: ASTM GrL, GrLL
4. Other metals and metal alloys, non-metallic compounds such as graphite, copper and copper alloys, aluminum compounds.

Fouling. Milk product must be filtered before heating. Otherwise, when heating the product, the gap between the plates is too small, and there is a high probability of jamming. In addition, it is necessary to pay special attention to the pH environment of the product. If the pH environment of the milk is high in acidity, it may change in the plate under the influence of heat during the heating process. Opening and repairing the heat exchanger and then assembling it takes a lot of time and costs a lot of money.

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