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ANALYSIS OF THE ESSENCE OF PROCESSES, APPARATUS AND METHODS FOR EVAPORATION OF SOLUTIONS

Narziev Mirzo Saidovich
Candidate of Technical Sciences, Associate Professor, Bukhara Engineering and Technology Institute
Ergasheva Muhabbat Komil kizi
Researcher, Bukhara Engineering and Technology Institute

Annotation: In the material, the authors provide material on the essence of the process, methods of introduction, and evaporation apparatus. Methods of evaporation when introducing it at different pressures in the apparatus, and the economic efficiency of the method are analyzed. Technological schemes for implementing the processes of evaporation of solutions have been studied.

Key words : evaporation, crystallization, primary steam, secondary steam, temperature depression, vacuum, atmospheric pressure.

Introduction. Evaporation is a chemical-technological process used to thicken solutions in order to concentrate solid non-volatile substances in liquid volatile solvents. During the evaporation process, water from a solution is evaporated in the form of steam, but the solute or dispersed phase of emulsions and suspensions remains in unchanged quantity. The concentration of dissolved substances increases due to the transformation of emulsions and suspensions into solvent vapors or dispersion media. Evaporation is widely used in technological processes, and substances of various natures are evaporated. The whole process consists in the fact that by heating and sometimes lowering the pressure, some part of the solvent is converted into a vapor state and removed from the liquid mixture in the form of vapor.

Materials and methods. Evaporation is applicable both for partial separation (concentration) of solutions and for the complete separation of solids from solution; releasing all solids from solution, evaporation proceeds to the crystallization stage. As in all processes, there are some losses in the evaporator, and they are usually called temperature depression, hydrostatic depression, hydraulic depression .

Temperature depression Δ′ is the difference between the boiling point of a solution and the boiling point of a pure solvent at the same pressure. Δ′ depends on the natural origin of solutions and solvent, solution concentration and pressure. It can be calculated as follows:

Empirical method for calculating Δ′:

$$\Delta' = 1{,}62 \cdot 10^{-2} \frac{T^2}{r} \Delta'_{атм},$$

T is the boiling point of a pure solvent;

r is the heat of evaporation of a pure solvent.

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Hydrostatic depression Δ″ – represents the vapor-liquid mixture that is located in the tubes of the heating chamber, the vapor content in which increases with the height of the pipe. The boiling point of the lower layers is higher due to the hydrostatic pressure of the column of the vapor-liquid mixture than the boiling point of the upper layers. Hydrostatic depression is the process of increasing the boiling point of a solution under the above conditions. It depends on the intensity of circulation and the changing density of the vapor-liquid mixture. Δ″ is determined from practical data, but to a first approximation it can be calculated. For vertical devices Δ′ ′ =1-3 ^{o}C. Hydraulic depression Δ‴ is associated with hydraulic resistance (friction and local) that the secondary steam must overcome when moving. Reducing the secondary steam pressure in this way leads to a decrease in its saturation temperature. The increase in boiling point associated with hydraulic depression is 0.5-1.5 ^{o}C.

Boiling point of the solution taking into account losses:

$$t_K T' + \Delta' + \Delta'' + \Delta''' ,$$

T′ is the temperature of the secondary steam.

An evaporator is a technological device in which evaporation is carried out. In this apparatus, it is customary to use water vapor as a heating agent, which is called heating or primary. secondary steam is the steam generated during the evaporation of a boiling solution.

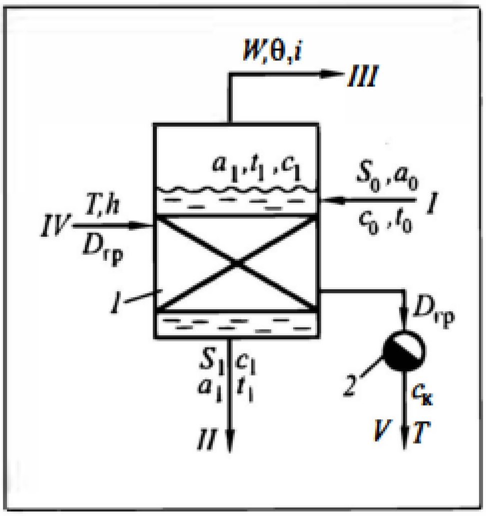

Figure 1. Typical evaporator circuit and main flows:

1 - evaporator, 2 - condensate drain

The first method of evaporation is vacuum evaporation, at a pressure in the apparatus low from atmospheric. Vacuum evaporation has a number of positive aspects. There is an increase in the useful temperature difference between the heating agent and the solution under rarefaction, which makes it possible to reduce the heating surface area of the apparatus (all other things being equal). If the useful temperature difference is the same during the evaporation process under vacuum, you can use a heating agent with lower parameters (temperature and pressure).

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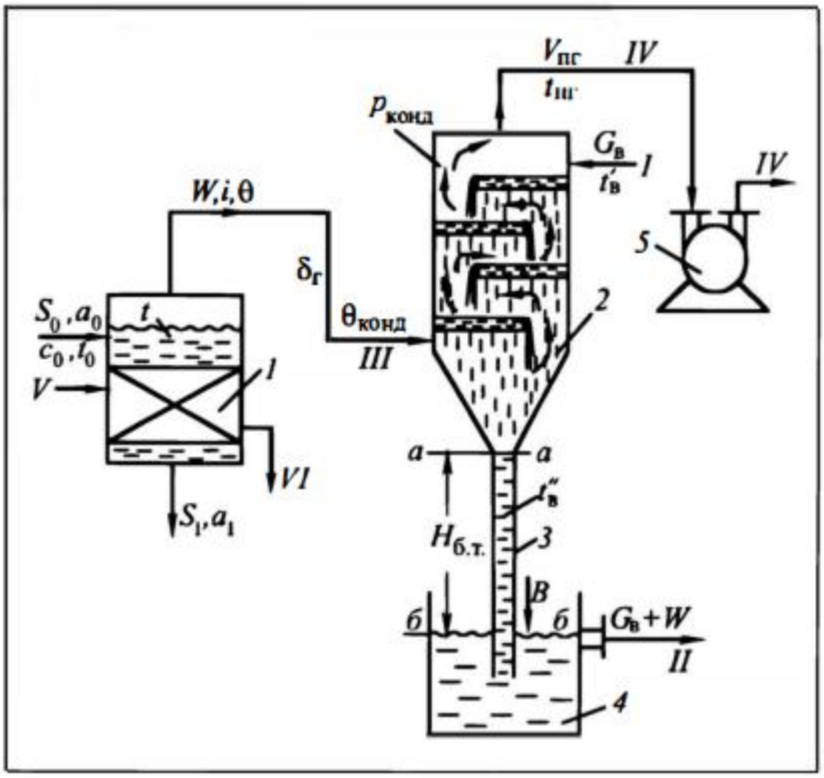

Figure 2. Diagram of an evaporation unit operating under vacuum:

1 - evaporator, 2 - barometric mixing condenser, Z - barometric pipe, 4 - barometric box, 5 - vacuum pump; / - cooling water, // - heated water, /// - secondary steam, /V - non-condensing gases , V - boiling steam, V/ - condensate

Once you have the ability to lower the temperature of the heating agent, you can use secondary steam from the same evaporation unit, which allows you to reduce the consumption of primary heating steam. Along with this, there are also negative aspects: the cost of a vacuum evaporation unit increases, since this requires additional costs for devices for creating a vacuum: vacuum pumps, condensers, separators for separating solution droplets. Accordingly, operating costs increase. Evaporation under excess pressure leads to an increase in the boiling point of the solution, so this method is used quite rarely only in cases of evaporation of thermally stable substances . By evaporating under atmospheric pressure, secondary steam is not used and is released into the atmosphere. In this method, evaporation is periodic and the simplest, but at the same time the least economical. During periodic evaporation, the incoming solution into the evaporator is condensed to a given concentration, or a fresh solution is introduced into the apparatus until the boiled mass fills the apparatus. Evaporation can be carried out in single evaporators with a single-effect evaporator, as well as in installations with several evaporators with a multi-effect evaporator. Multi-case installations are more common; in them, the secondary steam from each previous case is sent as heating steam to the subsequent case. In order to ensure evaporation, it is necessary to create a difference between the temperature of the secondary steam from the previous housing and the boiling point of the solution in this housing. The temperature difference is the driving force of the evaporation process, and is created by reducing the pressure in series-connected housings. In installations of this kind, only the first housing is heated with primary steam from a boiler room or other steam generator. Multi-effect evaporator units save primary steam compared to single-effect units of the same capacity.

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In small industries, in particular, single-effect evaporation plants are used to thicken a small amount of solution; of course, installations of this kind are a less economical option. Scientists have obtained a lot of scientific results that intensify the evaporation process and improve the apparatus. Methods for calculating the process and evaporation apparatus for various solutions have been developed. Modern requirements for evaporation products that ensure healthy nutrition require the development of new methods and designs of evaporation devices. Our further scientific research is aimed at solving problems arising from the above requirements.

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