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IMPROVEMENT OF THE PROCESS AND APPARATUS FOR EVAPORATION OF FRUITS AND VEGETABLES JUICE

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The monograph provides a brief description. As is known, the concentration of a solution by evaporation is a thermal process consisting in the partial removal of water by evaporating it during boiling. The process is accompanied by the evaporation of water in the entire volume of the boiling solution, which significantly intensifies its removal.

Fruit and vegetable melon juice or apple pectin solution consists of a solvent - water and mono-sugars - glucose, fructose and sucrose dissolved in it. In this case, the osmotic vapor pressure of the dissolved substance is negligible compared to the vapor pressure of water. Therefore, when the juice boils, almost only pure water and aromatic substances evaporate, forming wet steam. The dissolved monosaccharide or pectin remains in solution, increasing its concentration. In this case, the boiling point of the solution is slightly higher than the boiling point of pure water.

Typically, only part of the water is removed from the juice, since in the apparatus used for evaporation, the dissolved substances must remain in a fluid state.The book is intended for engineering, technical and scientific workers, as well as specialists in the field of processing of agricultural products and design and technological bureaus.Will be useful for undergraduate and graduate students of higher technical and technological educational institutions.

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INTRODUCTION

The current level of development of the national economy of the Republic of Uzbekistan requires the creation of progressive innovative technologies for processing fruit and vegetable raw materials, the basis of which is the development, creation and scientific substantiation of highly efficient devices used for processing products in the agro-industrial complex. A special role in this regard is given to the waste-free processing of vegetable and melon crops to produce such valuable products as food pectin from apple pomace, melon peels, glycyrrhizic acid from licorice or Jerusalem artichoke roots. At the same time, the preservation of biologically active substances and valuable components is an acute problem in food technology.

As is known, many valuable components from plant materials are extracted by extraction followed by evaporation, precipitation and drying. These include the production of sugar from sugar beets, pectin from dried apple pomace or beet pulp, and tomato paste, which uses the evaporation process. Modern evaporators are well known and quite well studied, but they are very heat and energy intensive.

This dissertation research is aimed at fulfilling the tasks provided for in the Resolutions of the President of the Republic of Uzbekistan UP-4947 dated February 7, 2017 “On the strategy of action for the further development of the Republic of Uzbekistan”, PP-2789 dated February 18, 2017 “On measures to further improve the activities of the Academy of Sciences, organization, management and financing of research activities”, UP-5388 dated March 29, 2018 “On additional measures for the accelerated development of fruit and vegetable growing in the Republic of Uzbekistan” Therefore, all over the world, there is a tendency to improve the designs of evaporators in order to reduce energy consumption.

TECHNOLOGICAL AND TECHNICAL BASICS OF CONCENTRATION OF FRUITS AND VEGETABLE JUICES AND SOLUTIONS.

Methods for concentrating edible fruit and vegetable juices

In world practice, there are various methods for obtaining and concentrating food juices and products. They depend on the method of extracting the primary juice: direct pressing, extraction with the application of physical and mechanical influences, physical and chemical composition, density and viscosity, etc. Depending on the type of agricultural raw materials processed, be it fruits, vegetables or berries, in each country the preference is also given to mechanical means of processing. For example, in Western European countries, Poland, Bulgaria, the main attention is paid to the processing of apples and pears; in Hungary and Romania, preference is given to plums. We produce natural juices in Uzbekistan [43.92]. from grapes, apples, cherries, pomegranates, and it is planned to develop the production of melon juice and even melon honey. Much attention is paid to the production of drinking tomato juice, concentrated tomato paste and tomato-watermelon fortified juice [97; pp.171-177]. In the USA, they mainly produce concentrated extracts of Coca-Cola, Pepsi-Cola, and Fanta, the compositions of which are classified and patented.

The most common methods of concentrating food fruit and vegetable juices are: evaporation of weak solutions by thermal heating using water steam [14; pp.240-247, 16; pp.574-583, 24; pp.340-347, 28; p.8-12], freezing, diffusion using membrane technology [30; p.100-109], physical and electrical methods [8; pp.15-28, 61; pp.142-147, 74; p.5, 77; p.80-90].

In foreign countries, industry uses a single-stage freezing concentration process, which proceeds as follows: pre-cooling, crystallization freezing, phase separation and continuous separation of concentrated juice.

In this case, the total energy consumption of the process includes the energy consumption consumed by the refrigeration unit, the energy required for pumping the liquid phase, mixing, removing ice, etc. The amount of heat to be removed consists of the heat of crystallization of the cooling heat, technological losses for thermal conductivity and part of the mechanical energy of the drives, converted into heat.

The temperature difference between the condensing and evaporating refrigerants should be as small as possible. This is achieved if the crystallization is carried out in a cascade manner and the latent heat of the ice crystals is used to condense the refrigerant. The cascade method allows you to remove most of the heat of crystallization at temperatures above the melting point of the final concentrated product.

The cost of this method of obtaining concentrated juice is relatively high. At the same time, achieving a dry matter content of no more than 45 - 50%, which is not a profitable production.

A more advanced method for concentrating liquids is the use of membrane technology with selective characteristics of the processed products [30; p.36-43]. This technology is based on reverse osmosis.

Concentration using membranes has also not yet found widespread use, although it is being intensively studied. Reverse osmosis or membrane concentration process can be used to produce fruit juices at room temperature without any change in the physical structure of the water, thus minimizing the damage caused by heat recovery. In addition, the costs of processing with membrane technology are lower and high quality products are achieved by maintaining the aroma and taste of the mixture [77; p.75-85].

In this process, it is necessary to use dense membranes with high resistance, since this process requires the application of high transmembrane pressure (0.8-1 MPa) to overcome the high osmotic pressure from fruit juices. However, concentration using membranes is also limited to a concentration of 35 - 40% solids.

Recently, research has been carried out on the use of electrophysical methods of influencing the process of concentrating various liquid materials by microwave generation. There have been attempts to concentrate apple juice in industry using microwave radiation [87].

To concentrate fresh apple juice in continuous production, it is proposed to use a microwave concentrator, which has high efficiency and sterility of production. The parabolic waveguide provides a more uniform distribution of microwave radiation. Microwave concentration has great advantages in terms of technological process organization and design, high productivity, concentration coefficient and efficiency.

However, industrial tests have shown that fruit juice concentrates are of poor quality due to the destruction of some nutrients and vitamins. This is due to the local selective effect of microwave rays on the molecules of complex organic components of natural juices and the presence of local overheating zones. In addition, microwave radiation negatively affects the body of service personnel and requires special precautions.

The predominant method of concentrating various solutions in the food industry is evaporation [64; p.366, 106; pp.566-569, 66; p.4-10]. Classic examples of the use of evaporation are the production of tomato paste, the processing of sugar beets to produce a sugar solution and crystallization into granulated sugar, the production of condensed milk, the production of casein from bone broth, etc. In the USA, the company Sosa-Cola produces a concentrate obtained from aqueous extracts of wild herbs; in Bulgaria, it produces concentrated apple juice. Concentrated juices can be obtained from any fruits and vegetables.

Evaporation, namely vacuum evaporation, is the most commonly used process in the production of concentrated juices. The main advantages of evaporation are the ability to achieve high concentrations, the versatility of concentrating various products and the ability to combine other stages of the process. The disadvantages include the fact that degradation of heat-sensitive composites is possible, as well as loss of volatile substances, darkening reactions, turbidity, coagulation, flocculation and sedimentation, in addition, this is a very energy-intensive process [66; p.203-213].

The evaporation process is carried out at as low temperatures as possible and for a short time. This is necessary to achieve a higher quality product, namely to preserve the nutritional value of the juices. Modern technology for the production of juice concentrates includes obtaining juice, removing suspended matter, then capturing flavor-forming substances, fermentation and filtering of dearomatized juice, as well as evaporation. Technological equipment for producing juice concentrate includes a separate unit for capturing flavor-forming substances. With its help it is possible to evaporate different amounts of steam with aromatic substances depending on the type of raw material.

Thus, for example, the technology for producing concentrated apple juice includes the following technological cages: crushing fresh apples, pressing to obtain natural juice, purifying the juice from suspensions in centrifuges, heating, trapping aromatic substances, filtration and evaporation, packaging and packaging. In this case, 10-15% of the water evaporates at the stage of capturing aromatic substances.

Flavor-forming substances distilled off together with water are concentrated 100 - 200 times in a cascade of distillation columns.

In such a concentrate, there is one part of aromatic substances per 100 parts of water and ethyl alcohol. Ethanol content is limited to 5 to 20% in flavor concentrates depending on the juice raw material.

Typically, flavor concentrates are stored separately from juice concentrates at a temperature of about 0°C or can be directly returned to concentrated juice, but the quality of the flavor suffers.

Next, the resulting juice is cooled to a temperature of 41-46°C and sent for clarification. It is carried out using enzyme preparations, bentonite and gelatin. Physical methods of juice clarification include: heating, decanting suspensions and polishing filtration. The process is carried out in fermenters with purified pectolytic enzyme preparations, for example, pectofoetidin P11X. Filtered juice is concentrated up to 60-70% in multi-effect evaporation units.

A good example of the evaporation process is the concentration of tomato pulp, which is a kind of suspension in which the dispersion component is crumb particles with insoluble substances: organic fibers, cellulose, peel and seed particles. After centrifugation, the resulting centrate contains water and soluble substances, which is concentrated in the MWU [111; p.25-36]. The process of concentrating tomato pulp is limited to a concentration limit of up to 35-40%, corresponding to the maximum permissible boiling temperature of the treated solution at a given total pressure in the apparatus. In this case, further removal of water from the solution without changing its temperature is impossible.

In Uzbekistan, the production of tomato paste is carried out by: Samarkand plant “Sickle and Hammer”, Novotashkent cannery, Shakhrisyab cannery and others, which mainly use three-effect evaporation plants produced by companies

“Unity” (Slovenia), “Martini” (Italy) and “Tambovkhimmash” (Russia)

By the decision of the Cabinet of Ministers of the Republic of Uzbekistan, it is planned to build a canning plant in Syrdarya for the complex processing of melon fruits with the production of a number of food products: dried melon, preserves, jam, juice and melon honey.

A promising raw material for the production of fruit juice in our republic is melon fruits, from which a sweetener can be obtained, which is an alternative to sugar beets [97; pp.235-241, 109; pp.109-110].

Industrial processing of melon fruits includes a number of technological processes, the schematic diagram of which is shown in Fig. 1.1.

It includes: washing and sorting, removing the peel, cutting the peeled fruit into ring segments, removing seeds with placents and grinding the pulp. Fruits are washed using an A9-KMT-8 machine or a roller conveyor with a showering device. Sorting and inspection can also be carried out on a roller chain conveyor, manufactured as non-standard equipment [125; p.12-15].

Removing the peel and cutting the fruit into slices is carried out on mechanized units ARD-2 and MKD-1, developed by a group of designers in collaboration.

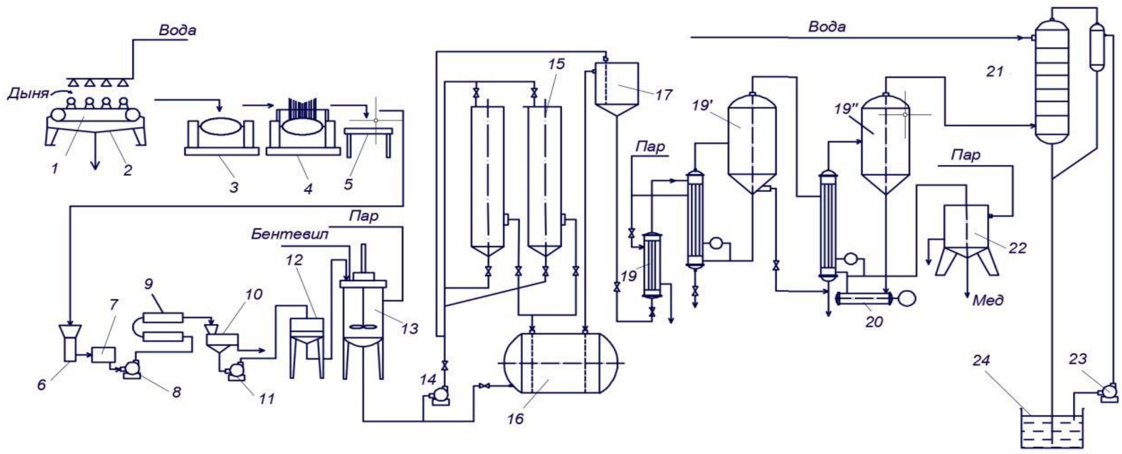


Fig.1.1. Principal hardware-technological diagram (ATS) for the production of melon honey

1-roller conveyor, 2-tub, 3-machine for removing the peel from the melon fruit, 4-apparatus for cutting the melon fruit into slices, 5-cutting table, 6-chopper A9-KV,7-rubbing, 8-piston pump, 9-casing boron sterilizer, 10-screw press, 11-centrifugal pump, 12-nut filter, 13-reactor with frame stirrer, 14-pump, 15-decanter, 16-clarified wort collector, 17-pressure tank,18 - shell-and-collection sterilizer, 19- second housing, 20- screw circulation pump, 21- collection of finished products, 22- barometric condenser, 23- water ring vacuum, 24-barometric pit.

Features of the technological process of concentrating fruit and vegetable juices

As you know, concentrating a solution by evaporation is a thermal process that involves partial removal of water by evaporating it during boiling. The process is accompanied by the evaporation of water in the entire volume of the boiling solution, which significantly intensifies its removal [13; pp.964-970].

To carry out the evaporation process, it is necessary to transfer the heat of the heating steam to the boiling juice, which is only possible if there is a temperature difference between them, i.e. at a useful temperature difference. The most widespread in industry are evaporators heated by condensing water vapor and, less commonly, by high-boiling organic coolants.

Fruit and vegetable melon juice or apple pectin solution consists of a solvent - water and mono-sugars - glucose, fructose and sucrose dissolved in it. In this case, the osmotic vapor pressure of the dissolved substance is negligible compared to the vapor pressure of water. Therefore, when the juice boils, almost only pure water and aromatic substances evaporate, forming wet steam. The dissolved monosaccharide or pectin remains in solution, increasing its concentration. In this case, the boiling point of the solution is slightly higher than the boiling point of pure water [16; p.601-606].

Typically, only part of the water is removed from the juice, since in the apparatus used for evaporation, the dissolved substances must remain in a fluid state. This is well illustrated in the production of tomato paste from tomato pulp or the production of granulated sugar from diffusion juice of sugar beets in multi-effect evaporation plants.

The main differences between the evaporation process, due to which evaporation is distinguished as an independent section among other thermal processes, are the features of its hardware design and the method of calculating evaporation units [31; p.375-377].

In essence, evaporators are heat exchangers in which part of a solution or mixture of liquids is partially evaporated as a result of the supply of heat. This produces a concentrated solution and secondary juice steam, which can be used as a coolant. This is used in multi-effect evaporation units (MEE), for example, in sugar production [66; pp.102-106].

The difference between evaporators and conventional heat exchangers lies in the conditional division into two interconnected thermal units: a heating chamber and a separator - a trap for catching solution droplets from the steam formed when the solution boils.

The calculation of the evaporator is somewhat different from the calculation of a conventional heat exchanger. So, for example, to determine the useful temperature difference across the housings, it is necessary to determine the boiling point of the solution, which depends on many technological factors: concentration of the solution, pressure above it, viscosity and size of the heating elements. In addition, it is not always easy to determine the temperature of the heating steam, since its pressure is not specified, but is presumably determined approximately.

In addition to the above, it is necessary to take into account the process of foaming when evaporating clarified melon juice and the possibility of intense carbon formation in the heating tubes due to an increase in dynamic viscosity and a decrease in the rate of natural circulation at the final stage of evaporation.

When calculating, designing and modeling the operation of evaporators for viscous solutions, it is necessary to take into account the circulation of the solution, which prevents and reduces the rate of scale deposition on the walls of the heating tubes. In this case, the speed of movement of the solution in the pipes must be at least 1.5-3 m/s [64; p.389-390].

Classification of evaporators and their general characteristics

Evaporators are classified according to many criteria [18; pp.98-103, 20; pp.21-27, 30; pp.100-109, 36; pp.385-390, 42; pp.55-57, 48; pp.359-362, 64; p.366-368], the main of which are:

- method of heat transfer;
- on the design of heat transfer surfaces;
- type of heating fluid;
- location in space of the geometric axis of the heating chamber;
- by the presence and frequency of circulation;
- by the method of creating circulation;
- according to the relative position of the solution heating and boiling zones;
- according to the relative position of the separator, heating chamber and circulation pipe (if any).

Evaporators are divided into surface and mixing (contact) evaporators according to the method of heat transfer from the heating fluid to the evaporated solution. Based on the design of the heat transfer surface, evaporators are divided into jacketed, coil, tubular, etc. Mixing evaporators are mainly bubbling and spray evaporators.

Water vapor in evaporators is used as a heating medium. Very rarely there are designs of devices that use hot gases or electrical energy as a heat source.

Depending on the location of the axis of the heating chamber, evaporators are divided into vertical, horizontal and inclined.

Depending on the amount of passage of the evaporated solution through the heating chamber, evaporators are divided into direct-flow and circulation devices. The final concentration of the solution in direct-flow devices is achieved in one pass through the heating chamber. In devices with circulation, the solution, in order to reach its final concentration, makes multiple passes through a closed circuit, including a heat supply zone. The circulation of the evaporated solution in evaporators can be natural or forced. Due to the formation of different densities (vapor-liquid mixture) in different zones of the apparatus, natural circulation of the solution occurs. It is due to the unequal intensity of heat supply to the solution in these zones. In devices with forced circulation of the solution, pumps of various designs are used. The natural circulation of the evaporated solution in evaporators can be free (chaotic, disordered) and directed (ordered).

Free circulation of the evaporated solution is found in capacitive-type evaporators with internal heating elements (coils, tube bundles, etc.), as well as in capacitive apparatuses with jackets. During the evaporation of solutions, the free circulation rate is low. Therefore, devices with free circulation are unsuitable for evaporating viscous, crystallizing, scale-forming, and heat-sensitive solutions. With free circulation, heat transfer coefficients are relatively small; in addition, it is difficult to create the necessary heat transfer surface in the form of internal devices and jackets. For this reason, free circulation devices are used mainly for low production capacities.

The combined heating chamber and unheated (less heated) circulation pipe creates a directed circulation circuit of the solution. In this case, the evaporated solution (or vapor-liquid mixture) in the heating chamber moves upward, subsequently separating in the separator into liquid and vapor. At the same time, the cooler solution in the circulation pipe goes down. Higher circulation speed can be achieved by increasing the height of the heating chamber and the temperature difference between the solution in the heating chamber and the circulation pipe. Increasing the circulation rate allows for an increase in heat transfer coefficients, a reduction in the amount of deposited solid phase in the apparatus and the formation of scale on heat exchange surfaces, and a reduction in cases of overheating of solutions, which is important when working with heat-sensitive materials.

Evaporators are classified depending on the relative position of the solution heating zones and its boiling, as well as the nature of the boiling. The solution in the evaporator, depending on its design, can boil in the heat supply zone (directly in the entire volume of the heating chamber), or outside it at its free surface (in the remote boiling zone). In film evaporators, the boiling of the solvent in the solution occurs on the surface of its film.

- Vertical tube evaporators are the most common modern industrial evaporators. Based on design features, relative position of the separator, heating chamber and circulation pipe, they are divided into devices:
- with a coaxial heating chamber and circulation pipe (relative to the separator);
- with a coaxial heating chamber and a remote circulation pipe;
- with coaxial circulation pipe and remote heating chamber.

Such designs of evaporators include devices with natural and forced circulation, with boiling of the solution in the heating zone and with a remote boiling zone, as well as film devices with flowing and rising films of the evaporated solution. Forced circulation evaporators are usually equipped with axial circulation pumps.

The vapor-liquid mixture formed as a result of boiling the solution is separated in gravity separators, which are usually located above the heating chamber. To catch liquid droplets carried away by the flow of secondary solvent vapors, inertial (louvre, centrifugal, etc.), mesh, and other drop catchers are used at the second stage of the separation process. The secondary steam at the exit from the layer of boiling liquid solution is superheated. Therefore, the drops of solution carried away by it are evaporated, and the formation of crystals is possible. For this reason, when evaporating concentrated solutions, periodic or constant flushing of the separator and droplet eliminator with condensate is provided.

To evaporate concentrated crystallizing solutions, evaporators can be equipped with a salt separation unit. Some designs of apparatus for evaporating highly viscous, crystallizing solutions (for example, rotary) have mechanical devices for forced movement of these solutions and removal of settled crystals.

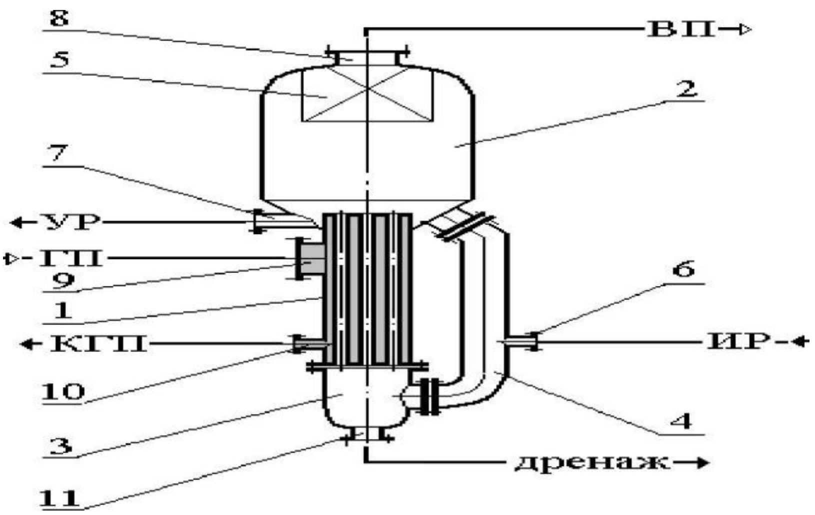
Vertical evaporators with steam heating chamber.

The most widespread in the food industry are evaporators with natural circulation of the solution with vertical pipes and its boiling in heating pipes. (Fig.1.2)

Integral parts of the designs of such devices are tube sheets in which boiling pipes heated by steam are fixed. The evaporated solution moves (circulates) inside these pipes. In devices with natural circulation, in contrast to devices with forced circulation, the driving pressure is created due to the difference in the density of the vapor-liquid mixture inside the boiling pipes and the non-boiling liquid moving inside the circulation pipes connecting the liquid space above the upper tube sheet. When calculating and designing devices with natural circulation, an important place is occupied by calculations of circulation, driving pressures and resistance of the circulation circuit, as well as calculations of heat transfer from the heating steam to the evaporated solution.

Of the evaporators produced by domestic factories and widely used in a number of industries, we will consider devices with natural or forced circulation and film.

Depending on the design, evaporators with natural circulation can have a coaxial or remote heating chamber, with a non-remote heating chamber (the solution boils in tubes) or a remote boiling zone. The apparatus with natural circulation of the evaporated solution has a remote heating chamber. The solution boils in tubes 3-7 m long. They are manufactured with heating surfaces from 25 to 1000 m^2.



Rice. 1.2- Vertical tubular evaporator with a pine heating chamber with natural circulation of the solution and its boiling in the heating zone (pipes)

1-heating chamber; 2- separator; 3 - lower cover (bottom) of the heating chamber; 4- circulation pipe; 5-drop catcher. Fittings: 6 - for inlet of the initial solution; 7-to release the evaporated solution; 8 - for the release of secondary steam; 9 - for heating steam inlet; 10 - for heating steam condensate outlet; 11 - for emptying.

Streams: TS - initial solution; UR - evaporated solution; VP - secondary steam; GP - heating steam; KGP - heating steam condensate.

Figure 1.3 shows a similar evaporator with a remote heating chamber and forced circulation of the solution. When the evaporator 1.2 or Figure 1.3 is operating, the initial solution is fed into it through fitting 6, embedded in the unheated circulation pipe 4. The solution fills the pipe space of the device, including including boiling pipes of heating chamber 1.

Evaporators with forced circulation have a number of disadvantages: additional energy consumption for organizing the circulation of the evaporated solution. increased design complexity and reduced reliability due to the presence of circulation pumps

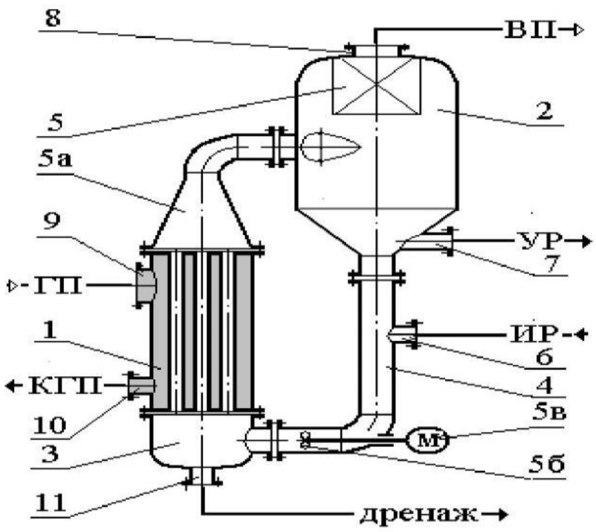


Fig. 1.3-Vertical tubular evaporator with a remote heating chamber and forced circulation of the solution

1-heating chamber; 2-separator; 3- lower cover (bottom) of the heating chamber; 4-circulation pipe; 5-drop catcher; 5a-boiling pipe;

5b - circulation pump; 5v - circulation pump drive.

Fittings: 6 - for inlet of the initial solution; 7 - for the output of the evaporated solution; 8 - for the release of secondary steam; 9 - for heating steam inlet; 10 - for heating steam condensate outlet; 11-for emptying

Film evaporators are mainly used to evaporate non-heat-resistant solutions. In devices with a film structure, the film-like liquid of the evaporated solution boils, located on the heat transfer surface. The advantage of such devices is the absence of a column of liquid (solution), as a result, hydrostatic depression and overheating of the solution do not occur. In addition, due to the direct flow of liquid, the duration of exposure of the evaporated solution under the influence of temperature in the apparatus is very short. Tubular film evaporators are available with a flowing or rising film of the evaporated solution. An example of such a device is the device shown in Fig. 1.4.

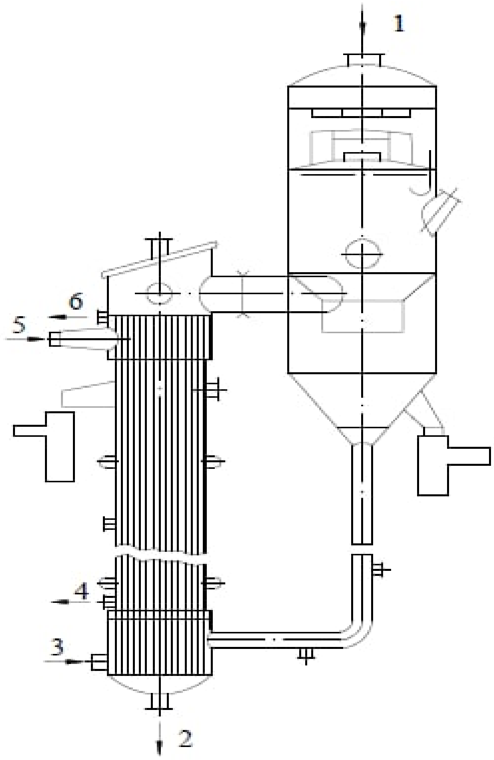


Fig. 1.4. Diagram of a vertical long-tube evaporator from the Japanese company Tsukishima Kikai Co., Ltd. [37; p.239].

1.5 - secondary and heating steam, respectively; 2- evaporated solution; 3-source solution; 4-condensate; 5-heating steam; 6-uncondensed gases

Devices with natural circulation of this type are classified as medium-sized devices, i.e., average between short-tube and homogeneous long-tube ones. The heating chamber is removed from the evaporation unit, which makes it easier to clean the pipes from carbon deposits. The incoming liquid is mixed with the circulating liquid and passes through the heating pipes from the bottom to the top, then thrown into the evaporation chamber and separated from the solution. This evaporation unit is easy to use, as scale does not form in it and salts do not fall out. The heating pipes in this installation can be made of special material. Manufacturing the installation is simple and requires lower costs than the production of a conventional type of evaporator..

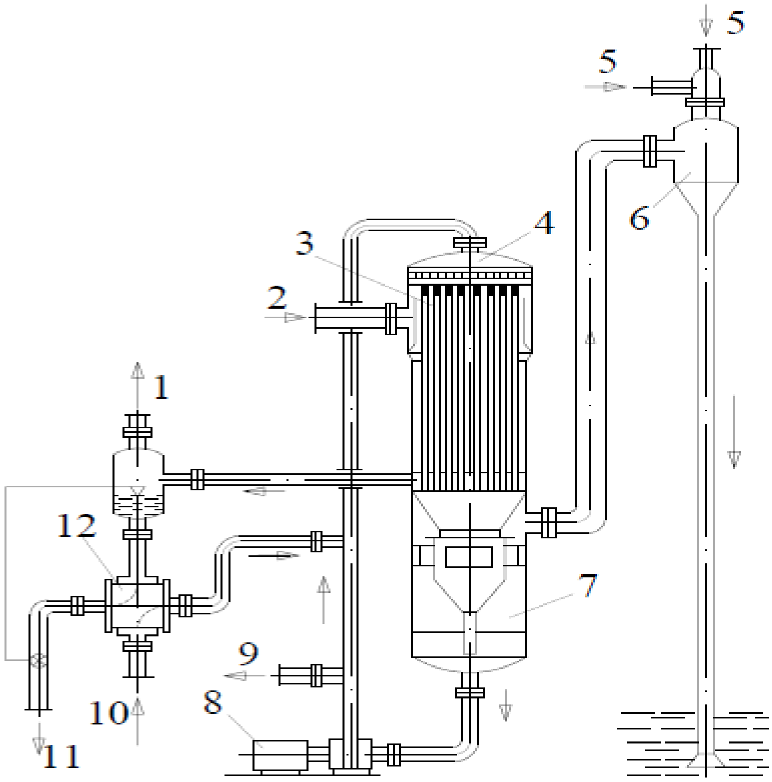
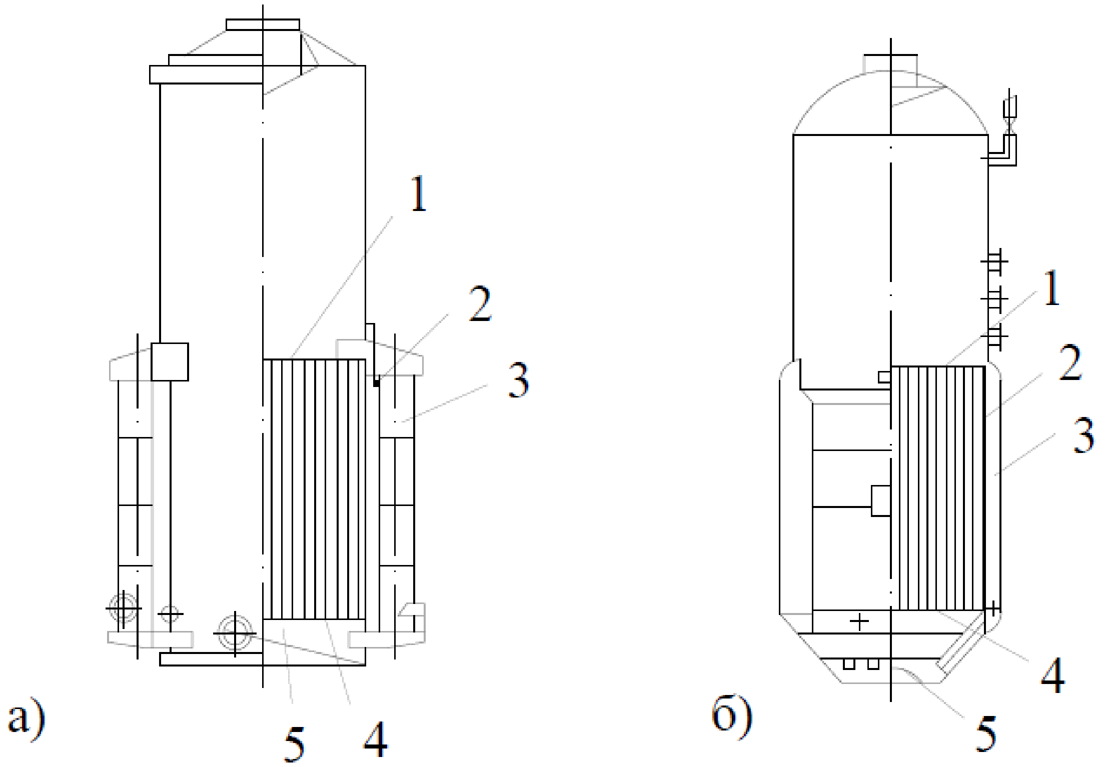


Fig.1.5. Design diagram of a circulating vertical long-tube falling film evaporator:

1-exhaust device; 2-heating steam; 3-heating chamber; 4-distributor; 5-cooling water; 6-jet condenser; 7-chamber extra steam; 8-circulation pump; 9-evaporated solution; 10-original solution; 11-condensate; 12-spiral preheater.

In long-tube vertical evaporators with natural circulation (Fig. 1.5), the length of the pipes is 6-12 m with a diameter of 25-50 mm. Their main modifications are: devices with or without recirculation with rising film; devices with feeding film, or multi-pass with variable stroke (up and down sequentially). The advantages of such devices are: low cost, large heating surface per unit volume, small overall dimensions, high steam velocity and heat transfer coefficients at high and medium (rising film), as well as low thermal loads (falling film).



Rice. 1.6- Design diagram of a VTs type evaporator;

a) VTs -58; b- VTs-62; 1.4 - upper and lower tube sheets, respectively; 2-weirs; 3-circulation pipes; 5-bottom.

The distinctive characteristics of these devices are that the upper and lower tube sheets are flat and gable, made with an inclination to the outer wall of the device body. The inclination of the lower tube sheet ensures complete removal of condensate from the heating chamber, and the inclination of the upper tube sheet ensures rapid removal of condensate into the circulation pipes. VTs type devices are equipped with a remote trap-separator. Tangential supply of extra steam to the trap.

Scheme of operation of a direct-flow evaporator [37; pp. 76-80], (Fig. 1.7) from the Bukkau-Wolf company (Germany) differs from the operation scheme of domestic and other imported circulation evaporators. The juice in it from below enters the first passage, located in the center of the tube bundle, and boils at the exit from it. Then, mixed with steam, it passes through the central circulation pipe into the second passage located along the periphery. At the exit from this tube bundle, secondary steam is released. The condensed juice is removed from the upper tube sheet with partial circulation. According to the company, with this scheme of operation of the device, the circulation speed and, accordingly, heat transfer coefficients increase. The distance between the tube sheets in this apparatus is 3665 mm, the diameter of the tubes is 33 mm.

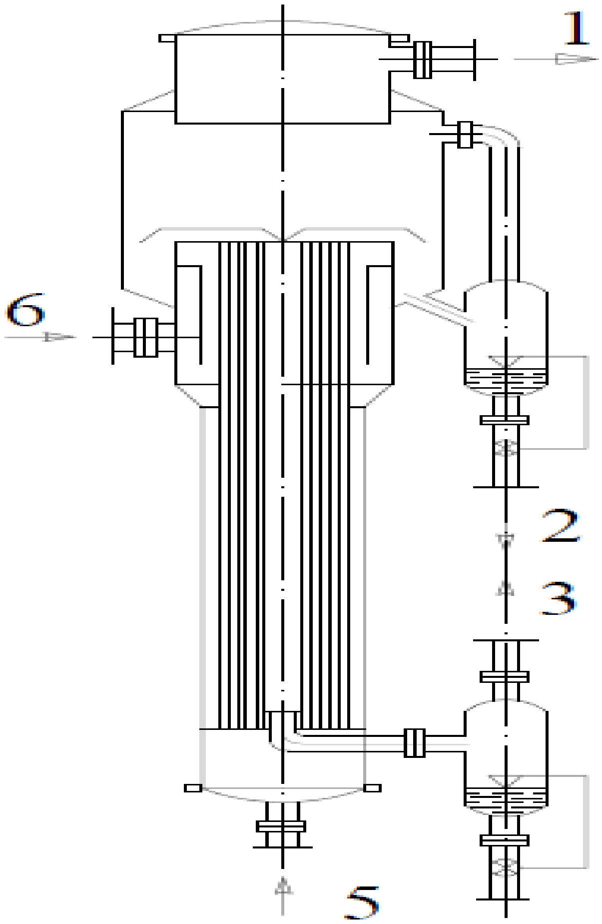


Fig. 1.7 - Diagram of the design of the evaporator from the Bukkau-Wolf company

1- self-evaporation vapor; 2.6 juice and heating steam; 3-separator; 4-cap; 5-evaporated juice; 7, 8-boiling tubes; 9-juice input; 10-dip pipe; 11-distribution chamber; 12 condensate pump.

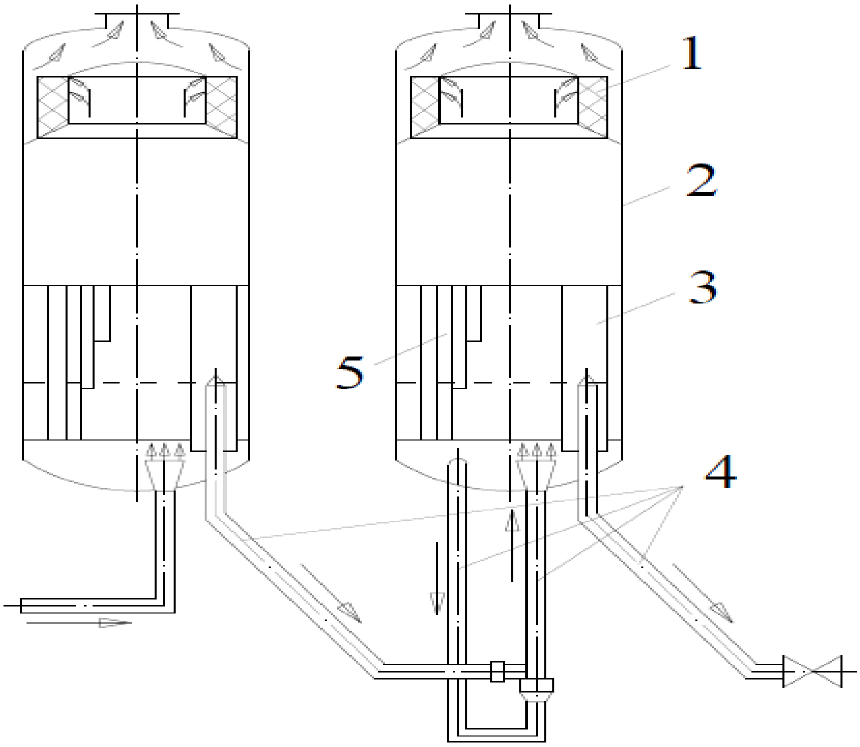


Fig. 1.8 - Design diagram of the Sangerhausen evaporator

1-separator; 2-body; 3- circulation pipe; 4- juice transfer pipes; 5-boiling tubes.

Evaporator from Sangerhausen [37; p.229-235], GDR) has an eccentrically installed circulation pipe 3 (Fig. 1.8), circulation stimulators located on the juice transfer pipes 4, and other details that distinguish it from domestic circulation-type evaporators. In addition, the pipes on the body serve to extract secondary steam from the chambers of the apparatus in order to increase the speed of the heating steam.

Evaporators from other foreign companies are also widely known: Kostner, BMA (Germany), Fives-L'Isle-Caille (France), Rosenblad (Sweden), Unity (Slovenia), Martini (Italy) etc. These devices are varied in design, supply of heating steam and purpose.

Table 1.2 shows comparative data on the design of evaporators (diameter of boiling pipes 30\33mm) manufactured by domestic manufacturers or foreign companies.

Table 1.1

Comparison table of evaporators.

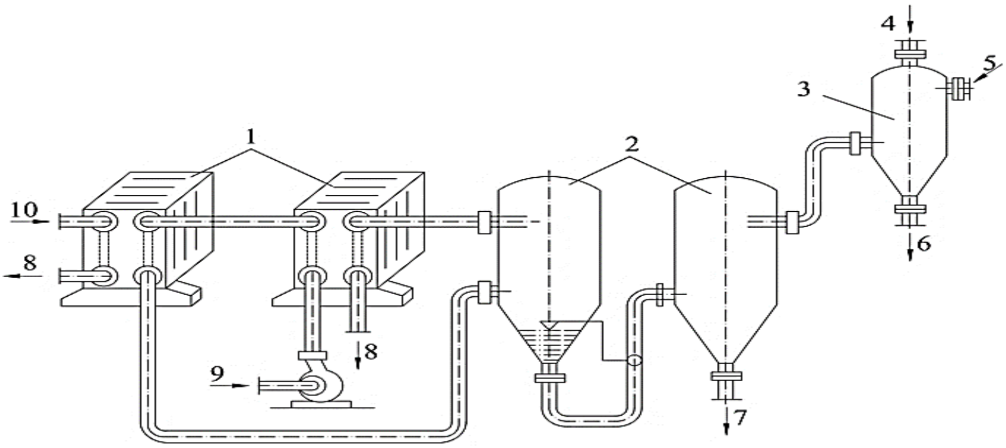
A country	Heating surface . м^2	Active length of boiling pipes, мм	Specific metal consumption per 1m^2 heating surface, kg	Device weight, kg
(CINS-1) Russia	300	1450	34,0	10400
	400	1450	31,0	12600
	500	3000	29,4	147 00
	600	3000	26,6	15900
	800	3000	24,3	19400
	1000	3000	23,1	23100
	1180	3000	30,7	29600
(VC-62) Russia	1500	3400	21,2	31700
	1800	4080	20,4	36800
	2120	4295	20,2	42300
Czechoslovakia	400	3000	34,2	13700
	1800	3740	20,8	37400
Poland	400	2000	45,0	18000
	800	2500	30,0	24000
	1800	3700	22,0	39600
FRG (BMA)	1000	1500	53,2	53300
FRG (BMA)	1500	2650	40,5	60900
	1650	2650	39,6	65300
	2000	2650	39,0	77800
France ("Fiv-Lil-Kai")	690 2000 3200	1920 2900 3700	38,4 32,2 30,0	26500 64500 96000
England ("Duncan-Sewart")	650 1150 1750	3100 3100 3100	35,0 33,8 30,3	22800 38800 53000

* Diameter of boiling pipes 33\29 mm

The main disadvantage of these devices is the difficulty of ensuring uniform distribution of the solution through the tubes, the need to use distributors with small calibrated holes to achieve this goal.

Of great interest is the plate evaporator with flash evaporation (Figure 1.9), which has a very high heat transfer coefficient and the most compact design. A high heat transfer coefficient is achieved by making 0.6 mm thick plates from a titanium alloy with an admixture of tantalum. The advantages of this device include a compact design, simple mechanical cleaning and a short residence time of the solution in the device. Its use is optimal for liquids without suspended particles and heat-sensitive products.

These devices are used for evaporation of salt solutions and organic chemicals. The disadvantage of these devices is their unsuitability for evaporating liquids with suspended fibrous crystalline particles.



Rice. 1.9- Diagram of a two-stage plate evaporator with flash evaporation;

1-heaters; 2-expanders; 3-condenser torus; 4- cooling water;

5- pipe to the vacuum pump; 6-barometric tube; 7- evaporated solution; 8-condensate; 9- initial solution; 10-heating steam.

Figure 1.10 shows an evaporator with natural circulation of products, which can be used in the chemical, food, metallurgical and other industries [3; c.46-49].

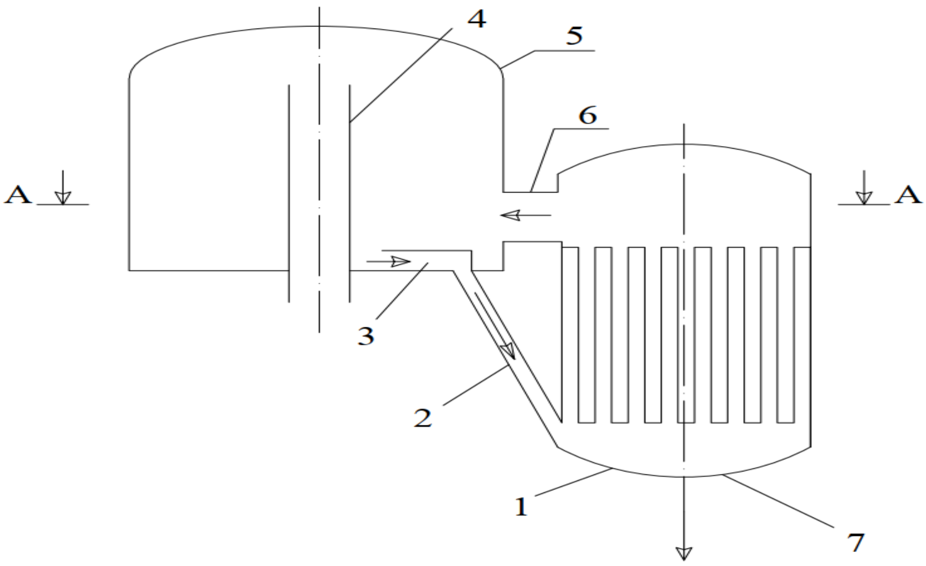


Fig. 1.10 - Diagram of an evaporator with natural circulation:

1-remote heating chamber; 2.6 circulation pipe; 3-traps; 4.7-pipe; 5- steam separator

The disadvantage of this apparatus is its relatively low productivity due to the fact that the solution undergoes a rotational movement in the steam separator and the speed of such movement is not the same and the lower it is, the closer to the center of the steam separator. When the solution moves inside the conical trap, the layers of solution swirl, moving at high speed, and this reduces the speed of movement of the solution at the entrance to the circulation pipe. In addition, installing a conical trap in the separator reduces the steam precipitation time, since part of the flow travels inside the trap.

Figure 1.11 shows an evaporator with horizontal pipes.

The disadvantage of the apparatus is that the horizontal heating elements, which are arranged in a checkerboard pattern, do not provide an organized circulation circuit for the product and thereby an effective heat exchange process between the evaporated product and the condensing steam. Therefore, there is a need to install a large number of heating elements to develop the intensity of the heat transfer surface.

Also, in the boiling zone there is a high level of solution, which leads to noticeable temperature losses due to the hydrostatic effect and possible overheating, and, as a consequence, to the decomposition of thermolabile products.

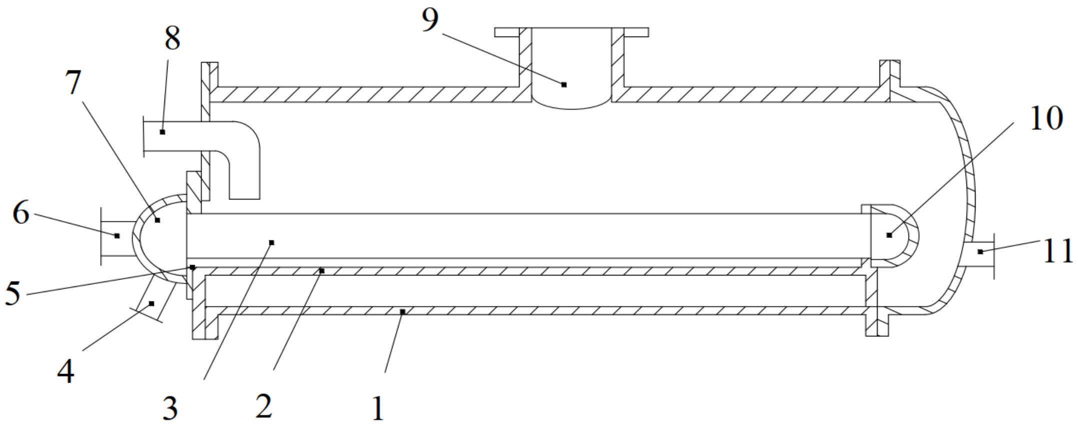


Fig.1.11 - General view of the evaporator: horizontal type.

1-body; 2-horizontal partition; 3- heating elements; 4,6,8,9,11 fittings; 5,10-pipe grids: 7-manifold for supply and distribution of heating steam.

To eliminate the disadvantage, it is necessary to ensure effective heat exchange during the evaporation process, eliminate overheating of the solution and possible thermal decomposition of products, creating an organized flow of product circulation at the heat transfer surfaces in the boiling zone, and reduce temperature losses to a minimum due to the hydrostatic effect.

The set task is achieved in a modernized evaporator, shown in Fig. 1.12. [74; p.5]. In this device, heating elements having a flat-oval shape are rigidly fixed at the ends into the tube sheets of the collectors for removing condensate and supplying heating steam in sections of three pieces each with a ratio of gaps between sections to gaps between elements equal to 2.5. During operation, it is necessary to maintain the distance between the heating elements and the horizontal partition and maintain the height of the solution level above the upper oval heating elements.

The efficiency of heat exchange in the modernized heat exchanger is achieved by organizing its active circulation at the outer surface of the heating flat-oval elements due to their sectional arrangement.

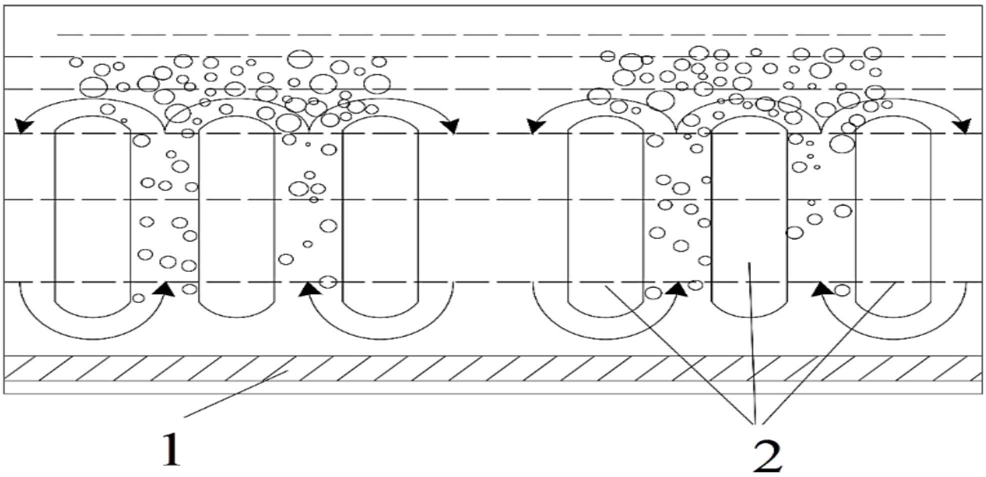


Fig. 1.12 - Diagram of the organized circulation mechanism:

1-horizontal partition; 2- heating elements

Manufacturing the installation is simple and requires lower costs than the production of a conventional evaporator.

Design features of evaporators depending on the method of heat supply and evaporation zone.

Existing evaporators, despite their various designs, are not classified and are usually divided according to the principle of operation, type of circulation, method of heat supply, nature of solution movement, orientation of the heating surface, location of the evaporation zone, design of the separator and other parameters [79; 248-250].

According to the patent and licensing search and scientific and technical analysis, table 1.2 provides summary information on evaporators used in industry.

Table 1.2

Designs of evaporators and features of their application.

Design Features	Type of evaporator (VA)	Advantages and disadvantages of evaporators and features of their use
Circulating the pipe is taken out	VA with coaxial heating chamber	More compact and occupy less production space. Natural circulation of solution Low productivity and low heat transfer coefficient from the wall to the solution
Steam separator removed	VA with remote heating chamber	They occupy a large area. Convenient for cleaning pipes from scale. Moderate heat transfer coefficient. Difficulty in maintenance.
The boil-off pipe is placed in the seperator	VA with extended boiling zone	Increased circulation rate. Heating a solution above its boiling point.
The circulation pipe is located behind the heating chamber	VA with remote heating chamber and forced circulation	Complicating the design and reducing reliability leads to excessive consumption of electricity. Increase in heat transfer coefficient.
The separator is taken out and placed below	Film VAs with a remote heating chamber and falling film	Evaporation of non-heat-resistant solutions. A high degree of evaporation from the solution film flowing down the tubes, providing a high heat transfer coefficient. Repairable.
The separator is equipped with bumpers	VA with rising solution film.	For evaporation of non-aggressive and non-heat-resistant solutions, it is difficult to distribute the solution through the tubes
Equipped with shaft drive and steam jackets	Rotary film evaporators	For paste-like non-heat-resistant solutions. Disadvantages – complexity of design and low productivity
Equipped with external expanders for vapor-fluid-bone phase	VA with flash evaporation	High heat coefficient, used for clean solvents in the chemical industry. Manufacturing is very expensive
Two-stage steam separator carried behind the heating chamber	Long pipe VA Japanese company Tsukishima Kikai	Features large dimensions and a high heat transfer coefficient from the heating steam. Low scale formation

- In the food, chemical and related industries, a large number of different designs of evaporators are used, depending on the technological requirements, technical design and type of coolant used:
- • on the type and physical properties of the solution being evaporated: viscosity, density, boiling point, critical heat flow, etc.;
- • on the technological characteristics of the evaporated solution: foaming, thermolabile, crystallizing, degrading, etc.;
- • on the functional purpose of the evaporator: obtaining a dissolved substance or distillation will dissolve;
- • depending on the type of coolant used: steam, electric, high thermal organic liquids;

• on the purpose and position of the evaporator in the overall technological process.

When selecting and modeling the operation of evaporators, it is necessary to take into account the circulation of the evaporated solution, which is created to reduce the rate of deposition of contaminants (scale) on the walls of the heat exchange surfaces of the apparatus. The speed of movement of the solution in the pipes must be at least 1-3 м/с [64; с.359].

Analysis of the shortcomings of modern evaporators and ways to improve them

Thermal processes are widely used in the food industry in the production of concentrated juices, sugar solutions, milk, tomato paste and in the chemical industry in the production of various solvents and detergents. Many of them are purely heat exchangers, devices for heating interacting components, while others are for concentrating liquid media, caused by the transfer of heat from one substance to another or from one material state to another [48; p.364].

These include the evaporation process, the main purpose of which is to obtain food concentrates while maintaining the physicochemical and biologically active properties of the processed product [73; pp.55-58, 74; p.5].

When selecting and designing newly created, new designs of evaporators, it is necessary to strive to increase the efficiency of heat transfer, as well as take into account and minimize heat loss to the environment.

So, in the devices most used in the national economy, which have a vertical arrangement of heating pipes with a central circulation pipe, heating water vapor is used as a heating agent during evaporation. The main elements of the heat exchange surface of evaporation devices, the circulation pipe, like boiling pipes, are heated by dead steam, which reduces the difference in the densities of the solution and the vapor-liquid mixture and can lead to unwanted vapor formation in the circulation pipe itself. Their disadvantage is the rigid fastening of the boiling pipes.

Film evaporators are used to evaporate highly foaming and heat-sensitive solutions. Their advantages are the absence of hydrostatic depression, low hydraulic resistance, high heat transfer coefficient, high productivity with relatively small volumes of devices and the areas they occupy, short duration of contact of the solution with the heat exchange surface.

The disadvantages are ensuring the uniform supply of the initial solution and the complexity of cleaning the heating surface [37; p.124].

To increase the circulation intensity and heat transfer coefficient, devices with forced circulation have recently begun to be used. The advantages are high heat transfer coefficients, as well as the absence of contamination of the heat exchange surface when evaporating crystallizing solutions and the ability to operate at small temperature differences, while the disadvantage is the need to consume energy to operate the pump.

Analysis of analytical studies of the evaporation process

Many works of scientific researchers are devoted to the mathematical description of the ongoing processes in various types of evaporators, used mainly in the chemical and food industries, most of which describe models of surface-type evaporators with natural and forced circulation included in multi-effect evaporation plants [21; pp.43-49, 26; 331-337]. Single-shell evaporators with natural and forced circulation, as well as with a falling film of the working solution, are used much less frequently and when evaporating a small amount of the initial solution [31; p.362]. Basically, evaporators heated by dead water vapor are considered [48; p.359].

Most of the developed models of evaporators are built on the basis of the following assumptions:

- the density of the substance being processed at any point in the evaporator is equal to the density at its outlet;
- secondary steam formed during evaporation and the solution in the separator are in the same thermodynamic equilibrium;
- the heat capacities of all process flows are assumed to be constant;
- accumulation of condensate during heat transfer from dead water vapor to heat exchange surfaces, i.e. absent on the walls of the heating chamber and separator;
- the temperature of the evaporated solution at all points of the apparatus is the same;
- the solution is not carried away by secondary vapors;
- crystallization processes of the substance do not occur;
- there are no heat losses through the device body.

The development of a mathematical description of processes in a surface-type evaporator with natural circulation of the solution is considered in detail in [49; p.222-225].

According to the reviewed scientific research works, the following main processes occurring in the evaporator can be distinguished:

- condensation of heating dead steam in the heating chamber;
- heat transfer from the heating dead steam through the heating surface and the layer of contaminants to the boiling evaporated solution;

-evaporation or boiling of a solution, as a result of which solvent vapors are released and the concentration of the solution increases;

separation of pure solvent vapors from the solution, and separation of entrained liquid vapor mixtures.

In work [52; pp. 223-228] the mathematical description of evaporation is based on consideration of the above processes in interrelation, i.e. equations describing individual processes are considered together.

In all evaporators, the design is considered in the totality of conventional elements such as: heating chamber, heat exchange surface and vapor-liquid space.

In work [53; p.325, 54; p.330] to describe the energy balance of the process of evaporation of a solution occurring on an evaporator, a system of three differential equations is used that describe changes in the temperature of dead steam in the heating chamber, the heating surface and the temperature of the vapor-liquid space. Together with these equations, two more differential equations are considered that describe the change in the level and concentration of the solution in the separator of the evaporator.

A system of differential equations describing steady-state and transient modes in the evaporator, according to work [54; p.330] has the form:

$$\alpha_1 \frac{dT\pi}{d\tau} = -\alpha_2 T_{\Pi} + \alpha_3 T_{\text{пн}} + \alpha_4 (W_S - W_{\Pi}) + \alpha_5 (T_{\text{п}}) \quad (1.1)$$

$$c_1 \frac{dT\pi\text{н}}{d\tau} = -c_2 T_{\Pi н} + c_3 T_{\text{п}} + c_4 T$$

$$d_1 \frac{dT\pi}{d\tau} = -d_2 T + d_3 T_{\text{пн}} + d_4 W_v + d_5$$

$$e_1 \frac{dh}{d\tau} = S_f - S_p - W_v$$

$$f_1 \frac{dC}{d\tau} = C_f S_f - C (S_f - W_v)$$

where TP, TPN, T - respectively, the temperature of the steam in the heating chamber, heating surface, solution in the apparatus, °C;

S_f, S_p - respectively, mass flow rate of the initial and evaporated solution, kg/h;

C_f, C - respectively, the concentration of the original and evaporated solution, kg/m^3;

h - solution level in the apparatus, m;

W_s, W_v, W_n - respectively, the consumption of heating steam, secondary steam and steam for extracting non-condensable gases, kg/h.

The coefficients a_1, c_1, d_1, e_1, f of the equations characterize the inertia of the evaporator, respectively, according to the temperature of the dead steam in the heating chamber, the temperature of the heating surface, the boiling solution, concentration and level. The remaining coefficients characterize the static properties of the apparatus. The coefficients of the above equations are determined, in particular, by the thermophysical parameters of steam, water and solution, and also depend on the heat transfer coefficients during condensation and boiling of the liquid. When developing mathematical models of heat exchangers, the mathematical description of the phenomena is reduced. to compiling equations of material and heat balances of the system, subject to the fundamental laws of conservation of mass and energy [26; c.331-337, 54; c.330, 59; c.222-231].

Due to the fact that at the stage of performing the work there was no a priori. information on the thermodynamic properties of the evaporated solution, physical and thermodynamic parameters of the secondary juice steam, as well as the necessary data to describe the loss of heat into the environment, etc. it was necessary to significantly simplify the mathematical description.

So in the works [52; pp.223-228, 53; p.325] the dynamics of material and heat flows in the evaporator are described by the following system of equations:

$$\begin{cases} \frac{dh}{dt} = \frac{1}{A} \cdot \left(Q_f + Q_r - Q_\rho - \frac{W_v}{\rho_{\ w}} \right) \\ \frac{d\rho}{dt} = \frac{1}{Ah}\left(W_v \left(\frac{\rho}{\rho_w} - 1 \right) \right) - Q_f \rho_f \left(\frac{\rho}{\rho_f} - 1 \right) \\ \frac{dT}{dt} = \frac{\lfloor Ws(i_s - i_c) + Q_f \rho_f (if - i) + Q_r \rho_r . (ir - i) + W_v (i_v - i) + L(T - T\ a_r) \rfloor}{\rho_f \cdot c_{f.} \cdot Ah} \end{cases} \quad (1.2)$$

A-cross-sectional area VA, m^2

Ow-density of water, kg\m3

c f—specific heat capacity of the input solution

Wf-mass flow rate of heating steam kg/h

i-respectively, the enthalpy of the solution in the apparatus, heating steam, initial solution, phlegm and secondary steam J/kg;

The mass flow rate of secondary steam W is determined by the following algebraic expression [60-63]

$$Wv = \frac{Q_f \cdot \rho_f \cdot c_f \cdot T_f - Q_f \cdot \rho \cdot c \cdot T + Q_{f \cdot P_{f} \cdot i_f i + W_f} Q}{i_r} \quad (1.3)$$

The enthalpy of heating, secondary steam and condensate is determined by the expression obtained by approximating tabular data [60-63]

$$i_{s\,v} = 2.5 * 10^6 + 1813 * T_{sat} + 0.417 * T_{sat}^2 -$$
$$-0.11 * T_{sat}^3 + 2090 * (T_{s\,v} - T_{sat})$$

$$T_{sat} = \frac{2147}{(1076 - \lg(P_s))} - 273.2; \quad (1.4)$$

$$i_{c=}(-0.0051 * T_s^2 - 1.5595 * T_s + 2467.1\ ) * 10^3$$

The developed mathematical model of the evaporator as a control object was implemented as a computer model in the package MATLAB\ Simulink.

Setting the goal and objectives of the study.

The Republics of Uzbekistan, including Karakalpakstan, produce a significant amount of fruits, which are high-sugar, vitamin-containing raw materials for industrial processing. Concentrated natural juices are the basis for the preparation of many food products: melon honey, various soft drinks, desserts, confectionery fillings for bread and bakery products, fruit and vegetable milk yoghurts, etc..

Therefore, a new innovative approach to the method and method of processing fruits to obtain concentrated juice is required. Further development and deepening of the theoretical foundations of the evaporation process, and the creation on their basis of easy-to-use and reliable evaporators is an urgent task that attracts the interest of many scientists.

The purpose of the dissertation work is to improve the process and apparatus for evaporating solution and fruit and vegetable juice, creating a computer model for calculating the process and evaporation apparatus.

To achieve this goal, it is necessary to solve the following research problems:

- conduct a system analysis of the process and evaporation apparatus;
- develop mathematical and computer models of processes occurring in individual elements of the working area of the evaporator;
- study of the process of evaporation of a weak pectin solution on a computer model and identification of the nature of changes in the influencing main technological parameters;
- development of a semi-industrial experimental setup to study the process of evaporation of pectin solution;
- study of the process of evaporation of a pectin solution on a semi-industrial experimental installation to study the process of evaporation of a pectin solution;
-development and justification of a pilot industrial model of an evaporator for evaporating a weak pectin solution;
- technical implementation into production and calculation of economic efficiency from the introduction of a new design of the evaporator.

MATHEMATICAL MODELING OF THE PROCESS AND EVAPORATORY EVAPORATOR WITH A DOUBLE HEATING CHAMBER

Systems thinking and systems analysis.

Studying the current state of any complex technological process, including evaporation, is impossible without systemic analysis and thinking. The latter make it possible to obtain reliable current data and results about the process, correctly assess the possibility of increasing efficiency, the degree of use of raw materials, reducing energy consumption in production, and propose an acceptable research system.

An analysis of the development of research methodology, characterized by the terms: “systems analysis, systems approach”, and, more recently, “systems thinking” shows that they still have not found a generally accepted, standard interpretation.

First stage (systems thinking and analysis**)**

an object is pre-selected, the selected object is studied, consisting of an element - a system and a process. Requirements are formed;

in each system (element) many processes occur, from which those processes that are necessary for the correct decision-making of a given problem are selected; the process under study in the system is preliminarily studied;

the input and output parameters of both the system and the process under study are determined. relationships between parameters are determined, in most cases requiring in-depth study of the system.

elements - subsystems - are determined. (For a group of problems of the composition and structure of the object under study, the study can be carried out without taking into account processes). The system (element) under consideration is divided into its component elements, the process and its parameters are specified for each selected element, etc. Deepening into the system - the division of an element (system) into subsequent systems is not limited. It is carried out according to the degree of need and the possibility of research to make the optimal decision.

Second stage (Determining the relationship of parameters**)**

Here, depending on the type of object and the content of the task, each researcher can use a large arsenal of methods from the industry in which the research is being conducted. Determining the quantitative relationship between parameters requires the use of mathematical expressions, which leads to recourse to mathematical or computer models.

Third stage (Selection of the optimal solution**)**

Here the requirements are clarified and specified based on system analysis. Optimization criteria are selected for both the primary system and the subsystems of each hierarchical level. A method for finding the optimal solution is selected. The optimal solution is determined. In most cases, the calculation of optimization criteria using computer models can be carried out using the directed random search method. Based on the target function, a calculation is carried out according to the selected search methodology. A solution that satisfies the stated requirement is considered optimal.

Model of an evaporator for concentrating fruit and vegetable juice

.

The peculiarity of the process of evaporating fruit and vegetable juice in an evaporator, despite its relatively low productivity, can be attributed to continuous-action devices, which excludes the possibility of complete evaporation of the juice, but at the same time it must be evaporated to the required density.

When developing a mathematical model of an object (process, apparatus), it is necessary to take into account the purpose and operating conditions of the object. This information determines the main purpose of the modeling and makes it possible to formulate the requirements for the developed mathematical model. One of the ways to move from a meaningful to a mathematical description is to create a formal information model of an object, taking into account input and output parameters [29; p.36-43]. Let's consider the process of concentrating juice using the example of using a developed evaporator with a bifurcated heating chamber. (Fig. 2.2). It is obvious that the density of the evaporated juice during evaporation depends on the flow rate and density of the solution initially entering the apparatus, as well as the intensity of evaporation.

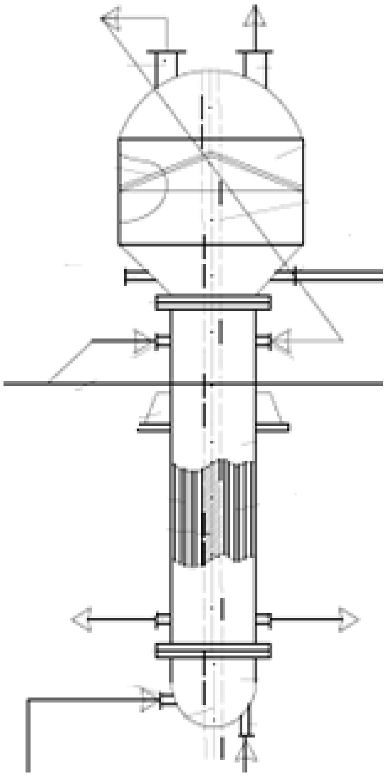


Fig.2.2. Evaporator with divided heating chamber

The intensity of evaporation depends on the transfer of heat from the heating agent to the evaporated juice, the design of the heating chamber of the evaporator, determined by the steam flow and its temperature. The boiling point of juice depends on its density and the vapor pressure above it, and the temperature of the juice must be stabilized, i.e. tboil= const.

When removing the evaporated solution from the apparatus, the material balance must be maintained at the same level, i.e. maintain equality between the amount of concentrated solution leaving the apparatus and the amount of substance entering with the original solution. Therefore, the level of the evaporated solution in the apparatus is the main parameter of the evaporation process, since the thermal and hydrodynamic operating conditions of the apparatus depend on it.

The main requirement for the mathematical model of the evaporator is a mathematical description of individual sub-processes, taking into account the dynamics of the physical processes occurring in it.

Reproduction in the model of dynamic relationships between the input and output variables of the solution evaporation process is necessary for conducting computational experiments of possible options, and changes in these variables must correspond to real ranges.

Figure 2.3 shows the composition of the input and main output variables of the mathematical model of an evaporator for concentrating melon juice in accordance with established requirements.

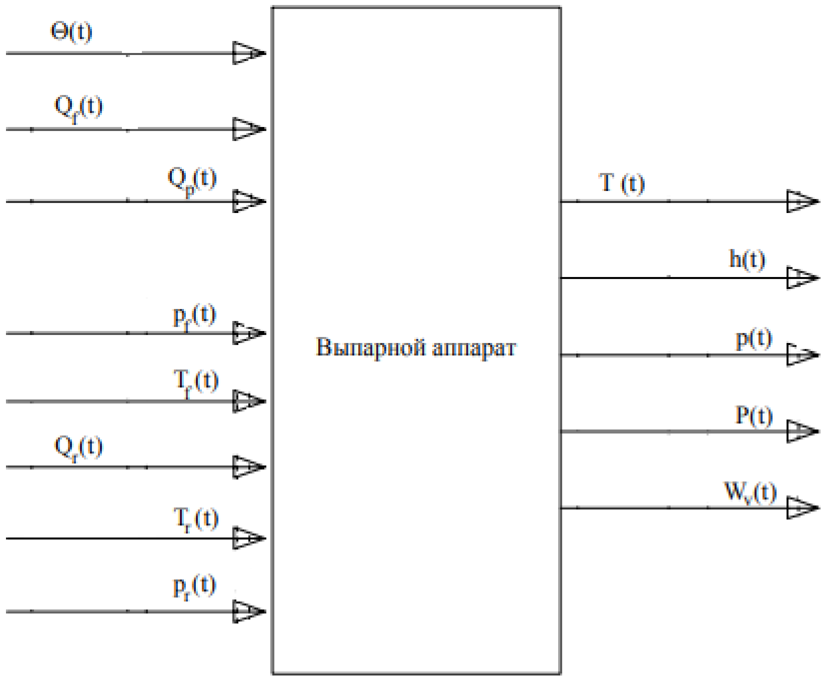


Fig.2.3. Composition of the main variables of the computer model of the evaporator

Analysis of the computer model variables showed that for a stable process of evaporation of melon juice, it is necessary to ensure intensive circulation and stabilization of the temperature of the solution in the apparatus.

Mathematical modeling of the evaporation process in the heating chamber of the apparatus.

For a more detailed study, let's consider the heating chamber of the evaporator based on system analysis and thinking, decomposing it into quasi-heat exchange apparatuses, such as a quasi-apparatus for the steam zone and condensate Processes in an evaporator heated with water vapor are divided into the following elementary processes:

- the process of throttling water steam, steam is transferred into the steam space through a valve - a restriction device.
- steam accumulation process;
- cooling the steam to the condensation temperature;
- formation of condensate and heat transfer through condensate;
- thermal conductivity through the walls of the heat exchanger;
- heating and evaporation of liquid.

Simulation of the process in the heating chamber

The heating chamber is a hydrodynamic capacity structure of flows, which can be expressed by the structure of ideal mixing, where the condensation temperature of the heating steam in it is usually the same throughout the total volume. Therefore, when mathematically describing the pressure in the quasi-apparatus (heating chamber) along the heating steam supply channel, it can be considered as a model of ideal mixing.

A mathematical description of pressure changes can be described by the following equation, which shows that the pressure in the apparatus is directly proportional to the temperature of the solution

$$P = f(t_k)$$

The condensate flow rate generated from the heating dead steam can be determined from the equation

$$D = \kappa\sqrt{P_л - P_к}$$

From the heat balance equation of the evaporation process, we can describe the equation for the change in solution temperature having the following form:

$$\frac{dt_k}{d\tau} = \frac{1}{m_k c_k}(Q_0 - Q - \Delta Q)$$

The amount of heat supplied by the heating steam can be determined from the equation

$$Q_0 = Di$$

The amount of heat leaving the working area of the apparatus with formed condensate can be determined from the following equation

$$Q = D_k c_k t_k$$

the amount of heat transferred by condensate by heat transfer to the outer surface of the wall of the heat-conducting pipe can be determined using the following equation

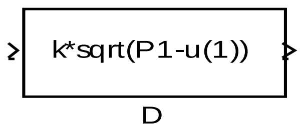
$$\Delta Q = \alpha_1 F_1 (t_k - t_c)$$

By combining all the calculated equations of the evaporation process into one system of equations, one can obtain a complete mathematical model of the process occurring in the heating chamber of the apparatus.

The process in the heating chamber is represented by the following system of equations:

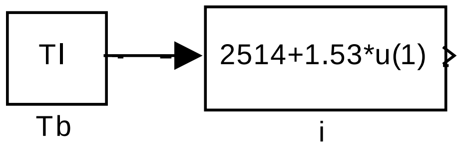
$$\begin{cases} D = \kappa\sqrt{P_{л} - P_{к}} \\ \dfrac{dt_k}{d\tau} = \dfrac{1}{m_k c_k}(Q_0 - Q - \Delta Q) \\ Q_0 = Di \\ Q = D_k c_k t_k \\ \Delta Q = \alpha_1 F_1 (t_k - t_c) \\ P = f(t_k) \end{cases} \quad (2.5)$$

where: k - proportionality coefficient, (k=K*F) is characterized by the flow area of the restriction device (regulating body)
t_k - condensate temperature;
m_k – mass of condensate
ck is the heat capacity of the condensate;
Q_0 is the amount of heat during steam accumulation;
Q is the amount of heat from the leaving steam condensate;
ΔQ - the amount of heat transferred by condensate by heat transfer to the outer surface of the wall of the heat-conducting pipe
D
D_k - condensate flow;
c_k is the heat capacity of the condensate;
t_k - condensate temperature
α_1 - thermal conductivity coefficient;
F_1 surface area of the heat exchanger wall;
t_c is the wall temperature.
Steam flow through the orifice is represented in the computer display of the application program MATLAB

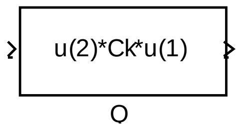


In this case, the coefficient (k=K*F) is characterized by the flow area of the restriction device (regulating body) and steam parameters (density, compressibility coefficient, etc.).

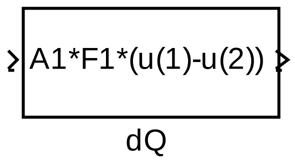
Heat exchange in a heating chamber with ideal mixing can include elementary processes of devices where the liquid temperatures throughout the entire volume will be close. The process is described by a mathematical model with lumped parameters. The enthalpy of steam depends on its temperature i.e. and according to the MATLAB application program (u(1) is the condensation temperature, it can be expressed in a computer display as



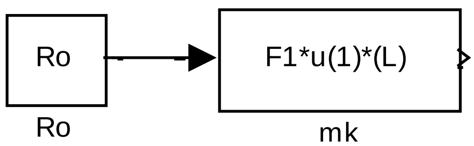
The amount of heat with the leaving condensate is determined by multiplying the temperature (or u (1), flow rate (u (2) in the MATLAB application program) and c_k - the heat capacity of the condensate.



The amount of heat transferred by condensate by heat transfer to the outer surface of the wall of the heat-conducting pipe in a computer display of the application program MATLAB (u (1), u (2)



The mass of condensate in the heating chamber is determined by multiplying the density Ro (u (1) in the heating chamber by the volume of condensate, consisting of multiplying the outer surface of the pipe by the thickness of the condensate.

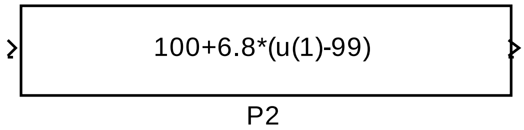


From the operating conditions of heat exchangers in the food and related industries, the condensation temperature of water vapor can be analytically determined by the equation [5]:

$$t = 86 + 0{,}15P, \ ^{o}C \ , \qquad (2.6)$$

where P is pressure in MPa.

Or, for the water vapor pressure in the heating chamber, the equation that determines it from the condensation temperature can be transformed in the MATLAB application program, by the model.



Based on the mathematical description in the steam space of the heating chamber, a computer model of the processes of hydrodynamics and heat changes was compiled in the MATLAB application program (Fig. 2.5.)

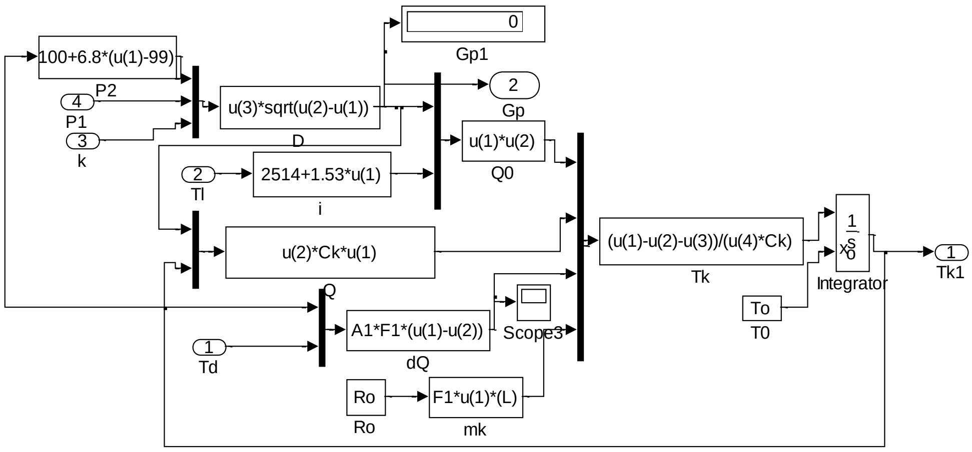


Fig.2.5. Computer model of hydrodynamics and heat transfer processes in a heating chamber in the MATLAB application program

Thus, on the basis of the mathematical descriptions given in the equations, a computer model of the evaporation process occurring in the heating chamber is formalized using the MATLAB application program, where the following output parameters are entered: the condensation temperature of the heating steam, the wall temperature, the pressure of the heating steam, and the flow rate of the heating steam. And at the input of the computer model of the heating chamber, the input parameters are indicated: steam pressure in the pipeline, supply of heating water steam, temperature of the heating steam in the pipeline and wall temperature.

Computer model of heat transfer through the heating wall of an evaporator

The next step is to create a computer model of heat transfer through the wall. Here the main indicators are: heat transfer from steam to the wall, heat transfer from the wall to the concentrated liquid, heating surface area and other physical and technical indicators. The input indicators here are: steam condensation temperature, liquid temperature, with these data the wall temperature will be determined. This data is used in previous and subsequent models.

The rate of wall heat accumulation (i.e., change in wall heat) depends on the difference in heat inflow and flow to the wall

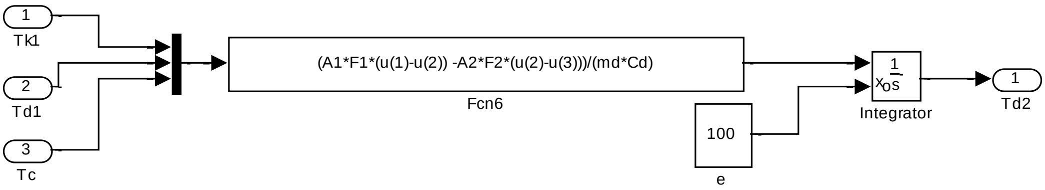


Fig.2.6. Computer model of the process of heat accumulation by a wall in a computer display of the MATLAB application program

Simulation of the evaporation process in a boiling and concentration chamber

The heating chamber or vapor-liquid space of the evaporator is formed by the inner part of the boiling pipes of the apparatus, in which the complex process of evaporation of raw materials occurs through complex heat exchange, characterized by the continuous distribution of its parameters (concentration and temperature) throughout the volume of the evaporator.

The structure of the semi-product solution flows in the working area of the apparatus can be described by the ideal mixing model. In accordance with the accepted premises, the movement of the vapor-liquid mixture in the circulation evaporator is accompanied by stirring. In this case, the mathematical description of the change in heat of the process of evaporation of a weak solution in the vapor-liquid space is described by the differential equation of ideal mixing.

$$\frac{dQ_{пж}}{d\tau} = Q_o - Q - Q_{исп} + Q_{cm} \qquad (2.7)$$

Each component of the equation for the process of evaporation of a solution in the boiling and concentration chamber is considered. Such as the amount of heat of the vapor-liquid space depending on the concentration of the evaporated product in the concentration zone, the amount of heat of the incoming solution, the amount of heat of the evaporated - concentrated solution Q in the boiling and concentration chamber, the amount of heat leaving the working area of the apparatus along with secondary vapors Q_{isp}, the amount of heat Q_{st} transmitted through the heating walls of the apparatus pipes.

$$\frac{dQ_{пж}}{d\tau} = Q_o - Q - Q_{исп} + Q_{cm}$$

The amount of heat supplied by the solution to the evaporation process is determined by the equation

$$Q_o = m_o c_o t_o$$

Taking into account the initial solvent content, the amount of heat supplied with the initial solution can be written in the form of the equation

$$Q_{пж} = mct + m_o \frac{a_o}{a}\left(1 - \frac{a_i}{a_{i-1}}\right) \cdot r$$

The amount of heat lost with a concentrated solution can be determined by the equation

$$Q = mct = \frac{a_o}{a} m_o ct$$

The amount of heat lost with the secondary vapors formed during the process of evaporation of the solution can be calculated using the following equation

$$Q_{исп} = m_o\left(1 - \frac{a_o}{a}\right) i_T$$

The amount of heat transferred from the heating pipes of the evaporator can be determined by the equation

$$Q = \alpha_2 \mathrm{F}_2 (\mathrm{t_c} - \mathrm{t})$$

The change in heat in the vapor-liquid space is calculated by the equation

$$\frac{\mathrm{dQ_{пж}}}{\mathrm{d}\tau} = \frac{m_o}{a}\left(a_o \cdot c \frac{dt}{d\tau} + i \frac{\mathrm{d}a}{\mathrm{d}\tau}\right)$$

The temperature during the evaporation process will depend on the total pressure in the apparatus and the conductivity temperature of the solution

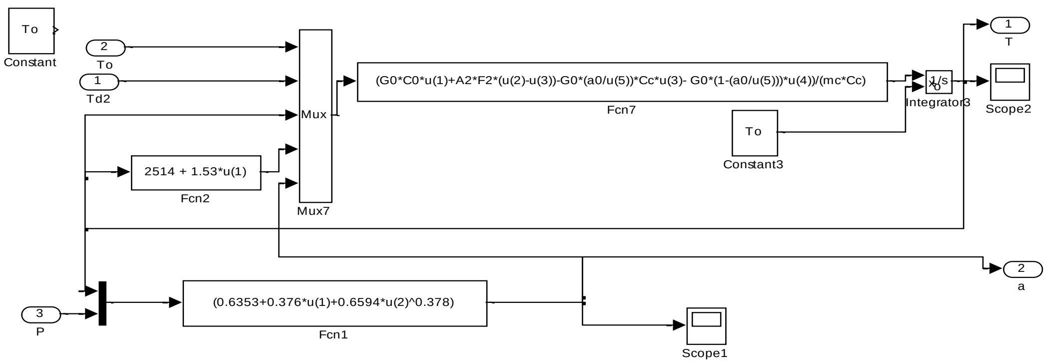
$$t = f(P, a)$$

By combining the developed mathematical descriptions of phenomena into a single system of equations, a complete mathematical model was obtained for the process occurring in the vapor-liquid space of the evaporator:

$$
\begin{cases}
\dfrac{dQ_{пж}}{d\tau} = Q_o - Q - Q_{исп} + Q_{ст} \\
Q_{пж} = mct + m_o \dfrac{a_o}{a}\left(1 - \dfrac{a_i}{a_{i-1}}\right) \cdot r \\
Q_o = m_o c_o t_o \\
Q = mct = \dfrac{a_o}{a} m_o ct \\
Q_{исп} = m_o \left(1 - \dfrac{a_o}{a}\right) i_T \\
Q = \alpha_2 \mathrm{F}_2 (\mathrm{t_c} - \mathrm{t}) \\
\dfrac{\mathrm{dQ_{пж}}}{\mathrm{d}\tau} = \dfrac{m_o}{a}\left(a_o \cdot c \dfrac{dt}{d\tau} + i \dfrac{\mathrm{d}a}{\mathrm{d}\tau}\right) \\
t = f(P, a)
\end{cases} \tag{2.8}
$$

Mathematical description (2.8) characterizes the change in the composition of the solution during evaporation, i.e. concentration and temperature of the vapor-liquid mixture by volume of the apparatus and over time. Model (2.8) facilitates the study of the process occurring in the vapor-liquid space of the evaporator.

Based on a system of equations describing a mathematical model for the process occurring in the vapor-liquid space of the evaporator, a calculation algorithm was developed and a computer model of the process was built in the MATLAB application program.



Rice. 2.7. Computer model of the process occurring in the vapor-liquid space of the evaporator in the MATLAB application program.

A calculation algorithm has been developed (Fig. 2.10) and a computer model has been built to represent the input parameters of the process of evaporation of a weak solution in the MATLAB application program.

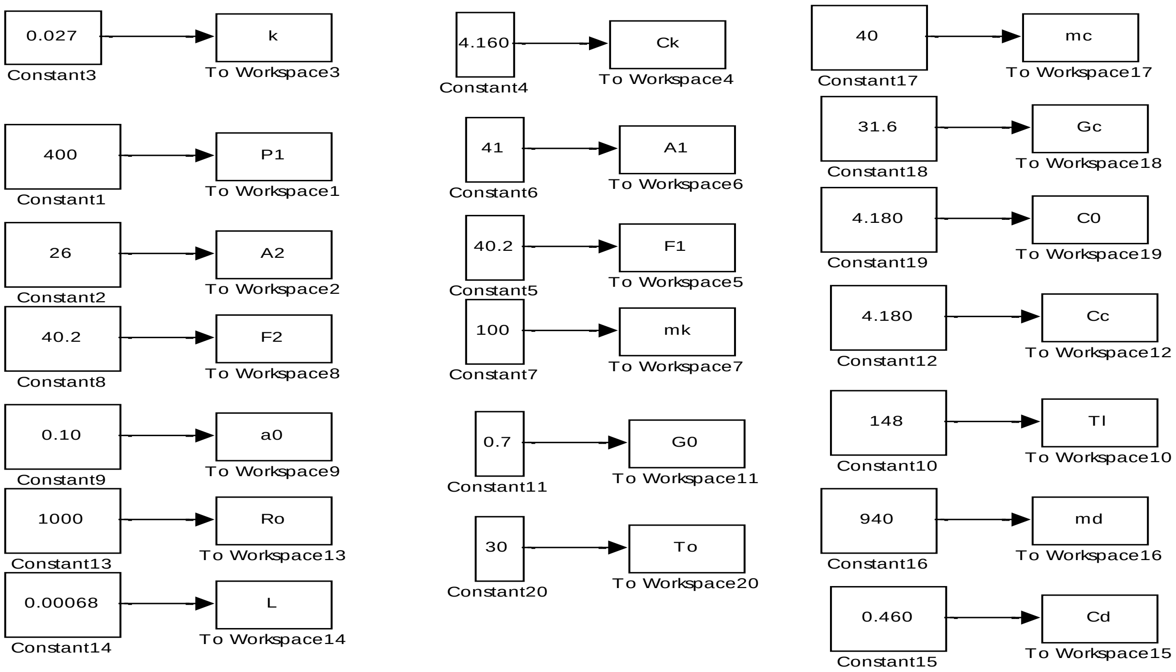


Fig.2.8. Computer model for representing input indicators of the evaporator process in the MATLAB application program.

Study of the process and evaporation apparatus with a bifurcated heating chamber on a computer model

By combining a system of equations of mathematical and computer models of the evaporation process occurring in quasi-apparatuses, a computer model (Fig. 2.9) of the entire evaporation apparatus process was built in the MATLAB application program, according to which an intelligent control program is compiled

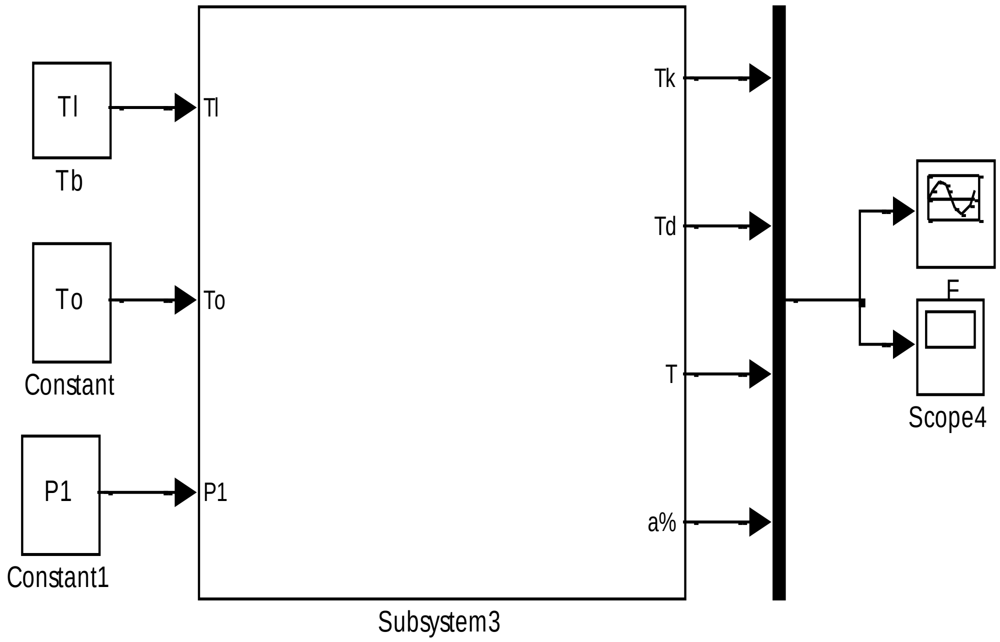


Fig.2.9. Computer model of the entire process of an evaporator with a bifurcated heating chamber in the MATLAB application program

A computer model of the entire process of the evaporator in the MATLAB application program, consisting of computer models of the process occurring in the quasi-apparatus, the heating chamber, the wall of the boiling pipes of the apparatus and in the vapor-liquid space of the evaporator is shown in Fig. 2.10.

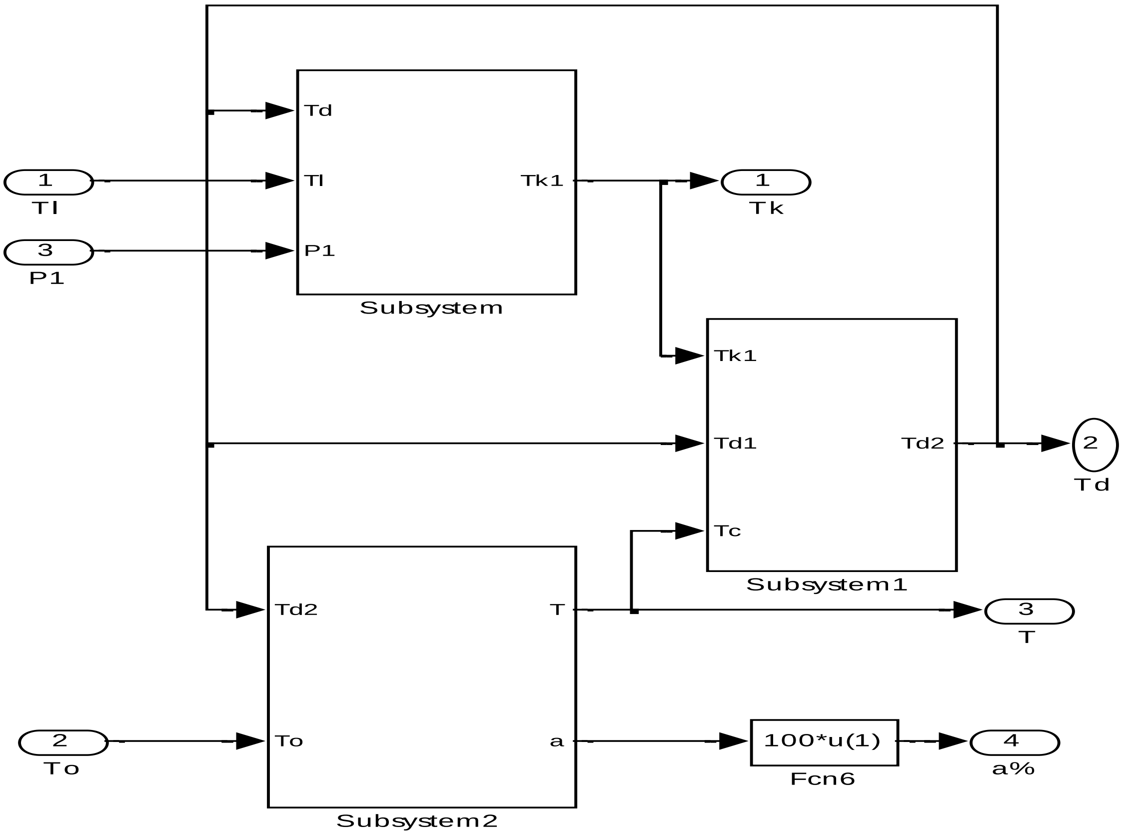


Fig.2.10. Computer model indicating the quasi-elements of the entire evaporator process in the MATLAB application program.

The following values are taken as the initial parameters for studying the computer model, which are given in Table 2.1

Table 2.1

Parameter name	Unit
Temperature of the solution in the apparatus	T, 0C
Solution level in the apparatus	h, m
Density of the evaporated solution	ρ,y kg/m3
Heating steam consumption	G, п kg /h
Consumption of the initial solution	G, и, m3/h
Consumption of evaporated solution	G, y, m3/h
Density of the initial solution	ρи, kg/m3
Temperature of the initial solution	Ti, 0C
Steam pressure in the separation chamber	R, Pa

The result of calculating one of the options, the initial data of the evaporation process occurring in the elements of the evaporator in the MATLAB application program is shown in Fig. 2.11.

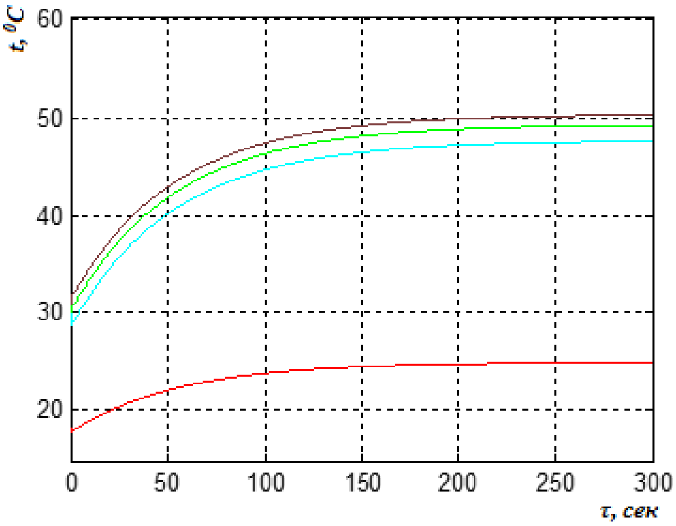


Fig.2.11. The result of calculating one of the options for the dynamics of the evaporator process in the MATLAB application program

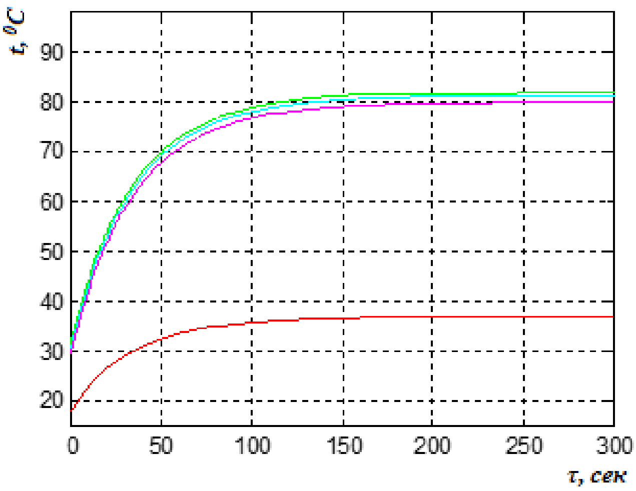


Fig.2.12. The result of calculating one variant of the dynamics of the general process of the evaporator using a computer model in the MATLAB application program.

As can be seen from Fig. 2.12, after the start-up of the evaporator, the parameter change curves are shown from top to bottom, the condensation temperature of dead water vapor, the temperature of the heat exchange surface-wall of the boiling tubes of the apparatus, the temperature of the vapor-liquid space of the evaporator increases from the initial value to a steady value after approximately 250 seconds. In this case, the evaporated liquid passes into a more highly concentrated state.

The concentration of the evaporated liquid, being a control parameter, will be calculated by the microprocessor of the intelligent control system. Thanks to the computer model, calculations were made of the evaporation process and the shell-and-tube apparatus for evaporating liquid products.
The results of calculating the parameters of the evaporator using a computer model of the dynamics of the process of evaporation of a pectin solution at atmospheric pressure in the MATLAB application program.

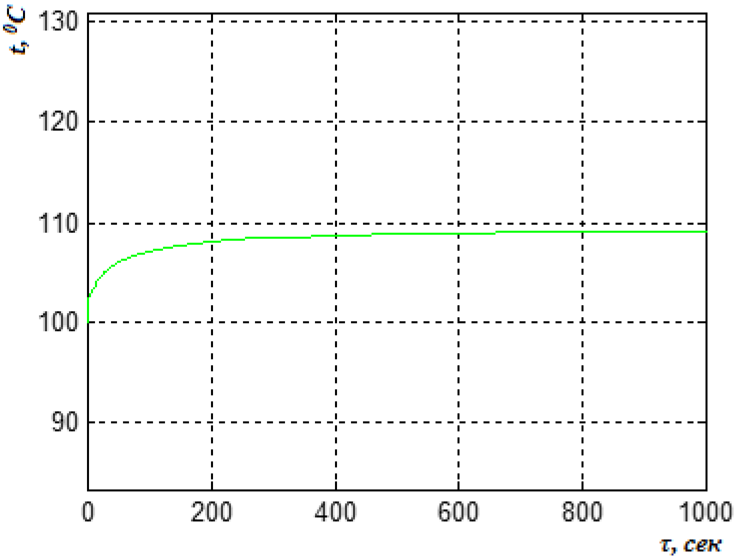


Fig.2. 13. The result of calculating the temperature of condensate, heating water vapor on a computer model of the dynamics of the process of evaporation of a pectin solution at atmospheric pressure of the evaporator in the MATLAB application program.

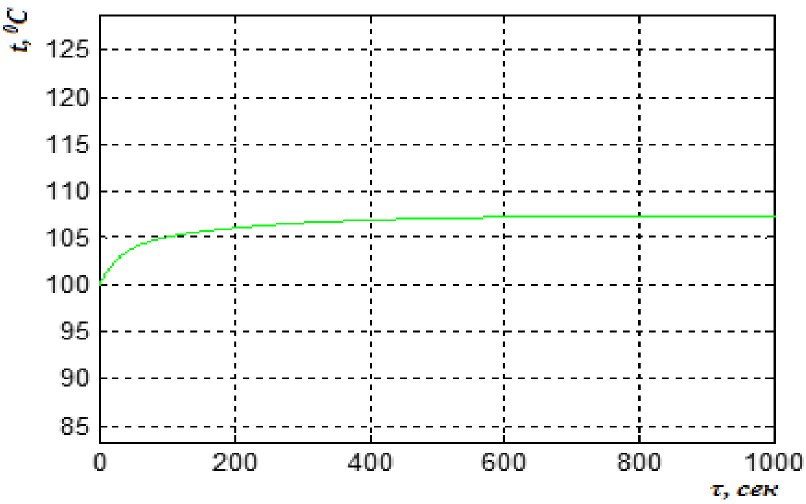


Fig.2.14. The result of calculating the temperature of the wall of the heating pipes on a computer model of the dynamics of the process of evaporation of a pectin solution at atmospheric pressure of the evaporator in the MATLAB application program.

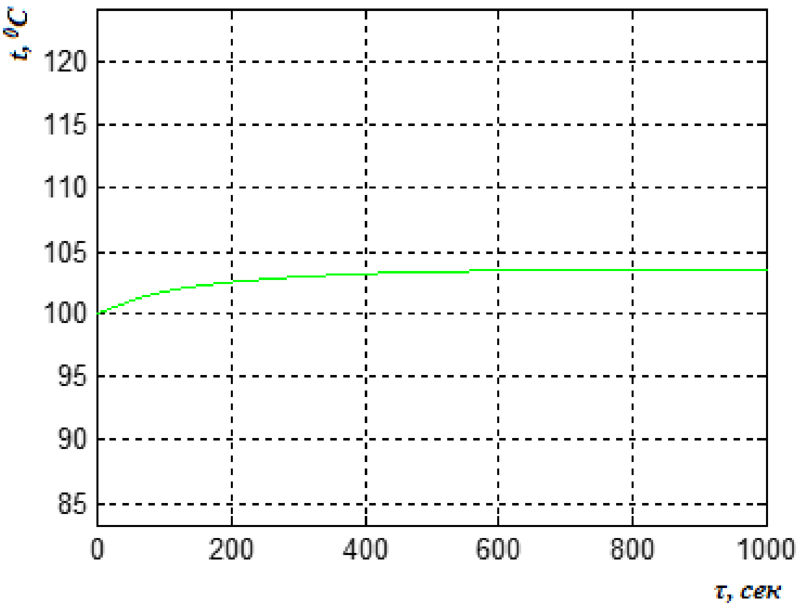


Fig. 2.15. The result of calculating the temperature of a pectin solution using a computer model of the dynamics of the process of its evaporation at atmospheric pressure of an evaporator in the MATLAB application program.

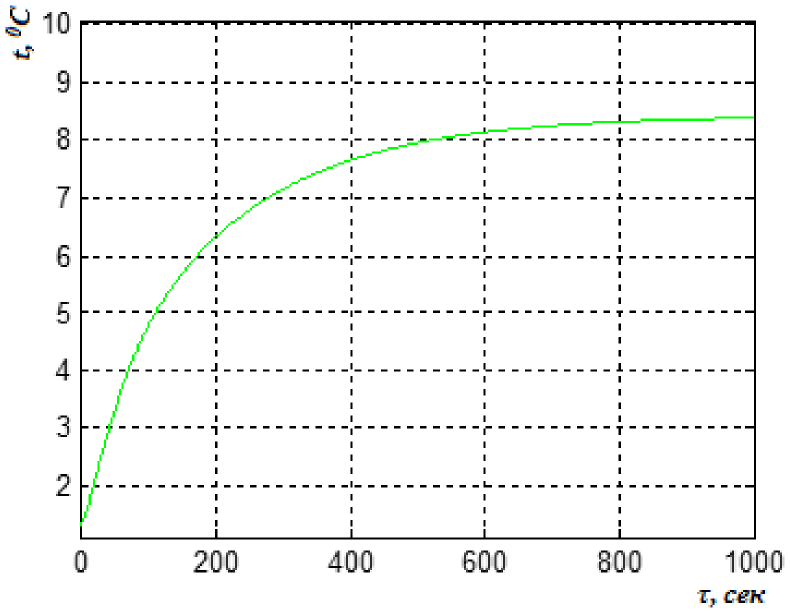


Fig.2.16. The result of calculating the concentration of a pectin solution on a computer model of the dynamics of the evaporation process at atmospheric pressure of an evaporator in the MATLAB application program.

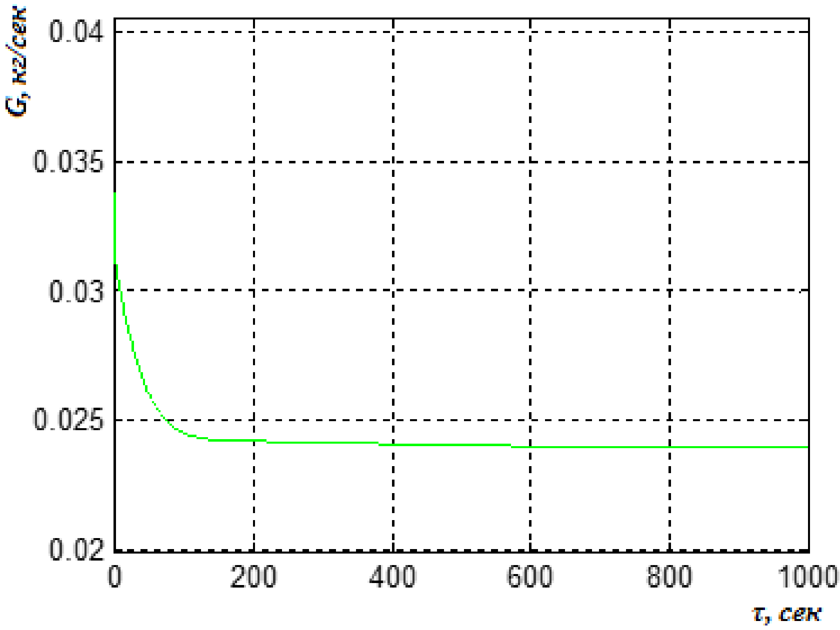


Fig. 2.17. The result of calculating the flow rate of secondary steam, the dynamics of the process of evaporation of a pectin solution at atmospheric pressure of the evaporator on a computer model of the evaporator in the MATLAB application program.

From the above graphs obtained on the basis of calculating the process of evaporation of a pectin solution, it is clear (Fig. 2.11 to Fig. 2.17) that when the process is carried out under atmospheric pressure, the temperature of the condensate, heating steam is reached up to 108 ° C, the temperature of the wall of the heating pipes is up to 104 ° C , and the temperature of the pectin solution reaches 103 ° C, the concentration of the solution changes by 8.3%, the consumption of secondary vapors formed during evaporation ranges from 0.03-0.02 kg/sec.

Results of calculation of indicators at a residual pressure of 28 kPa of the evaporator on a computer model of the dynamics of the process of evaporation of a pectin solution in the MATLAB application program.

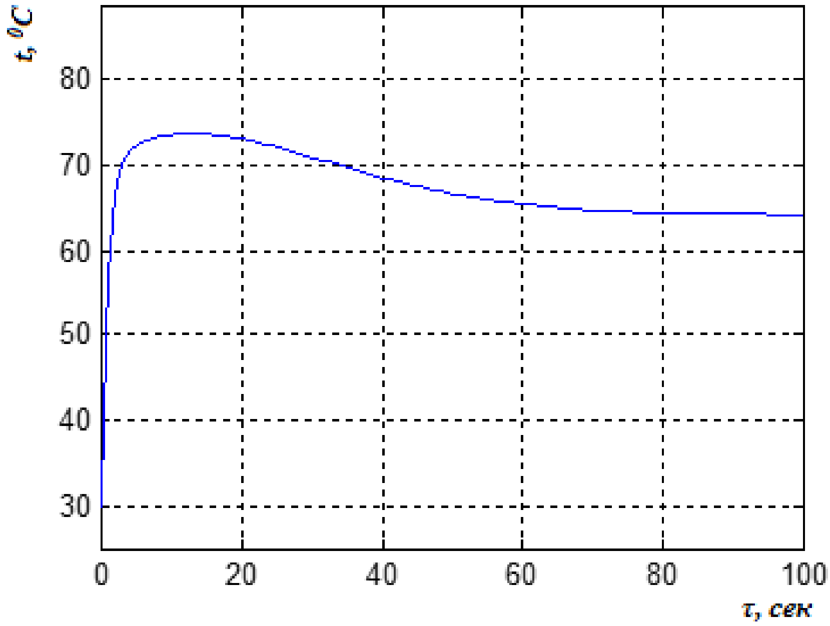


Fig.2.18. The result of calculating the temperature of condensate, heating water steam on a computer model of the dynamics of the process of evaporation of a pectin solution at a pressure of 28 kPa of the evaporator in the MATLAB application program.

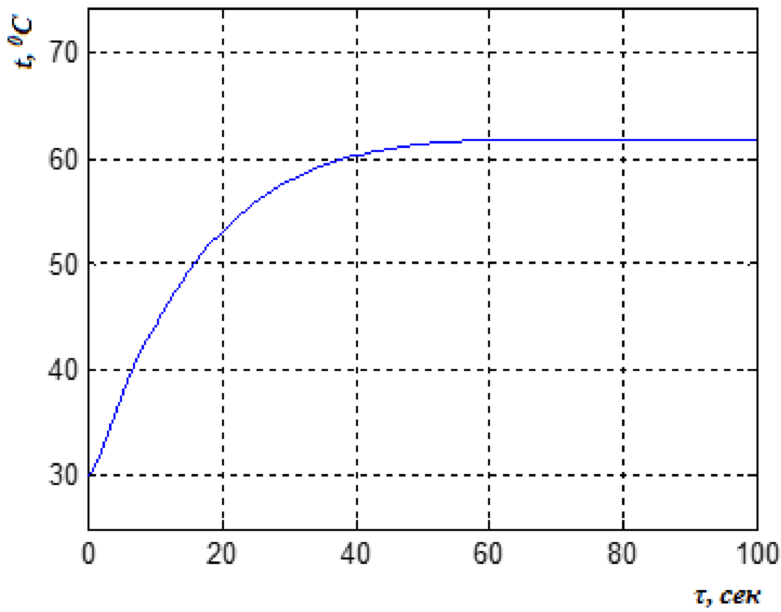


Fig.2.19. The result of calculating the temperature of the wall of the heating pipes on a computer model of the dynamics of the process of evaporation of a pectin solution at a pressure of 28 kPa of the evaporator in the MATLAB application program.

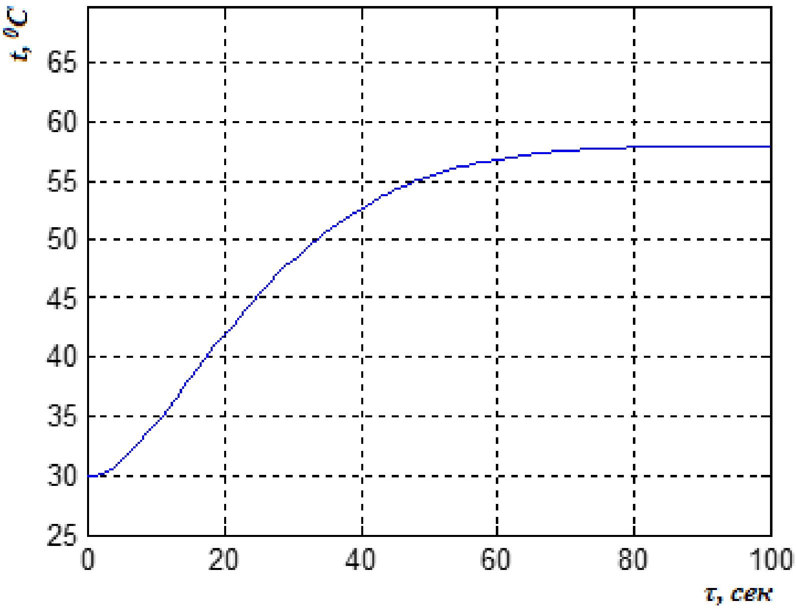


Fig. 2.20. The result of calculating the temperature of a pectin solution on a computer model of the dynamics of the process of its evaporation at a pressure of 28 kPa of the evaporator in the MATLAB application program.

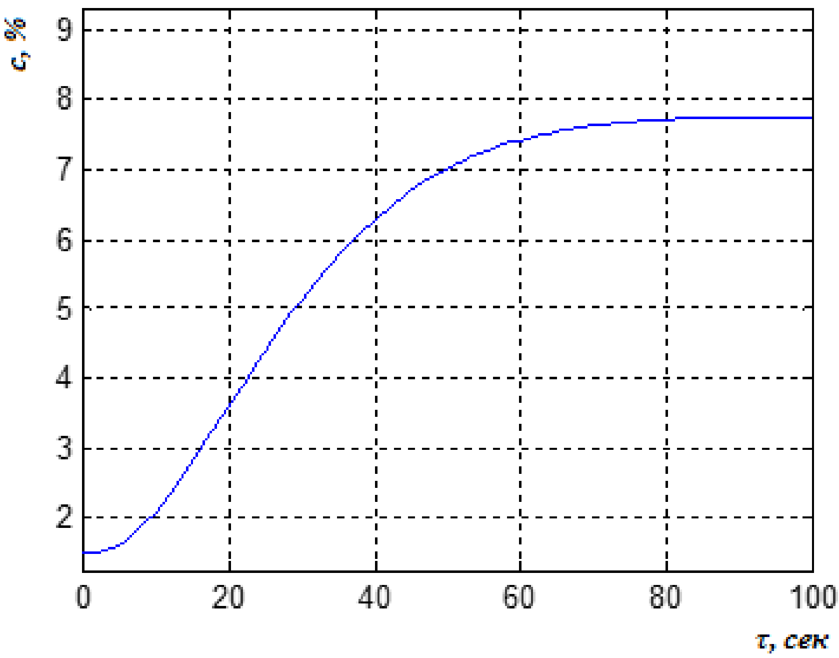


Fig. 2.21. The result of calculating the concentration of a pectin solution on a computer model of the dynamics of the evaporation process at a pressure of 28 kPa of the evaporator in the MATLAB application program.

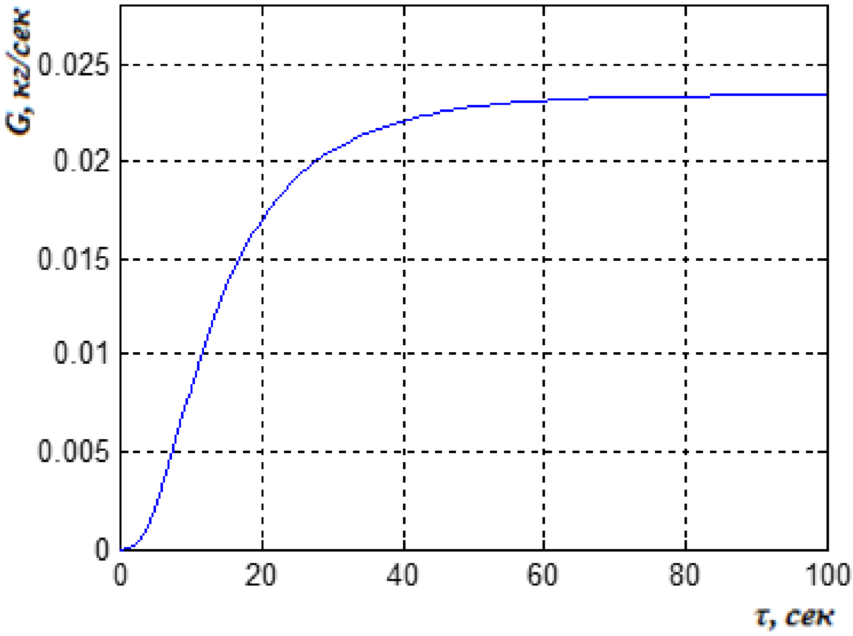


Fig. 2.22. The result of calculating the flow rate of the resulting secondary steam, the dynamics of the process of evaporation of a pectin solution at a pressure of 28 kPa of the evaporator on a computer model of the evaporator in the MATLAB application program.

From the above graphs obtained based on the calculation of the process of evaporation of a pectin solution, it is clear (Figure 2.18 to Figure 2.22) that when the process is carried out under a pressure of 28 kPa, the temperature of the heating steam condensate at the beginning of the process reaches 74 °C, then the wall temperature begins to decrease to 64 °C heating pipes reaches 64 °C, and the temperature of the pectin solution reaches 58 °C, the concentration of the solution changes by 7.8%, the consumption of secondary vapors formed during evaporation reaches about 0.023 kg/sec.

EXPERIMENTAL STUDY OF THE PROCESS OF EVAPORATION OF PECTIN SOLUTION IN AN EVAPORATORY PLANT WITH A DIVIDED HEATING CHAMBER.

Description of the experimental setup

The diagram of an experimental two-body installation implemented at the Pektin production enterprise (Tashkent region) is shown in Fig. 3.1.

The installation includes two evaporators, each of which is a single-shell evaporator with a bifurcated body, both in terms of the movement of the evaporated solution and the movement of the heat agent, primary water vapor and secondary juice steam. [Application No. FAP 20200313]. The buildings are technologically connected to each other in a similar way to a double-shell evaporation plant, but with some adjustments.

According to the design features, the developed evaporator is a flow-type apparatus and consists of three main, joined together, structural blocks: heating chamber 1, separator 2 and bottom 3 (Fig. 2.1, chapter 2)

The heating chamber contains a cylindrical shell 4 welded to the upper 5 and lower 6 tube plates, on which heating pipes 7 and 8 of different diameters and quantities are located. The pipe space is divided into two unequal parts, vertically installed between the tube sheets 5 and 6, bent by a curved partition 9. On the shell there are nozzles 10 and 11 for the input of heating steam, nozzles 12, 13 for the removal of condensate forming, support legs 14 and bosses 15 , 16 for installing temperature sensors.

A bottom 3 is connected to the lower tube sheet 6 by means of a flange 17, containing a dividing partition 18, a pipe 19 for the initial solution inlet and a pipe for a 20-return solution.

A juice steam separator 3 is connected to the upper tube plate 5 on the flange 21, containing a dividing partition 22, a drop reflector 23 with a hole 24, a pipe 25 for the outlet of the circulating solution and a pipe 26 for the outlet of the concentrated solution. On the upper elliptical bottom there is a pipe 27 for the outlet of secondary steam and a pipe 28 for discharging the secondary steam to the barometric condenser.

The evaporator is insulated from the outside with mineral wool to avoid burns to operating personnel and reduce heat loss to the environment.

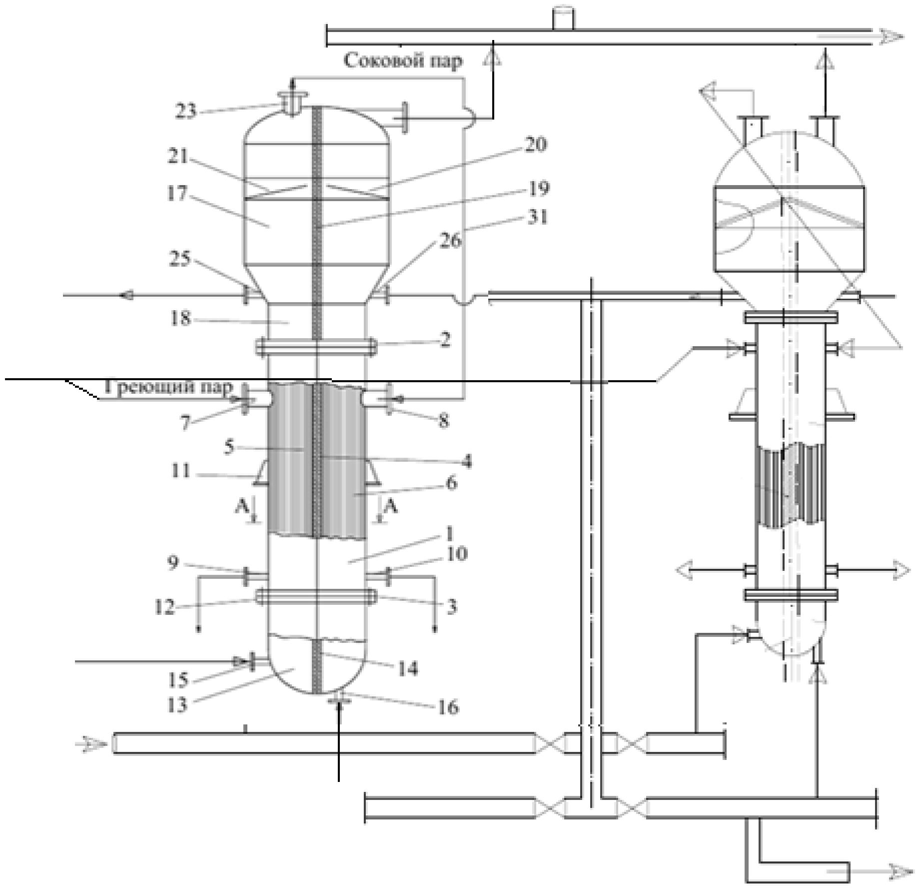


Fig.3.1. Schematic diagram of an experimental double-effect evaporation unit for concentrating a pectin solution.

For technological reasons, buildings I and II are connected in such a way that each case can work individually or together in pairs. They have a common primary steam pipeline, a vacuum-barometric line and a single recirculation circuit for the evaporated solution and are equipped with pipelines for supplying the initial and pumping out the evaporated solution, equipped with a shut-off valve system.

First, we will study the process of evaporation of a weak solution of pectin at atmospheric pressure. To do this, we prepare the first body for work: we leave the juice steam selection fitting open, and set up the evaporator in the mode, operation at atmospheric pressure.

In this case, through pipe 10, water steam is supplied at a pressure of P = 0.3 MPa into the first half of heating chamber 1, and through pipe 19, an evaporated solution with an initial concentration of CH = 1.5% is supplied. Under the influence of high temperature, the solution boils inside pipes ø 25x2 mm and in the form of a vapor-liquid mixture enters the left side of separator 2, where the vapors are separated from the droplets and flow through pipe 21 and a bypass steam line to heat the second half of the heating chamber 1.

The partially evaporated solution flows through pipes 25 and 20 into the second part of the apparatus, where it boils in pipes ø 32x3 mm, steam is removed through pipe 28 to the outside, and the evaporated solution with a concentration of C = 8% is discharged through a common riser from the installation.

The experiments were carried out under the following physical air parameters to the conditions for the city of Tashkent:

initial air temperature 25-300C;

residual pressure in the apparatus 99-100 kPa

the average pressure in Tashkent is 730 mm. Hg

The experimental data are summarized in Table 4.1.

Table 3.1.

Experimental data on the evaporation of pectin solution at atmospheric pressure

№	G	P	C_n%	Tk	T	Gпара	C_k%	C_p%	dC_k	dC_k^2
1	0,03	98	14	109	103	0,025	8.1	8.3	-0,2	0,04
2	0,03	98	14.5	107	102	0,022	5,5	5,3	0,2	0,04
3	0,03	97	15,1	108,5	102,5	0,022	6,3	6,4	-0.1	0,01
4	0,03	99	15,2	108	103	0,019	7,4	7,9	-0,5	0,25
5	0,03	99	15,9	109	103,2	0,024	8,2	8,4	-0,2	0,04
6	0,03	98	16	110	104,3	0,024	8,3	8,4	-0.1	0,01
7	0,03	98	15	109	105,5	0,024	8,1	8,4	-0,3	0,09
										∑0,52

Conclusions from the first experiment

Analysis of experiments shows that the error in deviations of readings from real values is about 7.5%, i.e..

$$\sigma = \sqrt{\frac{\sum \Delta t^2}{n}} = 0,52/7*100\%=7,43\%,$$

где n-число измерений (опытов),

The second version of the experiment was carried out in the same way, but under residual pressure in the apparatus P = 25-35 kPa. Average pressure in Tashkent is P=725 mmHg. or 97 Kpa.

The summary results of the experiments are shown in Table 3.2.

Table 3.2.

Experimental data on the evaporation of a pectin solution under vacuum

	G	P	Cn%	Tk	T	Gпара	Ck%	Cp%	dCk	dCk^2
1	0,03	30	14	66	59	0,023	7,9	8.3	-0.4	0.16
2	0,03	29	14.5	69	62	0,023	8,6	8,8	-0.2	0.04
3	0,03	32	15,1	65	58	0,022	7,5	7,8	-0.3	0.09
4	0,03	31	15,9	68	59	0,020	7,9	8,1	-0.2	0.04
5	0,03	29	14,7	65	57	0,019	7,3	7,5	-0.2	0.04
6	0,03	31	15	67	56	0,019	6,9	7,1	-0.2	0.04
7	0,03	28	15,2	64	58	0,019	7,4	7,9	-0.5	0.25
										∑0.66

The results of experiments and their comprehensive analysis on an evaporation unit for evaporating a pectin solution at a given flow rate, initial temperature 25-300C and residual pressure in the apparatus 25-35 kPa, showed that the average static error in deviation from real indicators is:

$$\sigma = \sqrt{\frac{\sum \Delta t^2}{n}} = 0,66/7*100\%==4,46\ \%$$

The third version of the experiment is to determine the pattern of changes in the concentration of the evaporated solution from the consumption of heating steam and juice steam according to the operating conditions of a divided apparatus, with a partition in two under the apparatus.

According to the conditions of the experiment, the evaporated solution should enter the first half of the apparatus (Fig. 3.1.), where it is concentrated due to steam supplied to the heating chamber, and then enters the second part of the apparatus, where further concentration of the solution occurs due to juice steam coming from the first half of the device.

To increase the productivity of the workshop for the production of pectin from apple pomace, the evaporators were duplicated and combined in the form of a double-effect evaporation unit with a single power supply system and selection of the evaporated solution.

According to the conditions of the experiment, the evaporated solution enters the first half of the apparatus, where it is concentrated due to the heat of the steam supplied to the heating chamber, and the juice secondary steam enters the second part of the apparatus, where further concentration of the solution occurs due to the heat coming from the first half of the apparatus.

Thus, the initial data for the third experiment can be:

incoming steam flow G_1;

temperature of the incoming solution T_1;

concentration of the incoming solution C_1;
heating steam pressure P;
At the exit from the first half of the apparatus we have:
concentration of the exiting solution C_2;
temperature of the exiting solution T_2;
With these parameters, the solution passes from the first half of the apparatus to the second, for which we have:

consumption of concentrated solution $G\frac{1}{1}$;

concentration of the exiting solution T_2;

juice steam consumption
temperature of the incoming solution;
pressure inside boiling pipes;
output solution flow rate
concentration of the exiting solution
temperature of the exiting solution.

When the installation was in stable operation, the following initial data were recorded for the first half of the evaporator:

flow rate of incoming solution, G = 0.03 kg/s;
primary steam flow, Gn= 0.0125 kg/s
temperature of the incoming solution, Tn = 970C
heating steam pressure, P = 200 kPa

Experimental data on the evaporation of pectin solution with an initial concentration from CH = 1.5% to C = 2.25% in the first half of the apparatus are shown in Table No. 3.3.

Shown here are the average values of the concentration parameters of the exiting solution $C_к^1$ = 2,1….2,4, or $C^1_{к. опт}$ =2,35 %;

outlet solution temperature $Тк^1$= 100,5 ^{0}C;

heating steam consumption Gп = 0,0113 …. 0.0127, or $G_{п\ опт}$= 0.0125 кг/с,

juice steam consumption $Gп^1$ = 0,091 - 0.0107 or opt 0.0105 кг/с,

In the same way, the results of changing the parameters for the second half of the evaporator were obtained, shown in table. 3.4.

Here, the temperature of the solution inside the boiling tubes T_2 = 49…60,5^{0}C;

effluent concentration Ck^1 = 6,8… 8,8%;

secondary heating steam consumption

$G_{пара}^1$ = 0, 091…. 0.0107; or $G_{опт}^1$= 0,0105 кг/с.

Experiments were also carried out on a computer model for compliance with adequacy (Fig. 3.4.) and a computer model for entering data from the processes of the first and second halves of the evaporator. Simulation of changes in parameters was introduced by introducing a disturbance for the first half of the evaporator body and response curves were obtained in the form of curves of changes in parameters: condensation temperature of the heating steam, wall temperature of the heating pipes, solution temperature inside the boiling pipes and the concentration of the waste solution in %, multiplied by 10 All curves are displayed in Fig. 3.2 with different line colors.

Table 3.3.

Experimental data on the evaporation of pectin solution in the first half of the apparatus

№	G кг/с	Gп кг/с	Pп кПа	Cн %	Ck[1] %рас	Tн ^0C	Tк ^0C
1	0,03	0.0113	98	1,5	2,1	97	100,4
2	0,03	0.0116	97	1,5	2,2	98	100,4
3	0,03	0.0118	97	1,5	2,2	97	100,4
4	0,03	0.0121	97	1,5	2,4	97	100,4
5	0,03	0.0123	97	1,5	2,3	98	100,5
6	0,03	0.0123	97	1,5	2,3	98	100,5
7	0,03	0.0122	97	1,5	2,2	97	100,5
8	0,03	0.0125	96	1,5	2,3	97	100,5
9	0,03	0.0127	97	1,5	2,3	98	100,5

Table 3.4

Experimental data on the evaporation of pectin solution in the second half of the apparatus

№	Pп[1] кПа	Cн %	Ck[1] %рас	Tн ^0C	Tк[1] ^0C
1.	49,0	2,1	6,8	97	49,0
2.	51,2	2,2	7,5	98	51,2
3.	52,2	2,2	7,5	97	52,2
4.	54,2	2,4	8,3	97	54,2
5.	57,1	2,3	8,2	98	57,1
6.	60,0	2,3	8,1	98	59,9
7.	56,0	2,2	8,0	97	55,7
8.	59,2	2,3	8,2	97	59,2
9.	60,5	2,3	8,8	98	60,5

In this case, experimental curves were obtained for the first and second half of the body (Fig. 3.2, Fig. 3.3).

Changes in parameters of the first evaporator

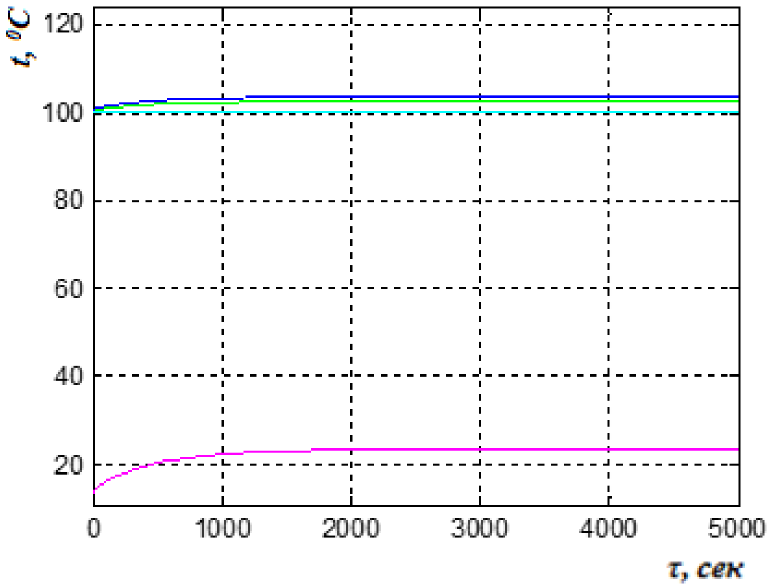


Fig.3.2. Curves of changes in parameters in the first housing of the evaporator,:

where the first upper line is a graph of the temperature of the heating steam condensate, the second lower line is the temperature of the heating wall of the boiling pipes, and the third lower line is the temperature of the liquid inside the boiling pipes. the lowest red line is the concentration of the exiting liquid as a percentage for clarity, multiplied by 10.

Changing the parameters of the second evaporator

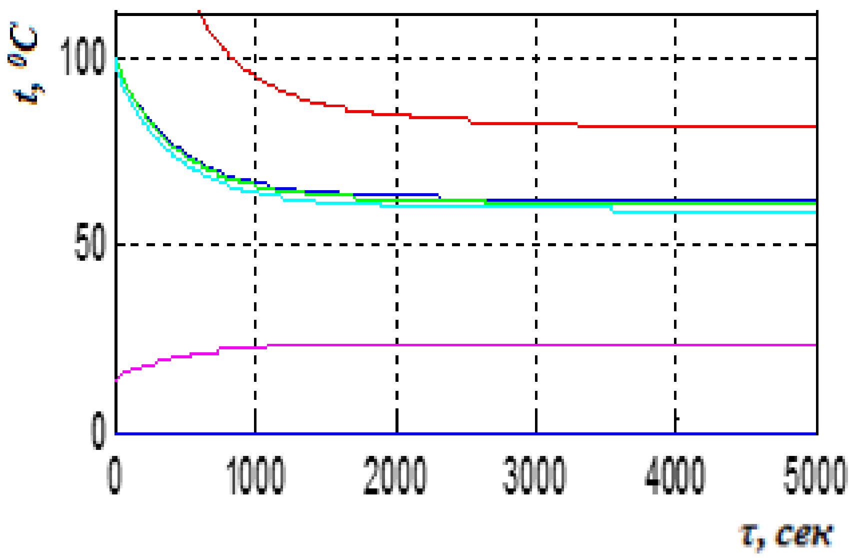


Fig.3.3. Curves of parameter changes in the second body of the evaporator.

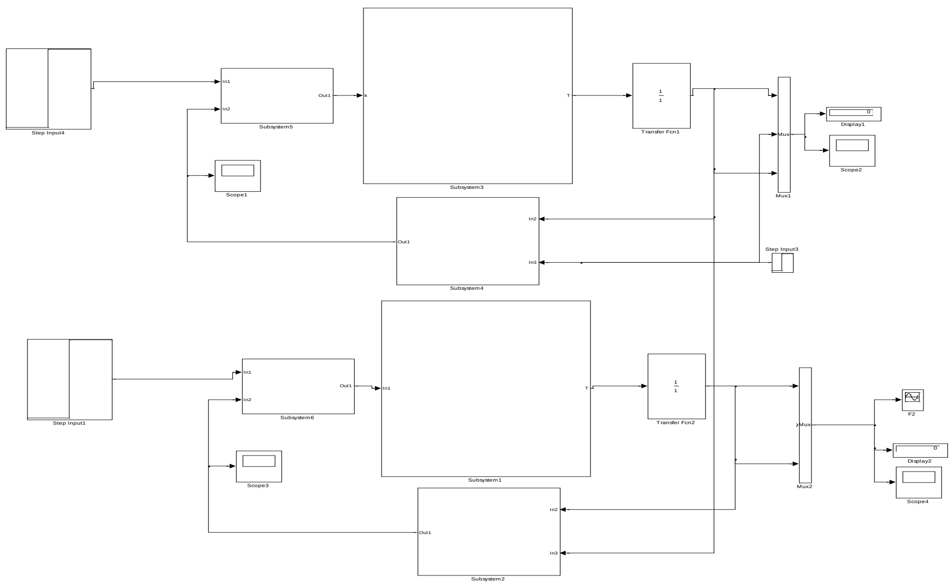


Fig.3.4. Computer models of the processes of the first and second buildings of the installation

Analysis of the curves shows that the first red line identifies the change in the concentration of the solution leaving the apparatus in percent (for clarity, multiply by 10), the upper green line is a graph of the condensation temperature of the heating steam, the second lower green line shows the temperature of the wall of the heating boiling pipes and the lower blue line - temperature of the solution inside the boiling tubes.

It should be noted that we deliberately set in advance the heating surface of the first and second half of the evaporator, which was actually manufactured for the experiment. (32 pipes ø 25x2 and pipes ø 32x3).

When modeling on a computer model, changes in parameters were noticed for both the first half of the apparatus and the second. For example, a change in the condensation temperature of secondary steam, the wall temperature and the temperature of the solution inside the boiling pipes causes a change in concentration in the first half of the apparatus, which is regulated by the flow of heating steam, or the degree of opening of the valve device on the supply line of the primary heating steam. As a result of computer studies, the relationship between the flow rate of the initial evaporated solution with the initial concentration of CH and the pressure in the second body of the apparatus was clarified.

Method for determining the boiling point of a pectin solution from its concentration

When modeling and calculating the evaporation process in pectin production, clarifying the dependence of the boiling point of the solution on the water content is of great importance. Therefore, for a more accurate calculation of the process [10] with the development of a computer model, it is necessary to determine a more accurate pattern of the boiling point of the pectin solution from a number of parameters of the evaporation process.

To determine the boiling point of solutions, there are a number of laboratory instruments that can be used to determine the boiling point. This is a boiling flask, thermostat and other devices. The most advanced device is the Washburn ebulliometer, shown in Fig. 3.5.

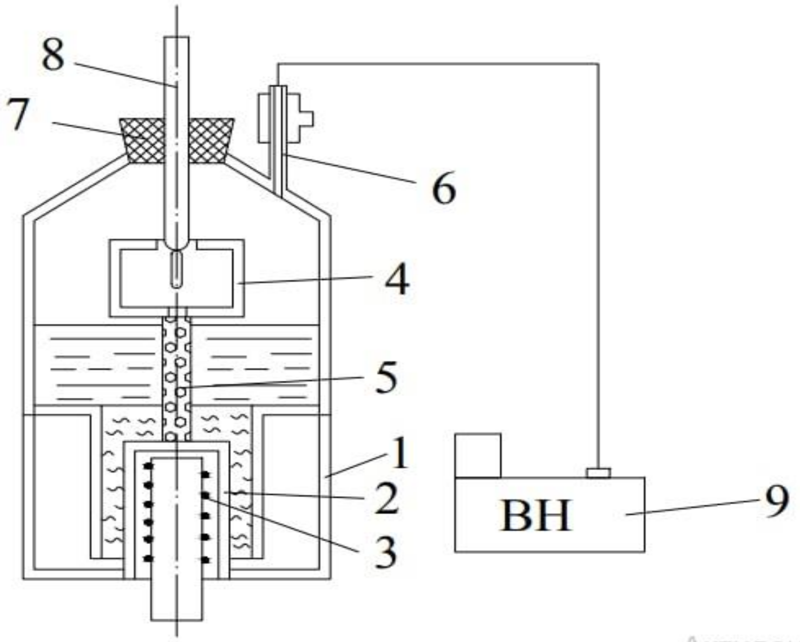


Figure 3.5. Washburn ebulliometer for determining the boiling point of solutions

The device is a glass container 1 with a cap 2 placed at the bottom, coaxially with an electric heater 3 installed inside.

Above the cap there is a funnel 4 that communicates with tube 5. A thermometer 8 is passed through plug 7, the lower end of which is placed in the center of funnel 4. The device communicates through nipple 6 with vacuum pump 9.

The purpose of the device is to determine the boiling point of solutions of various concentrations depending on the residual pressure. To do this, a vacuum pump is used to create a vacuum (simulating a vacuum in the apparatus) and determine the boiling point of a solution of a given concentration.

The device works as follows. 200 ml of the test solution is poured into it, the electric heater is turned on and a vacuum pump creates a vacuum (calculated). Upon reaching the boiling point, intense formation of vapor bubbles is observed, which rise through tube 5 into funnel 4, where the current temperature of the solution is measured with a mercury thermometer 8.

To test the boiling point of weak pectin solutions, 10 samples of 200 mm each from 1.5 to 9.2% pectin were prepared. Each measurement was carried out three times and recorded in the log book. On table 3.5. the boiling points of pectin solutions at different concentrations are presented.

Table. 3.5.

Boiling points of pectin solution at different average concentrations

№	Concentra tion of solution, %	Boiling temperature By race couple, ºC	Boiling point, according to experiment that, ºC	Temperature depression this calculation Naya Δt, ºC	Measure ment error Nia ºC.	Quadra-Typical error Δt^2
1	0	100	100	0	0	0
2	1.5	100,135	100.1	0,135	0,035	0,004225
3	2.5	100,225	100.2	0,225	-0,025	0,000625
4.	3.5	100,315	100.4	0,315	0,085	0,007225
5.	4.7	100,423	100.4	0,423	-0,023	0,000529
6.	5.3	100,477	100,6	0,477	0,123	0,015129
7.	6.1	100,549	100,7	0,549	0,151	0,022801
8.	7.4	100,66	100,7	0,66	0,04	0,0016
9.	8.1	100,729	100,7	0,729	-0,029	0,000841
10	9.2	100,828	100,9	0,828	0,072	0,005184
						∑0.058159

Standard deviation of measurements

$$\sigma = \sqrt{\frac{\sum \Delta t^2}{\Delta tmax^2 n}} = 0{,}092103203$$

where Δt_{max} is the maximum temperature deviation;

n is the number of experiments performed.

Analysis of the experimental results shows that the boiling temperature of weak pectin solutions is characterized by a linear relationship, confirmed by the MATLAB program. (Fig.3.6.)

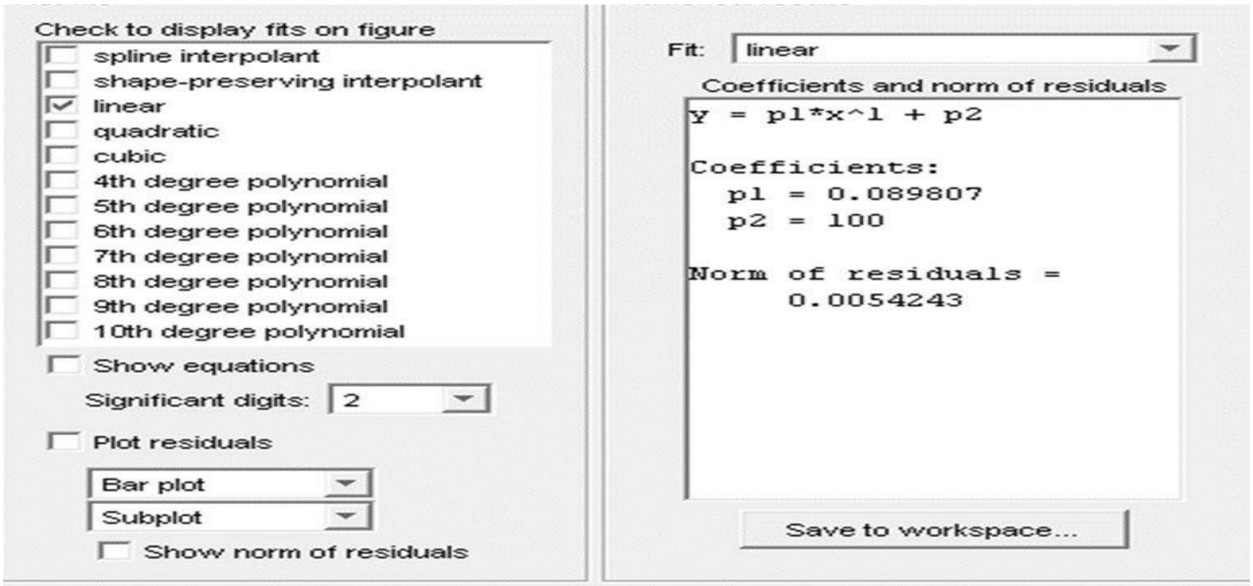


Fig.3.6. Determination of the boiling point of an aqueous solution of pectin from concentration using the MATLAB program

The boiling point of a pectin solution depending on the concentration is described by the equation using the MATLAB program:

$$y = k \cdot x + b \qquad (3.1)$$

where: k= 0.089807-proportionality coefficient

b=100-coefficient characterizing the boiling point of the solution at 100 °C.

A graph of changes in the boiling point of a pectin solution versus concentration is shown in Figure 3.7 and Figure 3.8 shows the error in measuring the boiling point of a pectin solution.

Based on the tabular data, the dependence of the boiling temperature of the solution on the concentration was plotted.

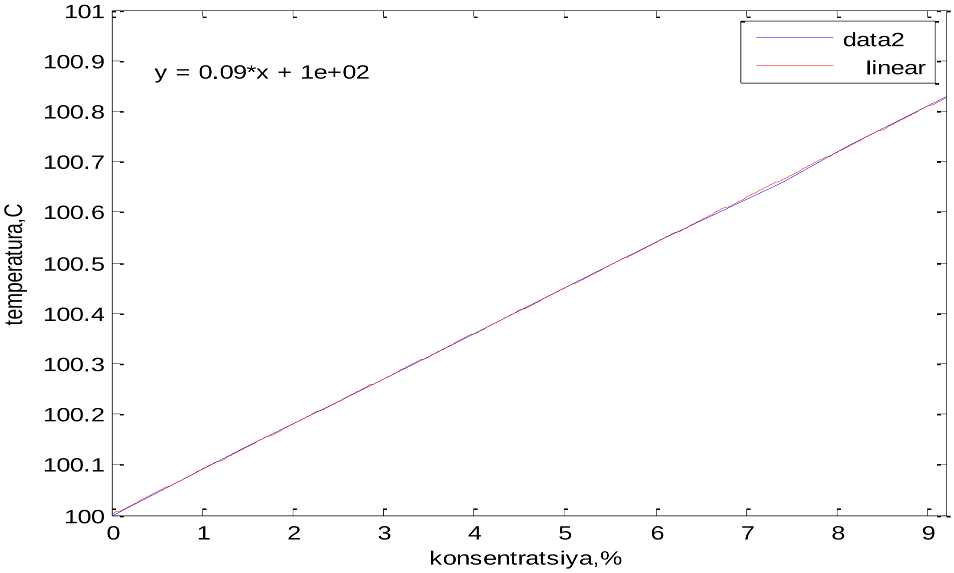


Fig.3.7. Dependence of the boiling point of an aqueous solution of pectin on concentration

As can be seen from Fig. 3.7, obtained by the MATLAB program, pectin is described by a linear dependence and is characterized by a small absolute error, Fig. 3.8.

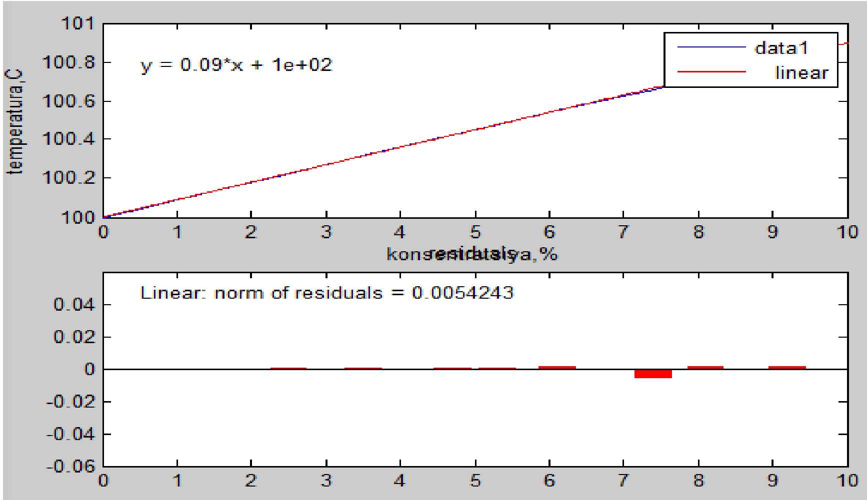


Figure 3.8. Absolute error in experiments on the boiling point of a solution based on its concentration

After transforming the equation for the dependence of the boiling point of a pectin solution on concentration (from Fig. 3.7) in the form of a straight line, we obtain an equation characterizing the boiling point from changes in concentration.

$$t= 0.089807*a + 100 \quad (3.2)$$

Or, conversely, for the concentration of pectin on temperature, taking into account the initial concentration, it was obtained

$$a=11{,}11111\cdot t – 11111{,}11 \quad (3.3)$$

Here, the dependence of the temperature depression of a pectin solution on concentration is expressed by the equation,

$$dt=0.089807*a \quad (3.4)$$

For other pressure values in the technological operating mode of the evaporator, the dependence can be written down after processing the tabulated data for the equilibrium of saturated water vapor. Taking the boiling point of pure water to be 100 oC, we can write

$$t_r=0.09*x+100 \quad (3.5)$$

Table 3.6.

Boiling point of water versus pressure

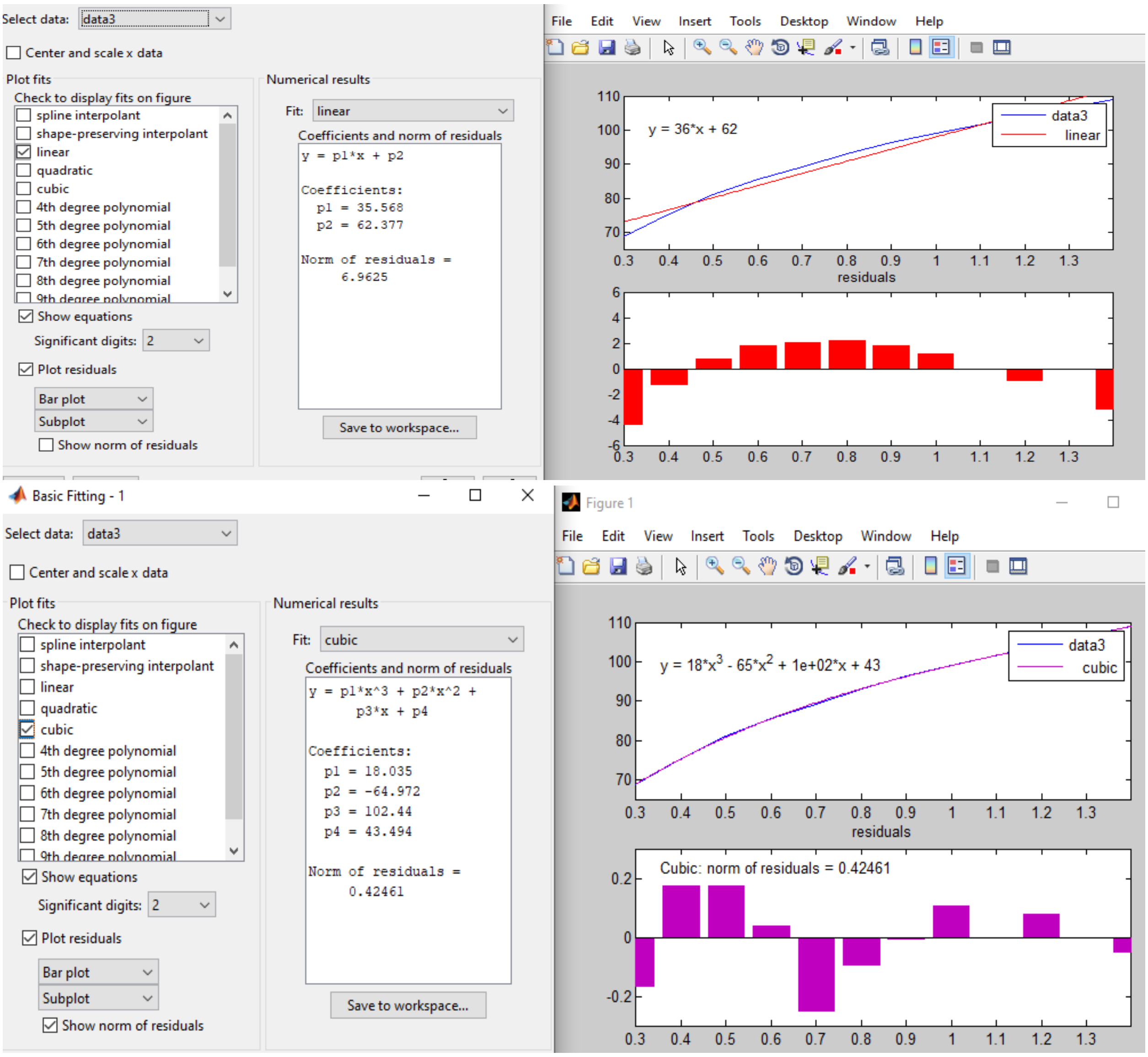
P, кПа	t, °C	P, кПа	t, °C	P, кПа	t, °C
1	2	3	4	5	6
5,0	32,88	91,5	97,17	101,325	100,00
10,0	45,82	92,0	97,32	101,5	100,05
15,0	53,98	92,5	97,47	102,0	100,19
20,0	60,07	93,0	97,62	102,5	100,32
25,0	64,98	93,5	97,76	103,0	100,46
30,0	69,11	94,0	97,91	103,5	100,60
35,0	72,70	94,5	98,06	104,0	100,73
40,0	75,88	95,0	98,21	104,5	100,87
45,0	78,74	95,5	98,35	105,0	101,00
50,0	81,34	96,0	98,50	105,5	101,14
55,0	83,73	96,5	98,64	106,0	101,27
60,0	85,95	97,0	98,78	106,5	101,40
65,0	88,02	97,5	98,93	107,0	101,54
70,0	89,96	98,0	99,07	107,5	101,67
75,0	91,78	98,5	99,21	108,0	101,80
80,0	93,51	99,0	99,35	108,5	101,93
1	2	3	4	5	6
85,0	95, 15	99,5	99,49	109,0	102,06
90,0	96,71	100,0	99,63	109,5	102,19
90,5	96,87	100,5	99,77	110,0	102,32
91,0	97, 02	101,0	99,91	115,0	103,59

Pressure units in the table: kPa.

1 kPa = 1000 Pa = 0.00986923 atm. = 7.50062 mm. rt. Art.

Normal atmospheric pressure is 765 mm. RT. Art. = 101.325 R, kPa

The equilibrium temperature of saturated water vapor after processing using the MATLAB application program is expressed as the equation



$t_v=f(P)$ (3.6)

$t_v=18{,}035*x^3-64{,}972*x^2+102{,}44*x+43{,}494;$ (3.7.)

Taking into account the boiling point and the equation of temperature depression of the pectin solution, an equation was obtained characterizing the boiling point of the pectin solution at various pressures, expressed by equation (3.8).

$t_{water\ boiling}=18.035*x3-64.972*x2+102.44*x+43.494+(0.09*x+100)$ (3.8)

The results obtained were used to construct a computer model of evaporation of a pectin solution and to synthesize the optimal process occurring in the apparatus.

DEVELOPMENT OF AN EVAPORATOR WITH A DOUBLE HEATING CHAMBER.

Semi-industrial evaporation plant for concentrating fruit and vegetable juices and technical solutions.

Based on completed patent and licensing work and analysis of existing designs of evaporators, we have developed a single-shell evaporator with a bifurcated heating chamber. [Application No. FAP 2020 03.13 [5].

According to the design features, the developed evaporator is a flow-type apparatus and consists of three main structural blocks that can be connected together: heating chamber 1, separator 2 and bottom 3 (Fig. 4.1)

The heating chamber contains a cylindrical shell 4 welded to the upper 5 and lower 6 tube plates, on which heating pipes 7 and 8 of different diameters and quantities are located. The pipe space is divided into two unequal parts, vertically installed between the tube sheets 5 and 6, bent by a curved partition 9. On the shell there are nozzles 10 and 11 for the input of heating steam, nozzles 12, 13 for the removal of condensate forming, support legs 14 and bosses 15 , 16 for installing temperature sensors.

A bottom 3 containing a dividing partition 18, a pipe 19 for the initial solution inlet and a pipe for a 20-return solution will be connected to the lower tube sheet 6 by means of a flange 17.

A juice steam separator 3 is connected to the upper tube plate 5 on the flange 21, containing a dividing partition 22, a drop reflector 23 with a hole 24, a pipe 25 for the outlet of the circulating solution and a pipe 26 for the outlet of the concentrated solution. On the upper elliptical bottom there is a pipe 27 for the outlet of secondary steam and a pipe 28 for discharging the secondary steam to the barometric condenser.

The evaporator is insulated from the outside with mineral wool to avoid burns to operating personnel and reduce heat loss to the environment.

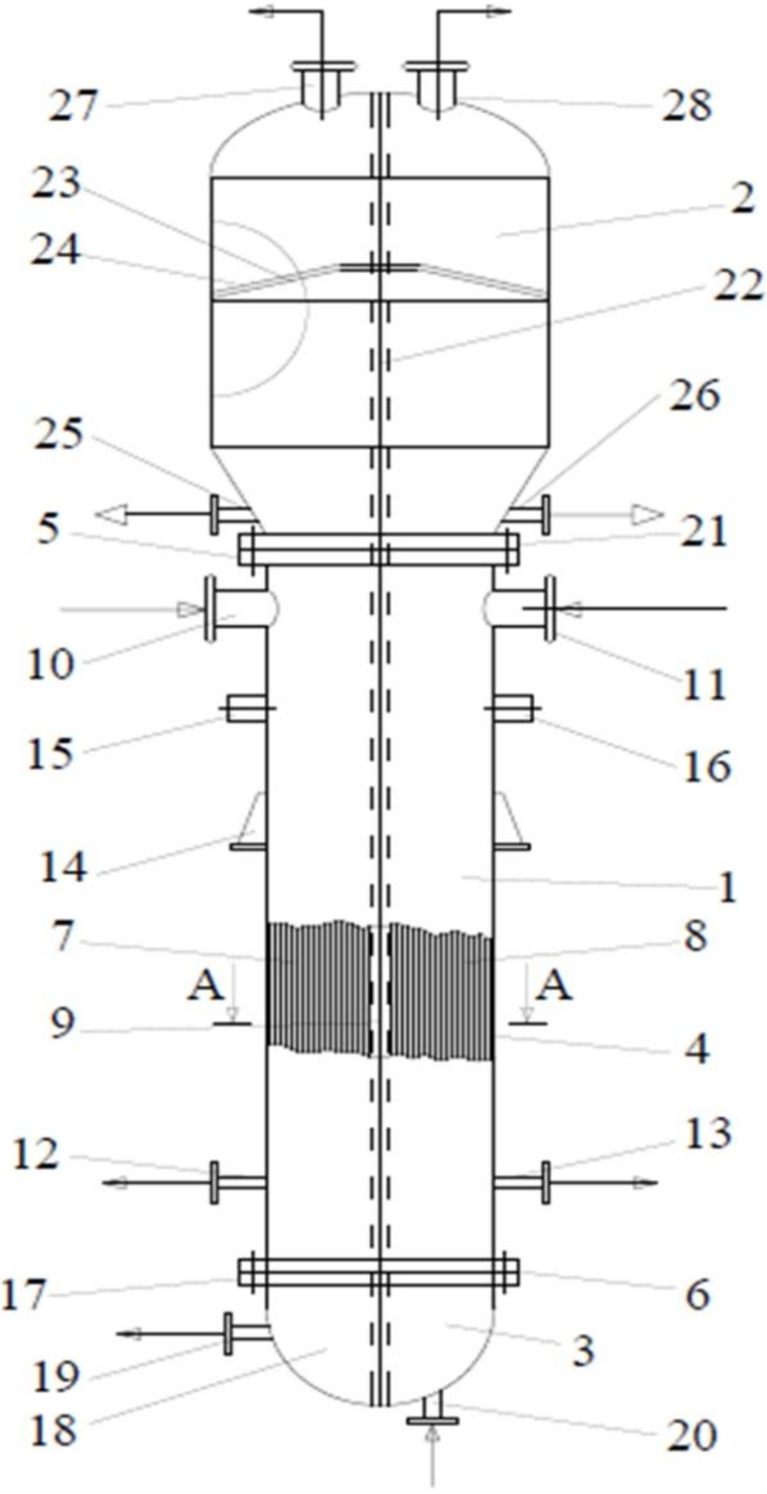


Fig. 4.1 - General view of an evaporator with a divided heating chamber

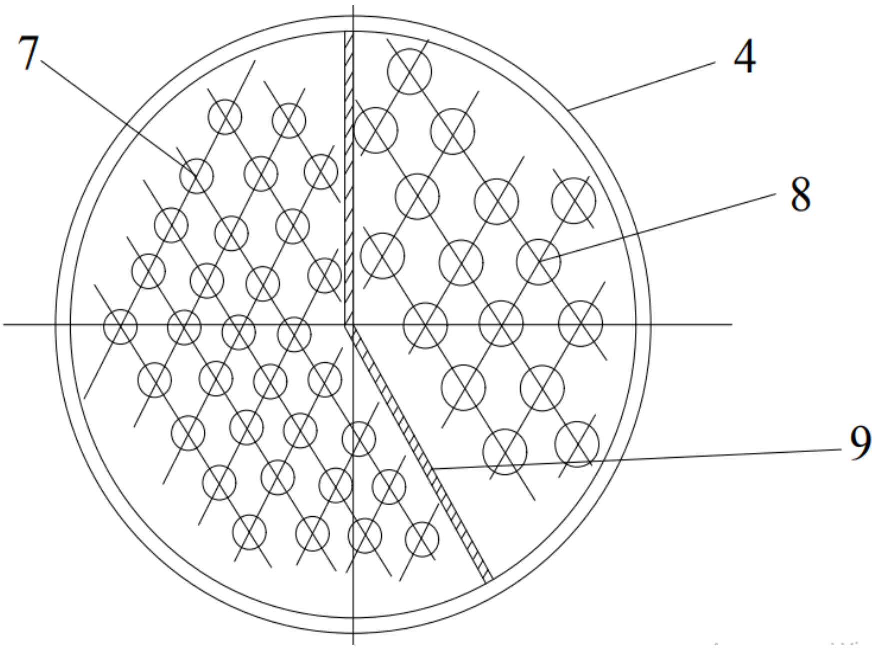


Figure 4.2 - Section A-A shown in Figure 1

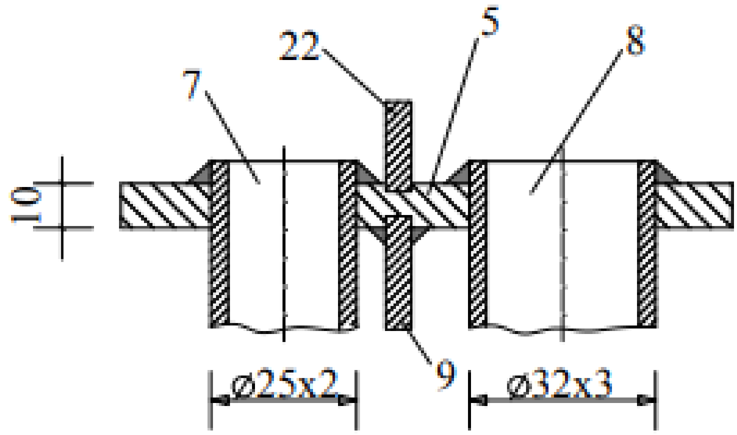


Fig 4.3-Pipe fastening unit to the tube sheet

The most labor-intensive part is assembling heating chamber 1. According to the developed drawings, holes for heating pipes 7 and 8 with dimensions ø 25.2 and ø 32.2 mm are drilled on the top 5 and bottom 6 tube boards. The breakdown of tube sheets is carried out according to the hexagon principle. The number of holes is ø 25-32 pcs., and ø 32-16 pcs. Then, using a finger cutter, cut a groove for the curved partition 9, mirror-like on both sides. Install a partition between two pipe boards and weld the ceiling and vertical seams. Afterwards, most of the shell 4 is placed on the tube sheets and the circular joining seam is welded. In the same way, a smaller shell is placed on the tube sheets and the joining seams are welded, forming a solid shell. In this case, before welding the composite joints, holes must be provided for pipes 10,11,12,13 and bosses 15,16.

After these procedures, pipes 7 and 8 are pulled through the holes of the tube sheets and finally welded, and all prepared pipes are installed along with the return flanges.

Separator 2 is manufactured as follows. The cylindrical frame of the separator, made by rolling, with a design diameter D and high h, is welded at the end to the elliptical bottom and then a curved partition 22 is installed by welding inside the frame. Then, asymmetrically prepared floor cones 23 are welded on both sides of the partition 22. After that, a cone-shaped skirt is welded to the frame, connected to the upper flange 21, on which holes for pipes 25 and 26 are located.

The manufacture of the bottom 3 consists in the fact that a hemispherical shell with a diametrical curved partition 18 welded to the floor is welded to the flange 17, dividing the space into proportional parts in accordance with the tube sheet 6 of the heating chamber 1.

At the bottom there is a pipe 19 for the input of the initial solution and a pipe 20 for the circulating solution.

After the manufacture of all component blocks 1, 2 and 3, they are joined together by installing paronite gaskets, coupling bolts and nuts between flanges 5, 21, 6 and 17. M 16 (GOST 8724-81) and check the prefabricated unit for tightness, both by the movement of material flows and by the movement of the heat agent supply.

To do this, all pipes are closed with plugs. First, check the steam space of the heating chamber with compressed air, applying excess pressure and saponifying all connectors. If necessary, install a standard pressure gauge on boss 15 and record the pressure drop after a period of time.

The food space is checked in the same way and, if there is no air leakage, the device is considered accepted for operation.

Operating principle of the evaporator

As previously noted, the developed evaporator, in terms of design, relates to flow evaporators and in it

there is no circulation pipe [3; pp.46-49, 5].

The solution is fed into the apparatus through the planer 17 and rises up through the pipes 7 of the heating chamber 1. In them, the solvent (water) evaporates due to heat supplied through the heating steam pipe 10. The vapor-liquid mixture enters the part of the separator separated by partition 22, wet secondary steam passes through the drop trap 23 and is removed through pipe 27 to heat the second half of the apparatus, and the pre-concentrated solution through pipe 25 enters the second part of the apparatus through pipe 20.

Since a slight vacuum is maintained in the second part of the device

($P = 0.4$ kgf/m^2), then the solution flows from the first part of the apparatus to the second by gravity. Entering the pipes 8, the solution boils due to the heat entering through the secondary wet steam pipe 11 from the first half of the apparatus and, in the form of a boiling vapor-liquid system, enters the separator part of the apparatus.

Here, secondary low-pressure steam is removed through pipe 28 for condensation into a barometric condenser, and the concentrated solution through pipe 26 is removed from the apparatus for cooling. Condensates from the heating chambers are removed through pipes 12 and 13 into the circulating steam supply system (boiler room)

The advantages of this evaporator compared to known evaporation units are as follows:

1. The simple design and small weight and overall dimensions allow its production in small mechanical assembly shops without special equipment:
2. Dismantling the separator and the bottom ensures quick cleaning of the heating pipes from the formation of burnt marks:
3. The process of carbon formation when boiling various solutions (apple, tomato and melon juices) decreases by 1.3 -1.6 times.

TECHNOLOGICAL TESTING OF AN EVAPORATOR PLANT FOR CONCENTRATING PECTIN SOLUTION AND CALCULATION OF ECONOMIC EFFICIENCY

Simplified technological scheme for obtaining pectin extract from apple pomace

The technology for processing dry apple pomace to produce a pectin-containing extract has been developed and introduced into production is shown in Fig. 5.1. The circuit includes an extractor 1 with a steam jacket and a propeller stirrer, equipped with a rotating lid and a mesh insert located inside.

Above the extractor there are two 20 liter measuring tanks for citric acid solution, and next to it there is a suction filter 3, connected to the vacuum line.

The filter drain pipe is connected to a centrifugal pump 4 for pumping the filtrate into two buffer tanks 5 with a capacity of 1000 liters each.

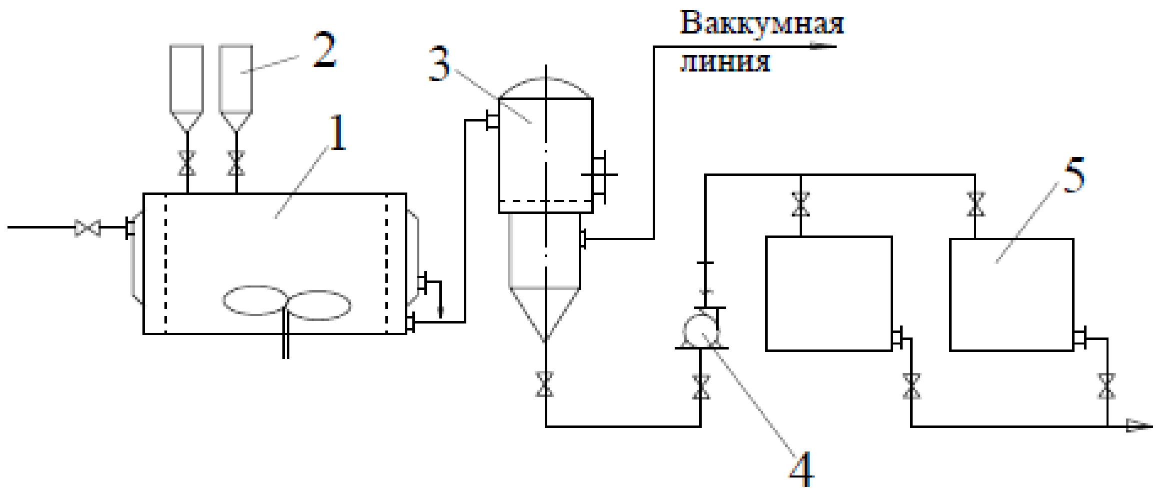


Fig.5.1. Dry apple pomace extraction line

Operating principle of the extraction line.

80 kg of dry apple pomace are loaded into the extractor and water is poured at the hydromodulus ratio of 1:10 and 7.2 kg of citric acid solution is added.

Turn on the propeller mixer and carry out the extraction process for 4 hours at a temperature of 70ºC. After the extraction is complete, turn on the vacuum pump and pump the coarsely purified filtrate through a mesh insert into a nutsch filter for deeper cleaning.

In a Nutsch filter, the extract passes through a felt filter and enters two temporary storage tanks before entering the evaporation department. The filtered pulp from the extract and nutsch filter is sent to feed livestock. The clarified solution contains from 1.5 to 1.6% protopectin.

Vacuum evaporator 2-hull installation with bifurcated heating chambers

To concentrate a weak pectin solution, we have developed a hardware and technological diagram of an evaporation unit (Fig. 5.2)

It contains a weak solution supply tank, two centrifugal pumps, a double-effect evaporator with a common secondary steam separator, a concentrated solution storage tank and a barometric condenser with a VVN-5 liquid ring vacuum pump. The automatic transmission systems of the entire pectin production and a number of non-standardized stainless steel equipment were developed at the EKB Tekheksppromt LLC and manufactured at the private company YATT Daniyar-Khojaev.

The evaporator installation is equipped with instrumentation and means of automatic measurement and regulation of temperature in the evaporator housings.

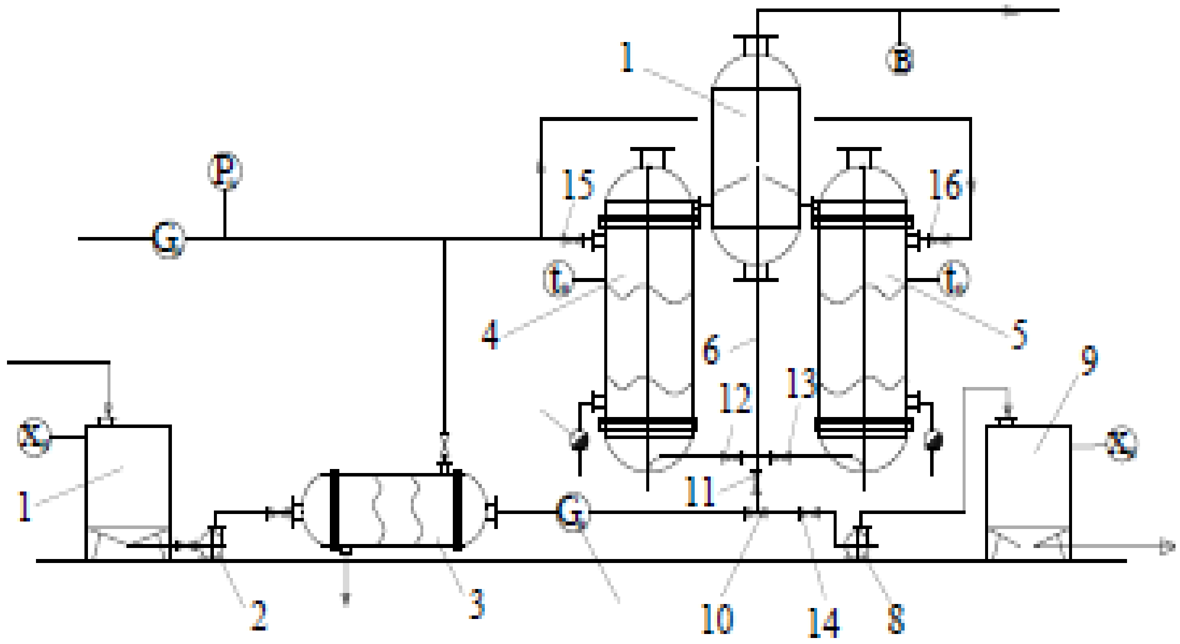


Fig.5.2. Hardware and technological diagram of an evaporation unit for concentrating a pectin solution

1-consumable tank of initial solution; 2-centrifugal pump; 3-heater; 4.5 - evaporator; 6- circulation pipe; 7- separator; 8- centrifugal pump; 9- tank of evaporated solution.

The installation includes a bran heater casing 3 and two evaporation housings 4 and 5, united by a common separator 7. Both housings are connected to a single steam supply system, the flow of evaporated solution is connected to a barometric condenser line, including a water ring pump VVN-5. Evaporating housings 4 and 5 are connected technologically in such a way that they can work independently. The concentrated solution is removed into buffer tank 9.

From the evaporation department, the solution is supplied to precipitation, where pectin is precipitated with an alcohol solution, its subsequent drying and distillation of the waste solution with the return of ethyl alcohol (We do not consider these processes).

Evaporation plant production tests

During the period from July 3 to July 20, 2021, at the pilot industrial enterprise "PPZ Pectin" of the private company "ONSITE", located in the village. "Avlie-ota" of the Tashkent region, Tashkent region, production tests were carried out on an experimental line for the production of food pectin from dry apple pomace.

The pectin production was located in a one-story building with a total usable area of 240 m2 and a height of H = 3.5 m. Extraction and filtration workshop, evaporation station with boiler room, pectin precipitation department, distillation of circulating alcohol solution and pectin drying, storage rooms are partitioned with walls and equipped with supply and exhaust ventilation.

The production has a water supply system, centralized sewerage, local gas boiler room and electricity: voltage

U= 380\220 B.

Sequence of pilot tests

During the test period, 11,000 kg of dry apple pomace with a moisture content of W= 9% was processed. delivered from a private fruit processing plant.

70-80 kg of apple pomace are placed in extractor 1 (Fig. 5.1.), 700 liters of water and 3% citric acid or a prepared solution from a measuring cup are poured at the hydromodulus ratio of 1:10. 2. Steam is supplied to the jacket, the mixer is turned on and extraction is carried out at a temperature of 70ºC for 4 hours. Then the extracted suspension containing fine suspended matter is sucked through a mesh insert into a suction filter 3. The filter partition of the filter is covered with a coarse glass cloth and a felt layer.

The filtered solution is pumped by pump 4 into buffer tanks 5 (see photos No. 1-4).

Extraction waste – residual pulp – is sent for fattening livestock.

Next, the filtered pectin-containing solution with a concentration of Xn = 1.5% is heated in a shell-and-tube heat exchanger 3 (Fig. 5.2.) to a temperature of

95-98 ºC and fed to an evaporation station, which includes two shell-and-tube evaporation bodies 4 and 5 with a common juice steam separator 7 (see photo No. 5-6) and a barometric condenser with a vacuum pump VVN-5.

Evaporation bodies can work both jointly and individually. The evaporated solution with a concentration of Xc = 7.2-7.5% is cooled to a temperature of 25 ºC and sent to the pectin precipitation department.

It contains a precipitator—a cylindrical reactor with a boiled lid, where pectin coagulates under acidified ethyl alcohol in the form of a "cap" (see photo No. 7-8). The cap is removed, squeezed out and dried, and the spent alcohol solution is rectified in a distillation apparatus and returned to production.

The material calculation for the production of edible pectin from dry apple pomace is given below.

Calculation of economic efficiency from the sale of the resulting apple pectin

Prices for starting and auxiliary materials

1	Pomace	1000 sum/kg
2	Ethanol	15500 sum/l
3	Lemon acid	10000 sum/kg
4	Water	220 sum/m^3
5	Electricity	450 sum/ кVt.h.
6	Pectin (market) 6$/kg	62400 sum/kg
7	Cost of equipment	167 mln.sum

Technological standards

1	Pectin content in pomace	9 %
2	Extractability no more 8,0 %	0,8
3	Hydromodulus during extraction	1:8
4	Extraction time	4ч
5	Dry matter content in the extract	1,2 %
6	Dry content after concentration	7%
7	Hydromodulus during deposition	1:3

Technological calculation

1. When calculating, we proceed from the possible turnover of an extractor with a capacity of 800 liters. With a hydraulic module M of 1:8, the one-time load of apple pomace will be: G_1=80kg.
2. When the workshop operates in three shifts, the following is processed:
3. Gcm=G1·3=80·3=240kg, or 7200 kg\ month
4. 4. Daily water consumption:

$G_в$=V·3=800·3=2400l=2,4m^3

5. Extraction is carried out with a 3% solution of citric acid, then the lemon consumption will be
   $G_л=G_в \cdot X_л=240 \cdot 0,03=72$ l
6. xpected concentration of dry substances in the extract according to standards
   $X_1 \approx (1,2\text{-}1,5)$ %

The concentration of dry matter in the extract after evaporation is X_2 = (7-8)%, then the amount of evaporated water will be

$$W=G_H\left(\frac{1-X_H}{X_K}\right)=2472\left(\frac{1-1,5}{8}\right)=2008 \text{ кг}$$

7.Amount of concentrated extract

$G_2=G_H-W=2472-2008=464$ кг

8.Alcohol consumption for pectin precipitation at the ratio 1:3

$G_{сп}=G_2 \cdot 3=464 \cdot 3=1392_{л.} \approx 1,39 m^3$

9. Annual productivity of the dry apple pomace processing workshop

$G_г=M \cdot T=7200 \cdot 12=86400$ кг=86, 4 т

10. Annual water consumption

$G_{в \cdot г}=G_в \cdot \tau=2,4 \cdot 365=876$ $м^3$

11. Annual consumption of alcohol (circulating)

$G_{сп \cdot г}= G_{сп} \cdot 365=1,38 \cdot 365=503,7$ $м^3$

12. Annual consumption of citric acid

$G_{л \cdot г}=\cdot G_л \cdot 365=72 \cdot 365=26280$ kg

13. Annual production of food pectin

$G_{п \cdot г}=G_г \cdot X_п=86400 \cdot 0,08=6912$ kg

14. Amount of extracted solution

$G_р= (G_в+G_м)\ 365= (2400+240) \cdot 365= 963600$ $м^3$

15. Return of production waste: apple pulp after bioconversion is used to feed cattle. During extraction, the pomace swells 1.5 times. Then the yield of pulp will be$G_ж= G_г \cdot 1,5= 86400 \cdot 1,5=$ 129 600 kg

Стоимость жома составляет $C_ж$= 200 сум \ кг

16. Alcohol is in circulation by repeated distillation, then the real consumption (approximately) can be accepted G сп.р ≈ 503700 l

The wage fund of main, auxiliary workers and engineers (on average) number of employees is 4·3= 12 people. Engineers - 2 people average salary -2 million\month. The annual fund including social insurance (40%) will be

$C_{з.п}= (12+2) \cdot 2,0 \cdot 1,4=$ 39,2 млн, сум

18. Cost of circulating alcohol

$C_с= G_{е.р}$x 15500 = 503700 x15500=7807350 mln.cum

19. Cost of water:

$C_в = G_{в.г} \cdot 220 = 2{,}400 \cdot 220 = 528x365 = 192720$ mln.sum

20. Cost of a lemon:

$C_л = G_{л.г} x10\ 000 = 72 \cdot 10000x365 = 262800$ mln.sum

21. Cost of equipment including depreciation 10 %.

$C = c_o \cdot 1{,}1 = 167 \cdot 1{,}1 = 183{,}7$ mln.sum.

22. Consumption of electricity (approximately) and steam (electric boiler room)

$C_э = 195$ mln.sum

23. Returns from the sale of apple pulp

$C_ж = c \cdot G_ж = 200 \cdot 129600 = 25{,}920$ mln.sum.

24. Cost of raw materials - apple pomace

$C_я = c \cdot G_г = 1000 \cdot 86400 = 86400$ mln.sum.

25. The total cost of pectin production will be minus working capital

$\Sigma C = C_{з.п} + C_с + C_в + C_л + C_о + C_я - C_ж = 39{,}2 + 780735 + 262800 + 182{,}7 + 195 - 25{,}92 = 104\ 391$ mln.

26. Expected yield of pectin when processing 86.4 tons of apple pomace

$G_п = G_г \cdot x_в = 86400 \cdot 0{,}08 = 6912$ kg

27. Cost of 1 kg of obtained apple pectin

$c = \frac{\boldsymbol{\Sigma} C}{\boldsymbol{G}_п} = \frac{10439159}{6912} = 15102{,}9$ сум/ кг

28. Expected production profit at the market value of citrus pectin 6 \$ = 62400 sum / kg

$П = (Cp - C) \cdot G_г = (62\ 400 - 15102) \cdot 6912 = 104269$ mln.sum

29. Equipment payback period

$T = \frac{Co}{П} = \frac{183{,}7}{104{,}3} = 1{,}76$ g.

CONCLUSION

1. The peculiarity of the technological process of concentrating fruit and vegetable juices by evaporation is revealed.

2. An analysis of existing evaporators used in the food and chemical industries was carried out and a classification assessment of these devices was given according to the principle of operation and the type of coolants used.

3. Recommendations are given for improving the design of some devices in order to increase their productivity.

4. Using the method of multi-stage systems thinking and quasi-models, mathematical and computer models of the process of evaporation of solutions flowing on the elements of the apparatus, such as the heating chamber, the wall of the boiling pipes of the evaporator, and the vapor-liquid space, have been developed.

5. The results of the study using a computer model show that the condensation temperature of dead water vapor, the wall temperature of the boiling tubes of the apparatus, the temperature of the vapor-liquid space of the evaporator and the concentration of the exiting solution increase exponentially

6. Based on mathematical models, the evaporator is calculated based on changes in the concentration of the evaporated solution, the flow rate of the supplied initial solution, the temperature of the heating steam and its flow rate.

7. The dependence of the boiling point of the solution on the concentration of pectin was studied, since a weak solution of apple extract is supplied for evaporation.

8. An evaporator of a fundamentally new design has been developed, and is divided by a heating chamber both along the flow of the heat of the agent and along the movement of the evaporated solution.

9. A pilot production of pectin concentrate from 11 tons of dry apple pomace was carried out.

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TABLE OF CONTENTS

Karimullaeva M.U

IMPROVEMENT OF THE PROCESS AND APPARATUS FOR EVAPORATION OF FRUITS AND VEGETABLES JUICE

Written on the basis of the results of scientific research conducted by M.U.Karimullaeva

MONOGRAPHY

Monograph reviewed and published and session protocol of the Karakalpak Institute of Agriculture and Agrotechnology