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Climate Management System in the Vegetable Storage of Perishing Agricultural Products

Yakubov S.Kh., Pirova R.K.
Karshi State University

Abstract: Microclimate control systems based on controllers, sensors and ventilation equipment allows more accurate control of climate parameters, eliminates the human factor, saves energy, makes it possible to install refrigeration systems with simplified control cabinets.

Key words: microclimate, vegetable storage, control system, temperature sensors, humidity sensors, ventilation, automatic control system.

Introduction

The safety of vegetables strongly depends on the microclimate created in the vegetable storage. Temperature, humidity and carbon dioxide concentration are most influenced. Root crops, vegetables and fruits constantly release heat, moisture and carbon dioxide into the ambient air during off-season storage. The increased temperature affects the activation of the activity of bacteria in agricultural products. This threatens to contaminate products with fungal infections and the appearance of rapidly growing mold colonies.

The microclimate control system in the vegetable store performs the following tasks: temperature control accordingly; humidity; air composition [1, 2].

The vegetable storage ventilation control system includes:

Duct fans to provide the main ventilation of the vegetable store.

Heated anti-condensation ceiling fans to prevent condensation from forming on the ceiling structures of the vegetable store.

Valves with actuators and valve position sensors that regulate the air supply from the street and mixing the air inside the vegetable store,

Automatic control units of the vegetable storage ventilation system, including the control unit and switching units of the executive elements of the ventilation system (fans, valves, and others).

Air temperature and humidity sensors, inside and outside the vegetable store, product temperature sensors, a carbon dioxide concentration sensor (desirable) and other elements.

With the bulk storage of vegetables, the ventilation control system of the vegetable store must include special perforated ventilation ducts for air supply located along the floor of the vegetable store.

The calculation of the number and size of channels required for high-quality ventilation of vegetables is carried out when designing a vegetable store with a bulk storage method.

The potato storage ventilation system can be built on the basis of one or more powerful duct fans (two-fan system), or using a large number of relatively low-power fans (multi-fan system). A two-fan ventilation system for a potato storage will be cheaper than a multi-fan one, but the requirements for the design of a vegetable storage will be more stringent, and the calculation of the ventilation system elements will be more complicated.

In container storage, vegetables are stored in special containers. To create the best microclimate for storing vegetables in container storage, general exchange ventilation is usually used.

Advantages of container storage: ease of control and sorting of vegetables during storage, a simpler system of air supply to the vegetable store (a system of general exchange ventilation is sufficient).

Short term storage. With this option, the crop is not stored for long, since such a vegetable storage uses developed networks of sorting and distribution lines with additional storage facilities (for certain types of vegetables).

Long term storage. With long-term storage of vegetables and fruits, it is necessary to have modern equipment to maintain the required indoor microclimate. This is the most profitable option for a vegetable store, since there is no need for a quick sale of products due to the seasonality of the business.The main ideal condition for storing vegetable products is the availability of separate premises for receiving and sorting crops. At the second level, there is the ability to control the temperature regime and the level of relative humidity (microclimate) inside the pre-fabricated vegetable store [8,9, 11,12,13].

The ventilation system of vegetable stores is a complex of devices (exhaust and supply valves, ducts and fans) that ensure the longest possible storage period for vegetables and fruits. The most common are considered automatic forced ventilation units [2].

This is a specialized equipment that will maintain the required concentration of gases in the warehouse. A complex of the following devices is widely used: a nitrogen level generator, carbon dioxide absorbing machines, devices for manually reducing the oxygen concentration in a vegetable store.

Vegetables and fruits require a special temperature storage regime, which directly affects the appearance and overall preservation of the fruit. Usually the temperature of the warehouse is close to 0 ℃, however, it should be understood that in order to stimulate the regeneration of the outer shells of the fruit, the temperature inside must rise by 15-25 degrees.

Humidification systems include humidifiers and industrial dryers. The principle of operation is clear to everyone: dryers help dry fruits, and humidifiers maintain the microclimate of the room at the proper level.

At the moment, there are several types of premises designed for long-term storage of vegetables and fruits:

Hangar: It is characterized by the fact that their construction takes a minimum amount of time, and a special spraying of polyurethane materials is used as a heater. It is applied in several layers to ensure the best performance. A very unpleasant drawback also emerges from the main advantage - such storage facilities are quite severely limited in terms of installing special climatic equipment due to poor thermal insulation. In this regard, they are used for temporary storage of products, and mainly in bulk.

Frame vegetable storage: They are erected from light steel structures and allow organizing individual sections inside the premises with special climatic conditions, designed for the storage of specific products. Also, such storages allow the installation of a number of special technological equipment - conveyors, automation systems, conveyors for cleaning, washing and packing vegetables, as well as special sorting tables. Among the disadvantages of such structures should be considered weak resistance to wind loads, as well as a large amount of precipitation in the form of snow.

Frame structures with additional insulation: This is one of the most expensive options and is perfectly adapted to almost any climatic conditions. Nevertheless, the construction process is less costly, and the variability of the internal configuration makes such a solution one of the most profitable and practical. Insulation of vegetable stores of this type is carried out using special sandwich panels, the thickness of which is easily selected in accordance with the requirements of each specific project. Also, a huge number of materials are available to choose from as the main insulation inside the panel and the variability of the outer protective layer made of moisture-resistant materials.

As for the principle of operation of modern refrigeration equipment used in hangars of vegetable stores, it looks like this in stages: injection and cooling of air received from outside; displacement of heated air outside; compensation for moisture loss by vegetables.The last point is especially difficult, since to compensate for the loss of moisture during active ventilation, a whole complex of control and monitoring systems is needed, which constantly respond to a number of indicators, while providing drying or humidification of the air, cooling and heating, as well as forced ventilation and a number of other parameters. ...

For long-term storage with minimal losses, vegetable stores should be equipped with effective humidification systems and refrigeration equipment. Remote climate control systems with various storage statistics options are already an integral part of high-tech containers.

Methods

Different vegetables require their own storage mode. You can store vegetables in containers and in bulk. For vegetables such as carrots and cabbage, container storage is recommended. Firstly, we get the best results in terms of the quality of the product due to the fact that the product is better blown, an even distribution of air is achieved throughout the entire storage chamber. Secondly, storage in containers allows you to build optimal logistics in the warehouse for unloading the product from the chamber and feeding it to the processing line. In addition, this way the product is less injured. The recommended storage temperature for cabbage and carrots is 0 ... + 1 ° C with a relative humidity of at least 95%. Potatoes and onions can be stored in bulk at temperatures up to +4 ° C. Carrots differ from potatoes in the absence of a peel; they are a delicate product that requires special attention when storing them. Carrots are cooled gradually, creating conditions close to natural, degree by degree, allowing it to "fall asleep", in this case, in addition to temperature, is the humidity inside the storehouse: ideally, it should be no more than 75% [12].

At the initial stage, it is important to dry the onion with high quality, otherwise you will not be able to preserve it for a long time - with high humidity, the rapid spread of bacterial diseases begins in it, the commercial qualities decrease,

For storing cabbage, beets and carrots, it is necessary to provide a room with air of at least 75-110 m^3 / t per hour.

Carrots must remain dormant, maintaining quality and not losing weight. Thus, the storage temperature is 0-0.5 ° C. The relative humidity in the storage should be at least above 95%. Lower moisture levels will cause rapid weight loss and product quality. Many people try to achieve this level of humidity by spraying cold water on the floor of the store, which will evaporate, maintaining the humidity level. But it is incredibly difficult to raise humidity in this way in low temperature conditions. Spraying fine water droplets into the air is more effective.

The most common way to cool carrots is the conventional cooling method, where the air passing through the evaporator is cooled, thereby lowering the temperature in the storage.

Bulk storage is the most common way to store vegetables. With proper organization of ventilation, during storage in bulk, air blows over each fruit, keeping it in a state close to the state “immediately after harvesting”.

Storage in containers is a modern and high-tech method of storing vegetables. With the help of the forced ventilation systems "Aspiration System" or "Pressure ventilation" the prepared air is delivered to the product and ensures the preservation of the quality of vegetables. Also, when storing in containers, maximum flexibility in warehouse logistics is provided (the ability to ship exactly as much products as needed in a short time without using additional equipment).

Controlled and uniform cooling is the basis of long-term storage technologies for vegetables. During the period when the outside night temperature drops below +5 ° C, the automatic system uses the outside air to cool vegetables, mixing it with the inside in the air preparation chambers. In order to cool the products as efficiently as possible, and not to depend on the vagaries of nature, as well as to ensure high-quality storage in the warm season, we use refrigeration equipment integrated into the ventilation system: special heat exchange equipment for vegetable stores.

Moisture management is an important factor for storing vegetables. For uniform humidification of the air, we use a unique development of Mooij Agro - mattress-type humidifiers that prevent water droplets from appearing in the atmosphere of the store and on vegetables.

To control ventilation systems, specially developed software is used. It allows you to remotely administer all systems in several vegetable stores, program and manually change storage parameters, records all parameters for analysis, notifies about errors and critical temperatures.

The microclimate maintenance scheme in a bulk-type vegetable storehouse implies the presence of an air preparation chamber, which is located along one of the outer walls of the storage building and is separated from the storage chamber by an inner wall. Through the intake valves, fresh air enters the preparation chamber, where it acquires the required temperature and humidity. To correct the temperature and humidity of the incoming air, recirculation valves, humidifiers, heaters and coolers located in this chamber are used.

When using the bulk storage type with underfloor ducts, the prepared air is fed into special underfloor concrete ducts by means of high-pressure forced-air fans. The fans can be installed either directly into ducts or into a raised floor in the air preparation chamber. Through the channels, air is then fed into the storage, where it passes through the thickness of the vegetables, ventilates and cools or heats the product, and also adjusts its moisture content. The exhaust air is removed by gravity through the open exhaust valves, or through the recirculation valves it is added to the newly supplied fresh air. To prevent the formation of condensation in the vegetable storage room, accelerating fans are suspended.

Results and Discussion

To automatically maintain the desired microclimate in the storage, an automatic control system is used, which is controlled by a computer and, using product and channel temperature sensors, internal and external humidity sensors, monitors the state of the microclimate in the vegetable storeroom [1,10,14].

The container type of storage is convenient in that it allows you to ensure a higher safety of the crop, monitor the quality of products in storage and promptly remove spoiled vegetables, provides more convenient loading, unloading of products and mechanization of most technological processes, and also makes it possible to store different types and varieties of vegetables in one storage or one chamber and unload part of the product without disturbing the temperature regime.

The types of vegetables that require special attention - carrots and cabbage - are stored in containers, as soon as with this method it is possible to achieve the necessary values of temperature, humidity and air exchange characteristics of the storage environment that do not change over time. Increasingly, this type of storage is used for potatoes, onions and garlic.

The ventilation system is fundamental and is used to dry, cure, lower and maintain the temperature of the product. The refrigeration system is used in cases of storage at high external temperatures (May, June) or in cases where the temperature of the product must be sharply lowered in a short period of time.

The mathematical description of thermal processes in the mass of stored products can be determined analytically from the equation for the dynamics of heat exchange between stored vegetables and ventilated air [7]. Heat transfer in the bulk of piece agricultural products is a complex physical phenomenon. The temperature on the surface of the product is determined not only by the intensity of heat removal from the surface, but also by its removal from the inner volume of the tuber. This component of heat is formed as a result of biochemical processes.

Heat exchange control taking into account internal sources and heat consumption for evaporation of moisture from the product can be written as follows:

$$CV(1-\mu)\frac{d\theta}{dt} = q - q_u - \alpha V(\theta - \theta_B), \qquad (1)$$

where C is the volumetric heat capacity of tubers, J / (m^3°C); V-layer volume of stored products, m^3 ; p is the duty cycle of the layer of stored products: for potatoes 0.38 ... 0.45; K_0 - tubers volume, m^3; θ is the temperature of tubers, °C; t - time, s; q is the amount of heat released in the volume of Vproduction per second, J / s; q_and-the amount of heat spent on evaporation of moisture w (kg / s) with the heat content of water vapor i (J / kg), J / s; α-volumetric heat transfer coefficient, J / (m^3°C); θ_B-air temperature in the intertubular space, °C. Move the components q and q_and to the left side of equation (1) and place V dθ / dt outside the brackets. Then

$$\left[C(1-\mu-\frac{q}{V}\frac{dt}{d\theta}+\frac{q_u}{V}\frac{dt}{d\theta}\right]V\frac{d\theta}{dt} = -\alpha V(\theta - \theta_B), \qquad (2)$$

Also, since all the quantities in parentheses on the left side of equation (2) have the dimension of the volumetric heat capacity [J / (m^3°C)], it can be represented as:

$$C_p\frac{d\theta}{dt} = -\alpha(\theta - \theta_B), \qquad (3)$$

Where C_p is the calculated volumetric heat capacity of the potato layer.

Passing to the operator form and transferring the terms containing θ to the left side, we get:

$$C_p p\theta/\alpha + \theta = \theta_B \qquad (4)$$

Then the transfer function of the process can be written as follows:

$$W(p) = \frac{1}{Tp+1}, \qquad (5)$$

Where$T = C_p/\alpha$.

The heat balance equation for air passing through a layer of tubers with a thickness h has the form:

$$C_в\mu\frac{d\theta_B}{dt} = \alpha(\theta - \theta_B) - C_B V\frac{d\theta_в}{dh}, \qquad (6)$$

Where $C_в$ is the volumetric heat capacity of air, J / (m^3 · °C); v is the air velocity equal to its quantity (m^3) passing through the cross section of the product layer (m^2) in 1 s, m / s.

From equations (2) and (6) it can be seen that the intensity of temperature change in the mass of products depends on the rate of passage of the supply air, the thickness of the layer h of the embankment of tubers, the duty cycle of the layer p, as well as on the initial values of the temperatures θ of tubers and $\theta_в$ of air.

Experience shows that the temperature of the supplied air and the tuber mound is not the same along the layer height. The layers of tubers are quickly cooled at the air inlet and 4 ... 5 times slower at the outlet from the four-meter layer of the potato mound. The highest temperature of the mass of the stored product is observed at a depth of 0.4 ... 0.6 m from the surface of the embankment.

The thermo physical properties of the tuber mound depend on its temperature and type. Due to the listed features, it is difficult to accurately determine the result of the joint solution of equations (3) and (6). Transfer functions of thermal processes in the mass of stored products can be determined from the acceleration curves.

It was found that when air supply L <50 m^3 / (t • h), that is, for 1 ton of tubers, the transfer function can be expressed as follows:

$$W(p) = \frac{k}{Tp+1}, \quad (7)$$

and at L <50 m^3 / (t • h)

$$W(p) = \frac{k}{T_2^2 p^2 + T_1 p + 1}. \quad (8)$$

С ростом подачи воздуха от 50 до 250 $м^3$/(т • ч) значение коэффициента передачи k снижается с 0,03 до 0,008. Коэффициент передачи k показывает, на сколько градусов снижается температура насыпи клубней за 1 ч при подаче 1 $м^3$ воздуха на 1 т клубней. Постоянные времени также зависят от подачи воздуха: при LL ≤< 50 $м^3$ /(т • ч) T= 7...8 ч, при L> 50...250 $м^3$ /(т • ч) $T_1 = 8 ... 6$ $ч$, $T_2^2 = 2 ... 1,6$ $ч$.
With an increase in air supply from 50 to 250 m^3 / (t • h), the value of the transmission coefficient k decreases from 0.03 to 0.008. The transfer coefficient k shows how many degrees the temperature of the tuber embankment decreases in 1 hour when 1 m^3 of air is supplied per 1 ton of tubers. The time constants also depend on the air supply: at LL≤ <50 m^3 / (t • h) T = 7 ... 8 h, at L> 50 ... 250 m^3 / (t • h) T_1 = 8 ... 6 hours, T^2_2 = 2 ... 1.6 hours.

When the ventilation is off, the temperature of the mass of the stored product rises due to the heat of self-heating. Transfer function of the product mass during self-heating without heat removal

$$W(p)=k_c/p, \quad (9)$$

Where k_c is the transfer coefficient, showing how many degrees the temperature of the product mass rises during 1 hour of self-heating without heat removal: for root crops $k_c = 0.14$, for cabbage $k_c = 0.13$.
The transfer function of the upper zone of the vegetable store can be determined from the differential equation of the heat balance:

$$CG\frac{d\theta}{dt} = q - \alpha F(\theta - \theta_B) - CG_B(\theta_B - \theta), \quad (10)$$

where C is the specific heat capacity of air, J / (kg · °C); G — air mass in the upper zone, kg; θ - is the air temperature in the upper zone, °C; q — heat release of products, J / s; a - coefficient of heat transfer of air to fences, J / (m^2 · s · °C); F- is the surface area of the fence, m^2; $G_в$ — specific air consumption at the entrance to the upper zone, kg / s; θ_0 is the temperature of the barriers, °C; $\theta_в$ - air temperature at the entrance to the upper zone, °C.

If, due to the lack of numerical values of the quantities included in equation (10), it is difficult to find an analytically quantitative expression of the transfer function, then the experimental acceleration curve should be removed and the transfer function of the upper zone should be determined from it. It is expressed by three components (according to the number of parallel acting disturbances):

$$W_1(p) = \frac{k_1}{T_1 p + 1}; \quad W_2(p) = \frac{k_2}{T_2 p + 1}; \quad W_3(p) = \frac{k_3}{T_3 p + 1}.$$

For a typical vegetable storehouse for 1000 tons, you can take $k_1 = 0.3$, $k_2 = 0.5$, $k_3 = 0.2$, $T_1 = 2.3$ h, $T_2 = 0.12$ h, $T_3 = 0.04$ h.

All vegetable stores with automatic microclimate control use a mixing device. As a control object, this device can be described by the thermal balance equation in increments:

$$C\theta_н \Delta G_н + C\theta_p \Delta G_p = C\Delta\theta_n G_n \quad (11)$$

где$\theta_н$иθ_p—temperature values for outdoor and recirculated air, respectively, ℃; $\Delta G_н = -\Delta G_p$ — increment of mixed amounts of outdoor and recirculated air, kg / s; $\Delta\theta_n$ — temperature increment, ℃; G_n — specific consumption of supply air, kg / s.

Taking into account these relations, equation (11) can be represented as:

$$\frac{\theta_н - \theta_p}{G_n} = \Delta G_н = \Delta\theta_n$$

from where to determine the transfer function of the mixing device, as an inertialess link:

$$W(p) = \frac{\Delta\theta_n}{G_н} = \frac{\Delta\theta_н - \theta_p}{G_n} = k \qquad (12)$$

The obtained mathematical expressions can be used when choosing elements of control devices, as well as when adjusting the regulators of automatic microclimate control systems in potato storages.

Fruit and vegetable storage designs have a lot in common. A feature of the technological process of storing fruit is the need to cool the product and precisely maintain the relative humidity of the air. Therefore, the automation scheme of the fruit storage equipment includes control systems for air cooling units and steam supply for humidifying the air in the chambers.

In fruit storage rooms (fruit storages), the concentration of carbon dioxide is maintained at a level significantly higher than in the atmospheric air, reaching 1% or more. In this case, the oxygen content decreases, while the nitrogen content increases. These circumstances improve the storage conditions for fruits. The CO2 content is regulated by passing the circulation air through the milk of lime or by burning the gas with a controlled air supply. The resulting gas mixture, enriched in nitrogen, is cooled and fed to the storage. The recommended storage temperature - less than 5 ° C, but not lower than the freezing temperature of the fruit - must be maintained with high accuracy. It is also of great importance to control the moisture content of the gas mixture, on which the moisture loss of stored fruits depends and the control of the ethylene gas content emitted by the fruits.

For fruit storages with a capacity of 1000 ... 3000 tons, a set of electrical equipment has been developed, which provides automatic control of the operation of condensing and evaporation equipment, control of the operation and protection of refrigerating machine compressors from emergency modes and signaling of normal and abnormal operating modes of equipment. One set can automatically control two to four cameras

The automatic microclimate control system is designed to maintain the specified values of temperature, humidity in the chambers, and its cyclic mixing in the chambers; switching on and off supply and exhaust ventilation units, ammonia and water pumps; defrosting air coolers, as well as to control the temperature and humidity in the chambers and the temperature at individual points of the refrigeration unit [1].

Active ventilation allows you to maintain optimal temperature and humidity conditions in the storage facilities. At the same time, it removes moisture from the surface of vegetables, and respiratory products from their mass, leading to the development of pathogens.

Air is supplied to the mass of the stored product using supply ventilation systems equipped with centrifugal or axial fans. The operating mode of the ventilation system depends on the outside temperature, the type and weight of the stored product. To reduce the temperature of the stored product, the outside air is blown by a fan through the supply shaft along the ventilation duct into the product mass. At unacceptably low and high outdoor temperatures, the fan drives internal (recirculated) air through the product, and the supply chamber is closed by a valve at this time.

In the technological process of storing potatoes, three periods can be distinguished: treatment, cooling and storage. The treatment period is necessary for the rapid healing of mechanical damage to the potato. For this purpose, in the inter-tuber space of the embankment, it is necessary to maintain the temperature at 14 ... 18 ° C and high relative humidity (more than 90%) with minimal air exchange. At a potato temperature above 18 ° C, the active ventilation system should be turned on and air should be supplied with a temperature of 3 ... 4 ° C below the temperature of the mass of the stored product. If diseased potatoes (affected by late blight, nematode, etc.) are laid in the storage bin, then the treatment period is carried out at a temperature of 8 ... 10 ° C, followed by cooling to 1 ... 2 ° C. When laying wet potatoes, they are immediately dried with enhanced active ventilation at a relative humidity of not more than 80%.

$$W(p) = \frac{k}{Tp+1} \qquad (13)$$

and at L <50 m^3 / (t • h) tubers transfer function can be expressed as follows:

$$W(p) = \frac{k}{T_2^2 p^2 + T_1 p + 1} \qquad (14)$$

The cooling period begins after a two-week treatment period, the temperature of the stored potatoes is gradually reduced to 2 ... 4 ° C. For this, potato tubers are ventilated with outside air or with a mixture of it with internal air during those periods of the day when the outside air temperature is at least 4 ... 5 ° C lower than the temperature of the potato mound. The tubers are cooled slowly: by 0.5 ... 0.6 ° C per day at a maximum air humidity of up to 100%. The cooling period lasts 20 ... 25 days.

The storage period (main) begins at a temperature of potatoes in the embankment of 3 ... 4 ° C. Ventilation units are switched on when the temperature in the embankment is 4 ° C or more. In winter, the product is actively ventilated with a mixture of outside and inside air, and in severe frosts - only with recirculated air. In all cases, the relative humidity should be maximum, but without condensation on the potatoes. At low humidity of the ventilation air, large losses of mass of tubers occur, and they lose their presentation. Similar agro technical requirements are imposed on the automatic microclimate control system of other vegetable stores.

In the "Treatment" and "Cooling" modes, the temperature of the mass of stored products is always higher than the set one, and the duration of the active ventilation system operation depends on the setting of the program relays and the outside air temperature, as well as on the mass of the stored products. When developing and choosing automation systems, it is necessary to know the transfer functions of the mass of the stored products and the upper zone in the main "Storage" mode.

The intensity of temperature change in the mass of products depends on the rate of passage of the supply air, the thickness of the layer h of the tuber embankment, the duty cycle of the layer μ, as well as on the initial values of the temperatures of the tubers Ө and air ӨB. Experience shows that the temperature of the supplied air and the rash of tubers is not the same in the height of the layer. The layers of tubers are quickly cooled at the air inlet and 4 ... 5 times slower at the outlet of the four-meter layer of the potato mound. The highest temperature of the mass of the stored product is observed at a depth of 0.4 ... 0.6 m from the surface of the embankment.

It was found that with air supply L <50 m^3 / h per 1 ton of embankment.

With an increase in air supply from 50 to 250 m^3 / (t • h), the value of the gain k decreases from 0.03 to 0.008. The gain k shows how many degrees the temperature of the tuber mound decreases in 1 hour when 1 m3 of air is supplied per 1 ton of tubers. The time constants T also depend on the air supply: at L ≤ 50m^3 / (h • t) T = 7 ... 8 h; at L≥50 ... 250 m^3 / (t•h) T_1 = 8 ... 6 h, T_2 = 2 ... 1.6 h.

When the ventilation is off, the temperature of the mass of the stored product rises due to the heat of self-heating. Transfer function of the product mass during self-heating without heat removal.

$$W(p) = k_c/\mathrm{p}$$

Where k_c — gain, showing how many degrees the temperature of the product mass rises for 1 hour of selfheating without heat removal: for root crops k_C = 0,14, for cabbage k_C = 0,13.

The transfer function of the upper zone of the vegetable store is expressed by three components (according to the number of parallel acting disturbances), namely, for a typical vegetable store with a capacity of 1000 tons, the following values of the coefficients can be taken: k_1 = 0,3; k_2 = 0,5; T_1 = 2,3 handT$_2$ = 0,12 h.

The transfer function of the mixing chamber in all vegetable storage facilities with automatic microclimate control uses a mixing chamber with an adjustable valve, the transfer function of which is defined as for an amplifying link: W(p) = k.

Automatic humidity control is rarely used due to the lack of sensors operating at a relative humidity of more than 90%. If necessary, the humidity is controlled manually by turning on the exhaust fans.

Conclusions

For fruit storages with a capacity from 1000 to 3000 tons, a set of electrical equipment has been developed, which provides automatic control of the microclimate in fruit storage chambers, control of the operation of condensing and evaporation equipment, control of operation and protection of refrigeration machine compressors from emergency modes, signaling about the operating modes of the equipment (Fig. 1). One set can automatically control two to four cameras.

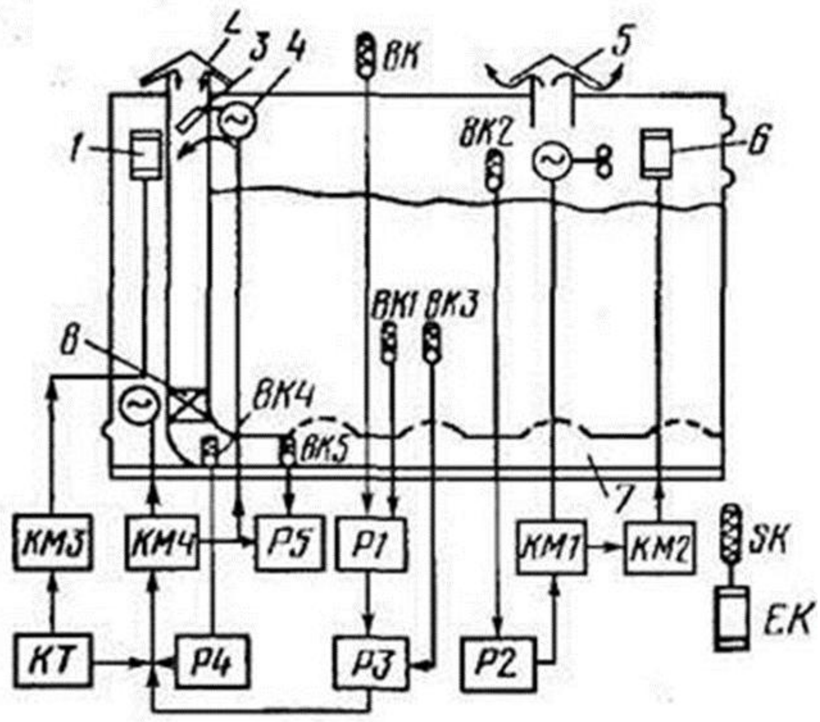

Fig. 1. Technological diagram of automatic control of temperature conditions in a vegetable store: 1- heater; 2, 5 - supply and exhaust shafts, respectively; 3 - mixing valve; 4 - executive mechanism.

A prerequisite for storing vegetables is a special temperature regime. For this, refrigeration technology is used. For air recirculation in vegetable stores, a ventilation system is required. Its control system will automatically control ventilation parameters at different times of the year, regulate humidity. The system for monitoring and controlling the microclimate of the vegetable storehouse allows you to control the temperature and humidity, simultaneously controlling the operation of the refrigeration and ventilation systems. Refrigeration units for vegetable stores automatically maintain the required temperature, their control system controls the operation of the compressor, air coolers and condensers. The monitoring function of modern refrigeration equipment will allow the owner of a vegetable store or a service organization to remotely monitor the temperature and operation of refrigeration units. And in the event of an emergency situation, quickly take the necessary measures.

The microclimate control system controls all the necessary technological equipment: dampers, EC fans, valves, jet fans, heaters, metering devices, shut-off valves for the gas medium. Placement of additional equipment: humidifiers, ozonizers, refrigerators - allows you to increase the shelf life and improve the quality of products [3,4,5, 19].

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Information about the authors:

[1]. Yakubov Sabir Khalmuradovich - Doctor of Technical Sciences, Professor of Karshi State University
[2]. PirovaRashidaKudratovna - Lecturer of the Department of Applied Mathematics, Karshi State University