Research of different heating modes of greenhouses

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Abstract. The article discusses ways to maintain a microclimate in greenhouse complexes. It is the most important task for growing various crops. The required temperature regime in the greenhouse is maintained according to weather conditions using a water heating system. The article presents an analysis of methods for regulating the consumption of thermal energy to identify the advantages and disadvantages of each of them. The review of tendencies in the field of regulation of heat consumption is carried out. The main direction of modernization of the modern system of regulation of heat energy consumption has been formed and considered.

1. Introduction

Specialized farms are created to supply the population with fresh vegetables. Shelving and ground greenhouses and greenhouses are being erected on their territory. That structures protect the soil from external factors. Greenhouse heating is one of the most important elements for growing various crops. It helps to maintain a certain temperature regime, which is important for plants. As a result, 2-3 harvests per year can be harvested [1].

The required temperature conditions in greenhouses are maintained by various heating systems such as: water heating, air heating, electric heating. Water heating is the most affordable option for maintaining the required temperature conditions in greenhouses. Hot water is used as a heat carrier in water heating systems. The constituent components of a water heating system are the water heating boiler, pipes, heat exchangers, radiators and automation such as thermostats and sensors. Heating devices are placed at the outer vertical longitudinal and end walls. Radiators and smooth pipes located along the walls, under the racks and in the upper area of the greenhouses under the glazing (figure 1) [2]. The location of the heating pipes under the glazing contributes to the quickest release of the greenhouse cover from snow.

The principle of operation of water heating is that the heat carrier leaving the boiler enters the heat exchanger, where it heats the internal heat carrier from 30°C to 40°C. Further, the heated internal heat carrier enters the pipe system and heats the main heat pipe and pipes for heating the soil. This system is considered traditional. The advantages of this system are such factors as:

- Even distribution of heat, which has a positive effect on plants;
- Simultaneous heating of air and soil;
- Low operating costs.
Figure 1. Location of heating pipes in the greenhouse:
a – ground greenhouse;
b – shelving greenhouse;
1 – main heating pipe for hot water;
2 – pipes for heating the soil.

It should also be noted that an optimal microclimate is established and maintained in the greenhouse. Air does not dry out in that climate. The disadvantages of hot water heating of greenhouses are the complexity of the installation of the pipe system and the need for constant monitoring of the subsoil [3].

It is necessary to reduce energy losses in the heat supply system for more efficient use of the water heating system. Most of the losses are associated with the uneven distribution of heat energy over the heat consumption object and with the inconsistency of the nature of heating with the current weather conditions. This article will consider methods for regulating the release of heat. It will allow more efficient use of the water heating system [4].

The article is devoted to the analysis of methods for regulating the consumption of thermal energy. The advantages and disadvantages of each method were considered. In this regard, the following tasks have been identified:

- An overview of historical and modern methods of regulating heat consumption;
- An overview of trends in the regulation of heat consumption;
- An overview of possible directions of modernization of modern control systems.

2. Materials and methods

The heat load of greenhouses varies depending on the outside air temperature. Corrections for the influence of the sun, wind, changes in absolute air humidity, water consumption for watering greenhouse plants and a number of other factors are also taken into account. Thus, it is necessary to use appropriate methods for regulating the supply of heat to ensure a high quality of heat supply to greenhouse complexes and for the efficiency of operation of heat supply systems [5]. There are central, group, local and individual forms of regulation. Individual regulation of heat consumption has not become widespread due to the significant costs of installing regulators and the need to reconstruct existing heat-consuming installations. Combined regulation should be used to ensure a high level of reliability and efficiency of operation of heat supply systems. It consists of a combination of two stages of regulation - central and group stages or central and local stages.

There are three methods of central regulation of heat supply:

- Qualitative, which is carried out by changing the temperature of the coolant at the outlet of the boiler unit at its constant consumption to the consumer;
- Quantitative, which is carried out by consist in changing the flow rate of the coolant through the boiler unit without changing its outlet temperature;
- Qualitative and quantitative, which carried out by consist in a simultaneous change in the flow rate and temperature of the coolant.
The use of a high-quality control method allows to provide the stability of the hydraulic regime of the heating network and the ability to connect greenhouses according to a dependent scheme with a mixing device. This scheme is the most affordable, reliable and easy [6]. There are some disadvantages of using the qualitative method for regulating heat supply in comparison with the quantitative method, for example:

- Higher power consumption for the transportation of coolant. This is due to the fact that with quantitative control the flow rate of the coolant changes and accordingly the consumption of electrical energy for the pump drive also changes. The flow rate of the coolant assumed to be constant and equal to maximum possible value according to the temperature regime with qualitative control model.
- High intensity of pipeline corrosion. The temperature difference of the coolant in different sections of the metal pipeline causes various thermal expansions and internal structural stresses. This leads to the formation of microgalvanic couples with the subsequent destruction of the metal.
- Transport lag in the regulation of heat load. It is characterized by the thermal inertia of the heating network and arising due to the duration of movement of water masses heated to a different temperature over considerable distances.
- Unprofitable use of centralized weather regulation due to the thermal inertia of the heating network. An attempt at centralized weather quality control will lead to a sharp decrease in the quality of heat supply and fluctuations in air temperature in the building.

The implementation of quantitative and qualitative-quantitative methods for regulating heat supply allows partially reducing the disadvantages inherent in the qualitative method of regulation [7]. The advantages of using qualitative and qualitative-quantitative methods of regulation include following factors:

- Energy savings for the transportation of the coolant arise. It is associated with the operation of the heat supply system with reduced consumption of network water for most of the heating period.
- Less inertia of heat load regulation occurs. It is expressed in the fact that the hydraulic effect spreads through the heating network faster than the temperature one.
- Reduction of corrosion damage to pipelines of heating networks occurs. It is associated with the constant temperature of the coolant in the supply line.

An important indicator of the operation of the heat supply system is the coefficient of hydraulic stability $Y$ [8]. This coefficient is equal to the ratio of the actual flow of heating water through the heat-consuming installation $V'$ to the maximum possible (calculated) flow through it $V_{\text{max}}$ (1):

$$ Y = \frac{V'}{V_{\text{max}}} \quad (1) $$

The deviation of the actual flow rate of the coolant at the consumer input from the calculated value leads to hydraulic misalignment of the subscriber systems. The value of the hydraulic stability coefficient can also be determined by the following formula (2):

$$ Y = \frac{\Delta P_c}{P_p} = \sqrt{\frac{\Delta P_c}{\Delta P_c + \Delta P_n}} \quad (2) $$

Where $\Delta P_c$ – pressure at the consumer input at the calculated value of the heat carrier flow;
$P_p = \Delta P_c + \Delta P_n$ – pressure of the network pump;
$\Delta P_c$ – pressure loss in the heating network at design mode;
$\Delta P_n$ – pressure loss in the main networks.
It follows from formula (2) that the coefficient of hydraulic stability of the heat supply system is directly proportional to the value of the hydraulic resistance of heat-consuming installations of greenhouse complexes $\Delta P_c$ and inversely proportional to the value of pressure losses in the main heating networks $\Delta P_n$. Thus, it becomes necessary to reduce pressure losses in the main networks and to increase the hydraulic resistance of the heat-consuming installations of greenhouse complexes in order to increase the hydraulic stability of the system. For this, it is advisable to install throttle and control valves at the inputs of consumer units, which create local pressure losses at the consumer input.

3. Results
Currently, one of the most common methods for automating heat consumption regulation is the installation of an individual heating point (IHP) directly at the consumer. Installation of IHP’s implies the presence of a separate room. Most often they are mounted in technical rooms, annexes or detached buildings located in the immediate vicinity of the consumer. As standard, the IHP includes the following devices:

- Heat exchangers;
- Shut-off and control valves;
- Devices for monitoring and measuring the parameters of the coolant;
- Pump equipment;
- Control panels and controllers.

The district heating system does not take into account the nature of an individual building as an object of regulation of heat consumption. The use of an automated system for regulating the consumption of heat at the consumer can reduce the consumption of thermal energy by 15-30% due to a number of factors:

- Application of the temperature regime in industrial and administrative buildings at night and during non-working hours can reduce heating costs for 10-14 hours per day;
- Elimination of heat overruns in the autumn-spring period due to the installation of a weather regulator allows to reduce heat overruns while reducing the actual difference between the external and internal temperatures relative to the design one.

When the outside air temperature fluctuates, the boiler houses switch to a new mode very slowly and maintain the temperature in the network above that required to prevent freezing of the heating main pipe. Using the sensors of the weather controller, the outside air temperature and the temperature of the heat carrier in the heating network are measured. The programmable controller calculates the delta of the coolant temperature in the heating network and the required temperature of the coolant in the heating circuit according to weather conditions at a particular time. The regulation of heat consumption can be done in two ways: qualitative (by changing the temperature of the coolant) and quantitative (by changing the flow rate of the coolant).

Qualitative regulation consists in changing the temperature parameters of the coolant by mixing it from the return line with lower temperature parameters into the supply pipeline by installing a mixing device with a check valve.

The quantitative method of regulation is carried out in two ways: analog (continuous) method and digital (pulse) method.

The analog (continuous) method of quantitative control consists in changing the flow rate of the heating medium through the heating devices by acting on the control valve to change the flow rate of the heating medium.

The digital (pulse) method consists in periodically stopping and resuming the supply of the coolant to the consumer's heating system according to a predetermined algorithm (regulation by gaps).
implement such regulation, a solenoid valve is used related to the individual heating point shut-off valves. However, this method has a significant drawback: closing the solenoid valve (when the coolant supply is interrupted) violates the thermal balance of the building and causes a hydraulic misalignment of the heating system, creating pressure surges of the coolant both in the heating network and in the heating system of the greenhouse complex [9]. Differential pressure regulators that are installed at the consumers inputs are not able to smooth out sudden pressure surges in the system due to the inertia of the pressure pulse transmission to the diaphragm boxes of these regulators. Thus, the regulation by gaps has a number of significant drawbacks. It lead to the loss of the obtained financial benefit due to the additional costs of maintaining and repairing heating networks and heating systems.

4. Discussion

As it mentioned [10], the main disadvantage of using quantitative and qualitative-quantitative methods for regulating heat supply is the hydraulically variable operating mode of heating networks. A change in the flow rate of the coolant leads to a change in pressure in the heat supply system. Thus, the thermal regime and the hydraulic regime of the greenhouses are violated. When developing the hydraulic regime the main condition is to ensure the necessary available pressure from the condition of normal operation of heat-consuming objects. The pressure at any point of pipeline must ensure that the system is filled with a coolant. The pressure must not to exceed the permissible strength of heat-consuming plants and pipelines of the heating network [11]. The maximum pressure should be limited to prevent water boiling. To fulfill this condition, the pressure developed by the pumps in the heat source pipelines must ensure that the hydraulic resistances of the network and heat consumption systems are overcome.

5. Conclusion

Combined regulation is carried out due to the heterogeneity of parameters of the coolant and the nature of the consumption of the heat load in modern heating systems of greenhouse complex (central regulation is supplemented by regulation on the individual heating point). The use of individual heating point really helped to improve the quality of heat supply due to the adaptation of the temperature parameters from the heat source to the needs of the heating systems of each greenhouse complex. However, the installation of an individual heating point to automate the regulation of heat consumption also has a number of disadvantages.

One of the most significant disadvantages is the high cost of equipment, handling and transportation. The individual heating point installation presupposes the availability of the required construction area for placing equipment at each heat consumer. An important disadvantage of using individual heating point is the dependence on the supply of electrical energy. The supply of the heating agent to the heater is interrupted in the event of a power outage of the consumer. Control panel is an important element of the technological scheme of an individual heating point. The main function of the control panel is to regulate the flow rate and temperature of the coolant. There is also a shortage of qualified specialists to service for the installation and maintenance individual heating point.

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