Development of microclimate control system in cattle barns for cattle housing in the Perm region

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Abstract. The economic efficiency of intensive livestock farming on an industrial basis depends on the rational housing of animals, which is largely determined by the presence of an optimal microclimate in the premises. Whatever breed and pedigree qualities the animals may have, without creating the necessary microclimate conditions they are unable to maintain their health and show their potential productive capabilities due to heredity. Between 2018 and 2020, 11 farms in Perm Region were surveyed for respiratory and digestive diseases, skin diseases, and in some cases stress was observed in the animals. The costs of heating livestock buildings are, as a rule, much lower than the losses due to mortality, loss of productivity and overconsumption of feed. The physical properties of the air environment are factors that are not constant and are subject to large fluctuations. To optimize the microclimate in a livestock building, a program algorithm has been developed for a computer. That will create a system, which provides optimal conditions for the maintenance and service of animals and increase the life safety on livestock farms. In this regard, in order to improve conditions for keeping calves and cows, a project for a device to control the parameters of the microclimate in farms in the Perm region has been developed. The microclimate control system is developed on the basis of: Order of the Ministry of Agriculture of the Russian Federation from October 21, 2000 № 622 "On approval of Veterinary rules of keeping cattle for its reproduction, rearing and realization" and Set of rules 106.13330.2012 "Cattle-breeding, poultry-breeding and beast-breeding buildings and premises". At the heart of the monitoring is an automated analysis and regulation of microclimate parameters. Hardware-software implementation is made on PLC Omron.

1. Introduction
The production of meat and dairy products is an important link for human livelihood. At present, farms are being modernized to improve the profitability of livestock products [1-3]. The introduction of automation in the calf feeding farms of Perm Region is also an urgent task. The climatic zone of Perm region in recent years is characterized by great variability, for example in 2020 there was an abnormal summer heat, in 2018 on the contrary there was a cold rainy summer, in February 2021 there was a cooling to −30 °C, which is much lower than the average temperature during this period, in this
connection, the solution of the problem of normalizing the microclimate in cattle housing in the Perm region is an important task. The influence of microclimate is manifested through the total impact of its parameters on the physiological state, heat exchange, health and productivity of animals [4,5]. When keeping cattle, there are specific temperature-humidity regimes of microclimate, in which animals feel comfortable and have the highest productivity. For cows with high milk yield the comfort zone is in the range of +9 to +16 °C. If these parameters are not respected, there is a decrease in productivity. For example, when the air temperature in the cow's room is 25 °C, the animals lose up to 17%, and at 30 °C they lose about 33% of their productivity. Lowering the air temperature is much easier for cows, at 5°C milk losses can be up to 14%. Air temperature should always be considered in conjunction with humidity. For example, while at a relative humidity of 60% the limit of normal well-being is up to 28°C, at a humidity of 80% it drops to 23°C. It is especially important to comply with the requirements for the microclimate in the rearing of young animals. Even a short-term deviation of air temperature from the permissible temperature can lead to the death of animals or cause massive colds.

2. Equipment and devices used in studies
The regulatory framework governing the microclimate of the premises for cattle were documents: Set of rules 106.13330.2012 - Cattle - breeding, poultry - breeding and beast - breeding buildings and premises and Order No. 622 of October 21, 2020 Ministry of Agriculture of the Russian Federation. During the construction of the microclimate control system we used the theory of finite state machines, IEC 61131-3 is the third part of the open international standard IEC 61131 for programmable logic controllers. The hardware-software implementation is made with the Omron CP1H PLC.

3. The results of the study and their discussion

3.1. Main parameters of the microclimate in livestock buildings
The main parameters of the microclimate, according to the Set of rules (SR) 106.13330.2012, include: temperature, relative humidity, air exchange and air speed. Order № 622 in addition to SR regulates the direction: dairy or meat production of livestock.

We will describe the parameters of the microclimate with the function MC(T, V, W), and the array of equipment with the function ENG(H, C, F, M). To maintain the necessary conditions of the microclimate it is necessary to use technological equipment: to maintain the temperature (T) – a heat gun (Heater) in winter or air conditioner (Cooler) in summer, to control the speed of air (V) and air exchange – ventilation system (Fun), to control humidity (W) – moisturizer (Moisturizer) [6,7].

To develop the computer program, let's set the system of memory addresses of the device and the input-output unit (CIO) (table 1).

3.2. Development of the technological map of microclimate management
In accordance with the methodological recommendations of the above normative documents developed a graph-scheme of technological map of microclimate control (figure 1).
Table 1. Address system of the device memory and I/O unit of the climate monitoring and control system.

| №  | Sensor and equipment system | Designation | Controller memory address | I/O unit |
|----|-----------------------------|-------------|----------------------------|----------|
| 1  | Air Speed (m/sec.)          | V           | Current                    | D 300    |
|    |                             | Vmin        | Min                        | D 305    |
|    |                             | Vmax        | Max                        | D 306    |
| 2  | Air Humidity (%)            | W           | Current                    | D 100    |
|    |                             | Wmin        | Min                        | D 105    |
|    |                             | Wmax        | Max                        | D 106    |
| 3  | Temperature (°C)            | T           | Current                    | D 200    |
|    |                             | T min       | Min                        | D 205    |
|    |                             | T max       | Max                        | D 206    |
| 4  | Heater                      | H           |                            | 100.10   |
| 5  | Moisturizer                 | M           |                            | 100.11   |
| 6  | Fun                         | F           |                            | 100.09   |
| 7  | Cooler                      | C           |                            | 100.08   |
| 8  | Season switch               | S           |                            | 0.03     |
| 9  | Manual/ Automatic control mode | Avt        |                            | 4.00     |
| 10 | Meat / Bossy                | MB          |                            | 0.04     |

3.3. Making logical equations and developing software for equipment operation

Logical equations for monitoring the microclimate parameters and equipment control are shown in table 2.

Table 2. Block of logical equations for dairy winter season.

| Logical equations                                                                 | Equipment |
|----------------------------------------------------------------------------------|-----------|
| \((\overline{Avt} \lor (Avt \cdot \overline{S} \cdot MB)(H \lor (T < T_{min}))(T < T_{max})) = H\) | Heater    |
| \((\overline{Avt} \lor (Avt \cdot \overline{S} \cdot MB)(C \lor (T > T_{max}))(T > T_{min})) = C\) | Cooler    |
| \((\overline{Avt} \lor (Avt \cdot \overline{S} \cdot MB)(M \lor (W < W_{min}))(W < W_{max})) = M\) | Moisturizer |
| \((\overline{Avt} \lor (Avt \cdot \overline{S} \cdot MB)(F \lor (V < V_{min}))(V < V_{max})) = F\) | Fun       |

The ladder diagram is based on the IEC 61131-3 standard. Fragments of the relay-contact diagram for the Omron controller [7,8] are shown in figure 2.
Figure 2. Fragments of Ladder Diagram.

For the convenience of controlling the microclimate parameters, a program interface was developed that includes a parameter monitoring block and a block of control keys (figure 3). The interface of the farmer-operator program is shown in figure 3.
3.4. Program operation simulation

To verify the functionality of the program, a simulation of the main control units of the equipment was carried out. An example of the operation of the room heater in different temperature modes is shown in table 3.

Table 3. Simulation of the operation of the room heater at different temperature regimes.

| Clarification                                                                 | Simulation |
|------------------------------------------------------------------------------|------------|
| The air temperature is 80°C, the lower and upper temperature limit condition operators are active. | ![Diagram](image) |
| The air temperature exceeded the lower threshold, the heater is controlled by the blocking branch of the equipment. | ![Diagram](image) |
4. Conclusions
The work substantiates the need to maintain the necessary parameters of the microclimate in livestock buildings when keeping cattle. Software was developed to implement the algorithms of microclimate control. The simulation of the program showed that the scheme works correctly. The implementation of the developed software and hardware will contribute to the economic efficiency of farms.

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