Energy-saving automated IR heater for calves

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Abstract. The analysis of local infrared (IR) heaters of young animals with an assessment of their energy efficiency is carried out. Energy saving infra-red heater with regulated heat flow depending on position of animal, for calves, has been designed. The fittings and the reflector of the IR heater allow the use of various heating elements. Electrical circuit diagram of automatic control unit of energy-saving IR heater for prophylactorium period calves, in single penning breeding technology, has been described. The outlay of installation with electric heater has been described and an example of irradiance calculation has been presented. Mathematical expression for calculating irradiance from electric radiant heater, in particular point on the heated surface, has been defined by experiments. It was found that the proposed design and heater control scheme provide a reduction in energy consumption by up to 35% compared to traditional methods of maintaining the temperature in the area where the calves are located.

1. Introduction
The following weak points of the majority of existing infra-red heater designs [1-3], in Russia and abroad, have to be mentioned: inconsistence of the surface area heated by radiation source compared to standard zones where young cattle is kept (quarters, hutchs, cubicles, etc.) resulting in inhomogeneous heat flow distribution over a particular area (150 W/m² to 250 W/m²) and partial dissipation of heat flow outside zones where animals are found thus reducing the efficiency of radiation use [4], non-compliance with the conditions of aggressive ambience of cattle-breeding premises, complicated design [5]. Unlike household general purpose industrial grade products, domestic industry does not produce, in serial scale, ‘dark’ agricultural radiators for heating young cattle. That is why radiation sources with the use of inexpensive infra-red specular lamps of type (IRSB) are widely applied today though it is not a proper solution, in many cases [5-7]. Besides, a principal disadvantage of practically all existing structures of IR radiation sources is that they are not completely designed for the purpose of heating calves [8-10]. According to observations by livestock experts, calves are laying down during approx. 50 % to 60 % of hours while the rest of the time they stand on their hooves. The height of caves at the withers is 2 to 2.5 times greater compared, for example, to piglets. In this position, animal’s back is located rather close to a radiant surface of IR heater installed above. It may result in overheating of animals associated with unreasonable energy consumption. To a greater extent it can be observed for cattle breeding with the use of individual hutchs.

2. Objective
Designing IR-heater, for calves, with homogeneous heat flow regulated depending on the animal position. In this concept, capacity of the heating element of IR heater can be reduced 1.3 to 1.4 times.
3. Development of an IR heater for calves

On the base of IR heater of type REH (radiant electric heater) with standard heating elements (tubular electric heater, micaceous laminate, quartz tube) [11] and individual hutch for calves [12], technical parameters (see table 1) and operation conditions have been determined and the energy saving unit for heating calves of prophylactorium period has been designed (figure 1).

Table 1. Technical parameters of IR heater.

| Parameter                           | Unit | Value         |
|-------------------------------------|------|---------------|
| Capacity of radiator, not exceeding | W    | 250           |
| Output power control range          | %    | 40 to 100     |
| Surface temperature of heating element | °C  | 600           |
| Dimensions of radiator             | mm   | 500×170×100   |
| Weight of radiator                 | kg   | 3.0           |
| Dimensions of hutch                 | mm   | 1200×520×1300 |

A required value of heat flow for calf heating is maintained automatically by controlling the output power of heating element with the regard of animal position (either vertical or horizontal). IR heater generates and directs the heat flow towards the area where calf is located insuring the uniformity of temperature field over the entire surface of animal position. Owing to such approach animal safety and productivity (gain in weight) can be increased, while the consumption of fodder per unit of weight gain can be reduced, thus improving the efficiency of the installation.

Electric circuit diagram of the automatic control unit of IR heater is shown in figure 2.

Since the heating element of energy saving infra-red electric heater for calves operates in its low output power mode during approx. one half of the hours its lifespan can be increased significantly (to 16,000 hours). Unlike other heating principles applied today for newly-born calves, he developed design structure ensures energy consumption by down to 35 %. This heater installation can be easily integrated into the complexes of industrial equipment (individual hutches and cubicles) designed for calf breeding and managing.

Electric circuit diagram of the automatic control unit of IR heater is shown in figure 2.
With the help of automatic switch QF1 voltage is applied to the electric control circuits of symistor VS1 and to the sensor of animal position PCBB (comprising photoemitter and photoreceiver integrated into one device), via transformer TV1 and rectifier VD1-VD4.

The maximum heat flow of the radiator is required when calves are in their horizontal position. In this operation mode, power is supplied to terminal 2 via the internal switch of animal position sensor PCBB, LED VD6 'max' is switched on signifying that the maximum voltage is applied to radiator ЕK1, and heater emits its full power. In this case, radiator is fed via normally closed contact of relay KL1.1 that shunts symistor VS1.

![Diagram](image)

Figure 2. Circuit diagram of automatic controller of IR heater for calves. VS1 – symistor, VS2 – dinistor, VD1-VD4 – rectifier, VD5-VD7 – LEDs, TV1 – step-down transformer 220V/24V, KL1 – DC relay, PCBB – diffusive sensor of animal position, QF1 – switch, C – condensers, R – resistors.

When calf changes its position (vertical position) animal position sensor PCBB activates and applies voltage to the winding of relay KL1 via terminal 4 of the sensor. Its contact KL1.1 opens thus connecting radiator ЕK1 to mains voltage via symistor VS1. Symistor opening degree is controlled with the help of adjustable resistor R2 in order to change voltage applied to radiator ЕK1 and, consequently, power consumed by the radiator and the heat flow directed towards the zone where animal (calf) is found. LED VD7 'min' indicates operation of heater (radiator) in its low-power mode.

Heater has to be suspended above calf at the height defined by the solution of heat balance equation, for the system comprising animal and environment (maintaining conditions and technology, season of the year, animal age etc.) [13].

Irradiance \( E \) (or heat flux density) can be calculated with the application of the method described in [14,15].

\[
t_0 = t_{pr.r} + k_1k_2E,
\]

where \( t_0 \) is apparent temperature (°C), \( t_{pr.r} \) is resultant temperature in premises (°C), \( k_1=0.95 \), \( k_2=0.04 \).
\[ t_{pr,r} = 0.5(t_a + t_w), \]

where \( t_a \) is air temperature in premises (°C), \( t_w \) is temperature of walls (°C).

For calves in the age of 1 to 2 weeks, temperature \( t_0 \) shall be equal to 16 °C to 20 °C, in zones where they are found.

For \( t_0 = 18 \) °C, irradiance \( E \) is about 185 W/m².

For radiators of type REH having capacity of 250 W, the following expression can be applied deduced from the results of our experiments for calculating the required heat flow, in a particular point \( r \):

\[ E = 512.6 - 350.3r - 535.1h + 321rh - 0.3r^2 + 148h^2, \]

where \( h \) is suspension height of heater above animal (m), \( r \) is distance (m) from the projection of the central axis of suspended heater onto the plane to a measuring point on the same plane.

Figure 3 shows graphs of the heat flux density on the irradiating surface, obtained experimentally from an IR lamp and a radiant electric heater with a power of 250 W. The height of the heater suspension was 0.8 m from the floor level. The new design of the irradiator provides a more uniform heat flux on a given surface, the area of which corresponds to the floor area of the cage for keeping calves. The uniformity of the heat flux is ensured by a special profile of the linear heating element reflector.

4. Conclusion

For calves of prophylactorium period managed in individual hutches, our design of IR heater insures energy consumption reduction by to 35 % compared to conventional methods of animal management with the use of heaters built on the basis of various infra-red lamps (tungsten, halogen, etc.), carboxylic, quartz, ceramic and other heaters. Energy saving effect is achieved mainly owing to the control of heat flow depending on animal position, as well as owing to homogeneous heat flow distribution, in the area where animal is found.
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