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# Combined Heating Systems of Premises For Breeding of Young Pigs And Poultry

*The use of traditional air heating systems in conjunction with supply ventilation for breeding of young animals in industrial conditions is not sufficiently effective. Their work is based on providing the necessary temperature regime indoors, creating a large air exchange and, as a result, increasing the thermal load on the ventilation system. To increase the productivity of livestock production and reducing the energy consumption of heating system it is expedient to create separate zones for the breeding of young animals with combined heating systems. The purpose of the study was to determine the efficiency of combined heating systems with infra-red heater and inlet ventilation system with the keeping of young pigs and poultry.*

***Keywords:*** *pigs and poultry breeding, infrared heating, air distributor, relative air temperature, heat capacity.*

## 1. INTRODUCTION

The main source of increasing production and improving the quality of agricultural products is the specialized breeding of meat of young pigs, chickens, etc. It is based on the use of advanced non- trans–plantable, low-cost technologies at local breeding of animals using process equipment, which ensures high productivity of production and at the same time considerable energy savings.

The peculiarity of technological process in the breeding of young animals and poultry lies in the need to provide a dynamic temperature mode in pig farms and poultry houses. In this case, the air temperature should change constantly as the animals grow.

The use of traditional air heating systems in conjunction with supply ventilation for breeding of young animals in industrial conditions is not sufficiently effective. Their work is based on providing the necessary temperature regime indoors, creating a large air exchange and, as a result, increasing the thermal load on the ventilation system. In addition, such system of heat providing promotes rapid dissemination of infection in the agricultural complex, which is a negative phenomenon in the breeding of young animals.

In the premises of livestock breeding complexes, such as pig farms and poultry houses, it is necessary to provide an air movement and its exchange, especially in places where animals are located and where the most intense allocation of moisture and harmful substances occurs [1,2].

Appropriate air treatment devices can become necessary to optimize the indoor climate of confined livestock buildings because of a high inlet air temperature, whereas the thermal stress of the body is accompanied by performance depressions (e.g. daily weight gain, egg production, mortality, feed conversion rate). In [3-5] were shown the results of analysis of the effects of the energy saving air treatment devices.

Results of research of air exchange rate in ventilated agricultural buildings are described in [6]. By the use of a steady-state analysis, the effects of the air flow rate on indoor temperature and on energy losses in a livestock building were analyzed [7-10].

Paper [11] shows the results of researches on the use of controllers for control of heating and ventilation systems in livestock buildings. Disturbances investi–gated included: variations in outside temperature, inter–nal heat load and step changes in set point temperature. A new controller has been developed, in an attempt to achieve improved control of air flow and hence more effective environmental control in livestock buildings [7].

Maintenance of the temperature regime in the zone for location of young animals should be carried out by low-inertial heating devices for local heating. Such devices are infrared heaters. The use of infrared heating in the first days of life of animals significantly improves their physiological state, promotes rapid growth and development, as well as raises appetite and assimilation of feed. As a result, the body weight increases and the body's resistance to infections also increases. This is confirmed by the results of scientific research conducted in Ukraine and abroad [12-14].

In [15,16] the energy-efficient nature of infrared radiator and experimental and numerical analysis of a parabolic reflector with a radiant heat source has been established.

Radiant infrared heaters are an alternative to unit heaters that transfer heat to spaces via a mix of radiant and natural convection heat transfer (the latter is often primarily a loss because most of that heat ends up near

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the ceiling). They can use either gas, oil, or electricity to produce heat [11,17,18].

Results of research of infrared heater are described in [12,19,20,21]. A measurement system has been designed to characterize the radiant energy efficiency of infrared heating elements. The results indicate that the radiant efficiencies are strongly dependant on the input power to the element.

Paper [22] shows the results of experimental studies on examining piglet preferences for different types of infrared temperatures and flooring at 24 h of age. In experiments piglets from litters were distributed bet– ween three pairwise infrared temperature treatments (6 litters in each pairwise test): 26°C vs. 34°C, 26°C vs. 42°C or 34°C vs. 42°C. In another experiment litters were tested in an identical set-up with infrared temperatures of 30°C vs. 34°C, 30°C vs. 38°C and 34°C vs. 38°C. And then other new litters were used to test the choice between foam mattress vs. sawdust, foam mattress vs. water mattress, and sawdust vs. water mattress. The results indicate that piglets have a preference for high infrared temperatures and sawdust flooring

Experimental studies were conducted to investigate how do piglets' use of a creep area is affected by using radiant heat compared to an incandescent light bulb. Radiant heat gave an earlier and increased use of the creep area on the critical days after birth [23,24].

Paper [25] presents the theoretical research of temperature control in poultry house. The influence of factors on the formation temperature regime in the poultry house were taken into account when used as heaters of infrared emitters. As the result of the calcu– lation of system`s equation can determine the necessary power of infrared heater for ensuring temperature cont– rol in the area of breeding birds. This will provide the necessary conditions in zoo-hygienic stay with quality bird control temperature to the extent of poultry growth.

To increase the productivity of livestock produ– ction and reduce the energy consumption of heating system it is expedient to create separate zones for the breeding of young animals with combined heating systems. Thus, ensuring a dynamic microclimate in piglets and broiler-chickens' location area is achieved with the use of an infrared heater for local heating and ventilation system for supplying fresh air to the animal's location area.

The purpose of the study was to determine the efficiency of combined heating systems with infra-red heater and inlet ventilation system with the keeping of young pigs and poultry. In the process of experiment conducting, it was planned to investigate the regularities of the formation of temperature regime in places of the piglets and broiler-chickens' location area and the influence of external factors on it.

## 2. EXPERIMENTAL SETUP FOR RESEARCH OF COMBINED HEATING SYSTEM

The main parameters that influence the formation of temperature regime in the piglets and broiler-chickens' location area are the power of the infra-red heater, the height of its installation and the air velocity in the animal's location area. Therefore, an experimental setup was installed to study the temperature of the air in the piglets and broiler-chickens' location area when using a combined heating system, taking into account the above-mentioned factors. The scheme of installation is shown in Fig. 1.

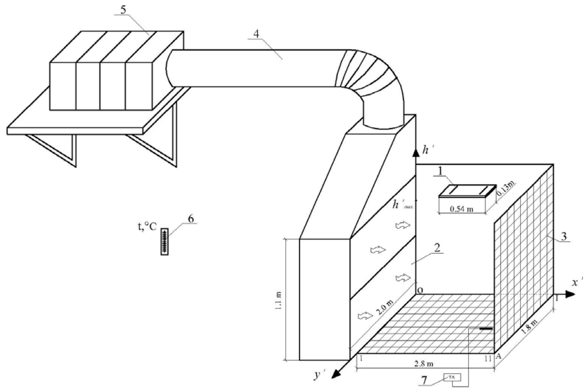



**Figure 1. Scheme of an experimental installation for determining the air temperature and air velocity in the animal's location area:**

**1 - infra-red heater; 2 - source type air distributor; 3 – coor– dinate grid; 4 - supply air duct; 5 - ventilation unit; 6 – meteorological thermometer; 7 – thermo-anemometer ATT-1004**

The installation works as follows. Electric infra-red heater 1 QH 1500 with variable thermal capacities of 500, 1000 and 1500 W was appointed for local heating of the piglets and broiler-chickens' location area. Dimensions of infrared heater were 0.54x0.13 m [20]. Inlet air was supplied to the box for animals through the source type of air distributor 2 with dimensions 2.0x1.1 m, and with the help of which the inlet air flow was modeled. Quantity of the supply air varied within 800 – 3960 $m^3/h$. Supply air duct 4 was connected to the ventilation unit 5. For the convenience of conducting a, research coordinate grid 3 was made. Dimensions of the box for animals were 2.8x1.8x1.1 m. The background temperature in the room was measured by a metro– logical thermometer 6. Temperature and air velocity in the irradiation zone were measured by a thermo-anemometer 7 ATT-1004.

## 3. RESEARCH OF TEMPERATURE REGIME OF PIGLETS' LOCATION AREA

The first stage of the research was to determine the air temperature in the piglets' location area with the use of a combined heating system.

During the experiment, the height of installation of an infra-red heater varied from 0.8 to 1.4 m. The irradiation area, which was changed depending on the height of installation of heater and its geometric dimensions, was determined. Air temperature in the piglets' location area was measured by using the thermo -anemometer ATT-1004. The research was carried out in the studied area, which corresponded to the piglets' location area.

The temperature of internal air in the piglets' location area is influenced by the power of the heater $Q_{heat}$, W, air velocity $V_0$, m/s, relative height of the heater installation $\overline{h'}_h = h'_h / h'_{max}$, $h'_h$ = [0.8…1.4] m, $h'_{max}$ = 1.4 m, and relative height of the piglets' location area $\overline{h'} = h' / h'_{max}$, $h'$ = [0.1…0.7] m, $h'_{max}$ = 0.7 m. These values were the input parameters of the experiment planning.

Output parameter is the relative air temperature in the piglets' location area $\overline{t^{pig}} = t_\infty / t^{pig}_{zone}$; $t_\infty$ – background air temperature, °C; $t^{pig}_{zone}$ – air temperature of the piglets' location area, °C.

The scope of definition of input parameters varied within: $Q_{heat}$= [500…1500] W; $V_0$ =[0.1…0.5] m/s; $\overline{h'}_h$=[0.6…1]; $\overline{h'}$=[0.1…1] [14].

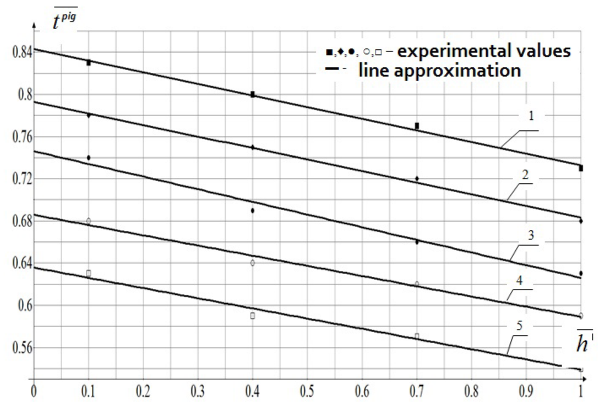



**Figure 2. Dependence of the relative air temperature $\overline{t^{pig}}$ on the relative height of the piglets' location area $\overline{h'}$ per $Q_{heat}$ = 1500 W, $h'_h$ = 1.4 m, y '= 0.4 m, x' = 0.5 m and for the velocities of the air:**
**1) $V_0$ = 0.5 m/s; 2) $V_0$ = 0.4 m/s; 3) $V_0$ = 0.3 m/s;**
**4) $V_0$ = 0.2 m/s; 5) $V_0$ = 0.1 m/s**

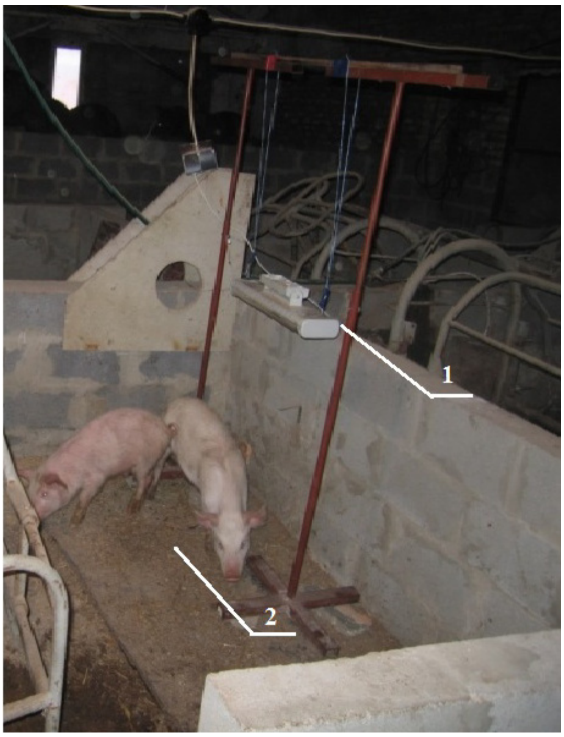



**Figure 3. Photo of the experimental installation for determining the air temperature in piglets' location area with the use of combined heating system:**
**1 - infra-red heater; 2 - piglets' location area**

As a result of experiment, we obtained the dependence for determining the temperature of the air in the piglets' location area at different values of relative height of this area at different air velocities (Fig. 2).

To confirm the adequacy of laboratory tests, experimental studies were conducted in real conditions to determine the temperature of the internal air in the piglets' location area with the use of an infra-red heater (Fig. 3).

As a result of research in real conditions a graphic dependence was constructed to determine the internal air temperature in the piglets' location area on the heater power, $Q_{heat}$, W, air velocity, $V_0$, m/s, heights of heater installation $h'_h$ and running coordinate at the height of the piglets' location area $h'$ (Fig. 4).

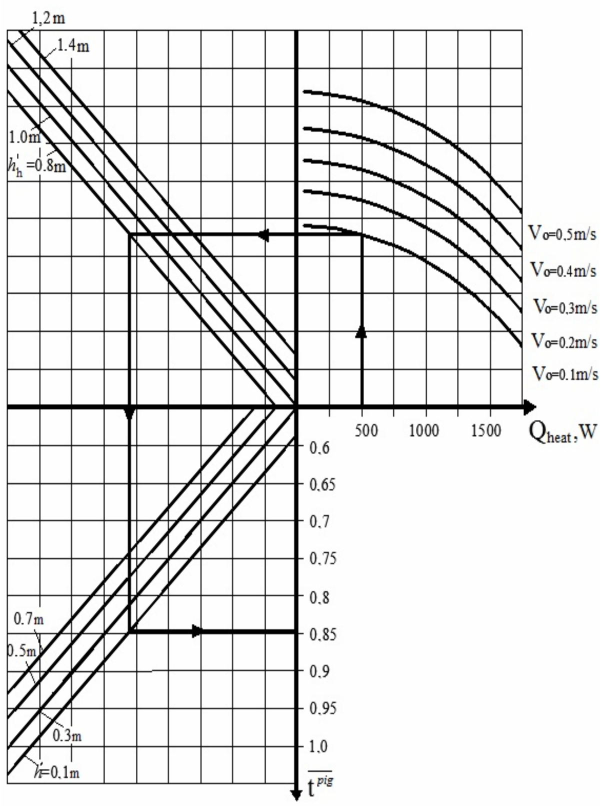



**Figure 4. Dependence of the relative temperature of internal air in the piglets' location area $\overline{t^{pig}}$ on the heater power, $Q_{heat}$, W, air velocity, $V_0$, m/s, heights of heater installation $h'_h$ and running coordinate on the height of the piglets' location area $h'$.**

As a result of the approximation, we obtained a dependence to determine the relative temperature of the internal air in the piglets' location area:

$$\overline{t^{pig}} = (0.6 - 0.18 \cdot h') + 0.1 \cdot (((1.8 - 1.78 \cdot h'_h) + \\ +(0.98 + 0.004 \cdot h'_h) \cdot ((2 + 4.33 \cdot V_0) + \\ +(-0.0001 + 0.000038 \cdot V_0) Q_{heat}))). \quad (1)$$

As can be seen from the obtained results, the temperature of the air in the piglets' location area is significantly influenced by the power of the infrared heater and air velocity.

## 4. RESEARCH OF TEMPERATURE REGIME OF BROILER-CHICKENS' LOCATION AREA

At the next stage, a study of temperature regime at local breeding of chicken meat with the use of a combined heating system in real conditions was conducted (Fig. 5) [14,26,27].

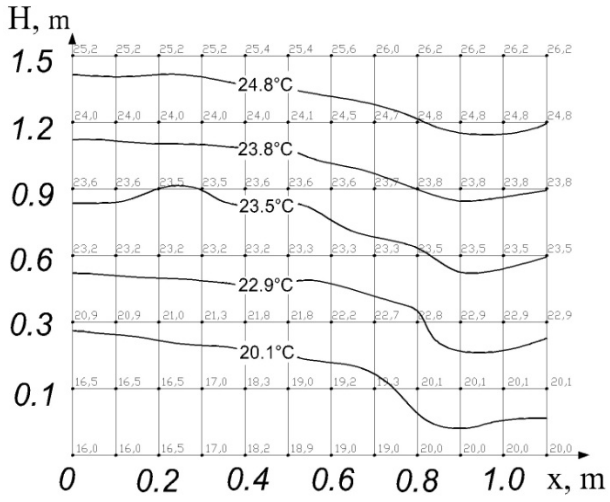

**Figure 5. Photo of experimental installation for determining the air temperature in broiler-chickens' location area with the use of combined heating system:**
**1 - infra-red heater; 2 - broiler-chickens' location area**

Research was carried out at the change of height of the heater installation from 1.5 m to 1.0 m and at various heat capacities of emmiter: 500 W, 1000 W, 1500 W.

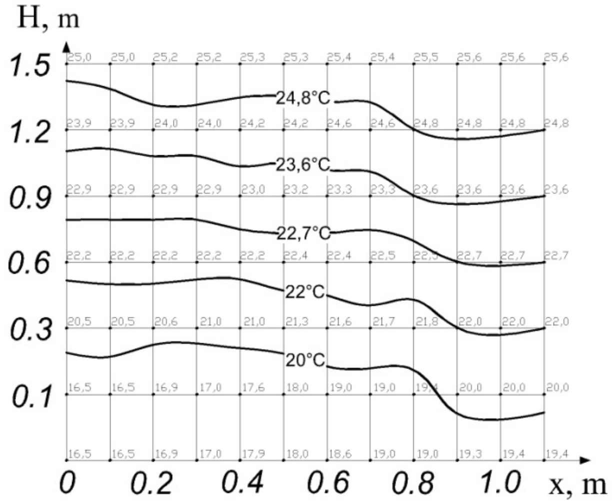
The temperature of internal air in the broiler-chickens' location area is influenced by the heat capacity of infra-red heater $Q_{heat}$, W, height of the heater $H$, m, and air velocity of inlet air flow $V_0$, m/s. These values were the input parameters for the experiment planning.

Output parameter is the relative air temperature in the broiler-chickens' location area $\overline{t_{air}} = t_{air} / t_0$; $t_{air}$ – air temperature in the broiler-chickens' location area, °C; $t_0$ – temperature of the inlet air flow, °C.

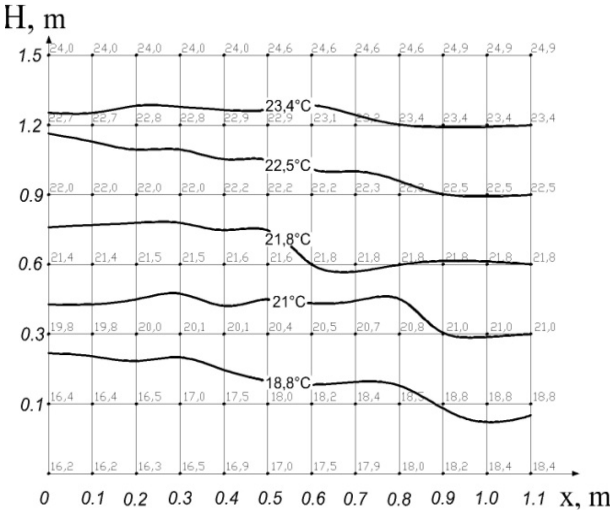
The scope of definition of input parameters varied within: $Q_{heat}$= [500…1500] W; $H$=[1.0…1.5] m; $V_0$=[0.1…0.3] m/s.




a)




b)




c)

**Figure 6. Distribution of temperature fields in the cross section at heat capacity of the heater $Q_{heat}$ = 1500 W, height of heater's installation $H$ = 1.5 m and temperature of the inlet air $t_0$ = 18°C at air velocities:**
**a) $V_0$ =0.1 m/s; b) $V_0$=0.2 m/s; c) $V_0$=0.3 m/s.**

In figure 6 are shown the results of experimental studies of temperature regime in broiler-chickens' location area. Graphical distribution of heat flows shows change of temperature regime at heat capacity of the heater $Q_{heat}$ = 1500 W and different values of height of its installation $H$, m and velocity of inlet air flow in the poultry location area $V_0$, m/s.

Distribution of temperature fields indicates a uni–form temperature rise in height and as it is removed from the air distributor. At the same time significant decrease in temperature with increasing air velocity is observed.

Presented graphic results show a qualitative picture of distribution of the temperature fields in the broiler-chickens' location area. For scientific substantiation of air temperature dependence on the above-mentioned factors, the nomogram was built shown in Fig. 7.

At the received intervals of variation for input factors on the basis of constructed nomogram an empi–rical dependence was obtained for finding the relative air temperature $\bar{t}_{air}$ in the poultry location area at 500 W $\le Q_{heat} \le 1500$ W, 1.0 m $\le H \le 1.5$ m, 0.1 m/s $\le V_0 \le 0.3$ m/s.

$$\bar{t}_{air} = 1.41 + 0.07\frac{Q_{heat}-1000}{500} - 0.045\frac{H-1.25}{0.25} - 0.075\frac{V_0-0.2}{0.1} - \\ -0.02\frac{Q_{heat}-1000}{500}\cdot\frac{V_0-0.2}{0.1} + 0.0125\frac{H-1.25}{0.25}\cdot\frac{V_o-0.2}{0.1} \quad (2)$$

The results of experiment show that the greatest influence on the value of relative air temperature is exerted by the thermal power of infra-red heater and air velocity in the broiler-chickens' location area.

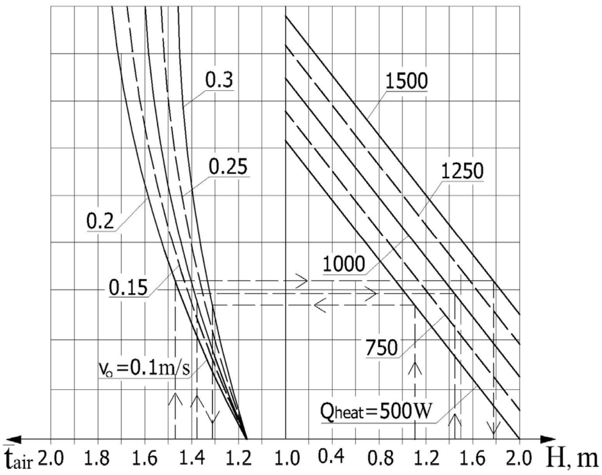



**Figure 7. Dependence of relative air temperature $\bar{t}_{air} = t_{air} / t_o$ on the heat capacity of heater $Q_{heat}$, W, height of its installation $H$, m and velocity of the inlet air flow in poultry location area $V_0$, m/s**

## 5. CONCLUSION

The results of experimental studies as well as their geo–metric interpretation lead to the following conclusions.

It is established that the greatest influence on relative air temperature in the animal's location area is exerted by the thermal power of the heater and air velocity.

With growing chicken-broilers and with increasing of thermal power of infrared heater by 500 W, the air temperature increases by 5.8%, with growing of piglets the air temperature increases by 12.9%.

Air temperature increases in height, closer to the infrared heater and the farther away from the air distri–butor. The temperature increase is uniform for different air velocity values and is about 2.5 °C in the piglets' location area and 4.7 °C in the chicken- broilers' location area.

The advisability of using a combined heating system with an infra-red heater and a supply ventilation system was substantiated. Bringing output parameters to the relative values makes the obtained research results universal and allows them to be used in the design of such systems in poultry houses and pig farms.

## REFERENCES


[1] Homidan, A., Robertson, J.F., Petchey, A.M.: Review of the effect of ammonia and dust concentrations on broiler performance, *World's Poultry Sci.* J., Vol. 59, pp. 340-349, 2003.

[2] Pinilla, J.C., Williams, A.M.: Managing sow farms for high performance, *Allen Leman Swine Conference Proceedings*, pp. 134–140, 2010.

[3] Vitt, R., Weber, L., Zollitsch, W., Hortenhuber, S.J., Baumgartner, J., Niebuhr, K., Piringer, M., Anders, I., Andre, K., Hennig-Pauka, I., Sch€onhart, M., Schauberger, G.: Modelled performance of energy saving air treatment devices to mitigate heat stress for confined livestock buildings in Central Europe, *Biosystems Engineering,* Vol. 64, pp. 85 – 97, 2017.

[4] Deglin, D., Caenegem, L., Dehon, P.: Subsoil heat exchangers for the air conditioning of livestock buildings, *Journal of Agricultural Engineering Research*, Vol. 73(2), pp. 179–188, 1999.

[5] Mitchell, M.A., Kettlewell, P.J.: Physiological stress and welfare of broiler chickens in Transit: Solutions not problems, *Poultry Science*, Vol. 77(12), pp. 1803–1814, 1998.

[6] Samer, M., Müller, H. J., Fiedler, M., Ammon, C., Gläser, M., Berg, W., Sanftleben, P., Brunsch, R. (2011). Developing the 85Kr tracer gas technique for air exchange rate measurements in naturally ventilated animal buildings. *Biosystems Engineering*, 109(4), 276-287.

[7] Berckmans, D., Goedseels, V.: Development of new control techniques for the ventilation and heating of livestock buildings, *Journal of Agricultural Engineering Research*, Vol. 33(1), pp. 1-12, 1986.

[8] Korbut, V., Voznyak, O., Myroniuk, K., Sukholova, I., Kapalo, P.: Examining a device for air distribution by the interaction of counter non-coaxial jets under alternating mode, *Eastern European Journal of Enterprise Technologies*, Vol. 2(8), pp. 30-38, 2017.

[9] Zulovich, J. M.: Ventilation for warm confinement livestock buildings. Extension publications G1107, *University of Missouri, Columbia*, 1993.

[10] Gumen, O., Dovhaliuk, V., Mileikovskyi, V., Lebedieva, O., Dziubenko, V.: Geometric Analysis of Turbulent Macrostructure in Jets Laid on Flat

Surfaces for Turbulence Intensity Calculation, *FME Transactions*, Vol. 4, pp. 236-242, 2017.

[11] Chao, K., Gates, R. S., Sigrimis, N.: Fuzzy logic controller design for staged heating and ventilating systems, *Transactions of the ASAE*, Vol. 43(6), pp. 1885-1894, 2000.

[12] Brown, K. J., Farrelly, R., O'shaughnessy, S. M., Robinson, A.J.: Energy efficiency of electrical infrared heating elements. *Applied Energy*, Vol. 162, pp. 581-588, 2016.

[13] Yurkevich Yu., Spodyniuk N.: Energy-saving infrared heating systems in industrial premises, *Budownictwo o zoptymalizowanym potencjale energetycznym*, Vol. 2 (16), pp. 140-144, 2015.

[14] Zhelykh, V., Kozak, Ch., Furdas, Y., Spodyniuk, N., Dzeryn, O.: Energy saving technologies in production complexes for agricultural purpose, *Journal of Lviv Politechnic National University. Theory and practice of building*, Vol. 781, pp. 230–233, 2014.

[15] Lee, E.H., Yang, D.Y.: Experimental and numerical analysis of a parabolic reflector with a radiant heat source, *International Journal of Heat and Mass Transfer*, Vol. 85, pp. 860-864, 2015.

[16] Shepitchak, V., Savchenko, O., Spodyniuk, N., Zhelykh, V.: The study of temperature fields in exposure zone of the rotary infrared heaters, *Budownictwo o zoptymalizowanym potencjale energetycznym*, Vol. 1(15), pp. 178-181, 2015.

[17] Dudkiewicz, E., Fidorow, N., Jezowiecki, J.: The Influence of Infrared Heaters Efficiency on the Energy Consumption Cost, Rocznik Ochrona Srodowiska – Vol. 15, pp. 1804–1817, 2013.

[18] Guo-Jun, Li, Jian Ma, Ben-Wen Li.: Collocation Spectral Method for the Transient Conduction, Radiation Heat Transfer With Variable Thermal Conductivity in Two-Dimensional Rectangular Enclosure, *Journal of Heat Transfer*, 137(3), 2015.

[19] Zhelykh, V., Dzeryn, O., Shapoval, S., Furdas, Y., Piznak, B.: Study of the thermal mode of a barn for piglets and a sow, created by combined heating system, *Eastern-European journal of enterprise technologies*, 5/8(89), pp. 45-50, 2017.

[20] Zhelykh, V., Ulewicz, M., Spodyniuk, N., Shapoval, S., Shepitchak, V.: Analysis of the processes of heat exchange on infrared heater, *Diagnostyka*, 17(3), pp. 81-85, 2016.

[21] Hsieh, C.T., Tzou, D.Y., Huang, Z.S., Lee, C.Y., Chan, J.K.: High performance infrared heaters using carbon fiber filaments decorated with alumina layer by microwave-assisted method, *Journal of the Taiwan Institute of Chemical Engineers*, Vol. 59, pp. 521-525, 2016.

[22] Vasdal, G., Mogedal, I., Knut, E., Kirkden, R., Andersen, I.: Piglet preference for infrared temperature and flooring, *Applied Animal Behaviour Science*, Vol. 122, pp. 92-97, 2010.

[23] Kramer, S., Gritzki, R., Perschk, A., Roesler, M., Felsmann, C.: Numerical simulation of radiative heat transfer in indoor environments on programmable graphics hardware, *International Journal of Thermal Sciences*, Vol. 96, pp. 345-354, 2015.

[24] Larsen, M.L.V., Thodberg, K., Pedersen, L.J.: Radiant heat increases piglets' use of the heated creep area on the critical days after birth, *Livestock Science*, Vol. 201, pp. 74–77, 2017.

[25] Spodyniuk, N.A.: Theoretical investigation of temperature regime in poultry house`s premise, Scientific Bulltin of Lviv National University of Veterinary Medicine and Biotechnology named by Gzhytsky S.Z. Technical sciences, Series "Food Technologies", Vol. 16, 2(59), pp. 176-181, 2014.

[26] Shcherbovskykh, S., Spodyniuk, N., Stefanovych, T., Zhelykh, V., Shepitchak, V.: Development of a reliability model to analyse the causes of a poultry module failure, *Eastern-European Journal of Enterprise Technologies*, Vol. 4(3), pp. 4-9, 2016.

[27] Al-Helal, I.M.: Environmental control for poultry buildings in Riyadh area of Saudi Arabia, *Journal of the King Saud University Agricultural Science*, Vol. 16, pp. 87–102, 2001.

## NOMENCLATURE

| | |
|---|---|
| $h_h^{'}$ | height of heater installation |
| $h^{'}$ | height of the piglets' location area |
| $H$ | height of the heater |
| $t_0$ | temperature of the inlet air flow |
| $t_\infty$ | background air temperature |
| $t_{zone}^{pig}$ | air temperature of the piglets' location area |
| $t_{air}$ | air temperature in the broiler-chickens' location area |
| $Q_{heat}$ | heat capacity of infra-red heater |
| $V_0$ | air velocity |

### *Superscripts*

| | |
|---|---|
| h | height |
| heat | heater |
| max | maximum |
| pig | pig |
| zone | zone |

## КОМБИНОВАНИ СИСТЕМ ГРЕЈАЊА ОБЈЕКАТА ЗА ГАЈЕЊЕ ПРАСАДИ И ЖИВИНЕ

**Н. Сподиниук, В. Желих, О. Дзерин**

Примена традиционалног система грејања у комбинацији са вентилационим доводом ваздуха за гајење младунаца домаћих животиња у индус–тријским условима није довољно ефикасна. Функ–ционисање система се заснива на обезбеђењу пот–ребног температурног режима у затвореном прос–тору и стварању велике размене ваздуха, при чему се повећава топлотно оптерећење на систем за вентилацију. У циљу повећања продуктивности сточарске производње и смањења потрошње топлотне енергије потребно је направити одвојене

зоне за гајење младунаца домаћих животиња са комбинованим системом грејања. Циљ рада је био да се утврди ефикасност система грејања комби–нованог са инфрацрвеним грејачима и системом вентилационог довода ваздуха код гајења прасади и живине.