Efficiency of poultry house heating and ventilation upgrading

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Abstract. The genetic potential of bird productivity can be fully revealed only in conditions of an optimal microclimate to be ensured by sufficiently energy-intensive ventilation and heating (cooling) air systems. In this regard, energy conservation is an urgent task for poultry farms given the significant share of the energy component in the cost of poultry products (9-14 %) and rising energy prices. In poultry houses, the greatest heat losses are in exhaust ventilation (up to 29,000 gigacalories in poultry farms for the heating season), where heat recovery units are needed, which are designed to perform high-quality sanitation in heat-exchange channels; for the economical heating of poultry and premises, the use of local gas heating systems able to work with positive pressure and depression in the poultry house and disinfect the air is required. The experiments on the use of gas air heaters for growing meat chickens showed that in an autonomous heating system with heat recovery units, air heaters become the main heat generators and heat source that heats up the air supply, which allows the system to be used in “hybrid” modes, i.e. at high pressure during the first period of broiler operation and with depressurizing during the second period of broiler operation. At the same time, there was no negative effect of burning oxygen and combustion products on livestock productivity; a high level of veterinary and sanitary protection of the livestock due to air disinfection by gas burners is provided as well.

1. Introduction
Energy costs in the cost of poultry production of Russian poultry farms (PF) are the third component after feed and salaries. This is because Russian poultry industry is the most “cold-latitude” and requires significant heating costs. Minimizing heating costs in the Russian Federation’s PF is a very urgent issue, because Russian poultry products must be more competitive in quality and cost as compared with foreign ones. This will preserve domestic production, eliminate the capture of local markets by import, and is extremely important for an increase in the export of Russian eggs and poultry [1].

The large-scale PF switch in all regions of the country over to local heating systems for poultry houses using gas air heaters (GAH) significantly reduced fuel costs by 42-51 % due to the fact that heat
losses in heating mains and central boiler houses were excluded [2]. In addition, since the 97-98 % of heat energy of fuel in such heating systems reaches in the poultry house premises, this heat energy should be used here with the maximum effect, i.e. to solve the problems of recovering heat of the replaced air and minimization of heat loss through the building envelope taking acceptable measures to enhance their thermal insulation. Currently, a serial thermal imager will provide high-quality system monitoring of the condition of PF building envelope thermal protection, and the farm workers will perform the current repair of areas with weakened thermal insulation of poultry houses by spraying polyurethane foam (PUF) with a minimum expenditure of funds.

A lot of Research & Development work (R&D) has been performed on the exhaust air heat recovery; serial equipment is being produced in the Russian Federation and abroad. Nevertheless, on the one hand, the constant task of saving heat in production and, on the other hand, the problem of reducing thermal “pollution” of the atmosphere (Kyoto Protocol 12.1997) leave the subject of heat recovery units (HRU) being extremely popular. Energy conservation in the poultry industry is devoted to many works of researchers.

Of the domestic developments, it is necessary first of all to note studies on improving efficiency, eliminating freezing of heat transfer channels and access to them (relevant for the north) [3], reducing the heat recovery unit dimensions, aerodynamic resistance and energy consumption for pumping air through a heat recovery unit [4]. A HRU with the optimal selection of its power in a changing heat load is effective and cost-effective it in standard terms in cowsheds [5] and is certainly highly economical in poultry houses [6]. Of the foreign works, it is necessary to single out studies on cross-flow lamellar HRU with an intermediate heat carrier [7,8] and especially works on thermal analysis of the environment of livestock houses [9], optimizing the energy costs of ensuring optimum housing conditions [10], and effect of energy-saving systems for air treatment [11].

Operation of the first imported (Jet Master, Ermaf, Gasolec, Cumberland, etc.) and domestic (Samum, VGS-200, VG-0.07) GAH sets has showed that a powerful system consisted of 5 protections makes such heaters absolutely safe. In the case of the interruptions in supply and unacceptable abnormalities in the gas and electric networks, flame extinction, fan shutdown, housing overheats and gas leaks in the poultry house, the air heaters and the low pressure gas pipeline in the poultry house are switched off (for comparison, the protection uses only 2 parameters in gas brooders). A comprehensive GAH assessment is necessary due to the fact that air heaters become the main heat generator in the poultry house and a heat source that reheat input in a self-contained heating system fitted with HRU.

The introduction of new heating systems according to the most popular version fitted with GAH requires the following issues to be solved: a) identifying the possible negative impact of burning oxygen and combustion products on livestock productivity, b) determining the level of veterinary and sanitary protection of the livestock due to air disinfection by gas burners in the poultry house and the efficiency of heating and ventilation systems equipped with GAH operating in “hybrid” modes, i.e. with air back-up at the start and “evacuation” the poultry house until the end of feeding.

2. Materials and research methods

The materials to be used in the work comply with the standard (GOST 23708-84) and the guideline for the study of technologies for the production of poultry meat. The concentration of carbonic anhydride in the air of the poultry houses was determined using the colorimetric method (the UG-2 gas analyzer), the level of bacterial seed of the air medium was determined by pumping a certain amount of air over meat-peptone agar (A Krotov's device). The calculations were made as per the following equation:

$$
\varepsilon = \left( \frac{\tau_s^2 - \tau_s^1}{\tau_s^3 - \tau_s^1} \right) \left( \frac{\tau_s^3 - \tau_s^1}{\tau_s^1} \right).
$$

where $\varepsilon$ is a HRU thermal efficiency, $\tau_s^1$ is a supply air temperature at the HRU inlet, $\tau_s^2$ is a supply air temperature at the HRU outlet, $\tau_s^3$ is an exhaust air temperature at the HRU inlet.
In general, the analytical justification for the HRU design was a standard algorithm for calculating a gas plate heat recovery cross flow exchanger for the exhaust and supply air while providing high-quality sanitation of heat-exchanging surfaces.

3. Result and discussion
To return the heat of the exhaust air (“secondary heat”) and reduce the cost of heating, the poultry industry needs to have a heat recovery unit that meets the PH specifics. We are talking about the conformity of the HRU design (collapsible, partially collapsible) to the basic requirements for the operation of such equipment in poultry houses: a) the HRU design should be designed to perform high-quality, low-cost and quick sanitation in a preventive break; b) HRU performance must exclude freezing during peak cold periods and comply with the equipment that operates in standard poultry houses; c) HRU maintenance should be simple and not requiring high qualification of repairmen; d) HRU must ensure the efficiency of heat recovery sufficient for its payback within the regulatory period.

However, to choose a serially manufactured HRU that meets all requirements, including those regarding its integration into standard poultry ventilation systems is difficult, it was decided in the pilot project to make a plate HRU of an original design that fully complies with all the above requirements. A reequipped with a HRU ventilation system of a typical poultry house is shown in the figure 1, where: 1 – VO1 exhaust fan; 2 – louvered intake of the summer “tunnel”; 3 – VO7 axial heating season exhaust fan; 4 – inlets for transitional periods; 5 – roof air intake duct for winter time; 6 – HRU; 7 – KSk inlet re-heater; 8 – VTs4-70 winter intake fan; 9 – metal air duct manifold; 10 – air ducts.

![Figure 1. Layout of the ventilation and heating system using a HRU.](image)

HRU is made in the form of a parallelepiped having dimensions in plan (L×W) in accordance with standard galvanized metal sheets 2500×1250 mm in size and a thickness of up to 0.7 mm. The HRU
height is piled of the sheets and is 1720-2540 mm depending on the power required. The height of all slotted air ducts that are the vertical gap between adjacent sheets is 40 mm and the width is 400 mm. At such a distance, rows of planks (made of plastic or water-repelling wood) that form layers are laid; the planks are placed parallel to the longitudinal size of the sheet in the odd layers and transversally to the longitudinal size of the sheet in even layers. HRU is designed for fast high-quality performance of sanitation (with only the inlet disconnected): the parallelepiped is installed with transverse and longitudinal slopes of 3-5 degrees to the horizon (for water flow during washing); the adapter casing from the inlet to the HRU is quick-detachable. This allows you to perform its effective washing and hydraulic cleaning using high-pressure (7 MPa) installations, carry out wet disinfection and gas treatment.

The HRU tests at an experimental poultry house showed sufficient operation efficacy of the installation: the 0 °C airflow was supplied to the preheater at a temperature of exhaust air of 20 °C and outdoor air temperature of minus 15 ºC. This means that the HRU efficiency was:

$$\frac{0 - (-15)}{20 - (-15)} \cdot 100 = \frac{15}{35} \cdot 100 = 0.4286 \cdot 100 = -0.43 \cdot 100 = 43 \%,$$

and this is enough for the pay-back of construction of such an original HRU in just a single heating season. This gave rise to the co-developers of the considered HRU (V Minaev, V Mokhov et al. (ChPH) to organize the widespread introduction of the heat recovery unit described. While using only funds allocated for depreciation of equipment, ventilation and heating systems have been reconstructed for several years and heat has being recovered at 45 poultry houses (81% of the PH buildings). Large-scale re-equipment made it possible for the poultry house to reduce the annual heat consumption by one third (79,000 gigacalories (Gcal) instead of 119,700 Gcal) in comparison with broiler factories of comparable capacity (13,500-15,000 metric tons / year) located in a similar climatic zone (Sheksninskaya, R-Vysotskaya, etc.). In terms of the scale of only broiler production in Russia, the annual decrease in heat emissions in accordance with the Kyoto Protocol will amount to 8.6 million Gcal, gas consumption will decrease by 1.075 billion m³.

The study in assessing the potential negative effect of burning oxygen by GAH on poultry, GAH disinfecting capabilities, as well as the creation of positive air pressure in the poultry houses by such heaters has been performed in broiler houses of the Burlatskaya poultry farm (Stavropol Territory). Table 1 shows the results of broiler growing during gas combustion in an experimental poultry house and regenerative heating of broilers in a control room.

| Item | Heating system | Slaughter number of species | Poultry integrity, % | Daily gain in live weight, g | Average carcass weight, g | $\sqrt{=}265$ | $\frac{131}{136} - d_{1-0.05} = 0.49$ |
|------|----------------|-----------------------------|---------------------|-----------------------------|--------------------------|-------------|----------------------------------|
| 1 (Test) | GAH (air thru the burner) | 136 | 98.55 | 46.1 | 2.025±28 | 2=20 | md=41 |
| 2 (Control) | TG-2.5(regenerative heating) | 131 | 94.93 | 45.7 | 2.005±30 | 0.49 <2 P<0.05 |

Note: The total number of individuals for slaughter is 287: 136 of them are from the experimental group and the 131 of them are from the control group. The number of degrees of freedom is 265 (136 − 1 + 131 − 1 = 265). According to Student's test, $P$ ranks of reliability ($P>0.95, 0.99, 0.999$) or unreliability ($P<0.005$) are estimated at three standard levels of 2, 2.6, 3.3, if our criterion turns out to be above 2, then this is $P>0.95$, if it is more than 2.6, then $P>0.99$, etc.

We define the reliability criterion of the conducted experiment as the ratio of the difference of the average poultry weights in grams (g) in the groups $d=2025−2005=20$ g to the representative error $m_d=\sqrt{m_1^2+m_2^2}$, where the scatter in live weight of poultry from the experiment being equal to $m_1=28$ g and from the control being equal to $m_2=30$ g will be equal to $\sqrt{28^2+30^2}=41$, the reliability criterion
will be equal to \( \frac{20}{41} = 0.49 \), which is less than the smallest level of the standard Student confidence criterion being equal to 0.49 < 2. That is to say, the difference in live weight of the poultry from the experiment and control is unreliable and equal to \( P < 0.05 \).

The live weight in the experiment is even slightly higher than the control one at an unreliable difference of \( P < 0.05 \). A relatively small decrease in the oxygen level in the air of the poultry house during operation of all burners (20.8 % of \( O_2 \) instead of 21 %), as well as intensive air exchange in the house even in the cold season (7,000-15,000 m\(^3\)/h at a building volume of 3,700 m\(^3\)) allow excluding reliably the effect of burning \( O_2 \) by heaters.

Table 2 shows the results of the experiment on GAH air disinfection at the poultry house.

**Table 2.** The results of the experiment air disinfection in the poultry house

| Process options                     | Number of microbial bodies in 1 m\(^3\) of poultry house air, ‘000 microbial bodies | Poultry mortality, % |
|-------------------------------------|--------------------------------------------------------------------------------------|----------------------|
| Gas disinfection by the GAH burner| 5,413 ± 960, 14,117 ± 2460, 20,110 ± 2133, 25,408 ± 6,193                          | 2.45                 |
| TG 2.5 regenerative heating         | 9216 ± 1611, 21246 ± 1935, 30861 ± 4108, 37522 ± 5306                            | 5.07                 |
| Bacterization MPC for poultry growers | 1-4 weeks: up to 30,000 microbial bodies in 1 m\(^3\) of poultry house air | 5.9 weeks: up to 50,000 microbial bodies in 1 m\(^3\) of poultry house air | 3.07 |

In the experimental version, during the first 3 weeks, air disinfection with the GAH torch burner (made by Cumberland) was combined with air supply in the poultry house (20-30 Pa) at 2-3-fold aeration. It is just such a combination of sanitary protection measures, i.e. the constant active thermal disinfection of aerosols in combination with increased air pressure in the poultry house, that allows stably maintaining indoors, for five weeks, dependably (\( P > 0.95 \)) a lower level of contamination than that in the control room and specified in regulations (MPC). This explains the higher preservation of livestock in the experimental building.

The economical decentralized heating and ventilation systems equipped with GAH, as the results of these experiments show, make it possible to provide reliable veterinary and sanitary protection of the livestock from air from the exhaust ventilation from adjacent buildings during the start-up period of poultry operation while performing disinfecting treatment of the influx when building up the indoor pressure. And with the age of the bird and the increase in aerated air volumes, such systems are rationally transferred to the operating mode with depressurizing in the poultry house. In addition to minimizing the energy consumption for ventilation with depressurizing in the poultry house (20-30 Pa), for the first time, it is possible to disinfect the exhaust ventilation unit at the end of the building using a poultry manure remover. Cleaning air emissions from poultry houses is undoubtedly of interest to domestic and foreign poultry farming.

**4. Conclusion**

Switching over to local heating systems for poultry houses by gas air heaters has shown its high efficiency, such as reduced fuel consumption by 42-51 % due to the exclusion of heat loss in heating mains and boilers of central boiler houses. The most efficient use of the heat energy of the fuel of local heating systems through returning the heat of the replaced air and minimizing heat loss through the building envelope significantly increases heating efficiency with a significant reduction in costs. It is also recommended to increase the cost of insulation of premises in accordance with the data of studies of enclosing structures obtained with thermal imagers, which can be implemented with the minimum cost of funds by the farm workers themselves. The plate heat recovery unit developed and passed extensive production tests allows one to: significantly reduce heat emissions into the atmosphere; save energy resources for the poultry farm (thermal efficiency is equal to 43 %), be used in serial sets and heating and ventilation systems of typical poultry houses; constructively ensure low-cost operational
high-quality sanitation and control of 100% heat transfer surfaces unlike foreign and domestic counterparts. At the same time, it quickly pays back in 1-2 heating seasons.

Ventilation and heating systems of poultry houses equipped with gas air heaters and designed to work with an adult poultry in the mode of depressurizing in the poultry house (20-30 Pa) can also be rationally used in the starting period of livestock operation with building up the positive pressure in the premises given that:

a) the movement of heated air through the zone of the torch burner of a gas air heater at temperatures of 300-1500 °C allows reducing the level of its infection dependably lower (P>0.95) of the permissible normative indicator for conditionally pathogenic microflora, providing reliable veterinary and sanitary protection;

b) the maximum amount of oxygen used to burn gas in the burners of a gas air heater is not comparable with its volumes even at the lowest levels of aeration of the house (0.3%), therefore this factor does not negatively affect poultry production and its safety.

The results of the study show that existing heating technologies can be used in poultry houses for poultry of different ages with the possibility of their upgrading for energy saving. Nevertheless, economic assessments are necessary to understand whether the effects of the proposed energy-saving devices and measures to reduce heat losses justify the additional costs and investments in their installation and maintenance. Such studies will be required for certain types of energy-saving devices in relation to specific farms and their premises in any country in the world.

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