Using of evaporative cooling systems in poultry farms

IOP Conf. Series: Earth and Environmental Science **614** (2020) 012015 doi:10.1088/1755-1315/614/1/012015

Using of evaporative cooling systems in poultry farms

A Anarbaev[1*], R Zakhidov[1], O Tursunov[1,2,3], D Kodirov[1], U Vakhidov[1], U Khaliknazarov[1], Z Yusupov[4], and A Kushev[5]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000, 39 Kari Niyazov, Tashkent, Uzbekistan
[2]School of Mechanical and Power Engineering, Shanghai Jiao Tong University, 200240 Shanghai, China
[3]Research Institute of Forestry, 111104 Tashkent, Uzbekistan
[4]Department of Electrical-Electronics Engineering, Faculty of Engineering, Karabuk University, 78050 Karabuk, Turkey
[5]JSC Uzbekenergo, Scientific Technical Center, Tashkent, 100143, Uzbekistan
Institute of Forestry, 111104 Tashkent, Uzbekistan

[*]Email: anizan6004@mail.ru

Abstract. This article is devoted to the development of promising low-power evaporative cooling systems in poultry farms. At the same time, the placement of elements of the system in determining the temperature, humidity and gas composition of the air in such indoor areas is determined by the parameters at which the most favorable conditions for the life of their bodies and their high productivity are created. The promising method of intensifying the process of heat and mass transfer between gaseous and liquid is considered. The article presents the structural and thermodynamic parameters of the developed evaporative cooler air. Create a layout of the plant shown efficiency and effectiveness of the cooling air. Preliminary methods of calculation thermodynamic parameters of this installation are presented for the conditions of the Republic of Uzbekistan and are more effective with comparison in widely used at present time I-d diagram.

1. Introduction

In large poultry farms, it is necessary to maintain the temperature, humidity and gas composition of the air of such parameters that create the most favorable conditions for the life of their body and their high productivity. The animal body has the ability to maintain body temperature at the level of optimal biological activity [1]. When eating food, animals receive energy and the overall energy balance of their body should correspond to the amount of heat given by the body to the environment. If the room temperature is maintained below the optimal level, the temperature-regulating organism of animals will reduce the return of heat to the environment and expend feed energy to maintain the body temperature at the level of biological activity. If the air temperature is maintained at an optimal level, the feed energy will be spent as much as possible to increase the productivity of the animal: cows give maximum milk yield; laying hens give maximum egg production [2].

When the air temperature increases in the animal habitat, its bodies overheat and they reduce feed consumption, which leads to a sharp decrease in productivity. Year-round operation of microclimate systems in animal housing areas should ensure that the air parameters in the area of their habitat are close to or even meet the conditions for maintaining optimal biological activity [3].
There are numerous studies showing a decrease in the productivity of animals when the air parameters deviate from the recommended values. Figure 1 presents a graph of the dependence of the productivity of laying hens and their feed consumption. The highest productivity of laying hens is observed at an air temperature of 16÷18° C and a relative humidity of 60-70%. At the same time, of course, it is necessary to maintain the normalized gas composition of the air according to the norms [4]. Reducing the air temperature to 0°C leads to a sharp reduction in egg production and almost double the feed consumption. This shows that at low ambient temperatures for hens, the energy of the feed consumed is mostly spent on maintaining the body temperature at the level of vital activity.

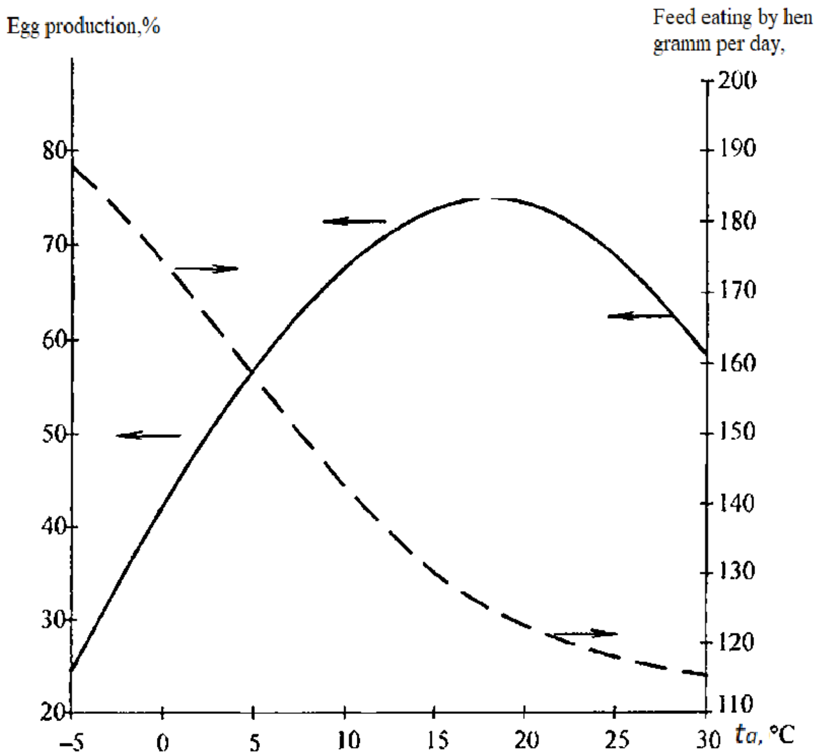

Figure 1. Influence of ambient air temperature on the productivity of laying hens and their feed consumption [3]

2. Methods

The design scheme of the proposed installation of indirect evaporative cooling is shown in Figure 2. From the supply air ducts along the walls of the poultry farm, supply nozzles 1 are made, which are connected to the branch pipe 2 in the upper part of the body 3. Under the nozzle 2 nozzles 4 are arranged, via which supply air outside air L_{nh} into the housing 3, with speed 8 m/s, which ensures the ejection into the housing 3 from the upper zone plant indoor air 1 to outer and inner air ejected L_n on the height of the working area of 1.5 m enters the room with speed not more than 0.5 m/s. At a distance of 0.4 m from the front section of the housing 3, the supply air velocity decreases to 0.3 m/s, which corresponds to the conditions for comfortable supply air flow to the working area [5].

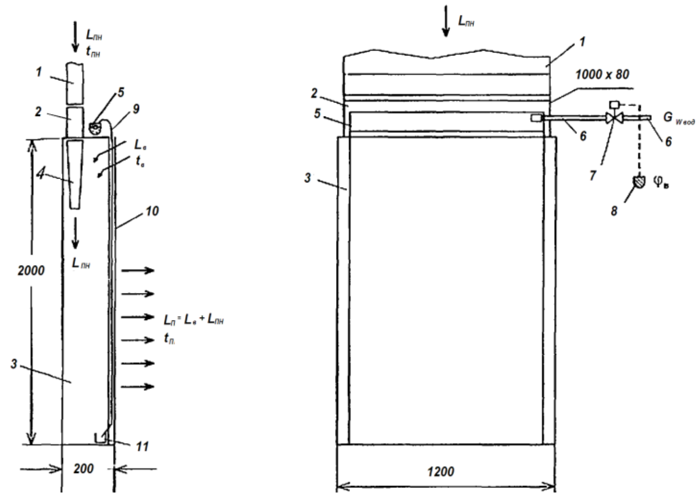

Figure 2. The proposed scheme of optimal organization of air exchange in micro-climate systems using energy-saving technology of indirect evaporative cooling in poultry farm

At low humidity in the area of the poultry room controlled by the sensor 8, a signal is given to open the solenoid valve 7 on the water pipe 6 connected to the float valve in the tray 5. Tap water entering the tray 5 fills it up to the level controlled by the float valve. In the tray 5, the ends of the cloth 9 made of a hygroscopic material are lowered, which overlap the front section of the housing 3. The lower ends of the web 9 are lowered into the pallet 11. Outside, the facade section of the housing 3 is closed with a decorative plastic mesh 10, which simultaneously serves as a filter for dust retention in the poultry farm premises.

The hygroscopic material 9 must well absorb moisture, which quickly spreads along the capillaries of the fibers along the entire height of 2.0 m of the facade section of the housing 3. Passing through the upper part of the hygroscopic material, the ejected $L_{пн}$ air is adiabatically humidified with the indicator E_a =0.6. The supply air mixture L_P exits through a wet hygroscopic material 9 at a height of 1.5 m and is adiabatically moistened with an indicator E_a = 0.65. The loss of water in the tray 5 from evaporation is replenished through the pipeline 6. When the air humidity φ in the shop reaches the value required by the technology, the sensor 8 sends a command to close the solenoid valve 7. For 10-15 minutes, the intensity of adia6ate humidification of the main $L_в$ and supply air will decrease due to a decrease in the water level in the tray 5.

During the hot season, the bird consumes an additional 7% of water for every degree over 21^{0}C [6, 7]. Therefore, any water shortage leads to rapid dehydration and death of the bird. In order to avoid this, the watering system should provide round-the-clock free access to water for birds. If possible, it is desirable to increase the watering front by 20÷25% [8]. In addition, studies have shown that cool water (15^{0}C) increases feed consumption by 5-10% compared to warm water (30^{0}C).

Principles of operation of climate equipment used for cooling poultry at high external temperature: 1- convection; 2 - evaporative (humidity) cooling [9].

The convection method involves cooling due to the high speed of air movement – the so-called tunnel ventilation. It is acceptable for regions where the peak daytime temperature does not exceed 42^{0}C for no more than 3 hours in day for 5-10 days a year.

For effective operation of tunnel ventilation, it is necessary to provide the maximum level of air exchange C = 5-7m^3/kg of mass per hour to create an air flow at a speed of V = 2-2. 5 m / s at the bird level. V > 3m / sec does not have an additional cooling effect, and V > 4 m / sec-causes the bird even more stress [10].

Unfortunately, in practice, there are various situations that do not allow to achieve the desired effect even after the reconstruction of old poultry houses and installation of a tunnel ventilation system.

In climatic zones where the maximum summer temperature is stable above 35^0C, and the internal temperature of the poultry house for a long period exceeds 30^0C, there is a need to combine a tunnel ventilation system with additional evaporative air cooling systems [11].

The evaporative cooling method is based on the principle of heat absorption by the vaporized liquid [12]. The heat-absorbing capacity of air directly depends on its temperature and relative humidity. The higher it is, the more difficult it is.

For example, for air with the parameter humidity 40%, reducing the temperature from 30 to 15^0C will increase the humidity to 100%. When the air is heated from 16 to 22^0C, the indicator will drop from 60 to 40% [13].

Research to determine the optimal operating conditions of a three-phase fluidized bed and equations for calculating the process of evaporative cooling of recycled water in a three-phase layer for air conditioning systems, as shown by the literature review, has not been carried out. In this regard, we focus on experimental studies of the process of cooling recycled water in a three-phase layer. For this purpose, an experimental installation was developed and assembled to study the hydrodynamics of a three-phase fluidized bed, the optimal conditions for its stable operation mode and technological parameters of the water cooling process in the three-phase layer were determined.

We compared the water temperatures in the case of water irrigation of a stationary nozzle and when cooling in a three-phase fluidized bed. The comparison showed that cooling water in a three-phase fluidized bed is 2 times more efficient than a cooling tower. The comparison of the degree of cooling was performed at the same speeds (1,8÷2 m/s) and irrigation densities and showed that on a fixed nozzle, water cools by an average of 1÷5 ^{0}C, and in a three-phase fluidized bed by 9-14 ^{0}C [14].

Increasing the air velocity in the fluidized bed of wetted balls to 3.4 m/s per free section of the cooler increases the turbulence of the air flow, and accordingly the rate of water evaporation.

One of the main indicators of the evaporative cooler of recycled water is its efficiency *E*.

As for other heat and mass transfer plants, the *E* value for coolers of the type in question is determined from the equation [15]

$$E = \frac{Q_{real}}{Q_{teory}} \tag{1}$$

hear the actual value of the heat flow from the cooling water to the air

$$Q_{real} = G^0\, c_{p_s}(t_{inlet} - t_{out}) \tag{2}$$

the theoretical (i.e. maximum possible) value of the heat flow from the cooled water to the air;

$$Q_{teory} = G^0\, c_{p_s}(t_{inlet} - t_{wet}) \tag{3}$$

For the case of an ideal evaporative cooler, the value *E* is equal to one.

From the ratio for determining the efficiency of evaporative coolers of recycled water (4), it follows that, other things being equal (meaning and), the value of *E* depends on t_{wet} – the maximum possible value of the temperature of the recycled water cooled in evaporative coolers [16].

3. Results and Discussions

In the current practice of calculating water-air heat-and-mass transfer and drying installations, the temperature of a wet thermometer is equal to the temperature of saturated air and the I-d diagram of wet air or the psychrometric method is used to determine its value [17-19].

It should be noted that the existing I-d diagram of humid air is presented for the values of barometric pressure 745 and 760 mm Hg.st [20].

In the conditions of the Republic of Uzbekistan, the barometric pressure value ranges from 685 to 715 mm Hg.st and application of I-d diagrams for barometric pressure 745 and 760 mm Hg. st. changes in the calculation of t_{wet} that leads to significant in the calculations by method [21].

Table 1. Dates of calculations for the conditions of the Republic of Uzbekistan

$t_{wet}\,^0C$	$P\delta$, mm Hg.st						
	670	685	700	715	730	745	760
10	31627.40	31154.90	30702.65	30269.38	29853.91	29455.18	29072.18
11	34142.66	33637.09	33153.19	32689.59	32245.05	31818.40	31408.60
12	36750.24	36209.58	35692.09	35196.31	34720.91	34264.65	33826.40
13	39454.93	38877.05	38323.93	37794.62	37285.89	36798.22	36329.80
14	42261.70	41644.36	41053.48	40487.39	39944.57	39423.60	38923.20
15	45175.74	44516.60	43885.70	43281.28	42701.70	42145.46	41611.18
16	48202.45	47499.04	46825.78	46180.76	45662.25	44968.65	44398.48
17	51347.46	50597.19	49879.07	49191.09	48531.37	47898.22	47290.07
18	54616.62	58816.76	53051.19	52317.74	51614.43	50939.44	50291.09
19	58015.98	57163.70	56347.94	55566.41	54817.00	54097.76	53406.92
20	61551.80	60644.17	59775.37	58943.02	58144.98	57378.87	56643.10
21	65230.87	64264.61	63339.76	62453.71	61604.08	60788.66	60005.43
22	69059.75	68231.65	67077.62	66104.87	65200.87	64333.27	63499.01
23	73075.60	71952.23	70905.72	69903.12	68941.72	68019.03	67132.77
24	77195.75	76033.51	74921.08	73855.32	72833.36	71852.56	70910.47
25	81517.81	80282.93	79100.98	77968.62	76882.79	75840.68	74839.72

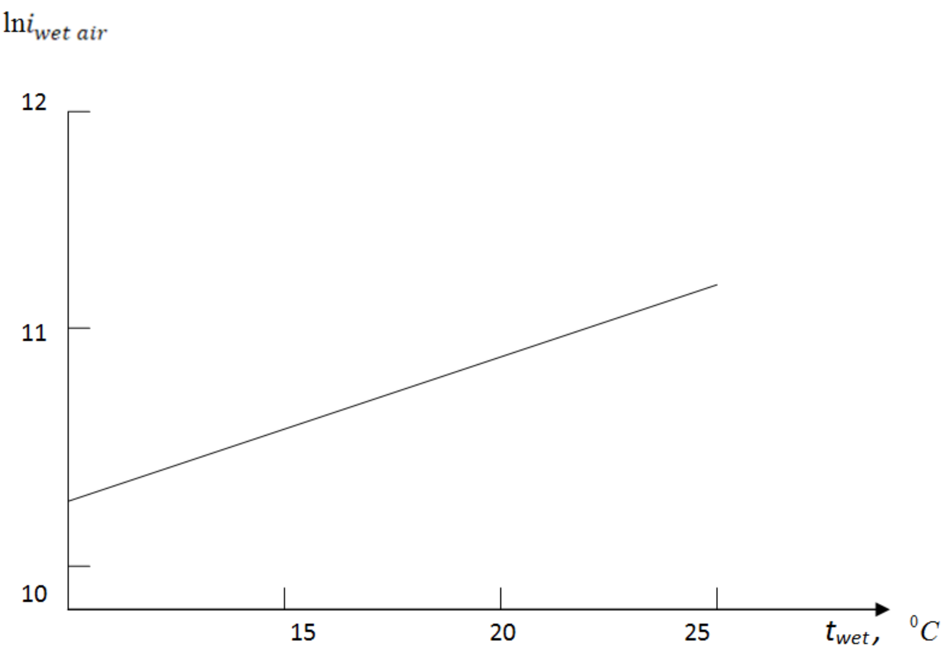

Figure 3. Dependence $i_{wet\ air}$ from t_{wet}, for P_δ =*715* mm Hg.st

It is taken approximated formula

$$t_{wet}=16,65 \ln i_{wet\ air} - 162,5\,^0C \tag{4}$$

Here is a numerical example of practical implementation of the proposed method for calculating the maximum possible value of the temperature of water cooled in evaporative coolers. It is necessary to determine the values and t_{wet} at ambient t_a =35^{0}C, φ_0= 35% barometric pressure= 715 mm Hg.st (see Figure 3).

IOP Conf. Series: Earth and Environmental Science **614** (2020) 012015 doi:10.1088/1755-1315/614/1/012015

4. Conclusions

The main results of this work are the development of a method for cooling recycled water with evaporative cooling and recommendations for creating an effective device for cooling poultry farms.
There are developed methods for calculating the maximum possible value of the temperature of water cooled in evaporative coolers. Approximative equations were given take into account the conditions of the Republic of Uzbekistan and are more effective with comparison in widely used at present time I-d diagram.
According to the results of calculations at 715 mm Hg.st. which pressure is typical for Tashkent, the approximation value within the range of its change from 18 to 260C is 1.94%.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Dobrowolski JW, Bedla D, Czech T, Gambus F, Gorecka K, Kiszcak W, Kuzniar T, Mazur R, Nowak A, Sliwka M, Tursunov O, Wagner A, Wieczorek J, Swiatek M 2017 Integrated Innovative Biotechnology for Optimization of Environmental Bioprocesses and a Green Economy *Optimization and Applicability of Bioprocesses* eds Purohit H, Kalia V, Vaidya A, Khardenavis A (Singapore: Springer) chapter 3 pp 27-71.
[2] Saeed M, Abbas G, Alagawany M, Kamboh AA, El-Hack M, Asmaa F.Khafaga, Chao S 2019 *Journal of Thermal Biology* **84** 414-425.
[3] Gad S, El-Shazly MA, Wasfy KI, Awny A 2020 *Renewable Energy* **154** 278-289.
[4] Izar-Tenorioa J, Jaramilloa P, Griffin WM, Small M 2020 *Journal of Cleaner Production* **255** 120306.
[5] Li B, Liang Ch, Zheng W 2020 *Computers and Electronics in Agriculture* **168** 105127.
[6] Nawab A,Ibtisham F, Li G, Kieser B, Wu J, Liu W, Zhao Y, Nawab Y, Li K, Xiao M, An L 2018 *Journal of Thermal Biology* **78** 131-139.
[7] Vitt R, Weber L, Zollitsch W, Baumgartner J, Niebuhr K, Piringer M, Anders I, Andre K, Hennig-Pauka I, Schauberger G 2017 *Biosystem Engineering* **164** 85-97.
[8] Bartzanasa T, Kittas C 2018 *Computers and Electronics in Agriculture* **149** 101-109.
[9] Kassem AS 1994 *Conservation and Recycling* **12** 135-146.
[10] Wolfenson D, Bachrach D, Maman M, Graber Y, Rozenboim I 2001 *Poultry Science* **80** 958-964.
[11] Vondra M, Touš M, Teng SY 2019 *Journal of Cleaner Production* **23820** 117870.
[12] Butera F, Aste N, Adhikari RS, Del Pero C, Zanelli A 2017 *Energy Procedia* **105** 53-960.
[13] Ahmed EM, Abaas O, Ahmed M, Ismail MR 2011 *Saudi Journal of Biological Sciences* **18** 45-51.
[14] Lieffering M, Newton PCD, Vibart R, Li FY 2016 *Agricultural Systems* **144** 77-86.
[15] Bottcher RW, Baughman GR, Magura JT 1996 *Journal of Applied Poultry Research* **5** 56-62.
[16] Franco A, Valera DL, Peña A, Pérez AM 2011 *Computers and Electronics in Agriculture* **76** 218-230.
[17] Nacer T, Hamidat A, Nadjemi O 2016 *Journal of Cleaner Production* **112** 3631-3642.
[18] Haeussermann A, Hartung E, Jungbluth T, Vranken E, Berckmans D 2007 *Biosystems Engineering* **97** 395-405.
[19] Calvet S, Cambra-López M, Blanes-Vidal V, Estellés F, Torres AG 2010 *Biosystems Engineering* **106** 423-432.
[20] Wani Ch, Ghodke S, Shrivastava Ch 2012 *International Journal of Advance Research in Science, Engineering and Technology* **1** 15-20.
[21] Shackelford AD, Whitehead WF, Dickens JA, Thomson JE, Wilson RL 1984 *Poultry Science* **63** 927-931.