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THE PROBLEMS OF THE AIR ENVIRONMENT QUALITY IN INDUSTRIAL REGIONS

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Actuality of the problem.

Ensuring of indoor air quality is guarantee of comfort and ecological compatibility of our life. Control of pollutants at the source is the most effective means of promoting indoor air quality. An adequate supply of outdoor air is essential to diluting indoor pollutants. In the absence of adequate ventilation, irritating or harmful contaminants can build up, causing workers discomfort, health problems and reduced performance level.

The connection with scientific and practical tasks and analysis of the recent investigations and published works

The problems of the ambient air quality was considered by range of scientists, such as G. Belyavskii, M. Berlyand, V. Neckos, V. Sahaev, A. Chernomorets etc. The problems of the indoor air quality was considered by range of scientists, such as A. Stroi, Ingvar Weinberg, G. Fomin, O. Fomina, P. Shepher, . Ole Fanger, Xavier Guardino Sola etc.

The problem of the air distribution was considered by range of scientists. Among them there are Grimitlin M.I., Shepelev I.A., Abramovich G.N., Baturin V.V., Chesanov L.G. Regarding to foreign scientists there are Koestel who investigated jets from the radial outlet, velocities in 2 parallel jets. With Tuve and Hermann he carried out the comparative investigation of air jets from different types of the outlets.

The main goals:

- analysis of interrelation between the quality of ambient air and indoor environment;
- provision with optimal microclimate conditions due to elaboration of air distributor;
- reducing operation cost of the heating and ventilation systems due to application of waste energy and renewable energy sources.

The main material of researches and discussion of results.

Air environment is considered as ambient air and indoor air. These two components are interrelated. Considering the ambient air we imply hazardous substances that are emitted, the process of contaminants dispersion and ecological risk for people and nature environment. Saying about indoor air we imply firstly about microclimate which provision is achieved by the life supply systems, including heating and ventilation [1].

More than 300 kg per year of the emitted contaminants are calculated for each person. In the air of big cities more than 20 carcinogens exists of 300 known kinds. The total area of Ukrainian woods is 14% of the country territory while the norm is not less than 30%. In general 22% of Ukrainian territory is characterized as strongly and very strongly changed and improper one for constant use. The most part of

emissions is in Donetsk-Prydniprovsk region - about 80% of total quantity in Ukraine.

The Dnipropetrovsk region is one of the biggest industrially developed regions of Ukraine with high urbanization level. The volume of contaminants emission to the ambient air in the region is about 1.3 mln tons, or 17% of total quantity of the country [2].

Table 1 illustrates contaminants emissions to the ambient air from stationary sources in the districts of Dnipropetrovsk. Here the data about main contaminants is gathered. Carbon dioxide CO_2 emissions for Dnipropetrovsk is near 7 mln tons per year.

Table 1.

Contaminants emissions to the ambient air from the stationary sources in districts of Dnipropetrovsk (tons)

	Nitric oxide (in terms of NO_2)	Carbon monoxide	Sulfuric anhydride	Carbon dioxide	Substances in the form of suspended solid particles	Methane	Chlorine and its compounds
Dnipropetrovsk	19649,8	23888,9	44285,3	6671584,4	28311	6556,1	7,95
districts of Dnipropetrovsk:							
Amur-Nizhniodniprovskii	117,34	252,407	13,342	14832,94	198,1	0,535	1,34
Babushkinskii	282,3	372,459	34,994	277665,18	141,2	51,17	0,21
Zhovtnevii	198,98	213,432	0,766	884811,64	50,47	10,71	-
Industrialnii	3417,3	6617,6	527,249	72403,17	361,9	66,32	3,11
Kirovskii	137,23	68,213	3,600	26248,62	46,03	1,22	0,0
Krasnogvardeiskii	443,614	60,432	32,105	11813,066	83,72	3,56	0,91
Leninskii	1432,25	15537,1	1106,9	1465450,7	10088	6373	0,046
Samarskii	13620,8	766,801	42566,3	3918359,1	17341	49,24	2,33

In consequence of it we have the following situation: average annual contaminants concentrations through the town exceed maximum permissible concentrations:

- dust 1.3-3.0 MPC (maximum permissible concentration)
- nitric oxide 1.3-1.8 MPC
- formaldehyde 2.0-5.7 MPC
- benzpyrene 0.8-1.9 MPC

Table 2.

Contaminants emissions to the ambient air from the moving sources in Dnipropetrovsk (tons)

	Nitric oxide	Carbon monoxide	Sulfuric anhydride	Hydrocarbons	Carbon-black
Dnipropetrovsk	5313,5	45304,3	451,8	7609,2	469,6

Mobile sources make also significant contribution to the town pollution. In particular, carbon monoxide emissions is more than 45,000 tons, that is almost two times more than emissions from stationary sources (table 2).

In the following part of the article another aspect in the solving of task of air environment quality is presented. It is the maintenance of the optimal microclimate parameters in the space, providing with rational organization of air-distribution by means of supply air jet formation.

The existent methods of the air-exchange calculation are provided for preliminary data about dimensions of zone that is serviced with one air-distributor. Sizing of the diffuser is based on the required air volume and acceptable parameters of the jet at the entrance to the working area. Thus, the size of a priori assigned serviced area do not consider the nature of the distribution of the air parameters in it, that are determined, in turn, with the type of air distributor and air flow parameters at the discharge (at the end of the outlet). And air distribution in the building is calculated for the air-distributors of known design.

We have set the goal to elaborate air-distributors with required geometrical forms for each specific case. So in the result of prospected investigation we will try to elaborate a geometrical model of air distribution device with help of solution of the reverse task, a mathematical model of air distributor with elaborated geometrical forms, to estimate accuracy of calculations and effectiveness of the whole ventilation system with this product.

In the direct task it is know the form of the outlet, its diameter, initial velocity. And we can determine all parameters, such as jet throw, velocity distribution, the velocity at each point of jet. But it's difficult to determine the area covered with jet. Moreover, the problem of air-distribution is based on the fact that in the serviced zone the required microclimate parameters can be ensured not always because it's impossible to change the construction of air diffuser during the operational process.

In some cases to make system economical, to ensure adequate work of the whole system (e., in some premises the velocity in the grid is not equal especially because of duct bends), precise calculations, we need to change something. Our idea consists of the following: to ensure the fresh air supply to the working area pursuant to geometrical parameters of the maintained zone in the premises. So we know here the required velocity in the working zone (according to standards), radius of it or some geometrical forms. But we know nothing about initial parameters, parameters of the outlet (it is possible to use standard scheme for calculation and to choose typical air distributor but it cannot provide precise calculations).

The velocity of the air in ventilation is often determined with the Reihard's equation [3]:

$$U = U_x \cdot e^{-\frac{1}{2}\left(\frac{y}{c\,x}\right)^2}, \text{ where}$$

$$U_x = \frac{m\,u_0\sqrt{F_0}}{x}$$

So our main idea is to determine geometrical parameters of the air-distributor according to the area that is covered with supply air (solving of the reverse task).

Firstly we will try to solve the task for simple case. Afterwards, it would be rational to consider air distributors which have geometrically wrong cross-section. For the application of our elaboration in real condition (objects) it is important to take into account factors that are influenced the jet expansion. [4] Among them there are air discharge through the shaded openings; nonisothermality; development in the restricted space; interactions of jets with each other and with enclosures. All these features significantly complicate air jets calculation.

For solving our tasks it is planned to use mathematical modeling. It is possible that the packaged programs elements like SolidWorks or ANSYS will be employed. In case of having opportunity, we will check our results also in real conditions.

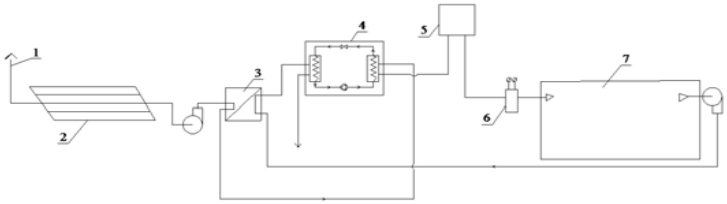
The following question concerns the utilization of waste energy and the renewable energy sources of heat in the heating and ventilation systems, since nowadays the question of energy conservation is of great importance. [5] The urgency is defined by economical reason. Thus, by the scientists'calculations, the cost of renewable and non-renewable energy sources will be equal up to 2007.

We have elaborated the ventilation system for the industrial building without utilization of traditional heat sources. This system can let reduce the electric energy expenses and decrease the environmental pressure.

The principal scheme of the air heating with recuperation of the air, that is removed, consists of the following elements: heat accumulator (air ground collector), recuperator, heat pump. Besides that the humidifier will damp the air. As a standby heat source the electric terminal unit is proposed. The system should be fitted up with automatic equipment.

The operation of the proposed system is conducted in following way. The air that extracted from the street (1) with air ground collector (2) takes the heat from soil. Next, the heated air (e.g., from -20 to 0 ^{0}C) goes to the heat exchanger (recuperator) (3), where it is heated with the air removed from the room (with a temperature of 13-18 ^{0}C). Then the heat pump (4) is installed. Here the air after the condenser achieves the required temperature (e.g., 25 ^{0}C). Then, for getting required humidity paramaters the air goes to humidity regulator (5). And directly before the entry of the air to the room (7) the electric terminal unit (6) is installed, which heat up the air if it is necessary. Besides that, here will be the standby equipment for the case of breakdown of one of the elements.

The air, extracted from the room, goes through the recuperator, where it gives its heat, to the heat pump (to the evaporator). Slightly cooled in refrigerator, it gives the heat here and get to the environment.



Pic.1. The principal scheme of the air heating with the extracted air recuperation

1 – the pipeline for the extraction of air (with hood); 2 – vertical ground collector; 3 – heat-exchanger (recuperator); 4 – heat pump; 5 – humidity regulator; 6 – electric terminal unit; 7 – serviced room.

These scheme makes it possible to ensure the required parameters of the air for the building with minimal expenses for energy consumption and without worsening of ecological situation. In the system the waste energy sources (the heat of extracted air), renewable sources (the heat of earth) and upheating in the heat pump are used. So it is the system of three-stage heating. Moreover, the air which is supplied to the room is pure and thus this system allows to avoid the release of CO_2, moisture and odours.

The application of the air-ground collector helps to avoid the frosting of air-exchanger (recuperator). The expanses during its exploitation are only on the energy for moving air through the embankment. In the period of the extreme weather conditions (with the boundary air temperatures) there are possibility to get more energy benefit from the ground collector application. The utilization of heat pump reduces the ecological load on the environment, because there are no processes of the combustion. The expenses are only on the compressor operation and the possibility of using the low-temperature air reduces costs. It increases the coefficient of performance.

Conclusions:

The problems of the air environment quality and increasing the efficiency of the heating, ventilating, and air conditioning (HVAC) systems become more and more actual in Ukraine. Rapid worsening of ecological situation due to accumulation of contaminants emissions in ambient air requires drastic solution of these problems.

The decision for solving the problem of the air-distribution was presented. The urgency of it was proved.

To reduce operation cost of the heating and ventilation systems the principal scheme that is based on waste energy and renewable energy sources utilization was proposed.

Similar investigations are applicable also for other anthropogenic loaded regions.

Bibliography:

1. Закон України «Про охорону атмосферного повітря» зі змінами внесеними згідно Закону N 5456-VI (5456-17) від 16.10.2012, ВВР, 2012.
2. Научно-практические аспекты охраны воздушной среды. Учебное пособие. Л.Г. Чесанов, А.И. Кораблёва, И.Л. Ветвицкий, С.З. Полищук, В.Л. Чесанов и др. Днепропетровск, 2008. – 324с.
3. Гримитлин М.И. Распределение воздуха в помещении / Издание третье, добавленное и исправленное. - С.-П., «АВОК Северо-Запад», 2004
4. Шепелев И.А. Аэродинамика воздушных потоков в помещении. М., Стройиздат, 1978.
5. Сибикин Ю.Д. Отопление, вентиляция и кондиционирование воздуха. – М.: Издательский центр «Академия», 2004.