IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Increase of Energy Efficiency of the Mechanical Ventilation System

To cite this article: A I Sharapov *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **272** 022218

Increase of Energy Efficiency of the Mechanical Ventilation System

A I Sharapov[1], E Y Myakotina[2], Y V Shatskikh[3], A V Peshkova[1]

[1]Department of industrial heat power engineering, Lipetsk State Technical University, Moskovskaya Street 30, Lipetsk 398600, Russia
[2]«Lipetskenergo» – the branch of Public Joint-Stock Company, 50 years NLMK street 33, Lipetsk 398059, Russia
[3]National Research University «Moscow Power Engineering Institute», Krasnokazarmennaya street 14, Moscow 111250, Russia

E-mail: sharapov-lipetsk@yandex.ru

Abstract. This article deals with an urgent issue - that of the deficit of natural energy resources, ways of their sustainable utilization and the need to find new alternative energy sources. It proposes a way to improve the efficiency of energy usage as well as to save energy in a mechanical ventilation system through the heat recovery of ventilation emissions by plate-type waste heat exchangers. Schemes of steam-curing the supplied air in ventilation systems featuring waste heat recovery and partial recirculation of exhaust air in a cold season have been developed for the dining halls of the canteen at Lipetsk State Technical University. This paper relies upon the results of microclimate parameter analysis in the scenarios of using the proposed scheme and the current direct-flow scheme of supplied air treatment in cold and transitional seasons. It provides conclusions on the possibility to attain optimum parameters of air inside the serviced rooms in case of implementing the scheme of steam-curing the supplied air with the recovery and circulation. The research also involved an appraisal of feasibility of using heat recovery installations in air ventilation systems.

1. Introduction

With the all-out deficit of energy resources, the quest for alternative sources of energy and ways of waste energy recycling is the priority.

Energy saving and energy efficiency legislation as well as relevant norms and guidelines (No. 261-FZ, No.384-FZ, SNiP 41-01-2003, SP60.13330.2012, etc.) dictate the necessity to use energy-saving materials, equipment and technologies while working out project documentation, carrying out construction, capital repairs and maintenance, reconstruction of utility systems of buildings, structures, and installations. The Ministry of Education and Science of Russia systematically monitors its subordinated bodies to verify their energy saving compliance and encourages the development and implementation of energy-saving activities at the community facilities.

In the harsh climate of Russia, about 40 % of all the fuel and energy are consumed for heating and ventilation [1]. This drives the search for up-to-date solutions, primarily those focused on the efficient use and saving of energy in the utility systems.

The operation of ventilation systems involves massive utilization of heat energy for preheating the defined air volumes to the preset temperature levels before the air is fed to the attended premises. One of the energy-saving measures, up-coming in Russia and widely used abroad, dedicated to mechanical ventilation systems having a high potential of thermal energy saving is the usage of ventilation emission heat recovery installations [2]. The recovery of heat from the vented air is ensured by direct-action waste heat exchangers operating at minor differences between heat-exchange media temperatures, and heat pumps that lift the temperature level of the working medium. Air-to-air plate-type waste heat exchangers have become most common in the ventilation systems due to their simple design and ease of operation [3].

Today, Russian design and engineering organizations have a solid experience with heat recovery units used in the systems of apartment ventilation in multi-storey residential buildings. In the year 2000, one of the first systems of apartment-wise forced supply-and-exhaust ventilation was designed with the recovery of the exhaust air heat for heating the air supply in a cross flow air-to-air plate-type heat exchanger. A similar project was implemented in 2011 in North Izmaylovo [2].

2. Methodology

The study of relevant publications has allowed to identify major lines of research, specifically, the designing of activities aimed at the upgrade of mechanical ventilation systems with a view to improve the efficiency of energy usage and to ensure its saving, at the development of energy-efficient steam-curing of the air inflow based on plate recuperators, and evaluation of the feasibility of their usage.

The study relied on the energy-efficient processes of inlet air treatment in ventilation units on the basis of waste heat exchangers with an intermediate heat carrier, designed by the author of article [4] for a swimming pool and a computer room.

The object of this research is the mechanical ventilation system of dining halls of the canteen with Lipetsk State Technical University. It is worth noting that public catering establishments, particularly canteens, are considered special facilities with high requirements to ventilation systems. The reason for them is the fact that practically all types of harmful emissions can be found in the different-purpose rooms of canteens where different technological operations are performed. And they are subject to very demanding norms of microclimate parameters and air purity. All this taken together asks for strict compliance with applicable norms and guidelines when performing the design and engineering of canteen rooms.

Air exchange in the hot shops is primarily ensured by supply-and-exhaust localization devices (SELDs) mounted above the standard electrical sectional modular equipment. A SELD allows the removal of 75 % harmful substances emitted in the hot shop. The balance 25 % heat emissions from the modular equipment as well as heat dissipation from people, natural and artificial light, and technological equipment lacking SELD, are absorbed by the inflow of the general ventilation air and are removed from the top area of a hot shop.

Dining hall ventilation is ensured by general dilution ventilation and exhaust systems. Where a dining hall is combined with a hot shop, the latter will need a vacuum to keep vapors and odors from the storages and kitchen from penetrating into the hall with diners. The vacuum can be produced by feeding into the dining hall about 40-60 % of incoming air intended for the hot shop ventilation and flowing through the serving port [5].

However, handling harmful emissions from technological processes is not the only task of a ventilation system in a public catering establishment. Supply-and-exhaust systems must also maintain the composition and condition of the indoor air in line with sanitary and hygienic rules, food storage conditions and, most importantly, create a comfortable environment for the employees and visitors. So, norms and guidelines which govern the operation of public catering establishments clearly prescribe the air flow rates per person depending on his/her labor intensity. Specifically, one employee (waiter, musician, cashier, etc.) must get 60 m^3/h of fresh air, and one visitor – 30 m^3/h [6], however not more than 80 m^3/h [7]. The amount of outside air required for one hot shop worker is at least 100 m^3/h [5].

There is a plan to replace the existing direct ventilation of the dining room for teachers (104 seats, 1st floor) and the trading floor (426 seats, 2nd floor) of the LSTU canteen with a ventilation system featuring waste heat recovery and partial circulation of the air vented from the room. This technical solution will not only cut the rate of thermal energy consumed to treat the air inflow but also ensure near-optimum microclimate parameters.

The principle scheme of a supply-and-exhaust ventilation system with heat recovery and partial air circulation includes fresh air preheating in the waste heat exchanger and it’s blending with a part of chilled exhaust air, followed by an additional heating of the resulting air mix in the heating unit (Figure 1).

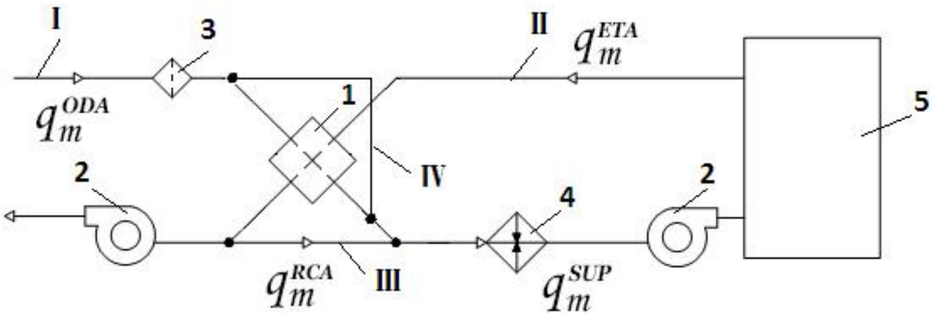

Figure 1. Principle scheme of a supply-and-exhaust ventilation system with heat recovery and partial air circulation:
1 – waste heat exchanger; 2 – fan; 3 – air filter; 4 – heating unit; 5 – room; I, II, III – fresh, exhaust and circulating air, respectively; IV – bypass
(Abbreviations: q_m^{ODA} – mass flow rate of fresh supplied air as regulated by sanitary norms (SanPiN), kg/h; q_m^{ETA} – mass flow rate of exhaust air, kg/h; q_m^{RCA} – mass flow rate of circulating air, kg/h; q_m^{SUP} – mass flow rate of air inflow, kg/h).

In cold and transitional seasons, the supply-and-exhaust ventilation system with heat recovery arranged in line with the proposed scheme shall operate as follows: to comply with the sanitary and hygienic norms, the predetermined amount of outside air will be drawn in, cleaned in the filter and preheated in the plate-type recuperator. Then the heated fresh air will be mixed with some part of the exhaust air chilled in the heat recovery unit. The resulting mix will then be sent to the heating unit to reach the required temperature of the inflow. The specific feature of this arrangement is that the flow of exhaust air through the recovery unit of a supply-and-exhaust ventilation system is 1.5-2 time higher than that of the supply air [8]. This difference between the temperatures of heat-exchange media results in a temperature of fresh air at the exit from the recovery unit much higher than in a system working with equal volumes of supplied and vented air. Moreover, circulation absolutely eliminates fogging.

Figure 2 illustrates the air treatment process in a ventilation system featuring a waste heat exchanger for a dining hall with 104 seats in a cold season with the indoor air parameters t_{IDA} = 20°C, φ_{IDA}= 20%.

The trading floor for 426 seats is connected with the hot shop via a service port, therefore its scheme of air treatment in a ventilation system equipped with a waste heat exchanger will be different from the one demonstrated in Figure 2, specifically, it will have an area ODA($SUP_{h.s.}$)$IDA_{t.f.}$, where the hot shop air inflow pre-heated by the heating unit will be mixed with the air flowing from the trading floor through the service port (Figure 3).

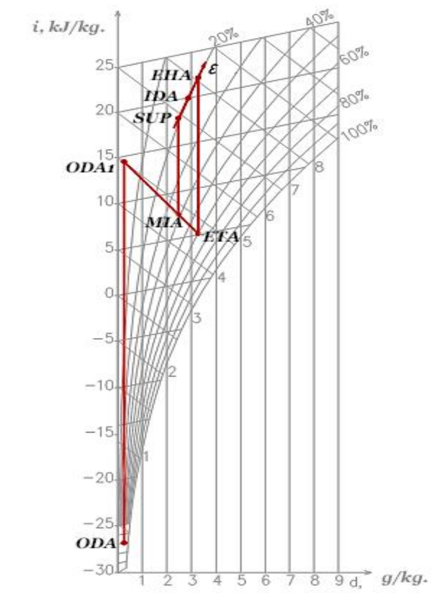

Figure 2. Air treatment process in a ventilation system featuring a waste heat exchanger for a dining hall with 104 seats in a cold season at t_{IDA} = 20 °C, φ_{IDA} = 20 %.
(Abbreviations: ODA – parameters of the outside air in a cold season; IDA – parameters of the inside air; EHA – parameters of the leaving air; SUP – parameters of the supplied air; ETA – parameters of the exhaust air at the exit from the waste heat exchanger; ODA_1 – parameters of the outside air at the exit from the waste heat exchanger; MIA – parameters of the mix; ε – a beam reflecting the direction of inside heat and humidity assimilation process).

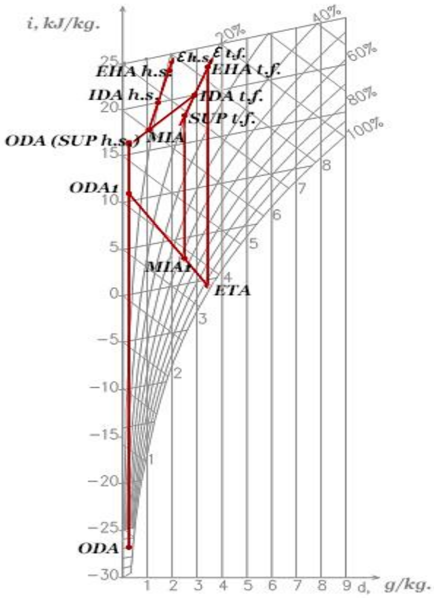

Figure 3. Air treatment process in a ventilation system featuring a waste heat exchanger for a trading floor with 426 seats in a cold season at t_{IDA} = 20°C, φ_{IDA} = 20%.
(Abbreviations: ODA – parameters of the outside air in a cold season; $IDA_{t.f.}$ – parameters of inside air on the trading floor; $EHA_{t.f.}$ – parameters of leaving air of the trading floor; $SUP_{t.f.}$ – parameters of supplied air on the trading floor; ETA – parameters of the exhaust air at the exit from the waste heat exchanger; ODA_1 – parameters of the exhaust air at the exit from the waste heat exchanger; MIA_1 – parameters of the mix; $IDA_{h.s.}$ – parameters of inside air in the hot shop; $EHA_{h.s.}$ – parameters of exhaust air of the hot shop; $ODA(SUP_{h.s.})$ – parameters of outside air at the exit from the heating unit, and supplied air of the hot shop; MIA – parameters of the mix of the supplied air of the hot shop and the air flowing through the service port from the serviced area of the trading floor; ε – a beam reflecting the direction of inside heat and humidity assimilation process).

3. Results and Discussions

The analysis of microclimate parameters when using the proposed procedure of fresh air treatment during cold and transit seasons shows that the maximum possible humidity obtainable in the said rooms at the design values of fresh air parameters will only make 20 %, while its optimum value will be in the range of 30-45 %. This is attributable to the limited volume of circulating air. Yet, the direct-flow air treatment scheme would produce max. 5 % in similar conditions. Besides, any change of outside air parameters during the period of operation at growing humidity would also cause an increase of humidity in the served rooms thus bringing humidity values closer to the optimum.

The quantity of thermal energy applied to the processed air in the heating unit of the proposed supply-and-exhaust system is 2-3 time less than the amount of energy produced by the recovery and circulation (Figure 4).

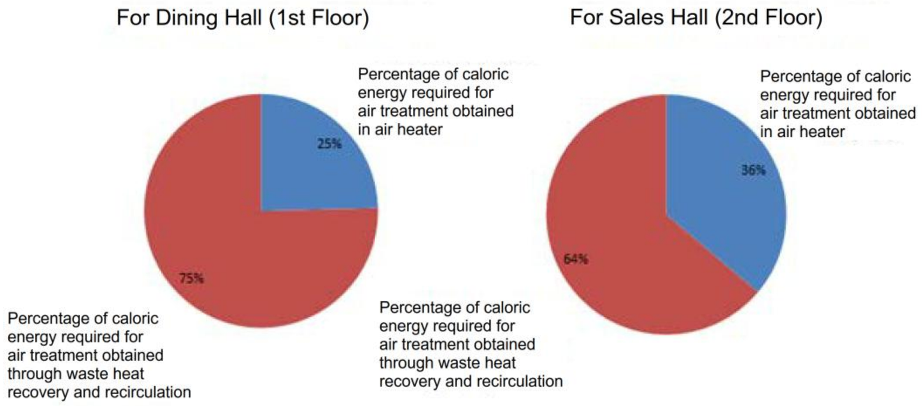

Figure 4. Proportion of thermal energy amounts used for heating fresh air supplied in the heating unit and produced by heat recovery and circulation.

As a result, recovery and circulation allow gaining up to 75 % of total heat required for the air inflow treatment.

Moreover, it was determined that the implementation of the arrangement illustrated in Figure 1 would allow a saving of 75-85 % thermal energy necessary for preheating fresh air in the heating unit compared to the existing direct-flow system.

Figure 5 shows graphs of yearly rates of thermal energy consumption for heating up air inflow in the heating unit following the proposed and the existing air processing arrangements.

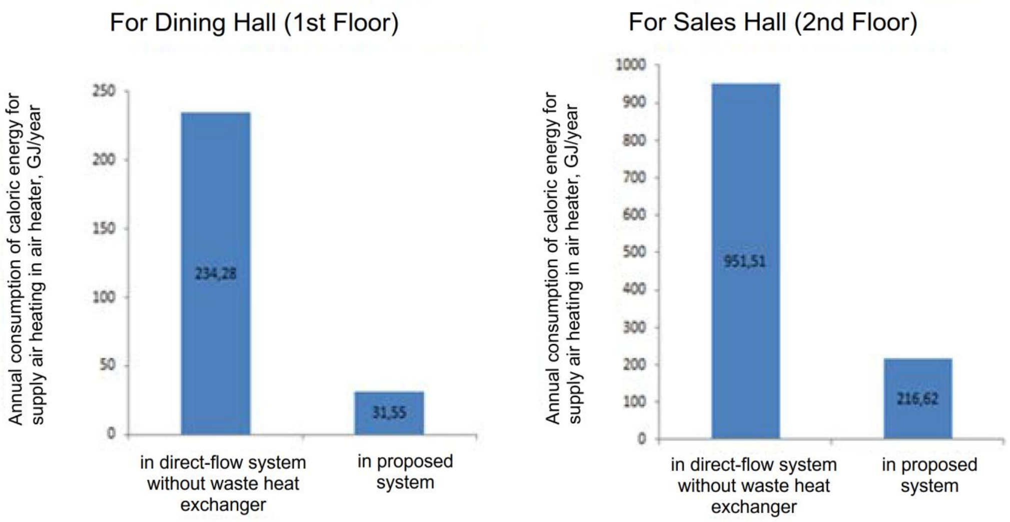

Figure 5. Yearly rates of thermal energy used for heating up air inflow in the heating unit.

4. Conclusion

So, the feasibility of using heat recovery installations in mechanical ventilation systems leaves no doubt, and the research findings lead to the following conclusion: a supply-and-exhaust ventilation system with waste heat recovery and partial air circulation ensures nearly optimum parameters of microclimate in serviced rooms at the outside temperatures in the range of -27 to 10 °C; the usage of waste heat exchangers allows a significant reduction of the amount of thermal energy spent for heating air inflow in the heating unit; it reduces financial costs of purchasing thermal energy from external sources at a set tariff. All the said above clearly indicates that the usage of waste heat exchangers is an economically feasible way of upgrading mechanical ventilation systems.

5. References

[1] Bukharkin E N and Ladygichev M G 2011 *Energy-Saving technologies for heat and gas supply systems* vol 1, book 1, ed Bukharkina E N (Moscow: Heat Engineer) p 347
[2] Milovanov A Y 2015 Recuperators of Exhaust Air Heat as a Perspective Energy-Saving Activity *Energy Saving* **5**
[3] Bogoslovskiy V N, Kokorin O Y and Petrov L V 1985 *Air Conditioning and Refrigeration Supply: Textbook for higher education establishments* ed Bogoslovsky V N (Moscow: Stroyizdat) p 367
[4] Samarin O D 2006 Combined Air Treatment in Ventilation and Conditioning Systems *SOK* **6**
[5] Zusmanovich L M 1975 *Guidelines to the calculations for air ventilation and conditioning systems of hot shops of public catering establishments* (Moscow: Stroyizdat) p 108
[6] TSN 31-320-2000 (Regional construction norms) 1998 *Public catering establishments* (Moscow: State Unitary Enterprise "NIAC" (Research & Development Analytical Center) p 41
[7] Guidebook for SNiP 2.08.02-89 1992 *Engineering of Public Catering Establishments* (Moscow: Stroyizdat) p 55
[8] Myakotina E Y, Sharapov A I and Peshkova A V 2016 Energy-Saving technologies in the mechanical ventilation system *The 3rd int. conf. with elements of scientific school "Actual problems of energy saving and energy efficiency in engineering systems*, Tambov pp 104-5