

Graph-analytical determination of heat consumption by a ventilation system in a sewage pumping station

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Abstract. In this paper, it has been described a methodology for constructing a chart of designed heat consumption by a ventilation system in a city's sewage pump station (SPS) through using a standard air exchange rate. This calculation method can be used in all climatic regions in the Russian Federation and in any other country. It has been reviewed only industrial part's inflow ventilation system (in the SPS) because of the fact that the administrative part uses its own individual system with its air quality requirements. In this article, there is some fundamental characteristics of the outdoor air, as well as the physical characteristics of the inflow air for the city sewage pumping station. The work will be useful for designers (to reduce the time for designing this type of rooms), as well as for the maintenance service of engineering ventilation systems of these constructions. In the future, the methodology can be expanded to all rooms of the SPS.

1 Introduction

The ventilation system in the city's sewage pumping station (SPS) directly affects to the health and performance of the staff in this building. A feature of this building is also that the SPS has two functional zones: the first is the industrial part, where wastewater is pumped, and the second is the administrative part, where emergency and controller's services are located. Another important feature of this construction is that the whole industrial unit can be completely underground, like some underground structures [1,2,3]. In this paper, it will reviewed the methodology for calculating the amount of air for ventilation system of the industrial part in the SPS, based on the standard of the air exchange rate and volume of the room for any pumping stations which are located in the Russian Federation.

There are a lot of characteristic divisions of sewage pumping stations: from the volume of the pumped liquid to the shape of the underground part in the plan [4,5]. Each extra characteristic makes its own adjustments to the correct design of the air regime in this building. In this paper, it has consider a pumping station with a machine room and a receiving tank combined in one building. There is a schematic picture of this type constriction in fig. 1.

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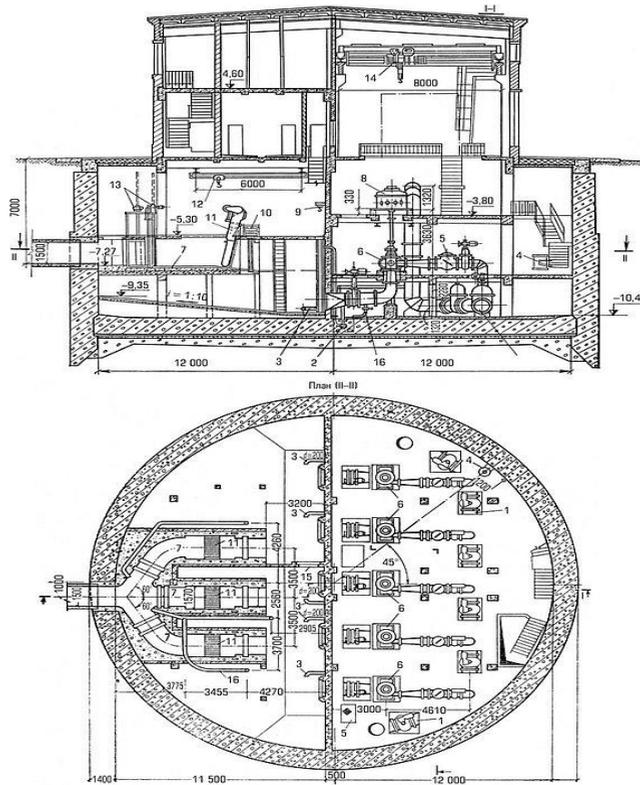


Fig. 1. City's sewage pumping station with a receiving tank and engine room combined in one building (1 - pressure collector; 2 - drain pump; 3 - pipe for stirring sludge; 4 - inlet channel; 5 - gate valve; 6 - crane-beam; 7 - grate; 8 - conveyor; 9 - winch; 10 - bridge crane; 11 - electric engine; 12 - main pumps; 13 - waste oil tank; 14 - shield valve; 15 - drain pipe; 16 - pumps of the technical water supply system).

2 Determination of air exchange rate in industrial unit in of SPS

There are several design and analytical methods for definition the volume of air for a room:

- Calculation of air exchange for total thermal excess;
- Calculation of air exchange for moisture excess;
- Calculation of air exchange for various gas emissions;
- Calculation of air exchange at the standard rate;

The calculation of air exchange for excess moisture is used for rooms with a large amount of moisture (rooms such as a pool or flower shop). Design for thermal and gas excess is used for both civil and industrial buildings. Some of heat sources in sewage pumping stations has been reviewed by V.I. Prokhorov, M.A. Razakov and others [6]. Calculation of air exchange rate according to the standard is carried out on the basis of sanitary and hygienical standards and for those conditions which a human will not receive huge damage to health also for rooms and buildings for various purposes [7]. Information for the design of the industrial part of the SPS can be found in different departmental standards and specialized documents like SP, SNiP, GOST [8,9].

To calculate the air exchange for any room is used formula (1):

$$L = V_{room} \times n, \text{ m}^3 / \text{h} \tag{1}$$

where: V_{room} - room volume by inside measurement, m^3 ;
 n - standard rate of air exchange for a the room, $1/\text{h}$.

3 Calculation method of Ventilation system's thermal power in waste water pumping stations

To calculate the thermal consumption for heating the air in ventilation system is used formula (2) [6]:

$$Q = \frac{L \times \rho \times c_p \times (t_i - t_o)}{3600}, \text{ W} \tag{2}$$

where: L - air consumption, m^3/h ;
 ρ - air density, kg/m^3 ;
 c_p - thermal capacity of air at constant pressure, $\text{J}/\text{kg K}$;
 t_i - inflow air temperature, $^{\circ}\text{C}$;
 t_o - outdoor temperature, $^{\circ}\text{C}$;

In Figures 2 it has shown the graph of changes in density as a function of air temperature. It was made according to the research experience of M.V. Vukalovich, V.P. Isachenko and others [7,10].

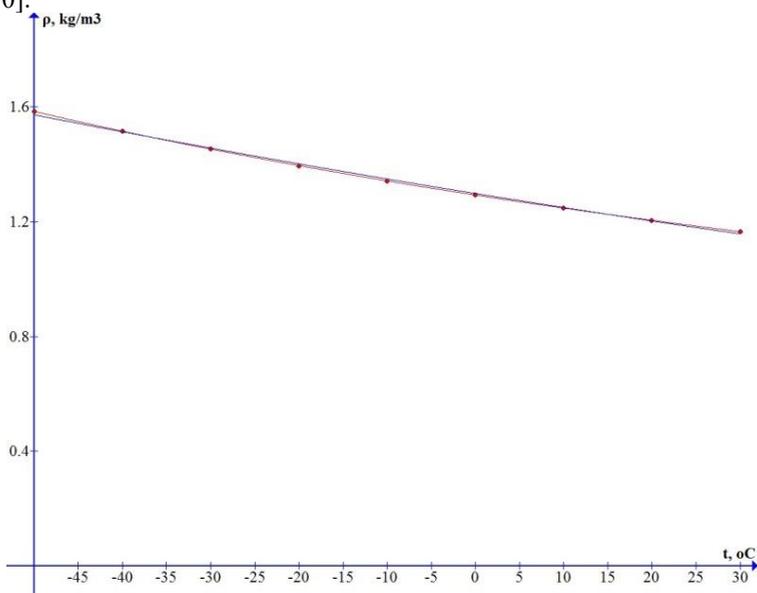


Fig. 2. Chart of changes between air density and air temperature.

4 Results

For the rooms of the engine room and the raking compartment it has been used special literature [5,8]. There is a chart of changes between air exchange and volume of the room according the standard of air exchange rate for these rooms in the sewage pumping station in Figure 3.

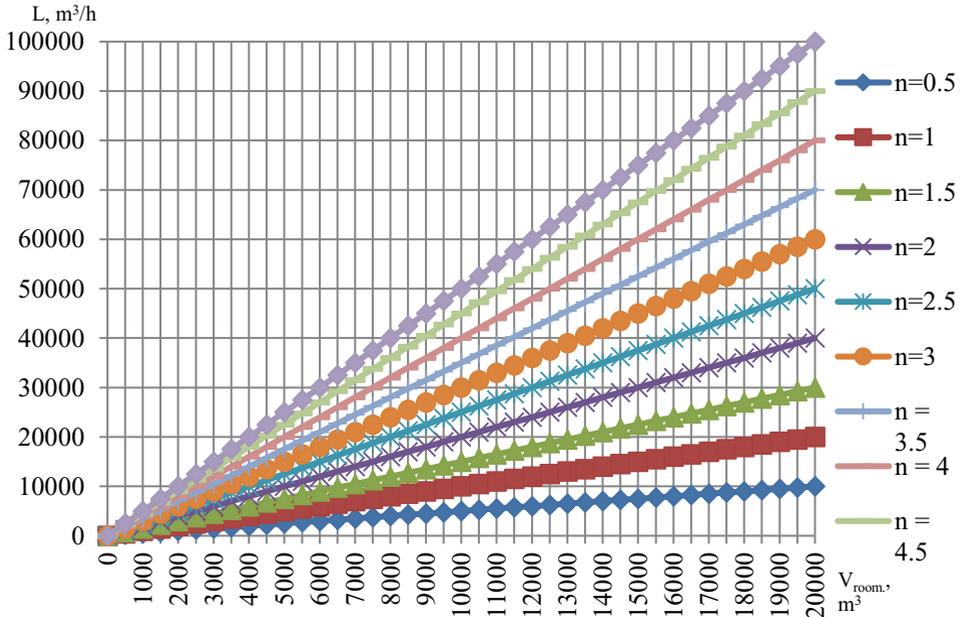


Fig. 3. Chart for the approximate determination of the inflow air in the engine room or rake room in the SPS (L is the required air consumption per hour; V_{room} is the volume of the room; n is the standard rate of air exchange).

Air temperature and air exchange rate for the rake room and the engine room of the SPS were determined in accordance with SP 32.13330.2012 "Sewerage. Pipelines and wastewater treatment plants". There is a chart of changes between air consumption and room's volume for the rake room and the engine room of city sewage pumping station in Figure 4. Also it has taken into account the difference in the inflow air temperature and the outdoor temperature in this region. In Figure 5 there is a combined chart of chart in Figure 3 and chart in Figure 4. It will help for engineers to use less their "projecting" time to count heat consumption than its necessary to do.

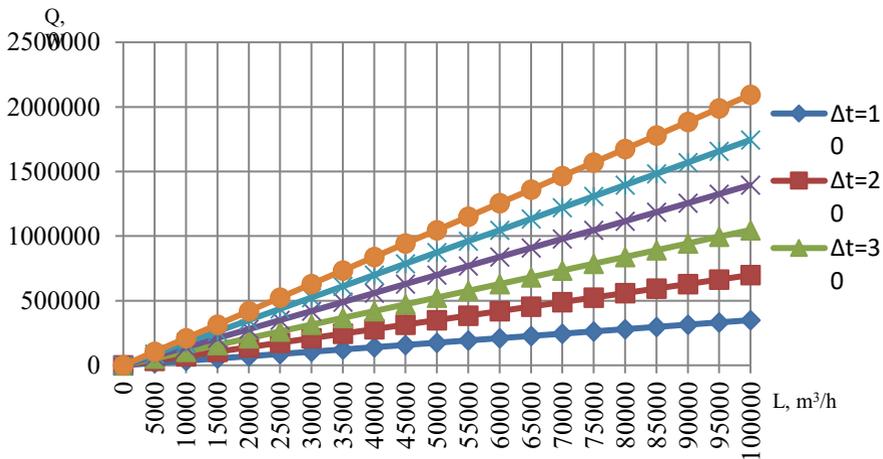


Fig. 4. Chart of the change between heat and air consumption for heating inflow ventilation system and the temperature difference between the inflow and outdoor air.

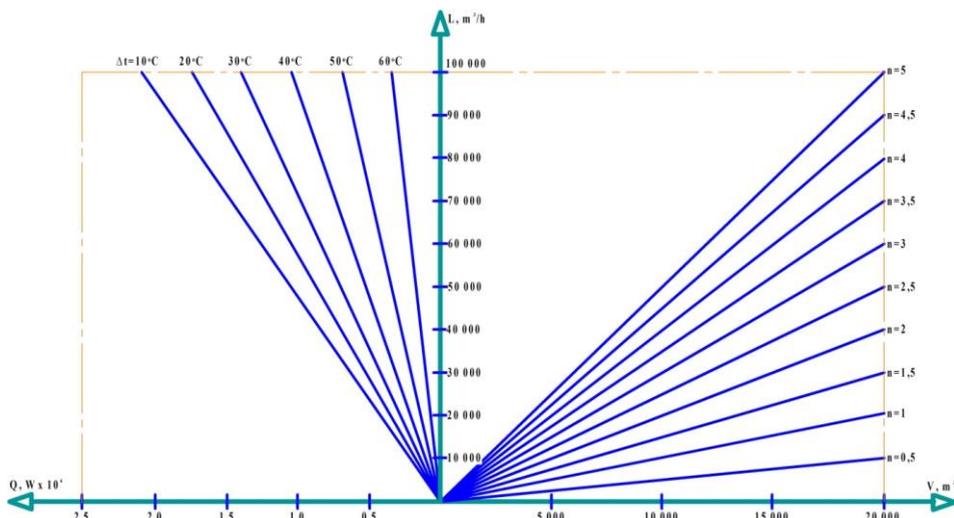


Fig. 5. Combined chart for the determination of heat and air consumption for heating inflow mechanical ventilation system.

This chart could be used not only in engine room of city's sewage pumping station but also it could used in other rooms of many building. For example, engineer, who does the project of HVAC system in office room or bedroom or others, could use this chart when he select the equipment to mechanical ventilation system.

5 Conclusion

In this paper, it has been analyzed the required air and heat consumption which are expended for the engine room and the rake room in the city's sewage pumping station for any region of construction and operation which has been based on sanitary and hygienically standards in the design. The maximum of heat consumption which has expended for heating the inflow air to the engine room and rake room will not exceed 2.5 MW with an air exchange of 100 000 m³/h and a maximum room volume of 20 000 m³. In this paper, it also has been created a new chart for the determination of heat and air consumption for heating inflow mechanical ventilation system, which could be used for any types of rooms in buildings by engineers of HVAC systems.

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