Research of Optimal Ventilation Schemes for Classrooms

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Abstract

The subject of this article's review is air distribution within a group of rooms (a model of groups of rooms is given in the article). For this group of premises, it is necessary to distribute air that will meet modern comfort requirements (temperature gradient, volume of supplied air, absence of noise and vibration), and also maintain the aesthetic architectural integrity of the premises. In order to ensure the necessary indoor climate parameters, it is necessary to provide a list existing ventilation schemes, conduct a review and comparative analysis of air distribution schemes and, in particular, ventilation ducts, diffusers, supply and exhaust grilles with different lengths and jet flow paths. The use of air distributors when designing ventilation that performs the distribution task of moving oxygen volumes, thereby creating circulation of air space in the work area. To avoid the presence of stagnant zones and uneven distribution of the temperature gradient, the best option, both for the conference room and the CD center, and for most of the teaching staff, is turbulent air distribution. At the same time, most of the air distributors considered are, for one reason or another, not suitable for use in this project.

Keywords: *ventilation, air flow, aerodynamics, three-dimensional model, air distribution*

1. Introduction

Air distribution devices have different designs: These can be either devices for a straight flow over a long jet length, or turbulizing diffusers and "spreading" diffusers, which change the flow by distributing it over an area. In view of this diversity, it is necessary to consider the shape of the stream emerging from the air distribution device and the flow rate at the outlet. In this case, the project faces a number of conditions that must be met:

1. Implementation of air mobility in the work area;
2. Compliance with the highest energy efficiency and the ability to function in various operating modes;
3. Comply with the requirements for the area in which they work.

Possible problems that may arise can be divided into three types:

- Insufficient air supply to the immediate working area, due to non-compliance with standards due to an insufficiently "powerful" system.

In this problem, with improperly designed ventilation in the room, stagnant zones with harmful gases will appear, uneven temperature gradients and a decrease in oxygen concentration in the volume of the room.

- Excess supply air.

To supply large air masses, correspondingly large air ducts and air distribution devices are required. When system performance is overestimated, the likelihood of noise and vibration increases. Since the group of premises considered in the project is intended for training and intellectual work, it is necessary to pay special attention to reducing the background noise inside.

- Incorrect placement of air distribution devices.

If the supply air distributors are incorrectly positioned, some people may be under the flow and experience discomfort from the directed air stream, while other people will be outside this area and will not experience discomfort.

2. Materials and Methods

When supplying air to a room, both the principle of displacement and the principle of mixing air masses are used [1,2] (Fig. 1).

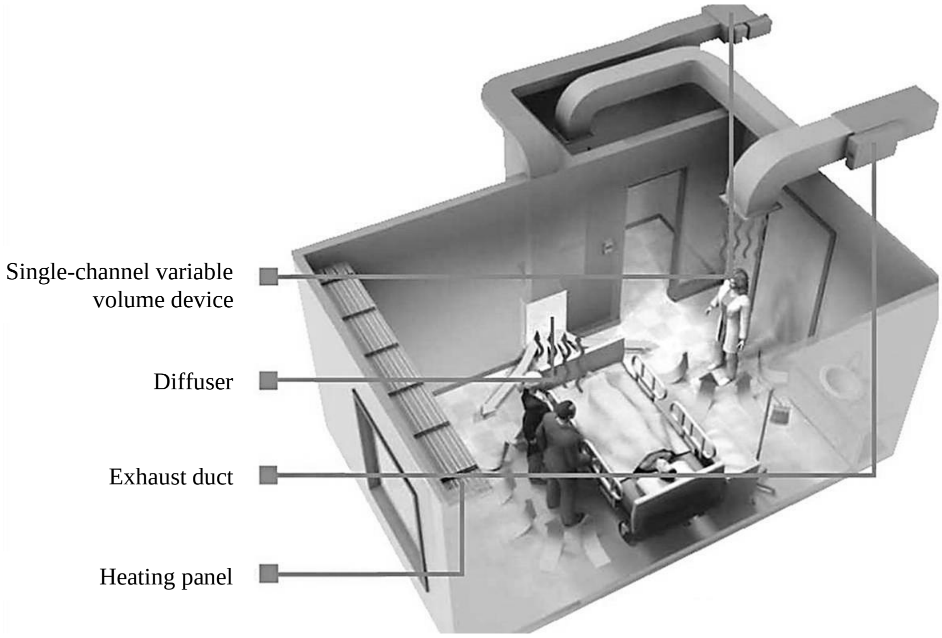

Fig. 1. Ventilation schemes for educational institutions.

If the displacement principle is applied, the air passes evenly through the air distributors, after which it passes through the entire room and leaves it on the opposite side. However, this method is mainly used to equip so-called “clean rooms”.

If we talk about mixing ventilation, then its principle is to supply air along the ceiling close to it, and due to the Coanda effect (“sticking” to the ceiling), it passes through the entire room in the form of an aerodynamic shaft.

If we consider the classification of air distribution devices, they are divided into [3-5]:

supply grilles -
o for installation in a wall or duct;
o with one or two rows of blades;
o with fixed horizontal blades;

ceiling air distributors (plafonds) -
o multi-diffuser round;
o multi-diffuser square (rectangular) with different directions of supply jets;

air distributors that form quickly decaying jets -
o slotted, installed in the ceiling or wall;
o square or round, installed in the ceiling;
o with adjustable elements;
o with perforated elements, installed in the ceiling or wall;

air distributors that form swirling jets
o round or square, with fixed or adjustable twisters;
o slotted, installed in the wall;

air distributors with adjustable geometry -
o with adjustable blades;
o with fixed blades and with an adjustable “cylinder”, two-jet;

nozzle air distributors -
o with a spherical or hemispherical chamber;
o with air-distributing twisting elements;
o with a number of air distribution elements;

floor air distributors -
o round, with swirling air flow;
o chairlifts;
o floor and staircase grilles;

Supply jets, in turn, are divided into the following types (Fig. 2):
o compact – flows out of round, square and rectangular openings, including from gratings with an aspect ratio of up to 1:10;
o flat – flows out of rectangular holes with an aspect ratio of more than 1:10;

fan - flows from diffusers or air distributors that have a disk (shield) in the path of the jet movement, turning the jet 90° and distributing the air flow in all directions. Moving on to the direct analysis of air distributors, it is worth starting by fixing the air exchange scheme; the most suitable is a top-up mixing scheme. Accordingly, the air will be supplied from above and mixed with the air inside the room. Natural convection is also used, the air rising up to the ceiling is removed using exhaust air distributors [6-8]. In addition, considering the architectural integrity of the premises and the “freshness” of the renovation, it is necessary to abandon wall air distributors.

The next point is to highlight the height of the premises, which does not exceed four meters; therefore, nozzle air distributors that supply air over long distances with a narrow-directed jet are also not suitable.

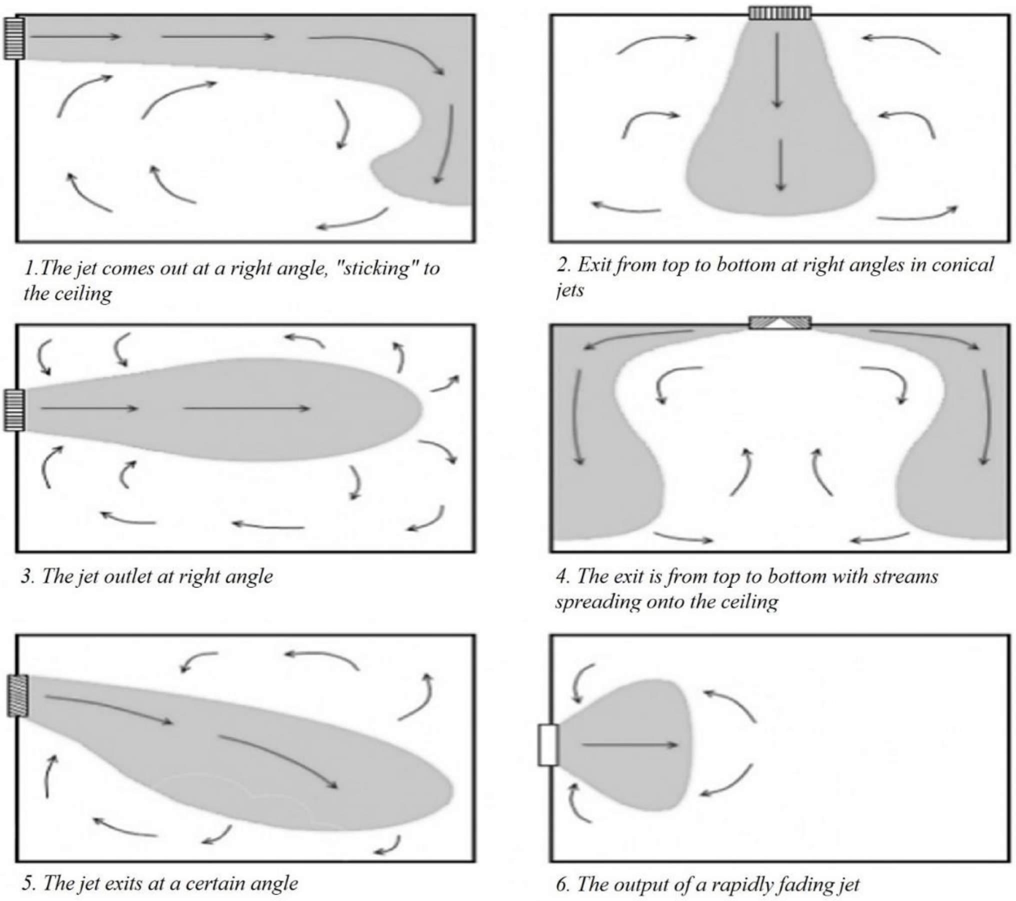

Fig. 2. Trajectory of movement of air masses with different jets

Standard diffusers, including conical and vortex diffusers, are limited by the inability to regulate the jet, therefore, a serious research goal is whether they can cope with the various required modes and, in general, whether they will allow changing the operating mode of the HVAC system [9]. A turbulizing diffuser fulfills all the above conditions. In addition, by organizing the supply of air with a turbulent flow, this air distributor ensures thorough mixing of air masses inside the room, neutralizes stagnant zones and equalizes the temperature gradient throughout the entire volume of the room.

A table is provided with the calculated required air flow rates for rooms divided into three characteristic groups: Conference room (CH), CC center, Teaching rooms (P) [10]

Tab. 1 Required characteristics implemented by the supply and exhaust ventilation system

No.	Plot	Maximum flow rate, m3/h
Central air conditioner (CC)		
1	To CC (outside air)	10200
2	From the CC (outside air)	18000
3	To CC (exhaust air)	12250
4	From CC (exhaust air)	18000
Conference room closer		
5	To the short circuit closer from the Central Committee	6400
6	From the closer to the short circuit	4650
7	From short circuit to recirculation	1250
8	From short circuit to central circuit (extract air)	4350
KD center closer		
9	To the closer KD from the Central Committee	3150
10	From the closer to the design room	2200
eleven	From CD to recycling	500
12	From CD to CC (exhaust air)	2200
Closer for teachers		
13	To the closer P from the Central Committee	8450
14	From closer to P	7700
15	From P to recycling	3200
16	From P to CC (extract air)	5750

Accordingly, according to table. 1 (lines 6,10 and 14) you can calculate the required characteristics of the supply air ducts to each room and group of teaching staffusing formula (1) [2-5]:

$$F = L/(3600 * v), \quad (1)$$

where: F – required cross-sectional area of the air duct, m2;
L – volumetric air flow, m3/h;
v– flow speed inside the air ducts, m/s;

Required characteristics of air ducts in the area from the closer to the conference room:

$$F = \frac{4614,86}{3600 * 4} = 0,32 \text{ м}^2,$$

Accordingly, we accept that the width of the air duct can be no more than 300 mm, due to the architectural features of the room, and we calculate the approximate value of the width:

$$a = \frac{F}{b} = \frac{0,32}{0,3} \sim 1,068 \text{ м.}$$

Since the width of 1068 mm is too large, it is possible to divide the supply branch into the conference room into two parallel flows with duct dimensions of 500x300 (a x b). (Fig. 3). The exhaust duct will have similar characteristics.

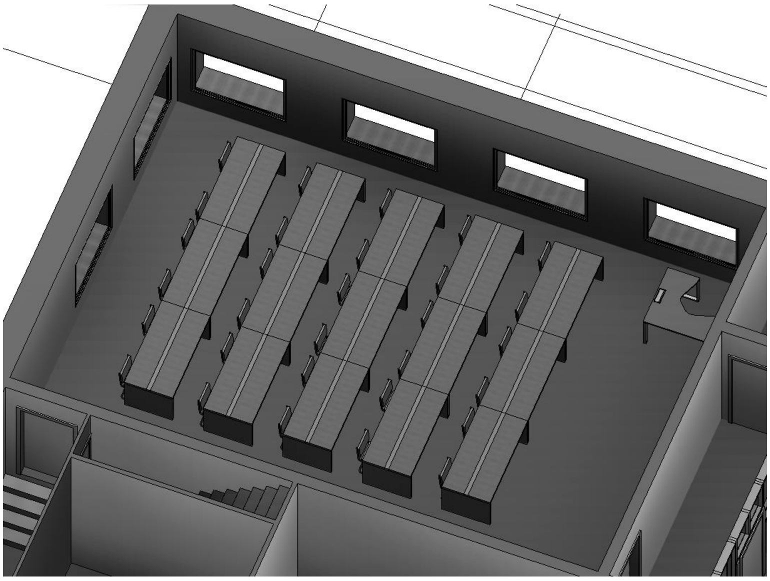

Fig. 3. 3D model of the conference room

Since most of the classrooms are located in the center of the room, the upward flow of exhaust air must be removed from the center and the exhaust branches of the air ducts must be positioned accordingly. In addition, since it is required that there be a distance of about 2 m between the supply and exhaust air distributors, the supply branches are located along the walls. For large rooms, it is important to organize thorough air mixing in order to avoid stagnant zones, therefore it is necessary to use,turbulizing air distributors [12] (Fig. 4).

Fig. 4. Turbulizing air distributor Systemair CAP-C-160-SW

The number of required air distributors per branch of the supply air duct is equal to:

$$L_{0.25} = \frac{L}{4} = \frac{4614,86}{4} = 1153,715\,\frac{м^3}{ч};$$

Accordingly, in order to evenly distribute the air supply throughout the audience, it is necessary to divide this amount into parts. For a given volumetric air flow rate, the air distributor shown in Fig.4, and has the following parameters: (Table 2).

At the same time, exhaust air distributors are used, two per branch, increasing them to the Systemair CAP-C-200-SW model [11-13] (Fig. 5).

Tab. 2 Parameters of the Systemair CAP-C-160-SW air distributor

Parameter	Magnitude	Dimension
Volume flow	384	m3/h
Pressure loss	50	Pa
Degree of implementation	93	%
Required quantity per branch	3	PC

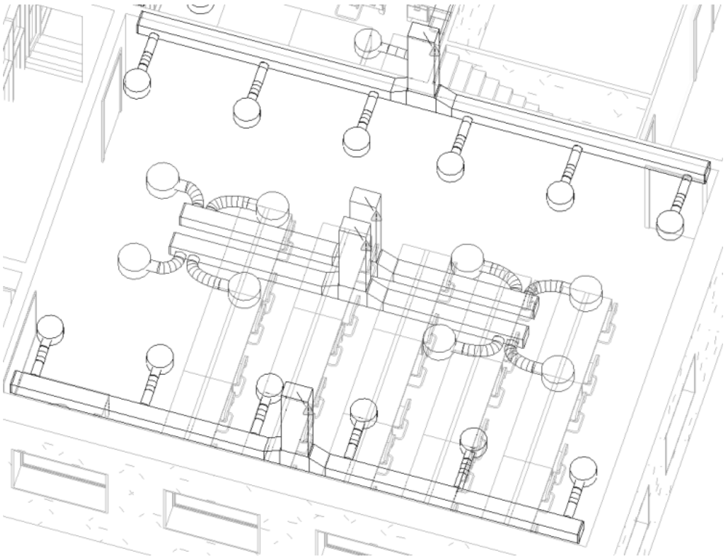

Fig. 5. Visualization of the placement of supply and exhaust air ducts in the conference room

The required characteristics of air ducts in the area from the closer to the center of the air conditioner are equal to:

$$F = \frac{2181,09}{3600 * 4} = 0,151\ м^2, \qquad a = \frac{F}{b} = \frac{0,151}{0,3} \sim 0,505\ м.$$

Similarly, to the conference room, the branches in the room are divided into two, bringing and removing a common air duct measuring 500 x 300 (axb), but dividing into two air ducts 250 x 300 and spreading throughout the room. The air distributors are the same as for the supply branch in the conference room. hall - Systemair CAP-C-160-SW (Fig. 6).

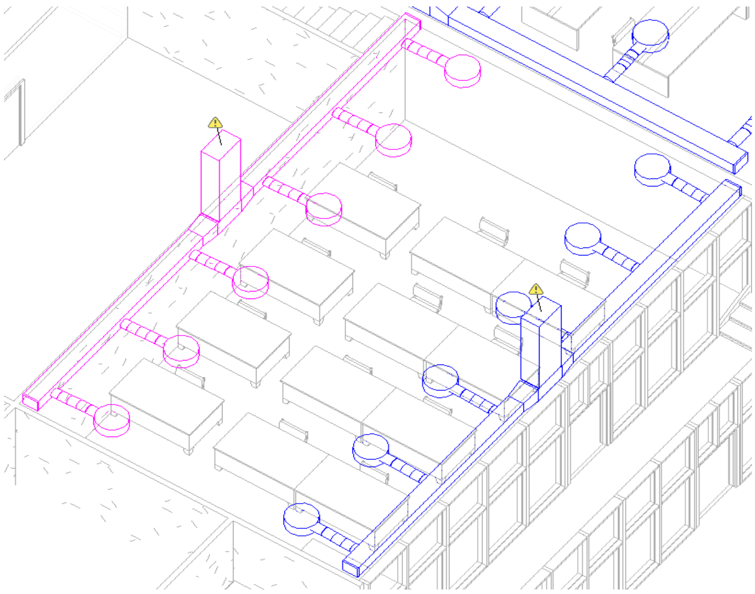

Fig. 6. Visualization of the placement of supply and exhaust air ducts in the center of the CD

The required characteristics of air ducts in the area from the closer to the teaching staff are equal to:

$$F = \frac{7660,2}{3600 * 4} = 0,532 \text{ м}^2, \quad a = \frac{F}{b} = \frac{0,532}{0,6} \sim 0,89 \text{ м.}$$

Since laying a 900x600 duct is unacceptable, similarly to previous situations, each duct can be divided into two streams with an overall duct size of 450 x 600. However, at this time it is not possible to decide how best to lay this duct and it is necessary to free up space on the fourth floor.

3. Results and discussion

To avoid the presence of stagnant zones and uneven distribution of the temperature gradient, the best option, both for the conference room and the CD center, and for most of the teaching staff, is turbulizing air distributors. At the same time, most of the air distributors considered are, for one reason or another, not suitable for use in this project.

4. Conclusions

1. In each room, it is preferable to use a top-up mixing ventilation system.
2. For the required volume of air flow, a large cross-section of the air duct is required, or a high flow rate, which leads to excessive noise;
3. To avoid excessive noise, it is necessary to divide the air duct into paired branches (Figure 5-6).

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