Analysis of the microclimate of the halls of worship

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Abstract. Carrying out rituals in the church hall of the cathedral is accompanied by a significant release of various hazards from parishioners and staff (heat, water vapor, carbon dioxide), when burning candles, from the use of censers and lamps (heat, carbon dioxide, fumes, soot, soot, water vapor), from consecration and solar radiation through external enclosures (heat). In the article, a local exhaust ventilation system with the use of umbrellas installed above the candlestick tabletop is proposed for trapping and removing harmful emissions from burning candles in a worship hall. To calculate air changes, it is important to have data on the amount of harmful substances emitted in the church hall of the cathedral. It is known that in the central part of the cathedral during the warm period of the year in the hall of worship at the permissible internal air temperature from 12 to 16 °C and the optimum temperature from 14 to 16 °C, one person emits an average of 50 g / h of water vapor. In the cold period of the year, when the permissible internal air temperature in the worship hall is from 12 to 16 °C and the optimal temperature is 14 to 16 °C, each parishioner emits on average up to 40 g / h of water vapor. Heat release from one person in full heat reaches 80 W in the warm season, and up to 100 W in the cold.

1. Introduction

The amount of carbon dioxide emitted by one person is 23 l / h. The permissible concentration of CO2 in the removed air is regulated to 2 l / m3, and in the supply air - from 0.33 to 0.5 l / m3, depending on the size of a settlement or a large city [1, 2, 10, 11].

When burning candles, water vapor is released up to 1.3 kg / h of paraffin, the amount of carbon dioxide is 1650 l / kg of paraffin, as well as soot and soot, which are carried in the volume of the worship hall by convective and ventilation flows [1, 2, 8, eleven]. According to [1, 2, 4, 10], for the design of air exchange in the cathedral, the consumption of candles is taken depending on the number of parishioners. When 60 people use candles 0.5 kg / h, 300 people - 1.5 kg / h, 600 people - 1.55 kg / h.

When calculating air changes in the worship hall, it is supposed to use the data given in [10, 11, 12], depending on the type and number of candles. The size and weight of the candles determines the burning time of the candle and the amount of emitted combustion products.

It is generally accepted in cathedrals in the halls of worship, mainly candles are placed on the tabletops of candlesticks and are in the hands of parishioners. Candlesticks do not have a permanent place of installation and are randomly installed and move around the area of the worship hall. A
survey of cathedrals showed that soot (soot), as a result of burning a candle, settles on the walls of the hall, icons, painting on easel paintings, ceilings, vaults, architectural elements, on gilding. As a result of exposure to smoke and soot, the interior decoration of the worship hall becomes dark and smoky, the smoke makes it difficult for parishioners to breathe [12, 13, 16, 17, 18].

To eliminate the negative effect of combustion products from paraffin candles on the microclimate of the worship hall, according to standards and scientific works, at present, mainly natural and mechanical ventilation, as well as air conditioning, are used. Along with this, the task of the ventilation and air conditioning system is to provide the calculated parameters of the internal air given in Table 1 [1, 2, 5, 6, 12, 13, 14, 15, 16, 17, 18]

2. Materials and methods

2.1. Materials

In order to reduce the flow of paraffin candles combustion products into the hall of worship, the authors of the article, along with general ventilation, propose to apply local trapping and removal of harmful substances directly in the candle combustion zone above the candlesticks. There are currently no technical solutions and theoretical studies in this area, there are no recommendations for the engineering design of a local exhaust ventilation system to remove the combustion products of candles outside the worship hall.

To solve this problem, this article uses well-known theoretical studies and engineering solutions in the field of ventilation, heat engineering and heat and mass transfer [7, 14, 15]. It is proposed to use local suction in the form of an umbrella above the candlestick table to catch the harmfulness of burning candles in the church service hall of the cathedral. A local suction in the form of an umbrella serves to localize harmful secretions in the places of their formation and to remove polluted air outside the church hall through a local ventilation system. The umbrella prevents the penetration of combustion products from the candle into the breathing zone of the parishioners. For practical application, various solutions are recommended for installing local suction devices to remove smoke, soot, burnt and other harmful products of candle combustion in reconstructed, restored and newly built cathedrals. For newly built cathedrals, an exhaust ventilation scheme is proposed at the design stage, where the exhaust duct is located in channels or basements under a canopy.

For practical application, various solutions are recommended for installing local suction devices to remove smoke, soot, burnt and other harmful products of candle combustion in reconstructed, restored and newly built cathedrals.

For newly built cathedrals at the design stage, a conventional exhaust ventilation scheme is proposed (figure. 1), where the exhaust air duct is located in channels or basements under a canopy.
2.2. Methods
With this solution, holes are made in the required places for the installation of candlesticks in the floors of the worship hall to connect the outlet pipe passing through the candlestick stand with the air duct. In view of the fact that the candlesticks are moved around the hall as needed, it is important to provide additional holes in the floor of the hall, which are closed from above by an artistically designed hatch (cover) made of the floor covering material.

New in the design of the candlestick is a channel (pipe) placed inside the rack, which is connected to the air duct. The channel (pipe) comes out above the countertop and is covered from above with an umbrella in the form of a cap to catch the hazards from burning candles. The convective air flow rises upwards, rests against the inside of the walls of the umbrella and, due to natural or artificial pressure, is diverted into the channel (pipe) and further along the exhaust duct is removed to the outside. The air removal process can be both natural and mechanical due to the fan installed in the air duct network.

3. Results
Recently, the country has been actively working on the restoration, reconstruction, restoration of cathedrals, temples, churches built in previous centuries. In cathedrals being reconstructed or under restoration, it is difficult to use the method of laying air ducts to remove harmful substances under the floor or in the channels. In this case, a group installation of umbrellas in one line above the
candlesticks is proposed to capture and remove combustion products from the candles to the outside. Candlesticks are proposed to be placed along the outer walls, windows at a distance of 1.5 m and also at 1.5 m from each other, this provides free access for parishioners to the candlesticks (figure 2).

Figure 2. Conventional arrangement of candlesticks in the hall of worship along the walls in existing cathedrals: 1 - hall of worship; 2 - exhaust air duct; 3 - umbrella over the candlestick; 4 - a place for removing polluted air outside the cathedral.

Candlesticks are installed in one row along the outer wall, their number is regulated by the need for worship and for the maximum number of parishioners, as well as full filling of the tabletop with candles. The heat $Q_{\text{candle}}$ from candles arises as a result of combustion, forming an ascending convective flow. Hot air together with combustion products (soot, soot, moisture, heat, carbon dioxide) rises up and is captured by the umbrella and then is removed through the air duct outside.

The lower edge of the umbrella should be at a distance of 1.8 - 2.0 m from the floor to ensure free movement of the parishioners (figure 3). A conventional axonometric diagram of local exhaust ventilation (natural, mechanical) to remove combustion products from candles in the church hall of the cathedral is shown in figure 3.
Figure 3. Conditional axonometric diagram of local exhaust ventilation for removing combustion products from candles in the church hall of the cathedral: 1 - air duct; 2 - umbrella over the candlestick; 3 - candlestick; 4 - candles; h is the distance from the tabletop of the candlestick to the base of the umbrella (determined by calculation).

With a sufficiently convective flow, the movement of air through the duct can be carried out in a natural way due to the difference in the densities of hot \( \rho_{yx} \) and cold air, or artificial air with a weak convective flow using a fan. In case of natural air movement in the air duct system, to ensure circulating pressure, it is necessary to ensure the air duct height from the outside at least 2 m from the lower edge of the umbrella to the mouth of the air duct.

For the efficient operation of the exhaust ventilation system in the worship hall, a number of technical and design requirements are imposed on the local suction: the source of the formation of hazards from burning candles must be effectively covered, the umbrella must not interfere with the movement of parishioners, the air movement in the local suction umbrella must coincide with the direction of natural convective motion. Flow together with hazards, local suction and air ducts should have an aesthetically pleasing appearance and be not bulky, the system should have a low hydraulic resistance.

4. Discussion
In technical solutions for the organization of local exhaust ventilation, various designs of local exhaust are recommended. They come in round, rectangular and other shapes. Possible types of umbrellas can be used to trap and remove hazards from burning candles in cathedral worship halls.

Local suction is suggested to be used for trapping and removing air together with combustion products from candles outside the premises.

For the umbrella to effectively trap hazards, burning, soot, moisture, heat, carbon dioxide, it is necessary to ensure the air speed in the working opening of the umbrella equal to the speed in the working space. This is possible provided that the angle between the conical part of the umbrella does not exceed 60°.

It is known that near the edge of the inlet of the umbrella, a vortex narrowing of the convective air flow occurs, as a result of harmfulness, it breaks out back into the room. It is possible to eliminate this phenomenon by means of "skirt" and "pocket" devices, which place an air vortex inside. As a result, the inlet of the umbrella catches harmfulness with a full section.
5. Summary
When trapping and removing non-toxic hazards as a result of burning candles, the value of the speed $v$ is taken to be $0.15 - 0.25$ m / s. The average speed in the convective jet should correspond to $0.5$ m / s.
In the calculations, the size of the umbrella must be calculated taking into account the maximum number of candles that can be burned, given that the use of the number of candles is periodic. For the effective operation of the umbrella, it is important to observe certain design dimensions and their ratio, proposed by a number of authors and given in the technical literature. Compliance with the specified design dimensions ensures uniform distribution of air in the inlet section of the umbrella and complete trapping of hazards in the ascending convective flow.

The use of local exhaust ventilation in the worship hall of Orthodox churches can significantly reduce the concentration of harmful substances coming from candles, smoke, soot, soot, moisture and carbon dioxide. This eliminates settling on walls, ceilings, vaults, domes, frescoes, icons, paintings, and architectural elements. Thus, the proposed local exhaust ventilation will reduce labor costs associated with the necessary cleaning and repair of internal surfaces, fences, icons, paintings, decorative elements, as well as expand the area of the hall and provide the required microclimate for parishioners. In addition, to keep the interior decoration inside the church hall of the cathedral in proper condition.

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