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Peculiarities of ventilating of the Lviv Opera Hall

Introduction

Lviv State Academic Opera and Ballet Theatre of Solomiya Krushelnitska is a peculiar building being of special importance for the architecture and culture of the city of Lviv. The building was designed by Zygmund Gorgolewski, an outstanding architect of his time, in 1897 [2], and was erected in 1900. The bulk of the Opera auditorium is 4374 m^2, the auditorium has room for 1000 spectators. The stage part of the theatre also has significant dimensions, being equipped with modern technologies with moving platforms.

The project of ventilation and heating systems of the theatre building was done by engineer Władysław Niemersz from Austrian designing firm "Johanes Haag" in 1897 in Vienna [6]. One of the projects of modernizing ventilation, central heating and temperature electrical regulation systems was developed in 1903 by Lviv engineering company "Michalski and Hupert" specializing in health recreation equipment [7]. Another project of reconstructing ventilation and central heating systems as well as their partial automatic control was developed in 1977 [8].

Analysis of design plan and specification of the ventilation system

The initial project provides for systems of direct flowing mechanical plenum-exhaust ventilation of the auditorium and the stage, recirculation mechanical plenum-exhaust ventilation of these main premises and the system of their thermostimulating (natural) ventilation.

For example, the system of mechanical direct flowing (without recirculation) plenum ventilation operates in the following way (Fig. 1). Due to rarefaction created by ventilator W1, the external air from the on-land cylindrical air collector, distanced from the building, flows through the underground duct, then through filter F_1 with duct F closed, goes through distributed horizontal underground (under-floor) ducts and flows into four (six) vertical ducts that are shown in the plan of the basement (Fig. 2, 3). Two of the ducts are embedded near the edges of the interior wall that limits the auditorium from the side of its entrance apertures and two others, in the same cross section, are attached to the partitions of two symmetrically located corridors.

Then the incoming air flows out from these vertical ducts and goes through distributed horizontal over-floor ducts to the ceiling air distributors of the auditorium as well as to the foyer and the entrances (valve C being open). When valve C is closed, the input air of the central mechanical ventilation system is distributed only in the

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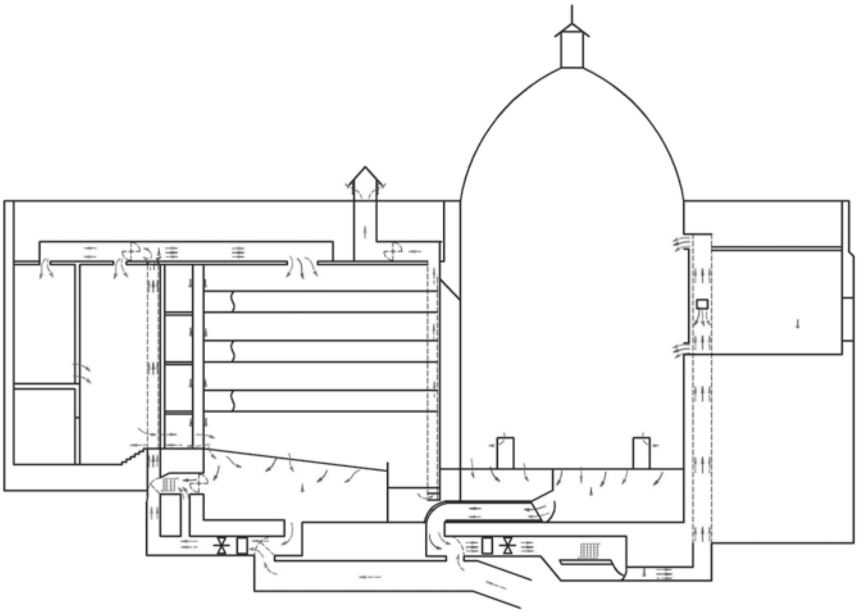

Fig. 1. Theatre ventilation system – longitudinal section

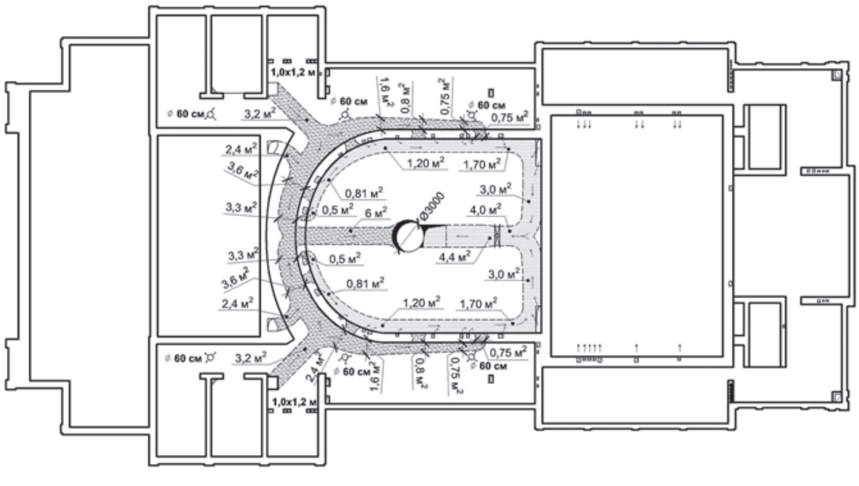

Fig. 2. Heating and ventilation system of the theatre – plan of the loft [6]

auditorium and flows through it upward–downward, as primarily the streams of incoming air are cool.

According to this scheme, the air flowing out of the auditorium should flow through ventilating grids, equally spaced in the floor of the stalls, into the under-floor rarefaction chamber, the rarefaction being also created in the under-floor balcony rarefaction chambers by a corresponding ventilator or ventilators. Then, the out-flowing air should be blown by the same ventilator (ventilators) into horizontal and then vertical ducts, the tips of which protrude from the roof, and should be dispersed in the atmosphere. Such a scheme cannot be seen in the drawings.

The proposed scheme of the auditorium hybrid ventilation (mechanical plenum with “upward–downward” air distribution and exhaust natural of the stalls under-floor space) cannot function effectively as no regulated air rarefaction is provided in the stalls under-floor space (such rarefaction can be created only by the ventilator of mechanical exhaust ventilation system; the ventilator, together with the expense regulator and noise suppressor, can be placed in a container on the roof of the building). Due to this rarefaction and additional (or zero) excessive pressure in the auditorium, the air will flow through floor grids into the under-floor space. The air flow through balconies floor grids is not foreseen at all.

The scheme of up–down air flowing can be effective only in case of cool air distribution and exhaust of the interior air out of the auditorium through the stalls floor

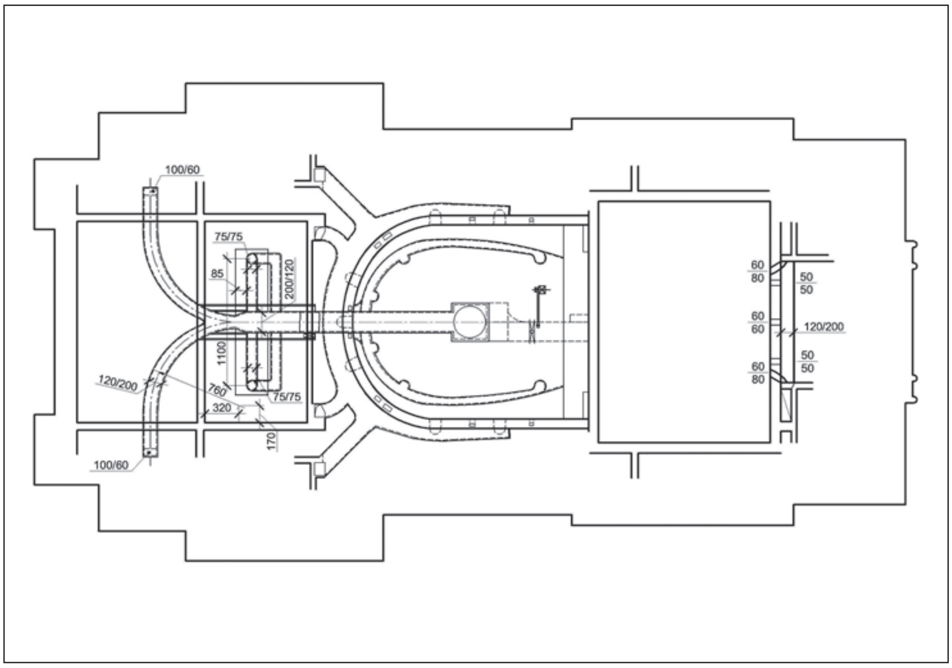

Fig. 3. The scheme of reconstructing airing, central heating and electrical temperature regulation systems. The loft – the plan at the mark of +15,0 m

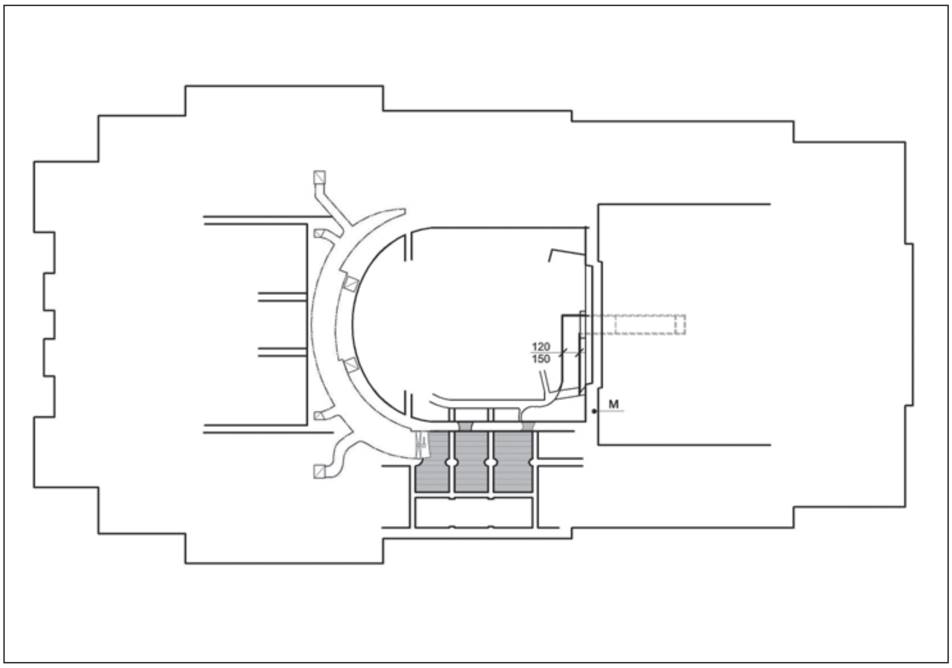

Fig. 4. The scheme of reconstructing airing, central heating and electrical temperature regulation systems. Basement – plan at the mark of –3,2 m

grids and balconies floor grids. The scheme cannot be used for air heating (heating ventilation) of the premises. Using such a scheme it is almost impossible to achieve the rated temperature uniformity tB and air velocities vb in the service zone.

In our opinion, in both warm seasons and cold seasons there can be an effective "down–up" scheme of air flowing through the auditorium premises using under-floor spaces of the stalls and balconies as the chambers of plus excessive pressure and floor, under-chair and chair air distributors (of the klimadrant type). The similar scheme of air flowing has been implemented for ventilating hall premises of the theatre in Milan as well as many other high-ceiling hall premises [1, 9, 10].

The initial project foresees the auditorium ventilation system operation in the mode of full and partial recirculation. It is assumed that during ventilation of the hall premises in the mode of full recirculation the exhaust air should flow through floor grids into the under-floor space of the stalls where ventilator W_1 creates rarefaction (at this, valve "E" should block the external air intake). Then, under the effect of additional excessive pressure of ventilator W1 the air moves through distributed horizontal and then vertical ducts and through loft distributed horizontal ducts to ceiling air distributors and is distributed by them in the auditorium premises as well as in the adjacent foyer and entrance premises. Operation of such a system without artificial air cooling in warm seasons and its heating in cold seasons are not logical as the system does not provide cooling and heating of recirculation air.

Also foreseen, is the operation of the plenum-exhaust ventilation in the mode of natural (gravitational) flow of the air through the auditorium. The system of such ventilation of the premises using “up–down” air flowing scheme has low efficiency or is not able to function at all. It is known that pressure effects caused by convection streams from heat sources serve as a thermostimulating force causing air flowing by “down–up” scheme [3–5]. As a result of convection streams action, there appears maximum rarefaction in near-floor space of the stalls, and in the near-ceiling space of the auditorium there appears maximum plus excessive pressure. So, it is the “down–up” air flow scheme that is desirable for thermostimulating ventilation of the auditorium premises, including natural ventilation (aeration).

In the system of mechanical direct flow ventilation of the stage premises the external air is made movable by ventilator W_2 and before reaching the ventilator it is purified from dust particles by the texture filter F_2. Then the air is forced into the vertical ducts by the system of horizontal ducts, in two levels of height, where there are provided apertures with air distributors: the apertures of the low level are made at the height of 1/3 and apertures of higher level are made at the 2/3 of the height of the stage premises including its cupola part. As the system of mechanical exhaust ventilation of the stage premises is not provided, we can conclude that in the stage premises, ventilation of plus excessive pressure should operate.

If valve “a” of external air intake from underground duct is closed, the ventilation system of the stage premises will operate in the mode of full recirculation with the account of the air by ventilator W_2 .

In the initial project, also foreseen is the system of natural thermal ventilation of the stage premises but by the scheme of “upward–downward” air flow. Such a system will not be able to operate effectively because all aeration ventilation systems function by the “downward–upward” air flow scheme.

Analysis of the existing state of the ventilation system

At present the plenum – exhaust systems of the auditorium ventilation are not practically in operation due to the following reasons:

– horizontal duct of external air intake in the limits of the building is blocked by the transversal mortar walls which, together with the walls of the duct, form some spare space used for household needs;

– ventilator W1 of the plenum ventilation system mounted according to the initial project is misbalanced and cannot be activated;

– the number of ventilation grids in the stalls floor and their dimensions are unable to provide the flow of designed amount of the interior air; besides, perforated grooves are fixed to floor grids, they being additional aerodynamic supports but performing no positive functions. These grooves were mounted during the last reconstruction of the theatre building that was completed in 1983.

– the under-floor space of the auditorium is filled with concrete and blocked up, so it is practically unable to serve as a chamber for uniform air rarefaction (when there is a corresponding ventilator in the system of exhaust ventilation);

– ventilation ducts from the side of the loft are blocked with building wastes; besides, pressure equalizing chambers placed in the loft are also blocked up with building wastes, or the apertures in the walls of these chambers are filled with more or less air permitting walls made to weaken cooling of the auditorium in cold seasons and they block the air flow along ventilation ducts both in winter and in summer.

Recommendations concerning reconstruction of the original ventilation systems and their modernization

1. To restore the original state of the ventilation systems and to ensure functioning of air flow according to the initial “upward–downward” scheme.

2. To ensure the flow-in of the air into the auditorium by providing modern air-maker with appropriate functions instead of ventilator W_1, filter F_1 and some regulators of air streams expenses.

3. To measure and evaluate the efficiency of the primary modernized system of premises ventilation.

4. To retain the system of cooling ventilation of the hall with “upward–downward” air flow scheme, but to make mechanical the system of exhaust ventilation ensuring rarefaction in under-floor spaces of the stalls and balconies and equal fixing of inner air exhaust grids in the floor of the stalls and balconies. To place a ventilator of vertical ventilation system, an air expense regulator and a noise suppressor in thermo-, sound-, wind-isolated container on the roof of the building.

5. When the system of cooling ventilation of the auditorium with the up–down scheme of air flow is used, it is problematic to ensure uniformity of tb and vb with allowed deviations in the whole horizontal space of the service zone.

6. The most high-quality hygienic conditions in the auditorium service zone as well as uniform distribution of tb and vb can be ensured using the system of thermo expense ventilation, i.e. “upward–downward” air flow scheme with air distribution through floor, under-chair and chair air distributors.

Conclusion

1. It is necessary to restore the original state of the ventilation system and to ensure reliable flow of air through the auditorium by "up–down" scheme including due to minimization of air flow into the adjacent premises.

2. In the system of plenum ventilation it is necessary to provide a modern air-maker with corresponding functions, at least with such functions as filtering, heating and cooling of the prepared air, a noise suppressor and a ventilation unit with the changeable number of the ventilator turbine rotations. Additional isothermic moisturizing of the air being prepared, especially in the heating season of the year, should be provided using pipe-line electrical steam generator placed in the air duct of the ventilation system containing air-maker.

3. The air exchange in the auditorium in warm seasons should be determined with the account of the fact that ventilation temperature indicator is in "up–down" air flow system.

4. Thermal efficiency of the air-maker during heating season should be determined at rated expense of the external air and its plus temperatures, assuming 0º C as a calculation temperature; and a half expense at negative temperatures assuming tex,b as a calculation temperature. The larger figure of the above two is taken as a calculation thermal efficiency.

5. Modernization of the ventilation systems, including recirculation ventilation, will allow to minimize expenses of thermal cooling energy, first of all, due to controllability and manageability of ventilation processes and due to accounting heat and cold accumulating ability of the bulk of building constructions.

Acknowledgments

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Osobliwości wentylacji sali widowiskowej opery we Lwowie

Opera lwowska jest wyjątkową budowlą, która zajmuje bardzo ważne miejsce w architekturze i kulturze miasta Lwowa. Budynek zaprojektował w 1897 roku Zygmunt Gorgolewski, jeden z najwybitnych ówczesnych architektów.

Projekt wentylacji i ogrzewania budynku teatru został wykonany przez inżyniera Władysława Niemersza z austriackiej firmy projektowej „Johannes Haag" z Wiednia w 1897 roku. Pierwszy z projektów modernizacji wentylacji, centralnego ogrzewania oraz elektrycznego systemu regulowania temperatury był opracowany w 1903 roku przez Przedsiębiorstwo Urządzeń Zdrowotnych we Lwowie "Michalski i Hupert". W 1977 roku opracowano natomiast drugi projekt rekonstrukcji systemu wentylacji i centralnego ogrzewania oraz ich częściowego automatycznego sterowania.

System wentylacji hybrydowej sali widowiskowej zaproponowany w pierwotnym projekcie (wentylacja mechaniczna nawiewna z nawiewnikami powietrza "góra–dół" i wywiewna naturalna grawitacyjna z kanałami w podpodłogowym obszarze parteru) nie może funkcjonować skutecznie, ponieważ nie pozwala na regulację podciśnienia w podpodłogowym obszarze parteru. W wyniku tego podciśnienia i nadciśnienia w sali widowiskowej powietrze zostaje sprowadzane przez podpodłogowe kratki do podpodłogowego obszaru. Wywiew powietrza przez podpodłogowe kratki balkonów i lodgii w pierwotnym projekcie w ogóle nie był przewidziany.

Key words: Lviv, opera house

Słowa kluczowe: Lwów, opera