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Study of aerodynamics of stream flow in server rooms using numerical modeling

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Abstract: This paper analyzes various schemes of air exchange in server rooms. Top-down and down-top vertical cooling schemes for small server rooms using local AC systems were analyzed. Numerical models were developed for the study of heat and mass transfer and server aerodynamics, which make it possible to evaluate the cooling efficiency of electronic equipment when placed in an arbitrary configuration. To study the thermal and velocity fields, numerical simulation of the stream flow processes was performed using the FlowVision software. This paper shows the advantage of the selected air-conditioning scheme compared to the existing ventilation system. Modeling results may be used for designing small server rooms.

1. Introduction

Server rooms are characterized by large heat formation. A total of 38% of the entire electrical energy is used by the cooling system. Unreasonable distribution of air in server rooms can reduce the cooling effect by up to 20%. The choice of the cooling method depends on many factors, such as the power of the cooling equipment, the location of the server room in the building, or the location of the building itself. The main purpose of the ventilation and AC systems in these rooms is to create schemes which would enable minimal energy consumption and optimal cooling of the equipment, as well as to ensure its correct operation.

2. Modern cooling solutions for server rooms

This paper analyzes various schemes of air exchange in server rooms [1-14]. The analysis has shown that the effectiveness of air cooling in server rooms depends on the power of the racks. In rooms with surplus heat of up to 6 kW per rack [1,2,10-12] it would be reasonable to implement the arrangement of “hot” and “cold” aisles. These aisles are formed when the equipment racks are arranged face to face and back to back to each other in an alternating pattern. This limits the mixing of air. This solution is best described in the article entitled “Alternating Cold and Hot Aisles Provides More Reliable Cooling for Server Farms.”



In server rooms with surplus heat of up to 10 kW per rack, it is reasonable to use the “cold pool” arrangement. At the same time, the air should be supplied out only to the cold aisle, while the hot and cold aisles should be isolated to prevent air overflow [2,9-10].

The “active floor” solution is relevant for server rooms with surplus heat of up to 25 kW per rack. The main principle of this solution is the supply of large amounts of controlled air flow, that is, at a rate of about 4,500 cubic meters per hour (instead of 800 to 1,000 from a traditional grid), as well as the control of cooling air pressure, direction, and temperature. If needed, the air could be supplied both to the top and the bottom of a rack [2,8,10]. One of the distinct advantages of this solution is its energy efficiency.

Thus, properly organized air exchange will not only save electricity, but also significantly increase the electronics’ service life. However, to date there is no unified approach to developing cooling solutions for server rooms due to the influence of a large number of different factors, such as the location of cabinets, the degree of mixing of hot and cold air flows, the interaction of streams with server equipment, the location of air conditioners in a cooled room and etc. Literature analysis has shown that this problem has not yet received a proper scientific assessment, and therefore the arrangement of air exchange and cooling of the electronics requires an individual approach for each server room.

The studied room is the server room of casting cranes located in an LD plant of MMK.

The server room located at + 12.300 m, houses crane engine control units. The measured air temperature of the LD plant is 47° C, which leads to an increase in heat flows to the server room. Electronics signals from the server are transmitted via the main trolleys to the crane engine and to the control panel in the crane operator's cab. The room is 3 x 6 m and is 4 m high.

With the existing electronics’ cooling scheme in the server room, the removal of surplus heat is carried out by forced supply and exhaust ventilation. The supply system consists of an air intake unit, two-stage filters, an air cooler, and a fan. Duct fan performs the exhaust. When the air is not clean, frequent replacement of filters is needed, and their cleaning is difficult, which significantly increases operating costs. In addition to that, increased contamination of filters reduces the performance of the supply ventilation and thereby reduces the efficiency of cooling the electronics.

The survey showed that the existing arrangement of air exchange in the server room does not provide the required cooling of electronics. This leads to an increase in operation failures of electronics and reduces its service life. According to the results of the survey, the following recommendations have been developed:

- it is recommended to be encase electronics in metal cabinets, which will lead to energy savings of up to 25%;
- arrange cabinets with electronics facing each other and without gaps, which will increase the efficiency of the cooling system;
- to improve the cooling efficiency, it is necessary to install plugs in the front panels of the cabinets, which will prevent the formation of local overheating zones and increase the cooling efficiency;
- explore the possibility of using server cooling schemes using a split-ceiling system and a floor-mounted AC.

In order to select air conditioners with the required cooling capacity, we have calculated heat gain within the server room. The calculation takes into account heat gain through enclosing structures, as well as heat gain from electronics and artificial lighting [5]. Total heat gain amounted to 8,760 W.

Nowadays, plenty of scientists are working on the development of AC and ventilation systems. Among them are V.V. Baturin, L.S. Klyachko, V.I. Posokhin, V.K. Khrushch, V.I. Polushkin, G.A. Maksimov, I.A. Shepelev, M.I. Grititlin etc. [15-24]. These authors have studied the processes of heat and mass transfer and aerodynamics of jet streams in a limited scope. However, when designing and reconstructing such premises as server rooms, it is impossible to use the obtained theoretical calculations, since they describe heat transfer and velocity fields on the inside without taking into account the complexity of the equipment. Therefore, the study of temperature and velocity fields in the

server room of an LD plant during the operation of local AC systems of top-down and down-top air distribution has been performed using numerical simulation [22-25].

3. Results

Numerical simulation has been carried out using the FlowVision software [25]. Simulation has helped us to analyze the distribution of temperature fields and velocity profile in space using computer graphics. The efficiency of air cooling within the room has been estimated using three-dimensional modeling of air flow directions, taking into account the boundary conditions. An isotherm field and air velocity field were the output data. The mathematical model of fluid motion has been analyzed in the approximation of an incompressible fluid, including the law of conservation of mass, the Navier-Stokes equation, and the k-e-model of turbulence. The FlowVision software is based on the finite-volume method for solving hydrodynamic equations and uses a rectangular adaptive grid with local refinement.

Local values of heat exchange coefficients along the x stream are described using the following equation:

$$Nu_x = 0,104 Re_x^{0,8} (a/x)^{0,4} \quad (1)$$

$$\alpha_k = \frac{Nu_x \lambda}{x} \quad (2)$$

where Nu_x , Re_x are Nu and Re numbers calculated for the current x value, λ is the air's thermal conductivity factor; a is the width of an air supply outlet.

Convective heat transfer between an air stream and a cabinet wall has been calculated according to the Newton-Richman equation:

$$Q = \alpha F (t_n - t_c) \quad (3)$$

where t_n is the temperature of the cabinet surface, F is the cabinet's surface area.

The heat transferred by the convective jet formed from heated cabinets has been determined according to the formula

$$Q_0 = (2\pi c^2) / (1 + \sigma) c_p \rho_\infty \omega_z t_z z^2, \quad (4)$$

where c , σ are experimental constants ($c = 0,082$, $\sigma = 0,8$); ρ_∞ is the density of air outside the convective jet; ω_z is the air velocity on the axis of a convective jet; t_z is the temperature on the axis of a convective jet; z is a coordinate.

Air cooling in the server room was carried out with the help of GREE split air conditioners.

This paper considers two options for cooling air in the server room: using a U-Match cartridge split system installed in the false ceiling with a cooling capacity of 9 kW and a floor-mounted air conditioner with a cooling capacity of 9 kW. The comparative analysis of two air cooling schemes will help us to choose the more effective of the two. For modeling in FlowVision, geometrical room models have been developed for the two cooling options.

Examples of options for calculating temperature and velocity fields are shown in Figures 1 and 2.

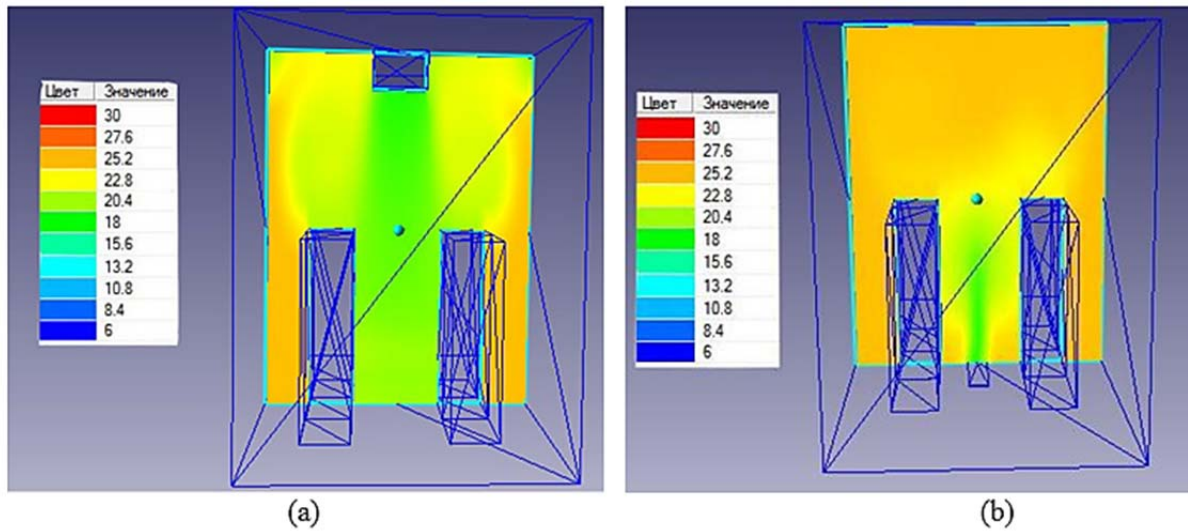


Figure 1. The temperature field in the server room when using (a) a cartridge air conditioner and (b) a floor-mounted air conditioner. The temperature at the AC outlet is 18°C, the air flow rate is 1 m / sec and 0.5 m / sec, respectively.

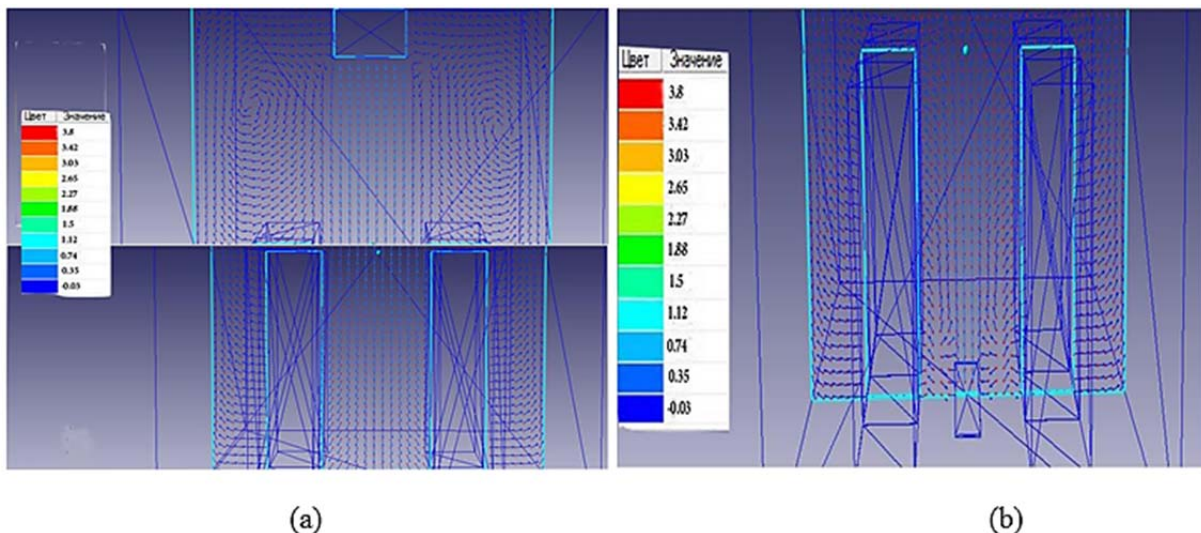


Figure 2. Air rate profiles when using (a) a cartridge conditioner unit and (b) a floor-mounted conditioner unit at the same starting conditions.

The study has been conducted under the following initial conditions: air temperature at AC outlets is 16°C, and 18°C, air flow rate from 4 m / sec to 0.5 m / sec.

Analysis of the study results has shown that when air is supplied from above, more uniform temperature fields are formed in the working area of the room, and the higher the initial air flow rate, the greater is the change in temperature along the height of the room and outside the jet. This is due to the formation of vortex air movement as a result of interaction with a convective jet, in which part of the cooled air is transferred to the upper section of the room and is not used efficiently. With an initial cooled air rate of 1 m / sec, normalized air parameters are established in the working area. When the down-top air supply scheme is utilized, it is difficult to ensure normalized parameters of temperature

and air motion in the working area. At normalized air rates, the cooling of electronic equipment is less efficient.

4. Conclusion

1. Numerical models for the study of heat and mass transfer and server aerodynamics have been developed. These models help evaluate the cooling efficiency of electronic equipment when it is arranged arbitrarily.
2. The analysis of study results has shown that when an air jet is supplied top-down, more uniform temperature and velocity fields are formed. When supplying conditioned air at a rate of 1 m / sec, it is possible to provide standardized temperature and air mobility in the working area. The obvious advantage of this method is the free space under the false ceiling so that the cables will be placed inside without unnecessary risk of damage to them in the future.
3. Analysis of the results of studies devoted to air supply by means of floor-mounted conditioning units and the server study has demonstrated that it was impossible to lay cables under the false floor, so the cable system would have to be laid above the racks.
4. To reduce the energy costs of cooling the air in the studied premises, it is recommended to choose cartridge conditioning units which should be installed within the false ceiling. The cooling temperature should be 18°C.
5. The air conditioning scheme selected in this paper is simple and does not occupy the usable floor space, which makes its use very attractive for cooling electronic equipment in small server rooms at other sites.

References

- [1] Grigoryev A D 2016 Computer centers: basic design requirements *Young Scientist* **8** 119–123
- [2] *Conditioning systems for server rooms* <http://www.xiron.ru/content/view/31215/28/>
- [3] SN 512-78 *Requirements for climatic conditions in computer rooms*
- [4] TIA 942 2005 *Telecommunications Industry Association. Telecommunications Infrastructure Standard For Data Centers (USA)*
- [5] SP 60 13330 2012 Revised edition of SNiP 41-01-2003 *Heating, ventilation, and air conditioning*
- [6] Chernov A N 2010 Problem of efficiency of cooling of IT-equipment in data processing centers, *Energo-Block*, **1(01)** 15–18
- [7] Martynov AV 1989 *Heat transformation and cooling units* (Moscow: Energoatomizdat) p 200
- [8] *Cooling of server rooms* <http://www.quantum-v.ru>
- [9] *Air conditioning in server rooms* <http://www.vidstroi.ru/kondicionirovanie/kondicionirovanie-servernyh>
- [10] *Solving the problem of cooling high-load server racks* <http://dcnt.ru/?p=2099>
- [11] *Requirements for air conditioning and ventilation systems in server rooms* <http://aeromast.com.ua/articls>
- [12] Kokorin O Ya 2003 *Modern air conditioning systems* (Moscow: Fizmatlit) p 283
- [13] Trubitsyna G N, Smolnikova P V 2014 Improvement of micro-climate in pilot cabs *Architecture. Construction. Education: proceedings of the International scientific conference* (Magnitogorsk: Nosov Magnitogorsk State Technical University) **1(3)** 291–294
- [14] Trubitsyna G N, Dyomin Yu K, Khasanova R V 2016 Some technological capabilities to increase economic efficiency of construction enterprises *Corporate Economy* (Magnitogorsk: Nosov Magnitogorsk State Technical University) **4(8)** 16–22
- [15] Grititlin M I 1994 *Air distribution in premises* (Saint-Petersburg: Ekoyurus-Vento research and production enterprise)
- [16] Kamenev P N, Tertichnik Ye I 2008 *Ventilation: Handbook* (Moscow: ASV Publishing House) p 624

- [17] *Designing engineers' manual. Internal and sanitary facilities*, pt. 3. Air ventilation and conditioning. Pts. 1 and 2, Ed. I.G. Staroverov (Moscow: Stroyizdat), 1992
- [18] Shepelev I A 1978 *Aerodynamics of air flows in premises* (Moscow: Stroyizdat) p 145
- [19] Shepelev I A 1961 *Turbulent convective jet under a heat source* (Moscow: Bulletin of Academy of Sciences of the USSR. Mechanics and machine-building)
- [20] Polushkin V I 1978 *Basics of air distribution aerodynamics in air ventilation and conditioning systems* (Leningrad: LGU) p 135
- [21] Maksimov G A, Deryugin V V 1972 Air circulation during the operation of heating and ventilation systems (Leningrad: Stroyizdat) p 97
- [22] Chernov A N 2008 Development of an energy-efficient system that provides set temperature in a server room using cooling models *Proceedings of the 66th scientific conference* (Magnitogorsk: Nosov Magnitogorsk State Technical University) pp 124–128
- [23] Chernov A N, Pavlov G A 2011 Modeling of the temperature mode in data processing centers *Proceedings of the 12th All-Russian Scientific Conference for Students, Experts, and PhDs* (Magnitogorsk) pp 120–121
- [24] Malozemov V V 1986 *Mathematical modeling of elements, nodes, and systems used to provide heat modes* (Moscow: MAI)
- [25] *FlowVision air and fluid circulation modeling system*. Rev 2.5.4. User's guide