Ultraviolet air disinfection in ventilation and air conditioning systems

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Abstract. Not only human health depends on the microbiological purity of air, but also the production processes efficiency at the enterprises of agriculture, food, pharmaceutical industry, and other human activities. To solve the problems of microbiological air pollution and ventilation as well as air conditioning systems, ultraviolet irradiation devices based on low-pressure Hg-lamps are traditionally used. Based on world experience in air treatment of ventilation and air conditioning systems, convenient to use, the energy-efficient, small-sized and safe-to-operate disinfection devices based on amalgam ultraviolet lamps have been created. Recognizing the importance of the problem and taking into account the regulatory documents requirements, we have created professional installations for the ventilation, air channels and air conditioning systems’ disinfection: ultraviolet modules MEGALIT and bactericidal cells MEGALIT AERO.

Introduction
Not only human health, but also the production processes effectiveness in agricultural, food and pharmaceutical industries depends on the microbiological purity of air. The most common method for preventing the microorganisms’ transfer by ventilation systems is the use of air filters. Modern filters remove solid particles, but do not destroy biological objects of the air environment, while microorganisms can be released from the attachment to the filters and returned to the air stream. Modern filters are not able to retain the particles smaller than 0.3 microns, and these are the sizes of nanobacteria and viruses. Microorganisms deposited on the filters multiply and grow, penetrating further through the fibrous structure of the filter into the indoor air. With condensation in moisture filters and insufficient care, a risk of mold colonies and other microorganisms arises.

The growth of microorganisms in air treatment systems contributes to: intensive clogging of filter pores and a drop in their filtering ability; biofouling of air channels and a decrease in energy efficiency of the entire air exchange system; biofouling of heat exchangers and the destruction of air conditioning systems’ pallets; infecting the room users.

Results
To solve the problems of microbiological air pollution and ventilation as well as air conditioning systems, ultraviolet irradiation devices based on low-pressure Hg-lamps are traditionally used [1 - 5]. However, the use of such devices in air exchange systems showed a number of significant drawbacks: the low power of Hg-lamps, the bactericidal flux of which does not exceed 30 W at 100 W consumed, forces the user to buy bulky and expensive systems with a large number of lamps [6]. The achievement
of an efficiency coefficient (Efficiency) acceptable for such lamps limits their use in the air exchange systems: the air temperature should not be lower than +15 °C, blowing speed no more than 2 m/s.

Based on our own research and the world experience in air conditioning in ventilation and air conditioning systems, we have created the devices based on amalgam ultraviolet (UV) lamps with an electronic ballast control device (electronic ballast) L~220-1x(95-145)-2202-184 convenient to use, energy-efficient, small-sized and safe to operate disinfection [7 - 15].

Under the influence of UV radiation on living microorganisms, there is an optimal wavelength range from 250 to 280 nm for their inactivation. The curve of the indicated bactericidal effect of radiation on microorganisms is shown in figure 1.

![Ultraviolet Bactericidal Curve](image)

**Figure 1. Ultraviolet Bactericidal Curve**

Air disinfection in the recirculator occurs due to exposure to microorganisms of bactericidal UV radiation with a wavelength of 254 nm. Microorganisms inactivation occurs due to the transfer them a sufficient dose of UV radiation.

Radiation dose $D$ or the amount of energy transferred to microorganisms is the main characteristic of a UV disinfection recirculator. It is equal to the product of the UV radiation average intensity $\langle I \rangle$ for the average exposure time $\langle t \rangle$:

$$D = \langle I \rangle \cdot \langle t \rangle$$

where, $D$ – UV dose,

$\langle I \rangle$ – defines an average UV exposure,

$\langle t \rangle$ – defines an average exposure time.

The experimentally established the values of UV radiation lethal doses for microorganisms of various species given in the Guide R 3.5.1904-04.

This electronic ballast is designed to ignite and ensure the operating mode of the amalgam discharge lamps of several types. Electronic ballasts operate in single-phase alternating current networks. Distinctive features of this type of electronic ballasts are:

- Enclosure 184 without a top cover and has IP-00 ingress protection;
- The output for connecting the “Work” indicator light - lights up when there is a lamp current and turn it on, goes off when it is turned off. The LED indicator is powered by a pulsed current of 5-10 mA from the source located in the electronic ballast;
Non-polar output (terminals 7, 8) for monitoring the presence of current in the lamp. Maximum switching current no more than 50 mA, voltage no more than 25 V. If there is current in the lamp, the key is open.

The main technical data of electronic ballasts are given in Table 1.

**Table 1.** Basic technical data of electronic ballasts

| No. | Controlled parameter                              | Value       | Permissible variations | measurement unit |
|-----|--------------------------------------------------|-------------|------------------------|------------------|
| 1   | Rated supply voltage                             | 220         | +30/-40                | B                |
| 2   | Rated current consumption, no more (depending on the type of lamp) | 0.75        | -                      | A                |
| 3   | Amplitude of inrush current no more, with duration no more than 20 ms | 16          | -                      | A                |
| 4   | Current consumption frequency                     | 50/60       | -                      | Hz               |
| 5   | Power factor (\(\lambda\))                       | >0.96       | -                      | -                |
| 6   | Heat loss (from power consumption)                | 8           | -                      | %                |
| 7   | Lamp rated current                               | 2.0         | \(\pm 0.1\)            | A                |
| 8   | Electrode heating current before starting         | 3.35        | \(\pm 0.15\)           | A                |
| 9   | Electrode pre-start time                          | 20          | \(\pm 1/2\)            | c                |
| 10  | Electrode heating current after starting          | 0.7         | \(\pm 0.1\)            | A                |
| 11  | Geometrical dimensions                            | 218x100x60  | -                      | mm               |
| 12  | Weight                                           | 0.8         | \(\pm 0.024\)          | kg               |

Modern people spend up to 85% of their time indoors. Therefore, ensuring sanitary and epidemiological safety inside the premises plays an important role in the construction and reconstruction of buildings. Indoor air can be several times more dangerous than the air outside. Most pathogens are transmitted by the airborne droplets. This is especially acute in crowded places - in industrial and public buildings, where air is instantly distributed by ventilation and air conditioning systems [1 - 5].

Air conditioning systems are infected by bacteria, viruses, and mold spores in the heat exchanger and condensate trays. Comfortable temperature, lack of sunlight and high humidity contribute to the rapid growth of pathogens in ventilation systems. Hence, the organic pollutants with air spread further through the systems of air channels into the rooms with people inside, causing harm to health. Infection of the ventilation and air conditioning systems themselves leads to an increase in operating costs, malfunctioning of the systems and premature wear of the equipment. In addition, there are a number of rooms (libraries, storage facilities, train stations, sports facilities) in which the modern building codes allow air recirculation in order to reduce energy consumption (reducing the supply air amount will reduce energy costs for heating and cooling). The use of the recirculation regime requires mandatory measures to clean and disinfect the air (Building Codes and Regulations 31-06-2009).

Recognizing the importance of the problem and taking into account the requirements of regulatory documents, we have created the professional installations for the ventilation and air conditioning systems’ air and ducts disinfection: ultraviolet modules “MEGALIT” and the bactericidal cells “MEGALIT AERO”, manufacturer of the scientific and production association “PTL” ("Pulse Technology Laboratory"), Moscow, Russia. Technical characteristics of MEGALIT modules are presented in Table 2. In Fig. 2. The MEGALIT module's front view is shown.

MEGALIT bactericidal modules are used in ventilation and conditioning systems of any public and industrial buildings, including those with special aseptic requirements (pharmaceutical and food production, etc.), as well as in agricultural enterprises (pig farms, poultry farms, cowsheds) and in the premises using the air recirculation mode.

**Table 2.** Technical characteristics of MEGALIT modules
| Name        | Weight kg | Number of lamps | The power of bactericidal radiation, W | Electric power, W | Productivity by Staphylococcus Aureus, m³/h |
|-------------|-----------|-----------------|---------------------------------------|-------------------|--------------------------------------------|
| MEGALITH 2  | 19.5      | 2               | 180                                   | 600               | 1300                                       |
| MEGALITH 3  | 23.5      | 3               | 270                                   | 900               | 2300                                       |
| MEGALITH 4  | 28        | 4               | 360                                   | 1200              | 3500                                       |

**Figure 2.** View of the MEGALIT module.

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Bactericidal modules “MEGALIT” provide:
- reduction of microbial contamination in accordance with the industry regulations requirements;
- safe operation due to the absence of liquid mercury in the lamp - there is no risk of poisoning by mercury vapor in case of damage to the lamp bulb;
- high level of bactericidal flow during disinfection of large volumes of air due to the increased power of amalgam lamps;
- profitability: lamp life reaches 16 00 hours of continuous burning, and this is about 2 years of service;
- effective efficiency (1.5 to 3 times higher than that of traditional Hg-lamps) at low air temperatures and high blowing speeds;
- high degree of integration in ventilation systems;
- have low pressure losses, low power consumption and small dimensions.

In order to effectively remove the contaminants arising in a confined space, it is necessary to supply a sufficient amount of clean or purified air to it. At agricultural enterprises and in other manufacturing institutions, it is often necessary to clean not only the incoming, but also the exhaust air infected by the aerosols of sick people and animals.

The bactericidal modules “MEGALIT” disinfect large air currents in the supply and exhaust ventilation systems with ultraviolet (UV) radiation, and also prevent the pathogens’ propagation inside the air exchange and air conditioning systems. They conform to modern requirements in terms of noise and electrical safety.

Bactericidal modules are easily integrated with existing and designed ventilation and air conditioning systems. The module is mounted in the air ducts after the air preparation systems using the connecting air duct reducing unit-diffuser adapter elements.

The bactericidal cells “MEGALIT AERO” are intended for disinfection by UV radiation of air flows in the existing channels and ducts of ventilation and air conditioning systems of any public and industrial buildings, their technical characteristics are presented in Table 3.
Table 3. Technical characteristics of the bactericidal cells “MEGALIT AERO”

| Name    | Performance, no more than m³/h | Bactericidal efficacy according by SA, % | Number of lamps | The power of bactericidal radiation, W | Electric power, W |
|---------|--------------------------------|------------------------------------------|-----------------|----------------------------------------|-------------------|
| Module 100 | 650                              | 99.9                                      | 1               | 90                                     | 300               |
| Module 200 | 1300                             | 99.9                                      | 2               | 180                                    | 600               |
| Module 300 | 2300                             | 99.9                                      | 3               | 270                                    | 900               |

The use of bactericidal cells “MEGALIT AERO” allows:
- to achieve the requirements of Russian standards for microbiological air purity;
- to prevent mold and bacteria from contaminating the ventilation and air conditioning systems;
- to simplify the air disinfection process, since the system can be equipped with a control panel and an alarm system and is integrated into an automated control system for the ventilation and air conditioning process (optional);
- to secure the disinfection process, since the absence of liquid mercury in PTL amalgam lamps makes it possible to disinfect the air without the risk of the toxic mercury vapor spread in case of accidental damage to the lamp bulb;
- to save on consumables by means of the energy-efficient PTL lamps’ use with a life of 16,000 hours of continuous burning.

The installation of UV cells in close proximity to “problem” zones (the zone of mold and biofouling growth) allows for continuous disinfection of air duct walls, reducing the level of ventilation equipment wear and the cost of the ventilation ducts’ mandatory cleaning. A photo of the MEGALIT AERO module is shown in Figure 3.

![Figure 3. Photo of Megalit Aero 300 module at SPO PTL enterprise.](image)

The bactericidal cell “MEGALIT AERO” is a stainless-steel panel with bactericidal amalgam lamps, which are protected against the accidental impact by a stainless-steel frame. On the other side of the panel is a power supply, control and monitoring unit. The device is equipped with an automatic control system for the lamps’ overheating. The versatility of bactericidal cells allows them to be used to disinfect the air and channel surfaces, both in intake and exhaust ventilation systems. They meet all modern requirements in terms of noise and electrical safety. Installation of cells is carried out in an existing ventilation duct, which makes it possible to upgrade the ventilation system with minimal cost. A technical window is cut out in the box; the bactericidal cell is then mounted into it.

Summary
The main source of microbiological air pollution is humans. One person is in the ambient air of 2000 - 6000 microorganisms per hour: when talking 800 particles / min, while sneezing up to 40,000, so the task of air cleaning is relevant and timely. From the foregoing, we can conclude that especially now, when the whole world is fighting with Coronovirus, it is necessary to clean air, surfaces, water by any available methods, and, therefore, extend the life of living creatures on the entire planet.

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