Electric power converters for air purification based on an electrostatic precipitator with an electro coronary principle of operation

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Abstract. The article presents converters and electricity for air purification methods of converter use. The article analyzes the methods of cleaning gases from suspended particles in medical institutions according to various criteria and suggests directions for the development of complex structures. The problems of air purification of medical premises, parameters of the purification quality are analyzed. Criteria and recommendations for improving air purification systems in medical institutions are presented.

1. Introduction
In modern conditions of the coronavirus pandemic, air filtration systems in medical institutions are of particular relevance. Obviously, the size of the SARS coronavirus is Cov-2.

A similar problem was present in the technique of electrocoronal treatment of cereal seeds [1,2]. Although the tasks were solved differently, but the similarity of problems is evident, first of all, if there is a similarity in the nature of the substance of the spores of pathogenic fungi and corona virus bodies, the size and shape of the bodies (Table 1).

| Characteristics of pathogenic fungi | Fusarium | Alternaria | Penicillium | Bipolaris | SARS-Cov-2 |
|------------------------------------|----------|------------|-------------|-----------|------------|
| 1. Sizes, nm                      |          |            |             |           |            |
| - length                           | -        | -          | 3-4         | 85-150    | -          |
| - diameter                         | 29-36    | 1,5-7,5    | 2-3         | 6,0-8,5   | 70-165     |
| - body shape                       | Ball     | Ball       | Ellipsoid   | Cylinder  | Ball       |
| 2. Substance                       | Cellulose + protein | Cellulose + protein | Cellulose + protein | Cellulose + protein | Protein |
| 3. Relative dielectric constant, F/m | 2-8      | 2-8        | 2-8         | 2-8       | 5-8        |
2. Materials and Methods

Compared to industrial air pollutants, a big difference can be seen (Table 2). Analysis of the characteristics of air pollutants in medical institutions (see Table 1) suggests that air filtration in special rooms, despite the presence of a large number of technical means in industry, is a very difficult process compared to air filtration in industrial enterprises, where the sizes of dust particles differ by 3 - 4 orders upward [3].

Industrial air filtration systems are classified into:
- dust-collecting chambers and devices for dry inertial purification of gases;
- devices for wet cleaning of gases (scrubbers);
- filters (fibrous, roll, granular, etc.);
- electrostatic precipitators.

Obviously, work on air filtration in medical institutions will best be carried out in wet cleaning devices and electrostatic precipitators - the size of the holes in the filter materials does not play a role in filtration is carried out by continuous media - an electric field and water. Other systems - dust collection chambers and porous filters will not work due to the very high dispersion of the filtered material (see Table 1) and the very low rate of soaring of spores and viruses. Air filtration of industrial enterprises is much easier due to the large size of dust particles (see Table 2).

At the same time, wet cleaning devices require complex maintenance and disposal of waste water and sludge during operation, and electrostatic precipitators; in addition, they require additional maintenance of high-voltage electrical equipment.

Despite the operational disadvantages, electrostatic precipitators have some advantages over other systems:
- small dimensions;
- low aerodynamic resistance of the tract due to the appearance of additional thrust in them, which coincides in the direction with the flow of the cleaned air [4,5];
- partial disinfection of air due to the thickening of the lines of force of the electric field in the volume of spores and coronaviruses and their burning with an electric current of a corona discharge [6].

Small dimensions are achieved by the fact that the cleaning process in electrostatic precipitators is active, i.e. when creating an "electric wind", the bodies of spores and viruses are charged with electricity, which are attracted by surfaces with a charge of the opposite sign [7].

The low aerodynamic resistance of the tract is achieved by the fact that a flow of charged particles (electrons and ions) arises in the corona electrode - collecting electrode system, which carries away suspended particles and molecules of air gases - "electric wind". In this case, most often the corona electrode is connected to the negative pole of the current source. To enhance the "electric wind", various devices are used that allow adding electric and magnetic fields to the working gap [8,9].

| Type of fuel         | Furnace type / Mill type          | Particle size, μm |
|---------------------|----------------------------------|-------------------|
| 1. Anthracite AK    | Manual service                   | 60 – 100 and more |
| 2. Vorkuta coal PZh | PMZ with fixed grids             | 10 – 44           |
| 3. Lump peat        | With mechanical chain grate      | 8 – 19            |
| 4. Kemerovsky coal  | Ball drum mill                   | 5 – 60 and more   |
| 5. Kanskoy coal     | Hammer mill                      | 15 – 60 and more  |

3. Results and Discussion

Disinfection of air by destroying spores of fungi and viruses occurs as follows. Under the action of the dielectric moment, the bodies of spores and viruses rotate along the lines of force of the electric field,
sticking them into chains, electrical breakdown of the discharge gap through the chains (i.e., through
the bodies of spores and viruses), their thermal heating and destruction. In addition, under the action
of electrostatic force, particles are attracted to the collecting surface and the air is filtered in this way
[10].

The dielectric moment of a particle under the assumption that the particle (spore or virus) has the
shape of a ball placed in an electric field and deforms the field with a dielectric (thickening the field
lines of force):
\[ M_e = a^3 \times \frac{(\varepsilon - \varepsilon_0) \varepsilon_0 E_0}{\varepsilon + 2 \varepsilon_0}, \]  
(1)
where \( M_e \) is the dielectric moment of the ball;
\( a \) is the radius of the ball;
\( \varepsilon_0 \) - dielectric constant of the medium;
\( \varepsilon \) is the relative dielectric constant of the sphere;
\( E_0 \) is the strength of the electric field in the medium.

In the limiting case, when the ball is made of a conducting material, which corresponds to \( \varepsilon = \infty \), the
dielectric moment at the electric field strength inside the ball \( E = 0 \) will be equal to:
\[ M_e = a^3 \cdot \varepsilon_0 E_0, \]  
(2)
and the deformation of the field and the rotational force respectively are maximum.

In addition, another phenomenon contributes to the selective flow of an electric current of a corona
discharge through the bodies of spores and viruses - the attraction of dielectric particles carrying an
electric charge to the plane, and the force of interaction between the charge that forms the field and a
dielectric body placed in this field [11].

An electric charge located near the dielectric causes the polarization of the dielectric and, as a
result, the charge is attracted by the dielectric. In this case, the charge \( Q \), located at a distance \( a \)
from a large flat surface of a dielectric with a relative dielectric constant \( \varepsilon \), is attracted by the dielectric with a
force:
\[ f_d = \frac{\varepsilon - 1}{\varepsilon + 1} \cdot \frac{Q^2}{(2a)^2}. \]  
(3)

Comparing this force with the force of attraction of a charge to a flat surface made of a conductive
material, it can be seen that:
\[ f_p = \frac{Q^2}{(2a)^2}. \]  
(4)

Hence, for dielectrics with large values of \( \varepsilon \), forces are close in magnitude (see Table 3).

| Surface material       | \( \varepsilon \) | \( f/m \) | \( f, \text{H} \) |
|------------------------|------------------|-----------|------------------|
| Metal                  | \( \infty \)     | 1         |                  |
| Optical glass          | 10               | 0.82      |                  |
| Wood                   | 2…8              | 0.33…0.82 |                  |
| Water (bidistillate)   | 81.7             | 0.98      |                  |

Thus, it has been established that the optimal design for the quality criterion of air purification from
coronaviruses is wet gas cleaning devices, according to the criterion of the minimum design
dimensions - dry inertial gas cleaning devices, according to the criterion of serviceability -
electrostatic precipitators. Analysis of designs and technologies for gas purification showed that
further development of gas purification systems that meet all the requirements would be integrated
systems that combine several principles of gas purification in their design. An example is an
electrostatic precipitator [12], which combines the principle of an electrostatic precipitator, a cyclone
and a dust collection chamber.
In practice, it has been determined that the filter elements in an air purifier can trap suspended particles due to the sizing of the filter meshes, in which air passes through the filter and the particles are physically captured. In the course of experiments, it was found that the distribution of particles in time by size inside the sealed chamber was in the range from 0.3 to 5.0 μm (Figure 1).

![Figure 1. Dependence of the conversion factor on the operating time of heat generators according to table 1 and table 2.](image)

4. Conclusion
Summing up, we can say that the rate of decrease in the number of microbes in the chamber with introduced microbes after a certain fixed time was constant. By calibrating the operating value against the rate of natural decomposition, the ability of the air purifier to remove bacteria can be tested. Thus, this method for assessing the performance of an air purification device is considered promising for improving air filtration technology. Analysis of the problem of air purification in medical premises showed that the quality of purification depends primarily on the choice of a filtration system. Improvement of air purification systems is possible by combining several purification principles to meet the maximum criteria: purification quality, minimum design dimensions, ease of maintenance.

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