Using of Electrostatic Precipitator Combined with Heat Exchangers in the Field of Residential Ventilation

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Ventilation systems equipped with counter current or cross current heat exchangers are widely used in residential, public, and industrial spaces that demand a flow of clean and filtered air. Taking this aspect into consideration, the group of researchers of the High Intensity Electric Fields Laboratory of Technical University of Cluj-Napoca proposes ways to equip these systems with electrostatic filters that will have a role in heat recovery. The objective is to increase the efficiency of the ventilation systems in terms of energy recovery factor and pressure drop and to purify the air using electrostatic filters.

Keywords: heat exchanger, heat recovery, electrostatic filter, geothermal system

Due to the environmental changes and the increasing of the pollution, especially in the urban areas, providing the ideal climate and comfort is a major issue in achieving a building, regardless of its destination. The state of comfort is being determined by the permanent heat exchange between the human body and the environment. In the human body is continuously formed the heat, a part of it being released outside by convection, radiation and evaporation of water through the skin and the lungs. The heat loss through sweating depends on the nature of the surrounding air, humidity and its velocity.

At the same time with the ventilation of the buildings with the introduction of fresh air from outside into the room there are also introduced microorganism, harmful vapors, gases, dust, etc. Therefore, in addition to maintaining the required temperatures, one of the functions that must be satisfied by the ventilation and air conditioning is the reducing of the filtering microorganisms. The air in a room is considered cleaned of micro pollutants if their numerical strength in the suspension does not exceed certain values.

General terms of indoor air civil constructions

The atmospheric air is a gas mixture of nitrogen and oxygen prevailing , the other gases such as: carbon dioxide, argon, helium, etc being in very small proportions. Besides these, the atmospheric air also contains water vapors in varying proportions.

The regulation on air properties from the civil construction falls within the following limits.

The respirable particles, the particles which are smaller than 10 microns in diameter, can penetrate into the human respiratory system. If some of these particles are porous, capable of absorption and resorption they can be the source of volatile organic compounds. These particles are the micron and the submicron resulting from burning most common being cigarette smoke and burning combustion. ASHRAE standards, 62/2001 [1] recommends not to exceed an annual average of 0.15mg/mc/day.

Air pressure, atmospheric air is moist air, consisting of an compound of humid air and water vapors. Water vapor content can not exceed a certain limit named state of saturation. This limit depends on the vapor pressure and air temperature.

*The air temperature t*hat surrounds us can be measured using: dry or wet bulb thermometer because the air is humid air. Temperature indicated by a thermometer used that point to get a camera installed is called temperature, which ranges from 16 to 25°C. The humidity of the air means the amount of water vapours in the air formed at a given time.

The velocity of air, in rooms is an important factor in creating the feeling of comfort, it should be routinely 0.15.... 0.20m/s.

The aseptic quality conditions of the air

In the ventilation systems a special attention is given to the air purity class, being very important that these values are not exceeded especially in rooms where is required high purity (hospitals, children's room, laboratories, pharmacies, etc.) called clean rooms [2]. Indoor air quality is a complex issue, requiring filtration systems, ionization, decontamination, etc., this can be reduced to the following requirements: health and comfort. Temperature, humidity, noise, air speed, contribute to air contamination affecting human health.

The contamination of the air can be with: harmful gases, vapours harmful microorganisms and respirable particles. Microorganisms which contaminate air from soil, water, plants, animals and people, and the various human activities, are presented in table 1 [3].

The Filtration systems used to capture these particles in the field of ventilation are HEPA filters, ULPA filters (especially clean room), activated carbon filter, electrostatic precipitators, (electrostatic) negative air ionization systems [4, 5].

Experimental part

The experimental procedure conducted by the authors consists in fitting a ventilation plant with heat recovery systems and electrostatic filter. Air ducts, fresh air intake, air speed, heating and cooling power were designed according to the previous requirements of comfort [6]. As fresh air was chosen twice the total room experimental value. Basically, when it comes to ventilation of buildings,

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Table 1
AVERAGE DIAMETERS OF MICROORGANISMS IN THE AIR

Crt No.	The bio aerosol category	Name of the micro-organisms	Diam [μ]
1	Spores	Paracoccidiodes	40
		Blastomyces, Alternaria, Pusarium, Criptococcus, Mucor,Bortrythis	10
		Coccidioides, Thricoderma, Penicillium, Histoplasma, Absidia	5
		Pneumocystis, Nocardia, Phialophora, Antrax	2
		Micropolyspora, Thermomonospora	1
2	Bacteria	Haemophilus, Mycobacteria tuberculosis, Moraxella, Streptococcus, Staphilococcus	1
		Legionella, Plague, Cardiabacterium, H. influenza, Coxiella	0.7
		Bardatella, Mycoplasma, Francisella	0.5
3	Viruses	Vaccinia, Arenaviruses, Parainfluenza, Varicella, Marburg	0.3
		Measles, Coronavirus, Influenza	0.1
		Hantavirus, Reovirus, Adenovirus, Togavirus	0.08
		Echovirus, Rhinovirus, Parvovirus	0.03

Fig. 1. Pleated Panel HVAC Air Filters and HEPA Filters

classic means exhaust ventilation (exhaust foul air) and input (fresh air).

In our case the fresh air intake is made through a geothermal system (ground-air) friendly environment for impurities, bacteria, etc. following that the air introduced to intersect the plates of the heat recovery through electrostatic filtration and ionization system and then to be distributed in rooms through networks of pipes. Foul air exhausts through the network by the pipes and plates of the heat recovery, sending energy to crossed route. The installation may contain a bypass for mix of air in the required proportions. The advantage of electrostatic filtration systems compared to HEPA (High Efficiency Particulate) mechanical filter or ULPA allow bypass installations. If this air exchange is done without heat recovery, cooling costs rise considerably and the energy loss is even greater as the volume of the exhausted air increases. This volume is calculated according to the space destination.

Cleaning the filtration systems, the heat recovery with plates and the subterranean air channels should be done by removing the existing pool water through these systems, the introduction of clean water and disinfectant solution followed by drying function performed by a preheating electric battery on the bypass system. The heat recovery with plates is a common part with electrostatic filter being a construction with sliding blades for easy maintenance. Experimental recovery unit size (L*W*H = 500mm *400mm* 400mm)

The air conditioning system of the building shown in figure 2 is composed of:

- zone 1, ground floor heating, chimney, solid fuel.
- zone 2, floor heating, hot air transported through piping network that crosses the chimney body;
- zone 3, SPA area, floor heating and fresh air preheated or cooled with dehumidification feature;

Table 2
SIZES OF THE AIRBORNE PARTICLES IN SUSPENSION

Nature of the particle	Dimension [μ]	Nature of the particle	Dimension [μ]
Bacteria	0.3 - 30	Particles in suspension in calm air	0.001 - 1
Pulverized coal	3 - 500	Particles in suspension in agitated air	0.001 - 10
Fog	max. 10	Particles in suspension from industrial installations	0.001 - 100
Fly ash from pulverized coal	1 - 50	Dangerous particles for lungs	0.5 - 6
Fly ash from burning oil	15 - 1100	Expectorants drops	100 - 1000
Flour	1 - 18	Pulverized drops	100 - 1000
Cotton fiber	15 - 30	Paint pigments	0.1 - 5
Alkaline puffs	0.1 - 5	Pollen	10 - 100
Metal puffs	0.01 - 1	Coal dust	1 - 100
Zinc oxide puffs	0.01 – 0.3	Cement dust	3 - 100
Tobacco smoke	0.01 – 0.15	Insecticide dust	0.5 - 10
Oil smoke	0.03 – 1	Milk powder	0.1 - 10
Permanent atmospheric impurities	0.001 – 1	Metallurgical powder	1 - 100
Temporary atmospheric impurities	1 – 100	Dust from foundries	1 - 1000
Black carbon	0.01 – 0.3	Dust from the ground	10 - 100
Thin sand	20 - 200	Spores	10 - 30
Large-grained sand	200 - 2000	Talcum powder	0.5 50
Thin human hair	50	Viruses	0.01 – 0.5
Rough human hair	75		

Fig.2. Family house equipped with experimental filtration system; Isometric diagram of filtration and ventilation

Theoretical foundation

Dust dynamics and the motion of a particle in the electric powered dust collector, most dust particles from the air have their own motion that ends after a certain period by depositing the particles. This movement of dust may be determined by the action of gravity, the force with which the particles were blown by the generating source, by the Brownian movement or by thermal forces. Knowing the laws by which dust movement occurs is very important concerning the ventilation for determining solutions and calculations. The size of force that tends to retard the particle movement due to air friction is given by the expression

$$F_R = C + \frac{\rho v^2\ A}{2[kgf]} \quad (1)$$

where:

C - resistance coefficient , adimensional;
ρ - Air density in kfg*s²/m⁴;
v - Particle velocity relative to the air in m/s;
A - projected area of the particle in m².

Due to thermal effects of floor heating, the dust particles have a tendency to rest on the floor, their removal being achieved by introducing an air gap below the level of the particles in suspension and their evacuation at the lower level of rooms.

In an electric powered dust collector, the relation [7] can describe the particles motion:

$$\overline{F} = \overline{F_e} + F_r \quad (2)$$

And by replacing the values of forces F, F_e, si F_r the equation becomes:

$$m\frac{dJ_m}{dt} = q \cdot E - 3pdhJ_m \quad (3)$$

where:

m - mass of the particle, [kg];
J_m - movement speed [m / s];
Q - electrical charge of the particle, [C];
E - electric field strength [V / m];
d - diameter of the particle [m];
η - viscosity [Pa.s];

F_e = q . E – Electric field strength [N]

In case of two equal forces, Fe and Fr, particle migration velocity towards deposit electrode is constant and has the expression:

$$J_m = \frac{q \cdot E}{3pdh} \quad (4)$$

Measurements were performed within a range of 24 h using the equipment of the plant, respectively gauges for the humidity, temperature and air velocity with an AM-4210 anemometer; we used a MAQS-oxide device for the air pollution measurements on the microbiological quality of air respectively.

Filtration plant / energy recovery is equipped with filters for gross particles larger than 10 microns, with active carbon filter, electrostatic filter and ionizer input, a fan and exhaust fan.

The operating principle of the electrostatic filter is based on loading with electric charge of particles that are in transport gas (in our case inserted air), by corona effect through intense electric field generated by an electrode with a smaller radius curvature. Dust particles are loading negatively with the same polarity of the emitting electrode and are deposited on grounded electrodes [8].

Particle precipitation mechanism occurs by combining the electric field action, the flow of gas (air) and the particles. Dust particles, loaded with electric charge are directed towards the collecting plate electrode due to coulumbiene electrical forces and their interaction with transport force of the gas (air). High DC voltage, U = 15, 100 kV, ensuring the generation of intense electric field between the emitting electrodes and the collection electrodes of the electrostatic filter.

This filter can reach efficiencies of up to 99.99%.

The form of the electrodes (length, position location), of the collector plates, air speed and the voltage affects the operation of the electrostatic filter or the electrostatic precipitator [9].

Heat recovery is interleaved between primary filter (mechanical) and electrostatic filter[10, 11] .The optimization of heat recovery for obtaining optimal maximum gauge and efficiency was developed in the Laboratory for Manufacturing Engineering of UTCN Cluj through the technology of Rapid Prototyping using selective laser melting machine (SLM) "ReaLizer 2000". The recovered was constructed using a CAD model, the

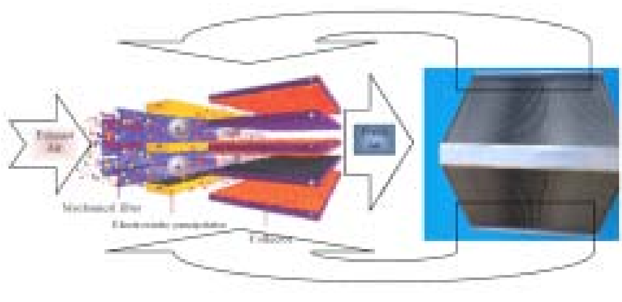

Fig. 3. The placement of the electrostatic filter in the recovery plant assembly

Table 3
CONCENTRATION VALUES OBTAINED FROM MEASUREMENTS OF AIR QUALITY

Air speed on main network	Measurements conducted before functioning of the equipment				Measurements conducted after functioning of the equipment			
	Determination of pollutants							
	Particulate matter mg/mc	Aldehyde	NO_2	SO_2	Particulate matter mg/mc	Aldehyde	NO_2	SO_2
0.6 m/s	0.610	0.121	0.173	0.013	0.142	0.043	0.084	0.08
0.8 m/s	0.221	0.128	0.173	0.00	0.131	0.038	0.063	0.00
1.2 m/s	0.118	0.122	0.172	0.00	0.092	0.020	0.041	0.00

Table 4
RESULTS ON MICROBIOLOGICAL QUALITY OF INDOOR AIR

Nr crt	Type of determination	NTG/mc AIR after cleaning	NTG/mc AIR after 1h	NTG/mc AIR after 24h
1	without electrostatic filter	420	410	115
2	With electrostatic filter	385	16	25

development of the construction principle being the research theme of the authors that will be presented in the next paper.

Results and discussions

The measurements concerning the air pollution were conducted within the Laboratory "Chemical Research Institute Raluca Ripan". Values obtained from measurements during the testing are presented below. Microbiological quality of air, is shown in table 3.

According to the regulations on air quality, allowed concentrations for the determined pollutants are:

- Particulate matter = 0.5 mg / m (for 30 min)
- Total aldehydes = 0.035 mg / m (for 30 min)
- Sulfur dioxide = 0.350 mg / m (for 60 min)
- Nitrogen dioxide = 0.200 mg / m (for 60 min)

The values given in table 4 indicate a significant reduction of microorganisms in suspension in a facility equipped with electrostatic filter. One hour after starting their microbiological load level is maintained even after 24 h of continuous operation.

Conclusions

The electrostatic filtration technology is primarily used in industrial filtration. Its use is mainly in residential area where efficiency requirements are high ensuring good results. Useing built-in central ventilation heat recovery ensures a compact design and low cost. Embedded electrostatic filters can have a wide range of applications among which: clinical, IT data centers, restaurants, shops, etc.

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