Variation of air condition parameters, in the conditions of the presence of carbon monoxide, in the duct of ventilation installations

Ion Gherghe[1*], *Doru* Cioclea[1], *Cornel* Boantă[1], and *Florin* Rădoi[1]

[1]National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea Street, Petroșani, Hunedoara, Romania

Abstract. Industrial ventilation and air conditioning systems aim to ensure the conditions of air purity and microclimate corresponding to the activity of man and the nature of the technological process. The parameters of the state of the air which are of interest for the technique of ventilation and air conditioning are: air temperature and humidity, atmospheric pressure, and air speed. For the study on the variation of the air state parameters inside the industrial ventilation installations, in the experiment laboratory, on the study of the industrial ventilation systems, the experiment was performed on the variation of the air state parameters in the conditions of circulation through the ventilation duct a quantity of carbon monoxide at constant pressure. Prior to the introduction of carbon monoxide into the piping, the ventilation system was started at nominal parameters. During the experiment, the operating parameters of the drive motor were changed using a frequency converter on levels 50; 40; 30; 20; 10 and 5 Hz. The ventilation system used was structured by means of flow converters which were fixed in the open position. The ventilation system as well as the flow variators were operated by the SCADA type command and control system. The paper will present the analysis of the variation of state parameters (temperature, humidity, absolute pressure, and air speed) by introducing a constant amount of carbon monoxide in the ventilation duct.

1 Introduction

The state of a thermodynamic system is defined by all the physical, chemical, biological, etc. quantities that characterize it. Some of these quantities can be measured directly and are called state parameters, for example temperature (T), volume (V), pressure (p). The state parameters change their value when the external conditions change.

Depending on the spatial or temporal variation of the state parameters, a thermodynamic system can be in:

- state of equilibrium - its state parameters remain constant in space and time.
- steady state - different parameters reach constant values, but which are still different from those in other areas of the system.

* Corresponding author: ion.gherghe@insemex.ro

- stationary imbalance - parameters vary from one point to another but remain constant over time.
- state of non-stationary imbalance - the parameters vary both in space and time.

Thermodynamic equilibrium can only be achieved in closed systems. In open systems, specific to biological systems, energy processes do not reach equilibrium, but only a steady state (dynamic equilibrium) to maintain the organization of energy processes, which ensures development through exchange of substance and energy [1, 2, 4].

2 Notions of air condition parameters

The main role of ventilation installations and especially air conditioning systems is to create indoor conditions and air quality independent of external atmospheric influences.
Among the climatic and meteorological elements, the outside air temperature usually has the most pronounced effect on the buildings and therefore on the installations that serve it. The heat exchange caused by the difference between outdoor and indoor air temperatures is decisive both for the capacity of the installation, when determining the maximum value of heat lost or penetrated into the room by conduction and convection, and for the control system.
Temperature, humidity, absolute pressure and air velocity are meteorological elements when monitoring their hourly or daily variation and are climatic elements when their behavior is monitored for long periods.
These parameters are the most important characteristics of the ambient air, having a direct influence on human health and on the effectiveness with which it carries out its activity [2, 3, 5, 8].

2.1 Absolute pressure

Pressure is one of the most important state parameters that characterize the state of a fluid. It is defined as the ratio between the force with which a fluid acts on a surface and its area.
Inside the fluids, each layer serves as a support for all the layers above it. As the gases are compressible, the action between the layers that make them up makes the density higher the lower the layer. Therefore, the static gas pressure will increase in the same direction. In practice, as the density of gases is very low compared to that of liquids, the pressure of the gases in a vessel can be considered to be the same at any point. [3], [9], [12]
There may be different types of pressures in nature and in technical installations:
a) atmospheric pressure pb. The pressure exerted by the gaseous envelope surrounding the globe is called atmospheric pressure or barometric pressure. It varies with altitude (due to the weight of the air), the weather (the date of movement of atmospheric air masses) and the geographical position of the globe.
b) absolute pressure pa. Absolute pressure is the fluid pressure considered relative to the absolute zero pressure. It is the pressure that is used in all thermo technical relations.
c) overpressure ps. When the absolute pressure in the technical installations is higher than the atmospheric pressure, the difference between them is called overpressure or manometric pressure.
d) depression pv. When the absolute pressure in the technical installations is lower than the atmospheric pressure, the difference between them is called depression, under pressure, vacuum or vacuum pressure.

2.2 Air temperature

Air temperature can be of two types:
a. Outdoor air temperature, te. An important factor in the sizing of ventilation and air conditioning systems, it is determined by the proximity of the earth's crust, on the one hand, to solar radiation and the average absorption or release of heat from the ground and, on the other hand, to wind.
b. Indoor air temperature, ti. In the work area, this is a relatively good basis for characterizing a microclimate. Relatively small variations in indoor air temperature are immediately noticed by the human body, which must quickly respond to new changes in order to maintain a constant exchange of human heat with the environment. All the research undertaken shows that the most decisive factor for the feeling of comfort is the air temperature. The measured air temperature is applied in the air density calculation relationship in order to calculate and correct the air flow rate inside a duct [7, 9, 13].

2.3 Air humidity

In the technique of ventilation and air conditioning, the water vapor contained in the atmospheric air is of particular interest, because their quantity greatly influences the physical properties of the gas mixture. At a certain temperature and barometric pressure, the water vapor content per kilogram of air cannot exceed a certain limit, which is the amount of water vapor that saturates the air.
Air humidity can be expressed in several ways, namely: absolute humidity; specific humidity and relative humidity [10, 11, 12].

2.4 Air velocity

The indoor air velocity movement is another parameter of thermal comfort. The feeling of discomfort is felt all the more as the temperature of the moving air is lower than the ambient temperature and this, all the more so when it decreases from a certain part of the body (neck, ear).
In order to function properly, a suction device must create a sufficiently strong airflow velocity at the release site to entrain and direct all harmful particles to the suction mouth. The condition is that the air velocity at the place of generation is higher than its own speed of movement of the particles. In order for any particle floating in the air to be entrained by a stream of air, it must have a speed greater than the speed of the particle's suspension. The velocity of suspension of a particle floating in the air means the maximum velocity of a current that still fails to move the particle from its equilibrium position [1, 6, 9, 11].

3 Experimental system with variable structure for the study of complex industrial ventilation networks

This experimental system consists of a fan unit - centrifugal motor and a complex structure of rectangular tubing with dimensions of 300/400 mm. The piping is located on the south, west and north wall, the fresh air inlet, respectively the air outlet is made on the east wall, figures 1 ÷ 3.
At the level of the complex piping structure, there are 18 flow variators [4, 7].

Fig. 1. The structure of the experimentation system on the northern wall.

Fig. 2. The structure of the experimentation system on the western wall.

Fig. 3. The structure of the experimentation system on the south-east wall.

The automation system of the flow converters is made with the help of servomotors and the control is made centrally with the help of a control desk, respectively with the help of a SCADA type program, figures 4 ÷ 8.

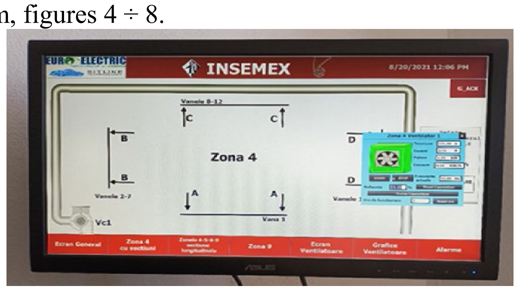


Fig. 4. SCADA software.

Fig. 5. Flow variator - western wall.

Fig. 6. Flow variator - southern wall.

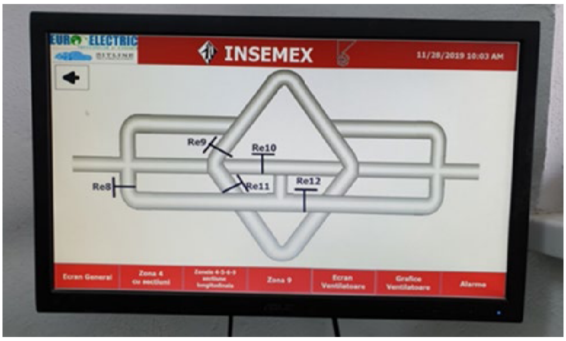


Fig. 7. Flow variator - western wall.

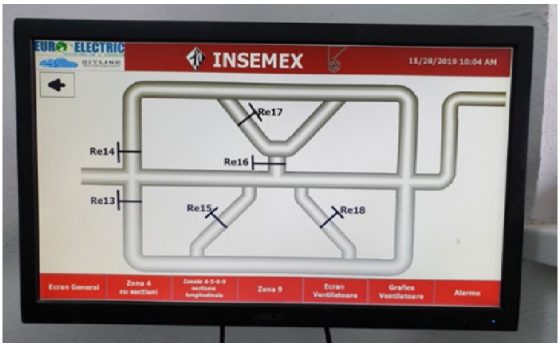


Fig. 8. Flow variator - northern wall.

4 Experiments on the variation of the state parameters when the carbon monoxide CO is passed through the ventilation network

The experimental system for the study of the variation of the air state parameters inside the ventilation installation, is composed of a data acquisition system consisting of a humidity sensor, a temperature sensor, and a pressure sensor. A system for measuring the dynamic pressure was also used to determine the circulation speed, two multi-gas detectors of MSA ALTAIR 5X and DRAGER X-am 8000 types, which can detect concentrations of O2, CO2, CO and CH4.
At the same time, a KIMO AMI 310 kit was used to measure the air condition parameters, respectively a device for measuring the electrical parameters of the FLUKE 345 PQ type.
The cross section of the pipe is rectangular with sides of 300/400 mm, with a section of 0.12 m2
For the analysis of dynamics of the formation of toxic atmosphere was used "Experimental system with variable structure for the study of complex industrial ventilation networks".
The initial conditions for experimentation were as follows:
Temperature: T = 10.9 ° C.
Atmospheric pressure: B = 9,520 da Pa.
Relative humidity: RH = 41.2%.
Average flow of discharged gas: q = 25 l / min.
The gas introduction system in the ventilation column is presented in figure no. 10.

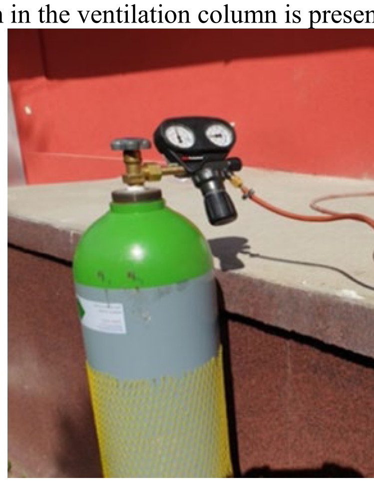


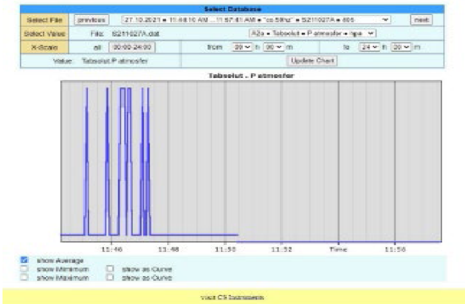
Fig. 9. Gas introduction system in the ventilation column.

The system consists of a 200 bar of compressed carbon monoxide at a pressure of 9998 ppm, a pressure reducer. The gas was introduced into the ventilation duct by means of a hose with an inside diameter of 8 mm. Carbon monoxide was discharged inside the ventilation duct by means of a hose fixed to the pipe wall.

Prior to the introduction of carbon monoxide into the piping, the ventilation system was started at nominal parameters. During the experiment, the operating parameters of the drive motor were changed using a frequency converter on levels 50; 40; 30; 20; 10 and 5 Hz. The ventilation system used was structured by means of flow converters which were fixed in the open position.

The ventilation system as well as the flow variators were operated by the SCADA type command and control system shown in figure 4 [4, 7, 8, 10].

The analysis of the variation of the state parameters by the introduction of carbon monoxide in the ventilation duct, based on the recordings made with the help of sensors, is presented below for the frequencies of 50, 54, 30, 20, 10 and 5 Hz, in figures 10.



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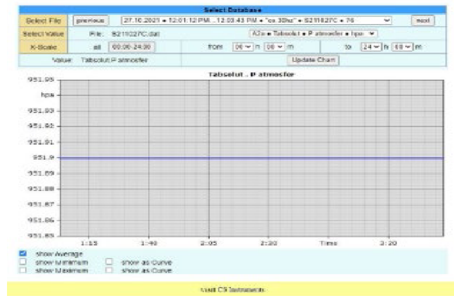

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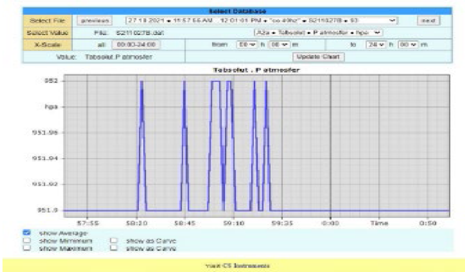

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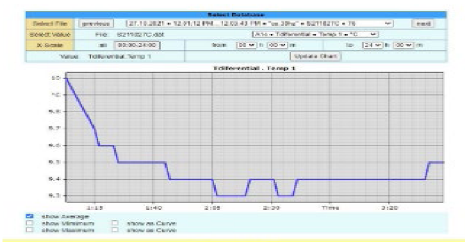

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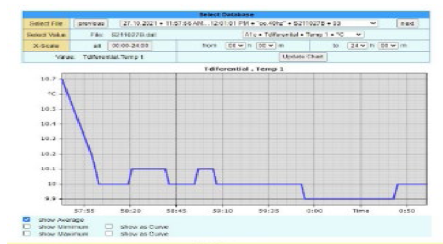

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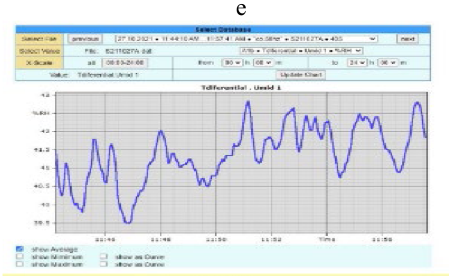

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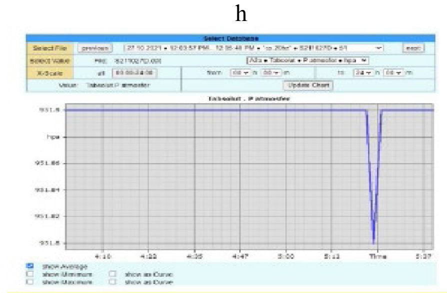

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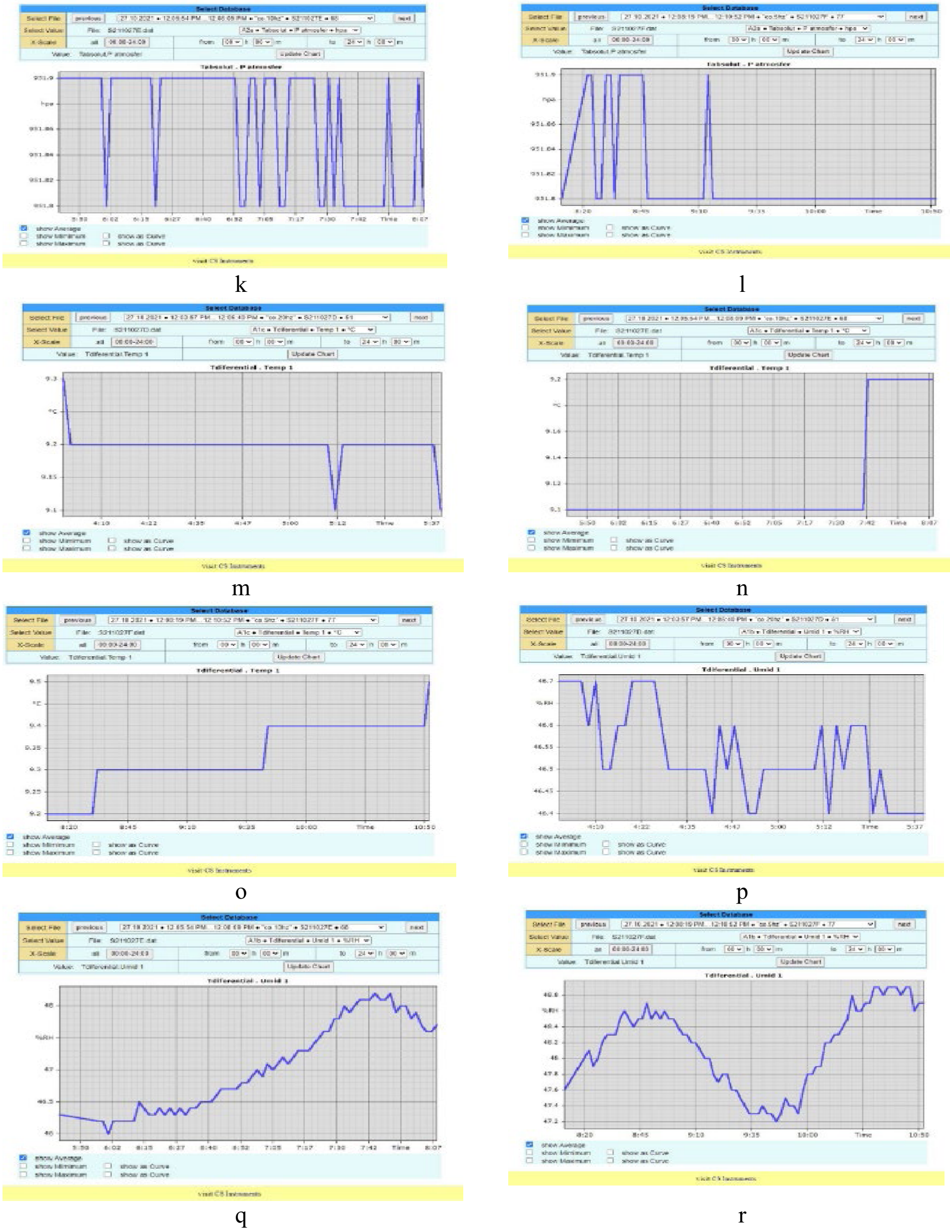


Fig. 10. a. CO - 50 Hz atmospheric pressure: b. CO - 40 Hz atmospheric pressure: c. CO- 30 Hz atmospheric pressure:d. CO - 50 Hz air temperature: e. CO - 40 Hz air temperature: f. CO - 30 Hz air temperature:g. CO - 50 Hz air humidity: h. CO - 40 Hz air humidity: i. CO - 30 Hz air humidity: k. CO - 20 Hz atmospheric pressure: l. CO - 10 Hz atmospheric pressure: m. CO - 5 Hz atmospheric pressure: n. CO - 20 Hz air temperature:o. CO - 10 Hz air temperature: p. CO - 5 Hz air temperature: q CO - 20 Hz air humidity: CO - 10 Hz air humidity: CO - 5 Hz air humidity.

As a result of the experimentation performed in order to establish the variation of the air state parameters in the ventilation duct, with carbon monoxide input, the following data regarding the respective aerodynamic electrical parameters specific to the experimentation conditions also resulted.

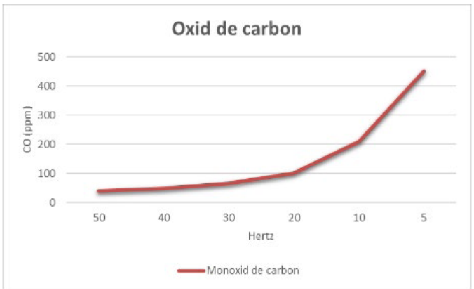
The variation of the parameters monitored / measured in relation to the frequency, in the conditions of the introduction of carbon monoxide in the ventilation duct, is presented in table no. 1

Table 1. Variation of air condition parameters, electrical parameters

and the concentration of carbon monoxide in relation to the electrical frequency.

Nr. crt.	Parameter	Frequency Hz					
		50	40	30	20	10	5
1.		40	49	67	100	210	450
2.	CO concentration [ppm]	385,5	300,1	177,1	99-100	40,3	8,04
3.	Motor supply voltage, U [v]	7,86	5,58	3,73	2,17	0,93	0,65
4.	Current, I [A]	4,81	2,71	1,068	0,334	0,056	0,008
5.	Power, P [kW]	0,917	0,932	0,934	0,920	0,831	0,75
6.	Cos ϕ	41,2	44,3	45,7	46,5	46,7	47,3
7.	Air humidity, RH [%]	10,9	10,0	9,4	9,2	9,1	9,3
8.	Temperature, t [° C]	952,0	952,0	951,9	951,9	951,9	951,8
9.	Barometric pressure, B [hPa]	161	128	66	28	7	1
10.	Static pressure, hs [Pa]	9,29	7,16	5,17	3,56	1,84	0,83

The variation of the carbon monoxide concentration, of the electrical and air state parameters measured in the ventilation duct, in relation to the frequency variation, is shown in figures no. 11.



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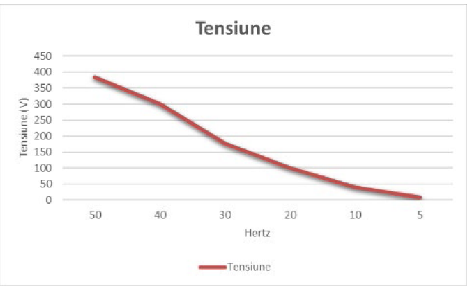

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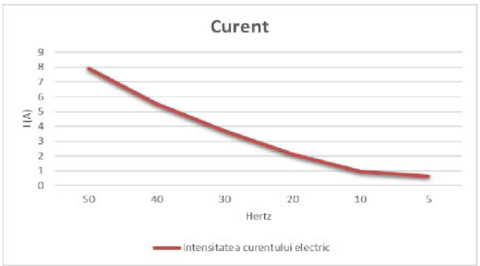

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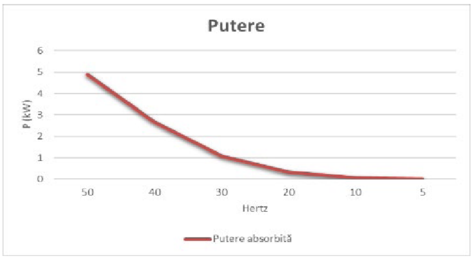

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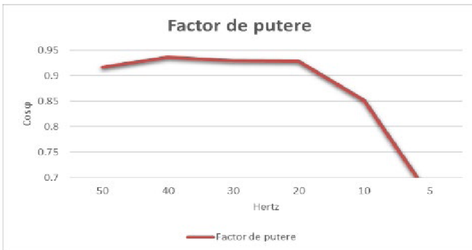

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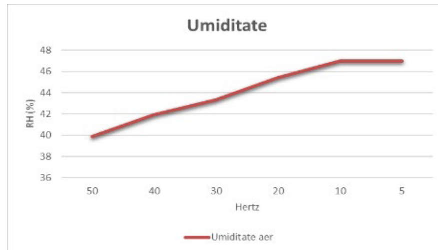

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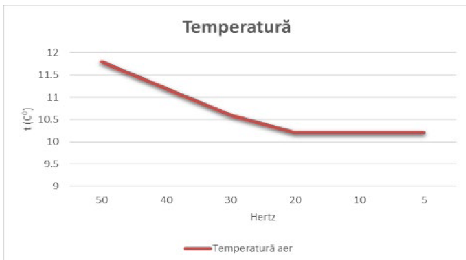

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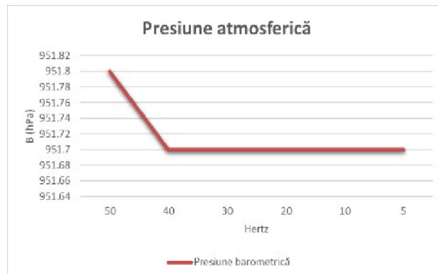

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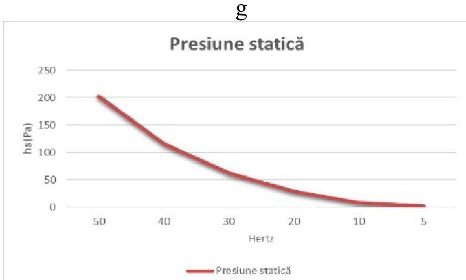

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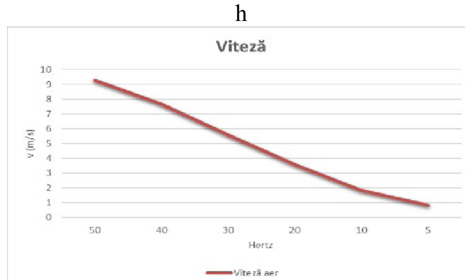

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Fig. 11. a. Carbon monoxide variation: b. Variation Voltage: c. Current Variation:d. Variation Power: e. Power factor variation: f. Variation Humidity:g. Temperature Variation: h. Variation Atmospheric pressure: i. Static pressure variation: j. Air velocity variation:.

5 Conclusions

This paper highlighted the following findings:
The parameters analysed in the experiment regarding the variation of the air state parameters inside a ventilation installation by introducing a constant amount of carbon monoxide, were state parameters, aerodynamic parameters, and electrical parameters.
The variation of the state parameters were analysed in relation to the frequency variation. For this purpose, the operating modes of the drive motor for the frequencies of 50, 40, 30, 20, 10 and 5 Hz were used.
The air state parameters, determined with the given acquisition system showed a variable evolution in relation to the respective time and to the frequency variation:

- The air temperature had a variable evolution between 9.1 and 12.1 ° C in relation to the frequency used.
- The air humidity showed a variable evolution between 39.5 and 48.2% RH in relation to the frequency used.
- The differential pressure showed a variable evolution between 0.0 and 195.0 Pa in relation to the frequency used.

- The absolute pressure showed a variable evolution between 951.8 and 952.0 hPa in relation to the frequency used.

The evolution of the carbon monoxide concentration in relation to the frequency showed a variation between 40 and 450 ppm.

Electrical parameters: motor supply voltage, absorbed electric current, absorbed power and power factor, showed a variable evolution in relation to frequency.

The air state parameters determined manually inside the piping had a variable evolution in relation to the frequency as follows: air temperature with values between 9.3 and 10.9 ° C, air humidity with values between 41.2 and 47, 3% RH, barometric pressure with values between 951.8 and 952.0 hPa, static pressure with values between 1 and 161 Pa and air velocity inside the piping with values between 0.83 and 9.29 m /s.

The process of air circulation enriched with toxic and explosive gases such as carbon monoxide presents an increased risk in terms of changing the functional parameters of the fan even in conditions of a constant flow of carbon monoxide.

In the conditions of an absolutely constant flow of carbon monoxide circulated by the ventilation installation, if the functional parameters of the fan change negatively, it can be reached in the situation that the level of carbon monoxide concentration increases rapidly exceeding the lower explosive limit.

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