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DETERMINING THE DYNAMICS OF CARBON DIOXIDE DISPERSION IN CLOSED SPACES

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Abstract: *Human society is in full development. Proportionately, the industrial activity continuously develops and diversifies. Various technological processes also bring with them specific risks such as the one generated by the presence of carbon dioxide in closed premises. The effect of this gas on the human body is destructive and can reach situations incompatible with life. Preventive measures presuppose a good knowledge of how this gas disperses. This paper details the experimentation carried out to identify how carbon dioxide disperses.*
Keywords: *asphyxiating gas, carbon dioxide, dispersion, gas dynamics, closed spaces, experimentation*

1. Introduction

Carbon dioxide is a gas that can generate atmospheres with an asphyxiating and suffocating effect.

Due to its high density (1.5291 kg/m3), carbon dioxide is usually found in low places and is a normal constituent of the air being normally present in a concentration of 0.034% vol. Carbon dioxide acts as a stimulus that regulates a person's breathing. When a person increases their activity rate, the amount of CO2 released by the lung alveoli immediately increases. In this case, the concentration of CO2 in the atmosphere also increases, causing faster and deeper breathing. CO2 poisonings are usually accidental or occupational. Its toxic action is exerted on the nervous and muscular systems. Carbon dioxide accumulates in the blood without combining with hemoglobin. A volume of blood can accumulate up to 1.3 volumes of CO2, and 100g of muscle can accumulate up to 50 cm3 of CO2.

The national mandatory occupational exposure limit value is 9000 mg/m3, or 5000 ppm. for exposure up to 8 hours.

2. General notions

Suffocation or asphyxiation phenomena can occur during industrial activities in closed premises and are generated by the atmospheres formed by the malfunctioning of technological processes [1, 2, 3, 4, 5, 6]. In such situations, workers who are exposed to different concentrations of gas can suffer long-term ailments. At an international level, these aspects regarding the dispersion of gases in closed, semi-closed, or open premises as well as their effect on the human body have been studied [7, 8, 9, 10].

This carbon dioxide dispersion phenomenon still has many aspects to be researched such as the aspect related to the gas dispersion dynamics that can be deepened through experimentation [11, 12, 13]. In order to avoid the exposure of workers to atmospheres rich in carbon dioxide, the information resulting from experimentation can be used to identify the best prophylactic measures [14, 15, 16].

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3. Experimental conditions

The research and experimentation activity to identify how carbon dioxide disperses as well as to obtain information related to dispersion dynamics was carried out in the industrial ventilation laboratory within INSEMEX Petroșani R&D National Institute [17, 18]. The experimental equipment comprises two main parts: a part related to data acquisition and a part related to monitoring elements. The monitoring system consists of pulleys on which ALTAIR detectors are placed, which can measure concentrations of O2, CO2, CO and CH4. The pulley system allows the variable placement of gas detectors in order to determine the speed of dispersion as well as the dynamics of the formation of asphyxiating atmospheres.

4. Laboratory experiments

6 MSA - ALTAIR detectors were used in the experiments. The characteristics of the experimental enclosure were 5.8x5.62x3.65m and the free volume of the premises was 116 m3.

The temperature, atmospheric pressure, and relative humidity were specific to the experimental premises. The introduced carbon dioxide flow rate was q = 4.5 l/min. The experimental system is shown in fig. 1 and consists of: a cylinder of compressed carbon dioxide, a pressure reducer, and a flow meter with a float. The gas was introduced into the enclosure by means of a hose with an internal diameter of 8 mm.

MSA - ALTAIR gas detectors were placed on pulleys 0.25 m from the floor fig. 2.

Fig. 1. Intake gas system

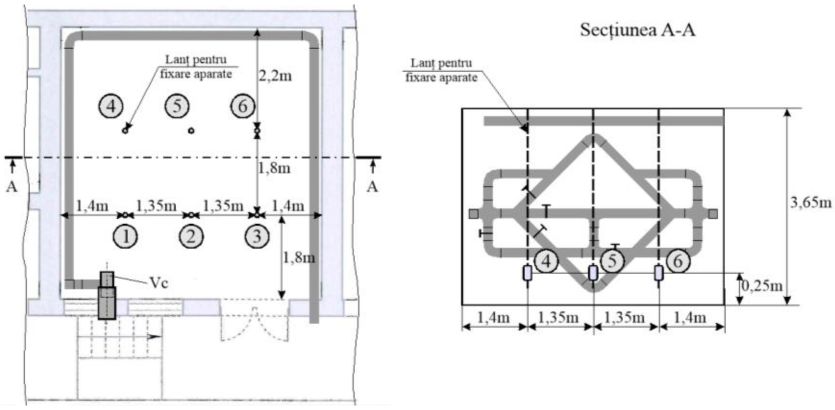

Fig. 2. Location of the detection system

The experiment took place over a period of 150 minutes, and the amount of gas introduced into the premises was 868.5 litters. The dynamics of the dispersion of Carbon Dioxide at the closed enclosure is shown graphically in fig. 3.

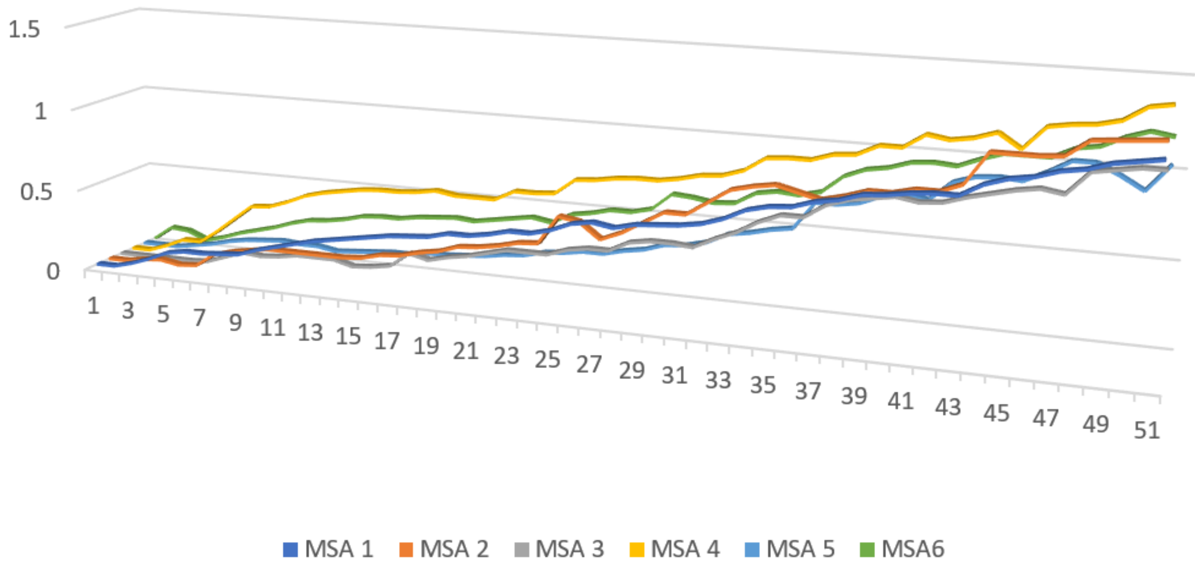

Fig. 3. Dynamics of carbon dioxide dispersion indoors

5. Discussions

The carbon dioxide dispersion process in the closed enclosure presented 2 distinct stages, namely: the incubation period in which the gas is dispersed and diluted without reaching a detectable concentration at the level of the MSA ALTAIR measuring devices, excluding the value of the natural background concentration; the accumulation period in which the gas is dispersed and reaches progressively increasing concentrations at the level of the MSA ALTAIR measuring devices;

The carbon dioxide dispersion phenomenon presented a variable spatial evolution argued by the variable values of the gas concentrations;

The incubation period presented different values, as follows: the incubation period was reduced in point 6, being 3 min.; it was average in points 1, 2, and 4 being 6 min.; it was high in points 3 and 5, being 15 and 9 min, respectively;

The accumulation period highlighted different developments, as follows: the accumulation period was reduced in point 3, being 132 min.; it was average in points 4, 5, and 6, being 144 min.; it was relatively high in points 1 and 2, being 147 min.;

The period of dispersion and progressive dilution of the gas, which includes the incubation and accumulation segments, presented different developments as follows: The period of dispersion and progressive dilution of the gas was reduced in points 3 and 6, being 147 min.; it was average in point 4, being 150 min.; it was high in points 1, 2, and 5, being 153 min.;

The maximum concentrations of carbon dioxide showed different evolutions, as follows: The maximum concentration of the gas was reduced in points 3 and 5, being 1.09 and 1.06% Vol., respectively; it was average in points 1, 2, and 6 being 1.2 and 1.27, respectively, 1.2% Vol.; it was high in point 4 being 1.4% Vol.;

The gradient of dispersion and progressive dilution of Gd gas had a variable evolution as follows: it showed reduced values in points 3 and 5, being 0.415% Vol./h; showed average values in points 3 and 4, being 0.445 and 0.559% Vol./h; presented a high value in points 1 and 6, being 0.470 and 0.489% Vol./h, respectively; presented a very high value in point 2, being 0.498% Vol./h;

Carbon dioxide showed an uneven accumulation process at the level of the hearth, proven by the fact that maximum gas concentrations were identified at the level of the detection devices between 1.06 and 1.4% Vol. compared to the value of the average concentration in relation to the total volume of the enclosure of 0.74% Vol.

6. Conclusions

The carbon dioxide dispersion process in the closed enclosure presented 2 distinct stages, namely: the incubation period and the accumulation period.

The dispersion process of carbon dioxide is characterized by a variable spatial evolution attributed to the different gas concentrations.

The incubation period showed values between 3 and 15 minutes.

The accumulation period showed developments between 132 and 147 minutes.

The period of dispersion and progressive dilution of the gas includes the incubation and accumulation segments, which showed a temporal extension between 147 and 153 minutes.

The maximum variable gas evolution was between 1.06 and 1.4% Vol.

The gradient of dispersion and progressive dilution, Gd, had values between 0.415 and 0.498% Vol./h.

The carbon dioxide pumped into the closed enclosure showed a phenomenon of uneven accumulation at the level of the hearth, proven by the fact that maximum gas concentrations were identified at the level of the detection devices between 1.06 and 1.4% Vol. compared to the value of the average concentration in relation to the total volume of the enclosure of 0.74% Vol.

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