How to make industrial ventilation systems and their efficiency (case study)

Răzvan Drăgoescu[1*], *Alexandru* Cămărășescu[1], and *Dorin* Tătaru[2]

[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
[2]University of Petrosani – 20, University Street, Petroșani, Hunedoara, Romania

Abstract. The role of a ventilation system is to establish or maintain conditions of temperature, humidity, dust content and gaseous products compatible with a certain degree of comfort, in the presence of various external inputs, respecting the noise level and air speed compatible with this comfort. In order to obtain prescribed (previously fixed) temperature, pressure and humidity conditions in ventilated premises, the air must first be subjected to a complex treatment process, a process that may include heating, cooling, humidification, dehumidification, filtration, etc. Technological processes are accompanied by significant releases of gases, vapors, dusts with toxic effects on the human body, noise, vibrations, radiation (ultrashort, nuclear, laser type, etc.). The quality of air in workplaces has a major influence on the health of workers, and it is important to keep pollutant emissions under control. The main industrial processes that emit noxious substances are:
- steel companies, which emit: dusts with a high metal content, iron oxides, silicon dioxide, manganese, phenols, polycyclic organic compounds;
- non-ferrous metal companies, which emit dusts, oxides of lead, zinc, arsenic, cadmium, mercury;
- chemical companies of inorganic products, release gases containing: sulfur dioxide, hydrogen sulfide, hydrofluoric acid, chlorine, acid vapors, ammonia, solid particles;
- chemical companies of organic products, emit: solvents, phenols, mercaptans, pesticides;
- pulp and paper companies, emit: dusts, sulfur dioxide, mercaptans, hydrogen sulfide, etc.;
- food industry enterprises release solid particles, ammonia, pathogenic germs, etc. into the air.

1 Introduction

Explosions and spontaneous fires are fortunately not the most common causes of work accidents. However, their consequences are spectacular and dramatic in terms of loss of life and economic damage. The humanitarian considerations are obvious: explosions and fires can cause extremely serious injuries and deaths.

* Corresponding author: rzavan.dragoescu@insemex.ro

Explosions can occur whenever the following conditions are met - simultaneously:

• flammable/combustible substances or preparations (fuel) have a high degree of dispersion in the air;

• the concentration of flammable substances or preparations in the air (oxidizer) is within the (lower and upper) explosion limits;

• the amount of explosive atmosphere (fuel - air mixture) is dangerous at the given time; a compact explosive atmosphere of at least 10 dm3, formed in a closed enclosure (room), regardless of its size, is considered dangerous;

• the ignition source exists and is also efficient (high enough in temperature and energy) to ensure the activation of molecules in order to initiate and propagate the rapid combustion reaction.

Each work and production process as well as each operating condition of an installation and each change to these conditions must be subject to an assessment. During the assessment of new or existing installations, the following operating conditions must be taken into particular account:

- normal operating conditions, including maintenance work;
- starting and stopping of the installation;
- operating accidents;
- incorrect use of installations, equipment, etc.

The risk of explosion can arise in all areas of activity in which flammable substances (gases, vapours, dusts, mists) are involved, which in mixture with air can give rise to potentially explosive atmospheres, it must be assessed as a whole taking into account: the equipment used; the construction characteristics; the substances used; the working conditions and industrial processes; the possible interactions between these various factors as well as with the working environment.[1]

Explosive atmospheres composed of several types of flammable gases, vapors, mists or dusts must be adequately taken into account when assessing explosion risks. The effect of the explosion can be considerably increased in the presence, for example, of hybrid mixtures.

In our country, in industrial processes with significant emissions of noxious gases, for the ventilation of workplaces with a potential risk of explosive and/or toxic atmospheres, various types of fans and ventilation systems are used, which achieve air flows ranging from 100 m3/h to 1,000,000 m3/h and depressions from below 10 Pascals to over 10,000 Pascals.

Industrial ventilation and air conditioning installations aim to ensure air purity and microclimate conditions appropriate to human activity and the nature of the technological process. These ventilation installations contribute to maintaining work capacity, eliminating occupational diseases, increasing labor productivity and the quality of products obtained through work.

Industrial buildings include large spaces with various sources of harmful substance emissions. The type of these sources and their location depends on the technological process in each section or room. In order to dilute contaminants, ensure the environmental conditions necessary for labor protection and achieve the microclimate required by the production process, industrial ventilation installations are required to transport medium and high air flows.

The structure of ventilation systems in industrial rooms and premises requires detailed knowledge of the technological processes taking place, of the equipment and their location in the premises, the nature and quantity of the gases emitted, the environmental conditions required from the point of view of occupational safety and health.

To choose a ventilation system, an analysis of the workplace to be ventilated must be made so that the chosen solution solves the problem of exhausting noxious substances but also respects the comfort of the working personnel.[2]

When choosing ventilation systems, the following are taken into account:

a) For the suction of harmful substances released by technological equipment, the most effective system is local ventilation, which consists of capturing harmful substances right at the point of generation, thus preventing their spread in the work area;

b) Local ventilation with the creation of depression in the work area is the most effective because it allows minimal escapes of harmful substances, being followed in order of efficiency by suction niches and open capture devices;

c) General ventilation systems in industrial buildings are less effective because they allow harmful substances to enter the work area and only dilute them with fresh air. They are applied when the sources of generation cannot be specified (vapour and gas leaks through leaks in containers or pipes), when the release of harmful substances occurs from large surfaces that cannot be ventilated by local ventilation, or when the sources of generation are fixed but in large numbers and harmful substances are released in small quantities;

d) The general ventilation system is used in public utility, administrative, sanitary and socio-cultural buildings, with the exception of technological rooms where local ventilation is more efficient (laboratories, laundries, etc.);

e) The indicated system for heat removal is organized natural ventilation, due to the high air flows that are required and which make mechanical ventilation too expensive. If natural ventilation is not feasible, the indicated system is general mechanical exhaust ventilation, in order to reduce the temperature of the indoor air by supplying cooler fresh air from outside;

f) For the evacuation of gases and vapors, general mechanical ventilation is applied in conditions where local ventilation cannot be applied. When applying general mechanical ventilation, it is necessary to know that usually the main installation is the introduction (exhaust) that performs the dilution of harmful substances with fresh air. If the contaminated room is closed without direct communications with other rooms, ventilation is performed by introducing air, without suction. If the contaminated room communicates directly and permanently with neighboring rooms with fresh air, ventilation must be performed by a gas suction installation from the contaminated area and an air introduction installation in the room without gas releases

g) For the elimination of dust, the only effective ventilation system is local mechanical ventilation. General ventilation for the elimination of dust is only a means of improving hygiene conditions;

h) For the elimination of water vapor, local ventilation remains the most effective system. Situations frequently created by technological processes often require the use of general mechanical ventilation systems;

i) emergency ventilation – which must automatically come into operation in the event of large accidental releases of explosive and/or toxic gases, as a result of failures in technological installations;

j) industrial air conditioning – which is imposed by manufacturing processes, by the need for precise conditions, in the case of high-precision processing, testing, calibrations, etc.[3]

The ventilation system that is chosen must take into account the technological process, the density of sources and the mode of propagation of gases, vapors, dust, and the intensity of releases.

When choosing ventilation solutions in an industrial facility, the following must be observed:

- the adopted ventilation scheme must ensure the movement of air in the direction of the release of the harmful source (explosive and/or toxic gases, flammable vapors, dust, etc.);
- the capture and evacuation of noxious substances at the place of their production (the use of local absorption facilities in the case of concentrated noxious substances or the provision of emergency facilities in the case of the danger of explosive and/or toxic gas leaks), in order to avoid their spread;
- introducing fresh air as close as possible to the area where people work;

- the ventilation system should ensure uniformity of air parameters throughout the room or space, to avoid the accumulation of explosive and/or toxic substances and gases;
- using overpressure or depression systems to limit the spread of gases or noxious substances in or from other rooms to avoid cold air currents.[4]

2 The purpose of industrial ventilation

Industrial air technology (IAT) can be defined as:

Airflow technology that controls the workplace environment and emissions.

Industrial air technology can also be defined as:

1. Airflow technology that achieves and maintains a safe, healthy, productive and comfortable environment in buildings and enclosed spaces where this is required not only by human presence, normal human activities, finished constructions and materials but also by other factors, such as production processes.
2. Air processing technology, such as air and gas purification, drying, or pneumatic transport.
3. Safety technology, including risk assessment, thus minimizing damage and risks from accidents, fires and explosions.

The scope of industrial ventilation installations also includes spaces other than traditional industrial processing buildings, such as: hospitals, underground parking lots, mining, railway and road tunnels; other buildings, premises and processes.[5]

2.1 Classification of ventilation technology systems

Industrial ventilation technology systems can be classified into two categories: industrial ventilation and air processing technologies.

2.1.1 Industrial ventilation

This system includes:

- Air conditioning systems that control the quality of air and the environment, both for the human factor and for processes.
- General ventilation systems in which certain internal parameters are only partially controlled. Target levels are usually lower than those for air conditioning.
- Local ventilation systems are used for locally controlled areas. These systems are based on local capture of contaminants.
- Process ventilation systems aim to maintain defined conditions to ensure process performance (e.g. paper machine hoods).

2.1.3 Air processing technologies

Within these technologies, the following ventilation systems are distinguished:

- Purification systems are used to remove contaminants, purify the resulting flows, and collect materials before exhausting the contaminated air;
- Pneumatic transport systems are used to transport pollutants captured from processes to a collection point.
- Drying systems are used to remove moisture, gases, and vapors from a product.
- Technological systems for ventilation safety can be designed to control smoke during fires or to reduce the risk of explosion.[6]

Also, the criteria for classifying ventilation systems are numerous, these criteria according to the forces that determine the circulation of air are classified into natural ventilation systems and mechanical ventilation systems.

Natural ventilation is carried out under the effect of natural forces, these being wind and temperature, and can be unorganized when air exchange occurs through leaks in rooms, or organized when air enters and exits rooms through adjustable openings.

Mechanical ventilation is done by circulating air using fans or even ejectors.

According to the spaces subject to ventilation, ventilation systems are classified into general, partial, local and mixed ventilation, as follows:

- general ventilation systems serve the entire room and consist of moving the entire volume of air in the occupied area,
- partial ventilation systems are applied in very large halls, serving only a certain portion of it;
- local ventilation systems are applied directly to the source of noxious emissions;
- mixed ventilation systems are achieved by simultaneously applying local, partial and general ventilation in the room.

According to the pressure regime that the ventilation system tends to create in the room to be ventilated, these systems are classified into systems for introducing fresh air by sucking air from outside and expelling it into the room and systems for sucking stale air from inside and expelling it outside[7,8]

3 Description of the economic agent S.N.G.N. ROMGAZ S.A. - S.Î.S.G.N. Ploiesti and the measurements performed

The following is an assessment of ventilation installations that operate or circulate in environments with a potential risk of explosive and/or toxic atmospheres at a representative economic unit in Romania, and named S.N.G.N. ROMGAZ S.A. - S.Î.S.G.N. Ploiești.

The objective of the activity is the compression of methane gas from the “Bucharest Ring” gas transport system, for storage, operating with a number of three compressor stations, namely: Butimanu compressor station, Bălăceanca compressor station and Urziceni M1 compressor station.

3.1 Butimanu compressor station

The Butimanu compressor station is intended for storing methane gas during the summer period, in order to cover the peaks of consumption during the winter period. This station operates only in the summer months, being under overhaul in the winter.

For the compression of methane gas, two flows (separate paths) are available, which have only the entry and exit points in common, for each flow the suction pressure in the distribution network is 13÷21 bar, and the discharge pressure in the layer is 150 bar. Since

The technological system can accidentally release methane gas emissions in dangerous concentrations, in the event of uncontrolled (uncontrollable) leaks: rupture, cracking, fracturing of material, destruction of sealing gaskets, premature opening of a safety valve. Methane gas accumulations in dangerous concentrations, in compressor halls, if ventilation possibilities are exceeded, in the presence of an ignition source, the methane gas-air mixture can cause an explosion if it exceeds the lower explosive limit. For prevention, gas detectors are placed in these buildings by alarm.

To eliminate methane gas accumulations and maintain them below the explosive limit, 33 axial roof fans are used, connected directly to the storage hall, made of explosion-proof construction, located outside the three halls 1 (M1), 2 (M2) and 3 (M3, with horizontal exhaust of the methane-air gas mixture. The ventilation system is not equipped with shutters (slats) that allow the regulation of the air-methane gas flows, discharged from the hall.

3.2 Bălăceanca compressor station

The Bălăceanca compressor station located in the Cernica commune is intended for compressing methane gas from the “Bucharest Ring” gas transport system and storing it in the related well field, in order to cover consumption peaks during the winter period.

The gas pressure at the entrance (suction) of the distribution network is 13÷28 bars, and the discharge pressure in the well field is 35÷61 bars.

Since the technological system can accidentally release methane gas emissions, in the event of uncontrolled (uncontrollable) leaks: rupture, cracking, fracturing of material, destruction of sealing gaskets, accumulations of methane gas in dangerous concentrations, in the compressor halls, if the ventilation possibilities are exceeded, in the presence of an ignition source, the methane gas-air mixture can explode if it exceeds the lower explosive limit. For prevention, alarm gas detectors are placed in these buildings.

To eliminate methane gas accumulations and maintain them below the explosive limit, a number of 8 axial roof ventilation systems are used, in explosion-proof construction, with horizontal exhaust of the methane gas-air mixture. The ventilation system is not equipped with shutters (slats) that allow the regulation of the air-methane gas flow rates discharged from the hall.

3.3 Urzicieni compressor station

The Urziceni compressor station is intended for compressing methane gas from the discharge pipeline of the Urziceni ME compressor station (the old station) for storage in the stratum, in order to cover the consumption peaks, in the cold season, in the south-eastern area of Romania.

Two flows (separate paths) are available for methane gas compression, which only have the entry and exit points in common, for each flow the suction pressure from the distribution network is 13÷21 bar, and the discharge pressure in the stratum is 150 bar. Since

The technological system can accidentally release methane gas emissions, in the case of uncontrolled (uncontrollable) leaks: rupture, cracking, fracturing of material, destruction of sealing gaskets, in dangerous concentrations the methane gas-air mixture can cause an explosion if it exceeds the lower explosive limit. For prevention, gas detectors are placed in these buildings by alarm.

To eliminate gas accumulations in the compressor hall, in order to eliminate the danger of explosions, 5 axial roof ventilations in explosion-proof construction are used, with horizontal exhaust of the methane-air gas mixture, and two centrifugal pressurization fans for cooling the two electric motors driving the compressors.

Nominal parameters of the fans used in the ventilation installations are presented in table no. 1

Table 1 Parameters of fans within S.N.G.N. ROMGAZ S.A. - S.Î.S.G.N. Ploiești

Nr. crt	Location name	Ventiltion type	Fan type	Nominal pressureh (daPa)	Fan air flowQ (m^3/h) nominal	Fan air flowQ (m^3/h) achieved	Rated powerN (kW)	Column length L(m)	Sealing type	Percentage loss of flow, Q (%) air
0	1	2	3	4	5		6	7	8	9
BUTIMANU COMPRESSOR STATION										
1.	Hall M 1 – FAN nr. 1÷4	suction	Axial MAICO DZD 30/4B EExe	28,0	1500	1080÷ 1440	0,095	-	-	4,0÷28,0
2.	Hall M 2 –FAN nr. 1÷8	suction	Axial MAICO DZD 30/4B EExe	28,0	1500	1116÷ 1332	0,095	-	-	11,2÷25,6
3.	Hall M 3 – FAN nr. 1÷23	suction	Axial MAICO DZD 30/4B EExe	28,0	1500	972÷ 1368	0,095	-	-	8,8÷35,2
BĂLĂCEANCA COMPRESSOR STATION										
4.	Bălăceanca – FAN nr. 1÷8	suction	Axial DH 400 - 4D	28,0	3775	2556÷ 2700	0,57	-	-	28,5÷32,3
URZICENI COMPRESSOR STATION										
5.	Hall M1 – V 1 și V2	discharge	Centrifugal V 472	230	1600	1260÷ 1296	2,2	7	Rigid	19,0÷21,3
6.	Hall M1 FAN nr. 1÷5	suction	Axial MAICO DZD 30/4A EExe	28,0	1500	1296÷ 1422	0,11	-	-	5,2÷13,6

3.4 Comparative analysis of the characteristic parameters of the fans belonging to each compressor station

At the Butimanu compressor station, the axial fans operate at flow rates close to their nominal values, but the percentage losses vary greatly, between 4% and 35%. This variation shows that some fans operate efficiently, while others lose a significant portion of their flow, suggesting differences in assembly, wear, or sealing problems.

At the Bălăceanca compressor station, the axial fans have a much higher nominal flow rate than those at Butimanu, but the flow losses are constant and high, ranging between 28% and 32%. This indicates low efficiency, possibly caused by longer ventilation paths, higher aerodynamic resistance, or poor sealing.

At the Urziceni compressor station, the situation is different. The centrifugal fan has high power and provides high pressure, but the flow losses are approximately 20%, making it less efficient. In contrast, the axial fans at this station have the best performance in the entire table: their losses are low, between 5% and 13%, and the achieved flows are very close to the nominal ones.

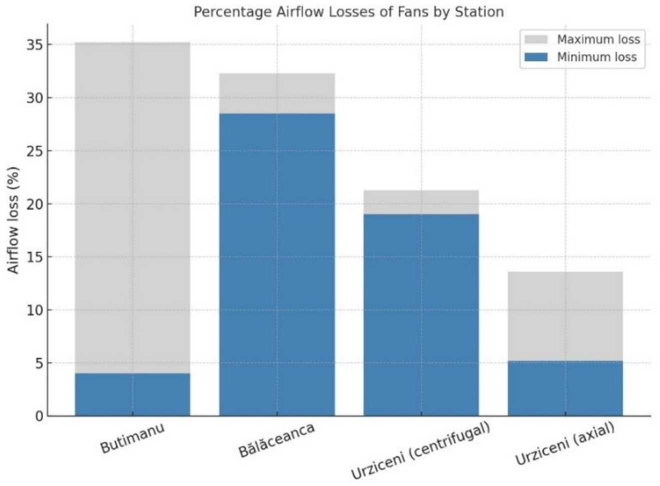

Fig. 1. Comparative graph of percentage flow losses for each station.

It is clearly observed that:
• Urziceni (axial) has the lowest losses.
• Butimanu has very variable losses, from very low to very high.
• Bălăceanca has high and constant losses.
• Urziceni (centrifugal) is in between, but weaker than axial.

4 Conclusions

From the data presented in table no. 1, the following findings emerge:

- industrial ventilation systems are equipped with both axial and centrifugal fans;
- the fans are driven by electric motors with powers ranging from 0.095 kW to 2.2 kW;
- axial fans are of the MAICO DZD 30/4B and 4A type and DH 400-4D type, with air flows ranging from 1500 m3/h to 3750 m3/h;
- centrifugal fans are of the V 472 type, with air flows of 1600 m3/h;
- individual fans without ducts and fans coupled to rigid metal ducts are used; one fan is located on each column related to the ventilation system;
- flexible rubber sleeves are used as sealing means between the column and the fan in order to connect the fan to the suction and discharge piping;
- the ventilation columns used are 7 m long;
- for the ventilation of workplaces, the suction ventilation system and the supply ventilation system are applied;
- due to the specific working conditions, it is necessary to circulate air flows that ensure the safety conditions of both the working personnel and the workplaces.
- within the analysis carried out, the air flows achieved at the level of fans were taken into account in relation to their nominal flow, which allowed establishing the share of the air flows achieved by the industrial ventilation installations in operation, in relation to the nominal air flows of the fans
- the air flow achieved by axial fans has values ranging between 64.8 ÷ 96.0 % of the nominal flow of these types of fans (the percentage air loss being 4.0 ÷ 35.2 %);
- the air flow achieved by centrifugal fans has values between 78.7 ÷ 81.0% of their nominal flow (the percentage loss of air being between 19.0 ÷ 21.3%), the flow loss is due to the connections between the fans and the rigid metal tubing;

- The axial fans at Urziceni are the most efficient fans, with low flow losses (5–13%) and flow rates close to the nominal ones, the ones at Butimanu have an average efficiency, but with large variations: some fans work well (losses of 4–11%), others have very high losses (up to 35%), and the ones at Bălăceanca are the least efficient fans, with high and constant losses (≈30%), although the nominal flow rate is higher than at the other stations. The axial fans at Urziceni are the most efficient fans, with low flow losses (5–13%) and flow rates close to the nominal ones, the ones at Butimanu have an average efficiency, but with large variations: some fans work well (losses of 4–11%), others have very high losses (up to 35%), and the ones at Bălăceanca are the least efficient fans, with high and constant losses (≈30%), although the nominal flow rate is higher than at the other stations.

This work was carried out through the NUCLEU Program within the National Research Development and Innovation Plan 2022-2027, carried out with the support of MCID, project no. PN 23 32 02 03 - The superior valorisation for energy purposes of coal deposits under the conditions imposed by environmental strategies (VSMET) and IOSIN PCDIEX

References

1 A. Cristea, Ventilarea și condiționarea aerului, Editura Tehnică, București, (1971)
2. A. Cristea – Ventilarea și condiționarea aerului – **Vol. I**, Editura Tehnică, București, (1968).
3. A. Cristea, N. Niculescu – Ventilarea și condiționarea aerului – **Vol. II**, Editura Tehnică, București, (1971).
4. A. Cristea, T.S. Terețean – Ventilarea și condiționarea aerului – **Vol. III**, Editura Tehnică, București, (1976).
5. H. Goodfellod, E. Tahti, Industrial Ventilation, Desing Guidebook, Academic Press, (2001)
6 D. Cioclea, C. Lupu, I. Gherghe, Ghid pentru dimensionarea instalațiilor de ventilație industrială, Editura INSEMEX, (2013).
7 O. Bancea, Sisteme de ventilare industrială, Editura Politehnică, Timimișoara, (2009).
8 N.Niculescu, Gh.Duţă, P. Stoenescu, I. Colda, Instalaţii de ventilare şi climatizare, E.D.P., Bucureşti, (1982).