Optimization of systems of industrial ventilation – case study

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Abstract. Industrial ventilation involves a deep knowledge of fluid dynamics, in the modern computerized version, three-dimensional heat propagation, complex fluid flow, equilibrium state and transient conditions, operating problems, contamination inside or outside the installations, etc.

Industrial buildings generally comprise large spaces with varied sources of damage. The type of sources and their location depend on the technological process in each section. In order to dilute the harms, to ensure the environmental conditions necessary for the protection of the work and the realization of the microclimate required by the production process, through the industrial ventilation installations large air flows are carried.

The design of the ventilation systems in the industrial sections requires a thorough knowledge of the technological process, of the machines and their location, the nature and quantity of the damages, the environmental conditions required from the technological point of view and of the labor protection.. In order to optimize the industrial ventilation systems, an industrial ventilation installation for exhausting and neutralizing VOC emissions was chosen. The optimization of the ventilation installation was possible with the help of the pressure loss balancing methodology.

The problem of industrial ventilation arose as a result of serious pollution problems arising in both industrial and industrial environments. Before approaching a study of industrial ventilation, the question is whether there are not simpler means of reducing or eliminating the causes of pollution, or of reducing pollution by modifying the production process or by designing and constructing the present ventilation system.

The commissioning of an industrial ventilation system takes place whenever a harmful workplace occurs to maintain a safe, healthy, productive and comfortable indoor environment under the conditions of occupational hygiene, safety and health of workers, if this necessity is determined not only by employment, but also by other factors, for example - production processes

1. Analysis of the initial situation

In order to optimize industrial ventilation systems, the industrial ventilation installation for exhausting and neutralizing VOC emissions was chosen, case no. 2, the dimensions of the installation being shown in figure 1.1.

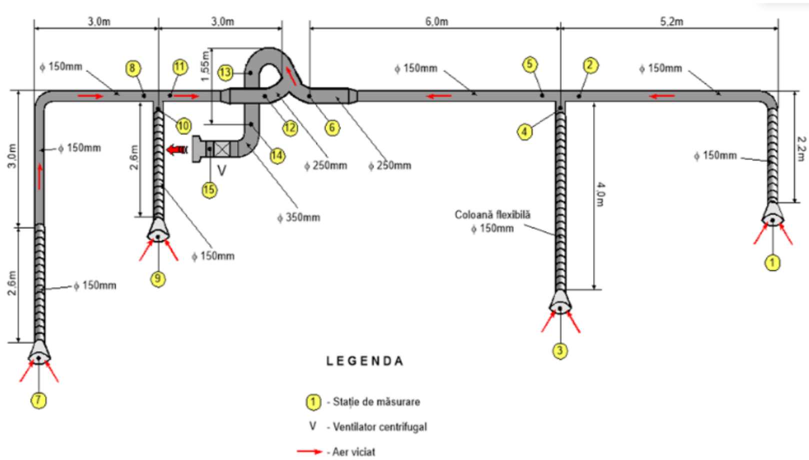

Figure 1.1 - Branched industrial ventilation plant

The total length of the aeration column is 33.2 m, of which branch no. 1 is 7.4m, branch no. 2 is 4 m, branch no. 3 is 8.6 m, and branch no. 4 is 2.6 m. The connection of the branched column to the fan is made by means of a rigid circular column with a diameter of 350 mm and a length of 1.55 m.

Since, the total aerodynamic resistance of the aeration column made up of tubes is the product of the unit aerodynamic resistance and the length of the column and is given by the equation $R_c=R_0xL_c$ to be able to determine the total resistance of the aeration column or a branch (in the present case we have two branches, the first of which has five measurement points) the following mathematical algorithm is followed:

$$R_{01}L_1+R_{02}L_2+R_{03}L_3+R_{04}L_4+R_{05}L_5=\frac{(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})(L_1+L_2+L_3+L_4+L_5)}{5}$$

$$(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})/5=R_{0m}$$

$$5(R_{01}L_1+R_{02}L_2+R_{03}L_3+R_{04}L_4+R_{05}L_5)=R_{01}(L_1+L_2+L_3+L_4+L_5)+R_{02}(L_1+L_2+L_3+L_4+L_5)+R_{03}(L_1+L_2+L_3+L_4+L_5)+R_{04}(L_1+L_2+L_3+L_4+L_5)+R_{05}(L_1+L_2+L_3+L_4+L_5)$$

$$5(R_{01}L_1+R_{02}L_2+R_{03}L_3+R_{04}L_4+R_{05}L_5)=R_{01}L_1+R_{01}L_2+R_{01}L_3+R_{01}L_4+R_{01}L_5+R_{02}L_1+R_{02}L_2+R_{02}L_3+R_{02}L_4+R_{02}L_5+R_{03}L_1+R_{03}L_2+R_{03}L_3+R_{03}L_4+R_{03}L_5+R_{04}L_1+R_{04}L_2+R_{04}L_3+R_{04}L_4+R_{04}L_5+R_{05}L_1+R_{05}L_2+R_{05}L_3+R_{05}L_4+R_{05}L_5$$

$$5(R_{01}L_1+R_{02}L_2+R_{03}L_3+R_{04}L_4+R_{05}L_5)=L_1(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})+L_2(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})+L_3(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})+L_4(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})+L_5(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})$$

$$5R_{01}L_1=L_1(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})$$

$$R_{01}=\frac{L_1(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})}{5L_1}=\frac{(R_{01}+R_{02}+R_{03}+R_{04}+R_{05})}{5}$$

From this relationship it follows that:

$$R_{01}\cong R_{0m};\ R_{02}\cong R_{0m};\ R_{03}\cong R_{0m};\ R_{04}\cong R_{0m};\ R_{05}\cong R_{0m}$$

After carrying out the necessary calculations, it turned out that the unit aerodynamic resistance related to branch no. 1 (point 1-2) has the value of 39906.422 Ns2/m8/m, and the average unit aerodynamic resistance related to branch no. 2 (point 3-4) is 5164.009 Ns2/m8/m. It follows that the aerodynamic resistance of the column for the two branches is:

- R_{1-2}= 39906,422 Ns^2/m^8/m x 7,4m = 295307,5228 Ns^2/m^8
- R_{3-4}= 5164,009 Ns^2/m^8/m x 4m = 20656,036 Ns^2/m^8

For the two branches connected in parallel (R1-2 and R3-4) it turned out that their total aerodynamic drag, $R_{1-2-3-4}$ is

$$\sqrt{R_{1-2-3-4}} = \frac{\sqrt{R_{1-2}} \cdot \sqrt{R_{3-4}}}{\sqrt{R_{1-2}} + \sqrt{R_{3-4}}} = \frac{\sqrt{295307,5228} \cdot \sqrt{20656,036}}{\sqrt{295307,5228 + \sqrt{20656,036}}}$$

it follows that $R_{1-2-3-4}$= 12918.8911 Ns2/m8

The total aerodynamic resistance R_{T1} related to the two branches has the value:
R_{T1}= $R_{1-2-3-4}$+R_{5-6}=12918.8911 + 304.383=13223.2741 Ns^2/m^8

Average unit aerodynamic resistance R_3 related to branch no. 3 (point 7-8) is 4262.586 Ns^2/m^8/m, and the average unit aerodynamic resistance R_4 related to branch no. 4 (point 9-10) is 36122.995 Ns^2/m^8/m.

It follows that the aerodynamic resistance of the column for the two branches connected in parallel (R_3 and R_4) is:
- R_{7-8}= 4262.586 Ns2/m8/m x 8.6 m = 36658.2396 Ns2/m2
- R_{9-10}= 36122.995 Ns2/m8/m x 2.6m = 93919.787 Ns2/m2

For the two branches connected in parallel (R_{7-9} and R_{9-10}) it turned out that their total aerodynamic resistance, $R_{7-8-9-10}$ is:

$$\sqrt{R_{7-8-9-10}} = \frac{\sqrt{R_{7-8}} \cdot \sqrt{R_{9-10}}}{\sqrt{R_{7-8}} + \sqrt{R_{9-10}}} = \frac{\sqrt{36658,2396} \cdot \sqrt{93919,787}}{\sqrt{36658,2396 + \sqrt{93919,787}}}$$

it follows that $R_{7-8-9-10}$= 13886.6425 Ns2/m8

The total aerodynamic resistance R_{T2} related to the two branches has the value:
R_{T2}= $R_{7-8-9-10}$+R_{11-12}=13886.6425 + 207.2066=14093.8492 Ns^2/m^8

The total drag associated with the two newly created branches is:

$$\sqrt{R_{T1-T2}} = R_{T1}+R_{T2} = \frac{\sqrt{R_{T1}} \cdot \sqrt{R_{T2}}}{\sqrt{R_{T1}} + \sqrt{R_{T2}}} = \frac{\sqrt{13223,2741} \cdot \sqrt{14093,8492}}{\sqrt{13223,2741 + \sqrt{14093,8492}}}$$

it follows that R_{T1-T2} = 3412.0318 Ns2/m8

The total aerodynamic resistance of the aeration column is:
R_T= R_{T1-T2} + R_{13-14}= 3412.0318+61.5898=3473.6216 Ns^2/m^8

The unit coefficient of air losses through the leaks in the tube column has the following values:
- Section 1-2 – K_0= 1.9457×10-4;
- Section 3-4 – K_0= 7.551×10-3;
- Section 5-6 – K_0= 3.227×10-5;
- Section 7-8 – K_0= 2.7195×10-4;
- Section 9-10 – K_0= 1.3785×10-3;
- Section 11-12 – K_0= 6.3372×10-5;
- Section 13-14 – K_0= 2.67×10-4;

The total air loss coefficient through the leaks in the column of tubes related to the industrial ventilation installation is: K_0= 1.393×10-3 $m^3/s/m$ at 1 daPa

Table 1.1 summarizes the parameters obtained from the calculations

Name of the work	Column dimensionsLxl [m	Way SEAL	Section lengthL [m]	THE STATION NR. 1		THE STATION NR. 2		Unitary aerodynamic resistance R_0	The unit coefficient of air losses through leaksK_0 [m^3/s/m la 1 Pa]	Aeration type
				h_{ST} [Pa]	Q [m/s]	h_{ST} [Pa]	Q [m/s]			
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
The installation for exhausting and neutralizing VOC emissions CASE NO.. II	Φ 150	Rigid	7,4	476,8	0,0262	990,8	0,065	39906,422	$1{,}9457\times10^{-4}$	aspirant
	Φ 150		4,0	245,3	0,161	995,7	0,235	5164,009	$7{,}551\times10^{-4}$	aspirant
	Φ 150-Φ 250		6,0	1628,4	0,29	1785,4	0,298	304,383	$3{,}227\times10^{-5}$	aspirant
	Φ 150		8,6	107,9	0,137	1030	0,191	4262,586	$2{,}7195\times10^{-4}$	aspirant
	Φ 150		2,6	82,4	0,0741	824	0,111	36122,995	$1{,}3785\times10^{-3}$	aspirant
	Φ 150-Φ 250		3,0	1736,4	0,329	1805	0,337	207,2066	$6{,}3372\times10^{-5}$	aspirant
	Φ 350		1,55	1667,7	0,634	1706,9	0,651	61,5898	$2{,}67\times10^{-4}$	aspirant

The parameters achieved by the ventilation installation before optimization are:
- Fan flow – 2,344 m3/hour;
- Fan depression – 1706.9 Pa;
- Absorbed power – 3.0 kW;
- Useful power – 1.23 kW;
- Plant efficiency – 41.0%;
- Total network resistance – 3473.6 Ns2/m8.

The centrifugal fan related to the installation had a nominal flow rate of 6,150 m3/h (1.78 m3/s), a depression of 194 mm col. water (1903 Pa) and a nominal power of 4.0 kW

2. Analysis of the optimized situation

The optimization of the previously presented ventilation installation was possible with the help of the pressure loss balancing methodology. The common factor of this methodology, to optimize the ventilation network, it is necessary that the pressure losses in each branch are equal. In order for the air to be evenly distributed from a branching point of the ventilation installation, it is necessary that the two columns of the branching have equal resistances, thus removing the shortcoming, that through one of the columns the flow of air that flows is more big. This fact is favored by a lower resistance of one of the columns.

This method has the advantage that, the sections that make up the route with the highest resistance are calculated successively, for the balancing of a branch, it is possible to resort to the modification of the air flow passing through it, which substantially eases the balancing calculations. In order to optimize the ventilation installation, the following was done:
- the ventilation sections that make up the pipe system were resized;

- the corrugated flexible pipes with a diameter of φ=150 mm were replaced with metal pipes of the same diameter, as high as possible and low roughness;
- bends with a 90° angle (with radius of curvature) were used;
- instead of the 250 mm diameter pipe, a 300 mm diameter pipe was chosen, respectively the 350 mm diameter pipe was replaced by a 400 mm pipe;
- special parts that change the direction of air flow were taken into account, namely: bends, curves, branches, parts with a sudden widening or reduction of the section, dampers, mixers and diffusers, parts that can increase the resistance of the installation with consequences in not realizing the flow rates air at workplaces, respectively at the level of the fan.

In order to evaluate the industrial ventilation network, it is checked whether the total pressure loss is equal to the pressure that the installation fan gives off, to ensure the air flow. Achieving a reduced energy consumption is done by correctly dimensioning the ventilation duct.

Next, the calculation of the branched pipe from figure 2.1, which must be optimized, is presented.

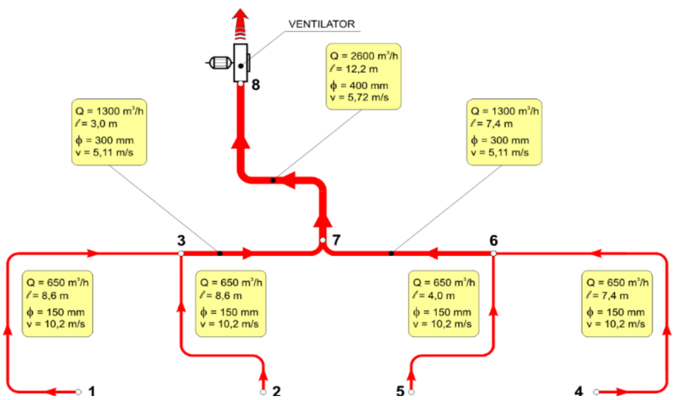

Figure 2.1. Scheme of the optimized ventilation system

According to this figure, the pipe was divided into pipe sections with the presentation of the air flow direction, its related ramifications, the related length of each column, the diameter for each column, the flow rate on each suction section (650 m3/h).

The following relationships are used to calculate the air losses in each duct related to the ventilation installation
- the dynamic pressure that is applied to the fluid to take it out of rest and keep it moving at speed v, is:

$$P_d = \frac{v^2 \gamma}{2g} \qquad [\text{mmH}_2\text{O sau Pa}]$$

where: v – air speed in the ventilation pipe, m/s;
γ – specific weight of air at a temperature of 20°, Kg/m3;
g – gravitational acceleration, m/s2.
the local fractional loss from the dynamic pressure is given by the relation:

$$P_l = \tau \frac{v^2 \gamma}{2g} \qquad [\text{mmH}_2\text{O}]$$

where: **τ** is local resistance coefficient, dimensionless.
- The total pressure loss is given by the relationship:

$$P_t = Rl + \tau \frac{v^2 \gamma}{2g} \qquad [\text{mmH}_2\text{O}]$$

where: R – pressure loss per unit length, mmH2O/m
l – pipe length, m.
- The pipe diameter can be calculated with the relation:

$$d = \frac{1}{53{,}2}\sqrt{\frac{Q}{V}} \text{ [m]}$$

Next, the calculation necessary to optimize the ventilation installation is presented .

1. Section 1-3

- Air flow (Q) – 650 m3/h (0.18 m3/s);
- Diameter of the ventilation pipe (φ) – 150 mm;
- Ventilation pipe section (S) – 0.01766 m2;
- The speed of the air in the pipe is 10.22 m/s;
- Length of the column section: l = 8.6 m;
- Local losses occur in the suction mouth, in the two 90° curves with radius R=2D, in the suction mouth and bifurcation;
- Since the column related to this section has two 90° bends, a suction mouth and a branch, the local losses presented by the local resistance coefficient, τ taken from the specialized literature, is:
    - ► for 90° bends - $\tau_{cot\ 90°}$=1.148x2 =2.296;
    - ► for the suction mouth – τ_g=0.15(1-A1/A2) + 0.12=0.2325;
    - ► for branching – τ_{ram}=0.35;

The local resistance coefficient, τ related to the branch will be 2.8785.

- The pressure loss per unit of straight column length, related either to the air flow rate of 650 m3/h or to the air speed of 10.22 m/s was taken from the nomogram presented in the specialized literature and has the value of 1, 1 mmH2O/m;
- The pressure loss for the 8.6 m long column is 9.46 mmH2O;
- The dynamic pressure loss on the column section is:

$$P_d=\frac{v^2\gamma}{2g}=\frac{10{,}22^2 x1{,}2}{2x9{,}81}=6{,}39 \quad [mmH_2O]$$

- The local pressure loss on the column section is

$$P_l=\tau\frac{v^2\gamma}{2g}=2{,}8785\,\frac{10{,}22^2 x1{,}2}{2x9{,}81}=18{,}39 \quad [mmH_2O]$$

- The total pressure loss on the column section will be:

$$P_t= P_l=Rl+\tau\frac{v^2\gamma}{2g}=9{,}46+18{,}39=27{,}85 \quad [mmH_2O]$$

2. Section 2-3

Since section 2-3 is identical to section 1-3, the air column having the same dimensions, being pipes connected in parallel at point 3, the pressure loss at this point being the one related to section 1-3, having the value of 27.85 mmH2O

3. Section 3-7

- Air flow (Q) – 1300 m3/h (0.361 m3/s);
- Diameter of the ventilation pipe (φ) – 300 mm;
- Ventilation pipe section (S) – 0.07065 m2;
- The speed of the air in the pipe is 5.11 m/s;
- Length of the column section: l = 3 m
- Local losses occur only on the tube column and on the trouser column with a diameter of 300 mm and the ratio R/D=2
- The local losses presented by the local resistance coefficient, τ is 0.05 and is taken from the specialized literature:
- The pressure loss per unit of straight column length, related either to the air flow rate of 1300 m3/h or to the air speed of 5.11 m/s was taken from the nomogram presented in the specialized literature and has the value of 0, 12 mmH2O/m /2/;
- The pressure loss for the 3.0 m long column is 0.36 mmH2O;

- The dynamic pressure loss on the column section is:

$$P_d = \frac{v^2\gamma}{2g} = \frac{5{,}11^2 x1{,}2}{2x9{,}81} = 1{,}59 \quad [mmH_2O]$$

- The local pressure loss on the column section is:

$$P_l = \tau\frac{v^2\gamma}{2g} = 0{,}05\frac{5{,}11^2 x1{,}2}{2x9{,}81} = 0{,}079 \quad [mmH_2O]$$

- The total pressure loss on the column section will be:

$$P_t = Rl + \tau\frac{v^2\gamma}{2g} = 0{,}36 + 0{,}079 = 0{,}439 \quad [mmH_2O]$$

The pressure loss related to sections 1-2, 2-3 and 3-7 will be:

$P_t = P_{t1\text{-}3} + P_{t3\text{-}7} = 27{,}85 + 0{,}439 = 28{,}29$ mmH_2O

4. Section 4-6

- Air flow (Q) – 650 m3/h (0.18 m3/s);
- Diameter of the ventilation pipe (φ) – 150 mm;
- Ventilation pipe section (S) – 0.01766 m2;
- The speed of the air in the pipe is 10.22 m/s;
- Length of the column section: l = 7.4 m;
- Local losses occur in the suction mouth, in the two 90° curves with radius R=2D, in the suction mouth and bifurcation;
- Since the column related to this section has two bends at 90, a suction mouth and a branch, the local losses presented by the local resistance coefficient, τ taken from the specialized literature, is:
  - ► for 90° bends - τ_{cot} 90°=1.148x2 =2.296;
  - ► for the suction mouth – τ_g=0.15(1-A1/A2) + 0.12=0.2325;
  - ► for branching – τ_{ram}=0.35;

The local resistance coefficient, τ related to the branch will be 2.8785.

- The pressure loss per unit of straight column length, related either to the air flow rate of 650 m3/h or to the air speed of 10.22 m/s was taken from the nomogram presented in the specialized literature and has the value of 1, 1 mmH2O/m /2/;
- The pressure loss for the 7.4 m long column is 8.14 mmH2O;
- The dynamic pressure loss on the column section is:

$$P_d = \frac{v^2\gamma}{2g} = \frac{10{,}22^2 x1{,}2}{2x9{,}81} = 6{,}39 \quad [mmH_2O];$$

- The local pressure loss on the column section is:

$$P_l = \tau\frac{v^2\gamma}{2g} = 2{,}8785\frac{10{,}22^2 x1{,}2}{2x9{,}81} = 18{,}39 \quad [mmH_2O];$$

- The total pressure loss on the column section will be:

$$P_t = Rl + \tau\frac{v^2\gamma}{2g} = 8{,}14 + 18{,}39 = 26{,}53 \quad [mmH_2O].$$

5. Section 5-6

Since section 5-6 is identical to section 4-6, the air column having the same dimensions, being pipes connected in parallel at point 6, the pressure loss at this point being that related to section 4-6, having the value of 26.53 mmH2O

6. Section 6-7

- Air flow (Q) – 1300 m3/h (0.361 m3/s);
- Diameter of the ventilation pipe (φ) – 300 mm;
- Ventilation pipe section (S) – 0.07065 m2;
- The speed of the air in the pipe is 5.11 m/s;
- Length of the column section: l = 6 m;
- Local losses occur only on the tube column and on the trouser type column with a diameter of 300 mm and the ratio R/D=2;
- The local losses presented by the local resistance coefficient, τ is 0.05 and is taken from the specialized literature;

- The pressure loss per unit of straight column length, related either to the air flow rate of 1300 m3/h or to the air speed of 5.11 m/s was taken from the nomogram presented in the specialized literature and has the value of 0, 12 mmH2O/m;
- The pressure loss for the 6.0 m long column is 0.72 mmH2O;
- The dynamic pressure loss on the column section is:

$$P_d=\frac{v^2\gamma}{2g}=\frac{5{,}11^2x1{,}2}{2x9{,}81}=1{,}59 \quad [mmH_2O];$$

- The local pressure loss on the column section is:

$$P_l=\tau\frac{v^2\gamma}{2g}=0{,}05\frac{5{,}11^2x1{,}2}{2x9{,}81}=0{,}079 \quad [mmH_2O];$$

- The total pressure loss on the column section will be:

Pt=Rl+τ (v^2 γ)/2g= 0,72 + 0,079 = 0,8 [mmH2O];

The pressure loss related to sections 4-6, 5-6 and 6-7 will be:

Pt= Pt4-6+Pt6-7= 26,53+0,8= 27,33 mmH2O;

Since the pressure loss on sections 1-2, 2-3 and 3-7 is 28.29 mmH2O being approximately equal to the pressure loss on sections 4-6, 5-6 and 6-7 of 27.33 for the calculation, then the highest value will be taken, namely 28.29 mmH2O.

7. Section 7-8

- Air flow (Q) – 2600 m3/h (0.722 m3/s);
- Diameter of the ventilation pipe (φ) – 400 mm;
- Ventilation pipe section (S) – 0.1256 m2;
- The speed of the air in the pipe is 5.75 m/s;
- Length of the column section: l = 12.3 m;
- Local losses occur only on the tube column and on the trouser type column with a diameter of 400 mm and the ratio R/D=2;
- The local losses presented by the local resistance coefficient, τ is 0.05 and is taken from the specialized literature;
- The pressure loss per unit of straight column length, related either to the air flow rate of 2600 m3/h or to the air speed of 5.72 m/s was taken from the nomogram presented in the specialized literature and has the value of 0, 1 mmH2O/m /2/;
- The pressure loss for the 12.2 m long column is 1.21 mmH2O;
- The dynamic pressure loss on the column section is:

$$P_d=\frac{v^2\gamma}{2g}=\frac{5{,}72^2x1{,}2}{2x9{,}81}=2{,}0 \quad [mmH_2O];$$

- The local pressure loss on the column section is:

$$P_l=\tau\frac{v^2\gamma}{2g}=0{,}05\frac{5{,}72^2x1{,}2}{2x9{,}81}=0{,}1 \quad [mmH_2O];$$

- The total pressure loss on the column section will be:

$$P_t=Rl+\tau\frac{v^2\gamma}{2g}=1{,}21+0{,}1=1{,}31 \quad [mmH_2O];$$

The related pressure drop in the column will be:

$$P_t=P_{t1\text{-}3\text{-}7}+P_{t7\text{-}8}=28{,}29+1{,}31=29{,}6 \text{ mmH}_2\text{O}$$

The value of 29.6 mmH2O represents the depression that the fan must develop to overcome the local frictional resistances at the level of the entire branched column.

In table no. 2.1 presents the value of the data obtained as a result of the calculations performed.

Section	Q [m^3/h]	V [m/s]	Φ [mm]	The loss /m of column	Total loss	The dimensionless drag coefficient	Pressure, dynamic, local and total			Branch point	
							P_d [Pa]	P_l [Pa]	P_t [Pa]	Nr.	Δp [Pa]
1-2	650	10,22	150	1,1	9,46	2,8785	6,39	18,39	27,85	2	27,85
1-3	650	10,22	150	1,1	9,46	2,8785	6,39	18,39	27,85	2	27,85
3-7	1300	5,11	300	0,12	0,36	0,05	1,59	0,079	28,29	3	28,29
4-6	650	10,22	150	1,1	8,14	2,8785	6,39	18,39	26,53	2	26,53
5-6	650	10,22	150	1,1	8,14	2,8785	6,39	18,39	26,53	2	26,53
6-7	1300	5,11	300	0,12	0,72	0,05	1,59	0,079	0,8	3	27,33
7-8	2600	5,72	400	0,1	1,21	0,05	2,0	0,1	1,31	4	29,6

Table no. 2.1. Calculation data optimized installation

The obtained data represent the new operating conditions of the industrial ventilation installation for exhausting and neutralizing VOC emissions, case no. 2. For the choice of the fan, in the case of design, the air flow and pressure will be increased by 20%, which will take into account the future evolution of the column, as follows:

- Calculated flow rate – Q= 2600 m3/h;
- Chosen flow – Q_a=2600+2600x20%=2600+520 = 3120 m3/h;
- Total calculated pressure – P_t= 29.6 mmH2O x 9.81= 290.37Pa;
- Total pressure chosen – P_t = 290.37+290.37x20%=348.44 Pa
- Total column resistance – R_c 460.35 Ns2/m8
- The power required by the engine at a 50% efficiency will be:

$$P_m = \frac{H_t x Q}{\eta} = \frac{348,44x0,87}{1000x0,5} = 0,61 \text{ kw}$$

After optimizing the installation, the following parameters were obtained:

- fan flow rate - 3120 m3/hour;
- fan depression - 348.44 Pa;
- nominal power of the drive motor - 0.61 Kw;
- resistance of the ventilation network – 460.35 Ns2/m8.

3. Comparative analysis of the parameters achieved by the aeration installation

The parameters achieved by the ventilation installation before optimization are:

- Fan flow – 2,344 m3/hour;
- Fan depression – 1706.9 Pa;
- Absorbed power – 3.0 kW;
- Useful power – 1.23 kW;

- Plant efficiency – 41.0%;
- Total network resistance – 3473.6 Ns2/m8.

The centrifugal fan related to the installation had a nominal flow rate of 6,150 m3/h (1.78 m3/s), a depression of 194 mm col. water (1903 Pa) and a nominal power of 4.0 kW

Following the optimization of this installation, the following parameters were obtained:
- fan flow rate - 3120 m3/hour;
- fan depression - 348.44 Pa;
- nominal power of the drive motor - 0.61 Kw;
- Useful power – 0.303 kW;
- Plant efficiency – 50%;
- resistance of the ventilation network – 460.35 Ns2/m8.

4. Conclusions

The following conclusions can be drawn from what has been presented:
- the calculated air flow rate is approximately 29.2% higher than the measured air flow rate;
- the nominal flow rate of the current fan (6150 m3/h) is double the flow rate of the fan chosen through optimization (3120 m3/h);
- the depression developed by the fan chosen through optimization (348.44 Pa) is approximately 5.5 times lower than the depression of the current fan (1903 Pa);
- the resistance of the ventilation network before optimization had the value of 3473.6 Ns2/m8, being 7.5 times higher than the network of the optimized column (460 Ns2/m8);
- the nominal power of the motor of the ventilation installation after optimization is approximately 0.6 kW, being 5 times lower than the power of the drive motor before optimization;
- for optimization, metal pipes with a diameter of 150 mm were used on the suction side, being replaced by corrugated flexible pipes that lead to high pressure losses and increased resistance;
- instead of pipes with a diameter of 250 mm and 350 mm, pipes with a diameter of 300 mm and 400 mm were chosen;

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