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LOOP NETWORK CALCULATION METHOD FOR AIR FLOW IN FLATS

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Abstract: Open collector and single flue chimneys together with mechanical ventilation systems can pose considerable problems in one space in both technical and legal terms. We attempt to investigate this issue from a technical perspective and we examine specific cases. If collector and single flue chimneys are used together with mechanical ventilation, in certain cases the functioning of the chimney can be hindered and even serious accidents can occur. In this case study, we have elaborated a calculation method which can show the circumstances of the functioning. This calculation method will be presented through some examples. We believe that generalizations can be made based on these examples. This calculation method enables the creation of a software, which can be used by an expert to control the air flow. Thanks to this procedure, one can test the effect of the depression on the collector and single flue chimneys. Firstly, the method will be presented in the case of a flat with 14 pipes, 7 of which are basic pipes. Some calculation examples will be presented for the given flat. In the second part, the air supply of a whole level including three flats with 42 pipes, 22 of which are basic pipes and loops will be analyzed.
Keywords: air flow in flats, calculation method, control, basic pipes and loops

PREVIEW

The calculation of the air flow of buildings have been dealt with by many and many times. With an increasing number of windows and doors replaced, this issue has become more urgent. In the case of heating systems connected to open flue chimneys, the appropriate air flow is a crucial issue. Even back in the 60s remarkable calculation methods were elaborated in Hungary in order to calculate the air flow of ventilation systems. In order to calculate the air flow of multi-storey buildings, a calculation method was elaborated by the Institute of Construction Science [11]. A natural ventilation system with a branch-pipe was examined in the case of a multi-storey building with the procedure above. The air flow of the building was presented in a loop graph. The volume flow was calculated as unknown in each loop. The equations of loops and nodes were used in the calculation of the results. The air resistance of the windows was calculated with a mathematical method. The effects of natural draught were also taken into consideration during the calculations. The Newton-Rapson method which applies for several dimensions was used in the solutions to the nonlinear equations. Back then, the special calculation method, used in the calculations of pipe systems developed by Almássy-Budavári-Vajna, was not applied. [1],[2].

In this latter method, the number of equations and unknown figures can be reduced considerably in comparison with the standard Newton-Rapson method. The major breakthrough was the graphic layout of the network, as well as the changes in the loop equations and the introduction of flow in basic pipes. The main characteristic of this method is that the equations describing the flow resistance of each tree are relatively simple. The derivations of these equations can easily be calculated. An important condition in the application of this method is that the connection between the pressure drop and the volume flow should be derivate continuously.

The application of the Almássy method in the calculations of heat and flow processes of collector chimneys is a further step forward in the network calculations of building's technology [11]. Its great advantage is that it makes really complex pressure drop-volume flow (volume flow) equations possible. The pressure drops equations do not need to be derivate, let alone there can be splits in equations. The method kept the reduction in the number of unknown figures from the Almássy method and the

extended procedure from the Newton-Rapson method. It creates a derivative tensor necessary for the iteration procedure through numerical way. In this present study, this procedure has been developed further in the calculation method of air flow in flats.

CASE STUDY: AIR FLOW CALCULATION OF A FLAT

The main principle of the Almássy method remains. The difference is that the pressure drop equation can be optional. In this case, a special pressure drop equation is used. It must be emphasized that a nearly randomly chosen pressure drop equation can be used with the given method. In the current case study, using randomly chosen equation parameters, the result was always convergent.

Pressure drop equations

In order to define the most general flow resistance, the pressure drop in tree spanning should be presented in a biquadratic equation:

$$\Delta p_i = a_0 + a_1 \cdot x_1 + a_{12} \cdot |x_i|^{1,5} + a_2 \cdot x_i^2 + a_3 \cdot x_i^3 + a_4 \cdot x_i^4 \qquad (1)$$

The a_0, a_1, a_{12}, a_2, a_3 and a_4 constants are randomly chosen parameters. The a_{12} characterizes the pressure drop incurring during the flow through the weep holes of windows. With this equation active and passive flow resistance equations can be defined. We call passive elements those through which pressure drops in the flow direction. For example such passive elements include doors and windows. We call active elements those through which pressure can grow in the direction of the flow. We can mention for example extractor fans, bathroom and toilet air fans as well as chimneys. In the case of chimneys, natural draught and inbuilt fans give the driving power.

If only a_2 constant is different from zero, we can get the pressure drop equation used in the Almássy method. The absolute value is needed in the equation in order to calculate the value of the pressure drop in the case of negative flow as well. The sign of pressure drop will be discussed later. In the rest of the components the signs are automatically integrated.

Pressure functions of fans, windows, doors, air inlets

≡ Small-sized fans (active elements)

In our case study we dealt with the characteristic curve of a Helios small fan. The resultant characteristic curve of the curves of a fan and a pipe was created on the basis of a hypothetical work point and a quadratic pipe resistance curve. We put a biquadratic polynome on this curve.

$$\Delta p = a_4 \cdot \dot{V}^4 + a_3 \cdot \dot{V}^3 + a_2 \cdot \dot{V}^2 + a_1 \cdot \dot{V} + a_0 \,[Pa]$$

The unit of volume flow:$[m^3/h]$

The values of each coefficient: $a_4 = 1,251*10^{-6}$, $a_3 = -3,636*10^{-4}$, $a_2 = 1,903*10^{-2}$, $a_1 = -0,6377$, $a_0 = 32,38$

≡ Extractor fans (active elements)

Similarly to small fans the connections are described by biquadratic polynome as well.

The unit of volume flow: $[m^3/h]$

The values of each coefficient: $a_4 = -3,52*10^{-8}$, $a_3 = 2,419*10^{-5}$, $a_2 = -5,81*10^{-3}$, $a_1 = 0,2881$, $a_0 = 213,6$

≡ Doors, windows (passive elements)

The calculation of the air flow is done by taking air-spaces into account. The air flows into and out of air-spaces of doors and windows due to pressure drop.

The equation:

$$\Delta p = \left(\frac{\dot{V}}{\sum a * l} \right)^{3/2} [Pa]$$

The unit of volume flow. In an equation "a*l", "a" means the extent of air closure and "l" means the circle of windows and doors.

≡ Air inlets (passive elements)

The approximate characteristic curve of air inlets is described by the tertiary polynome of the characteristic curve of Air-Tonic AT-G60.

The unit of volume flow: $[m^3/h]$

The values of each coefficient: $a_3 = -1,36*10^{-6}$, $a_2 = 1,10877*10^{-3}$, $a_1 = 6,739542*10^{-2}$, $a_0 = -0,16772825$

≡ Chimneys, boilers (active elements)

We examined chimneys with deflectors. The changes in the draught and resistance of a chimney were defined in the function of changes in the volume of the product of combustion. This latter changes because the volume of the air flow through the deflector changes.

The unit of volume flow: $[m^3/h]$

The values of each coefficient: $a_4 = 1,312*10^{-9}$, $a_3 = -1,6044*10^{-6}$, $a_2 = 5,8869*10^{-4}$, $a_1 = -0,23465$, $a_0 = 46,879$

Figure 1 shows the characteristics of elements.

A special feature of the calculation method used is that all active elements worked opposite the drawn network arrows. As a result they worked in the negative volume field. The positive field is also necessary as the calculations can extend to this area as well during the iteration. In the final result, the volume flow should fall in the negative domain. The passive elements (windows, air-inlets) can be found in the negative and positive field in the calculation method as well. This does not cause any problems as the passive elements are uneven equations.
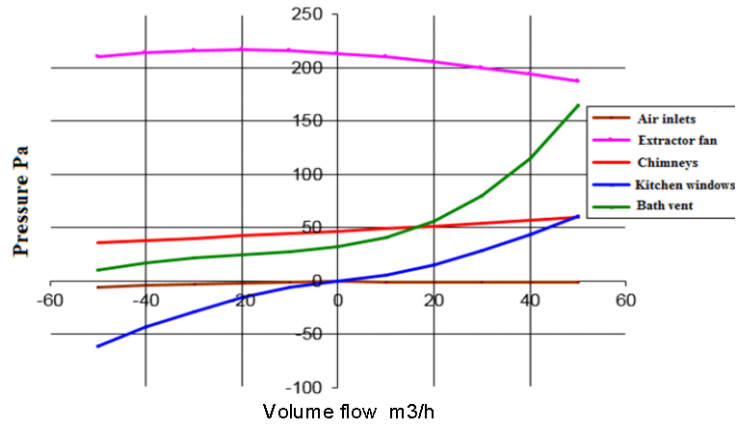

Figure 1. The pressure function of active and passive elements in a flat

The basic graph of air flow

We illustrate the network calculation method related to the air flow in a flat.

The numbers in pink squares are the number of nodes. In this case there are 8 nodes. The numbers in red or blue circle are the branch or pipe numbers.

Windows and doors which do not close fully were used for this experiment. An open chamber boiler (35) and an extractor fan can be found in the kitchen, so we have put in an air-inlet too. The numbers of the rooms were written in the cases on the figure. A North and an East direction point were also indicated. This can help to test the effect of wind. The numbers of the plan (in the circles) do not succeed each other continuously because the flat is part of a whole level (see later). Table 1 shows the number of each element, the number of each element of the „TREE" and their coefficient „K".
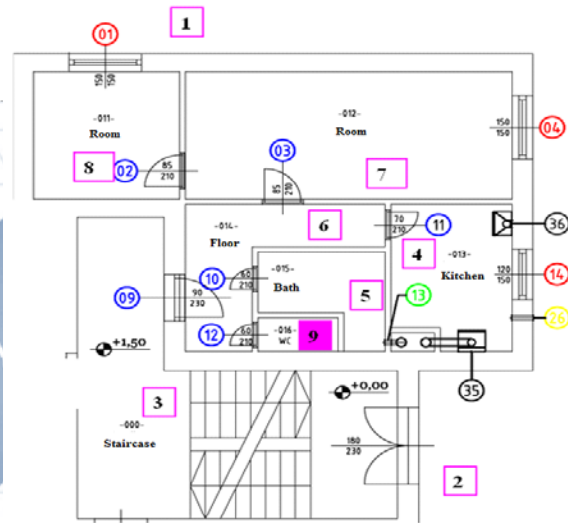

Figure 2. The plan of the flat

Next the basic network graph was drawn. There are 8 nodes. (In the toilet (9) there is no ventilation, so there is no airflow.)

This shows the connections of each node. This can be drawn relatively easily with a little practice but it is also possible to use an algorithm for example with a software designing chimneys. Figure 3 shows the basic network graph.

How to draw the TREE

The TREE can be drawn similarly to the Almássy

Table 1. The number of branches

Number of network in blue or red circle	Number of plan			„K" a_{12}	
1	4	Window	a*l=3,6	0,146402	Passive
2	21	Door	a*l=20	0,01118	Passive
3	14	Window	a*l=3,24	0,171468	Passive
4	26	Air inlet		a_2=0,0011	Passive
5	35	Boiler		a_2=0,00058	Active
6	36	Extractor fan		a_2=-0,0058	Active
7	13	Small fan		a_2=0,0019	Active
8	9	Door	a*l=19,2	0,011886	Passive
9	11	Door	a*l=16,8	0,014522	Passive
10	10	Door	a*l=16,2	0,015337	Passive
11	3	Door	a*l=17,7	0,013361	Passive
12	2	Door	a*l=17,7	0,013361	Passive
13	1	Window	a*l=3,6	0,146402	Passive
-	12	Door	a*l=16,2	0,015337	Passive

method. You can find the details of drawing method of TREE in [1], [2][12], [13].In this case the only problem can be to choose the smallest „K". There are six parameters in the (1) equation. We should decide which one to choose among them to replace „K" when drawing the TREE. As a guideline we can say that that dominant parameter must be chosen a_0, a_1, a_{12}, a_2, a_3 and a_4 which mostly defines the pressure drop (or pressure increase) in the pipe (or any other resistance or fan).

In the Almássy method the smallest „K" is the branch with the smallest resistance. However, if we cannot apply the branch with the smallest resistance when drawing the TREE because the TREE is drawn without this, the method can still be applied perfectly.
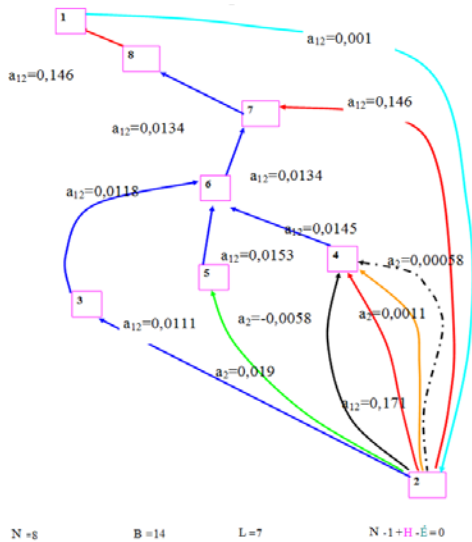
Figure 3. Basic network graph in a flat
"H" is the number of loops; "É" is the number of pipes or branches (We call the line between to nodes pipe or branch.); "N" is the number of nodes.
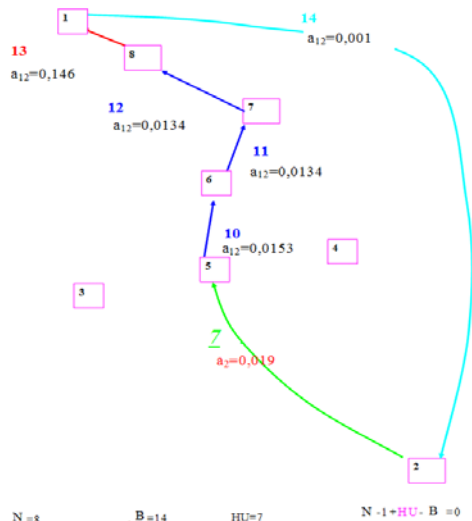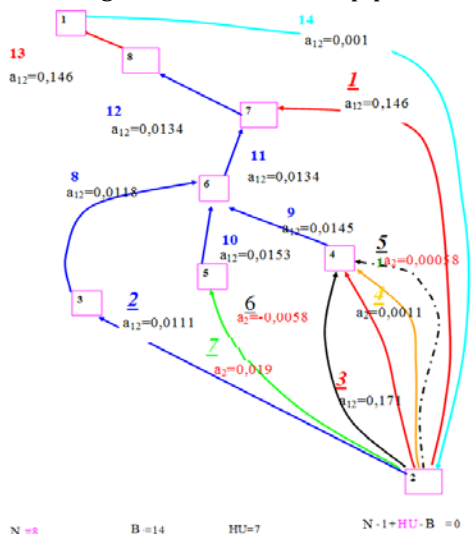

Figure 4. The first basic pipe

Figure 5. Basic network graph with 7 basic pipes

To simplify things we use a_2 instead of „K". Where a_2 is zero for example in the case of windows and doors, the value of a_{12} should be used. Table 1 and Figure 3 shows these characteristics.

The next step is to go along the branches. If we should decide where to continue at a junction, we should always use the pipe which coefficient is the highest. (In the case of Almássy method we chose the lowest.) This seemed to be the right method for reasons that we will explain later.

However it must be stressed that any other organizing strategy can be applied. The organizing principles can be altered within the network. An arrow facing the opposite direction of the way we progress needs to be put on each branch as we go forward as well as a serial number starting with the number of the branch.

If we start from the second node, p0 should be 0 Pa. The first and second node was chosen to be first connected element of the network as they are located out of the flat. The highest value of „K" is used in the flat. In fact, the organizing principles can be altered within the network as well. Thus we can move from the second node towards the first node which gets the highest serial number namely 14. Following our organizing principle, we can easily get to 5node.

We could only move from the 5node towards the 2node.

Let us state: if we move from a knot based on „K" and we have already used this way before but we also have other options, then we should choose an alternative way (where „K" has the highest value). If there is not such an option, the basic pipe found gets a serial number declining continuously and starting with HU (in this case 7). The pipe number (5;2) (start node number, end node number) would follow the 5 node but as we have already been on the 2node so this part of the pipe (5;2) which is the longest becomes the basic pipe number 7 (HU=B-K+1). This is very important rule when giving numbers to the network. When we get back to the node we have been to, we need to mark a basic branch.

The arrow should face that knot on the basic pipe from which we marked the basic pipe, which is node number 5 in this case. If we cannot move forward, we have to turn back on the way we have already been on and getting back to the knot number 5, we have to examine in which other direction we can move on. If there are other options, we should choose the one with the highest „K" value. If there are not any, we move back. In our case the pipe (6;4) is such an option. As we have not been on the 4node we can move on this pipe which can get the arrow and the serial number 9. On the 3node the same thing happens as on the 5node so we cannot move on as we have already been on the 2node and there are no more options. Thus, pipe (3;2) becomes the basic pipe with the serial number 6.

Node number 4 and 2 are connected by four basic branches. Only one branch remains without a serial number and that is number 2. Finally, we get the basic network graph Figure 5. In order to illustrate it, let us draw up a figure of the network pipe numbers and arrows. Figure 6 that we call TREE.

Based on the figure, we can define the term of independent loops: we will call loops
1. Loop elements:1,12,13,14No. pipes;
2. Loop elements: 2,8,11,12,13,14No. pipes;
3. Loop elements: 3,9,11,12,13,14No. pipes;
4. Loop elements: 4,9,11,12,13,14No. pipes;
5. Loop elements: 5,9,11,12,13,14 No. pipes;
6. Loop elements: 6,9,11,12,13,14 No. pipes;

Equations and solution

≡ **Laws of nodes**

The definition of node laws happens similarly to the initial method. The only difference is that there are two simplifications.

1. In the nodes there are not any values. (In case of many levels, only a few nodes have some.)
2. The basic flows can determine the flows of other branches.

The laws of nodes can be easily defined. The outgoing ones should be positive and incoming ones negative. In other words the outgoing ones are equal with the incoming ones.

Figure 6. A TREE of flat with basic pipes and loops

1. node $x_{14} = x_{13}$

2. node $x_{14} = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$

3. node $x_8 = x_2$

4. node $x_9 = x_3 + x_4 + x_5 + x_6$

5. node $x_{10} = x_7$

6. node $x_{11} = x_8 + x_9 + x_{10}$

7. node $x_{12} = x_1 + x_{11}$

8. node $x_{13} = x_{12}$

It can be demonstrated that the 8 node equations are not linearly independent. An equation can be defined with the others.

$$x_{14} + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} = x_{13} + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_1 + x_{11} + x_{12}$$

After simplifying the equation, we get the equation of the 2 node.

$$x_{14} = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$$

The typical characteristics of this method: The number of loops equals the number of the basic branch flows. This is the linear function of the total number of branch flows. If the basic branch flows are removed from the system, a radial network „TREE" is the result.

≡ **Laws of loops**

The number, direction of the loops remain. The number of each loop is marked with „r". The equation system consist of as many equations as the number of loops „L".

$$P_r = \sum_{i=1}^{n_r} \Delta p_i = \sum_{i=1}^{n_r} k_i x_i |x_i| \tag{2}$$

n_r means the number of branches in one loop.
For example for the "1" loop:

$$P_7 = \Delta p_{12} + \Delta p_{13} + \Delta p_{14} =$$
$$= [a0_{12} + al_{12} + a12_{12} \cdot |x_{12}|^{1,5} + a3_{12} \cdot x_{12}^3 + a4_{12} \cdot x_{12}^4] \cdot \text{sign}(x_{12})$$
$$+[a0_{13} + al_{13} + a12_{13} \cdot |x_{13}|^{1,5} + a3_{13} \cdot x_{13}^3 + a4_{13} \cdot x_{13}^4] \cdot \text{sign}(x_{13}) \tag{3}$$
$$+[a0_{14} + al_{14} + a12_{14} \cdot |x_{14}|^{1,5} + a3_{14} \cdot x_{14}^3 + a4_{14} \cdot x_{14}^4] \cdot \text{sign}(x_{14})$$

The other loop equations can be similarly defined. The sign function is necessary to show the direction of the branch flow and of the pressure drop. The main difference of this method is that the laws of loops are not transformed the same way as in the Almássy method.

≡ **How to make the equation system**

To start, we consider the basic branch flow to be zero. The other branch flows are thus calculated with the help of the loop laws. Then pressure drops are added with the proper signs in each loop. The total of the added pressure drops should come to zero in a loop but this does not happen because of the random values of the basic branches. Thus instead of zero, we get $P_1, P_2, P_3...P_7$ therefore the values of basic branches should be modified.
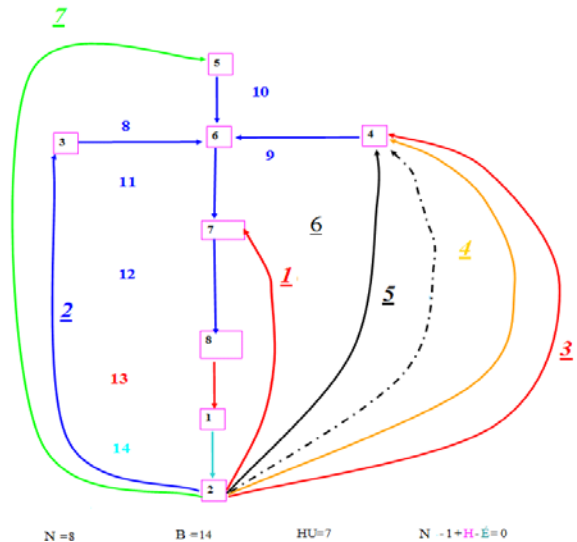The following equations are examined:

$$P_1 = P_1(x_1, x_2, x_3, x_4, x_5, x_6, x_7) \tag{4}$$

$$P_2 = P_2(x_1, x_2, x_3, x_4, x_5, x_6, x_7) \tag{5}$$

$$P_3 = P_3(x_1, x_2, x_3, x_4, x_5, x_6, x_7) \tag{6}$$

$$P_7 = P_7(x_1, x_2, x_3, x_4, x_5, x_6, x_7) \tag{7}$$

which are quite complicated in this case so they are linearized in the following way:

$$P_{1u} \cong P_{1r} + \frac{\partial P_1}{\partial x_1} \cdot (x_{1u} - x_{1r}) + \frac{\partial P_1}{\partial x_2} \cdot (x_{2u} - x_{2r}) + \frac{\partial P_1}{\partial x_3} \cdot (x_{3u} - x_{3r}) + .. + \frac{\partial P_1}{\partial x_7} \cdot (x_{7u} - x_{7r}) \tag{8}$$

$$P_{2u} \cong P_{2r} + \frac{\partial P_2}{\partial x_1} \cdot (x_{1u} - x_{1r}) + \frac{\partial P_2}{\partial x_2} \cdot (x_{2u} - x_{2r}) + \frac{\partial P_2}{\partial x_3} \cdot (x_{3u} - x_{3r}) + ... + \frac{\partial P_2}{\partial x_7} \cdot (x_{7u} - x_{7r}) \tag{9}$$

$$P_{3u} \cong P_{3r} + \frac{\partial P_3}{\partial x_1} \cdot (x_{1u} - x_{1r}) + \frac{\partial P_3}{\partial x_2} \cdot (x_{2u} - x_{2r}) + \frac{\partial P_3}{\partial x_3} \cdot (x_{3u} - x_{3r}) + ... + \frac{\partial P_3}{\partial x_7} \cdot (x_{7u} - x_{7r}) \tag{10}$$

$$P_{7u} \cong P_{7r} + \frac{\partial P_7}{\partial x_1} \cdot (x_{1u} - x_{1r}) + \frac{\partial P_7}{\partial x_2} \cdot (x_{2u} - x_{2r}) + \frac{\partial P_7}{\partial x_3} \cdot (x_{3u} - x_{3r}) + ... + \frac{\partial P_7}{\partial x_7} \cdot (x_{7u} - x_{7r}) \tag{11}$$

we get approximate equations.

Let us introduce signs:

$$x_{1u} - x_{1r} = q_1 \tag{12}$$

$$x_{2u} - x_{2r} = q_2 \tag{13}$$

$$x_{3u} - x_{3r} = q_3 \tag{14}$$

$$x_{7u} - x_{7r} = q_7 \tag{15}$$

A qi values will be the corrections of xi values. Derivatives are calculated in a numeric way. Their definition will be discussed later. Let us assume that derivatives have been defined. The left side of the 8 and 11 equations should be equal zero. This is the condition of calculating the correction.(This is a method used in other pipe network calculations) Let us mark P1r, P2r, P3r...P7r column vectors with Pr. A q means the q1, q2, q3,...q7 column vectors. Finally A tensor means a quadratic matrix formed from partial derivatives. Thus the above equation is the following.

$$-\underline{P}_r = \underline{\underline{A}} \cdot \underline{q} \tag{17}$$

Multiplying the equation from the left with $\underline{\underline{A}}^{-1}$ (assuming it exists) $\underline{q}$ can be defined:

$$\underline{q} = -\underline{\underline{A}}^{-1} \cdot \underline{P}_r \tag{18}$$

Repeating the above method many times in a row, the solution to the network can be found.

≡ **How to make the "$\underline{\underline{A}}$" matrix and its features**

Matrix „$\underline{\underline{A}}$" can only be calculated in a numeric way because of the complexity of the equations and the changes in the features of the materials. Let us examine $P_1 = P_1(x_1, x_2, x_7)$ $P_3 = P_3(x_1, x_2, ...x_7)$, $P_7 = P_7(x_1, x_2, ...x_7)$ functions, and values $P_1, P_2, P_3...P_7$ which are obtained by calculating the network with values $x_1, x_2, x_3...x_7$.

Let us change one of the x values for example x_1 to δ_1. Thus in the above equation $P_1, P_2, P_3... P_7$ values will be different after calculating the network. The new values are marked $P_{11}, P_{21}, P_{31}....P_{71}$.

$$P_{11} = P_{11}(x_1 + \delta_1, x_2, x_3, x_4, x_5, x_6, x_7)$$

$$P_{21} = P_{21}(x_1 + \delta_1, x_2, x_3, x_4, x_5, x_6, x_7)$$

$$P_{31} = P_{31}(x_1 + \delta_1, x_2, x_3, x_4, x_5, x_6, x_7)$$

$$...$$

$$P_{71} = P_{41}(x_1 + \delta_1, x_2, x_3, x_4, x_5, x_6, x_7)$$

With the results we can easily get the approximate value of the first column of matrix A.

$$\frac{\partial P_1}{\partial x_1} \cong \frac{P_{11} - P_1}{\delta_1} \tag{18}$$

$$\frac{\partial P_2}{\partial x_1} \cong \frac{P_{21} - P_2}{\delta_1} \tag{19}$$

$$\frac{\partial P_3}{\partial x_1} \cong \frac{P_{31} - P_3}{\delta_1} \qquad (20)$$

$$\dots$$

$$\frac{\partial P_7}{\partial x_1} \cong \frac{P_{71} - P_7}{\delta_1} \qquad (21)$$

We can get the second column of matrix „A" by changing only the value of x_2 with δ_2. The new P values become P_{12}, P_{22}, $P_{32}\dots P_{72}$. The other columns of matrix „A" are calculated in the same way. $\delta_1, \delta_2, \delta_3\dots \delta_7$ values should neither be too high nor too low. In the first case the approximative derivatives are inexact while in the second case the difference in P values can be zero due to illustration problems. In such a case all elements of the matrix can come to zero. In our example $\delta=0{,}00001$ but when we gave $\delta=10^{-10}$ the elements of the matrix became zero in more places in the case of the same initial values and same layout.

Matrix A has to be generated in each iteration step as the derivatives change. The number of iteration steps depends on the size of the matrix. In each of the following results, relatively exact values were obtained in 10-12 iteration steps. We used Excel software for these examples.

CALCULATION OF AIR FLOW IN A FLAT

In the following part the application of this method will be presented in different wind conditions. The risks in the calculations will be shown as well.

Normal functioning

Figure 7 shows the volume flow of incoming and outgoing air. The thickness of the arrows of the figure is in proportion to the volume flow. Figure 7 shows the exact volume flow values. The signs on the TREE can be plus or minus signs depending on the directions. The signs related to the normal functioning are marked in the last column of the table. Functioning is greatly affected by extractor fans in the kitchen. This can be seen well in Figure 8 in which the depression generated in the rooms is illustrated. The height of the small cylinders is approximately in proportion to the volume of

Figure 7. Normal functioning, incoming and outgoing air through each element

depression. There is depression in the kitchen (-27 Pa) and in the bathroom (-19 Pa) due to the effects of the kitchen extractor fan, the chimney and the small-sized fan in the bathroom. The air inlet clearly lets in a large volume of air (140 m3/h) but the depression is still considerable. Table 2 shows the exact pressure values in numbers in each room.
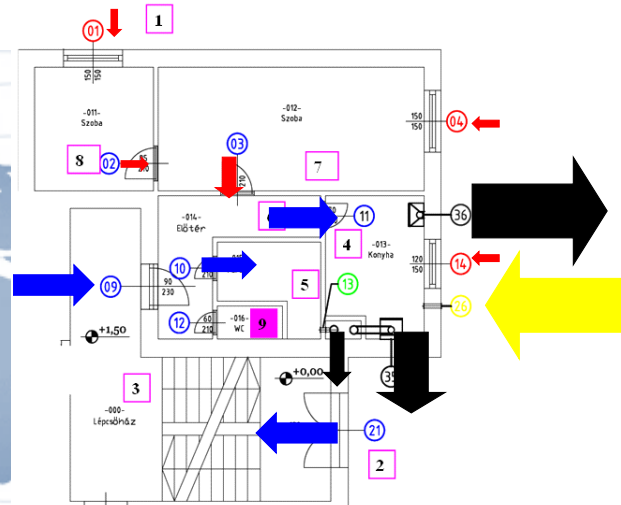
Table 2. Normal functioning, volume flow of incoming and outgoing and pressure drop in each room

Branch	Branchflow [m³/h]	Pressure drop [Pa]	Branchflow [m³/h]	Pressure drop [Pa]	Volume flow [m³/h]	Pressure drop [Pa]	Room
	Normal functioning		Open kitchen windows		Eastern wind		
1	20	13	4	1,4	21	14	04
2	79	7	18	0,9	82	8	21
3	29	27	461	0,0	29	27	14
4	140	27	2	0,0	141	27	26
5	-102	27	-281	0,0	-101	27	35
6	-149	27	-157	0,0	-149	27	036
7	-35	19	-53	7,	-33	20	13
8	79	8	18	0,9	82	8	09
9	-83	-11	25	1,8	-80	-10	11
10	-35	-3	-53	-5,9	-33	-3	10
11	-38	-3	-9	-0,3	-31	-2	03
12	-18	-1	-4	-0,1	-9	-0,4	02
13	-18	-11	-4	-1,3	-9	-4	01
14	-18	-0,1	-4	-0,0	-9	-10	East

Functioning in case of open kitchen windows

The thickness of the arrows of Figure 9 is more or less in proportion to the volume flow of the incoming and outgoing air. Table 2 shows the exact volume flow values. Apart from the air flows of the kitchen

windows, of the chimney, of the kitchen extractor fan and of the small-sized fans in the bathroom the other air flows can practically be neglected.
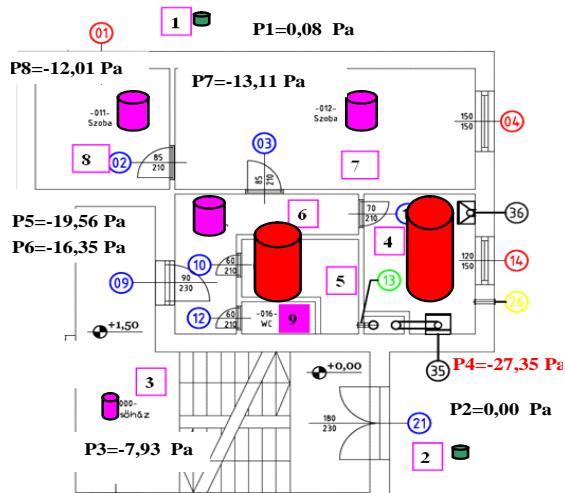

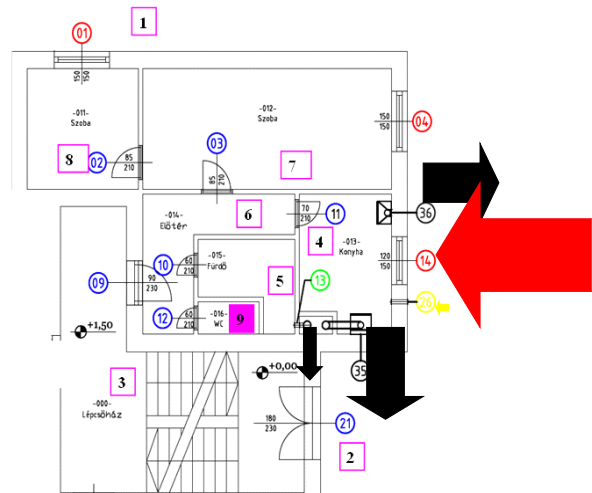Figure 8. Normal functioning, depression in each room

Figure 9. Incoming air and outgoing air through each element with open kitchen windows

The depression of the rooms disappeared, which can be seen in Figure 10. Only -7 Pa depression can be observed in the bathroom due to the ventilation system. Everywhere else the pressure is basically the same.

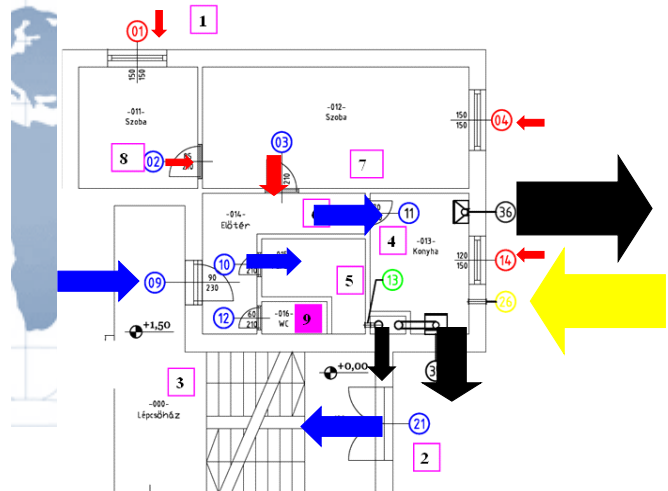Figure 10. The depression of the rooms when kitchen windows are open

Figure 11. Incoming air and outgoing air through each element in case of Eastern wind

Functioning in case of Eastern wind (10 Pa)

The thickness of the arrows of Figure 11 is more or less in proportion to the volume flow of the incoming and outgoing air. Table 2 shows the exact volume flow values. Figure 11 shows the air flows. The volume of the air flows did not change considerably compared to the normal functioning. However, the depression of the rooms fundamentally changed and this is shown in Figure 10. There is 1,6 Pa overpressure in the staircase. Thus the volume of the depression decreased in all the rooms compared to the normal functioning.

Safe functioning in many different cases

The different ways of functioning are summarized in Figure 13. The depression generated in the kitchen and the volume flow in the chimney were mainly examined. Apart from the above mentioned three functioning systems, two more options were also calculated in case of which the functioning of the chimney became dangerous. The kitchen
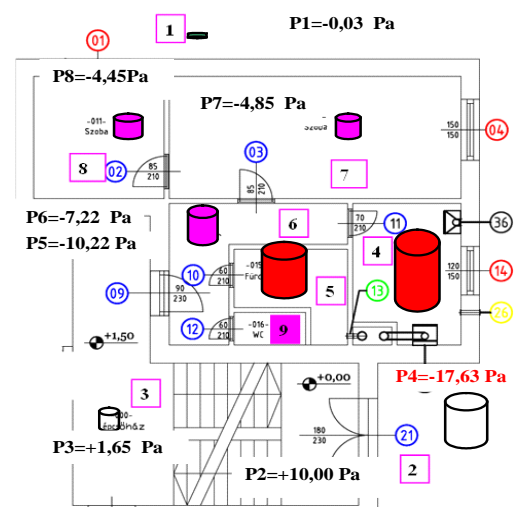

Figure 12. The depression of the rooms in case of Eastern wind

air inlet was closed in the fourth calculation option. In this case, the air (flue-gas) flows outside through the chimney but the decrease in the volume flow is dangerous, therefore this functioning is not safe! In the fifth option we examined the case when the kitchen door was made air fast and how this would change the functioning of the chimney. (This is often used by residents when they are cold. They close the kitchen inlet element not to be cold.) In this case there is practically no flow in the chimney! This functioning is absolutely dangerous!

Figure 13. The depression in the kitchen and the volume flow in the chimney in different functioning modes

CONCLUSION AND FURTHER STEPS

A calculation method was elaborated for natural ventilation and for technical ventilation in a flat and some examples were shown to present how this model works. Safe and dangerous functioning modes were examined with the help of the given example. This helped us to prove that this calculation is suitable to simulate the volume flow of a flat. We continued to develop the calculation and a model was created for more levels. We developed a user software with Bausoft ltd. to calculate, test and control the volume flow of multi-storey buildings. This calculation method points out some critical functioning modes when both natural and technical ventilation occur at the same time in mainly open collector chimneys. The fact that it is relatively easy to create dangerous functioning with „simple" devices makes gas providing utility companies ban technical ventilation in the case of flats with open collector chimneys.

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[15] Mónika Bakosné Diószegi, Miklós Horváth: Experiments with a Newly Developed Biogas Reactor Block, Acta Polytechnica Hu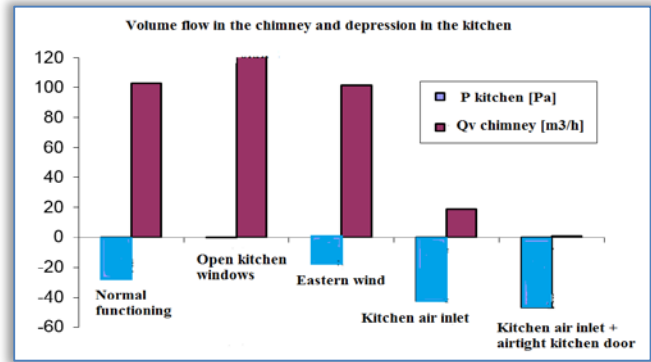ngarica 12:(1) pp. 175-188. (2015)