VENTILATION AND COOLING
18TH AIVC CONFERENCE, ATHENS, GREECE
23-26 SEPTEMBER, 1997

Title: **Prediction of the Potential of Self-Regulating Natural Ventilation Devices: Methodology and Practical Results**

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PREDICTION OF THE POTENTIAL OF SELF-REGULATING NATURAL VENTILATION DEVICES : METHODOLOGY AND PRACTICAL RESULTS

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ABSTRACT

The performances of self regulating natural ventilation devices (devices of which the opening section varies as function of the pressure difference across the device) strongly depend on the type of building and its leakage characteristics. In like manner, the climatic conditions strongly impact on the achieved ventilation rates. As a result, it is not possible to express the potential benefit of self-regulating natural ventilation devices in an unambiguous way. This is not contributing to a good understanding of the potential of such devices in daily practice. In order to increase the transparency of the results, a method has been developed which allows comparing the performances of various natural ventilation devices (fixed devices, self-regulating devices, etc.) for a range of building types and climatic conditions. The paper presents the simulation concept and the possibilities of the VENTEX programme. Results obtained for a range of combinations of ventilation devices are presented and discussed.

1. THE SIMULATION CONCEPT

1.1 BASICS

At present, there is a range of programmes, which allows detailed simulation of airflows in buildings. The basic idea of this programme called 'Ventex' was the development of a quick simulation tool which is very transparent and which allows one to come to useful results for a range building types. The major limitation is the fact that the simulation tool can only treat buildings that can be modelled as a combination of:

- one *central zone* which can be in connection with the outside and with adjacent spaces;
- as many *adjacent zones* as needed through which the airflow passes from the outside to the central zone. The temperature of adjacent zones equals the temperature of the central zone.

These assumptions permit to treat the problem numerically as a single zone problem and results in a Visual Basic programme in a Microsoft Excel 97 environment and a short calculation time.

1.2 THE AVAILABLE COMPONENTS

The following figure shows the complexity of the models that can be calculated using Ventex.

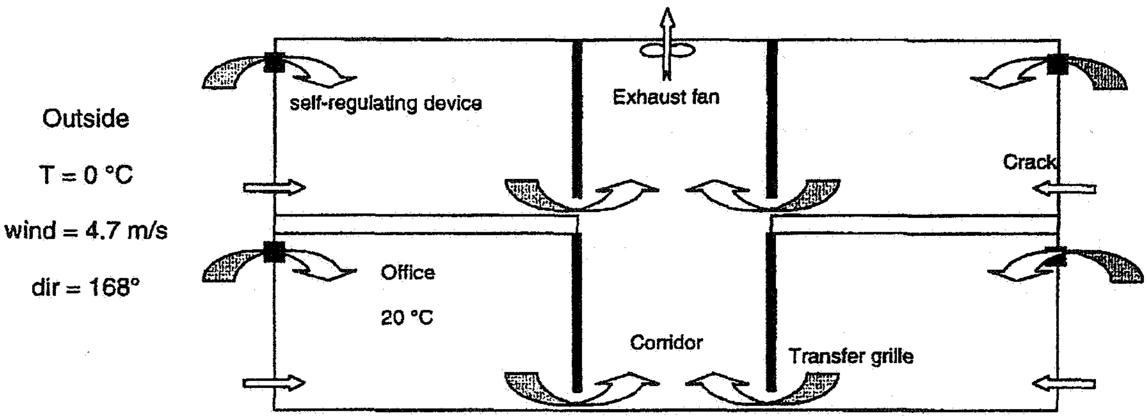


Figure 1 – Example of model that can be calculated with Ventex

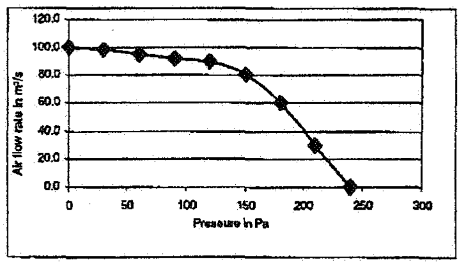
Essentially, 4 types of components can be simulated:

1. A leakage opening with constant characteristics (trickle ventilators with constant section, cracks, etc.)

   Leakages are described by the equation $q = C.\Delta P^N$. The user must specify C and N.

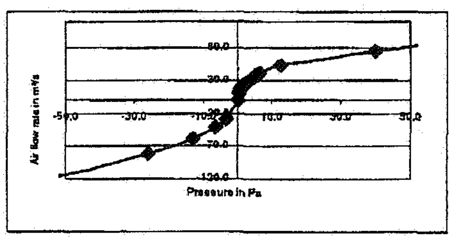
2. Fans

   Fans can be described as a device with a fixed air flow rate but it is also possible to define the q-ΔP relation for various pressure differences. The programme interpolates for intermediate pressure differences. The figure shows an example of fan characteristics as presented in the programme.



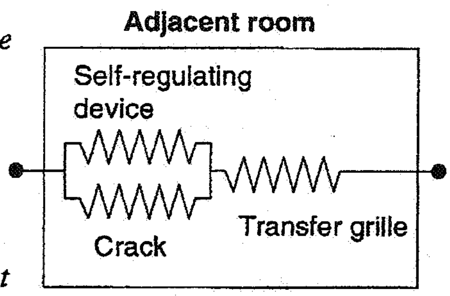
3. Leakage openings with variable characteristics

   The user can describe any kind of q-DP relation. The programme interpolates for intermediate pressure differences. The figure shows the q-ΔP relation of a self-regulating device.



4. Equivalent leakage consisting of variable or fixed resistance in parallel and in series.

The airflow through adjacent rooms is unidirectional (from the central room to the outside or from the outside to the central room, no 2-way flows). Therefore, it is possible to use an equivalent resistance that characterises the airflow through the room.



The example of Figure 1 shows an adjacent room with a ventilation device in the outside wall. There is a transfer grille in the inner door and a crack corresponding with the background leakages in the outside wall. Ventex determines the equivalent characteristics of the system consisting of these different components and simulates this system as one single component (see figure).

1.3 THE SIMULATION TOOL ©VENTEX

Ventex is running under Excel 97 and makes extensive use of Visual Basic programming. The user must define the number, type and characteristics of the components and the programme derives the equivalent characteristics and simulates the mass transport through the components.

The programme in its present version makes use of hourly data (e.g. the test reference year for Uccle in Belgium). The user can specify the time step (1 hour, 2 hours, etc.).

The output includes:

- Pressure differences across all components (for each time step);
- Air flow rates through all components (for each time step);
- Heating power for ventilation and monthly energy use for ventilation.

In principle, it is possible and not difficult to add prediction of CO_2 levels, which is not available at the moment.

2. EXAMPLE OF APPLICATION

2.1 THE BUILDING

The building taken as illustration has the following characteristics (see Figure 1):

- 2-storey building consisting of cellular offices at both sides of the corridor.
- Mechanical extraction with known q-ΔP characteristics.
- Natural supply openings in all offices (see Table 1).
- Background leakage corresponding with n_{50}-value of 2 h^{-1}.
- Each office has a floor area of 10 m², is occupied by one person.
- Air inlet of 30 m³/h are installed in each of the 4 offices.
- An exhaust fan is extracting air from the corridor. Its is nominal airflow rate is equal to the sum of the nominal airflow rates of all the ventilation supply device (number of offices X 30 m³/h).
- All windows and doors closed

Assuming that the resistance of the corridor and the open staircase is negligible, it is possible to model only a segment corresponding of 2 rooms at ground level, 2 rooms at top level and the corridor. This results in the model presented in the next figure.

The Cp-values for offices of the first floor are 0.2 (windward) and –0.2 (leeward) while for the ground floor, values of 0.15 and –0.15 were assumed. These values are related to the meteorological wind data.

Important remark :

It must be stressed that the results given in the paper are mainly aimed for illustration purposes. It is evident that the choice of the wind pressure coefficients and the local wind speed is extremely important. In the examples, we have assumed that the wind direction is always the same, this is also not a very realistic assumption.

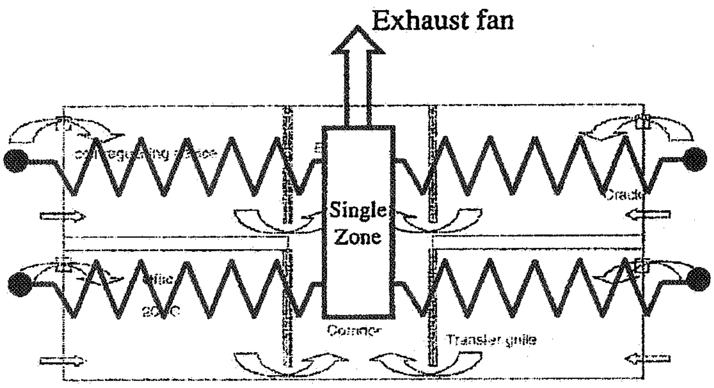


Figure 2 – Simulation model of the studied building

2.2 THE COMPONENTS UNDER CONSIDERATION

Table 1 described the different configurations that were simulated in the above-described building. Different ventilation supply devices were used as well as different kind of transfer openings between the corridor and the offices. Finally, simulations with open doors and windows were also tested.

The nominal pressure of the ventilation devices used is either 1 Pa (more or less representative for the approach used in e.g. the Netherlands) or 2 Pa (representative for the approach used in Belgium) or 20 Pa which corresponds with the approach of very small supply openings (to a certain extent the case in France).

The characteristics of the self-regulating devices used in the model are given in Table 2.

Case	*Generic description*	*Transfer opening*	*Doors*	*Windows*
1	Constant air flow rate device giving nominal air flow rate at pressure difference of 1 Pa	Fixed opening giving nominal air flow rate at difference of 1 Pa	All closed	All closed
2	Idem 1 at 2 Pa	Idem 1 at 2 Pa	All closed	All closed
3	Idem 1 at 20 Pa	Idem 2	All closed	All closed
4	Idem 1	Idem 1	All open	1 windward window open
5	Idem 3	Idem 1	All open	1 windward window open
6	Self-regulating device at 1 Pa	Idem 1	All closed	All closed
7	Self-regulating device at 2 Pa	Idem 2	All closed	All closed
8	Idem 1	Idem 1	All open	All closed
9	Idem 6	Idem 2	All open	All closed
10	Idem 2	Idem 1	All open	All closed
11	Idem 7	Idem 2	All open	All closed

Table 1 – Overview of the different simulation cases

Pressure difference	Fraction of nominal flow rate q_N (=air flow rate at the nominal pressure)
0-2 Pa	$\sqrt{P/P_{NOM}}$
5 Pa	1.2
10 Pa	1.2
25 Pa	1.2
50 Pa	1.5
100 Pa	2
200 Pa	3.0

Table 2 – Characteristics of self-regulating device (expressed as a fraction of the air flow rate at the nominal pressure)

2.3 SIMULATION RESULTS

2.3.1 IMPACT OF THE NOMINAL PRESSURE

The same building was simulated with the same climatic conditions using fixed ventilation devices giving the nominal airflow rate (30 m³/h for each office) at 1 Pa, 2 Pa and 20 Pa.

The simulations were performed for the whole test reference year with a time step of 1 hour.

The following figure shows the yearly average airflow rates in the 4 different offices as well as the standard deviations. The next one gives the yearly energy consumption due to ventilation per m² office floor area.

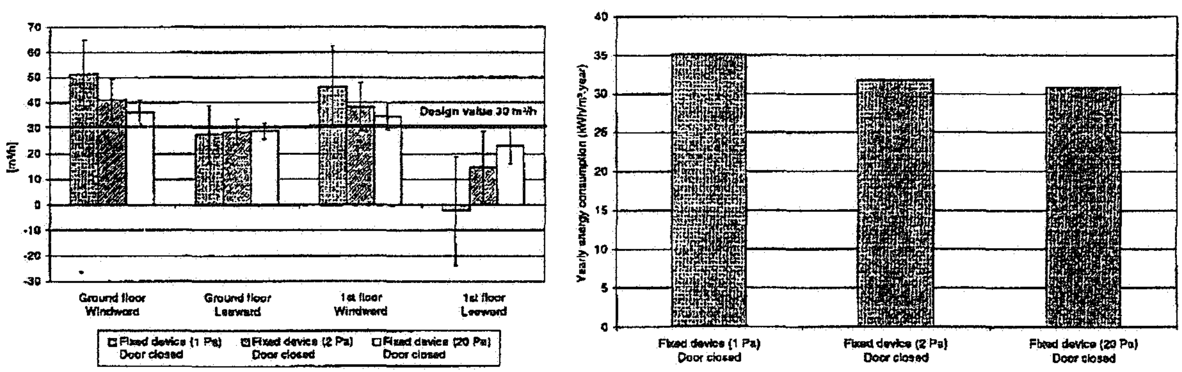


Figure 3 – Yearly average and standard deviation of the airflow rates in the 4 offices and total yearly energy consumption per m² floor area (case 1, 2 and 3).

The next figure represents histograms of the airflow rates in the different offices for a test reference year simulation (climatic conditions of Uccle, Belgium).

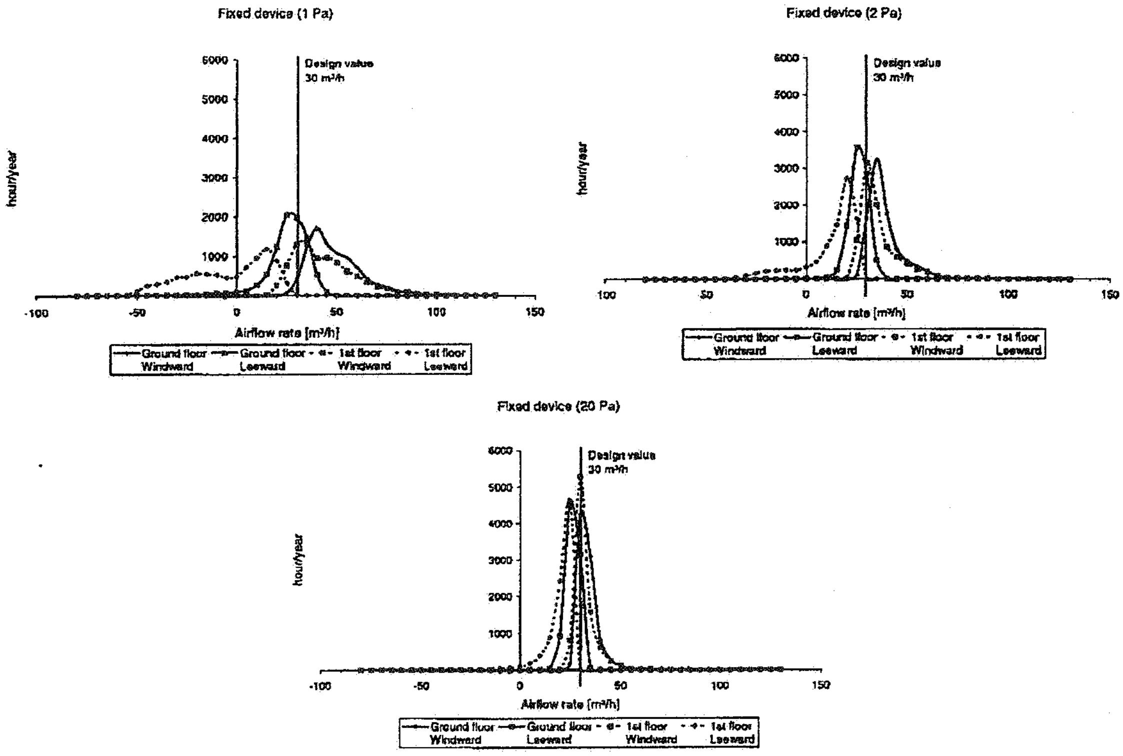


Figure 4 – Histograms of the airflow rates in the 4 offices (cases 1, 2 and 3).

As it can be seen on the previous figures, the higher the nominal pressure (the smaller the opening), the lower the variations of the air flow rates around the design values. The fan can always counteract the pressure drop through the ventilation devices (1, 2 or 20 Pa) but the wind induced and thermally induced pressure differences entail smaller airflow rates, as the openings are smaller.

The Figure 3 shows that the average airflow rates vary substantially from one room to another, the most underprivileged being the one situated leeward at the first floor because the stack effect and the wind effect play in the wrong direction. The energy consumption is about 12% less for a 20 Pa nominal pressure than for a 1 Pa nominal pressure.

2.3.2 WINDOW OPENING IN ONE OFFICE

The cases 1 and 3 were simulated again but with an open window (windward ground floor office) and all the internal doors open. Results are given in the next figures.

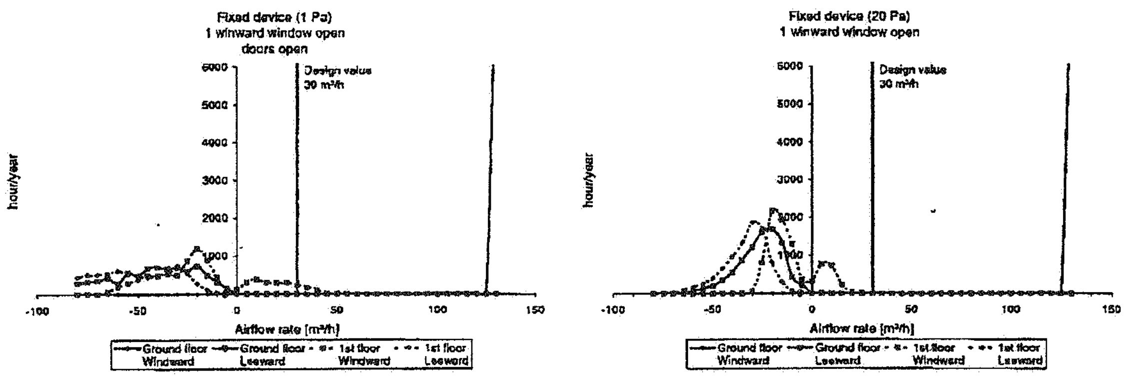


Figure 5 – Histograms of the airflow rates in the 4 offices (cases 4 and 5).

2.3.3 IMPACT OF SELF-REGULATING DEVICES

The next figures show the simulation results when using self-regulating devices instead of fixed ventilation devices. The doors are kept closed.

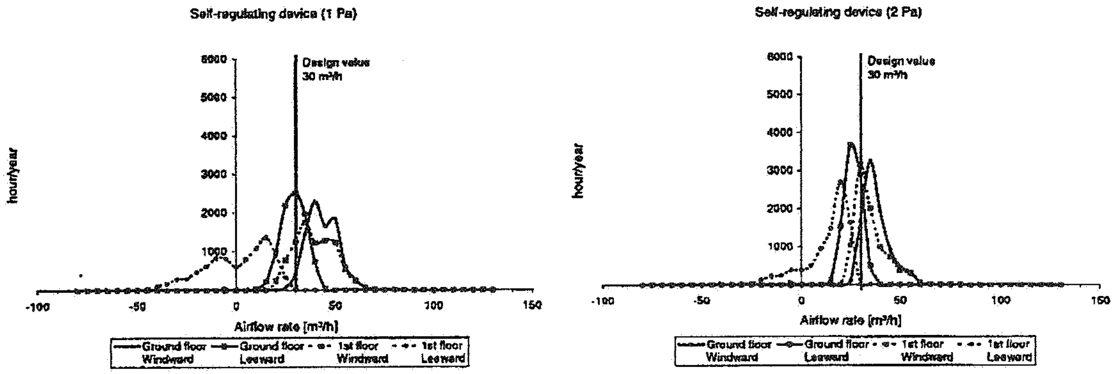


Figure 6 – Histograms of the airflow rates in the 4 offices (cases 6 and 7).

When comparing these results with the two first ones of Figure 4, one can see that the impact of the self-regulation is small. This is due to the relatively resistant transfer grilles that increase the pressure drop through the adjacent room and therefore limit the effect of the self-regulation.

The next 4 figures compare self-regulating and fixed devices for a situation where all the internal door between the corridor and the offices are open.

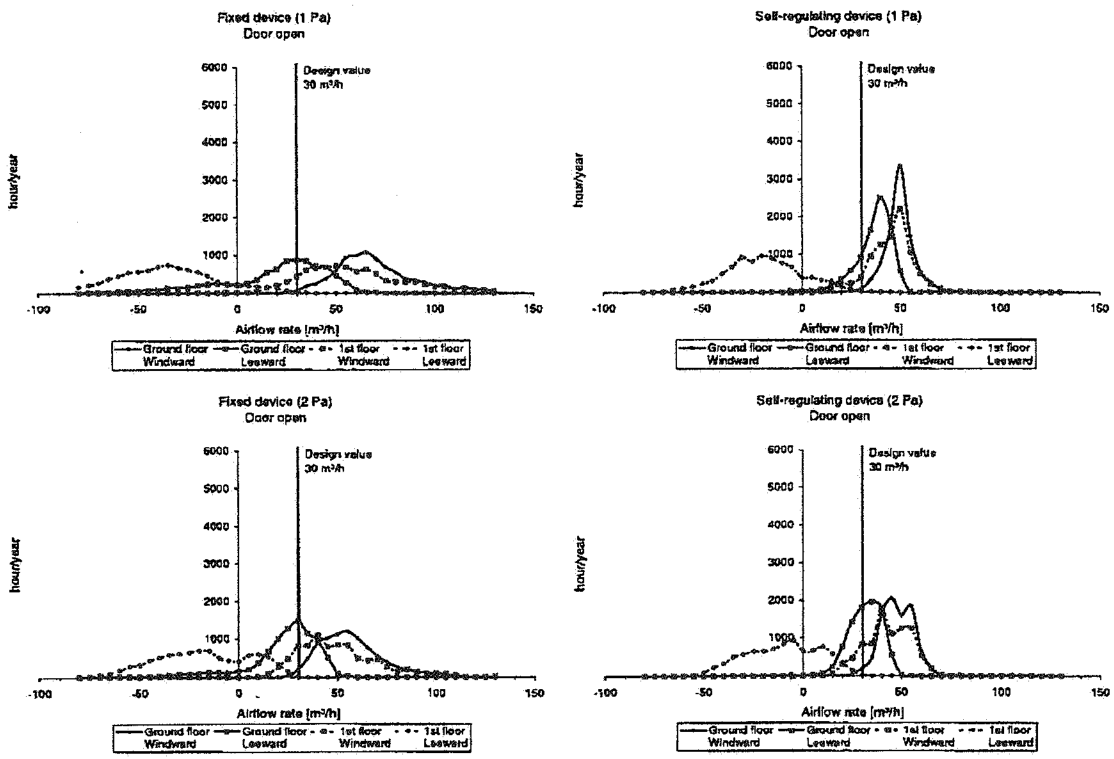


Figure 7 – Histograms of the airflow rates in the 4 offices (cases 8, 9, 10 and 11).

As it can be seen, the impact of the self-regulation is much bigger.

3. Conclusions

1. This paper presents the concept of the Ventex programme, allowing to predict in a straightforward way air flows in a multizone building
2. Results of the impact of the nominal pressure for natural supply openings on the airflow rates are presented for an office building with mechanical extraction. The impact of use of internal doors is presented as well as the contribution of self-regulating devices.
3. Further work is needed before clear conclusions can be drawn on the impact of nominal pressure on airflow rates, indoor air quality and energy use.

4. References

1. Microsoft Excel 97
2. A Guide to Energy Efficient Ventilation, March 1996.
3. BBRI Technical Note 203, Ventilatie van woningen – Deel II – Prestaties van ventilatiesystemen, BBRI 1997.

5. Acknowledgements

The Ventex programme has been developed in the framework of the Flemish Impulse Programme for Energy Technology VLIET, contract VLIET/930.245/RENSON. The authors wish to thank VLIET for the financial support.