MARKET OPPORTUNITIES FOR ADVANCED VENTILATION TECHNOLOGY

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VERY LOW PRESSURE FAN FOR NATURAL VENTILATION ASSISTANCE

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Approaching the efficiency and the controllability of the mechanical ventilation in natural ventilation constitutes the objective of this invention.

Simply integrated in whatever usual natural ventilation installation, this electrical device generates low depression that ensures almost constant and acceptable airflows all the year, for whatever meteorological conditions (excepted for exceptional strong wind), for whatever building type (until 7 floors) which means quite suitable for refurbishment, and for all the flats between the ground and the sixth floor.

Its very low electrical consumption (around 2 watt per flat) leads to very low energetic expenditures, and also provides a utter natural solution thanks to an eventual photovoltaic supplying.

When not working, this assistance fan presents negligible airflow resistance, so that the ventilation net can keep on working normally when the fan is off or out of order.

The fan efficiency can be easily adapted to any case and condition by simply tuning its low supplying voltage.

Consequently, this invention allows to conciliate the main advantages of both mechanical (stabilisation and controllability of the airflows) and natural ("no" energetic expenditure, low costs, good perceived comfort, low generated noise,…) ventilation.

Contents

1. Introduction

The main problem in natural ventilation is that its efficiency depends very tightly on the meteorological conditions : high wind velocity and outside temperature lower than inside are optimal conditions for efficient ventilation.
Consequently, air renewal inside buildings is very fluctuating from one moment to another, and extreme comportments can be reached from one season to another : in winter, ventilation is usually very satisfying, whereas in summer unwanted reverse airflows can hardly be avoided.

One solution is to use a fan that should work at least on the periods of bad efficiency, so that an acceptable ventilation rate can be ensured all the time. One crucial point is that this fan – integrated in an already existing ventilation net – should not decrease at all the performance of this original net in case of no working.

Such an electrical device has been developed by the AERECO and CERGA Companies, with such a low energetic consumption that only 1 to 3 watts per dwellings are enough to ensure all the year a ventilation efficiency at least equal to the best winter's one.

Thus, such a fan – that can be electrically supplied thanks to photovoltaic panels – puts forward a full natural and performing solution to the problems of traditional natural ventilation, taking into account the saving of energetic expenditures.

2. Natural ventilation

1.1. Natural ventilation in European Countries

In spite of the large development of mechanical ventilation systems in Europe on the last decades, natural ventilation still have a significant place (like in the building refurbishment), which is even expected to grow according to most of European architects.

Two principal actors fight either for mechanical or for natural installations :

- ⇨ ***Governmental decision makers*** (Norway, Sweden, Switzerland,…) require more severe ventilation performance – that can not be ensured by usual natural systems – for efficient pollutant and noise problems elimination, heat recovery system installation, fire regulations respect,…
- ⇨ ***Designers and contractors*** prefer natural solutions especially for question of lower maintenance and running costs, lower energy consumption, better perceived comfort,….

If countries like Norway and Sweden seem really linked to mechanical ventilation for its constant efficiency, controllability and "easiness" to be designed , most of other countries (Netherlands, Denmark, United Kingdom,…) still believe in natural ventilation in spite of the varying performance and the still lack of knowledge in that field (cf. Natvent^{TM} Report).

Development of – cheap and low energy consumption – devices, which could lead to better controllability and efficiency of natural ventilation, should no doubt be a way to reinforce the general idea that natural ventilation is still a very adapted solution in European countries.

1.2. Principle of natural ventilation

In whatever building types, the principle of natural ventilation consists in making new air coming from outside, into the "principal rooms" (bedrooms, living-rooms, etc…) and then, to extract this "foul" air from the "service rooms" (kitchen, bathroom, toilet, etc…), by the top of the building (*figure 1*).

Such air movements are allowed by the creating of depression inside extract ducts which are connected to service rooms.

So, air which is sucked from service rooms, has to enter from outside, through the inlets, and pass through principal rooms, before being extracted outside through the chimneys.

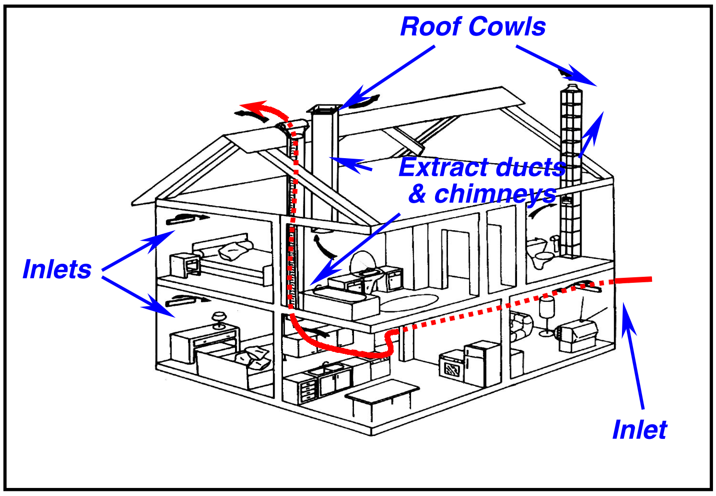


Figure 1 - Airflows in natural ventilation

Two driving forces can ensure the existence of a depression inside the service rooms :

1) ***Passive stack effect :***

The first force, provided by a ***difference of temperature*** between inside and outside buildings, is a phenomena that can be explained as follow.

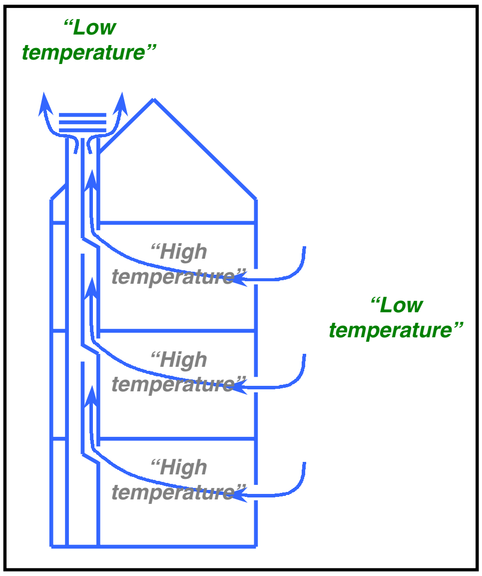


Figure 2 - Passive stack effect

Most of the time, temperature inside buildings is higher than outside. That difference of temperature is higher in the cold seasons and in the northern European countries.

When air is colder outside than inside, the density of air outside is higher than the density of air inside, so that this phenomena can be seen like a heavy column of air outside tending to fall down, and a light column inside tending to rise.

In order to reach a thermal balance, air flow coming from outside enters the building through inlets and gets exhausted up through vent ducts and roof cowls (*figure 2*).

Consequently, air renewal is closely linked to outside temperature. For temperature inside close to temperature outside, no real air renewal can be expected.

In case of outside temperature higher than inside – which often occurs on summer days – a reverse phenomena appears : airflows are generated, passing from service rooms to principal rooms. This means that "pollutants" (cooking smells, humidity, etc…) can be spread into all the principal rooms. In the case of a several floors building, "polluted" airflows can even come from a flat to the flats of the floors below.

2) *Dynamic effect of the wind:*

On the other hand the suction effect of the wind has to be considered.
When getting locally accelerated an air flow can generate a local static depression : this phenomena is called "Venturi Effect" (*figure 3*).

This phenomena appears as soon as air flows meet an obstacle.

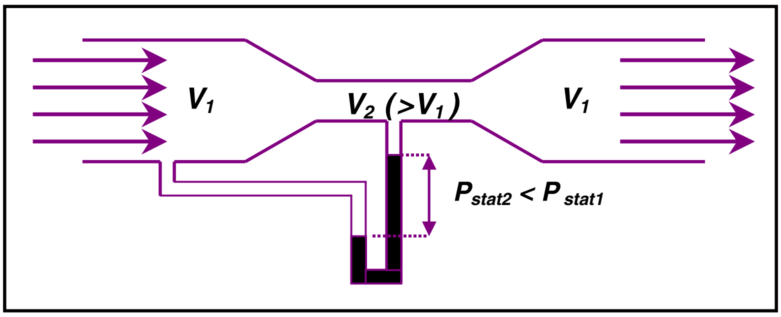


Figure 3 - Venturi effect

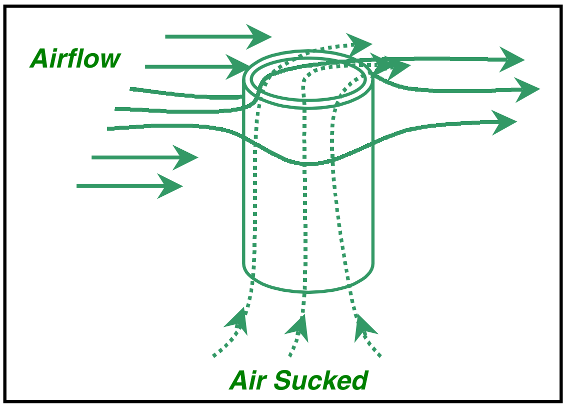


Figure 4 - Suction effect

For example, when arriving on the top of a cylindrical duct (*figure 4*), wind has to move around the duct : forced to take a longer way, the air flow gets locally a higher speed.

Consequently a local depression is created on the top the duct, so that air can be sucked at the bottom.

The more the wind is strong, greater is the depression created.

Roof cowls – settled at the end of the extract chimneys – are used in order to ensure a good suction effect, and to shelter ducts from rain. Given that wind strength and orientation are very fluctuating, depression induced by suction effect is also very fluctuating.

Paradoxically, it has to be noticed that, when not well chosen – which is the case many times –, roof cowls can be a break to airflows, especially in case of low wind velocity : although there is a very good passive stack effect, airflows may be very decreased and reverse flows can even occur in the higher floors of a several floors building.

1.3. Natural ventilation in terms of performance

Graphs presented hereafter show the evolution of airflows in a 1 floor dwelling on two extreme seasons : summer (on August) and winter (on December).

These are simulations that have been realised for a ventilation net having a global equivalent aeraulic section of 150 cm², and equipped with a rather efficient roof cowl with low pressure loss. Meteorological parameters (wind and temperature) taken into account in that case are the ones measured during 1999 close to Paris.

As shown hereafter (*figure 5*), almost "stable" airflows – around 90 m^3/h – are ensured during the cold month of December.

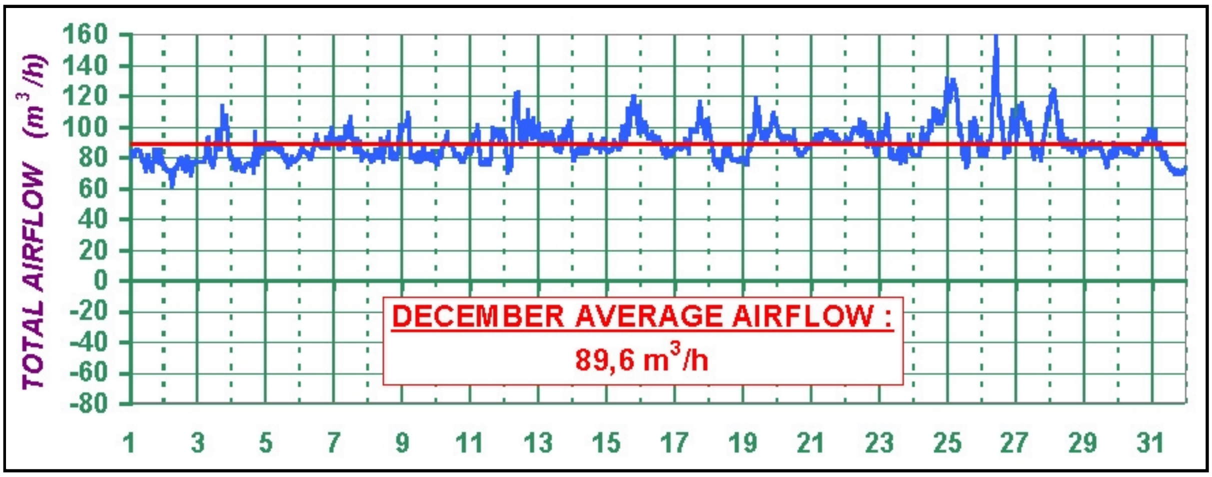


Figure 5 - Airflows in a dwelling on winter

Fluctuations – that are mainly induced by wind strength fluctuations – are rather limited : airflows generally vary between 80 m^3/h and 100 m^3/h.

On "hot seasons" (*figure 6*) fluctuations are very amplified and airflows are globally much lower than in winter. For many days, reverse airflows appear in the middle of the afternoon.

These substantial variations of airflows are mainly caused by the "passive stack effect" : on night, temperature inside is higher than outside, so that "normal" airflows can be extracted ; on day, temperature inside is lower than outside, so that reverse airflows are created, inducing failure of ventilation.

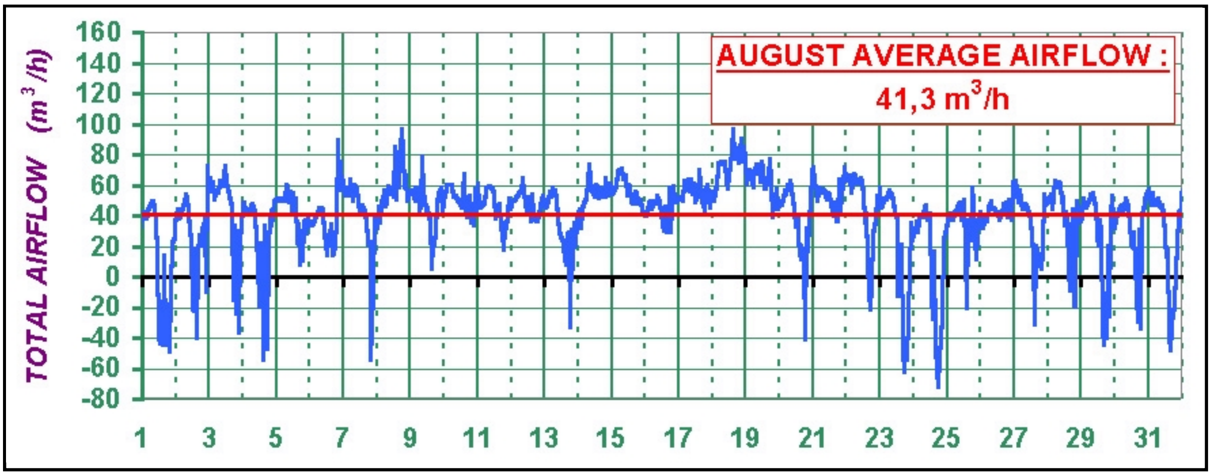


Figure 6 - Airflows in a dwelling on summer

3. Solution to natural ventilation failure : assistance fan

3.1. Objectives to be reached

During “cold periods”, natural ventilation is generally considered as quite satisfying so that airflows do not really need to be improved.
The problem stands in “hot seasons” when airflows are very low, and even harmful.
So, a “good natural ventilation” can be considered as a ventilation for which one, usual winter airflows could be ensured all the year.

By developing an assistance fan for natural ventilation, Aereco and CERGA Companis aimed to reach this target. Two conditions have to be respected then :

- ⇨ When not working (on winter periods for instance), the fan integration in the ventilation net should not decrease the ventilation net performance at all.
- ⇨ When working (on summer afternoon for instance), the fan should ensure airflows close to winter ones.

It can be noticed that one annex using of the fan on summer periods, may be the cooling of buildings : indeed, by making the fan run during the night, “cold airflows” through the rooms can be significantly increased, so that rooms may be substantially cooled.

3.2. Working principle

The main problem for the fan integration, is that it should not decrease at all the ventilation net performance. This means that, when integrated in a ventilation duct for example, the fan should not break airflows at all.

This is not possible with a classical electrical fan : as well as for a helicoidal propeller or a centrifugal turbine, the airflow resistance is to much important when the fan is not working.

As shown on *figure 7*, in the case of a helicoidal fan which is not working, airflow is deviated by the propeller blades, as if the “natural airflow” in the duct meets an obstacle.

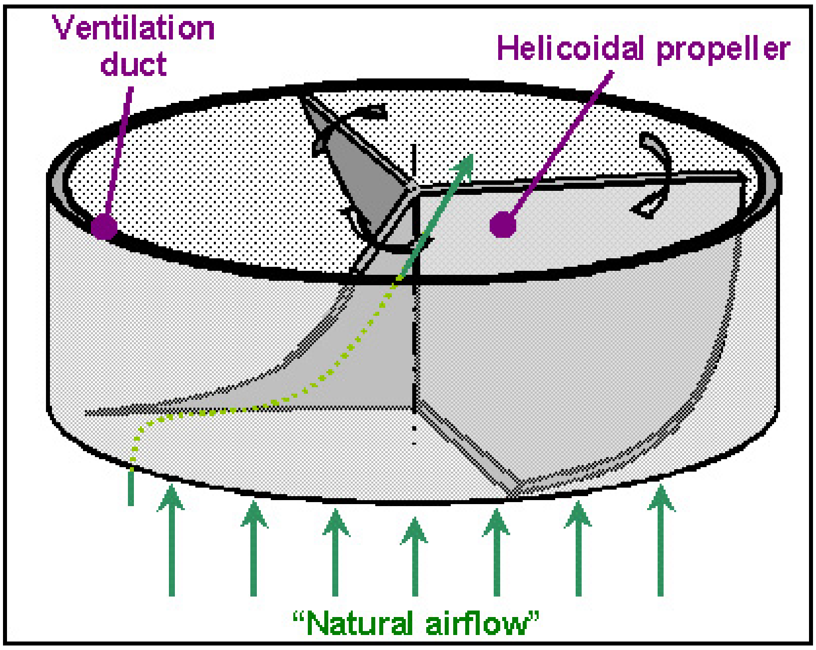


Figure 7 - Helicoid fan

One solution, so that airflows should not be broken by the propeller shape, is to have blades utterly parallel to the airflow.

In that case (*figure 8*), airflows are not deviated – and so, not weakened – since the only resistance is provided by the thickness of the blades that can be quite negligible.

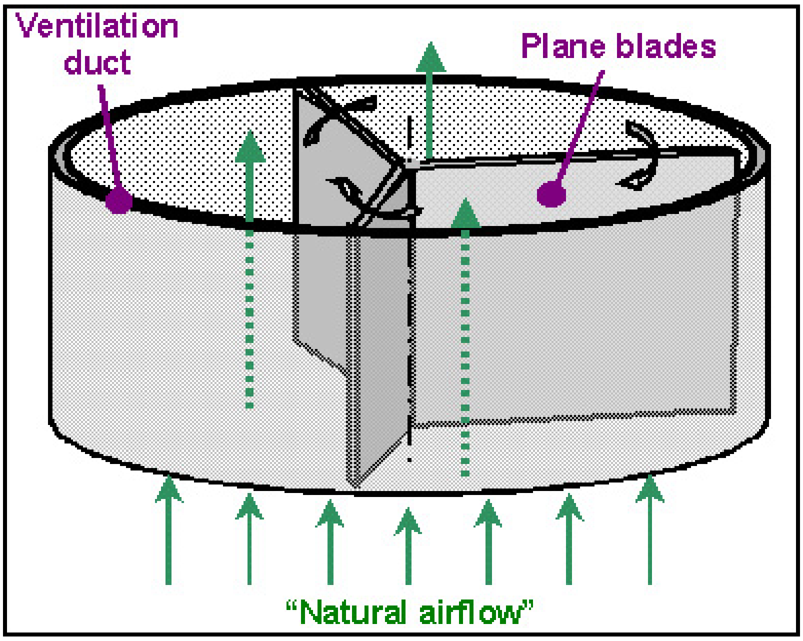


Figure 8 – Plane blades of the fan propeller

Of course, when working, such a propeller can not induce real airflows, since the only kinetic energy given is centrifugal (*figure 9*) : all the energy provided to air is rotating energy, and so no useful.
Velocity ***V*** (in m/s) of air at the extremity of the blades – that are ***r*** cm large – is around $V = 2.\pi.r.V^r / 60$ (V^r : rotating speed in rpm).

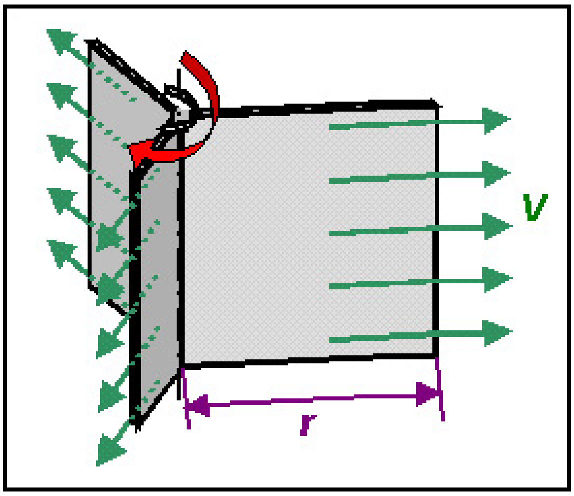


Figure 9 - Centrifugal acceleration

The idea is to change this "rotating energy" into a "longitudinal energy", so that airflow can be induced in the ducts.

By adding a weak longitudinal velocity component, the radial acceleration can be deviated, and consequently, the centrifugal energy can be transmitted in a longitudinal direction (*figure10*).

The more the longitudinal air stream is close from the propeller axis (small distance *d*), the more it will be accelerated : indeed the stream is under the blade influence for a higher time before being externally ejected. This phenomena is amplified by the fact that the kinetic energy given to air is proportional to the square of the distance ***d*** from the propeller axis.

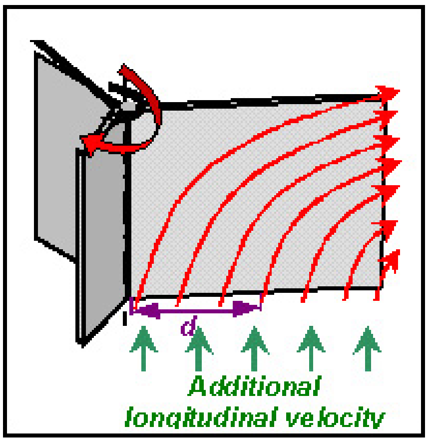


Figure 10 - Longitudinal acceleration

In case of important external velocity downstream the blades, a depression area may be created in the centre of the propeller : central reverse flows can be induced (*figure 11*).

One way to avoid this phenomena is to limit the downstream blades influence in order to have homogenous air velocity at the external border of the blades. This can be reached thanks to “quarter disc” shape of the blades (*figure 12*) : streams coming from the middle of propeller are under the blades influence for a shorter time before being ejected. By this way, it is possible to create streams with almost the same velocity ***v*** after their way through the propeller.

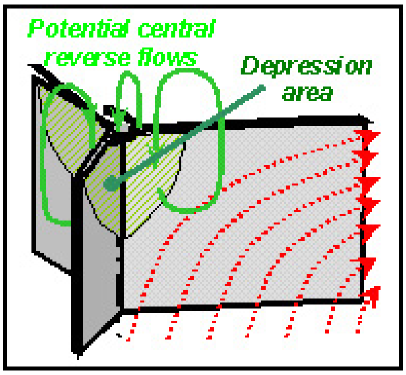


Figure 11 - Potential central reverse streams

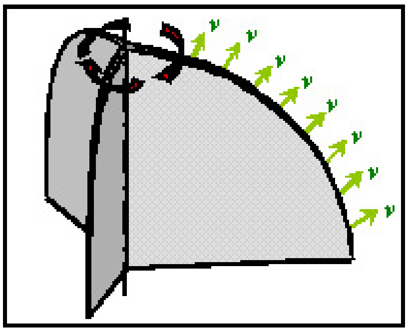


Figure 12 - Streams velocity homogenisation

“Half crescent shape” blades (*figure 13*) allow to optimise the acceleration of all the streams through the ducts : a more homogenous velocity profile can then be obtained.

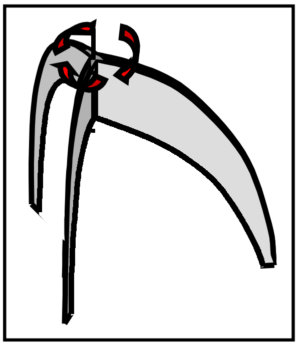


Figure 13 - “Half crescent shape” blades

Since a longitudinal velocity component does not always exist – or is not in the expected direction – one solution has to be found so that a significant longitudinal component is induced in the right direction : this can be done by creating an unbalance between the “top” and the “bottom” of the propeller.

A rough decreasing of diameter upstream the propeller avoid external streams to go downstream the propeller : “whirls” obliged preferentially airflows to pass from the “little diameter” part to the “big” one.

If at this stage, a significant longitudinal velocity component is created, a lot of energy is still lost in useless rotating streams. This is why orientating paddles can be settled in the internal side of the big diameter cylinder (*figure 15*), so that rotating streams are forced to escape through a longitudinal direction.

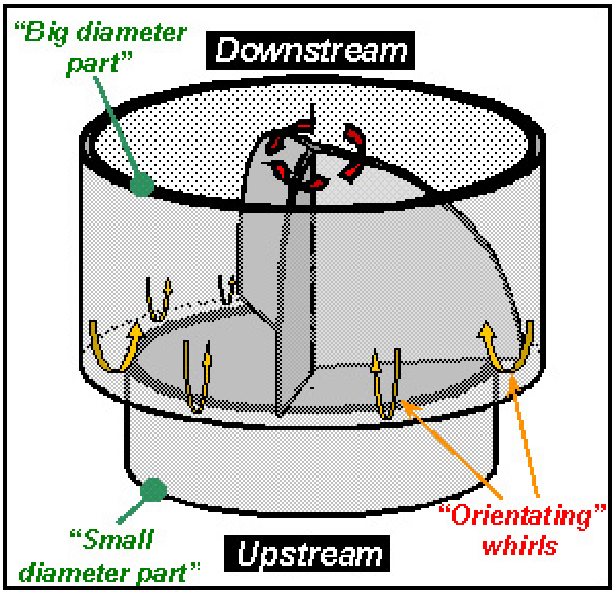


Figure 14 – Airflow orientating

In case of no working of the fan, the orientating paddles have no significant influence on the existing natural airflow : given the decreasing of diameter at the entering of the fan, streams do not straight meet the paddles (*figure 16*) ; bent parts of the paddles are sheltered from the

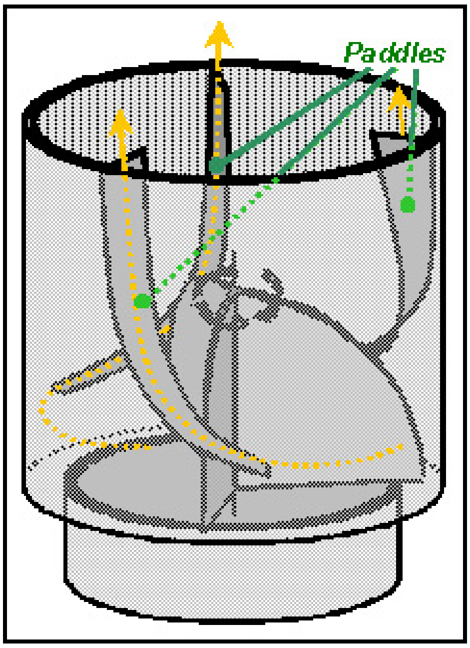


Figure 15 – Orientating paddles

entering streams. These ones only reach the edge of the "big diameter part" at the longitudinal level of the paddles, so that streams are not deviated at all, and so, not broken.

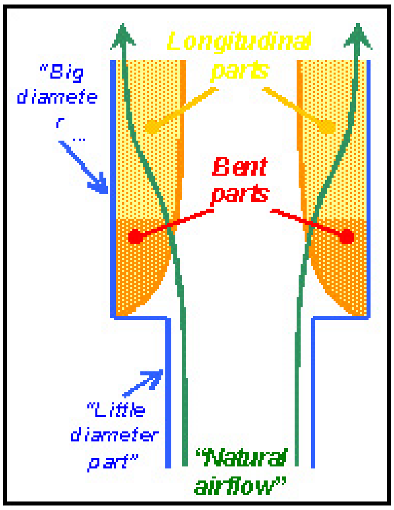


Figure 16 – Paddles low airflow resistance

3.2. Fan development

First developments have led to a fan especially designed for buildings until seven floors.

Rough parameters (sizes and shapes of each part, number of blades and paddles, rotating speed of the propeller,…) have first been approached by calculations. Given the calculation complexity of all the air flows, many tests have been required in order to reach optimum parameters.

These tests have chronologically provided optimum efficiencies for the principal following elements :

1 - propeller shape blades
2 - number of blades
3 - upstream and downstream parts diameter
4 - profile and size of the orientating paddles
5 - number of orientating paddles

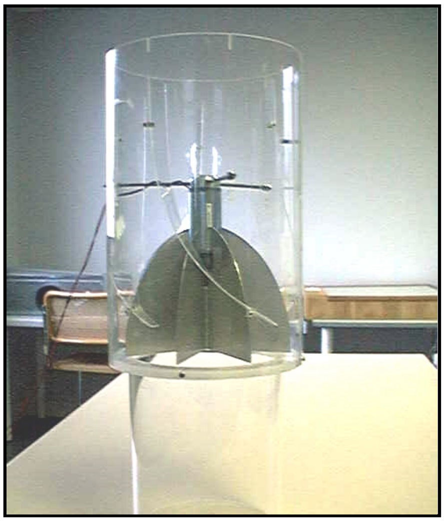


Figure 17 – Assistance fan prototype

A first prototype has consequently totally been characterised and realised (*figure 17*). In order to actuate the blades, an electrical motor has been integrated in the middle of the propeller.

4. Performance results

4.1. Intrinsic fan performance

Measurements realised on the prototype provide the evolution of the depression created by the fan according the demanded ventilation airflows, for several electrical supplying power of the fan (*figure 18*).

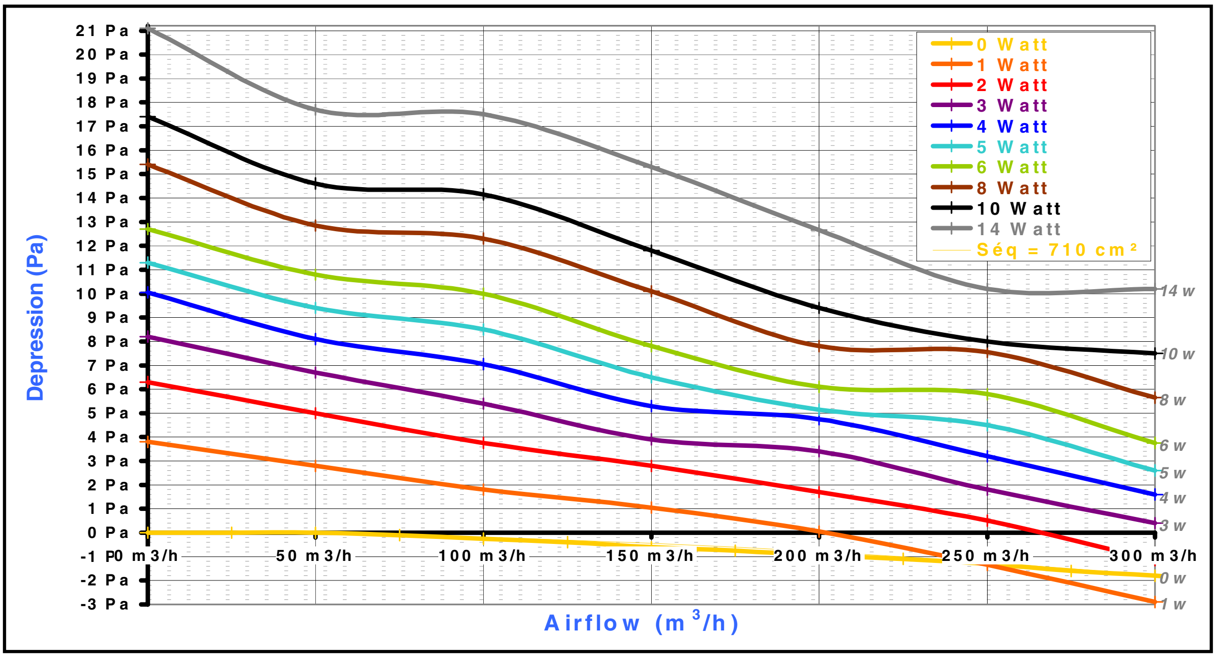


Figure 18 – Fan characterisation

The graph above shows that whatever reverse stack effect (usually lower than 10 Pa) can be fought for whatever usual expected airflow, by simply choosing the necessary electrical supplying power of the fan.

For the fan not working (*0 Watt*) it can be noticed that the pressure resistance remains under 2 Pa for 300 m^3/h, which is quite negligible in regards of usual ventilation net pressure loss.

4.2. Simulations results

First rough simulations have been done on a 4 floors building (*figure 19*), in order to evaluate the potential improvements provided by the prototype realised.

Calculations have independently been realised for the kitchen and the bathroom/toilet extraction column.

Same pressure resistance has been attributed to all the 4 floors through the following combinations :

⇨ <u>*kitchen column :*</u> constant inlets globally equal to 180 cm² with a 80 cm² constant extract grille.

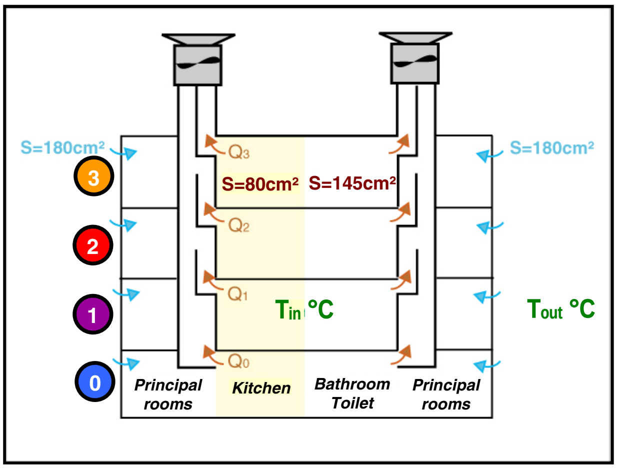


Figure 19 – Simulated building

⇨ <u>*bathroom/toilet column :*</u> constant inlets globally equal to 180 cm² with 2 constant extract grilles globally equal to 145 cm².

Simulations have been realised thanks to meteorological parameters measured close to Paris in 1999. Only temperatures have been taken into account here (wind effects have not been treated in these simulations).

The results presented hereafter deal with two extreme meteorological cases : summer and winter periods. Here, two fans are running at ***4 watt***, one installed on the kitchen column, and another on the bathroom/toilet column.

Airflows obtained for a "traditional" natural ventilation are represented in small lines, and airflows obtained thanks to the running fan are represented in big lines (*figure 20*).

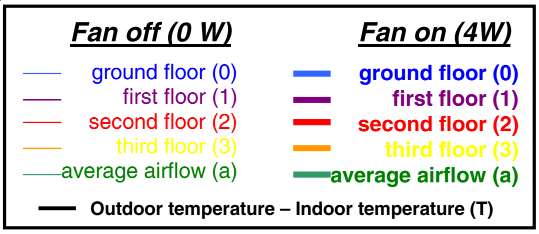
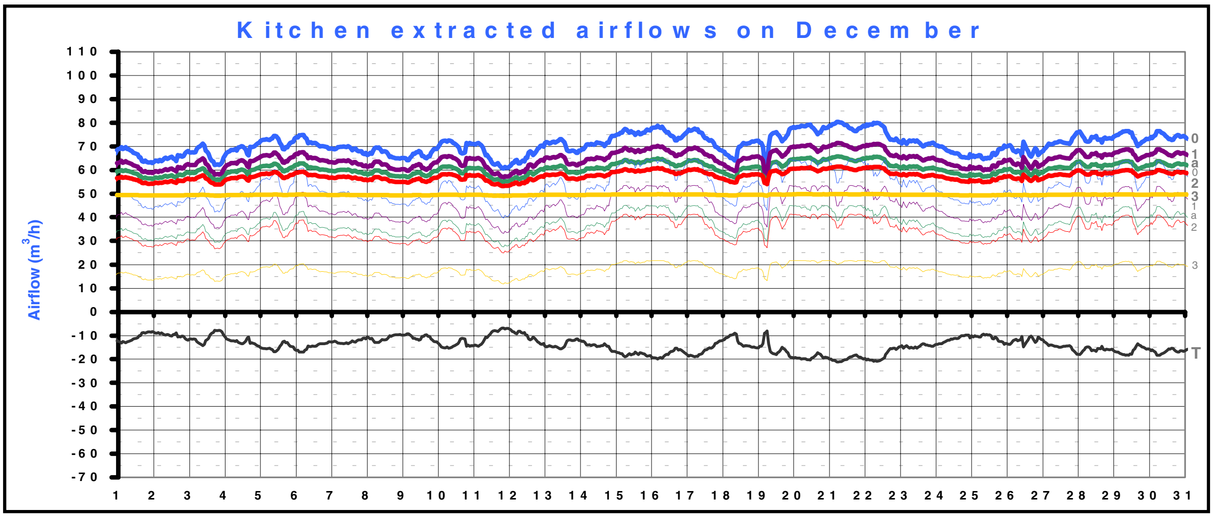
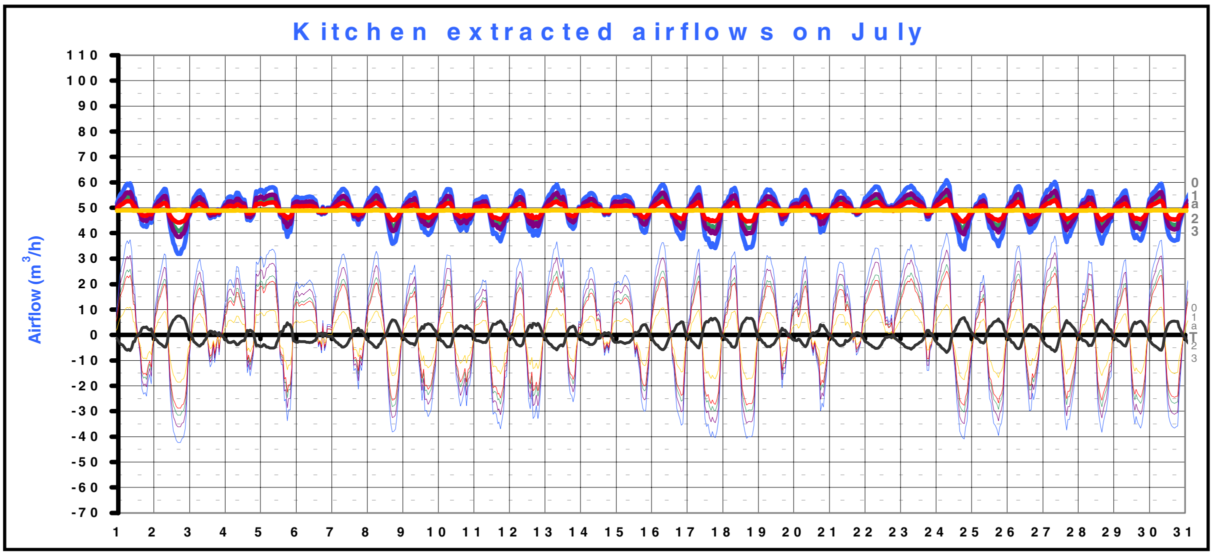


Figure 20 – Graphs correspondences

⇨ ***Kitchen extraction :***

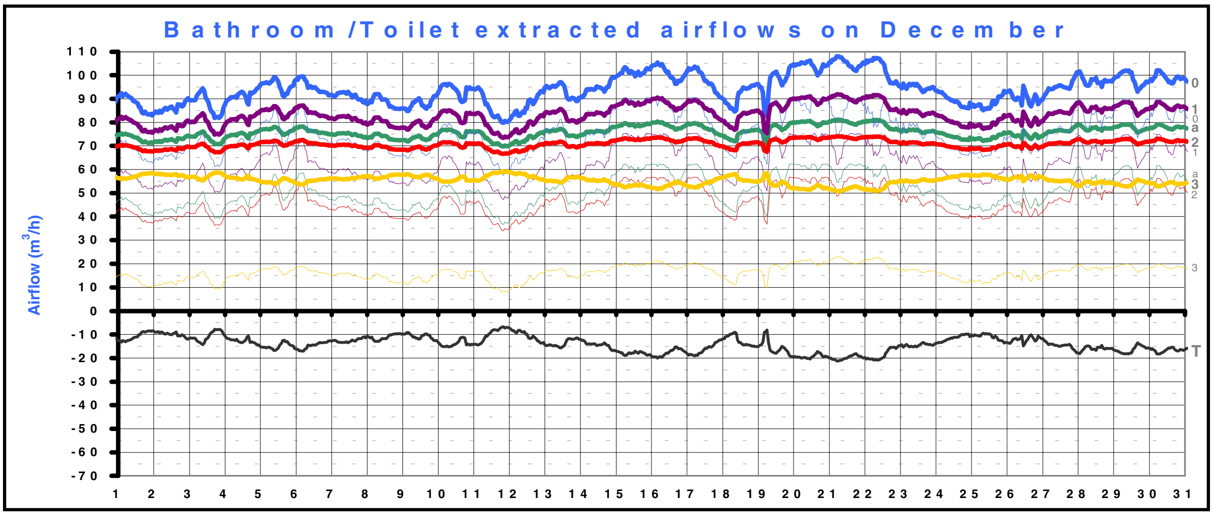


In winter period (December graph below), with a usual natural ventilation, acceptable airflows are ensured at every floors (between 30 m^3/h and 60 m^3/h), excepted at the last floor where the passive stack effect is really insufficient.
Thanks to the assistance fan, the difference between all the floors is significantly decreased, and an average airflow of 60 m^3/h is ensured.

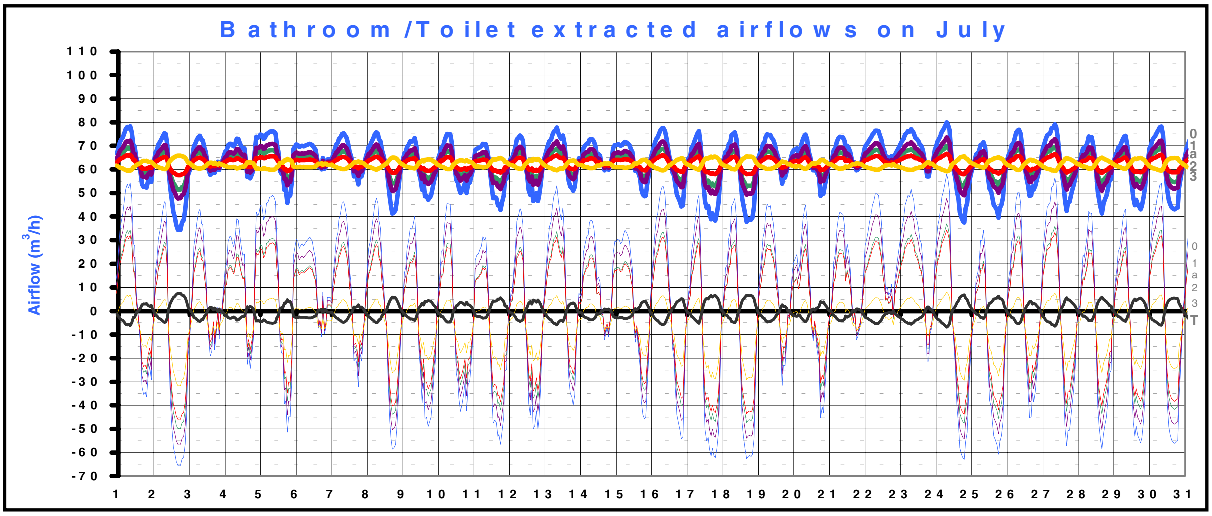


On summer (July), natural ventilation leads to important reverse flows during the afternoon. Thanks to the assistance fan, all the airflows are improved and stabilised around 50 m^3/h.

⇨ ***Bathroom/Toilet extraction :***



Excepted for the last floor, all airflows are acceptable in winter with a usual ventilation (from 40 m^3/h to 80 m^3/h). As for the kitchen column, the use of the fan allow to increase all the airflows (average airflow around 75 m^3/h), and limit the differences from one floor to another (from 55 m^3/h to 95 m^3/h against 15 m^3/h to 75 m^3/h).



On summer, the bathroom/kitchen extracted airflows are once again quite stabilised around 65 m^3/h (from 50 m^3/h to 80 m^3/h).

5. Conclusion

At this stage, a first industrialisation of the fan has already begun, so that in situ tests planned with French national partners should start as soon as September 2001.

This fan is meant to be placed at the end at the ventilation chimneys, instead of usual static roof cowls. This is why annex developments have been led, so that this device should be both an assistance fan, and a real efficient roof cowl when not actuated (*figure 21*).

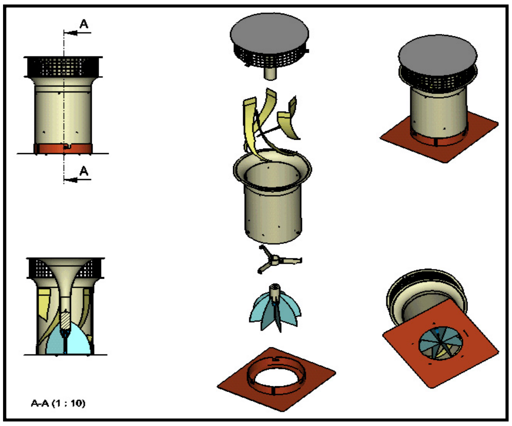


Figure 21 – Stato-mecanic assistance roof cowl developed

As a conclusion, the following characteristics can be stressed :

1- The fan can fit to **any usual natural ventilation installation**.
It can as well suit to shunt ducts or individual ducts installations.

2- When not working, the fan **do not decrease at all the efficiency** of the “former” ventilation net.

3- When working, the fan **eliminates all thermal reverse airflows** (which can not be guaranty in case of very exceptional strong wind).
Almost constant airflows are ensured all the year, providing **results close to traditional mechanical ventilation** ones. Moreover, differences of airflows from one floor to another in a several floors building are very limited, which means that **every floor always keeps a very acceptable air renewal rate**.
It can be noticed that the association with **modulating grilles and inlets** (such humidity control systems) allow to **erase the airflow differences** from one floor to another, since air renewal is mainly linked to evaluated needs.

4- Since “over ventilation rates” are allowed by increasing the electrical supplying of the fan, **cooling of building during summer nights** are possible.

5- The **very low energy consumption** of the fan (only **2 watt per flat**) leads to significant energy savings in regards of a usual mechanical ventilation (energy benefits ratio around 20).
Given the very low voltage of the fan, an **autonomous photovoltaic supplying** is also quite suitable, providing a **totally natural solution**.

6- The **performance of the fan can be easily chosen** by simply changing the supplying voltage, so that the fan can fit to many peculiar cases (1 to 7 floors buildings, deficient ventilation installations,…).

7- Given the very low rotating speed of the propeller (around 500 rpm)**, generated noises are very low**.

8- Designed for very low airflow resistance, the **fan hardly gums up**.

9- Manufacturing technologies required for the fan are very basic, so that**, in terms of costs, this solution is quite attracting** in regards of all the other very expensive assistance solutions that are spread nowadays.

10- In spite of its very important efficiency improvements, such a fan can not provide the boosted airflows usually excepted with mechanical ventilation.