NATURAL VENTILATION ACTIVATED BY INDUCTION

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This article describes a ventilation system, developed within the framework of a European project supported by the JOULE III programme (NAVAIR project). The concept used - natural ventilation assisted by air induction – combines the advantages of natural ventilation and the performances of mechanical ventilation. It is a particularly advantageous solution when renovating dwellings, all the more so because it can be installed at the end of existing ducts, providing both ventilation and for the evacuation of the products of combustion from a connected boiler running of natural gas.
After a general description, we will explain the dimensioning method used, based on the use of two mathematical models.
We will then look at an example installation in an experimental detached house, representative of French individual dwellings, equipped with a set of measuring devices which we used on the one hand to validate the models used for dimensioning and on the other to evaluate the system's performances objectively.

1. General description:

1.1 The requirements:

Natural ventilation consists of ensuring the air in a room is renewed by using the thermal motor generated by the difference in temperature between the air inside and the air outside. If naturally follows that this type of ventilation is more efficient the greater the difference in temperature. However, in summer, or even in spring or autumn, it may be useful to assist this ventilation, using a mechanical system, for example.
The purpose of this article is to describe one of the solutions found to this problem, **natural ventilation assisted by air induction**.

1.2 The principles:

Natural ventilation assisted by air induction is a compromise between natural ventilation and mechanical ventilation. A central fan, capable of feeding several ventilation ducts, is connected at the outlet of each duct to a device with several injection nozzles, which may be placed inside a Venturi tube to increase the efficiency of the system. The primary air, coming from the fan, is injected into the tubes by the nozzles at great speed, thus creating a drop in pressure upstream and drawing the stale air out of the house (secondary air).
This principles has numerous advantages over a traditional mechanical ventilation system, in terms of:

- Robustness: as the fan is not placed in the duct, should it break down, natural ventilation will continue to evacuate a lesser amount of stale air.

- Ease of installation: the induction equipment is relatively simple and can easily be inserted into the existing shafts or under the roof; additionally, as the speed of circulation of the air drawn out is about the same as in the case of natural ventilation, there is no need to line the ducts. Therefore, it is a very advantageous system when renovating housing.

- Compatibility with existing gas appliances: natural ventilation assisted by air induction can be used in ducts that provide for both the renewal of air in a room and the evacuation of the products of combustion of an appliance running on natural gas.

However, it is important to realise that the induction system is only provided to assist with the ventilation function and not the evacuation of the products of combustion. This latter (naturally favoured by the relatively high temperature of fumes) must be correctly provided for by the thermal draught alone. If this is not the case for an existing installation, then natural ventilation assisted by air induction is not the appropriate solution.

Finally, we should emphasise that the concept of natural ventilation assisted by air induction is equally well suited to collective housing as to individual dwellings. Figure 1 shows an example of an installation in a block of flats with collective ducts with individual "Shunt" type connections.

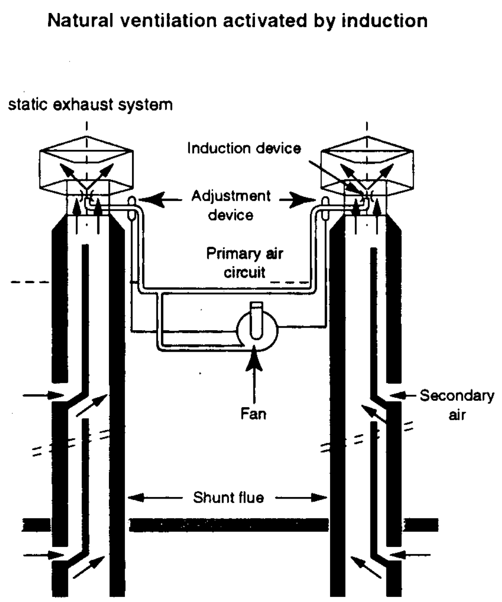


Figure 1: Assisted natural ventilation in Shunt type ducts

1.3 The means: The European NAVAIR project:

To implement the natural ventilation assisted by air induction system, to design the system and run a programme of tests on pilot sites, 5 small to medium sized companies, 4 research centres and the OPAC of Paris (Public Housing Office) combined their efforts in a European project within the context of the Joule III programme

5 small to medium sized companies:
- *ASTATO S.A. (France): ventilation systems manufacturer*
- *PAZIAUD S.A. (France): engineering design company*
- *FERIA & FERIA (Portugal): duct manufacturer*
- *ARTEA (Italy): engineering design company*
- *IEP (Austria): control electronics specialist*

4 research centres:
- *BERTIN (France)*
- *Gaz de France Research Department*
- *HTL (Austria)*
- *CAR Ltd (Great-Britain)*

The OPAC of Paris

This project, called NAVAIR (a New stAtic Ventilation system Activated by Induced aiR), started at the end of 1998 and will end during 2001.
By extension, in the rest of this article, we will call the system described NAVAIR.

The main phases in the project were as follows:

①Specification
②Design/Dimensioning
③Creation of the control system
④Building of prototypes
⑤Installation of the system and measuring devices for monitoring it on pilot sites
⑥Evaluation of the results

Four pilot sites, representative of a quite large range of possible configurations, were selected:

- An experimental detached house located on the Gaz de France Research Department site at Saint-Denis. This house is representative of an individual dwelling. A further advantage is that, as it is not occupied, it can be used to test extreme configurations.

- Two blocks of municipal flats in the Paris region, one with individual ventilation ducts and one with collective ventilation ducts.

- A school building with a collective ducts ventilation system in Austria.

We will now look further into the methods used to design and dimension the system. We will illustrate the complete design procedure and test phase by looking at the example of the Gaz de France experimental detached house.

2. General design and dimensioning methodology:

2.1 Specifications:

the performances required of the NAVAIR system vary according to country and depend to a large extent on local regulations and practices. The design and dimensioning will depend, to a large extent, on these specifications.
The specifications are expressed as air extraction flow rates.

During design, other parameters have to be taken into account, such as the shapes and the sections of the ducts, the configuration of the outlet, the air inlets, whether gas appliances are present or not, weather conditions…
All these functions and constraints have been formalised by a method of functional analysis.

2.2 Dimensioning:

When several different rates are specified, depending on the time (for example high extraction rate at times when meals are being prepared), the maximum flow rate is used when dimensioning the system.
It takes place in two stages:

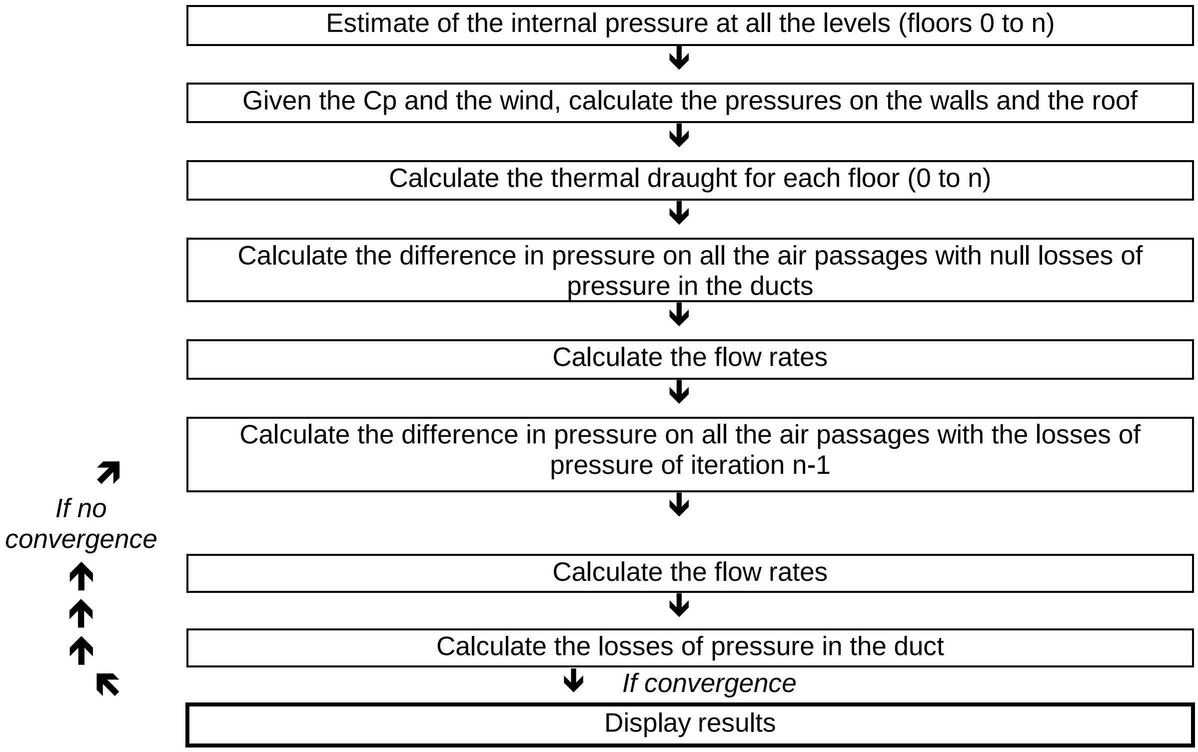
-Determination of the drops in pressure necessary at the head of the duct to create the flow rates specified.

-Design of an inductor capable of producing those flow rates and drops in pressure.

First phase:

The performance specifications are expressed in flow rates. To translate them into pressures we have to take into account the various losses of power (in the duct, the air inlets, the extraction outlets etc.), the effects of the wind pressure on the walls and the roof, the thermal draught, the influence of any gas appliances etc.
A computer program, SimVent, was written by ASTATO to carry out this phase. It calculates the necessary dimensions from the definition of the building, its different air inlets, its extraction ducts, the weather conditions and the additional drop in pressure caused by NAVAIR at the head of the duct.
This program, based on the method of the European standardisation group TC156/WG2/AH4, works both for individual dwellings and for blocks of flats with collective ducts.
For each dwelling, for a given internal pressure, all the incoming and outgoing flows are calculated (air extraction outlets, air inlets, leaks), taking into account the power losses of the different components. The internal pressure is adjusted to get a balance between the incoming and outgoing flows.

SimVent algorithm



Second phase:

Therefore, the new specification for the inductor gives a secondary flow rate and a difference in pressure. The dimensions of the duct are fixed, as is the pressure of the primary air (this depends on the choice of fan).

The inductor is made up of one or more primary air blowing nozzles, of a frame that is inserted into the duct and of an air supply line. It may or may not include a narrowing of the section (Venturi), designed to improve its efficiency.

The inductor is dimensioned by Bertin Technologies using a computer program that adjusts its parameters until the desired performances are achieved. The main parameters are the number of air blowing nozzles, their diameter, their positions and the narrowing of the section by any Venturi installed.

The plans of the inductors are then drawn up according to the constraints defined during dimensioning and taking into account manufacturing imperatives.

Inductors were dimensioned, the plans drawn up (ASTATO and Bertin Technologies) and the corresponding prototypes made for the 4 pilot sites within the framework of the European programme.

3. Example of the installation in the Gaz de France experimental detached house:

3.1 Description of the detached house:

The experimental detached house is a dwelling with three main rooms, representative of present French building practices and conforming to the 1988 heat saving regulations. It has been fitted out so that most types of ventilation systems found in individual dwellings can be installed and tested. It allows for a large range of tests and the acquisition of a large number of physical parameters because the different evacuation ducts installed are all accessible.
The measuring system in the house is made up of 250 sensors:

-thermocouples and heat sensors for the measuring air or fume temperature,
-a meteorological station located on the roof (wind speed and direction, temperature and relative humidity, atmospheric pressure),
-a set of devices used to trace and measure the ventilation flows and the efficiency of ventilation, using the tracer gas method,
-an internal pollution evaluation system.

3.2 Aims:

Within the context of the NAVAIR project, the aim is to attain, whatever the meteorological conditions, the extraction flow rates prescribed in the regulations. Remember that in France the statutory requirements for the ventilation of buildings are set by the **decree of the 24th of March 1982**. In dwellings built or renovated after that date, three main principles must be respected:

- ➢Ventilation must be general and continuous, with the air inlets located in the living rooms (bedrooms, living room) and the stale air extraction taking place in the service rooms (kitchen, bathroom, toilets),

- ➢The quantative requirements, in terms of the minimum flow rates to be extracted in the service rooms, depend on the total number of rooms in the dwelling,

- ➢It must be possible to change from the flow rates previously defined to reduced flow rates, particularly in the kitchen.

Thus, in the case of the Gaz de France experimental detached house (3 main rooms), the statutory requirements are interpreted in the following way:
-a flow rate of 105 m^3/h should be attained in the kitchen,
-a flow rate of 30 m^3/h should be attained in the bathroom,
-it must be possible to reduce the flow rate extracted in the kitchen to 45 m^3/h.

Furthermore, as the evacuation duct in the kitchen is also used to evacuate the products of combustion from a connected boiler running on natural gas (in this case the stale air is evacuated from the dwelling via the intermediary of the boiler's damper), it was important to check that in cases where the fan failed or the nozzles in the kitchen duct became blocked, the NAVAIR device did not cause the exhaust gases to flow back inside the dwelling.

3.3 Design/Dimensioning of the system:

For the experimental detached house, whose two extraction ducts, cylindrical with a diameter of 125 mm, correspond to the standard case in an individual dwelling, we chose the following solutions:

- For the bathroom, a Venturi type device, equipped with a single central nozzle.

- For the kitchen, we opted to tests two different systems:
  - a Venturi type device, equipped with a single central nozzle (called "Venturi" in the rest of this article),
  - a device without a reduction of section, equipped with six nozzles in a crown configuration (called "multi-nozzle" in the rest of this article).

The devices were dimensioned as described above.
For the ventilation/evacuation of exhaust gases in the kitchen, two flow rates were specified: a continuous base flow rate of 45 m3/h, and a full flow rate, selective, at meal preparation times of 125 m3/h.
The flow rate specified for the bathroom was 45 m3/h.
These values are a little bit higher than the statutory minimum requirements.

From these values, SimVent calculated the drops in pressure to be applied at the head of the ducts for spring and autumn conditions:

	Kitchen		Bathroom	
	Flow rate (m^3/h)	Drop in pressure (Pa)	Flow rate (m^3/h)	Drop in pressure (Pa)
Kitchen Base Flow Rate	45	7	45	7
Kitchen Full Flow Rate	120	27	45	20

Table 1 : Sim Vent results for the experimental house

Note that the estimated yield of the system equipped with a Venturi is better (induction rate - that is secondary/primary airflow rate ratio - of 15 against 9) but the loss of power produced is greater in static operation, which may prove a problem with a gas appliance connected.

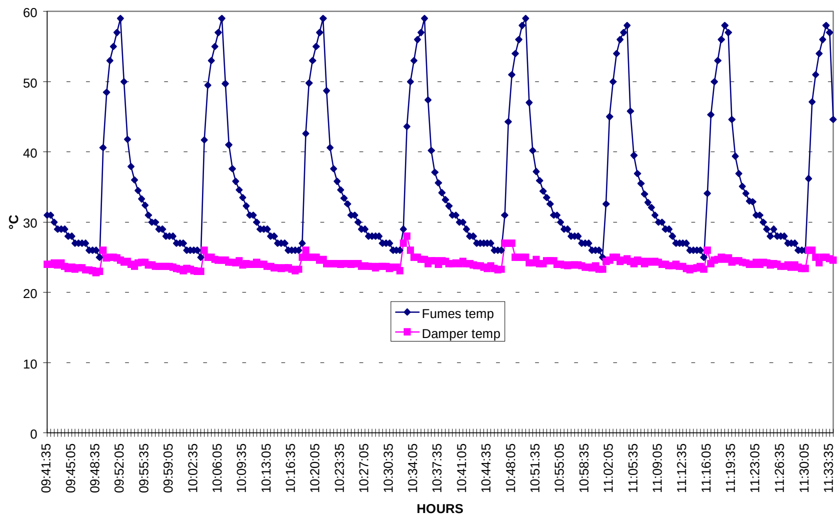
In the experimental house, the fan was located in the roof void.

3.4 Results:

3.4.1 Preliminary tests:

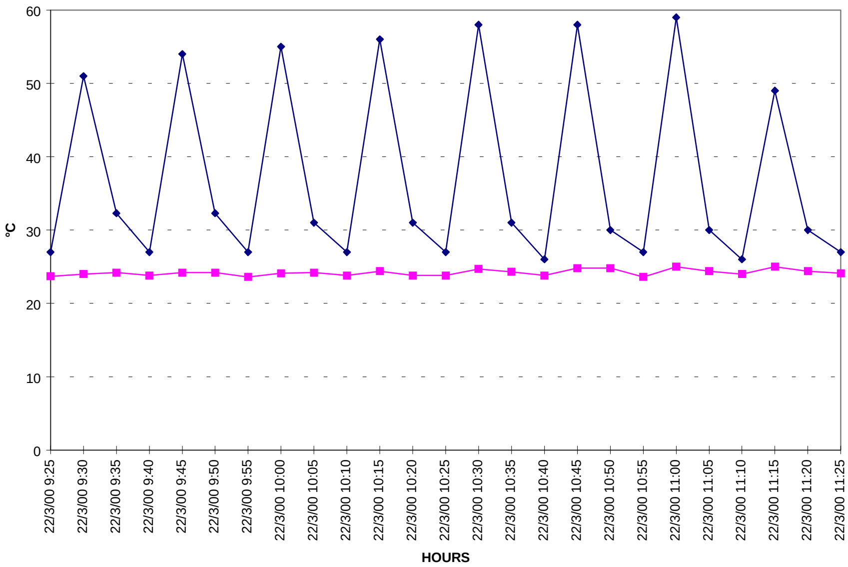
The first thing we had to check was that the NAVAIR system allowed correct evacuation of the products of combustion from the boiler when the fan was not working or the nozzles in the kitchen duct were blocked. In other words, that the loss of power caused by the device placed at the outlet of the duct was low enough not to noticeably disrupt the thermal draught. The main indicator we used to check correct evacuation was the temperature read at the boiler's damper. If evacuation is working correctly, this temperature should remain close to the room's ambient temperature. Any increase indicates that products of combustion are coming into contact with the damper and therefore there is a risk of them flowing back into the dwelling.

Curve 1 shows the reference test, taken in the initial natural ventilation configuration, before the NAVAIR was installed. The boiler is working in forced cycles (running for 3 minutes then stopping for 12 minutes). The temperatures of the fumes and the damper are represented. As you can see, the latter remains stable and at a low level.



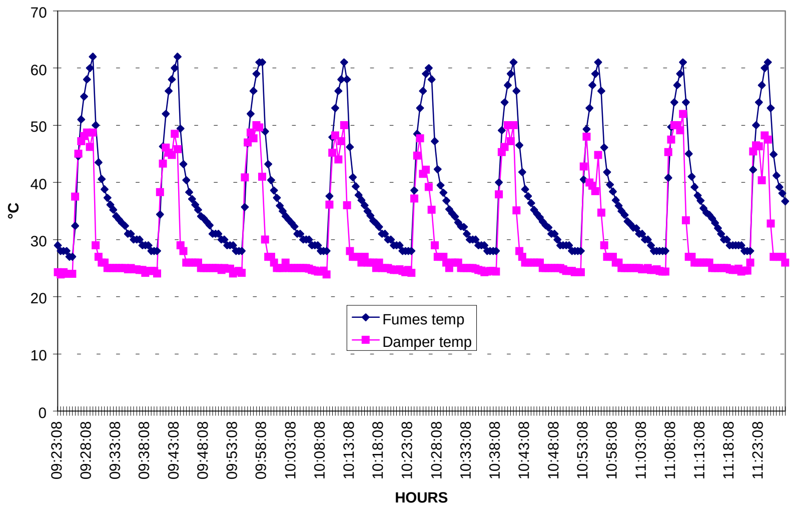
Curve 1

Curve 2 shows the same test with the "multi-nozzle" device. Once again there is no overflow problem.



Curve 2

By comparison, curve 3 still shows the same test, but this time with the "Venturi" and under very unfavourable conditions. Here, you can see that the temperature read at the damper follows that of the fumes, indicating incorrect evacuation of products of combustion.

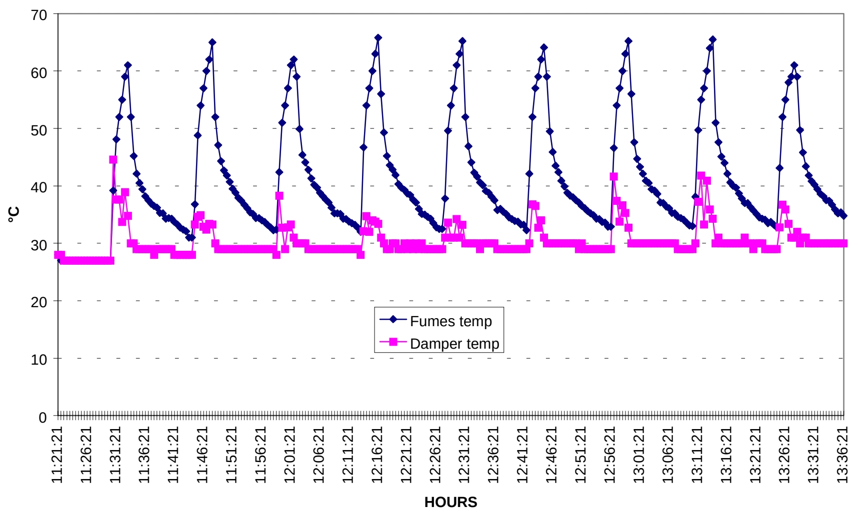


Curve 3

Note however that the CO detector placed near the draft damper never went off during any of the preliminary tests carried out, even the one when we registered a quite significant increase in temperature at the damper.

These safety related problems led us to opt for the "multi-nozzle" type system for installing in ducts that evacuate products of combustion.

To conclude the preliminary tests, we had the good luck to be able to evaluate the behaviour of the "multi-nozzle" system under very unfavourable climatic conditions for the thermal draught, with the external temperature remaining around 32 °C (see curve 4). In spite of a few peaks in the increase in temperature at the damper, the system seems to behave in a satisfactory manner.



Curve 4

3.4.2 Efficiency of the NAVAIR system:

As the preliminary tests had shown that the "multi-nozzle" system was compatible with the correct working of the boiler, all the rest of the tests were concerned with proving the efficiency of the system.

Table 2 illustrates the efficiency of the system by comparing the average values of the flow rate extracted in the kitchen under different configurations (boiler not operating) :

	EXTRACT AIRFLOW RATE (m^3/h)
no fan	22
fan set to intermediate speed	48
fan set to nominal speed	120

Table 2 : Extract airflow rate in the kitchen

Table 3 illustrates the efficiency of the system by comparing the average values of the flow rate extracted in the bathroom under the same different configurations.

	EXTRACT AIRFLOW RATE (m^3/h)
no fan	26
fan set to intermediate speed	32
fan set to nominal speed	48

Table 3 : Extract airflow rate in the bathroom

These values show that the system meets the specifications identified correctly, that is:

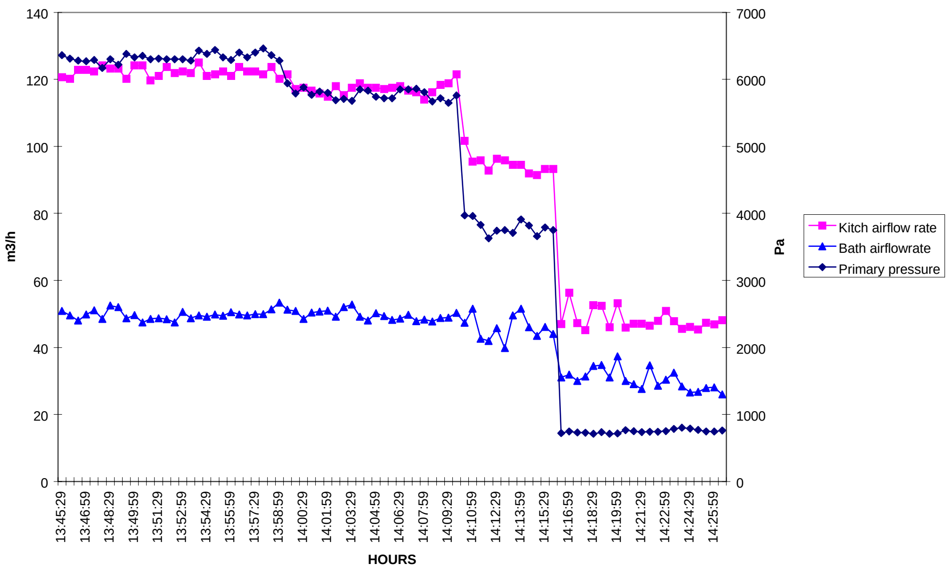
-at nominal speed, the peak flow rates in the kitchen and in the bathroom registered are close to the statutory objectives,

-at intermediate speed, the reduced extracted flow rate is obtained,

-at both speeds, an extracted flow rate is maintained in the bathroom that is satisfyingly close to the statutory objectives.

Additionally, these results show that the dimensioning method led to sets of pertinent parameters (in particular as far as the blowing section of the nozzles was concerned), allowing us to obtain the desired flow rates without a great margin of error.
We were therefore able to validate the models used.

Curve 5 summarises the performances described by showing, without the boiler operating this time, the way in which the extraction flow rates in the kitchen and the bathroom change according to the primary pressure read at fan level.



Curve 5

These results clearly show that the authority of the device in the kitchen duct is sufficient for a fall in the flow rate extracted in that room not to cause to great a fall in the flow rate extracted in the bathroom, which is the objective sought.

4. Conclusions and prospects:

The concept of natural ventilation assisted by air induction has proved to be an efficient solution, a good compromise between natural ventilation and controlled mechanical ventilation. We have checked that installation of a NAVAIR system is pertinent in an individual dwelling configuration both for installation in a ventilation duct and for installation in a duct evacuating the products of combustion of a boiler running on natural gas.

Now, the partners in the European project want to evaluate the performances of the NAVAIR system in the context of collective housing.

It would also be helpful to finalise the regulation principles, so that the system can adapt the flow rates extracted automatically (and not by manual adjustment or regulated by a timer as is the case at present). At minimum, the operation of the fan could be controlled by meteorological conditions.

5. Thanks to:

We would especially like to thank the European Union, for supporting this work financially, and all our other partners in the project: PAZIAUD SA, ARTEA, FERIA & FERIA LDA, IEP, Bertin Technologies, Car Ltd, HTL and the OPAC of Paris.