EXPERIMENTAL DEVELOPMENT OF A NATURAL CONTROLLED VENTILATION DEVICE

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ABSTRACT

The Building Components Technology Department of ICITE, the Central Institute for Industrialization and Technology in Building of the Italian National Research Council has started an experimental research on natural controlled ventilation devices.
Today the air quality of an indoor environment may have several effects on our health, due to the presence of polluting and extremely noxious agents in the places we most frequently use.
That is the reason why ICITE has undertaken to develop a research and an experimentation study aimed at establishing a device for the controlled natural ventilation of domestic environments.
In the report we will present the first experimental results about setting a calibrated opening to guarantee the needed air flow rate, independently of the pressure difference between indoor and outdoor environment. These results will be used as design characteristics to define the final solution for the prototype device.
Another objective has focused on the technical and performance-oriented characteristics of the devices that are already available on the Community market and on the regulative aspects for what concerns air healthiness in domestic environments.

INTRODUCTION

The attention drawn to the living environment has led ICITE to deal with several topics related to the environmental comfort. If, on the one hand, modern construction tends to emphasise the future quality of citizens' life, on the other hand, recent assessments, carried out on the national level, have revealed that nearly 40% of existing buildings can be classified as unhealthy. As a matter of fact, current recovery and maintenance works do not seem to take into account the consequences of noxious emissions, humidity, etc. on human health.
It is not exaggerated then to suggest that the increased demand on the construction market is now focusing on the correction of these factors and considering them as extremely important criteria in order to pursue quality-oriented innovative strategies.
The devices for the natural ventilation of indoor environment fall within the experimentation activities carried out at ICITE [1].
As a matter of fact, having overcome the economic restrictions which imposed the use of sealed enclosures , the indoor environment micro-climate is nowadays regarded to be essential to the general well-being of dwelling people.
Therefore, in considering that energy consumption must necessarily proportion with the healthiness of air, the frequency of air changes, mainly in winter, remains the crucial point of the problem.

In fact, a poor ventilation is accountable for the increase in relative humidity, the beginning of condensation phenomena and related mildew formation which are, in turn, responsible for serious breathing pathologies.

Moreover, the use of polluting building materials, such as for example some sealant materials and adhesives, releases in the environment highly noxious substances, like formaldehyde, radon, etc. which are considered to be carcinogenic.

External window-frames have always met the primary need of air change ensuring, by means of simple operations, the opening of one or many component parts, but leaving with the user the possibility of choosing the frequency and the amount of air to be recycled. The increased attention drawn to the safety and healthiness of homes and working places entails technical solutions able to ensure permanent safety conditions, irrespective of the operations of the users.

The preliminary market survey has pointed out that the currently available devices are equipped with an air grating that, with acceptable wind conditions, ensures a fair level of natural ventilation of the indoor environment but, as atmospheric conditions change, it has to be manually turned off.

To try and respond in a credible way to present needs and supply the building industry with useful directions, the Components Department of ICITE decided to start a research study about external window-frames with controlled natural ventilation with particular reference to the devices to be applied to the frame, which can self-adjust according to the external air pressure. In fact, such a device shall be prepared and managed bearing in mind that indoor ventilation conditions have to be kept at an acceptable level both with unfavourable atmospheric conditions and with no wind at all.

Once the ventilation values are known, it will be possible to optimise the air change constant flow for each dwelling need, requesting the device, for instance through shape memory materials, to set the air inlet useful section.

The work programme carried out so far has first of all given great importance to the enquiry stage related to existing buildings, on the national and international level, and was developed according to the following directions:

- state of the art;
- preparation of the test equipment needed to measure air permeability values with low pressures/low air flows;
- laboratory characterisation and performance evaluation of some samples taken from the market.

In considering hygiene and healthiness criteria of domestic indoor environments, regulative aspects will not be neglected during the assessment phase as well as when new projects, if any, are introduced. The survey will be carried out in the compulsory and in the voluntary sphere following the directions laid down by the national and international regulations, in order to evaluate the effectiveness of the equipment available today and to verify the compliance to fitness for use criteria, also in the spirit of the European Directive 89/106 with the final purpose of suggesting to the Body in charge, the demonstration of ventilation criteria, calibrated according to the different domestic indoor environments.

A further regulative aspect concerns the gap existing between low-permeability window-frames, as we know them today, and those equipped with the illustrated devices. The safety aspects related to the application of this device on the frames shall be reconsidered by means of laboratory tests.

FUNCTIONAL MODEL FOR A NATURAL CONTROLLED VENTILATION DEVICE

The examinations made on devices that are currently on the market and the studies made so far have given some initial suggestions for setting up some of the component parts of the prototype. In particular, the device will initially consist of the following:

- an external protective profile having the upper part shaped so as to be suitably contained within the leaf profile and the lower part shaped so as to be fit to contain the glazing unit;
- a hollow profile fitted with openings having a pre-defined circular section in which a thin plate, having openings with the same section as before, can freely move;
- a two-function filter to deal with acoustic comfort and air purity problems;
- an internal profile whose task is to convey the air flow upwards.

The moving thin plate will then be free to shift horizontally, in order to allow the adjustment of the useful ventilation section as a function of external pressure.

EXPERIMENTAL EVALUATION OF THE OPTIMAL PERFORMANCES OF A DEVICE FOR NATURAL CONTROLLED VENTILATION

The prototype should seek to maintain the exchange air flow rate as constant as possible in view of the change in pressure difference between the indoor and the outdoor. In the laboratory this condition can be obtained experimentally by imposing pre-set pressure differences and measuring the air flow rate, and hence permeability, by means of the device.
Since the flow of air through the opening is, in general, proportional to the surface of the opening itself and to the difference in pressure raised to the n^{th} power, a mechanism is to be developed which, as the pressure difference changes, modifies the useful ventilation section in a calibrated manner to achieve a constant flow rate.
The behaviour of this device can in fact be compared to the case of narrow openings where the flow of air tends to remain within the transition range between laminar and turbulent flow. The following equation governs it:

$$\mathbf{Q=kA\Delta p^n} \qquad \text{where:}$$

$Q(m^3/h)$ is the flow of air through the device
$A(m^2)$ is the useful ventilation section
$\Delta p(Pa)$ is the difference in pressure between indoor and outdoor
$k(m^3/hm^2Pa)$ is a flow coefficient
n is the flow exponent.

In order to characterise the system, the test chamber for the measurements of low pressures was built according to the provisions contained in the Belgian standard NBN D 50-001 [2]. See Figure 1.

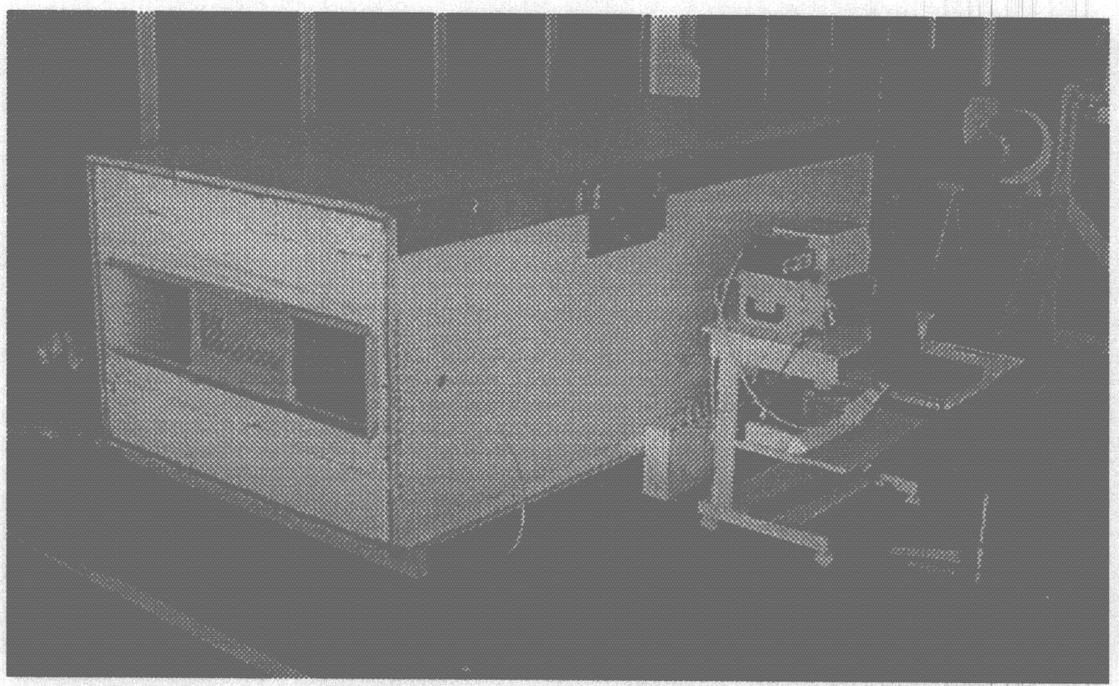

Figure 1. The test chamber and the data acquisition system

The $3m^3$ test chamber was built with bolted and silicone-bonded sandwich panels and provided with vertical walls allowing to apply a constant air pressure in the inside. The opposite closing walls were prepared to contain the test device and the air intake, with negative pressure, generated by a fan. A pressure gauge was used to measure the pressure difference between the test chamber and the laboratory, while inside the duct placed between the fan and the chamber, the air flow rate was measured by means of a Pitot tube. The device was installed with the internal face turned towards the laboratory and the external one towards the test chamber, in order to simulate, inside the chamber, the actual external atmospheric conditions.

A data acquisition system was set up for the experimentation, interfaced with a Personal Computer. The instruments, connected with this system were the following:

- a hot-wire precision anemometer for low speeds for measuring the air flow rate
- a differential pressure sensor for measuring the pressure difference between the inside and the outside of the airtight chamber

A software was realised to manage the experimentation, allowing real-time monitoring and graphic displaying of the measured values of air flow and pressure through a control panel. The data were also saved on file to allow following data elaboration. See figure 2.

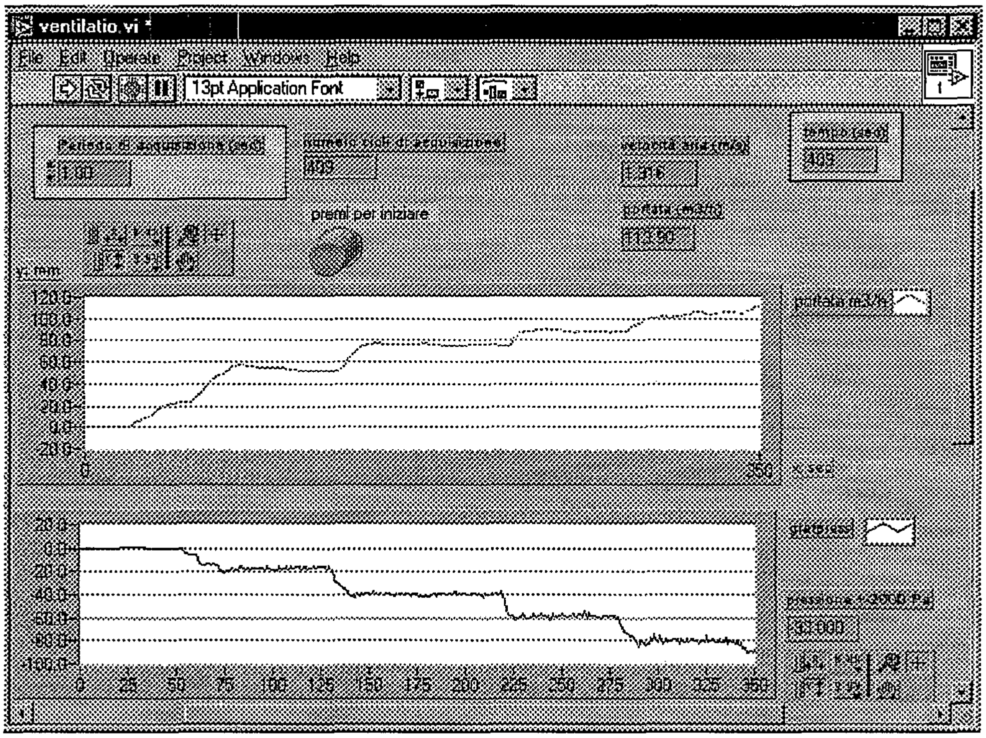

Figure 2 Control Panel of the data acquisition software

RESULTS

The first aim was to obtain the experimental relation between airflow and pressure differences to set up the calibration curves for useful section to maintain constant air change.Therefore the laboratory apparatus was used to test a reference sample with calibrated $1cm^2$ openings, which allowed us to obtain experimental curves with pre-defined section openings. See Figure 3.

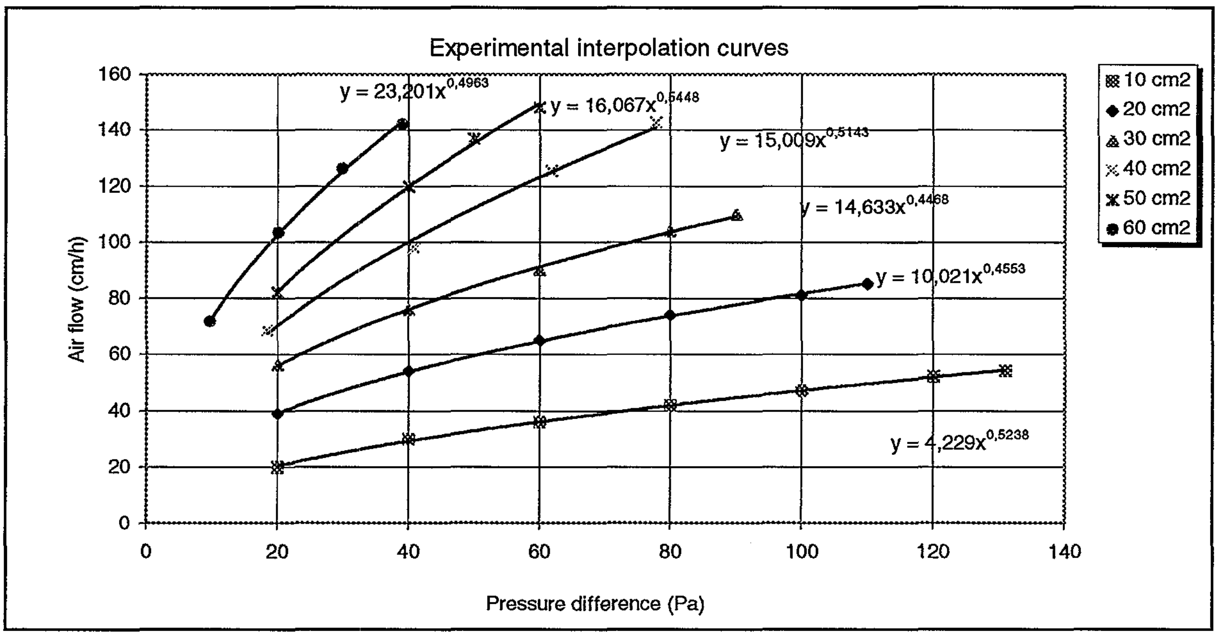

Figure 3 Experimental interpolation curves

The interpolation curves give the experimental values of the K coefficient and n^{th}-power for each constant surface.
Starting from these values it was possible to calculate the calibration curves for fixed air change per hour: 30, 60, 90 m^3/h, useful to set up the behaviour of the natural ventilation prototype device. See Figure 4.

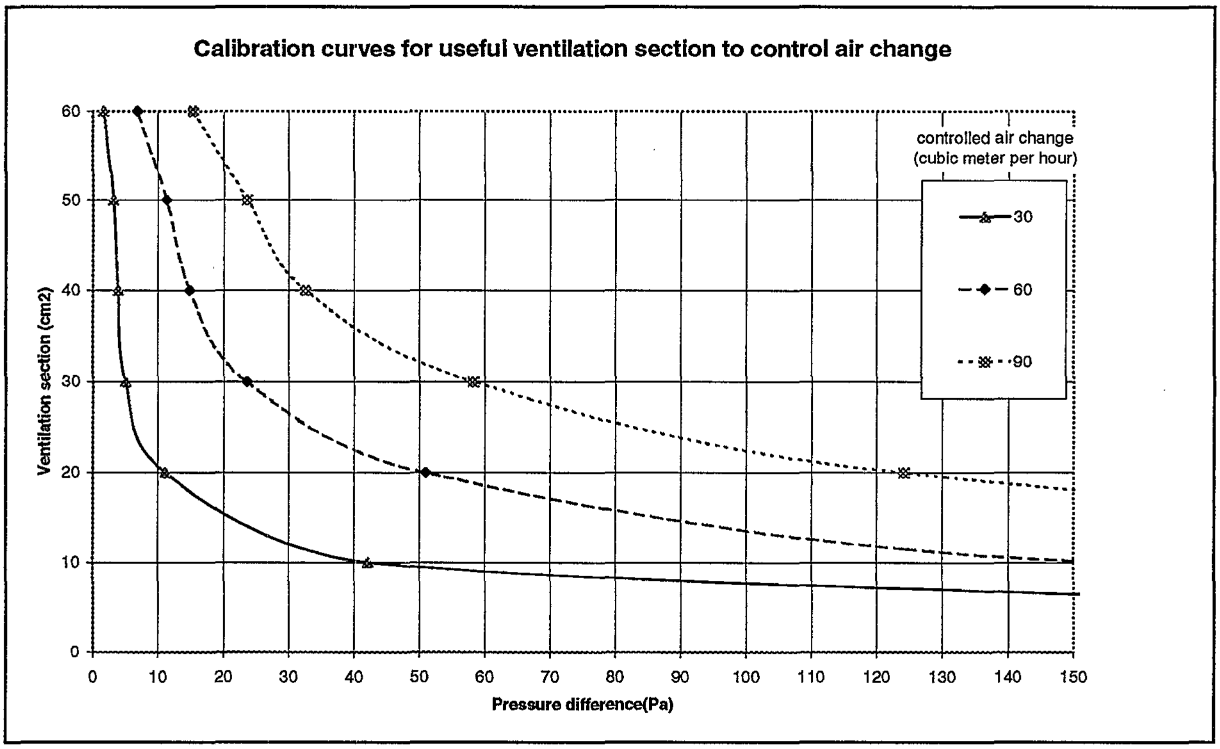

Figure 4 Calibration curves for useful ventilation section

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