ACKNOWLEDGEMENTS

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COMPARISON OF VARIOUS AIR INLETS : AIR DIFFUSION AND COMFORT

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ABSTRACT

Fresh air intake in exhaust ventilation systems requires air inlets located in the building facade. This device is often blamed for draught problems. In this research, we tested several air inlets at various pressure and temperature differences. In order to identify the flow pattern and thermal diffusion, smoke flow visualizations using laser sheet and local temperature measurements were performed. It was shown that pressure and temperature differences had no sensitive influence in the occupied zone under French climatic conditions. Differences were only noted above the diffuser in the jet stream. With regard to these results, we analyze the standards under discussion and make some recommendations.

INTRODUCTION

Today, exhaust mechanical ventilation systems represent an increasing market share in moderate climates. National standards have focussed on the performance of exhaust components which are the driven forces. However, the overall system requires air intake components commonly called air inlets. Fresh air is supplied to bedrooms and living rooms; polluted air is exhausted from kitchens, bathrooms and toilets. Air inlet devices are often blamed for draught problems. In order to overcome this potential issue, some are closeable and limit draught risk in case of overpressure on the facade. Unfortunately, this answer can no longer assure a continuous minimum air change with a good distribution because the air inlets could stay closed over a long period if the occupants do not understand their essential role. Unfortunately, occupants are rarely aware of the function of each ventilation element.

Another way to limit the draught risk is to require self regulated air inlets. France has adopted this technical solution which offers a constant flowrate with a pressure difference between 20 and 100 Pa.

The aim of this research was to study air flow patterns and diffusion within the room at various pressure and temperature differences and to identify any discomfort problems generated by various self regulated air inlets in real conditions [1].

EXPERIMENTAL PROCEDURE

Methodology

The airflow patterns induced by various air inlets were investigated using two experimental techniques :

• Flow Visualizations
The airflow was seeded with oil smoke particles which were illuminated using a laser light sheet located in a vertical plane 5cm from the airflow symmetry plane. Images were captured using a CCD video camera and qualitatively analyzed.

•Temperature measurements
Local mean temperature measurements were performed using a mobile 25 μm diameter Cr-Al thermocouple. The thermocouple was automatically displaced in the field to be scanned with the help of a two-dimensional motorized device monitored by a micro-computer.

For each air inlet configuration, measurements were carried out in the vertical plane 5cm from the symmetry plane. A variable area in the vicinity of the air inlet was scanned on the basis of a 5cm x 5cm grid mesh. Results were then processed and presented in a non-dimensional form in order to make easier the comparison between the different cases :

$$\theta = (T - T_i)/(T_a - T_i)$$

T is the local measured temperature
T_i is the air discharge temperature
T_a is the ambient temperature
$\Delta T = T_a - T_i$

Experimental set-up

A laboratory experimental set-up was realized in order to reproduce realistic thermal and air flow conditions. It was mainly composed of :
- an air supply compartment which could deliver air flowrates up to 50m³/hr with ΔT from 0°C to 20°C. One wall of this compartment was double glazed. The air inlet was located just above this double glazing 21cm below the ceiling (see fig.1a).
- a second compartment where the airflow was discharged. Vertical walls were made of glass in order to allow visualizations. This compartment was totally opened on its end face (see fig.1b).

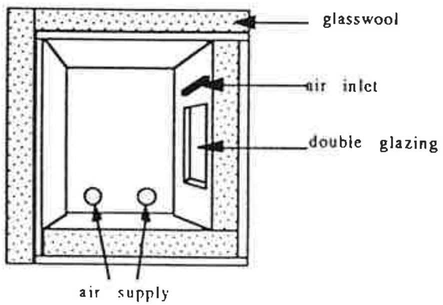


Figure 1a. Air supply compartment.

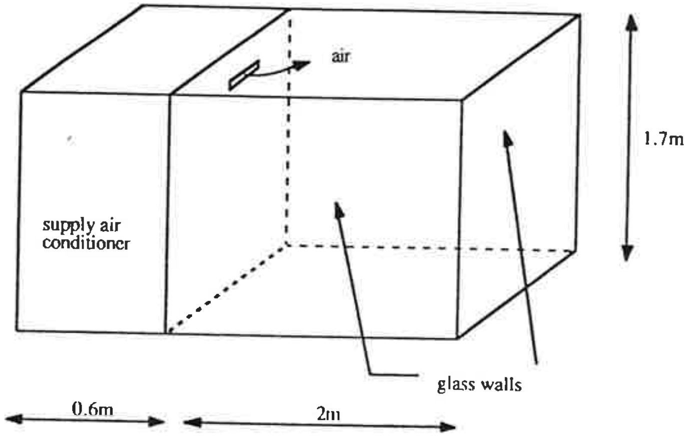


Figure 1b. Skethc of the experimental set-up.

RESULTS

Six commercial self regulated air inlets were tested for several temperature and pressure conditions. Three temperature (0°C, 10°C & 20°C) and four pressure (7, 20, 40 & 60 Pa) differences were successively investigated.

Visualizations and qualitative results

As a general result, visualizations revealed no major qualitative differences in the airflow patterns generated by the different inlets.

• Influence of pressure difference
Different pressure differences were successively imposed : 7, 20 , 40 and 60 Pa. When air inlets had a good self regulation, no important flowrate variations were noted and hence no sensitive changes in the flow patterns occured.

• Influence of temperature difference
The inlets were all characterized by a weak sensitivity to ΔT variations from 0 to 20°C (the air jet was colder than the ambient). This was mainly due to the small value of the Archimedean number which characterizes the ratio between inertia and buoyant forces. In the range of tested ΔT's and because of the magnitude of the mean air discharge velocity ($V \equiv 3m/s$), this number which is defined as

$$Ar = (g\,\beta\,(T_a - T_i)\,e)\,/\,V^2 \qquad \text{(where e is a characteristic length)}$$

still remained low enough not to create qualitative changes in the flow pattern - in the present study, this number varied in the range $[0;10^{-3}]$.

It is worth noting that with larger values of the Archimedean number which result from larger inlets, lower discharge velocities and higher temperature differences, qualitative changes in the flow patterns are noticed [2].

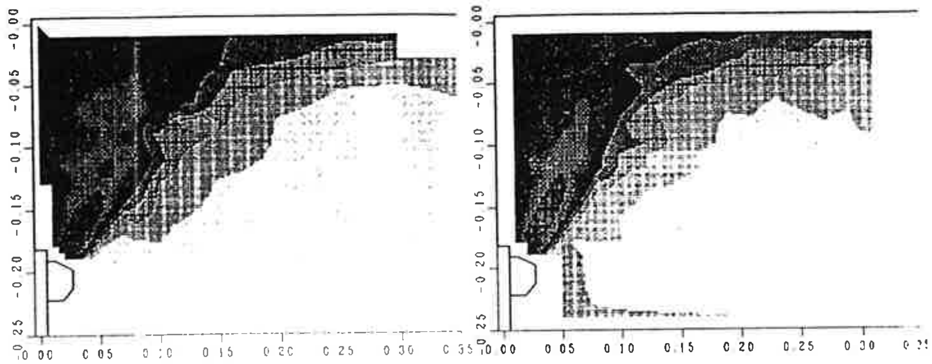
Temperature measurements

Taking into account the previous qualitative results, temperature measurements were carried out on a reduced number of air inlet configurations. We present here results concerning two different commercial inlets. The test characteristics are given in the chart below. Figures 2, 3 & 4 give measured isothermal lines in the vicinity of the air inlet (lengths are scaled and given in meters; each grey level represents 1/10 of the ΔT). In addition to these quantitative informations, the isothermal lines visualizes the flow patterns.

Table 1.

Test #	Inlet type	ΔP (Pa)	ΔT (°C)	inlet width (cm)	inlet length (cm)	Inlet area (cm^2)	Nominal flowrate (m^3/hr) at ΔP=20 Pa
1	1	20	15	1.2	23.5	28.2	30
3	1	7	15	1.2	23.5	28.2	30
4	1	20	7	1.2	23.5	28.2	30
6	1+ curtain	20	15	1.2	23.5	28.2	30
12	2+ curtain	20	15	1.1	25	27.5	30

In fig.2, the influence of the pressure difference is pointed out. The cases under comparison concerned the same air inlet (inlet type # 1). It appeared that reducing the pressure difference by a ratio of 3 (from 20 to 7Pa) had very little consequences on the thermal flow pattern.

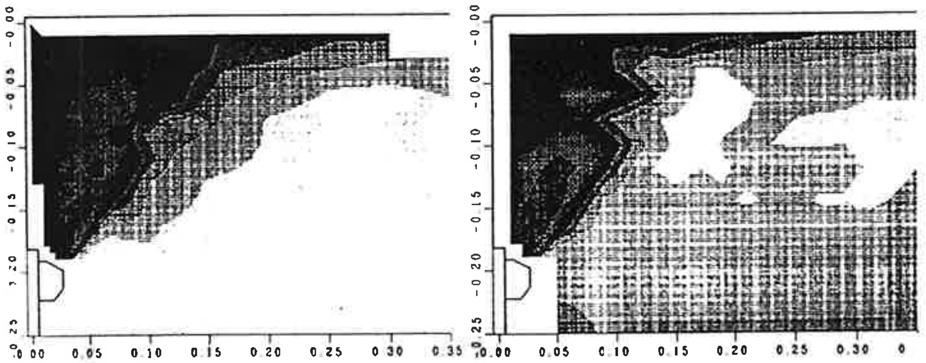


ΔP = 20Pa

ΔP = 7Pa

Fig. 2 Influence of the pressure difference (test # 1 & 3).

The influence of the temperature difference is shown in fig.3. The ΔT varied from 15°C to 7 °C. The same conclusion can be drawn as previously and no noticeable effect of the temperature could be detected. The flow still remained almost vertical and then continued next to the ceiling on a long distance downstream.

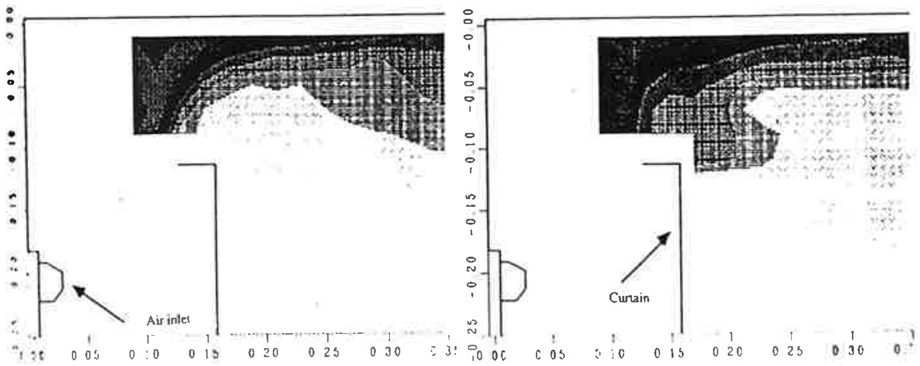


ΔT = 15°C

ΔT = 7°C

Fig.3 Influence of the temperature difference (test #1 & 4).

How can the presence of a curtain modify the flow pattern ? The question was answered as the curtain was placed 5cm in front of the inlets. Fig.4 gives test results for two different inlets. It can be seen that in spite of the jet impact on the curtain and the resulting velocity decrease, the flow still remained mostly horizontal.



Inlet type #1

Inlet type #2

Fig. 4 Influence of a curtain (test # 6 & 12).

STANDARDS UNDER DISCUSSION

Air diffusion characteristics of air inlets is an objective of any National or CEN standards. Moreover, due to the large number of air inlet types, it is difficult to write down a general test procedure. One solution is to multiply the number of experiments, which is the present way of investigation. However, this procedure is incompatible with the low price of such components. This research reveals that the multiplication of tests is not necessary if a comprehensive non-dimensional study is carried out. Consequently standards could be simplified. Test conditions could differ from one country to another because air inlet types and climate conditions can be different.

CONCLUSIONS

This experimental study pointed out three main conclusions :

- the good ability of the different air inlets to self regulate the discharge flowrate under variable pressure difference conditions varying from 20 to 100 Pa.

- no noticeable differences on the air diffusion could be detected between the six tested inlets which generate similar comfort conditions.

- the tested air inlets - under nominal working conditions- are not sensitive to temperature difference variations in the range 0-20°C, due to the small value of the corresponding Archimedean number.

ACKNOWLEDGEMENTS

This study was partly supported by the French ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie).

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INDUCING AIR VIA THE FACADE FOR BETTER COMFORT

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ABSTRACT

Most buildings in The Netherlands make use of natural ventilation, often combined with mechanical exhaust. However it is very important to improve the quality of the ventilation and at the same time to look for economical methods to control the comfort in buildings. The aim of this research project is the control of incoming fresh air via the facade by an air inlet (jet or vent). The incoming airstream just underneath the ceiling induces air in a room of an office building or a house and makes use of the "coanda effect". The air inlet and the air pressure regulation system reduces draught problems in the cold season, limits overheating in summer by nocturnal ventilation, and reduces noise from outside. The energy consumption by ventilation can be controlled as well. A prototype of an air inlet was tested in a laboratory. The quantity (velocity) and shape (flow visualisation by smoke) of the air flow was measured at variable small differences in pressure. The results of the measurements with the first prototype show that it is possible to get a high velocity of air even in case of small differences in pressure between inside and outside. This high velocity is necessary to achieve a good mixing of cold and warm air in a room. The experiments also show that the internal geometry of the vent can be reduced very much. This information is important to develop a vent with good sound insulation and to allow good architectural designs.
Not applying heat recovery systems with the incoming fresh air via the facade, seems to be a step backwards. However, the system can be combined with balanced ventilation as well. In summer, a cooling system will not be necessary if nocturnal ventilation is used combined with an adequate design of the facade and enough building mass. Theories and equations of fluid mechanics and of turbulence can be used, but they must be developed more in detail in relation to vent geometries.

INTRODUCTION

The Netherlands has a climate with a high degree of humidity and much wind. It has become common to use special vents for permanent ventilation in buildings to save energy and to improve comfort. In many cases these vents must have sound insulation properties too.
The Dutch building code (Bouwbesluit[1]) refers to norms like the NEN 1087[2] and the NPR 1088[3], which give many regulations for the properties of these vents. Regulations about sound insulation (like the NEN 5077[4] and the NEN 5079[5]) are also connected with the Bouwbesluit. In the future, international standards like the NEN-ISO 7730[6] should be used, to test the comfort qualities of vents; it should be possible to make a European standard for vents with improved methods of measuring air flows and sound insulation. For example, at this moment there are no generally accepted methods for measuring the air flow at a difference in pressure of 1 pascal. There is also scientific knowledge which can be tapped. Equations and theories of fluid mechanics[8] and about turbulence[9] can help to explain the results of experiments and to develop computer simulations (CFD).

Hypotheses

1. It is possible to get a high air velocity (2.5 - 2.8 m/s) in a vent when there are only small differences in air pressure (about 5 pascal).
2. By designing a vent which induces the air just underneath the ceiling, it is possible to bring sufficient quantities of air (40 - 80 m^3/h) into a room during the whole year, without causing serious draught problems.