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

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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.

3. It is possible to make a vent with a low pressure drop and with a good sound insulation as well.
4. It is possible to control the pressure differences between inside and outside, within specified levels, during most of the time.
5. It is possible to develop a control system, which controls the pressure, size of the air inlet-opening and the air flow of an exhaust -or a balanced ventilation- system, by sensors, microprocessors and valves.

This paper describes measurements which cover the first hypothesis.

Fig. 1. The air-inlet and -outlet with mechanical exhaust or balanced ventilation.

Objectives of the research project

1. To realize a modest installation for a building which helps the occupant to control the internal climate individually and to improve the relation with the climatical conditions outside.
2. To make (more) use of natural sources to control the internal climate, to improve the comfort and at the same time to make an installation which is more economical, due to low initial costs, maintenance costs and energy costs.

METHODS

There is a lot of information, mainly in factory reports (based on the NEN 1087 and the NPR 1088), about the quantity (velocity) of the air flow through a vent in relation to various pressure differences. In these cases differences in pressure between 15 and 100 pascal are measured. However, in facades the differences in pressure generally range from 1 - 10 pascal (NEN 2687[7]). To get more information about air flows at low pressure differences and about the characteristics of the flow, a special test formation in a windtunnel had to be developed. To make the flow visible, a transparent prototype of a vent has been designed.
The requirements for the prototype are: 1) letting in different quantities of air into a room and 2) at the same time creating a high velocity of air at small differences in pressure in order to induce the air into a room and to mix cold and warm air very well. At the moment it is difficult to predict the way the air flows through a vent at small differences in pressure. However, it is possible to make the flow visible by smoke. General theories can be used about the characteristics of air flows and the loss of kinetic energy (k - ε - models). By applying the general theories and using several studies of different prototypes, a CFD program can be validated. The program can be used to predict flows through vents. The next steps are: 1) finding a better combination with sound insulation properties, 2) finding a better integration with the architectural design of the facade of a building. Fewer draught problems are expected with the induced air flow. Draught and air flow patterns will be measured in a test chamber. Research will be done about the combination of vents with pressure controlled mechanical exhaust systems and balanced ventilation systems. It is anticipated that a rather simple system can be developed which has the advantage of lower costs as well.

Measuring methods

In a wind tunnel a screen with a hole where the vent is placed has been constructed. At two sides pitot tubes are located. In the tunnel, it is possible to make the following differences in air pressure: 0.5, 1, 3, 5, 10, 20 and 50 pascal. With the use of smoke from a smoke generator, the air flow becomes visible. With an anemometer the air velocity is measured. By using a videocamera the air flow pattern is recorded on a videotape.

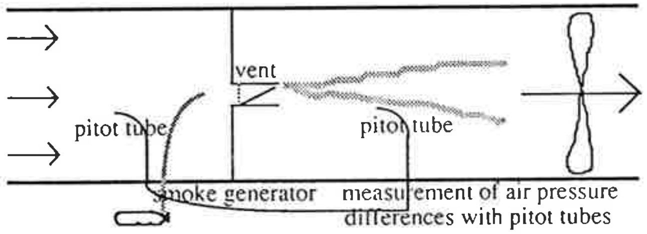

Fig. 2. Scheme of the wind tunnel test.

A lot of elements of the prototype are variable: The height of the inlet (0.5 or 1 cm), the use of the netting (1 mm x 1 mm network), and the varying of the blades under the edges of 15, 45, 75 degrees and a radial position of the blades. The same measurements on several improved prototypes, and also sound insulation tests, will follow. This information is used to validate a CFD program (Phoenics) to find good combinations of air flow- and (predicted and tested) sound insulation properties for different architectural requirements.

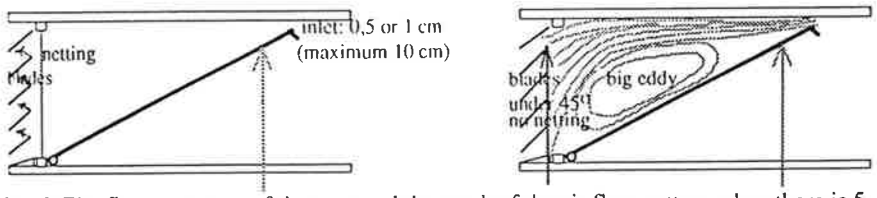

Fig. 3. The first prototype of the vent and the result of the air flow pattern when there is 5 pascal pressure difference (height of the inlet 1 cm, no netting, blades under 45°).

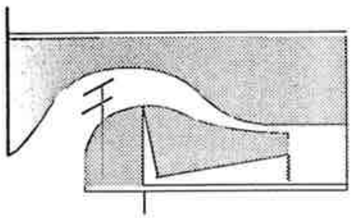

Fig. 4. Improved geometry of the vent with sound insulation.

In a test chamber comfort measurements will take place. Air flows will be analysed at several positions of jets, placed in different positions in the facade and under different climatical conditions in relation to a heating system, like a radiator or floor heating. The Phoenics program will also be used to examine the mixing process of cold and warm air in the test chamber. Furthermore, there will be a test of the air pressure control system.

Statistical methods

The results of the measurements of the first vent prototype are compared with results from calculations based on several equations from fluid mechanics. Generally a power law equation (1) is used. It is also possible to use some equations from fluid mechanics (2 - 6).

RESULTS

Equations and graphics

(power law equation) $$Q = C\,\Delta p^n \qquad (1)$$

Q = air flow in dm^3/s
C = resistance-coefficient $dm^3/s{\cdot}m{\cdot}Pa^n$
n = flow exponent ($n = 0.5$ = turbulent; $n = 1$ = laminar flow)

(law of conservation of volume) $$Q_1 = Q_2 \qquad (2)$$
$$Q = U_1A_1 = U_2A_2$$

U = air velocity in m/s
A = diameter of the flow in m^2

(law of conservation of energy, Bernoulli) $$p_1 + 1/2\,\rho U_1^2 = p_2 + 1/2\rho U_2^2 \qquad (3)$$

p = pressure in pascal, N/m^2
ρ = density of the air at 20°C, 1,20 kg/m^3

(variation of equation 3) $$p_1 - p_2 = \Delta p = 1/2\rho(U_1^2 - U_2^2) \qquad (4)$$
$$\text{When } U_1 = 0,\ U_2 = \sqrt{\left|\frac{2\Delta p}{\rho}\right|}$$

This is the maximum air velocity according to Bernoulli, see fig. 5.

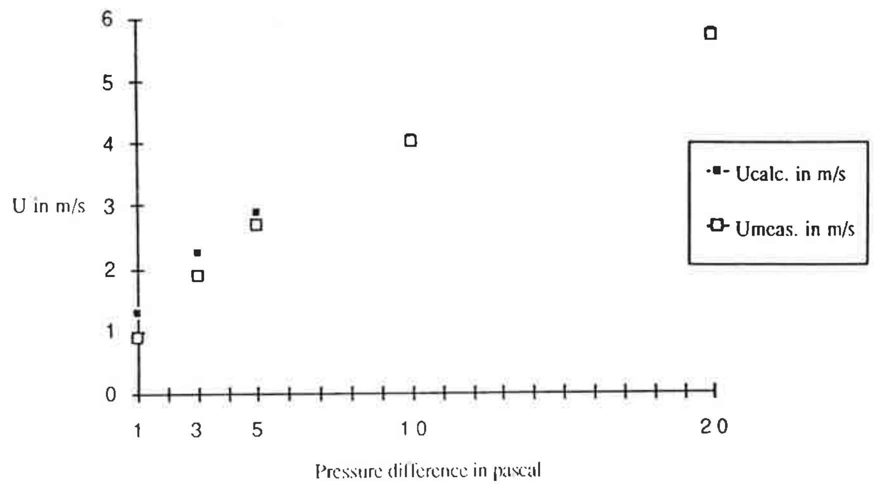

Fig. 5. Calculated values of air velocity according to equation 4 and measured values, when the height of the inlet of the vent is 1 cm (no netting, radial position of the blades).

(combination of equations 2 and 3) $$Q^2 = 2\,\frac{(p_1 - p_2)}{\rho}\,[A_2^{-2} - A_1^{-2}]^{-1} \qquad (5)$$

When equations 5 and 1 are combined, an estimation of the minimum air resistance is possible, assuming that the air flow is fully turbulent, $n = 0.5$, see fig. 6.

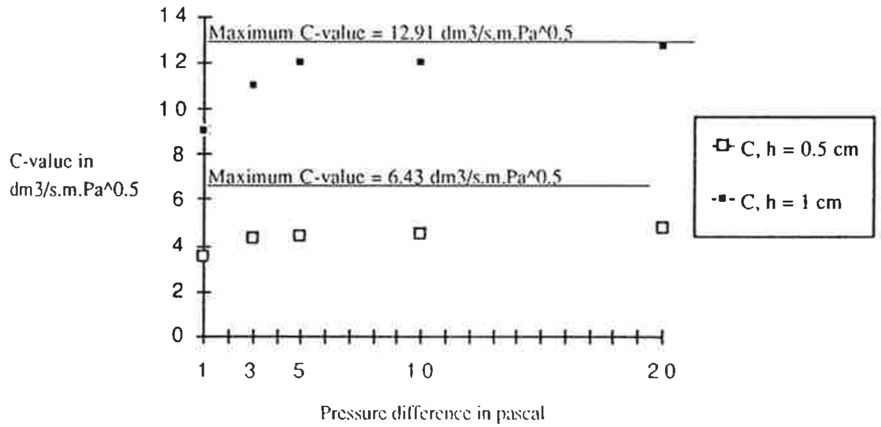

Fig. 6. Calculated maximum C-values according to equation 1 and 5 compared with measured values when the height of the inlet is 0.5 or 1 cm (no netting, radial position of the blades).

(extended equation 3) $$p_1 + 1/2\rho U_1^2 + \rho\,g\,z_1 = p_2 + 1/2\rho U_2^2 + \rho\,g\,z_2 \qquad (6)$$

z = reference height of the air flow in m
g = gravitational force, 9.8 m/s^2

This equation shows the effect of the density, gravitational forces, and the height of the air flow ($\rho\,g\,z$). For 0.1 m height, the difference in air pressure might be 1.2 pascal.

DISCUSSION

There are some findings shown by the way the air flows through the vent: 1) Under 5 pascal pressure difference the resistance (C-value) decreases according to a special curve, 2) between 5 and 10 pascal the resistance remains the same, 3) between 10 and 20 pascal the resistance decreases again and 4) above 20 pascal the resistance remains practically the same. The results at 3) and 4) can easily be seen by following the smoke patterns in the vent: The smoke contracts itself and pushes itself against the upper side of the vent. When the height of the air inlet is reduced from 1 to 0.5 cm the resistance increases with more then 60 %. In case of an inlet of 0.5 cm it is effective to have a netting at the outside of the vent. The resistance is practically the same than without netting. The visualisation of the air flow makes it possible to comment on the relation between air flow patterns and loss of energy. Seeing a big eddy at the bottom of a vent when the blades are under a position of 45 or 75 degrees- there seems to be a big loss of energy, but this loss is generally less then in the case of little eddies in the whole geometry.

Contraction of the air flow results in acceleration of the air flow, but not in rotation of the air flow. A big eddy preserves its own energy and causes no big losses in energy. Kinetic energy can only be conversed into heat in microscale by small eddies, due to viscous dissipation. That is why little eddies cause high loss of energy. Furthermore the air flow follows the shortest route, so the air flow contracts itself in the upper side of the vent. It is difficult to assess the influence of gravitational forces. According to Bernoulli's equation (6) it requires a lot of energy for an air flow to go upwards (10 cm, 1.2 pascal), but other forces like buoyancy show that even with small differences in temperature there will be an air flow.

Particles of smoke are heavier then the surrounding air, they influence the smoke patterns mainly under 1 pascal. It is also difficult to fix the exact size of the air inlet. An error of + or - 0.5 mm is possible. This has only a very small influence on the results.

Recommendations

It is possible to reduce the geometry of a vent without losing energy. This makes it possible to add sound absorbing materials. This phenomenon allows some freedom in the architectural design of the facade as well by integrating the vent in a window frame. Flat blades at the outside of a vent can be added without causing a significant loss of energy. Also a clean netting (with a big surface in relation to the air inlet) does not cause much loss of energy. Furthermore it is necessary to offer protection against some adverse climatical conditions, like rain and high wind velocity. In these cases, for example, a double closing system of the jet (compartment) is needed. New measurements show that there are even better results with smaller geometries, because the air flow becomes less turbulent. To get a better sound insulation it is necessary that the internal geometry of the vent has a big curve and that sound absorbing materials like rockwool are used.

Practical achievement of a healthy indoor environment

For a lot of buildings it should be possible to find a good combination of vents and an exhaust -or balanced ventilation- system to achieve a good indoor climate without too high costs. It is possible to construct an air inlet which induces the air and causes a good mixing of the air underneath the ceiling, making use of the coanda effect, even with a small pressure difference between inside and outside. In this way it is possible to use vents with a big capacity, without causing serious draught problems. These vents can be combined with a pressure controlled exhaust system. When a balanced ventilation system is used, there will still be refreshing of air, even when the vent is closed. Draught problems and a control system (air pressure regulation) will be studied in a test chamber. When the geometry of the vent is developed further, it should be possible to achieve a good sound insulation as well.

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ACCEPTABILITY OF WALL EXHAUST DISCHARGES IN RESIDENTIAL VENTILATION

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ABSTRACT

The usual way of extracting the waste air in a room is to conduct the air above the roof. However, it would be easier to install exhaust and intake vents on the outer wall of the building. This paper presents the results of full-scale experiments that were carried out on a three-storey building using tracer gas measurements and video recording. To assess the measured concentration on the building wall, the odour threshold values of exhaust air during cooking or smoking were used.

The results were in agreement with the theories underlying the use of roof exhausts near the exhaust opening, but at a greater distance (5 - 10 m) the theories indicated concentrations that were too low. The highest intake air concentration was 0.5 % of the exhaust air concentration and it was slightly smaller than the odour threshold value of 0.6 %.

On the basis of the tests performed so far, the wall exhaust system seems to be acceptable in residential buildings.

INTRODUCTION

The exhaust air from a building must be discharged outdoors in such a way that no harmful effects are caused to the building, its occupants, or the environment. The usual way is to conduct the exhaust air above the roof of the highest section of the building. However, it would be easier to install exhaust and intake vents on the outer wall of the building, particularly in renovating the ventilation system in old residential buildings, where an apartment-based mechanical ventilation system could be used. The purpose of this study was to examine whether exhaust vents could be mounted on the outer wall without polluting the intake air.

Very little information about a wall exhaust system is available in the literature. H. Niemelä et al have investigated the re-entry of exhaust air into the supply air in an apartment-based ventilation system in test houses in Kuopio, Finland (1). The proportions measured ranged from 0 to 2.3 %. On occasions, the amount of re-entry rose to almost 6 %. Re-entry was highly probable because the intake vent was spaced closely together with the exhaust vent in the same unit (distance between the vents was only 7.5 cm) and the exhaust velocity was small. Further, they found that the pressure-induced air leaks between the apartments can transport almost equal quantities of contaminants in the mechanical exhaust ventilation system. In this study the exhaust velocity was much higher and the concentrations of tracer gas were measured outside the assumed intake vents.