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Draughts Due to Air Inlets: An Experimental Approach.

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ABSTRACT

Draughts due to air inlets are one of the problems to be solved for improving the global performance of mechanical ventilation systems. The CSTB full scale test cell "EREDIS" has been used to quantify draughts risks due to air inlets by measuring air temperatures and velocities with known boundaries of wall temperatures and fresh air. The results allow to improve the design of these inlets and to give advices for a better use in residential buildings. Works are now going on for comparing the experimental results to the ones calculated with a CFD code.

1 - INTRODUCTION

Ventilation systems in residential buildings are primarily intended to insure adequate indoor air quality. They must comply with additional requirements : to limit energy consumptions and to provide a thermally comfortable indoor climate.

In practice, cold draughts due to air inlets may occur in the ventilated rooms. In the rooms where there are draught problems, the occupants often plug up the air inlets or stop the ventilation system and this will decrease the indoor air quality. The occupants too may increase the air temperature to counteract the draught and this will increase the energy consumptions. Therefore cold draughts prevention is a major requirement of air inlets.

Several studies have been conducted in the field of air flow within rooms and a few specific draught studies are available [1 - 5].

The present paper deals with air velocities and temperatures measurements carried out in a testroom at CSTB in order to assess the behaviour of the air jet discharged from a self-regulated air inlet.

2 - EXPERIMENTAL SET-UP

At Marne-la-Vallée, CSTB has a test enclosure, called EREDIS (Enceinte de Recherche sur la Diffusion de l'air et les Interactions Système-enveloppe), devoted to the study and analysis of thermoconvective phenomena inside rooms [6] [7]. EREDIS is a full scale test enclosure with lightweight walls or simulated walls made of water circulation pannels, enabling to bring to steady-state conditions in relatively short delays. It has two original characteristics : variable geometry and monitoring of the walls in temperature or in flux.

The three dimensions of the test enclosure can be modified thanks to the movable suspended ceiling and the three movable inside partitions (see figure 1). The ranges for varying the dimensions of the enclosure enable the reproduction of a large number of possible room geometries with a single façade, from a small bedroom (L x W x H = 2.7 x 2.7 x 2.5 m) to a large office (L x W x H = 7.2 x 4.5 x 3.0 m).

The inside partitions are adiabatic : they are cavity walls framed with plasterboards insulated outside by 10 cm of polystyrene. The façade consists of chilled water circulation panels, insulated outside. Their inside face can be covered with an appropriate thickness of insulation, simulating the unglazed part of the façade. All glazing geometries can be provided. Outside temperature simulation is by displaying the temperature of the glazing and by supply air at temperature equal to the outside temperature.

In this study, the test enclosure represents a dwelling room with dimensions of 3.6 x 3.6 x 2.5 m equipped with floor heating, uniformly distributed, providing an inside temperature at the centre of the room of 20°C. With a such heating method, the vertical air temperatures differences are minimized. Therefore the air flow patterns due only to the air inlet can more easily be assess. The fresh air is introduced at a temperature of 0°C through a self-regulated air inlet placed above a glazed bay (W x H = 2.0 x 1.4 m), (see figure 2). The surface temperature of the glazed bay is kept at 7°C so that it can simulate an outside temperature of 0°C. The air flow rate of the air inlet is 30 m^3/h which corresponds to an air change rate of the room of about 1 ach. Two rectangular exhaust openings are symmetrically located in the sidewalls, at the floor level, far from the air inlet so as not to disturb the air flow in the room.

3 - EXPERIMENTAL PROCEDURE

The fields of air velocities and temperatures were explored by the shifting of a measurement frame in the area of the supply air jet. This exploration method has made it possible to indicate a possible penetration of the cold air stream in the occupied zone. The measurements were carried out in the vertical symmetry plane through the air inlet.

Air temperatures were measured by a platinum resistance sensor. Air velocities were recorded with an constant temperature anemometer DISA 55M01/55M10 provided with an omnidirectional thin-film probe DISA 55R49.

The DISA 55R49 probe using a spherical sensor of small dimensions operated at low sensor temperature it is possible to measure velocities down to 5 cm/s without significants errors from free convection flows created by the sensor itself [8]. Therefore this probe is well suited for measurements air movements in full-scale models of air-conditioned rooms.

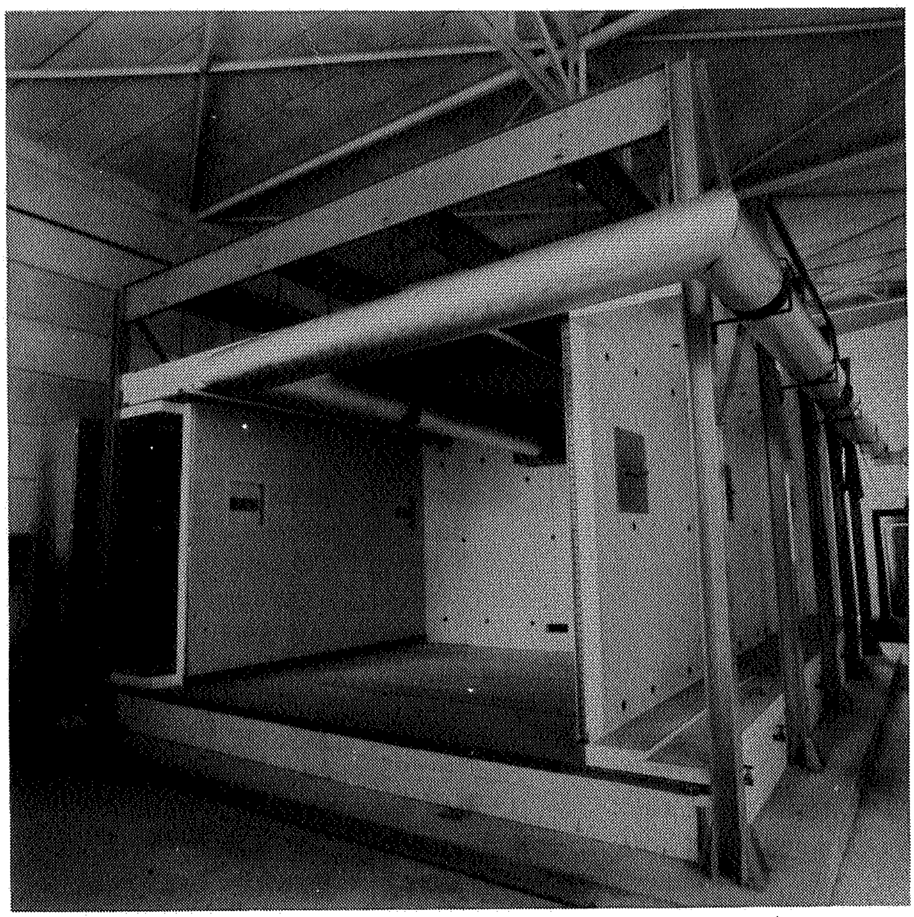


Figure 1 : Outside view of the test enclosure. In this photo, we can make out the lightweight partitions, the suspended ceiling and the supply air network

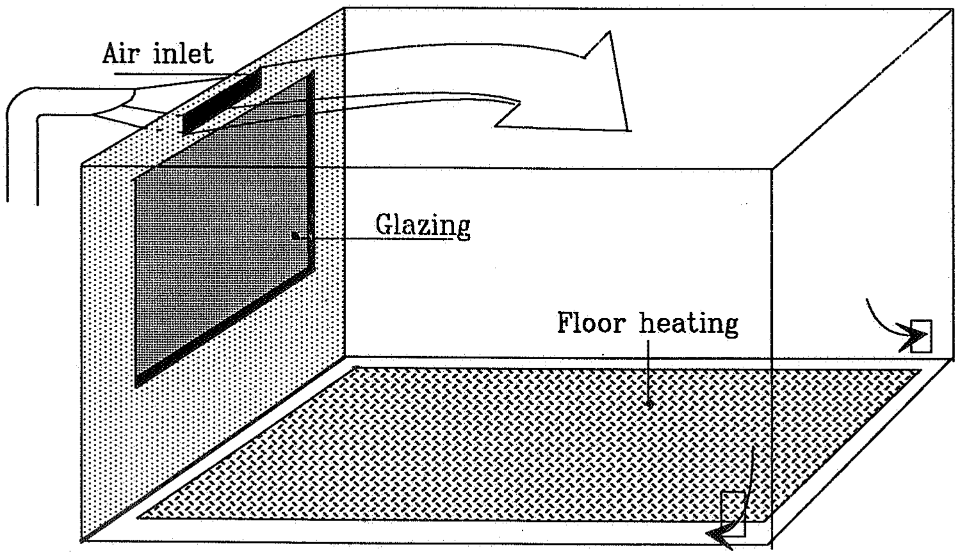


Figure 2 : Sketch of the test enclosure

As the velocity probe is non-temperature compensated and non linearized the real velocity was calculated from the measured temperature and from the measured voltage according to a calibration curve.

The probe was calibrated by using the DISA 55D90 calibration equipement. This equipement produces a variable-velocity low-turbulence free air jet in which the anemometer probe to be calibrated is placed. The relationship between anemometer voltage and air velocity was determinated on the basis of twelve calibration points in the range 0 - 1 m/s.

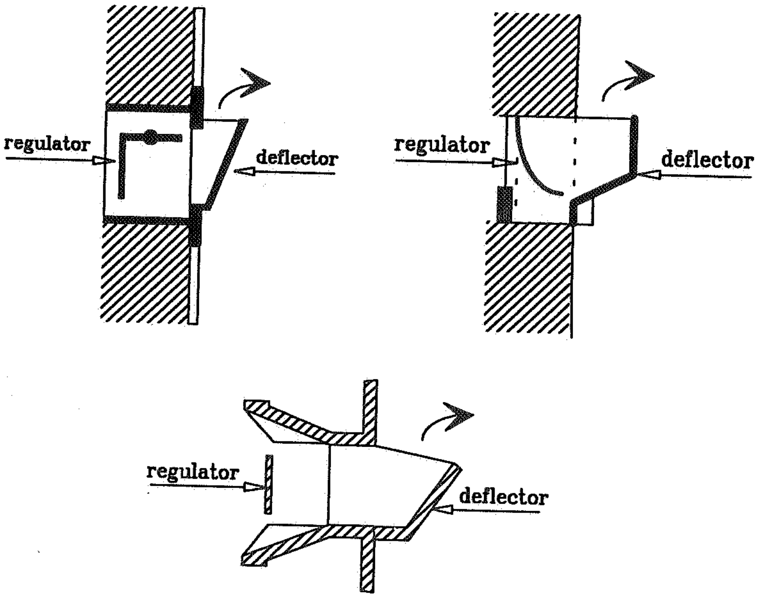
200 velocity measurements were collected at each point, the average of these instantaneous values being used to characterize the velocity at this point. As the temperature change in time was not important, the temperature was not measured at the same rate as air velocity : only one measurement was collected to characterize the temperature at a point. This value was used to accomplish the temperature compensation of the anemometer voltage.

4 - TESTS

In order to assess the risks of cold draughts due to a self-regulated air inlets, tests were performed in the EREDIS enclosure. Various types of self-regulated air inlets marketed in France were tested and the effect of the location of the air inlet on the air flow patterns was analysed.

The way of working of a self-regulated air inlet is the progressive modification of the air passage section of the inlet according to the pressure difference on either side of the inlet. The change in section is as that the air flow rate may be kept constant in a wide range of pressure difference.

The self-regulated air inlets use various air flow control devices : the moving component of the inlet may be either a plastic film shutter or a L profile shutter or a setting stick shutter (see figure 3).



Sketch of various self-regulated air inlet

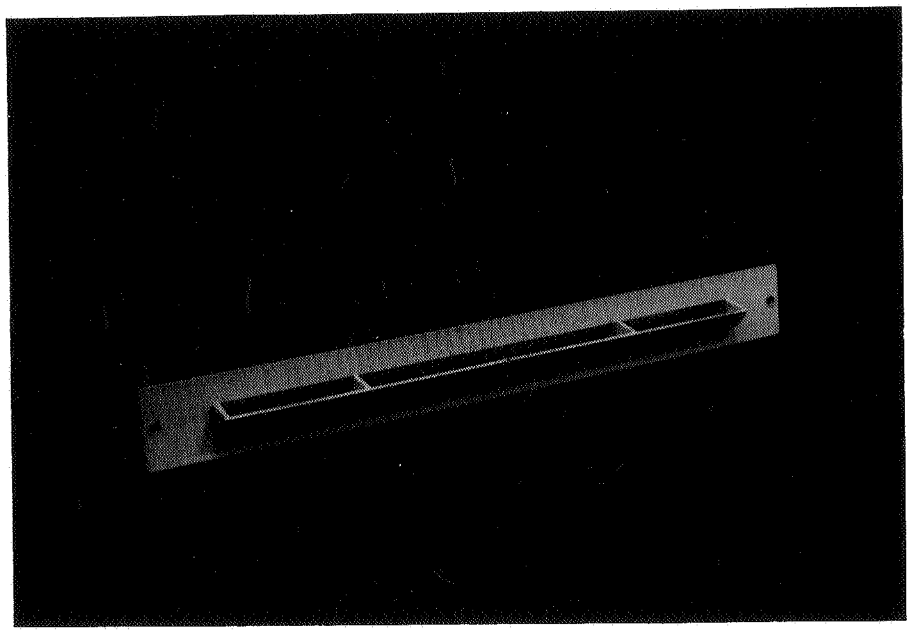


Figure 3 : Self-regulated air inlet devices

Figure 4 depicts a typical flow rate curve of a self-regulated air inlet. These inlets which are in widespread use for more than fifteen years help to prevent uncomfortable draughts when the wind pressure is too high. Also, they contribute to lower heat losses due to cross ventilation.

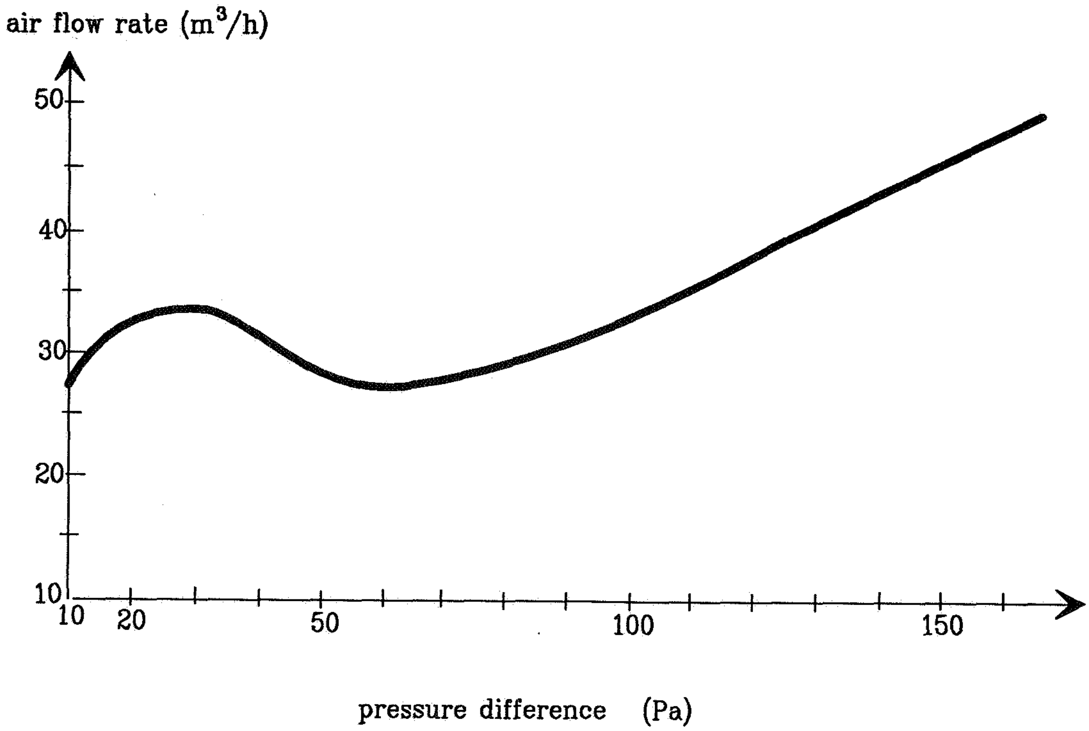


Figure 4 : Self-regulated air inlet characteristic curve

Two sets of tests were performed. In the first, the air inlet was placed in the façade in a vertical position near the ceiling (horizontal air jet). Various distances between the ceiling and the air inlet were chosen : 5 cm, 15 cm, 25 cm. In the second set, the air inlet was installed in the horizontal part of a rolling shutter housing (vertical air jet). The opening is located at 30 cm below the ceiling.

5 - RESULTS

5.1 - Horizontal air jet

The jet issued from the inlet is inclined to stick to the ceiling because the inlet is equipped with a deflector that points the jet upwards.

In addition, since the air inlet is located close to the ceiling there is a tendency for the jet to cling to the ceiling. This effect, called Coanda effect [9], also reduces the influence of temperature differences which normally cause the trajectory of a cold air jet to curve downwards.

The tests have shown that whatever the type of air inlet, when it is located in a vertical wall fairly close to the ceiling, the jet is strongly drawn toward the ceiling and the risk of penetration into the occupied zone is non-existent.

Figure 5 depicts the air jet behaviour issued from a self-regulated air inlet located close to the ceiling. It shows iso-velocity and isothermal maps. The isothermal lines indicates the difference between the air temperature at the centre of the enclosure (20°C) and the local air temperature in the stream.

The air jet behaviour is the result of the combining of the both antagonistic effects :

- thermal forces that incline the jet to curve downwards
- Coanda effect that incline the jet to curve upwards

Figure 5a shows the air jet split up into two parts : the one slightly curves downwards (free jet), the other clings to the ceiling (wall-jet).

5.2 - Vertical air jet

Tests were carried out with a self-regulated air inlet either equipped with a deflector or not. The results have shown the air jet behave like a wall jet running along the cold glazing. When the inlet device is not equipped with a deflector the cross-sectional area of the air jet increases so that the air stream comes into the occupied area (see figure 6).

When the air inlet is intalled in the horizontal part of a rolling shutter housing, it is necessary to deflect the air jet towards the façade ; in all the other cases, the discomfort appears locally near the façade.

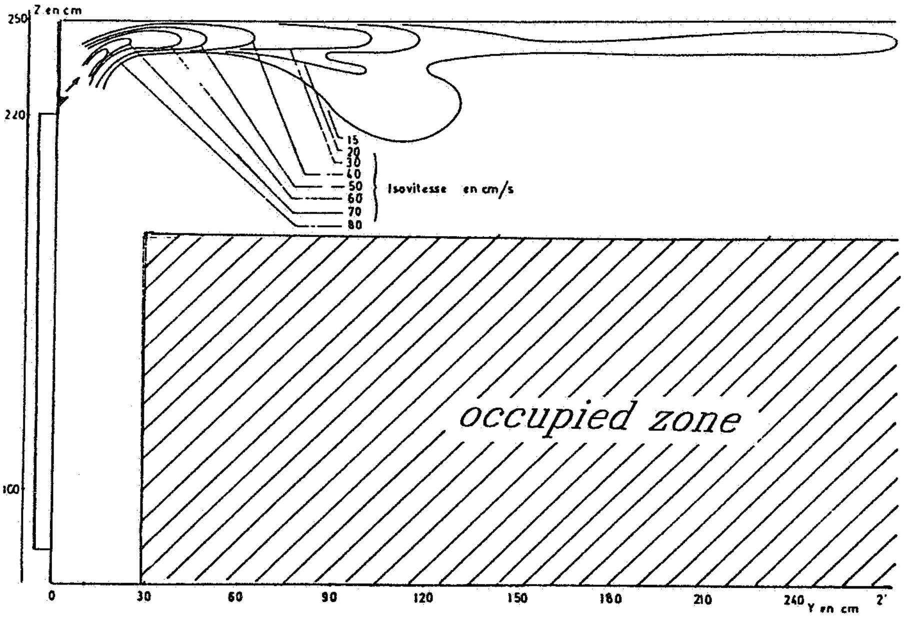


Figure 5a : Iso-velocity map

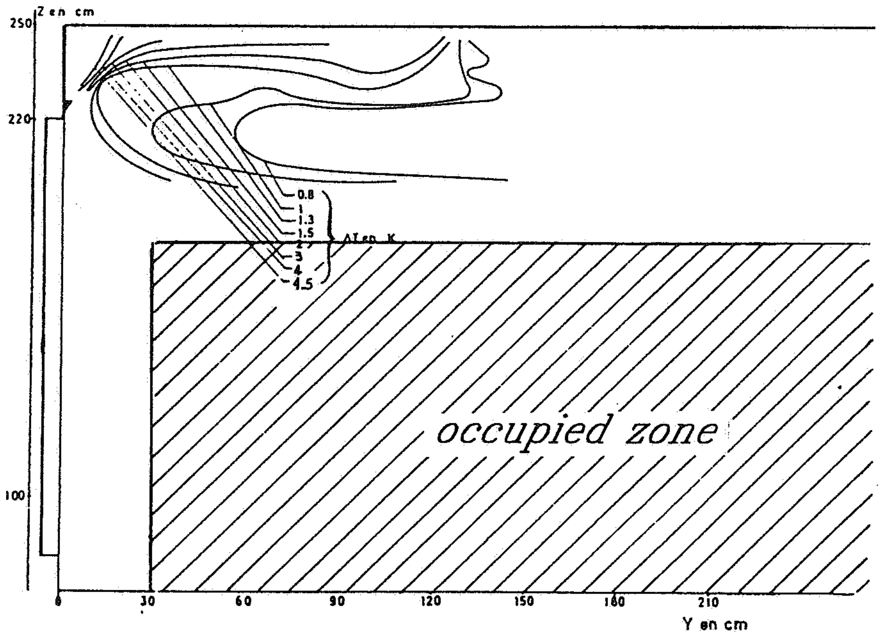


Figure 5b : Isothermal map $\Delta T = ti - tx$
ti = air temperature at the centre of the room
tx = local air temperature

Figure 5 : Air jet behaviour from self-regulated inlet set over a window in vertical position

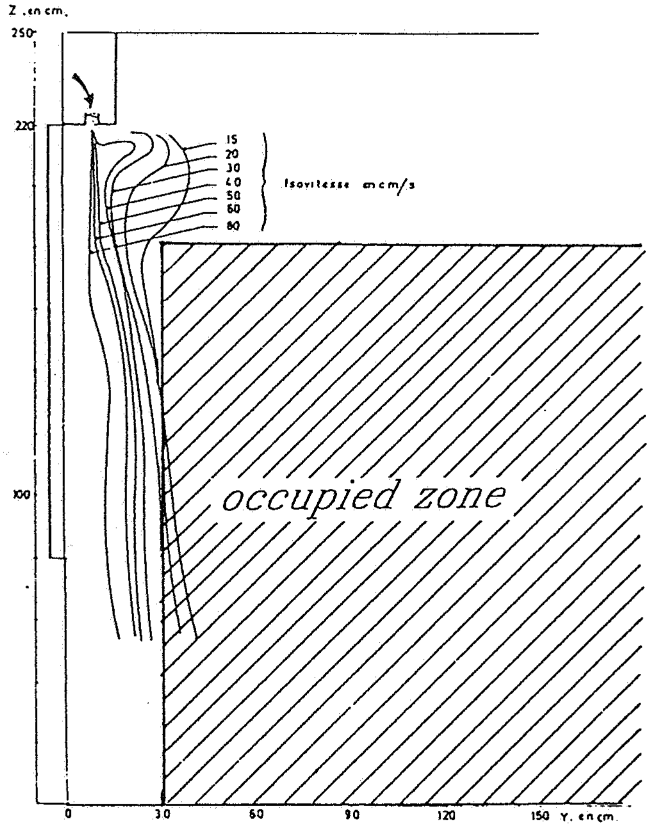


Figure 6a :
Iso-velocity map

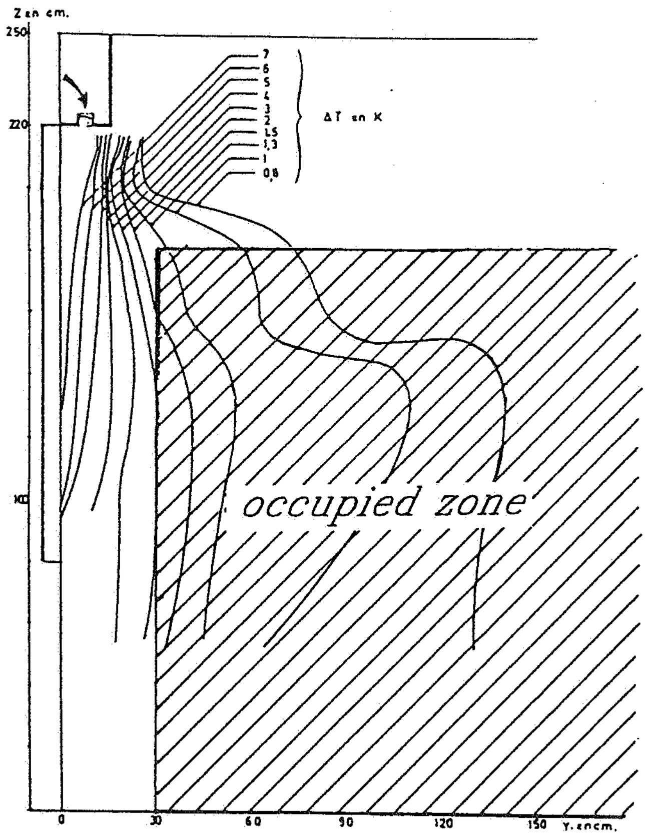


Figure 6b :
Isothermal map
$\Delta T = ti - tx$
ti = air temperature
at the centre of the room
tx = local air temperature

Figure 6 : Air jet behaviour from self-regulated inlet set over a window in horizontal position

6 - CONCLUSIONS

In a heated room where the heating provides the thermal comfort of the occupants at the centre of the room, the presence of a ventilation air inlet can affect the comfort conditions at certain points of the occupied area and risk of cold draughts can occurs.

Cold draught prevention is based on an adequate air diffusion in order to avoid the penetration of the air jet into the occupied area. The reduction in velocity and temperature difference must be executed outside this area.

When the air inlet is located in the façade so that jet is horizontally discharged, the air jet must be pointed towards the ceiling. The efficient way to avoid draught is the use of a deflector.

When the air inlet is underneath a rolling shutter housing so that jet is vertically discharged, the air jet must be pointed towards the façade ; therefore an air inlet with a deflector must be used. Result without deflector is hardly acceptable.

Thus, this study has shown that experiments in testroom may help to improve the design of air inlet device and their location in room. Also, it has been shown the self-regulated air inlet does not cause uncomfortable draughts if the installation of the inlet device is executed with a few precautions.

Research work is needed to establish correlation between jet characteristics and temperature and velocity field in the room. Nevertheless, the number of experiments to be undertaken to achieve this goal is very high. This is why recourse to numerical approach can enable a faster progress in understanding heat and mass transfer within rooms. Works are now going on for comparing the experimental results to the ones calculated with a Computational Fluid Dynamics code.

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