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AIR FLOW WINDOWS

F.Bonvehí
Consultant Engineer
C/. Pintor Pahissa nº 27, 4º E-08028 Barcelona
X.Traver and M.Miró
Ecotècnia
C/.Demóstenes, nº 6 E-08028 Barcelona
A.Trias
Architect
C/. St. Joan, nº 6 E-08629 Torrelles de Llobregat (Barcelona)

ABSTRACT. Air flow between two panes of a building's skin may provide optimal solutions to effectif control of energy fluxes through walls and by ventilation. The results reported in this paper refer to glazed walls only. The air flow window consists of two glazed panes with venetian blinds in between and air circulation in this space. This device is able to control Daylight Transmitance, Solar Protection, Solar Thermal Collection and Dynamic Insulation. This technology can be applied to windows, courtain walls and greenhouses. Our work has evolved from simulation by computer models and experimental analysis of prototypes on test-cells to several case application studies, single house equipment and retrofitting of a primary School under a EEC Energy Demonstration Project.

1. INTRODUCTION

Air flow windows associate ventilation inside the building and control of energy fluxes through the glazed walls. The basic equipment consists of two glass panes with a venetian store in between, the air flows in this space. This system can be applied to classic windows, double windows, courtain walls and greenhouses.

Design of air flow windows require a through analysis of kind and use of the building as well as of the local climate. Applications may enhance residential, office or leisure buildings, hospitals, schools, etc.

Among the institutions and companies revolved with the project at different stages are: Center National de la Recherche Scientifique, Agence Française pour la Matrisse de l'Energie, Commission of the European Communities, Generalitat de Catalunya, Asolba, Pechineg-Btiment, Folcrà, CICSA, ICIE and Ecotècnia S.Coop.

2. DESIGN CRITERIA AND ISSUES

In designing an air flow window for a particular application we have several elements to play with: glass panes, store and air circulation. Monolithic clear float panes are usually adequate. For settings with very cold winter seasons low emissivity glass may be considered or even a traditional double glazing for the external wall. To reinforce solar protection tinted or reflective glass for the external wall can be of interest. Material, color and dimensions of the venetian blinds must be adjusted to the actual requirements of visual comfort and esthetic appearance.

Concerning air flow several patterns are to be considered. The ventilated wall may function as an intake air system, in this case fresh air introduced into the building is being preheated in its passage through the air space in the wall.

The air flow window may operate as an exhaust air system as well. In this case used air is impelled off the building through the window, the effect is to level temperatures of room air and internal surface of the windows. As a consequence comfort nearby the glass walls is improved other in winter or in summer.

The air flows itself can be driven either by forced or by natural convection. Air flow windows may operate as an autonomous device or, if requested, the air flow can be integrated with a central ventilation system. On many days air temperature rise at the outlet of air flow windows can be 15 to 30% depending on flow conditions and blinds.

3. BASIC PRINCIPLES

The energy fluxes in an air flow window are described in figure nº1. Solar radiation impiping the external glass pane is transmitted, reflected or absorbed, the last fraction is remitted at infrared wavelengths. When the transmitted fraction strikes the slats of the venetian blinds a fraction will be absorbed depending on incident angle. This angle determines the function that eventually reads the internal glass pane which in turn undergoes the same process as in the external wall. The surface temperature of the internal glass wall determines infrared radiation exchanged with its surroundings. The air flowing in the cavity cools the venetian blinds an the glass walls as it increases its temperature. By evacuating heat from the window the equilibrium temperatures of the different parts is diminished.

The main properties of air flow windows related to energetical phenomena are:

- Natural Light Transmittance.
- Solar Protection.
- Solar Heat Collection.
- Dynamic Insulation.

To express the these properties in a quantitative way the following parameters are used:

- Daylight factor.
- Solar factor.
- Collector efficiency.
- Heat transmission coefficient.

For many window arrangements these parameters have a single value. Whereas for air flow windows these parameters offer a wide range of variation. An important part of our work has been dedicated to establish measured for these basic parameters.

4. METHODOLOGY ON RESEARCH AND DEVELOPMENT

4.1 Simulation

A mathematical model running on computers has been developed. The model is based on a set of equations describing dynamic thermal equilibrium. Temperature distributions are calculated through an interactive process, then thermal fluxes are evaluated. This model allows the determination of values of the basic parameters under variable environmental conditions and different system designs.

4.2 Experimental testing

Prototypes of air flow windows about 90 cm. width and 200 cm. high have been extensively tested. This

experimental work has been performed on test-cells under natural climatic conditions and on laboratory with artificial radiation. Locations of such tests include Toulousse-France, Barcelona-Spain and Bangkok-Thailand.
Experimental data obtained have enabled the validation of the mathematical model and the determination of the characteristic curves of solar radiation, solar heat collection and dynamic insulation as a function of air flow rate.

4.3 Case studies and projects

In parallel with the basic work described, several architectural projects for real buildings have been performed and some instructed. Windows, and attached greenhouses for single houses have been studied, also fenestration for hotels, hospitals, schools and office buildings.

5. NATURAL LIGHT TRANSMITTANCE

The ratio of daylight in a particular point of a room to the external available daylight, both measured on a horizontal plane, is a constant trough daytime and known as daylight factor.
In air flows windows the daylight factor may be adjusted to the needs by properly setting the inclination of the venetian blinds. This setting can be manually operated by the occupants or automatically controlled by sensors, timers or computers. With venetian blinds set at 45% inclination in south exposure we can have about 500-600 lux at 2 meters from the window in central day hours.

6. SOLAR PROTECTION

The efficiency of a shading device is expressed by the solar factor. It is defined as the ratio of the total energy flux into the building to the total solar radiation impiping the shading device. The air flow window has a variable solar factor.
When the store is retracted and without air circulation, we have the solar of our double glazing which is 78 for two 4 mm panes of clear float. This solar factor is suitable for direct heat gain. With white venetian blinds and slats inclined at 45º the solar factor is 26, it can be reduced to 20 by ventilating with exhaust air at 25 m3/hm2 rate flow. When the window's frame is taken into account the solar factor becomes 14. This results are shown in figure nº2. Typical values of solar factors for external shading devices with double glazing are about 10. The reduction of temperature on the surface of the internal glass has two effects: reduction of the cooling load and greater comfort nearby that surface.

7. SOLAR HEAT COLLECTION

Air flow windows under sunshine function as solar collectors. This characteristic is expressed by the solar collection efficiency, which is the ratio of the thermal energy evacuated by ventilation to the total solar energy striking the window. Experimental data are plotted in figure nº 3. With an air flow rate of 20 m3/hm2 efficiency is about 20%, with white/black venetian blinds and 15% with white only. Air temperature increase when air flows along the window may vary from 15 to 25% for a 2 meter high window.

8. DYNAMIC INSULATION

Ventilating air flow windows with exhaust air has the effect reducing the temperature difference between the room ambient air and the glazed wall. This differences may be about 1,5% at a flow rate of 20 kg/hm2 and outside/inside delta T of 18C. Heat loss through the glass wall are dismissed and discomfort nearby the window almost disappear.
The dynamic insulation effect is shown in figure nº4. The K value of the window varies with air flow. The K value of an air flow window with 20 m3/hm2 is 1 W/C m2. The K value of a window without ventilation is 2 W/or m2.

9. BUILDING APPLICATIONS

The air flow window system has been successfully applied to verandas in single houses and apartments. A greenhouse attached to a single house has been built using the technology of air flow windows.
The glazed pyramidal dome of an aquatic park in Le Tonquet France has ventilated double glass panes. The inclined walls have no venetian blinds.
Figure nº 5 shows the basic layout of the application. Renewal external air after preheating on an air exchanger flows in the dome's skin. The aim is to avoid condensation on the glass and therefore to suppress water drops falling over the users.
The retrofitting of a primary School in Agramunt/Lleida is under way. The ancient fenestration is being replaced by air flow windows working with air of classrooms. This project has been related as a Demonstration Energy Project by the E.E.C.

10. AGRAMUNT'S SCHOOL PROJECT

The primary school of Agramunt was built in the thirties. In consists of two floors of 750 m2, the ceiling height is 4,5 m. The fenestration surface is about 500 m2, which is a third of floor surface and with good exposure.
Retrofitting is under way and will be implemented in two stages. In 1989 the ground floor's window are being replaced and ventilation of the classrooms installed. In 1990 the works will be completed by replacing windows in the first floor and installing ventilation as well, the roof will be insulated and space redistributed.

10.1 Monitoring

Measurement of local climatic conditions, comsumption, thermal fluxes and internal ambient conditions will be under way for two years. Two classrooms will be intensively instrumented in order to have complete information of the performance of the system.

10.2 Working principles

An outstanding feature of this technology is its capacity to adapt to different weather conditions and school's occupational patterns.
In winter the system will function on the basis of heating the air renewal. The forced ventilation extracts air from the classrooms and fresh air is introduced by the air flow window. Intake air temperature will regulate blower's operation. Figures nº 6 7 shown the layout.
In summer the air circuit will be inversed and exhaust air will pass along the air flow window to the exterior by blower intaking air from the north façade. Figures nº 8 9 show this set-up.

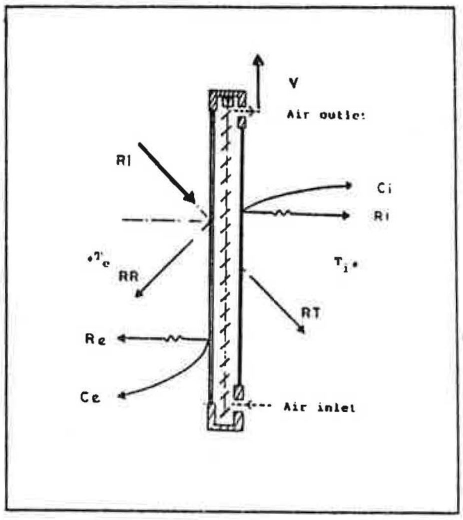

Fig. 1: Energy fluxes upon an Air Flow Window on sunshine:
RI: Incident solar radiation.
RR: Reflected " "
RT: Transmitted " "
V : Thermal energy avacuated by ventilation.
Re: Outwards infrared radiant flux.
Ri: Inwards infrared radiant flux.
Ci: " convectif flux.
Ce: Outwards " "
Te: External temperature.
Ti: Internal temperature.

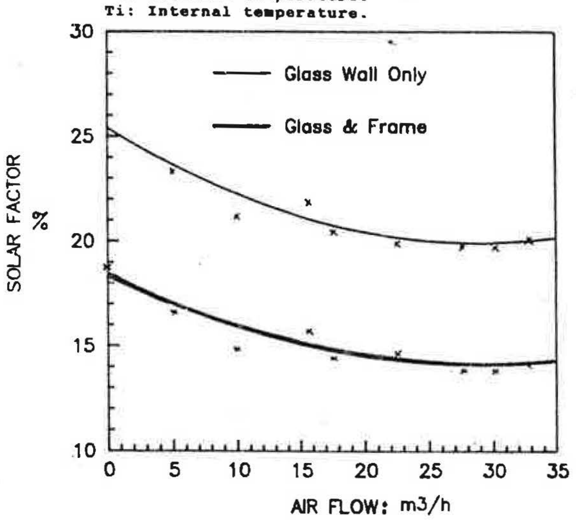

Fig. 2: Experimental data of solar factor vs. air flow.

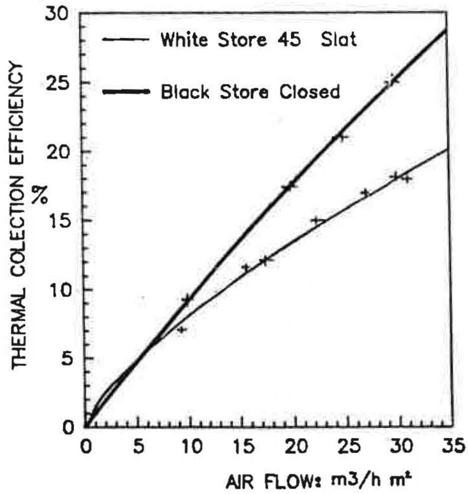

Fig. 3: Efficiency as a thermal solar collector.

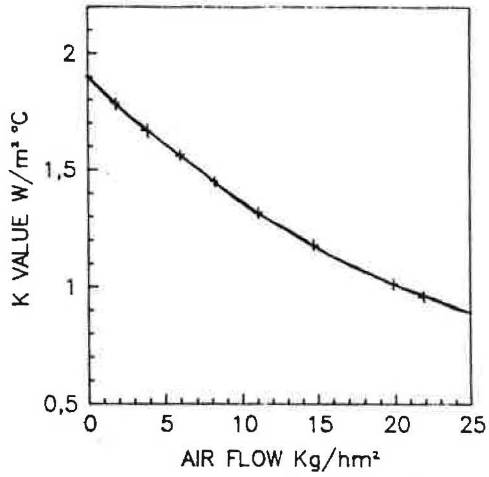

Fig. 4: Experimental data of the thermal transmission K as a function of the air mass flow.

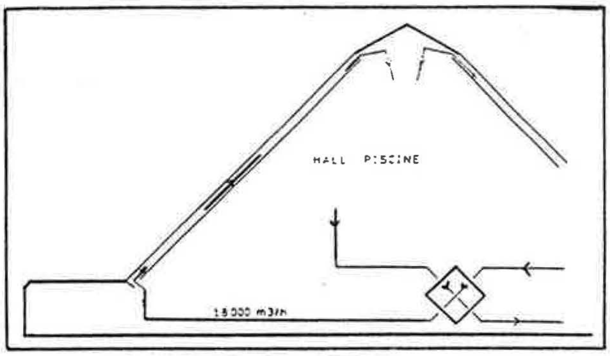

Fig. 5: Working principle of the ventilated skin of Le Tonquet's acuatic park (H. Farmellier I.C.)

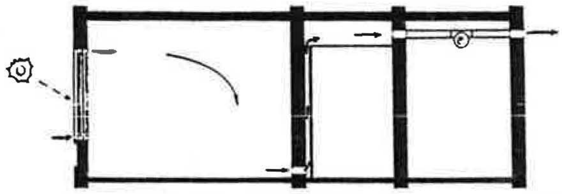

Fig. 6: Winter sunny day with forced ventilation (slats 15-25°).

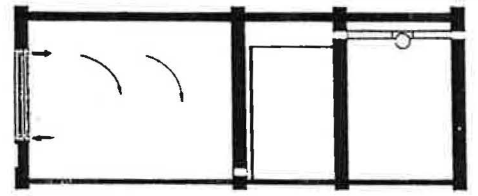

Fig 7: Winter sunny or cluded day without exhaust air extraction.

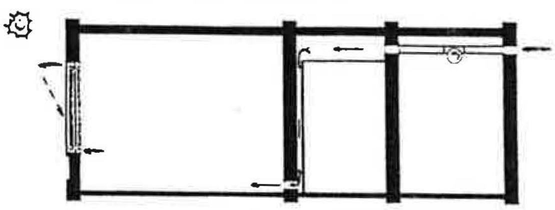

Fig. 8: Summer day with forced ventilation.

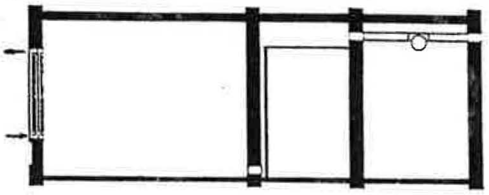

Fig.9: Summer day without exhaust air extraction.