ENERGY RESEARCH, VOL. 9, 441–447 (1985)

PERFORMANCE AND ECONOMIC ANALYSIS OF AIR FLOW WINDOWS IN A TROPICAL CLIMATE

L. B. WIART* AND S. SUVACHITTANONT

Energy Technology Division, Asian Institute of Technology, PO. Box 2754 Bangkok, Thailand

SUMMARY

An experimental study was conducted in Thailand to determine the thermal performance of twin glazed windows with dynamic insulation. The effects of blinds situated either between or outside the glazing were analysed. With an external blind, the heat transfer coefficient was 1·25 W/m^2°C with natural convection and 0·6 W/m^2°C for a flow of 20 m^3/h (glass area = 2·16 m^2).

The solar flux transmitted was evaluated analytically and experimentally depending on the blind's position. An economic study was performed on a six-sotrey air-conditioned building in Thailand. It showed in tropical countries that it may be more economical to use air flow windows than to have tinted single or double glass windows.

KEY WORDS Dynamic insulation Air flow windows

INTRODUCTION

With the increasing use of glazing in modern architecture, thermal comfort has become strongly dependent on mechanical facilities such as energy-consuming air-conditioners, air-heaters and blowers.

The solar flux on glazing results in a significant heat gain. In hot countries this thermal flux has to be fully compensated by the building's air-conditioner.

The use of double glazing and tinted glass panes only moderately reduces the flow of heat and the extra cost is not always recovered.

To give architects another alternative, a technique experimented on in cold climates was adapted to hot countries: the dynamically insulated window or air flow window (AFW). Normally, when air-conditioning a building, the air is renewed to the order of 13 m^3 per person and per hour.

Figure 1 shows an AFW. It consists of two glazings separated by an open channel. The air from the room is drawn through this channel and evacuated, thus serving as a dynamic insulator between the room and the environment.

The solar gain may be further reduced either by a venetian blind in the air channel or outside the window, a tinted glass or a shutter.

PERFORMANCE OF AN AIR FLOW WINDOW

AFW equipped with a blind

An AFW equipped with triple glazing (double glass outside the air channel) and an internal blind, was studied in Sweden in heated buildings. A day–night heat transfer coefficient of 0·5 to 1·5 W/m^2°C, depending on the air flow, was measured by Sodegren and Bostrom (1971). Chapman (1979) mentions a German study

* Present address: Laboratoire de Biotechnologie Solaire, Ecole Nationale Supérieure Agronomique, 145 Avenue de Muret, 31076 Toulouse Cédex, France.

0363–907X/85/040441–07$01.00

Received 17 April 1984

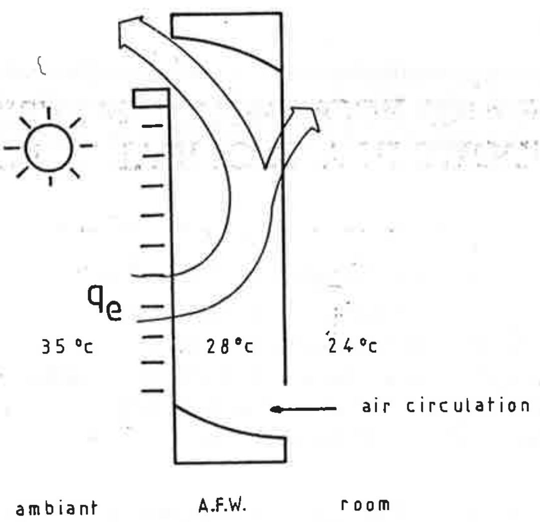

Figure 1. Air flow window. Heat (q_e) is partly evacuated by air circulation, thus decreasing the amount reaching the room

which found 0·7 W/m^2°C and an acoustic attenuation of 38 to 45 db. In France Miquel and Bonvéhi (1984) found 0·7 to 1 W/m^2°C for a double glazing AFW, this time in a moderate region.

In air-conditioned buildings, the heat absorbed by an internal blind increases the temperature of the air in the channel and reduces its insulating effect. As this effect is strongly dependent on the solar flux, the behaviour of a window equipped with an internal blind is not predictable. With the outside blind described below, we found a heat transfer coefficient of 0·4 to 1·25 W/m^2°C depending on the air flow.

Tinted glass AFW

Absorbent glass will transform the absorbed solar flux into heat, and transmit part of it to the air-conditioned space. In an AFW the air flow evacuates the solar heat before it reaches the room (Figure 2). In this case the performance of the window depends mainly on the panes's absorbtivity.

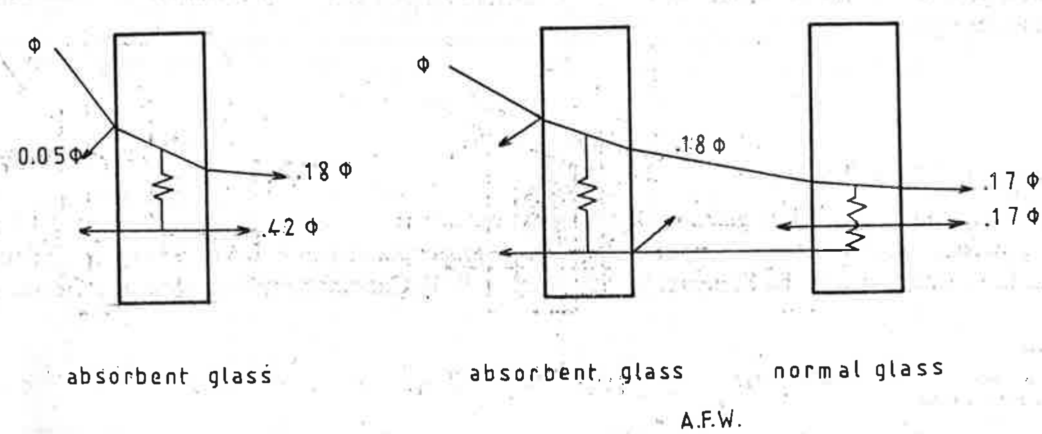

Figure 2. Solar heat gain in a grey absorbent glass pane (60 per cent of the solar flux ϕ reaches the room), and in an AFW equipped with an outer absorbent glass (34 per cent of the solar flux reaches the room)—wind < 2m/s

Effect of the blind's position

The channel air temperature was recorded in two windows, one with a blind in the air channel and the other with an external blind. Since the buffer effect of the window decreases as the channel air temperature increases, it is clear from our experimental results, shown in Figure 3, that an internal blind is not the most suitable for hot, tropical countries.

Number of glazings

In tropical countries, such as Thailand, the difference between room and outside temperature is small: 5 to 9°C, and the associated energy gain for the building is moderate.

In this case a triple glazed AFW is not economical. It would only be viable for very hot countries. In Europe the outside glazing is doubled to retain the solar flux absorbed by the blind (Figure 4). In hot countries the inside glass should be doubled to prevent the heat flow from entering the room. Triple glazing in a building heated and cooled alternately would be efficient but only seasonally.

TEST OF THE AFW IN TROPICAL CLIMATE

A 20 m³ air-conditioned test-house was built in the energy park of the Asian Institute of Technology, Thailand (Figure 5).

Three façades (East, South and West) are fitted with two 1 × 2·3 m removable panels. Each panel may be a complete wall, a standard window, or an air flow window.

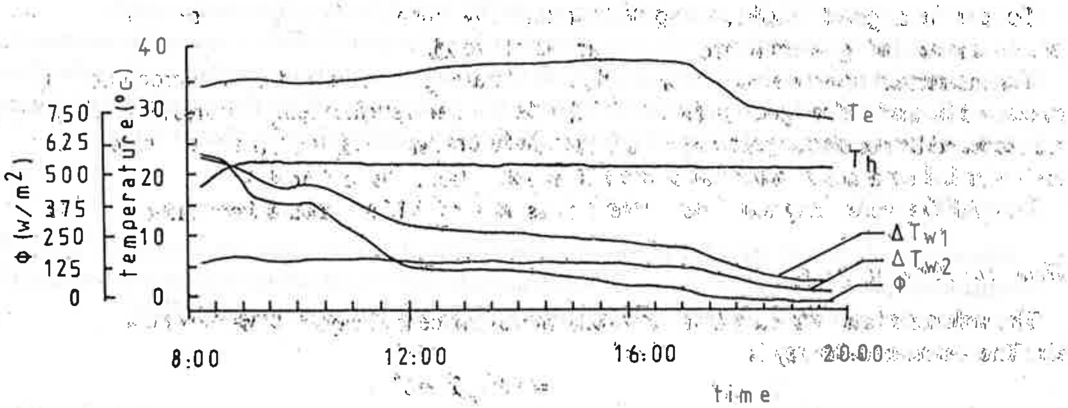

Figure 3. Windows behaviour according to the blind's position. Date: 26 May. Air flow: 20 m³/h. Window position: East. Window 1: external blind $\Delta T_{w1} = (T_o - T_i)_{w1}$ where T_o and T_i are the air temperatures at the output and input of the air channel. Window 2: internal blind $\Delta T_{w2} = (T_o - T_i)_{w2}$. ϕ is the solar flux; T_a and T_h are the ambient and the room temperatures

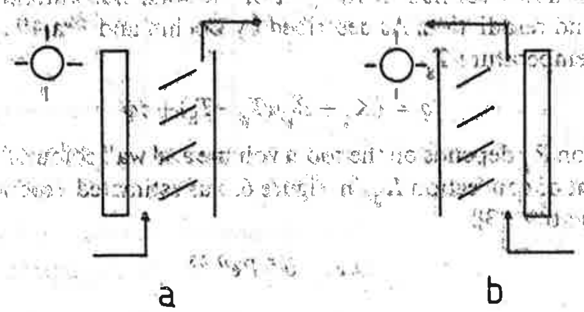

Figure 4. Design of a triple glazed AFW adapted for cold climate (a), and for hot climate (b)

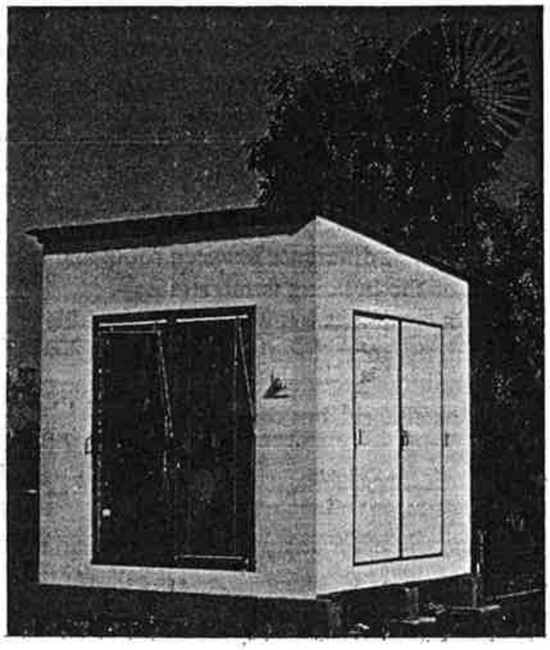

Figure 5. Test facilities and experimental AFW

To obtain a good insulation coefficient and low inertia, the walls were made of asbestos cement, polyurethane and gypsum board. The frame is of wood.

The instrumentation consists of a 32 channel datalogger monitored by a microcomputer. Solar energy is measured behind a clear glass and an AFW. Air flow, air and surface temperatures along the AFWs air channel are recorded by the datalogger every 5 minutes, 24 hours per day. Direct solar flux, wind velocity and humidity are recorded by a meteorological station 20 m away from the test house.

Two AFWs were designed. They have a glass area of 2·16 m², and a 6 cm thick air channel.

Heat transfer coefficient

The volume of air extracted from any conditioned space is always replaced by an equal volume of ambient air. The associated energy is

$$q = \dot{m}C_p(T_e - T_h)\eta \tag{1}$$

where η is the coefficient of performance of the air conditioner and the T_e and T_h the ambient room temperatures.

It should be mentioned that the rejection of air from the air-conditioned space either directly by a mechanical extractor or indirectly by circulation through the AFW, in no way affects the above energy gain.

The energy gain in the window consists of the part of the solar flux entering the room, $\tau\phi$, and the heat transfered by convection and reradiation. As described by Boehm and Brandle (1980), it can be estimated in terms of the inside glass temperature T_g.

$$q = (K_g + R_g)(T_g - T_h) + \tau\phi \tag{2}$$

The coefficient of radiation R_g depends on the room volume and wall colour. For our test-room we obtained 4·3 W/m²°C. The coefficient of convection K_g, in Figure 6, was estimated experimentally by Wiart (1981) and can be calculated from equation (3).

$$Nu = 0{\cdot}5\, Re^{0{\cdot}25} \tag{3}$$

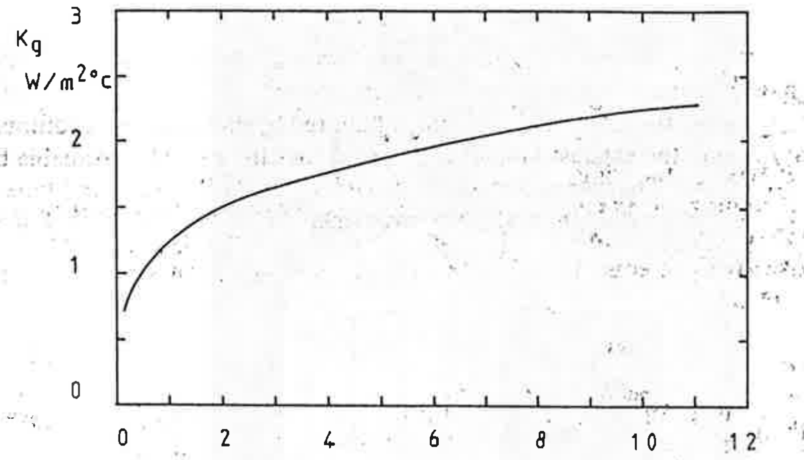

Figure 6. Coefficient of convection K_g between the indoor glass and the room against the temperature difference $T_g - T_h$

As it is difficult to estimate the glass temperature T_g, the window energy gain cannot be assessed with complete accuracy in a window fitted with an outside blind, the air and glass temperatures depend not so much on the solar flow as on the air flow. The thermal gain can be estimated from

$$q = \mathrm{CT}(T_e - T_h) + \tau\phi \tag{4}$$

where CT is an average heat transfer coefficient depending on the air flow. From our experiments we found that $\mathrm{CT} = am^b$ with $a = 1{\cdot}234$, $b = -0{\cdot}249$; m is the volume air flow (m^3/h) for a window with a glass area of $1 \times 2{\cdot}16\,m^2$ (Figure 7). CT is given in $W/m^2\,°C$.

In natural convection we found $\mathrm{CT} = 1{\cdot}25\,W/m^2\,°C$. These figures should be compared to the heat transfer coefficient for a single glass ($5{\cdot}3\,W/m^2\,°C$) and for a double glass window ($3{\cdot}5\,W/m^2\,°C$).

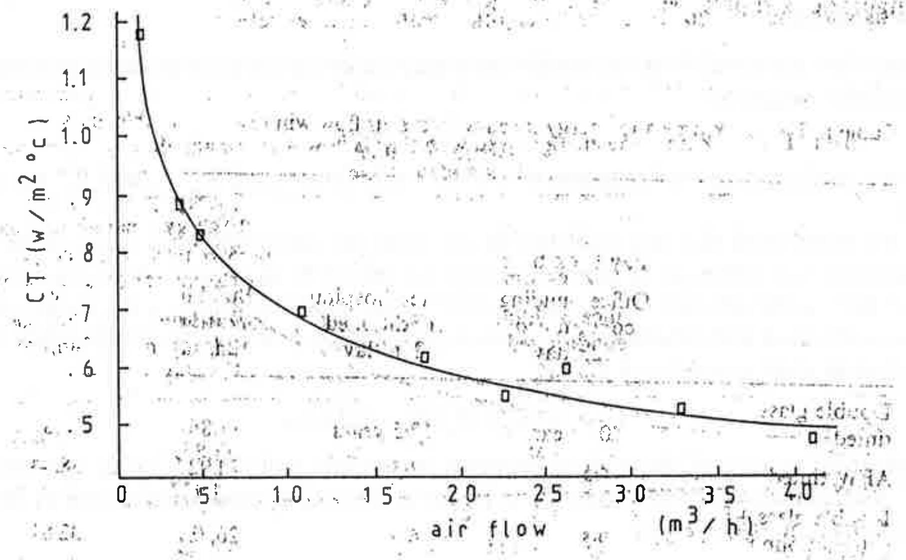

Figure 7. Heat transfer coefficient CT for an AFW equipped with an external blind.

ECONOMIC ANALYSIS FOR THAILAND

A well oriented 6-storey building was selected for our analysis. The building façades faces south with large glazed areas on the north and south.

The study is based on analysis of the additional investment required by more glazing, additional blinds, air conduits, and the cost of running the exhaust fans. It is assumed that the capital is available but could be invested at a 10 per cent interest rate. The energy cost is assumed to be constant. By pay-back time we mean the time needed for cumulative saving to equal the additional investment cost for an AFW or double glazing as compared to the cost of tinted glass.

Extraction by exhaust fan

A fan increases the air flow in an AFW, and thus reduces the heat transfer coefficient. However, because of the electricity consumed, the pay-back time of an AFW equipped with a fan is not less than 20 years in Thailand.

Extraction by hybrid convection

Air flows by natural convection and because of pressurization in the building by air-conditioner fans. The pay-back time depends on the cost of the window frame and the building's daily occupancy rate (Table I). It should be noted that the effect of the thermal inertia of the building has been neglected.

CONCLUSION

This study has shown that suitably modified AFWs can be used to reduce the cooling load requirement of air conditioned buildings in tropical climates. However their economic viability depends upon the specific climate and location. For regions such as Thailand where the difference in temperature between conditioned and ambient air is small, the benefits in using an AFW are fewer than for regions such as Singapore where the temperature difference and electricity costs are higher.

The exact economic merits of an AFW can only be evaluated by a case study for a specific application and at a given location. This study is limited to an AFW 1 m × 2·16 m high with a channel thickness of 6 cm. Since the thermal characteristics of this AFW are dependent on these physical dimensions, further studies on windows of different configurations should be made to enable greater generalization.

Table I. Pay-back time and energy saved with the air flow window and double glass window (wooden frame)

	Pay back time		Energy saved per year (kWh) compared to the performance of tinted glass	
	Office building conditioned 12h/day	Hotel, hospital conditioned 24h/day	Building conditioned 12h/day	Building conditioned 24h/day
Double glass tinted	20 years	12·5 years	11,861	17,879
AFW tinted	14·5	8·5	24,927	38,447
Double glass + external blind	9·5	6·5	26,787	32,815
AFW + external blind	8·5	5·5	32,342	45,714

ACKNOWLEDGEMENT

The work described in this paper was developed in close collaboration with the ENSAT laboratory. It was funded by the French Agency for Energy Management (AFME).

REFERENCES

Boehm, R. F. and Brandle, K. (1980). 'Solar energy transfer using window collectors', *Proceeding of the Western Sun* 1980 *Conference* 800995, pp. 157–161.

Chapman, W. F. (1979). 'Less refrigeration, more glass, a compatible idea?', *ASHRAE Journal*, **79**, 31–33.

Miquel, J. F. and Bonvéhi, F. (1984). 'Modelisation et expérimentation de lames d'air ventilées', *Final report*, Ecole Nationale Supérieure Agronomique-B.T.S., 31076 Toulouse, France.

Sodegren, D. and Bostrom, T. (1971). 'Ventilating with an exhaust air window', *ASHRAE Journal*, **71**, 51–57.

Wiart, L. B. (1981). 'Etude des mouvements convectifs dans un mur serre à l'aide d'un thermoanémomètre à impulsions', *Thèse de 3ème cycle*, Université P. Sabatier, Toulouse, France.