...ntage of time the room is uncomfortable (i.e. PPD > 10 %), we ...r and it is only for 20 % of the time that the room is a little too ...1 nobody uses the blind and windows correctly, the room can ...le. In figure 5 it can be seen how the temperatures reached 30°C ...they had been only 26°C on the weekdays before.

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...ater wall and PCM wall

...no significant differences in the comfort between the two half-units (east : ...est : PCM wall). The only differences are on the surface temperatures of the ...(figure 6). The temperature variations of the PCM wall are 2.4 times greater ...the water wall. This is due to the small storage capacity of the PCM wall which ...MJ K-1, whereas the water wall has 2.75 MJ K-1, and to the too high fusion ...of the PCM (31°C) which is seldom reached (during the heating season the PCM ...id only between 10 and 15 times). But these differences are not felt by the

5. Conclusion

...W offers excellent thermal efficiency and comfort level and is one of the best ...ed on the LESO building.

...gh insulation factor due to the double skin and the local storage capacity of the ...to low energy consumption.

...iter, the double skin with selective inner double glazing provides good thermal ...ven during the coldest periods. In summer, with well-instructed users, the correct ...ar protections and windows (during the day) and the possibilities of ventilation ...night) also allow good thermal comfort.

...is no need to use sophisticated systems. The PCM wall did not lead to better ...erformance or better thermal comfort.

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THE BARRA THERMOSYPHON AIR SYSTEM RESIDENTIAL AND AGRICULTURAL APPLICATIONS IN ITALY, IN THE UK AND IN THE SAHARA DESERT

OA.Barra*, G.Artese**, L.Franceschi**,
RK.Joels*** and A.Nicoletti**

*Physics Department, University of Calabria, 87030 Cosenza (Italy)

**LIFE Limited, Via Amerigo Guasti 9, 00139 Rome (Italy)

***Commission of the European Communities, DGXVII, 200 Rue de la Loi, B-1049 Bruxelles (Belgium)

1. Introduction

The Barra Thermosyphon Air System is a passive solar system suitable for single and multi-storey residential, agricultural and industrial buildings. It was conceived, modelled and set up in the 1970's as an evolution of the Trombe wall. As such as it was supposed to overcome most of its limits.

The Barra system was installed in over 100 houses throughout the world. The applications include an office block in the Egyptian Sahara desert where the system is used for cooling purposes.

In Figure 1., the four typical modes of operation of the system are given (N - S vertical cutaway sections. The main elements of the system are shown here: storage and air ducts in the ceiling, and insulated solar chimney on the south facade.

If a proper use of the dampers is ensured the system will allow for high overall efficiency in any climate conditions. Horizontal air distribution is possible and heavy walls are not required, which means no architectural limit. The following are typical characteristics of the system:

- The building is thermally isolated from the collector
- storage heat losses are nihil.

High turbulence in the chimeny can be achieved. This allows for high heat transfer and therefore, low absorber temperature and high efficiency.

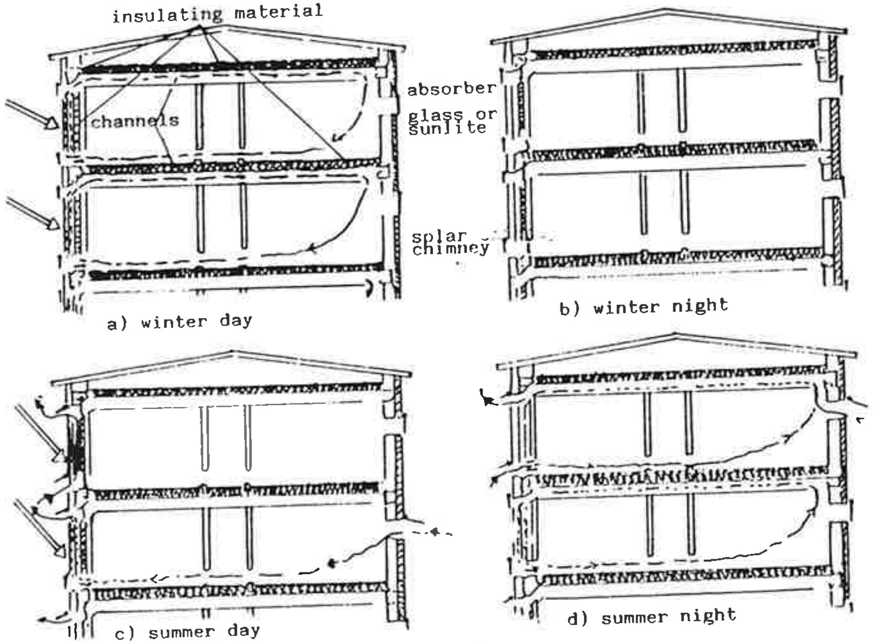

FIGURE 1. Schematic diagram of the system

In this paper particular attention will be given to an agricultural application in Verona, Italy, for the thermoventilation of pig sties. This project, which was sponsored by DG XVII of the EEC under contract n° SE/662/83, is interesting because the Barra system was modified to suit the particular geometry of pig sties.

2. Scientific Results

In about ten years of scientific activities, a sophisticated computer model of the system has been set up and many experimental measurements have been carried out. The former is described elsewhere in the literature (1, 2, 3, 4). The latter are summarized hereinafter. Figure 2 shows the measured air velocity profiles in the chimney gap, i.e., for various chimney depths d - for several insolation values Iv on vertical surface and different gaps between glass and wall, D, and wall and absorber, D_A, respectively.

The following correspondence in valid:

Curve	D (cm)	D_A (cm)	I_v (W/sm)	Curve	D (cm)	D_A (cm)	I_v (W/sm)
1	9	4.5	600	6	13	6.5	250
2	9	7	400	7	18	12	500
3	9	4.5	250	8	18	9	350
4	13	6.5	500	9	18	9	200
5	13	6.5	500				

The results suggest that higher insolation values and narrower gaps ensure turbulence. The profiles indeed, although in natural convection and asymmetric boundary conditions, are similar to the Nikuradse profiles more than to the Poisenille ones, and the Reynolds numer ranges between 2000 and 4000.

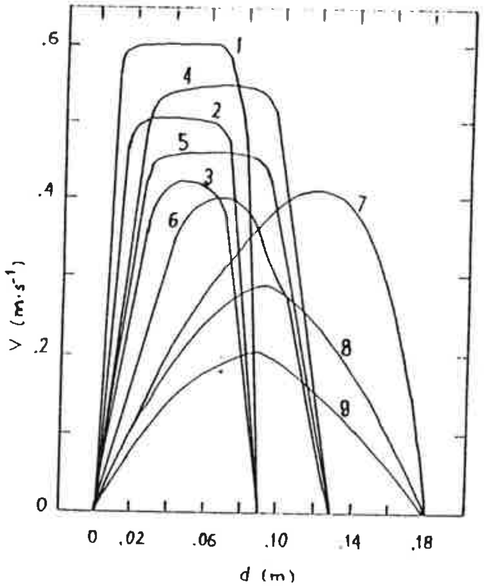

FIGURE 2. Air velocity profiles measured in different conditions

Figure 3 shows the measured chimney efficiency for different insolation I_v with different distances D and D_A as specified below:

Curve	D (cm)	D_A (cm)	Curve	D (cm)	D_A (cm)
1	9	4.5	4	13	9
2	9	6	5	18	9
3	13	6.5	6	18	12

The results indicate that for low insolation values larger gaps are better due to lower induced head losses. For high insolation values smaller gaps lead to absolute higher efficiency. This is also true because of the turbulence regime which in this condition would more easily take place.

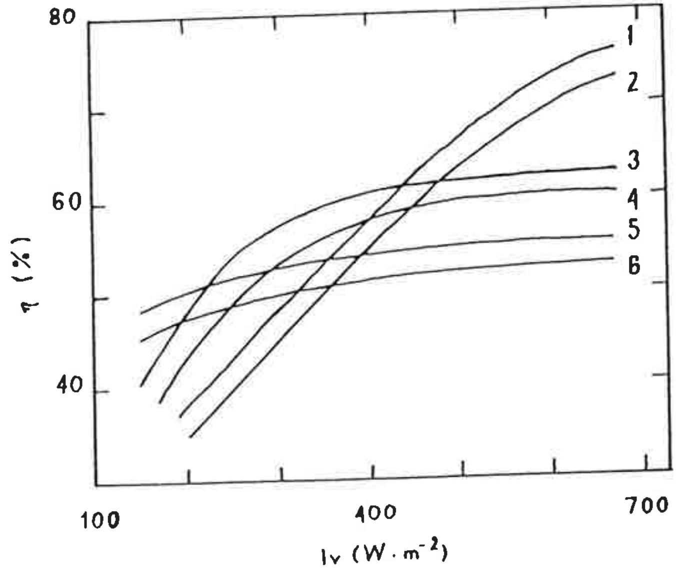

FIGURE 3. Chimney efficiency measured in different conditions

Furthermore all the experimental data today available allows to summarize the heat and mass transfer phenomena in the solar chimney by means of the following dimensionless equation:

$$Nu = 1.35\ Gr^{0.22} \qquad (1)$$

where the reference temperature in the Grashof number, Gr, has been assumed equal to the indoor ambient temperature and the convective coefficient h in the Nusselt number, Nu, has been assumed to represent the convective heat transfer absorber-air on both sides of the absorber. Eq (1) is the best fit of experimental data with a correlation coefficient r = 0.92 and it is valid for

$$10^6 < Gr < 5.10^7$$

Different absorber have also been tested. Detailed results are referred elsewhere (5), but in any case louver screens, blackned on the south facing side, should be preferred.

Finally as an example, figure 4 gives an idea of the overall building performance registered on the Salisano house in three consecutive days. Indoor Ti and outdoor To temperatures are represented hour by hour (refer to right hand scale on Figure 4) together with insolation Iv on vertical chimney surface S and the useful heat Pu extracted from the chimney (refer to left hand scale on Figure 4.).

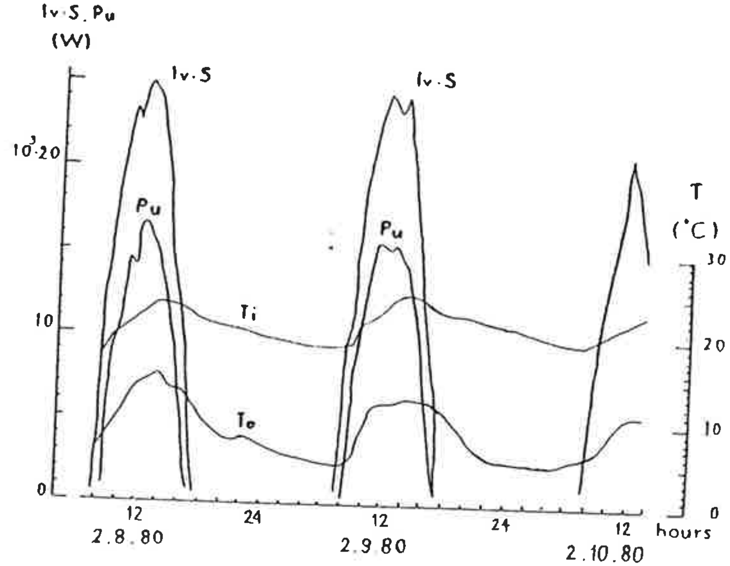

FIGURE 4. Overall Salisano house performance

3. Applications in Italy and in the UK (Ongoing Experiments Only)

Table 1 summarize the applications of the system, already accomplished, in Italy and in UK, together with the main characteristics and performance of each of them. The table speaks for itself but it is worth spending a few words of explanation.

It can be seen from the table that the Barra system was used in Italy in the residential as well as commercial and agricultural sectors whereas in the UK only residential applications have been carried out. The main reason lies in the fact that in the UK the research on TAP only started in 1983. It is hoped that the projects in the commercial and agricultural sectors will start in 1985.

The most recent and very interesting application in Italy is the Verona pig sty sponsored by the EEC where the system is used for heating as well as ventilation of building.

In this project both the traditional Barra system and a modified version of it were used. It was necessary to modify the Barra system in view of the particular geometry of the pig sties which do not have enough vertical south surfaces available for solar panels, whereas they have big pitched roofs suitable to house the collectors.

S I T E	DEGREE DAYS	HORIZONTAL INSOLATION IN JAN (Kwh/m^2 month)	BUILDING VOLUME V (m^3)	SOLAR CHIMNEY AREA S (m^2)	RATIO SV (m^{-1})	SOLAR HEATING FRACTION SHF %	TYPE OF BUILDING AND STOREYS	SPONSOR	TYPE OF CEILING (STORAGE)	YEAR	N O T E
Salisano (I)	2207	42	380	33	0.087	75 - 85	Residential house 2	Private	Concrete slabs	1979	
Castrovillari (I)	1016	50	1500	170	0.11	85 - 95	School 1	National Council of Research	Concrete slabs	1980	
Catania (I)	689	54	4378	198	0.045	72	Office Building 4	Private	Concrete slabs	1983	Both winter heating and summer cooling
Marostica (I)	2300	35	10000	585	0.059	50	Residential Block of flats 2 to 4	Private	Prefabricated slabs	1983	
Verona (I)	2054	35	7000	500	1/14	90 and 90 ventilation	Pig sty	EEC Contract SE 662/83	Concrete slabs	1984	Special project for summer and winter thermo ventilation of pig sty
Maple Cross Watford (UK)	2794	20	100	10	0.1	30	Residential house 2	ETSU DEn Contract E/5A/CON/1137/897	Timber suspended ducts	1983	Only part of the house was to be heated by the solar passive facility
Kirkcaldy Edinburgh (UK)	3511	15	200	17	0.085	UNDER MONITORING FORESEEN 30	Residential house 2	EEC Contract SE 594/83	Timber suspended ducts	1984	Installation finished end of 1984
Dalgety Bay Edinburgh (UK)	3511	15	50	5	0.1	UNDER MONITORING FORESEEN 40	Residential house 2	EEC Contract SE 594/83	Timber suspended ducts	1984	Installation finished end of 1984 Wimpey timber framed house
Bristol (UK)	3157	12	110	10	0.091	UNDER MONITORING FORESEEN 45	Residential farmhouse 2	EEC Contract SE 594/83	Timber suspended ducts	1984	Installation finished end of 1984
Plymouth (UK)	3145	16	30	7.5	0.094	UNDER MONITORING FORESEEN 38	Residential house 2	EEC contract SE 594/83	Timber suspended ducts	1984	Installation finished end of 1984
Leigh on Sea (UK)	3034	16	60	5	0.083	UNDER MONITORING FORESEEN 30	Residential house 2	EEC Contract SE 594/83	Timber suspended ducts	1984	Installation finished end of 1984

TABLE 1. ONGOING APPLICATIONS IN ITALY AND IN THE UK

A schematic of the modified Barra system is given in Figure 5. A total of about 600 sm of pig sties were retrofitted, 150 sm with the traditional Barra system and 450 sm with the modified version.

Monitoring in both sties ended in January 1987 and the final results will be published shortly. Preliminary results seem to indicate the following situation for a sty of 88 sm with 224 adult animals and retrofitted with 24 sm of solar panels, modified version type:

a) Winter conditions:
 - the internal air temperature can be considered constant around 19°C when the outside temperature ranges between -5 - 12°C in the 24 hours, whereas the panels reach an internal temperature of 40°C.

b) Summer conditions:
 - the internal air temperature at midday are 2-3°C above the ambient temperature instead of about 10°C or more without the thermo-ventilation system, whereas the panels reach temperatures of the order of 80°C.
 - without auxiliary system 5-7 ac/h guaranteed.

It is worth mentioning that the number of animals for unit area could be increased from 7 to 10 thank to the use of the Barra system.

A semi-detached house in Maple Cross, Watford was the first house retrofitted in the UK under a DEn-ETSU contract. System performance was good.

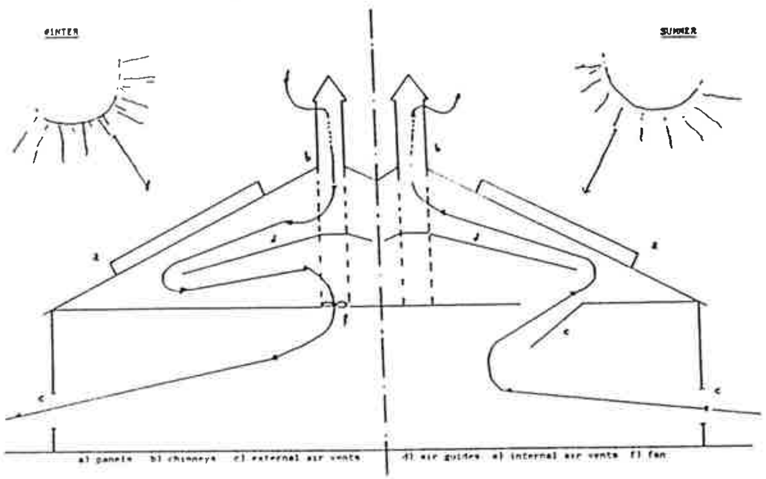

FIGURE 5. System modes of operation: Winter and Summer

The panel reached an average efficiency of 51% with an insolation level of about 580 W/sm in February. A temperature difference across inlet and outlet of 18°C and an absorber temperature of 48°C were measured when the average external temperature was 4°C.

The storage in the timber suspended floor ceiling behaved as predicted in the theoretical study. A maximum temperature difference across the storage of 14°C was measured in February.

The house performance was remarkably good. The internal temperature did not drop below 10°C when the outside temperature was -2°C in February. The house was unoccupied during the day and heating was only provided by means of a 2 KW gas fire in the lounge.

Five more houses, described in the table below, have been retrofitted in 1984 under the EEC contract n° SE/594/83. One of the houses is built in Timber frame, a typical english construction tecnique.

The monitoring ended in summer 1986 and the results will be published shortly.

It is interesting to note here that Italian panels were used in the Maple Cross house whereas UK manufactured panels developed under a DTI grant were used in the five houses involved in the EEC project.

More results on the DEn and EEC projects will be published in forthcoming papers.

Two more projects sponsored by the EEC, the first, to be built two passive greenhouses one in Italy and one in the UK, using the Barra TAP system and the second to built an Urban Greehouse in Caramanico, Pescara, Italy, started end of 1986 and they will be object of future pubblications.

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DEVELOPMENT AND PERFORMANCE OF MOVABLE SUNSPACES IN APARTMENT BUILDINGS

R. FANKHAUSER, HP. EICHER, H.-J. GÜNTHERODT
Institut für Physik der Universität Basel
CH-4056 Basel, Switzerland

M. STEINMANN
Ökozentrum Langenbruck
CH-4438 Langenbruck, Switzerland

1. Introduction

Movable sunspaces in apartment buildings allow in a simple way the passive use of solar energy during the winter season. Many existing residential houses have facades with balconies. In this case sunspaces are the only possibility to reduce the heat loss of the facade. Five different systems of movable sunspaces were developed in co-operation with Swiss industry. Eight sunspaces were installed in an apartment building and their performance was monitored during three winter seasons. The sunspaces were equiped with single glazing in the first winter. The following year different double and triple glazings were installed. During the last winter season the apartments were monitored without the sunspaces.

2. Description of the building and the sunspaces

The eight monitored apartments are located in a six floor high and south-oriented building. Figure 1 shows the facade of the building with the sunspaces. The mean U-value of the apartments is 1.8 W/m^{2}K because of the great window area and the badly insulated walls. The ground-plan of the flats is shown in figure 2.

Fig.1. Test building with sunspaces

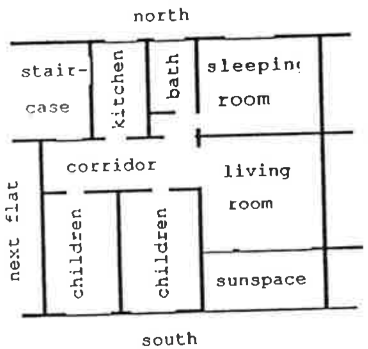

Fig.2. Ground-plan of apartments

The dimensions of the sunspaces are 4.5m x 1.8m x 2.7m. The glazing area is equal to the floor area ($\cong 8m^2$). Though the movable glazing systems are different to open, they all can completely be opened in summer. Figure 3 shows an overview of the different systems.

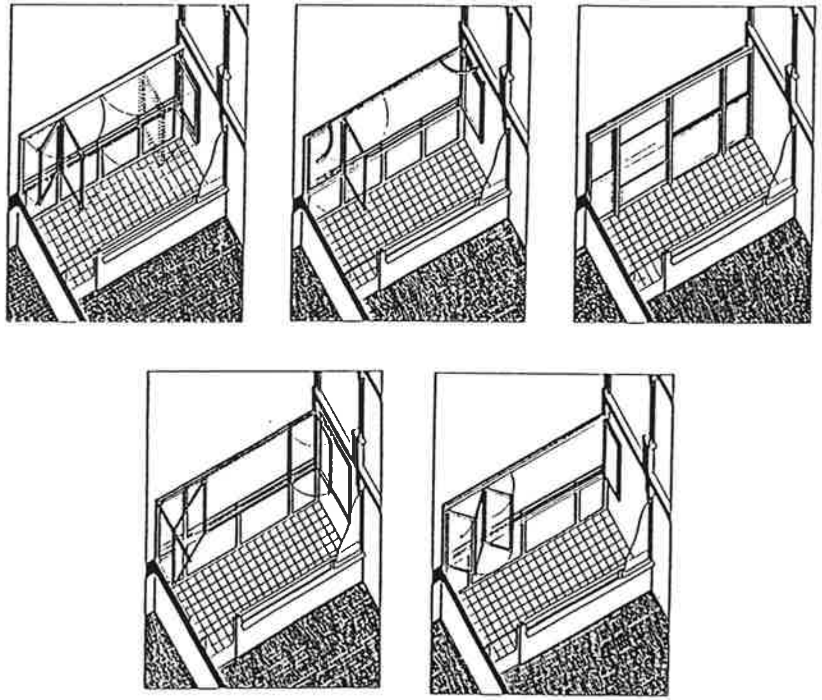

Fig.3. The movable glazing systems

The frames of the systems are all made of aluminium and are not insulated. They can be equiped with single, double and triple glazing. Figure 4 and 5 show two sunspaces from the inside.

Fig.4. sunspace from inside

Fig.5. sunspace from inside

3. Measurements and Data Collection

In order to study the effect of the sunspaces on heat energy consumption and the behaviour of the sunspace climate the following quantities were monitored:

- climatic data (outdoor temperature, global and diffuse solar radiation, wind speed, air humidity)
- sunspace and indoor air temperature
- auxiliary heat consumption
- position of the sunspace windows and the door between sunspace and apartment

The outputs of the sensors were transfered to a personal computer which averaged and recorded the data each hour. The data acquisition scheme is shown in figure 6.

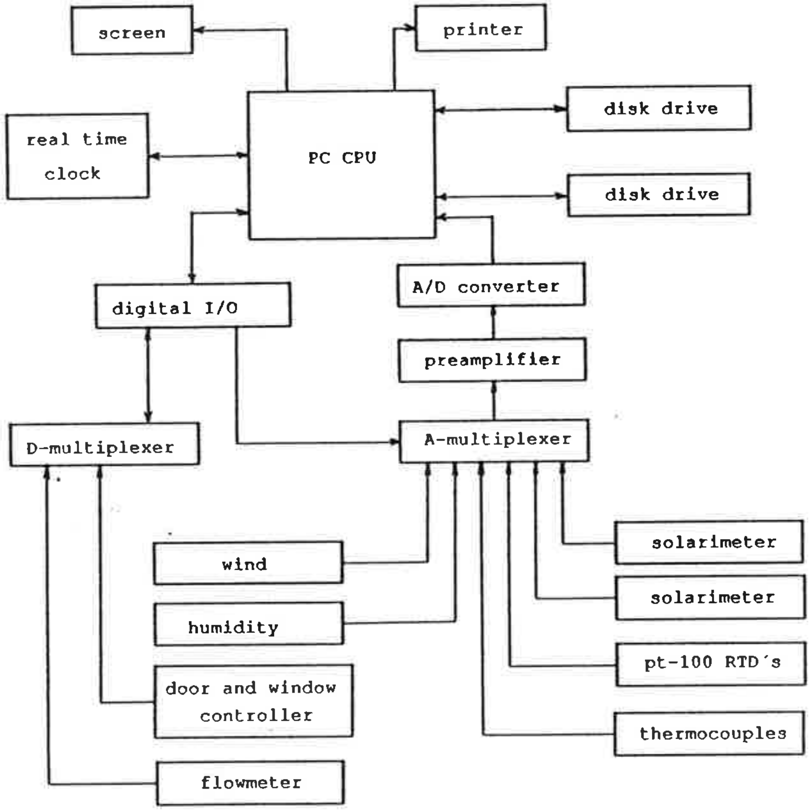

Fig.6. Data acquisition scheme

4. Results

4.1. General Results

The following conclusions have been obtained through the experiences of the occupants:

- the sunspaces shelter from noise, wind and dust
- it should be possible to close the glazing in summer too in order to use the sunspaces on rainy days and cool nights
- the way how to open the system is not very important to the user. All occupants were satisfied with their allocated sunspace
- the systems should be easy to handle and to clean. This requirement was fulfilled by most of the studied systems
- water condensation occuring on single glazing is a big problem, but correct airing and low absolute indoor humidity can prevent the condensation
- the blinds were rarely used because overheating was not a problem

4.2. Sunspace climate

The sunspaces were equiped with single glazing in the winter 1984/85 and with double/triple glazing in the winter 1985/86. In order to compare the results of the two periods with different outdoor climate the data measurements is analyzed by a multi-linear regression of the form:

$$T_{ss} = a\ T_{out} + b\ G_v + T_o$$

where T_{ss}: sunspace air temperature
T_{out}: outdoor temperature
G_v: vertical south radiation

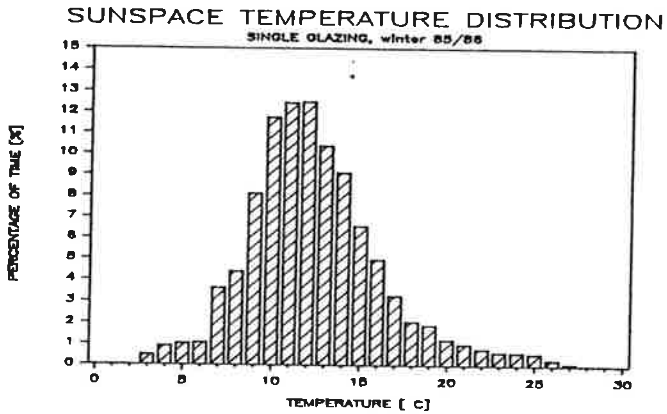

Fig.7. Sunspace temperature distribution for single glazing

Figure 7 and 8 show the sunspace temperature distributions for single and triple glazing estimated for the outdoor climate of winter 1985/86 by multi-linear regression of the data measurements. Triple glazing stabilizes the sunspace climate. With single glazing the temperature is in a wider range and even falls under zero for few hours.

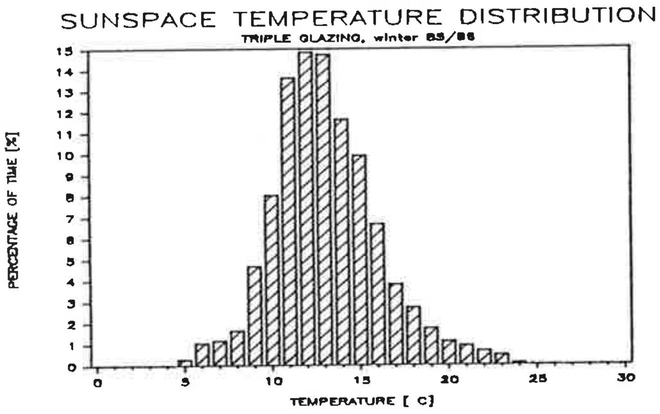

Fig.8. Sunspace temperature distribution for triple glazing

The monthly average of the daily sunspace temperature course for single and triple glazing of two extremely cold months (Jan 85 and Feb 86) is drawn in figure 9. The data measurements show no difference in temperature between double, infrared coated double and triple glazing.

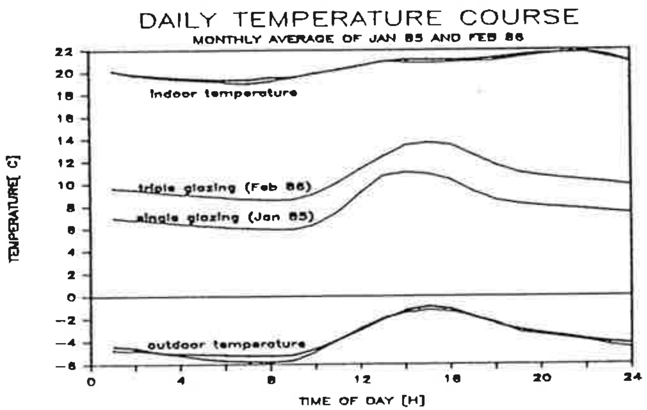

Fig.9. Daily sunspace temperature course for cold days

4.3 Heat energy consumption

To analyze the effect of the single and double/triple glazing sunspaces on the heat energy consumption of the apartments three months of the three different winters (Jan 85, Feb 86 and Jan 87) with nearly the same average outdoor temperature are taken. The energy consumptions are corrected with regard to outdoor and indoor temperature. Figure 10 show the heat consumption of the apartments without (NO) and with single (SG), double (DG) and triple (TG) glazing sunspaces. The consumption is devided in three parts: the consumption of the room behind the sunspace (living room), the room besides and the remaining rooms of the flat.

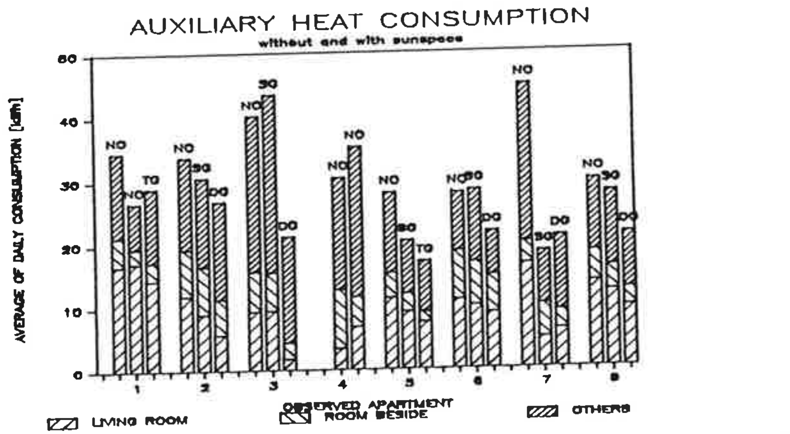

Fig.10. Heat energy consumption of the observed apartments

The occupants of apartment 4 did not use the sunspace, they always let the glazing open. In apartment 7 the occupants have changed. For that

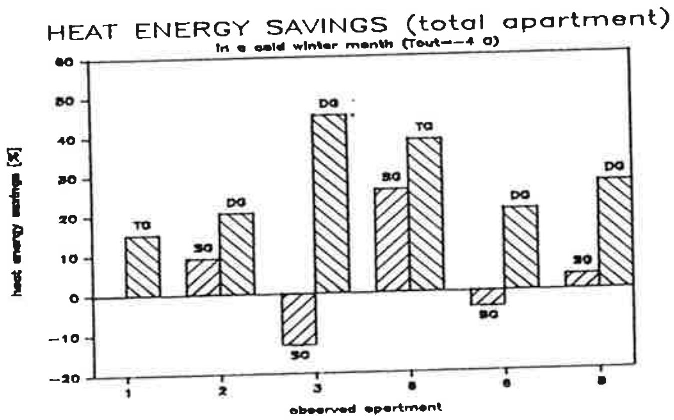

Fig.11. Energy savings to the whole apartment

reason these two apartments will not be considered in the further discussion. The heat energy savings with double glazing sunspaces are evident (Figure 12) with respect to the living room which is behind the sunspace, but even to the whole apartment (Figure 11). The effect of

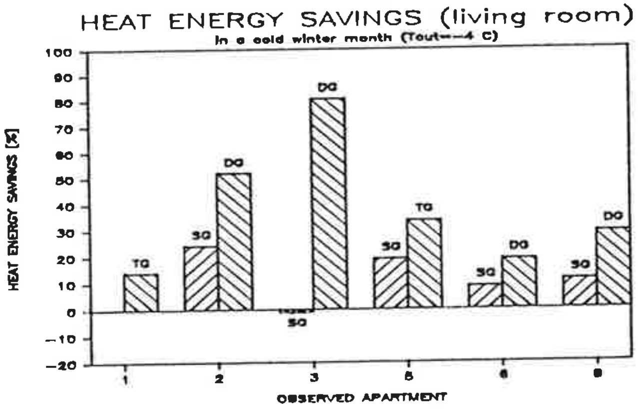

Fig.12. Energy savings to the room behind the sunspace

the single glazing sunspaces on the heat consumption is not so definite. The behaviour of the occupants is more important. Opened doors to the sunspace can lead to an increase of heat consumption (Figure 13 : apartment 3).

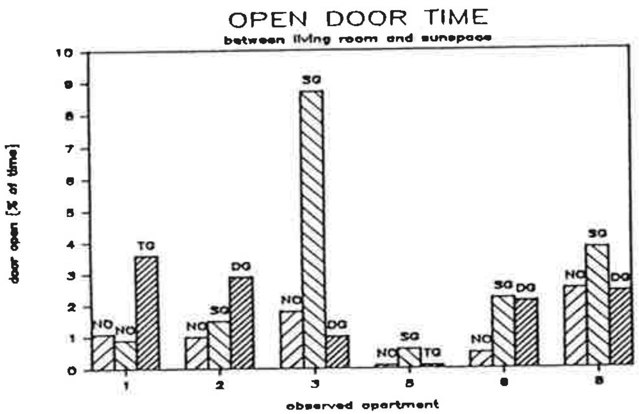

Fig.13. time of opened door between room and sunspace

5. Conclusions

The following conclusions can be drawn from the measurements:

- the monitored movable sunspaces are efficient in saving heat energy
- single glazing sunspaces are very sensitive to the behaviour of the occupants. Problems with condensed water on single glazing lead to an increase in the time of opened door between room and sunspace. This can even result in an augmentation of heat energy consumption. For that reason single glazing should only be used if the occupants pay attention to the fact that low absolute indoor humidity and temperature can prevent the condensation of water.
- double glazing sunspaces have reduced the heat energy consumption in all observed apartments. The average reduction is 28%.
- infrared coated double glazing and triple glazing increase the thermal comfort, but no significant differences in heat energy savings and sunspace air temperature were measured in respect to double glazing
- the coefficients of the multi-linear regression for the sunspace air temperature are (see 4.2.):

	single glazing	triple glazing
a ( )	0.554 ± 0.007	0.446 ± 0.006
b (°C/Wh)	0.0111 ± 0.0003	0.0082 ± 0.0002
T_o (°C)	10.9	11.7

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