User Influence upon Building Energy Management

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ABSTRACT

The thermal performance of a residential building has a strong dependence on the local climatic conditions and on its thermal characteristics. Moreover, occupant behavior can have a significant impact. In fact, roller-shade operation can lead to major deviations from the expected thermal performance. The objective of this paper is to assess occupant influence on a house under particular thermal and climatic conditions in Portugal.

Measurements were taken in an energy research building in OPorto, in two rooms of the first floor with basically identical conditions (i.e., equal floor and fenestration areas). Thus, the effects of different solar incidences resulting from distinct patterns of roller-shade could be measured.

A survey was conducted in two multifamily apartment complexes whose occupants come from different social backgrounds. The occupant patterns of roller-shade operation were recorded. The results from the survey were input into numerical simulation procedures and their thermal and energy consequences were obtained.

As a conclusion, we can see that the way in which the occupants operate the building controls is as important as the building thermal characteristics (insulation, thermal inertia, solar apertures) in determining overall building thermal performance.

INTRODUCTION

The cooling load due to solar radiation through fenestration is calculated by:

q = area times shading coefficient times maximum solar heat gain times cooling load factor

The area is the net glass surface of the fenestration. The maximum solar heat gain is obtained for the appropriate latitude, hour, and surface orientation. The cooling load factor

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values are listed (ASHRAE 1981) as a function of the three common room thermal characteristics: the latitude, fenestration facing, and the interior shading (with or without). The shading coefficient can be obtained by a combination of the fenestration and shading device. Moreover, occupant behavior can have a significant impact. In fact, roller-shade operation can lead to major deviations from the expected thermal performance.

MEASUREMENTS IN AN ENERGY RESEARCH BUILDING

Measurements were taken in an energy research building in OPorto (Figure 1), in two rooms of the first floor with basically identical conditions (i.e., equal floor and fenestration areas). Thus, the effects of different solar incidences from distinct patterns of roller-shade were measured (Figure 2).

In room R1 the roller-shade is always closed and in room R3 the roller-shade is completely open from 9 a.m. to 5 p.m. The influence of solar radiation due to the openness of exterior shading increases the indoor temperature by 2°C.

SURVEY

A survey was conducted in two multifamily apartment complexes (Figure 3) whose occupants come from different social backgrounds.

The high standard building is occupied by the owners, where the majority are college graduates. In the social building, the occupants are industry workers and pay a rent to the municipality. The occupant patterns of roller-shade operation were recorded and some results are shown in several figures.

Figure 4 shows the intensity of solar radiation on the horizontal surface during the survey. Figure 5 shows the variation during the day of the openness factor of exterior shading in January and February. The effect of solar radiation is important but not dominant. Figure shows the variation during the day of the openness factor of exterior shading for the high standard building and for the social building.

In the high standard building in which windows have more area than in the social building, the values of the openness factor of exterior shading are superior (5% to 10%). Thus, the contribution of solar radiation to comfort will be much more important in the high standard building than in the social building.

Figures 7 and 8 show the variation during the day of the openness factor of exterior shading as a function of the day (weekday or weekend) for the high standard building and for the social building, respectively. It can be seen that, in the case of the high standard building, the openness factor of exterior shading in the morning is lower during the weekend but increases during the day and in the afternoon presents a value that is above that for weekdays. In the case of the social building, we can see that for the weekend, the openness factor of exterior shading is larger than the corresponding weekday value almost all the time.

NUMERICAL SIMULATION

A numerical simulation with the BETEH program is used to predict the influence of the openness factor of exterior shading.

The BETEH program (Abrantes and Galanis 1981, 1982; Abrantes 1985), based on hour-by-hour heat transfer simulation, uses the so-called ASHRAE weighting factors to incorporate the heat gain effects.

Measured hourly values of the dry-bulb ambient temperature, the global radiation incident on a horizontal surface, and the wind speed and direction constitute the necessary meteorological inputs. A detailed description of the building's position, size, construction characteristics, and environment is also needed for the simulation.

The program calculates the amount of energy necessary to maintain thermal comfort at a desired level or, if the capacity is insufficient, evaluates the new temperature prevailing in each zone.

The effect of having the external shutter opened or closed is expressed by means of the indoor temperature difference for both situations.

Figure 9 shows the increase of indoor temperature for total openness of shading (when compared with the situation where the external shadings are closed) for different solar radiation intensities on a south surface. In winter, it is possible to observe a temperature increase between 2.2 and 3.0°C, but this influence is reduced when the day is cloudy. In summer, the value increase relative to the winter, because the angle of incidence of the sun is much larger than in winter.

Figures 10 and 11 show the increase of indoor temperature for total openness of shading (when compared with the situation where the external shadings are closed) as a function of the opening area for winter and summer, respectively. The values of the temperature increases are near 1.0°C in winter and 1.5°C in summer, when the area is 1.5 times greater.

Figures 12 and 13 show the increase of indoor temperature for total openness of shading (when compared with the situation where the external shadings are closed) for as a function of the surface orientation, for winter and summer respectively. In winter the influence is reduced when the orientation is west or east and the values of the temperature increase are less than 1°C. In summer, for west and east, the values become more relevant, oscillating around 3.5 and 4.5°C, respectively.

Figure 14 shows the results from the survey input and an openness choice that can be considered a good solution. In this case, the roller-shade is closed at night and completely open from 8 a.m. to 5 p.m.

It is possible to observe that the occupants' behavior significantly minimizes the possible effect of exterior shading openness. In winter, if a good choice of openness is used, it is possible to obtain a significant increase in indoor temperature, about 2°C for a southern surface.

CONCLUSIONS

Results of the survey and from the BETEH simulations indicate the following conclusions:

1. The openness factor of exterior shading is a function of the building occupants, climatic conditions, and days of the week.
2. The maximum average value of the exterior openness factor is only about 45%.
3. The influence of the openness of exterior shading on the indoor temperature is a function of the solar radiation intensities, surface orientation, and opening areas.
4. Roller-shade operation has an important influence on the indoor temperature and on thermal and energy performances. An increase of 2°C is possible if a good choice of roller-shade position is made during the day.

REFERENCES

Abrantes, V. 1985. "Un programme de simulation dynamique du comportement thermique des batiments d'habitation." *Proceedings of Eurobuild International Symposium - Computer Application in the Building Industry*, Brussels, Belgique, March.

Abrantes, V. and Galanis, N. 1981. "Prediction and measurement of the dynamic thermal behavior of buildings." *Proceedings of the Eighth Canadian Congress of Applied Mechanics*, Moncton, Canada, June.

Abrantes, V., and Galanis, N. 1982. "Um programa de computador simulando o balanco energetico de edificios para habitacao." *Proceedings of Congresso Iberico de Energia Solar*, Madrid, Spain, September.

ASHRAE. 1981. *ASHRAE handbook - 1981 fundamentals*. Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

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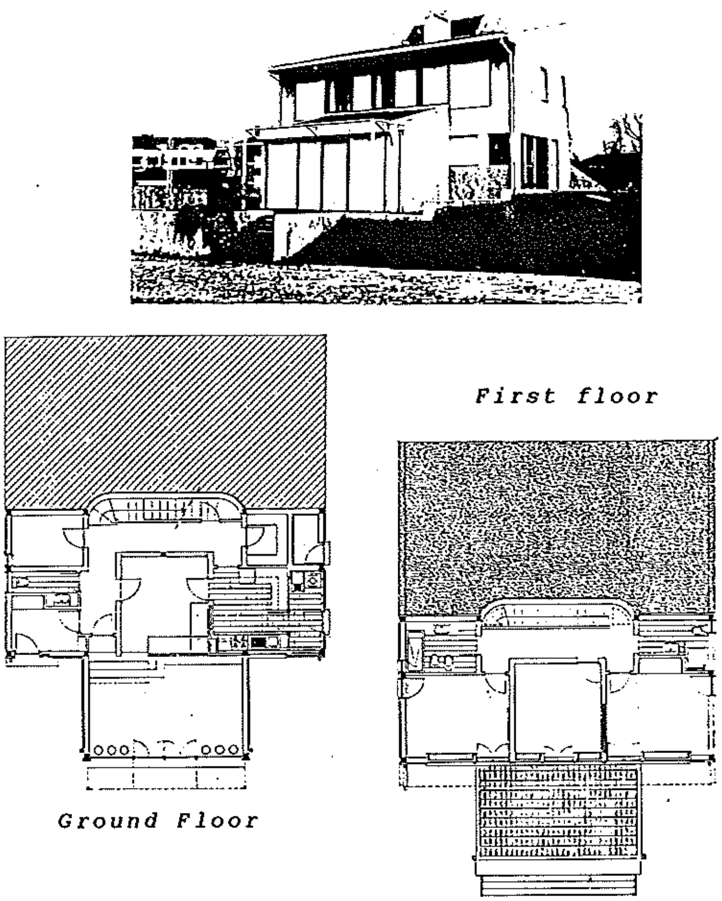


Figure 1. Energy research building

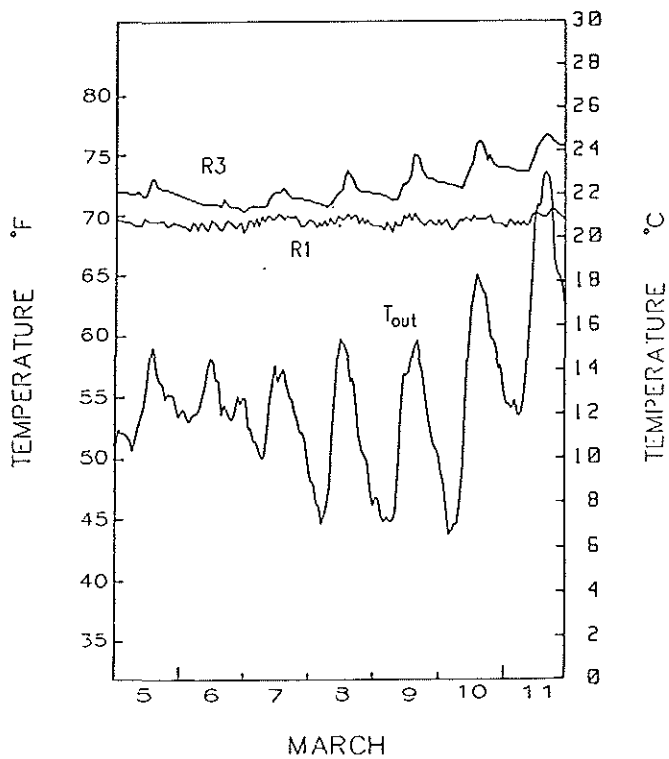
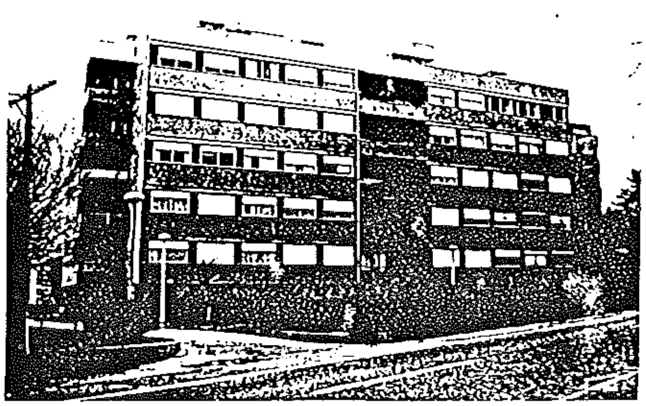
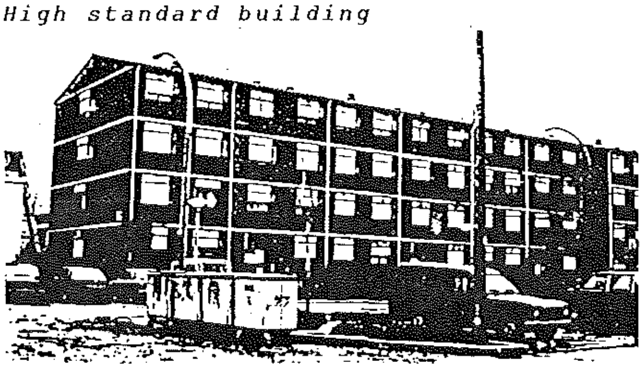


Figure 2. Measurements of indoor and outdoor temperatures at the energy research building



High standard building



Social building

Figure 3. Apartments surveyed

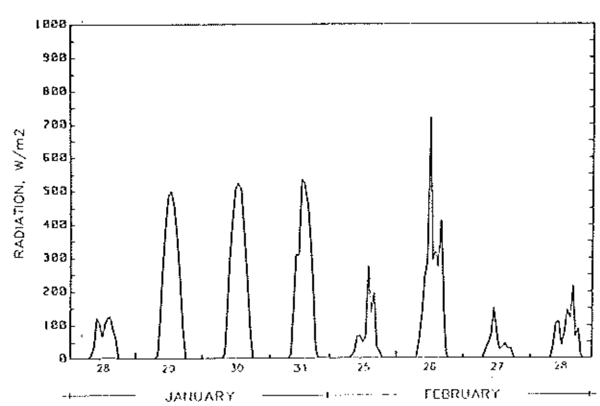


Figure 4. Solar radiation on horizontal surface

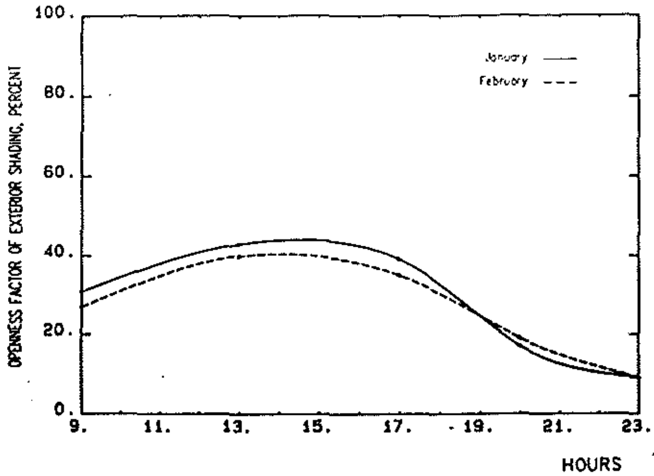


Figure 5. Openness factor of exterior shading vs. hours for different months

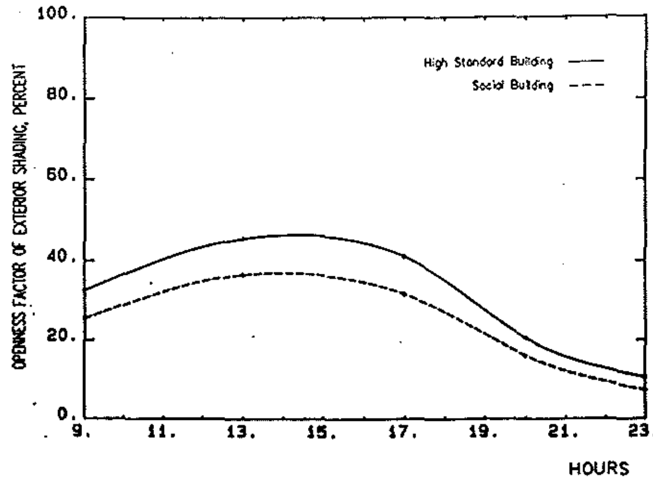


Figure 6. Openness factor of exterior shading vs. hours for different types of buildings

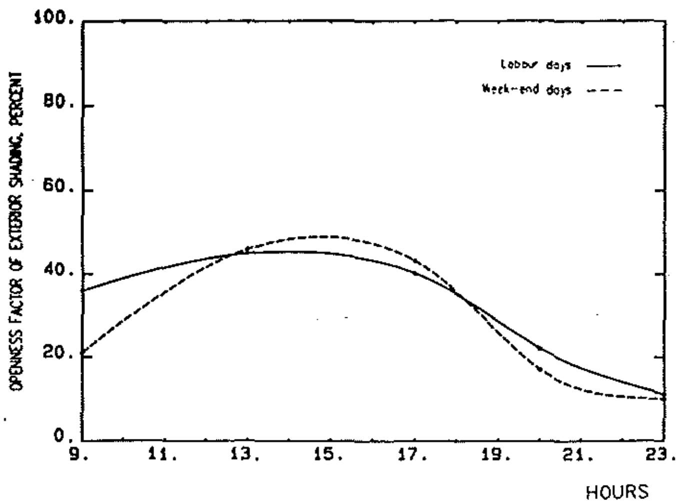


Figure 7. Openness factor of exterior shading vs. hours for a high standard building

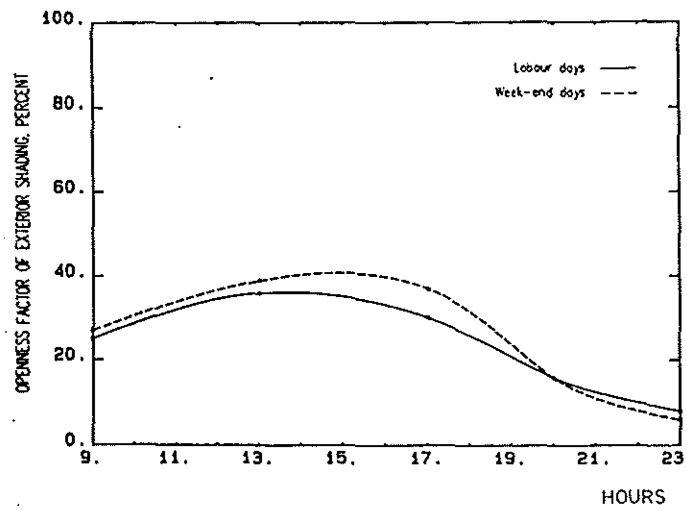


Figure 8. Openness factor of exterior shading vs. hours for a social building

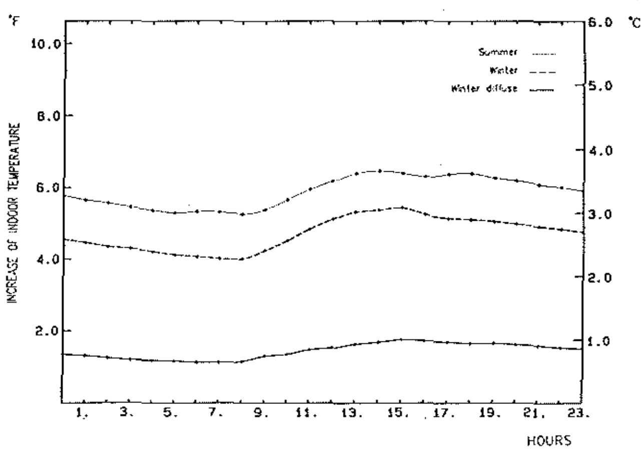


Figure 9. The increase of indoor temperature for total openness of exterior shading on a south surface as a function of solar radiation

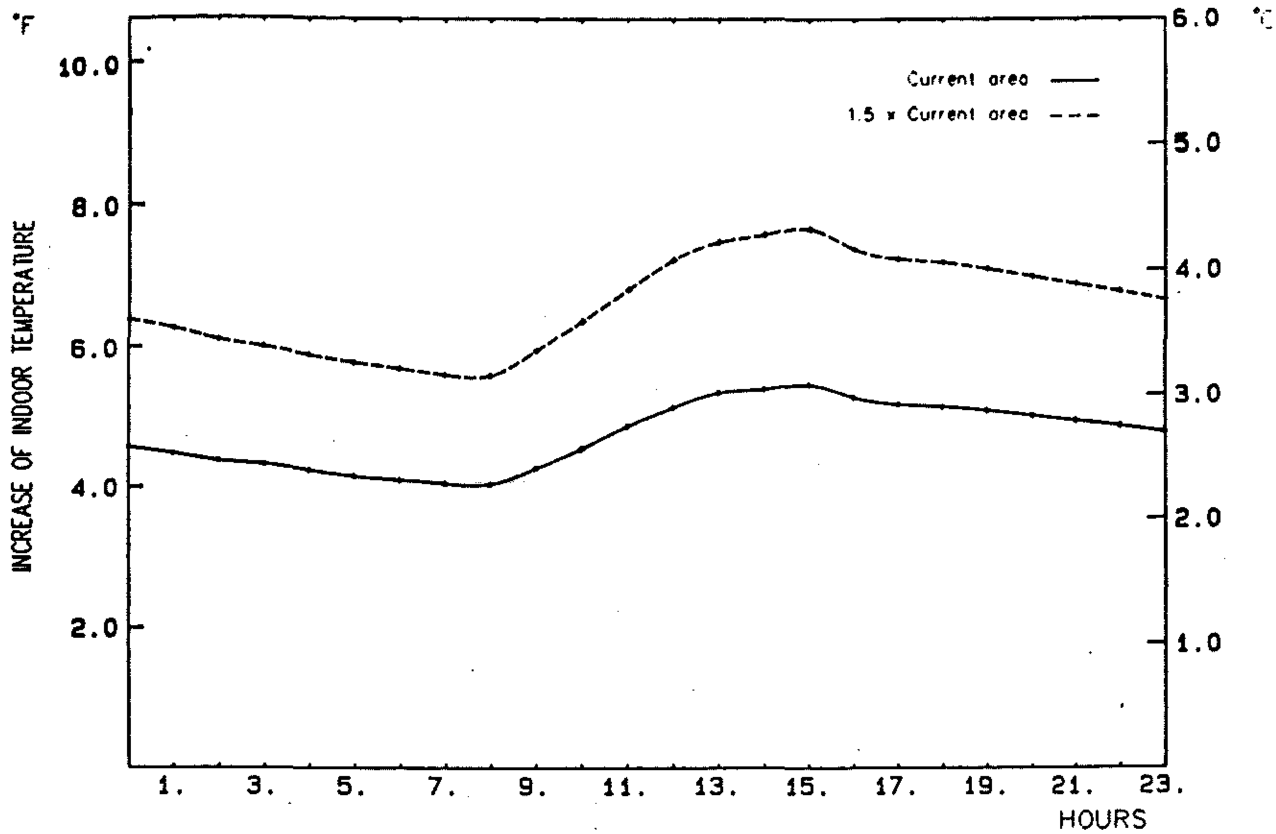


Figure 10. The increase of indoor temperature in winter for total openness of exterior shading on a south surface as a function of the area

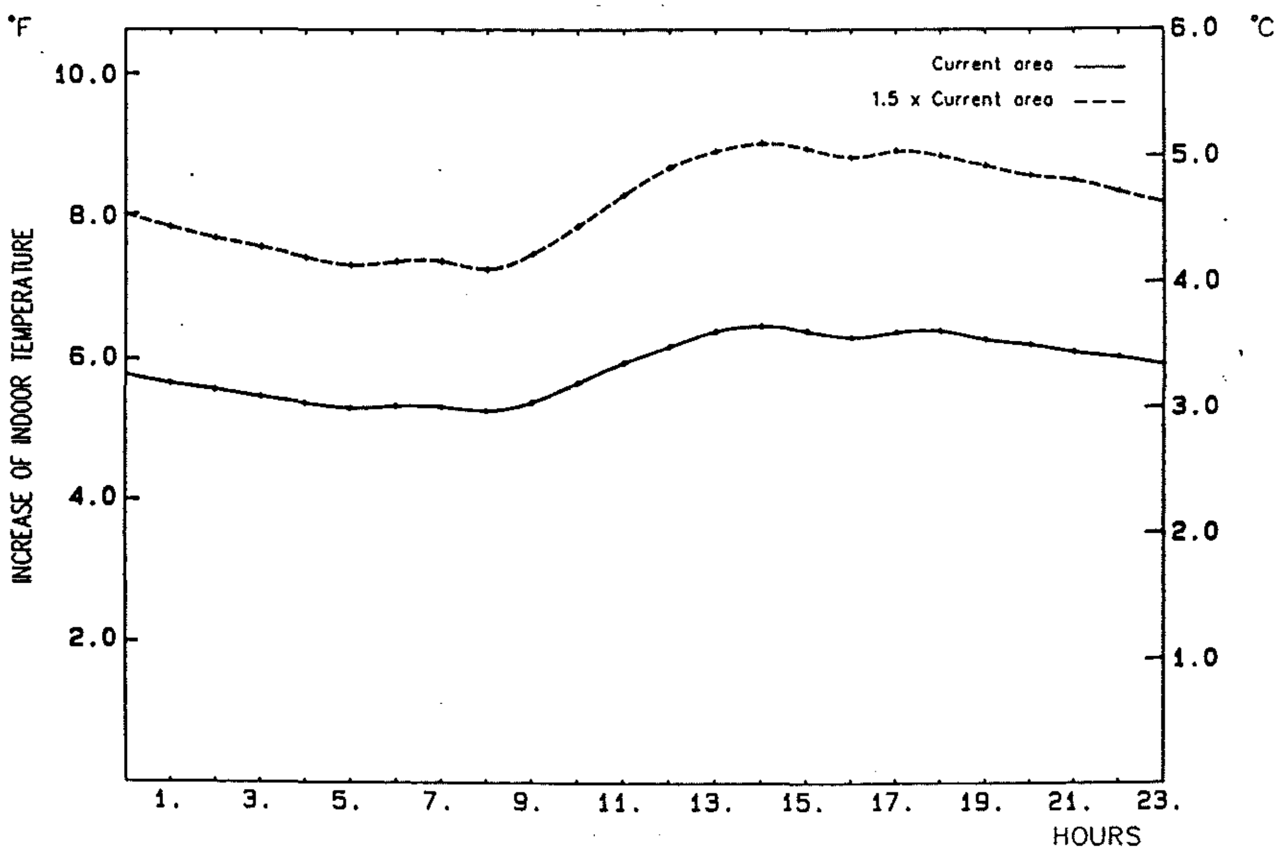


Figure 11. The increase of indoor temperature in summer for total openness of exterior shading on a south surface as a function of the area

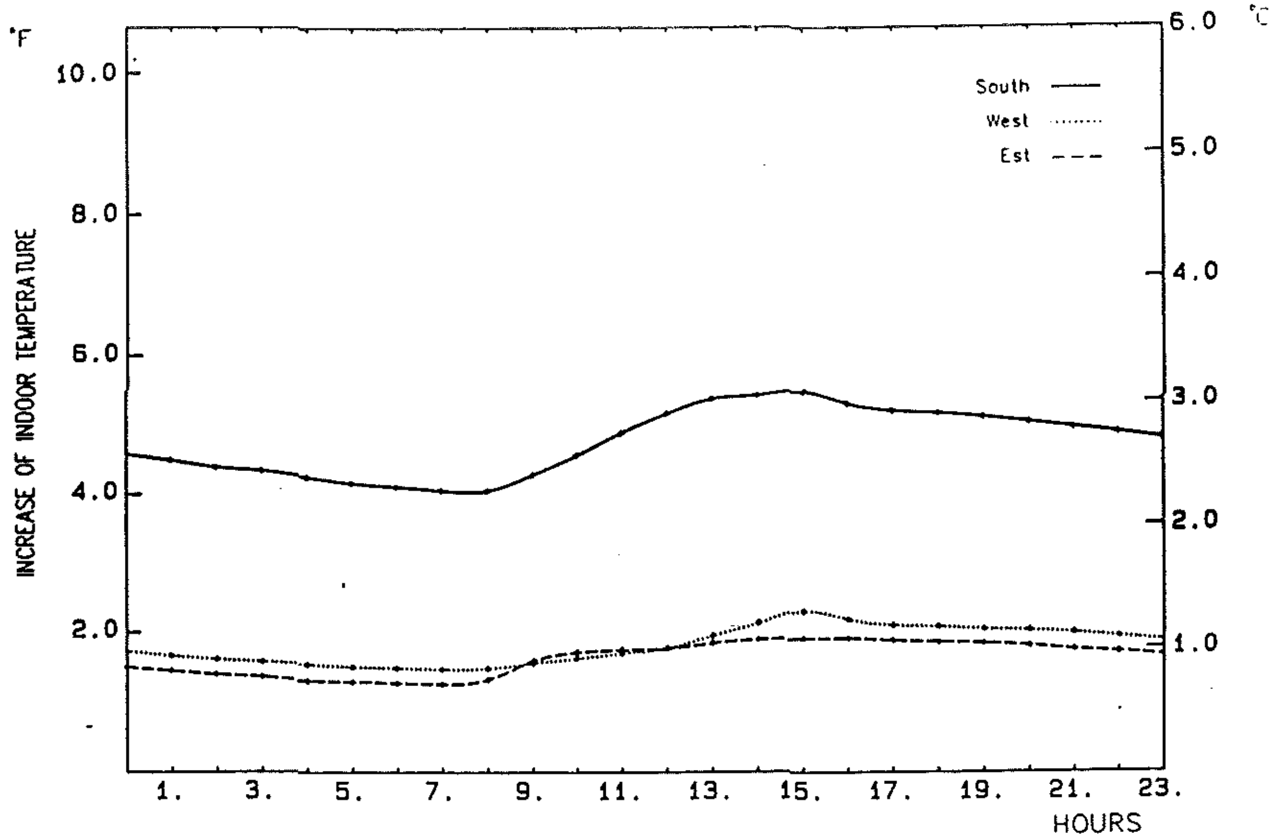


Figure 12. The increase of indoor temperature in winter for total openness of exterior shading as a function of the orientation

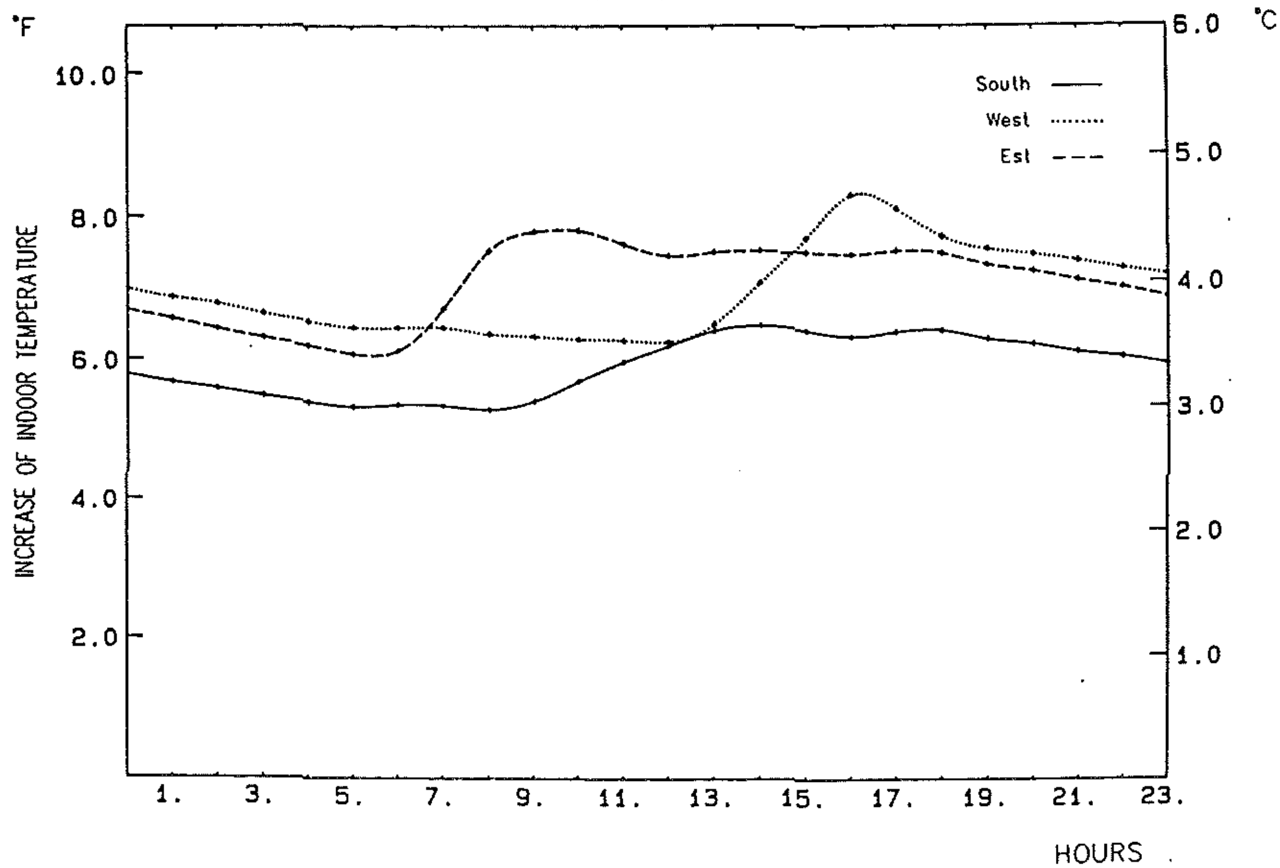


Figure 13. The increase of indoor temperature in summer for total openness of exterior shading as a function of the orientation

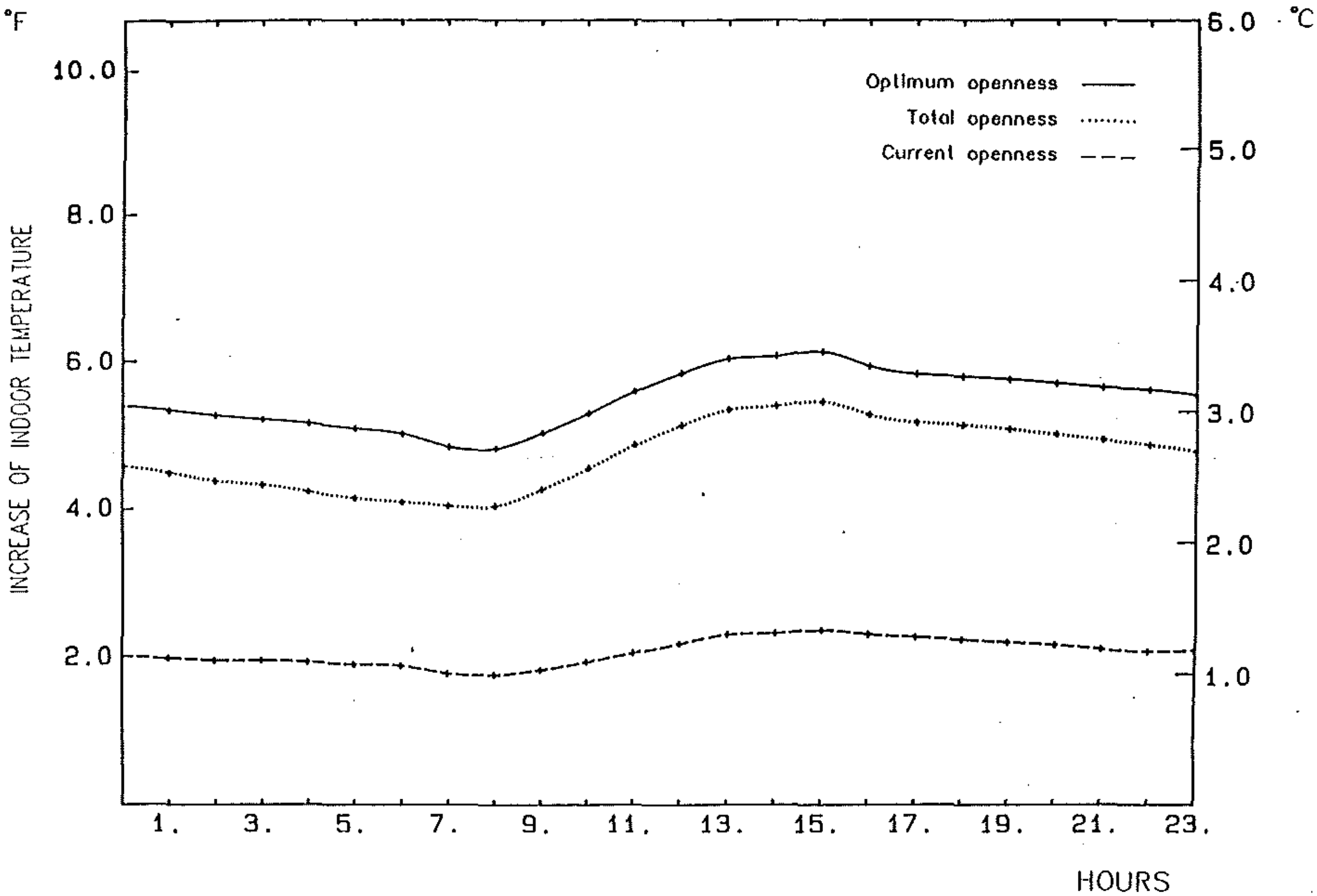


Figure 14. *The increase of indoor temperature in winter for a south surface as a function of the type of exterior shading openness*