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Bioclimatic passive designs rural buildings

I. Cañas [a], P. Núñez [b], S. Martín-Ocaña [a] F. R. Mazarrón [a] J.L.García-Grinda [a]

[a] Universidad Politécnica de Madrid. Research group: "Heritage, landscape, graphic representation and agroforestry construction"
[b] Universidad de Alcalá de Henares

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Corresponding author:
Ignacio Cañas Guerrero
Tel.:+34913365767
Fax.:+34913363688
e-mail: ignacio.canas@upm.es
Address:E.T.S.I.Agrónomos. Departamento de Construcción y Vías Rurales. Avenida Complutense s/n. 28040 Madrid.

Abstract

Purpose:
In this paper the evolution of the bioclimatic architecture is explained from the existing relation between climate and construction in the vernacular architecture, happening through the appearance of the term of bioclimatic architecture in the sixties, to the present time.

Method:
The two bioclimatic charts used by architects appear: Olgyay and Givoni´s, and its use to establish the strategies of design for each climate. Next a review of these strategies of design is done, explaining its operation and the climatic conditions in which its use is just. The explanations come accompanied from images that help to understand the mechanism of performance of each strategy.

Result:
On the strategies is insisted of design of simple incorporation in the building and low cost because it is to give bases for the bioclimatic construction of rural buildings

Discussion & Conclusion:
It is known that traditional rural buildings used strategies to take advantage of the factors the climate in which they were located, obtaining the conditions required for their process. Starting off of this hypothesis, it is wanted to transfer these present strategies to rural buildings and to incorporate other that we know after the bioclimatic study from the building and the environment.

1 Introduction

Bioclimatic architecture is an architecture adapted to environment; an architecture that acknowledges the visual impact and alteration it may create in nature; an architecture concerned by the pollution it generates, being it solid (solid residues), liquid (dirty waters) or gaseous (combustion gases from fossil energy resources).

Bioclimatic construction tries to reconcile the energy saving issue with the quality of the environment inside the buildings and the reduction of environmental impact.

Although the term bioclimatic construction is relatively new, we find that concern for climate in construction existed already in ancient times. Vitrubio would give some lines to place buildings in some spots instead of others based on the climatic features of the environment: "if they face noon or the West, they will not be salubrious because in summer the southern section of the sky warms up at dawn and it burns at noon". During hundreds of years man has developed some constructive techniques to obtain the internal comfort considering the local climatic conditions, the available materials and other conditions relating to culture [1].

In last century, in the 60's, the term bioclimatic architecture was coined by the brothers Olgyay, who developed the bioclimatic charts, where the bases of psychrometry are used to relate climate to strategies to be used to get thermal comfort [2]. Even today, most studies on bioclimatic architecture still use the bioclimatic charts.

Nowadays, research on bioclimatic architecture follows two diverging lines: the first one has in Hassan Fathy [3] its most prominent representative, and it is based on the capacity of this type of buildings to reduce energy consumption, stressing the importance of passive systems used in traditional architecture; the second line uses high technology to produce "ecologic" materials for construction and new active techniques to create renewable energy sources (photovoltaic and thermal panels, active ventilation systems).

From our point of view, before getting into using active systems of energy production, we should control, as far as possible, the passive behavior of the building. Some traditional rural buildings have followed this process in order to get the interior conditions the elaboration process demanded.

2 Results

We will focus on the passive systems that may be applied to rural construction.

This sequence in passive and active systems is proposed by Givoni [4] in his bioclimatic chart. This bioclimatic chart, although less used, is also based on psychrometry, and it classifies the temperature-humidity combinations in 14 areas of performance.

To carry out bioclimatic constructions is principal a previous analysis of the climate of the area where the building will be located. This includes a study as complete as possible of the climate factors, which are:

- temperature
-radiation
-humidity
-wind

To do so, we will need to look at the records of the closest weather stations.

Once studied the climatic conditions of the environment of the building to have into account, we will compare them with the thermal comfort needs, setting the comfort area in a range of temperatures between 20º and 26º C, and varying the humidity between 20% and 80%.

Having into account that the final goal of bioclimatic architecture is to benefit from the advantages that the environment offers, and reducing at the same time what is detrimental from it, we propose some design strategies that will allow us to get these objectives. Since our work focuses on agricultural buildings, the design strategies must be applicable to them, that is, they must be simple to execute and with a low cost. Examples of the design strategies used in vernacular constructions to adapt them to the environment can be obtained from the classical authors of Spanish vernacular architecture [5], [6], [7] and [8].

We distinguish the next strategies of bioclimatic design:

a) Location of the building.

The location of the building is the first strategy exposed because is the first one that should be decided in the sequence of choice of strategies (Fig. 1). A bad location could provoke that the rest of strategies had less influence than they should. However, this choice is quite limited today, particularly in cities, due to a space problem. This restriction is smaller in agribusiness than in other type of buildings, since many agribusiness built in Spain are located in a rural environment.

Even contemplating the above mentioned determinants, we propose the bases for a good election of the location:

-Avoiding close geographical features that would obstruct the radiation and/or wind circulation.

- Placing the building next to water layers (lakes, fountains) or green surfaces, since they reduce thermal oscillations.

There are other recommendations, like avoiding the city centre due to the thermal island effect produced in it, but that choice comes up against great obstacles today.

b) Shape and orientation of the building.

The orientation of the building is also a strategy of difficult choice nowadays, because it is influenced by the development of the urban framework where the building is located. Regarding this matter, in our latitudes it is recommended, as far as possible, a Southern orientation, because is on this façade where the building gets a bigger amount of solar radiation in winter, it being smaller in summer than the radiation on East and West façades. This situation happens in the Northern hemisphere due to the sun trajectory.

The shape of the building has influence on the building's surface exposed outdoors. So, compact forms result in a smaller surface exposed to the exterior. For this reason, the shape of the building depends on what goals we want to achieve:

-In dry, warm areas, the day solar radiation is huge and we need a minimum contact with exterior. Therefore, compact forms are used.

-In humid, warm areas, the biggest issue that must be avoided is environmental humidity. Therefore, a bigger surface exposed helps to the elimination of this humidity by allowing the ventilation. For that reason, there is a tendency to look for more open forms.

-In cold areas, the situation is similar to dry and warm areas. The outdoors is so unfavorable that we need to isolate from it. To do so, compact forms are used (Fig. 2) (An extreme case of this situation is the Eskimo igloo).

-In warm areas we will look for a balance between both situations depending on the goals to be accomplished.

c) Passive exploitation of solar energy.

This is one of the most important strategies and on which we can exercise our power of decision. The sun is the most important energy resource, used in prehistoric times. It fell a little aside with the arrival of fossil fuels, but now, with the XXI century is reemerging again. The proposed strategies have to capture the energy first, store it and then distribute it. There are direct systems: the building warms up by the direct action of the solar rays; and indirect systems: the energy warms up a thermal mass located between the exterior and the space to be heated, and afterwards this heat passes on to the building, like in the greenhouse or stopper space (Fig. 3), the Trombe wall and accumulations in other elements of the structure (cover, frameworks) and later distribution to the interior of the building.

d) Active exploitation of solar energy.

It consists in transforming the solar energy in other types of energy by means of elements integrated in the building or elements that are added on the cover of it. The European Union is boosting the development of these strategies by the creation of the programs THERMIE and JOULE that sponsor research projects with a huge technological component. There are two usual types of strategy:

-Photoelectric systems, where solar energy is captured by silicon photovoltaic cells and then transformed into electric energy, which can be accumulated in batteries for its later use. Or if the system is connected to a network, distributors can sell electric energy.

-Photo-thermal systems. By heat accumulating systems, hot water can be obtained (for sanitary use and/or heating). The elements are simpler than in photoelectric systems.

e) Cooling by evaporation.

By this strategy, we try to use the energy (vaporization latent heat) needed for the change of phase of the water for the air cooling in the interior of buildings. For this system to work, we need a low relative humidity environment. There are two modalities of cooling by evaporation: the active cooling, where the water source is meant for that finality; the passive cooling, where existent situations that provide humidity to the system are used.

The different methods used are:

- Underground water pipes
-Fountains, pumps or water layers
-Lush vegetation
-Patios with fountains or vegetation
-Water pulverization in the surroundings of the building or in structural parts of it.

These systems are of great interest in temperate climate areas with warm summers, like the one in our peninsula. This strategy is widely used in the cellars from Jerez, where the watering of albero (densely packed crushed rock) in summer provides mild temperatures and a high relative humidity, needed for the aging of wine.

f) Solar protection.

This is another particularly interesting system in our country. Moreover, its design is usually simple and logical. It is about designing mechanisms or devices that reduce the intensity of solar radiation to avoid its negative effect bonth on energy and light in some moments along the year. There are fixed and mobile solar protection elements, horizontal and vertical, interior and exterior:

-Horizontal elements: eaves (Fig. 4), portico or arcade (Fig. 5), corbels (Fig. 6), Venetian blinds: (Fig. 7),pergola (Fig. 8) canopy: (Fig. 9) and shield roof (Fig. 10).

-Vertical elements: screen (Fig. 11 and Fig. 12), sun breakers, vertical blind, double wall, and lattice.

-Combinations: recessing of windows (Fig. 13), change of orientation in windows (Fig. 14), shutters, new glazings, curtains and interior blinds, vegetation and color of the envelope.

Most of solar protection strategies require a good use by the user, so it is important that he is informed and involved in getting the comfort in the interior of the building.

g) High thermal inertia.

It is a design strategy that depends on the construction materials used. Its functionality is shown in climates where thermal oscillations are high, since it works reducing extreme temperatures and delaying the cycle.

Thermal inertia of a material is the difficulty it presents to change its temperature and it depends on the mass, the density and specific heat.

In old buildings where walls had the double function of closing and structure, thermal inertia was high due to the thickness of the material used. Nowadays, closings are not practically used for structure function, getting to the point where the closing is just like an exterior skin a few centimeters thick. To get the effect of thermal stability that inertia provides, we should find a balance between both extremes, although the cost of a construction element of bigger mass is higher, we must take into account the possible savings in HVAC that could be achieved with this strategy.

Examples of constructions of high thermal inertia are the traditional constructions earth based and underground caves that benefit from the thermal inertia of the soil (Fig. 15). As it has been mentioned before, there are many underground cellars in our country (Fig. 16), in communities as diverse as Castilla y León and Comunidad Valenciana. The high inertia of the earth is used to avoid thermal oscillations that could lead to the loss of the wine. Moreover, they provide an acoustic and light isolation which is essential to the elaboration process.

h) Isolation.

Isolation is the most efficient way of reducing the energy flow in a construction work, besides of being a requisite in all building to comply all the values regulated by regulation.

Increasing the isolation of a closing implies increasing the thermal resistance of it. This is accomplished by the use of insolating materials that enclose a big quantity of air in their interior in cells as watertight as possible.

We must reconcile the benefit produced by the thermal insulator and the cost it involves, since from a determined thickness of the insulator, the reduction of the energy flow created does not compensate the increment of the cost. We must also have into account the execution of it in order to avoid thermal bridges, where, besides of wasting energy, condensation can happen that could lead to exhaust the insulating capacity of the material.

Regarding the isolation, it must be considered that not only the wall must have a proper level of thermal isolation, but the glazing must have a transmission rate that does not allow a massive outlet of the heat accumulated in its interior. For this reason, double glasses are recommended, since between the two layers of glass it comes an air or inert gas layer that works as isolation.

i) Natural ventilation.

In the summer of Mediterranean countries, natural ventilation is the most effective system of passive cooling. It consists in inducing the passage of air from the exterior to renew the hot air from inside the building. This is basically accomplished by the design (mainly dimensions and orientation) of the holes in the façade, but there are also other mechanisms that force the movement of the air. The mechanisms that promote the air movement in buildings can be classified in two: by action of the wind and by difference of temperature. To use the favorable action of the wind, we need to know its distribution in the season we are interested in (usually summer). The more used strategies to favor ventilation are: crossed ventilation, vertical suction ventilation (Fig. 17), ventilation in patios, forced ventilation by fan in the upper part of the building (Fig. 18), chimney effect (Fig. 19), solar camera (Fig. 20), static aspiration (Fig. 21) and wind tower (Fig. 22).

3 Conclusion

Making a global classification of the climates of the Earth in 4 climates distinctly different (this classification cal also be applied to Spain because of the climate variation it presents) we will find: warm and dry climate, warm and humid climate, cold climate and temperate climate; we will give some clues about the recommended strategies to adequate the construction to climate where it is located.

As it has been mentioned, bioclimatic architecture must consider the factors of the microclimate that surround it, that is, the attached chart is only some general information, it is not a fixed document that should be followed in all situations.

A brief description of the climate in the peninsula follows, although given the complexity of it, it is only a summary. Spain, located between latitudes 36º and 44º North, belongs to the temperate climatic area, Mediterranean subtype, although it is true that because it is in the limits of cold and dry climates, Spain behaves as a continent where there is a wide climate diversity.

- Humid temperate climate, which corresponds to the North area of Spain, including Galicia and the Cantabrian coast.
- Mediterranean climate: it has features from temperate and tropical weather. There is a dry season which corresponds with the maximum temperatures. Almost the totality of the peninsula is within this area. However, there are some differences among interior areas (more continental), the Mediterranean coast (dryer) and the Atlantic coast (with more rainfall).
- Semi-desert climate, mainly in the province of Almería, with the minimum rainfall in all of Europe.
- Mountain climate. They appear in places higher than 1000 m characterized by cold winters.

Fig. 1 Location of the constructions. Traditional wind mills in Alcazar de San Juan, Spain.

Fig. 2 Shape and orientation of the buildings in Romanillos de Medinaceli,Spain [5]

the Atlantic coast (with more rainfall).

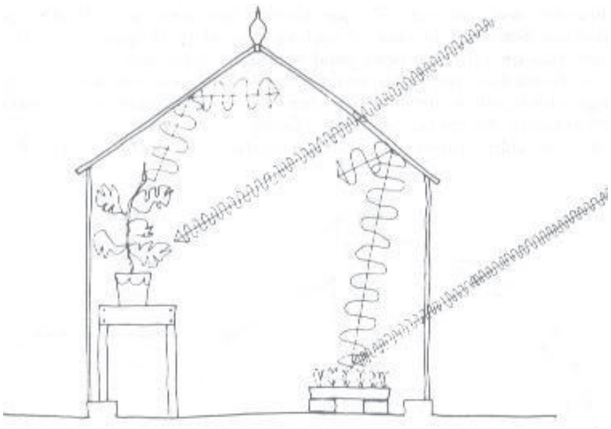

Fig. 3 Greenhouse or stopper space.

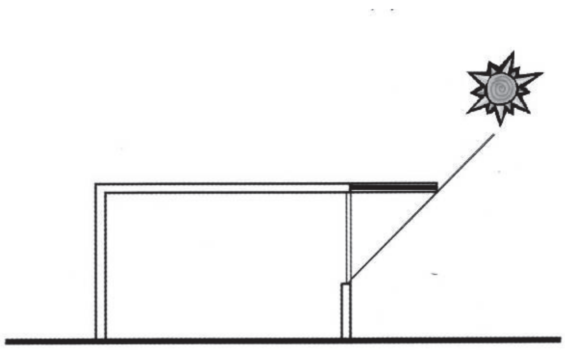

Fig. 4 Horizontal elements: eaves.

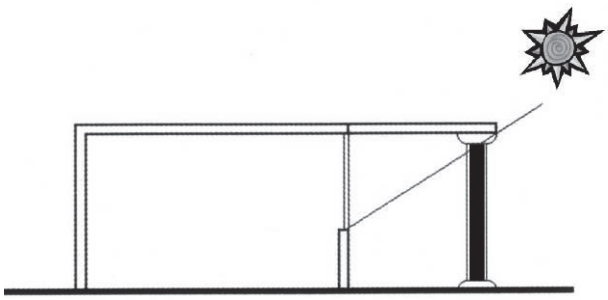

Fig. 5 Horizontal elements: portico or arcade.

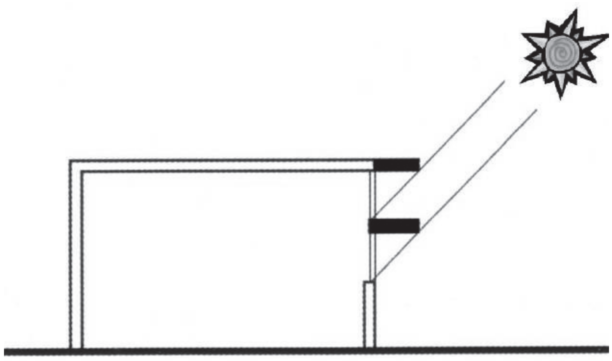

Fig. 6 Corbels.

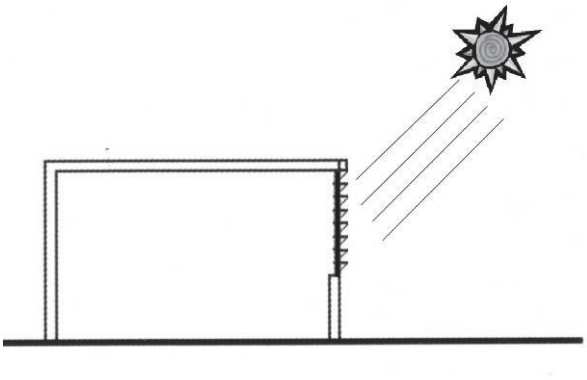

Fig. 7 Venetian blinds.

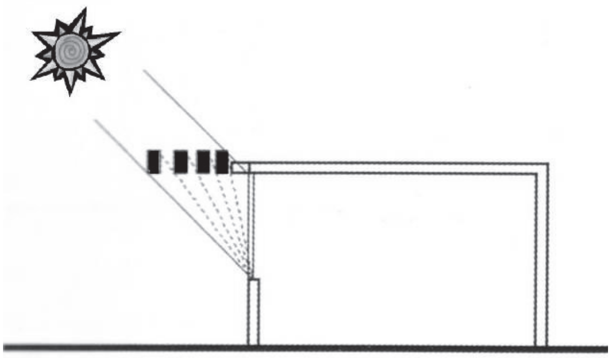

Fig. 8 Pergola.

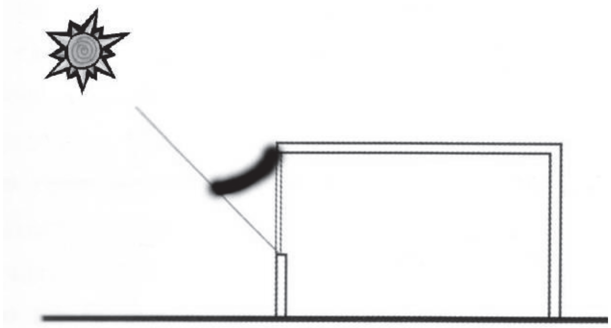

Fig. 9 Canopy.

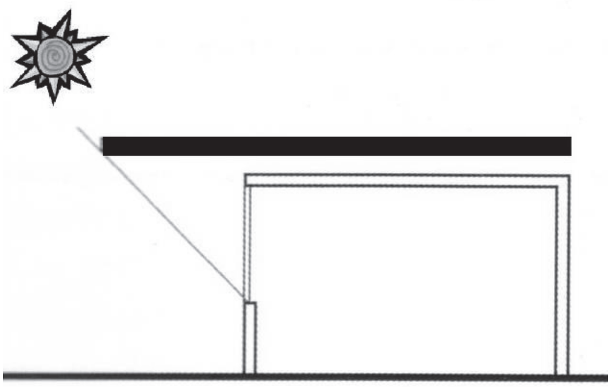

Fig. 10 Shield roof.

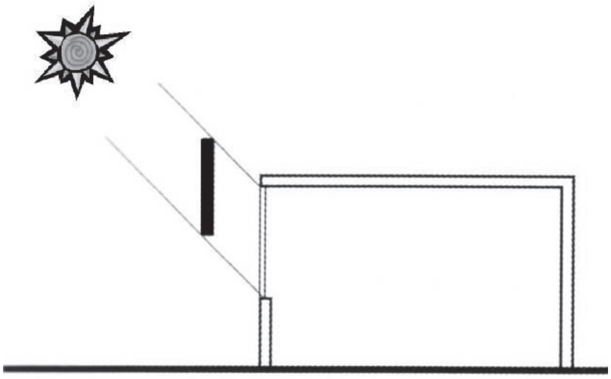

Fig. 11 Vertical elements: screen.

Fig. 12 Example of screen.Wine cellar in Aranda del Duero, Spain

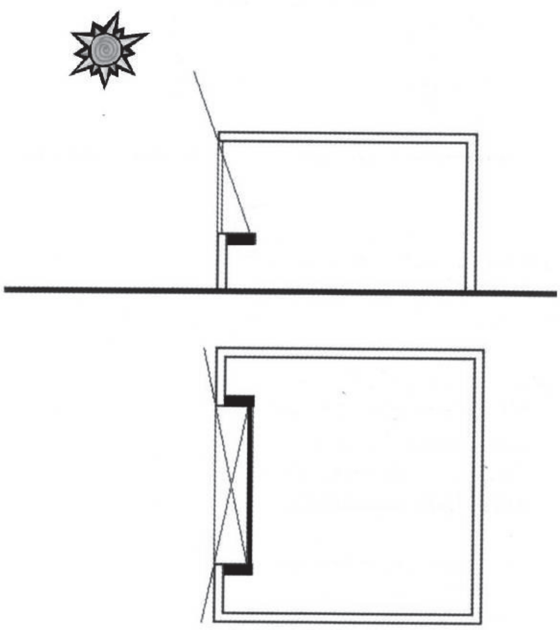

Fig. 13 Combinations: recessing of windows.

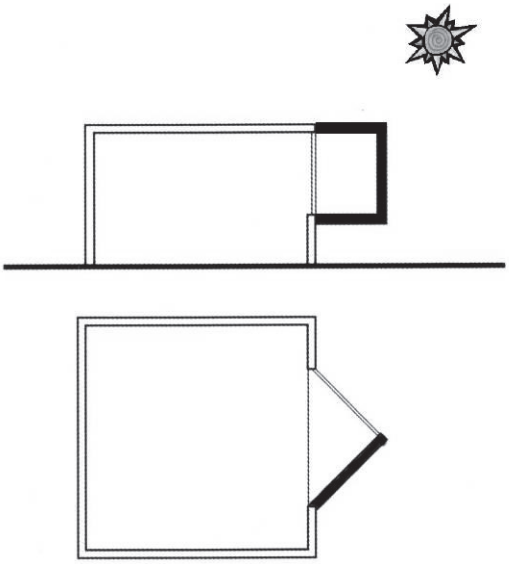

Fig. 14 Change of orientation in windows.

Fig. 15 High thermal inertia. Example of cave dwelling in Villacañas, Spain.

Fig. 16 High thermal inertia. Example of underground wine cellars in Atauta, Spain.

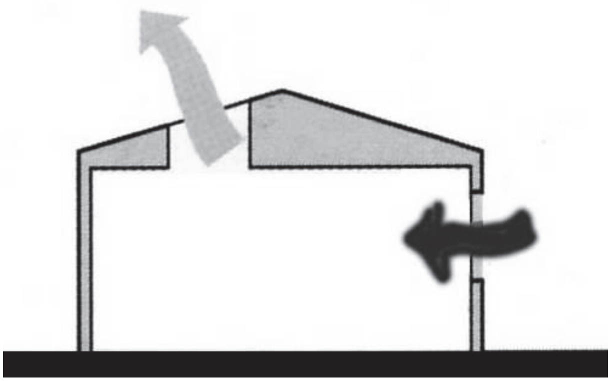

Fig. 17 Vertical suction ventilation.

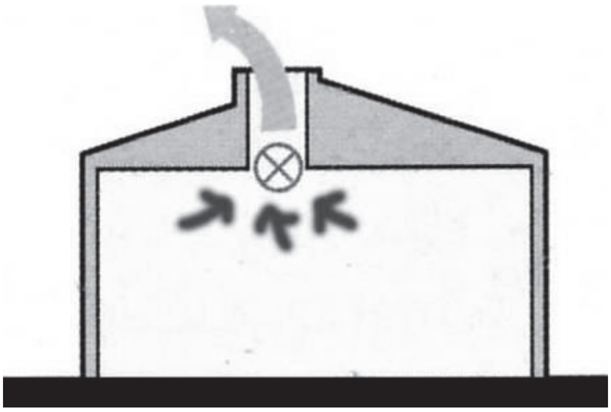

Fig. 18 Forced ventilation by fan in the upper part of the building.

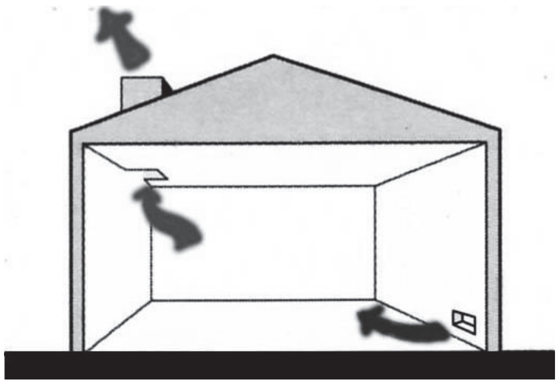

Fig. 19 Chimney effect.

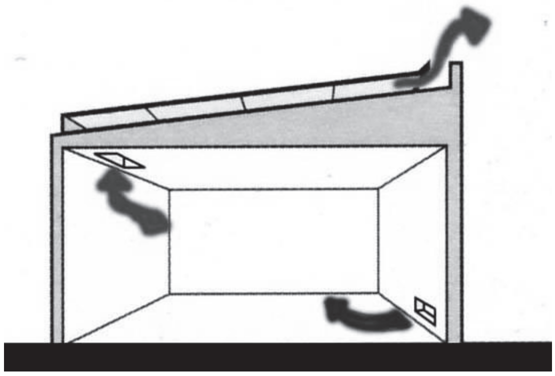

Fig. 20 Solar camera.

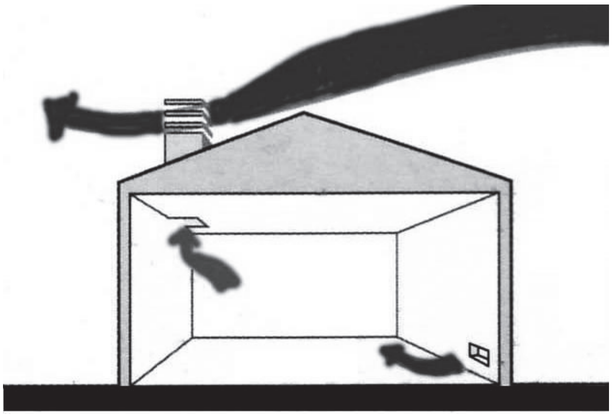

Fig. 21 Static aspiration.

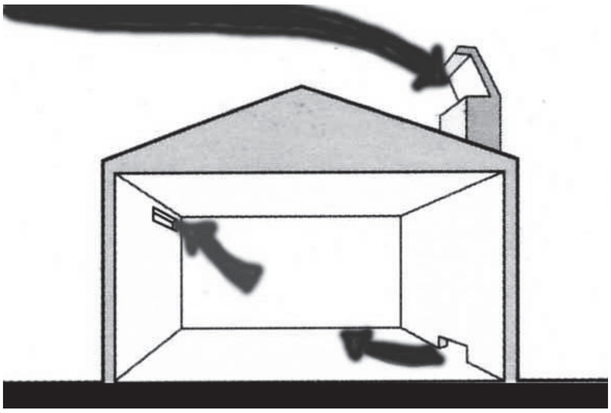

Fig. 22 Wind tower.

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