Use of an Expert System for Passive Cooling Design of Commercial Buildings

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Abstract

The work in progress of an Expert system called ISOLDE that is being prepared in a specific Task of the International Energy Agency is presented. This program will give intelligent user support on energy use and thermal comfort during the design process of commercial buildings through general advices, simplified methods, detailed simulations. In particular the paper focuses on the passive cooling approach covered by this tool.

1. The Isolde program: an expert system for energy advice on commercial buildings

In Task XI (Passive and Hybrid Solar Commercial Buildings) of the International Energy Agency a group of researchers is working on an expert system called ISOLDE (Integrated Knowledge Based Solar Design Tool) that shall primarily be a tool for interactive acess to the results and experience obtained from the work in the Task. The research is still at the beginning and the first prototype will be available in october 1990.

The architecture of the system, shown in fig.1, is divided in three parallel parts: General advice, Case oriented advice and Analysis.

The General advice part can be seen as the educational part of the system and includes an overview of possibile options to be used at the first steps of a project. Rules of thumb on different systems will be provided at this stage and the possible side-effects between cooling, heating and daylighting will be emphasized. To increase the usefulness of this part

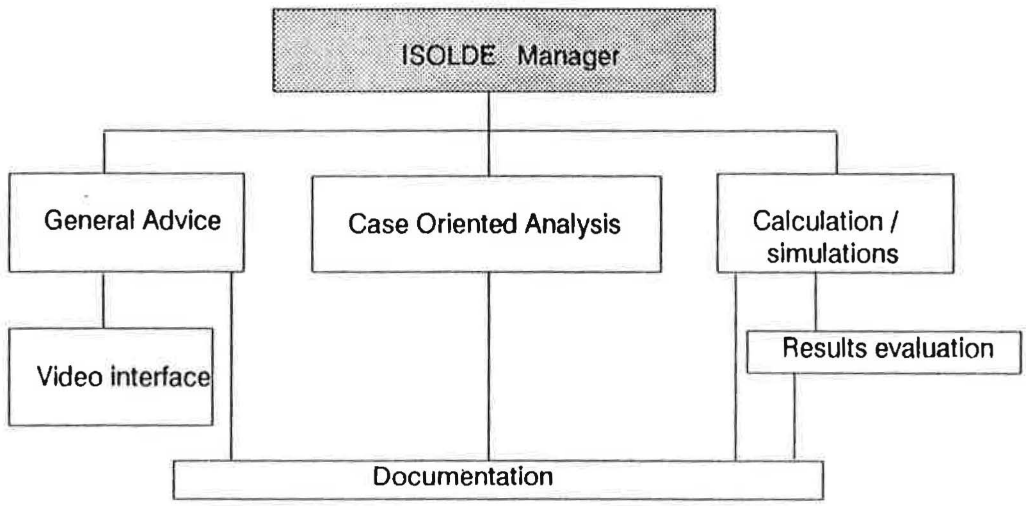

Fig. 1 General architecture of ISOLDE

it will be possible to access to a video system in order to show slides and illustrations mainly taken from the experience in monitoring and simulations gained in the IEA Task.

The Case oriented analysis will give the performance of a specific project proposed by a designer, given the climatic data and the building description. The results from simplified methods will be presented as graphs showing the sensitivity of choosen building parameters.

The Energy analysis will be performed, if necessary, by activating a simulation model; the results will then be evaluated giving more detailed informations to the designer.

ISOLDE is implemented on PC using the shell CRYSTAL. Simplified methods and simulation methods are standard tools that will be activated from a batch file when CRYSTAL closes down. When the calculations are finished the batch file will restart CRYSTAl.

In order to lower the computer answer time and to allow the separate work of the different research groups involved in the ISOLDE project it was decided to create many small knowledge bases (fig. 2). The structure includes a first strategy evaluation knowledge base, three strategy knowledge bases (heating, cooling and daylighting) and a number of principles and system knowledge bases. Based on the climatic region of the site analyzed and the building size (floor area, number of stories) and use (office, hotel, hospital, school, shopping-center, storehouse, sport center), Isolde will provide a simple ranking of strategies.

In this paper we will describe how the cooling strategy is organized.

2. Cooling strategies

If cooling is a recommended option in the case analyzed, more specific climatic data are required. According to the average summer weather data an indication of possible cooling strategies is provided (Tab. 1).

Three informations (not an issue, usable, recommended) will be provided by ISOLDE according to the input data.

	Summer Data	*Shading*	*Natural Ventilation*	*Forced Ventilation*	*Evaporat.*	*Underg.*	*Roof Pond*
Daily ΔT (C)							
T. max (C)							
Rel. Humidity (%)							
Wind Velocity (m/s)							
Solar Rad. (Wh/m^2 d)							

Tab. 1 Cooling strategies proposed in relation to summer climatic data

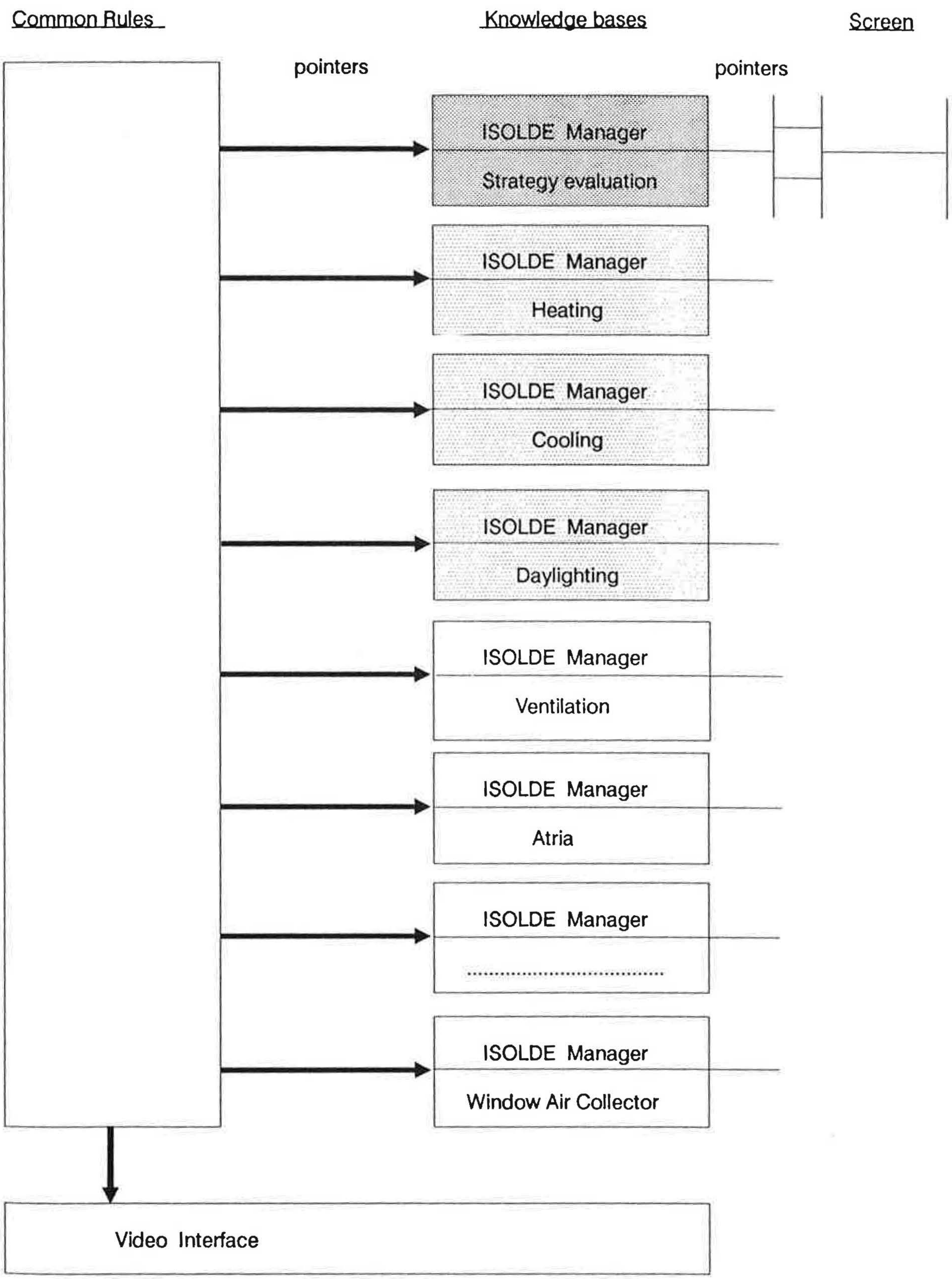

Fig.2 ISOLDE architecture (General advise part).

For each principle or system selected the knowledge base activated will provide:

- System/principle definition

- Advantages/disadvantages
- Side effects to other strategies/principles/systems
- Design Advice
- Rules of thumb for design

Climatic data combined with the building type permit to give some general recommendation. In Fig. 3 for five different climates the cooling strategies are explained for the case of office buildings (De Herde, 1990). Buildings at this stage are considered in relation to the level of internal heat gains and of permeability (a permeable building allows a large amount of heat to flow inside, or outside, the envelope). A bold square has been drawn each time a principle or a strategy proves to be relevant according to climate and daytime. In this way all possible cooling strategies relevant to the case analyzed are presented.

At this point it is possible to have more detailed informations on specific strategies concerning general advices,"advantages", "disadvantages", possible "side-effects" on other cooling strategies, on heating or on daylighting, rules of thumb for design.

In the following paragraphs some of the cooling strategies analyzed in Isolde are described in more detail.

2.1. Ventilation

For the different cooling startegies the first step has been an analysis of the literature in order to identify rules of thumb, correlations and simplified methods available.

In the following paragraph a review of tools identified to quantify natural ventilation in buildings is presented. A more detailed analysis The calculation of airflows through buildings is difficult and cannot be done with precision. Uncertainities on site wind speed, on surrounding landscape perturbance, on pressure coefficients are great. A growing amount of wind tunnel experiments however has recently permitted to define better correlations. A lot of research is at present focused on the improvement of the definitions of the parameters involved in natural ventilation.

Simplified methods and simulation models to be used for the evaluation of buildings ventilation are already available.

In many simplified calculation methods it is possible to evaluate the effect of different air changes. This is the case of the procedure to calculate summertime temperatures in buildings proposed by Loudon (1968).

Baer (1983) presents a simplified method that allows to calculate the internal temperature with a fixed ventilation rate. A manual calculation method that permits the evaluation of night ventilation is presented by Baker (1986).

A semi-empirical thermal analysis method has been developed by Mathews (1986, 1989). The same approach has been followed in a program, called QuickTemp, that has been validated against 39 separate commercial and residential buildings (Joubert, 1989).

Mc Farland (1989) calculates ventilation cooling using curves function of climatic data and building characteristics.

A simplified model for the prediction of air flow im multistorey buildings is proposed in Feustel (1989).

A model that has been used to illustrate the effects of wind on air change rate in relation also to terrain roughness is presented in Liddament (1988).

Etheridge (1988) has developed non-dimensional graphs that can be used to predict ventilation rates in buildings.

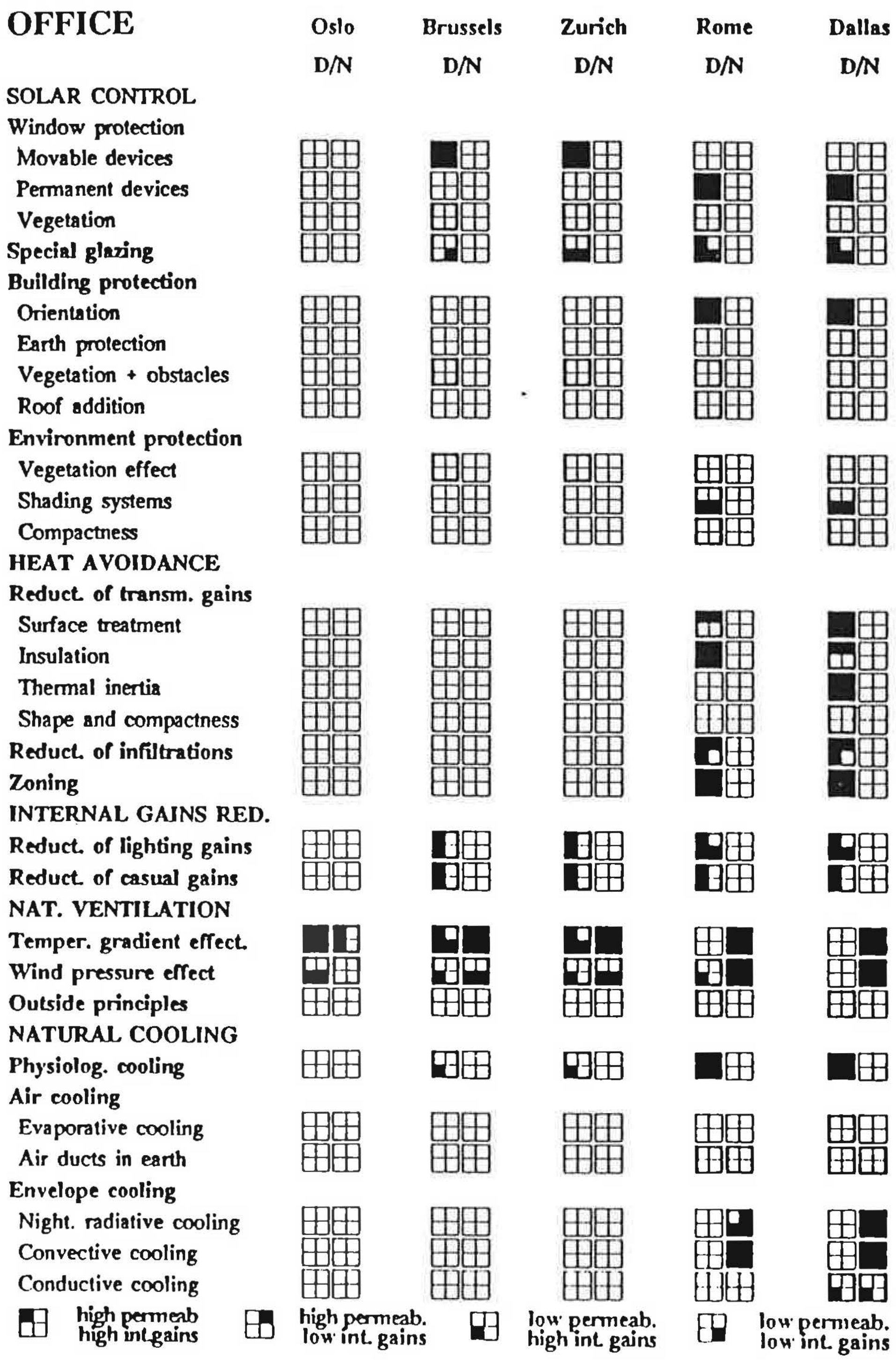

Fig. 3 Cooling suggestions for office buildings in different climate

Owens (1987) presents graphically the results of parametric analysis on ventilation rate of atria in relation to the openings area and the height of the atria.

In the General advice part of ISOLDE the use of natural ventilation is recommended in relation to values of wind velocity and building height.

The information related to natural ventilation appear in different screens.

Advantages

- Can improve thermal comfort of occupants
- When air temperature is lower than internal air the structure of the building can be cooled without any energy consumption

Disadvantages:

- Wind induced in the rooms may create discomfort in working places

Side effect:

- Orientation according to wind direction for best ventilation may be conflicting with orientation for best solar protection
- Wind ventilation is severly altered by earth sheltering, city compactness strategies, use of vegetation for shadowing

Fig. 4 presents general advices on the selected cooling principle.

For specific situation also quantitative informations will be provided. For example atria are more and more used in energy efficient commercial buildings. Information will be provided from momitored buildings and simulations that are carried in the Task XI. We will here present for this specific component some indications taken from literature.

Natural ventilation can be generated by a solar driven buoyancy effect in all sizeable atria. The air movement is related to the height of the atria, the openings area, the climatic data. In fig. 5 the air change rate and vertical air velocities have been calculated for different configurations of an atrium enclosed by a building of masonry construction during a day with an average temperature of 20 °C and a maximum temperature of 25 °C (Owens, 1987).

2.2. Forced ventilation

This option is suggested when the mean daily temperature swing during summer months is higher than 12 °C and the mean value of the maximum daily temperature is lower than 30 °C.

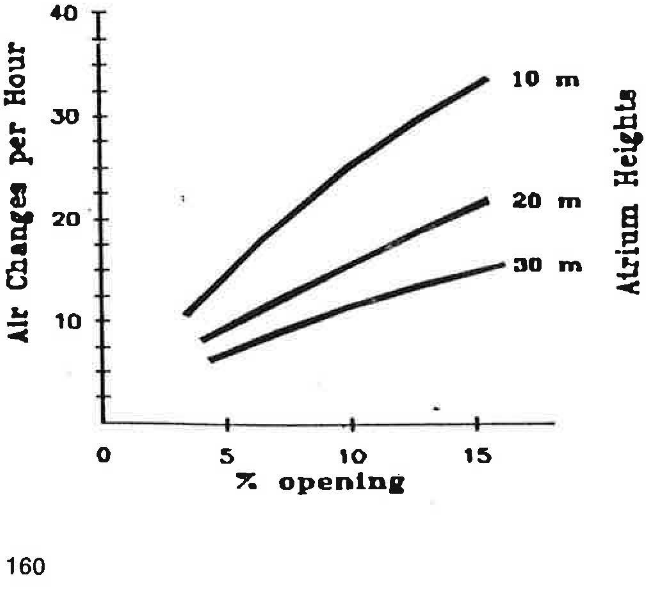

Fig. 5 Natural ventilation in atria due to buoyancy effect

In the following screen a set of suggestions to be kept in mind when using this strategy is proposed.

The building needs good thermal inertia (equivalent to more than 400 kg concrete per sqm of floor area)
Large surface area of the "mass" elements (about 4 times the floor area)
High outside insulation
Ceilings or floors with embedded channels recommended
Caution with daytime natural ventilation
Define appropriate control strategies for ventilator fans

Fig. 6 General recommendations for the use of forced night ventilation

A second screen presents some quantitative data on nocturnal forced ventilation for different climates (Givoni, 1988).

Climate	Ta (°C)	Tm (max)-Tm(min)	Q/A (W/mq)	COP
Hot-Humid	24	3	14.8	4.4
Hot-Arid	21	7	34.5	10.3
Temperate	18	9	44.3	13.2

Ta average summer night ambient temperate (Jun, Jul, Aug.) in New Orleans, L.A. Phoenix, A.Z. and New York.
Tm (max) (min) average maximum (minimum) - temperature
Q/A rate of cold storage vs area
COP coefficient of performance (ratio cold storage vs energy for the fan)

Tab. 2 Efficiency of forced natural ventilation in single storey buildings calculated for different climates

2.2.1 Use of hollow core ceilings

As in the case of atria informations taken from buildings monitored in the Task XI will be presented. In the following figures the stratgegy is described and some experimental data measured during the last week of July 1989 in an office building located in Giarre, near Catania, Siciliy are shown (Silvestrini, 1989 b). Parametric analysis using computer simulation models will give more general informations on this strategy.

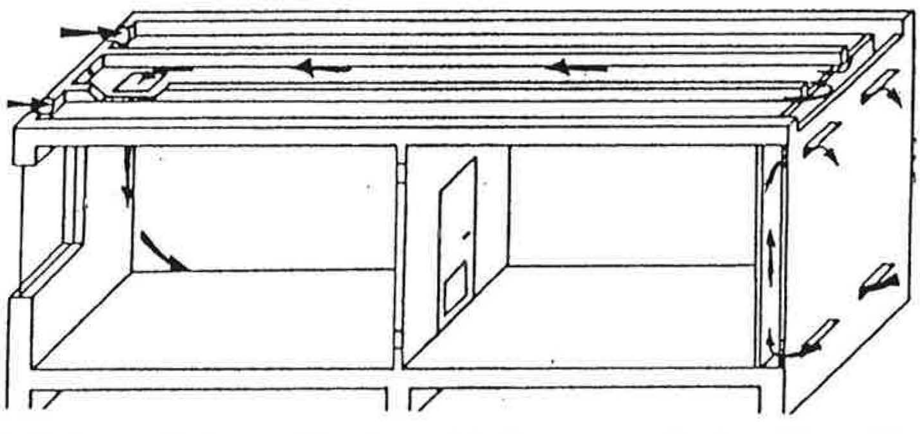

Fig. 7 Night ventilation cooling through hollow core ceiling in a Barra-Costantini passive component

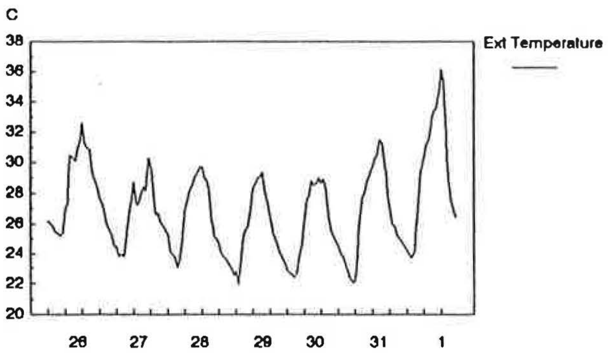

Fig. 8 External air temperatures measured in Giarre during the last week of July 1989

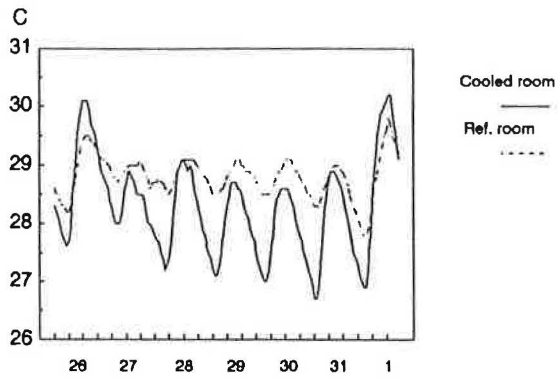

Fig. 9 Temperature values of the cooled and the reference ceiling monitored in Giarre

3. Conclusions

The work in progress on the cooling part of an expert system, called ISOLDE, to be used as an energy consultant has been described. The knowledge bases and rules will include all the informations that will be elaborated in the IEA Solar Heating and Cooling Task 11 and of more general indications found in literature.

Note:
The working group on Expert Systems of IEA Task XI is composed by Ove Morck (coordinator), Ida Bryn, Nicolas Morel, Rolf Stricker, Giovanni Silvestrini

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