GYMNASIUM FRESH AIR PREHEATING

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ABSTRACT

This study was carried out on a real site gymnasium situated in the center of France. The building is equipped with two remarkable energy saving systems; running together: a ventilated roof and an air-earth exchanger.

Experimental and theoretical studies were done on these two energy saving systems and a sensitivity factor analysis was performed which is presented in this paper. This analysis studies several types of fresh air preheating, varying the heating control temperature of building. Main results show that the economy on fresh air preheating can differ with the system used, and indicate the reasons of lack of efficiency of some systems.

Then, the authors model various possibilities, in order to optimise fresh air introduction in gymnasium. The combined influences on building global theoretical consumptions, of ventilation intermittency and climate are studied. It is shown that the optimisation of air introduction into the gymnasium has no influence on energy consumption of the building , for a rather cold climate. On the other hand, for a warmer climate, a significant econorny of energy can be obtained.

In conclusion, this study points out the general interest of simulation for new building designs But it can be also used for existing buildings to give significant information about equipement weaknesses and, of course, for improvements to be made.

1. DESCRIPTION OF THE ENERGY SAVING SYSTEMS

This building is equipped with two remarkable energy saving systems, Figure1.

* The first one is a ventilated roof which is made from the outside to the inside of the building of :

- metal covering (iron);
- forced ventilation air gap (0.08 meter thick);
- insulating material (0.08 meter thick) which is supported by metallic parts called "Alubac";

This sytem can be assimilated to an air-air exchanger which collects energy in one of the two ways, either from the building's thermal losses on cold days, or from the combined influence of the outside air and solar radiation on sunny days. Studies have been carried out on several sytems in France. The first one indicates the general thermal behaviour and the air preheating performance that we can expect from a ventilated roof, but for a private house [1]. The others were performed by authors themselves and correspond to the validation of a theoretical model which was developed using, over a two-year period, experimental measurements, [2] and [3].

* The second is an air-earth heat exchanger made of plastic tubes of different diameters, buried 1.7 meter depth beneath ground surface of gymnasium. It can be used to preheat fresh air in winter or to cool it in summer.

This type of installation is an old Persian concept which has existed for centuries. More recently, foreign and French authors have taken an interest in the performance of such systems, [4], [5], [6], [7], [8], [9], [10] and [11].

But, generally speaking, the air which goes into this pipe system comes directly from the outside which is not the case in our study. In winter, cold fresh air is first preheated inside the ventilated roof, then led through an air pipe network to the air-earth heat exchanger, and finally blown into the building. In summer, air is directly extracted from the ventilated roof or from the buried pipe system and thrown outdoors.

Thus, the performance of this buried pipe system can differ from that of the usual installations mentioned above. A simulation model was also developed and validated, using experimental measurements, [12,13].

Finally, in order to make a complete analysis of this buiding, the authors implemented the models mentioned above in a TRNSYS simulation environment, [14].

2. INFLUENCE OF TYPE OF CONFIGURATION USED FOR PREHEATING THE AIR

2.1 SIMULATION CONDITIONS

We simulated four different air renewal preheating configurations, Figure 2.

* The first one corresponds to the real configuration where the incoming air is preheated by the coupled action of the ventilated roof and the buried pipe system. We call it **"DYN"** for dynamic configuration.

* The other three are simulated configurations, which differ by the way of which fresh air is preheated before being blown into the gymnasium.

We call them:

* **"PITS"** configuration when air is only preheated by the use of the buried pipe system;

* **"ROOF"** configuration when air is only preheated by the use of the ventilated roof;

* **"STAT"** for static configuration, because room 1's roof is not ventilated. For this case, there is no preheating and outside fresh air is directly introduced into the building.

It should be noted that for each study case, the set point control temperatures of rooms 1 and 2 varied within the range of 12 /15 °C, as provided for by french building regulations, [15].

2.2 RESULTS OF SIMULATIONS

The results of these simulations were obtained using the following formulation:

$$Q = m\ Cp\ (Ts - Tz)\ \Delta h \qquad (1)$$

Comments:

* "Tz" represents the value of the zone temperature calculated hour by hour with the simulation model during the heating period of year 1991-1992.

* for the three configuration cases corresponding to **ROOF, PITS** and **DYN**, the parameter "Ts" is equal the temperature of air blown into the gymnasium after having crossed, either the ventilated roof of room 1, or the buried pipe system, or finally both. The higher the value of "Ts", the better the preheated of the air. So this parameter appears to be an interesting mean of studing the energetic efficiency of these different configurations.

* for the **STATIC** configuration, the same parameter "Ts" is taken as equal to the outside air ambient temperature value and it can be used as a reference for the other three configurations.

As it was foreseeable we note that, for all the configuration types in Figure 3, the set point control temperature of rooms 1 and 2 has a significant influence on gymnasium global consumptions.

Results presented in Figure 3 also show, that the comparative performances of the different configurations for the gymnasium as a whole were in decreasing order:

-1- **PITS** configuration;
- 2- **DYN** configuration;
- 3- **STATIC** configuration;
- 4- **ROOF** configuration.

We can see in Figure 4 that roof heat losses are greatly increased for the two configurations where the air gap of room 1 is ventilated. For these two cases, the energy collected inside the air gap for preheating fresh air is too low, and cannot compensate for the increase of roof heat losses of room 1, Figure 5.

A better explanation can be given if we analyse the air gap thermal behaviour more accurately. If we know that the ventilated roof is composed of twenty two iron elements which are two meters in length and present different inclinations, we can determine, using the simulation model, the changes in air temperature inside each element.

Generally speaking, this study shows that the air temperature increases all along the ventilated roof, see Figures 6 and 7.

However, the air temperature increase is very slight during the night and does not exceed half a degree celcius, Figure 6. Moreover, the increase in temperature is bigger in the first part of the ventilated roof than in the second and this is why the building thermal losses are increased.

On the other hand, the air temperature decrease can reach five degrees celcius during the day, particularly when there is sun, Figure 7. As the top covering of the ventilated roof is made of iron, it cannot be considered as a classical solar captor (with greenhouse effect).

Consequently, it presents a very poor thermal performance which cannot compensate for the increased thermal losses, particularly when ventilation is run during the night, as it is the case for that thermal installation considered.

It should be noted that these conclusions are only true for a permanent running of the ventilation and for the climatic site of Yzeure.

What would happen if the ventilation was stopped during the night or if an other climatic site was chosen ? We shall discuss this in the next paragraph.

3. OPTIMISATION OF GYMNASIUM FRESH AIR INTRODUCTION

3.1 THE PROBLEM

The aim is to blow fresh air into the gymnasium, at the the highest possible temperature.

First, we compared the different temperature values obtained when going (or not) through the different preheating systems for each time step of calculation. We kept the highest temperature value calculated by the model.

Second, we modulated the air renewal flow rate value, Table 1, according to:

* gymnasium occupation;
* comparison of air temperature values, "Ts" at the outlet of the preheating system considered and " Tz", the zone temperature.

Let us note that this study is not very realistic, except if the simulation program can be used as a predictive tool to pilot the gymnasium air ventilation system in real time.

3.2 CONDITIONS OF SIMULATION

This study was carried out taking into account the following conditions:

* Possibility of intermittent ventilation during the night;
* Study performed for two climatic sites: Yzeure and Montpellier;
* Study performed for two heating temperatures of room 1 and 2: 12 and 15 °C;
* Study carried out for only two types of configurations, the real configuration of the gymnasium **(Dynamic)** and the system which provided the highest energy economy (**Pits).**

3.2.1 Case of the Dynamic configuration

This is represented in Figure 8.

* For the air preheating temperature value of "Ts" we took:

- Ts = Maximum value of (Text, Tstoit, Tspuits)

* For the flow rate value "m" we took:
  - During the day : m = 2350 m3/h
  - During the night :

If " Ts " > Tz : m = 2350 m^3/h

If " Ts " < Tz : m = 0 m^3/h

3.2.2 Case of the Pits configuration

This is represented in Figure 9.

* For the air preheating temperature value of "Ts" we took:

With Ts = Maximum value of (Text, Tspuits)

* For the flow rate value "m" we took:
  - During the day : m = 2350 m3/h
  - During the night :

If " Ts " > " Tz " : m = 2350 m3/h

If " Ts " < " Tz " : m = 0 m3/h

3.3 SIMULATION RESULTS

We can see from Figures 10 and 11 that the fresh air preheating optimisation varies with the climatic site considered.

For the climatic site of Yzeure, if we compare the results obtained by optimisation with those from the use of ventilation intermittency alone, we can see that the optimisation influence is very weak, except for the Dynamic.15 configuration, Figure 10. Conversely, for the climatic site of Montpellier the optimisation influence can save more energy than the use of ventilation intermittency alone, Figure 11.

This difference comes directly from the difference in meteorological conditions between these two cities during the heating period, Table 2. The climate in Montpellier is warmer and sunnier than that in Yzeure, particularly if we compare the degree hours base 12. Thus, the temperature of "Ts" more frequently exceeds the zone temperature value "Tz", leading to a considerable decrease in energy consumption by the building .

4. GENERAL CONCLUSION

Generally speaking, these results show the great interest of simulation.

The use of a model can give more information about the advantages or weaknesses of components in system design.

A systematic analysis of several air preheating configurations has pointed out the order of efficiency of the different air preheating systems. Thus, it appeared that the use of an air-earth exchanger was a very appropriate solution for preheating fresh air in winter, even if its use was combined with an other energy saving system such as a ventilated roof.

For the other solutions, particularly for the ventilated roof, we have to take into account the reality of the climatic site. For a rather cold climatic site, like that of Yzeure, gymnasium air introduction need not to be optimised because it is not a mean of saving energy. But, if the climate is warmer and more sunnier, this solution can be used combined with ventilation intermittency.

Finally, we conclude that the use of simulation can be of great interest even for existing buildings which need energy saving improvments.

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NOMENCLATURE

Cp: specific heat of air (kJ/kg.K);
m : air gap flow rate (kg/s);
Δh = time step of calculation (hours);
Text: outside air temperature (°C);
Ts: gymnasium air inlet temperature (°C);
Tspuits: air outlet temperature of air-earth exchanger (°C);
Tstoit: Ventilated roof air outlet temperature (°C);
Tz : zone temperature (°C).

TABLES

AIR RENEWAL	WITH VENTILATION (8 A.M -10 P.M)	WITHOUT VENTILATION (10 P.M - 8 A.M)
Flow Rate Values (m3/h)	2350	0

Table 1 : Air renewal flow rate values throughout the day

CLIMATIC SITE	YZEURE	MONTPELLIER
SOLAR RADIATION	354 kWh/m²	579 kWh/m²
DEGREE HOURS BASE 12	32980	16397

Table 2 : Comparative table of the principal caracteristics of the climatic sites of Yzeure and Montpellier during the heating period of year 1991-1992

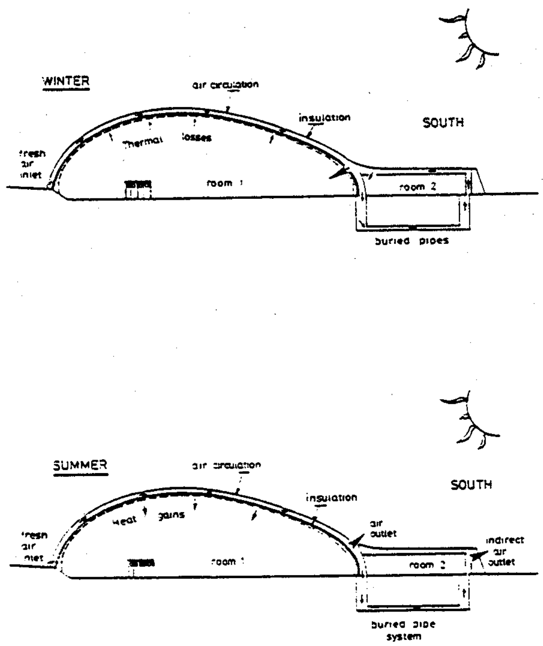


Figure 1: Diagram of gymnasium general ventilation

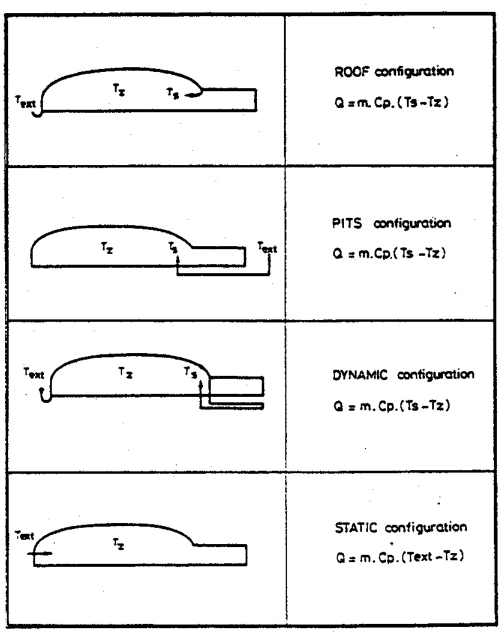


Figure 2 : Diagram of the different simulated configurations for fresh air preheating

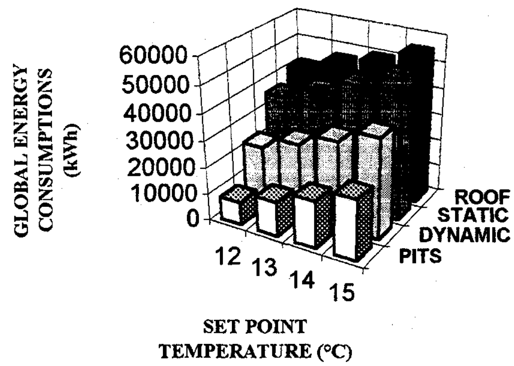


Figure 3: Set Point Temperature Influence on Global Thermal Balances (Roof of Room 1 + Gymnasium Air Renewall) for the Four Configuration Types Studied

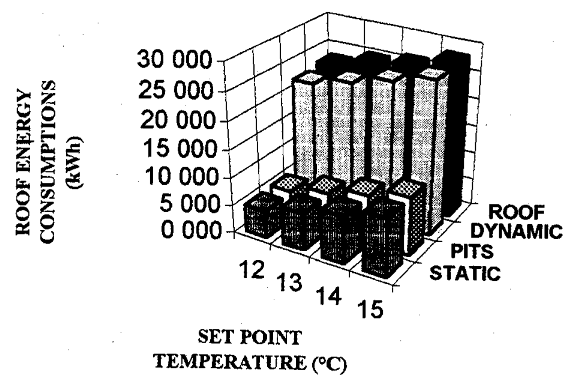


Figure 4: Set Point Temperature Influence on Roof Thermall Balances of Room1 for the Four Configuration Types Studied

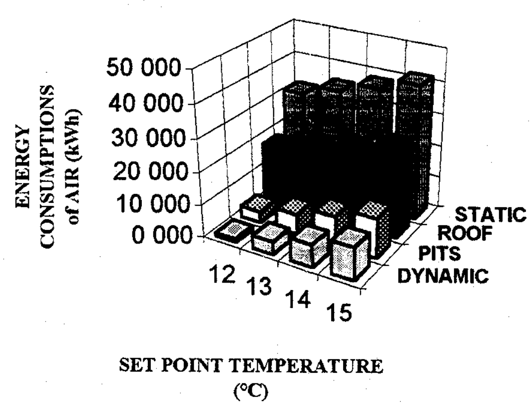


Figure 5: Set point Temperature Influence on Global Air Renewall Thermal Balances of Gymnasium Air Renewall for the Four Configuration Types Studied

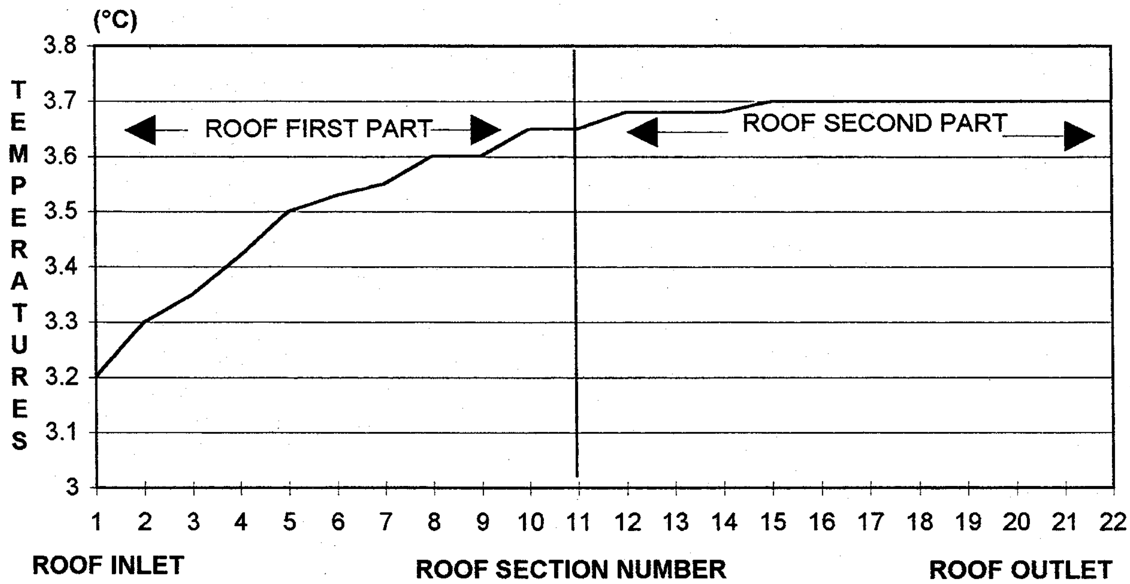


Figure 6 : Inside air gap temperature evolutions during the night

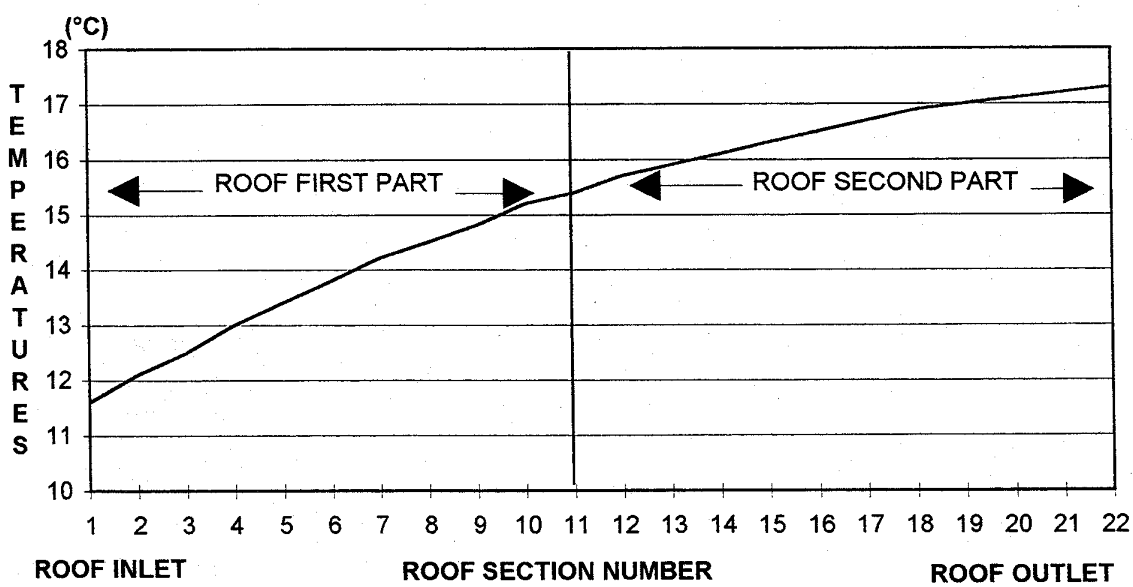


Figure 7 : Inside air gap temperature evolutions during the day

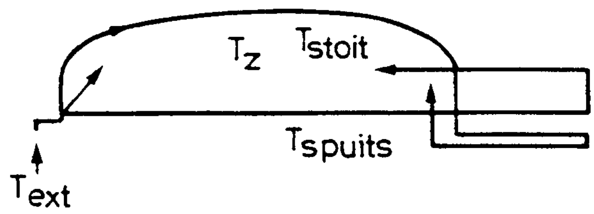
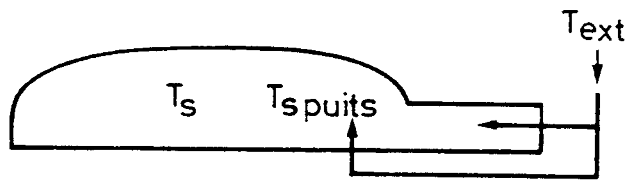


Figure 8 : Optimisation diagram for DYNAMIC configuration



Fgure 9 : Optimisation diagram for PITS configuration

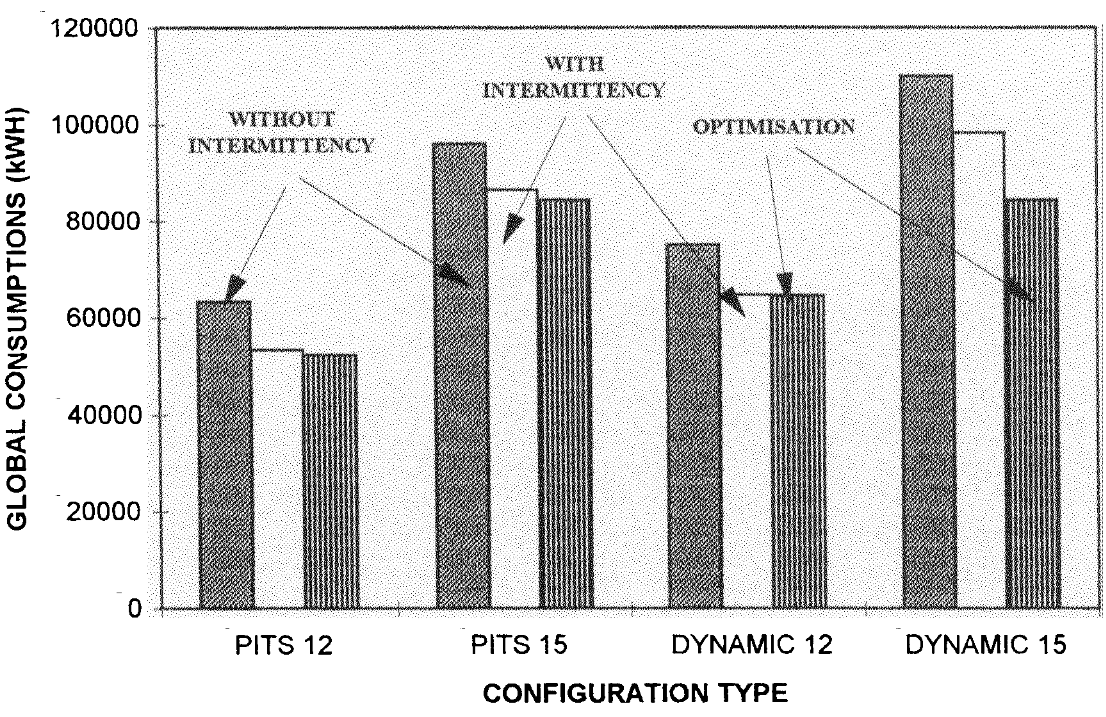


Figure 10 : Influence of optimisation on gymnasium global consumptions for the climatic site of YZEURE

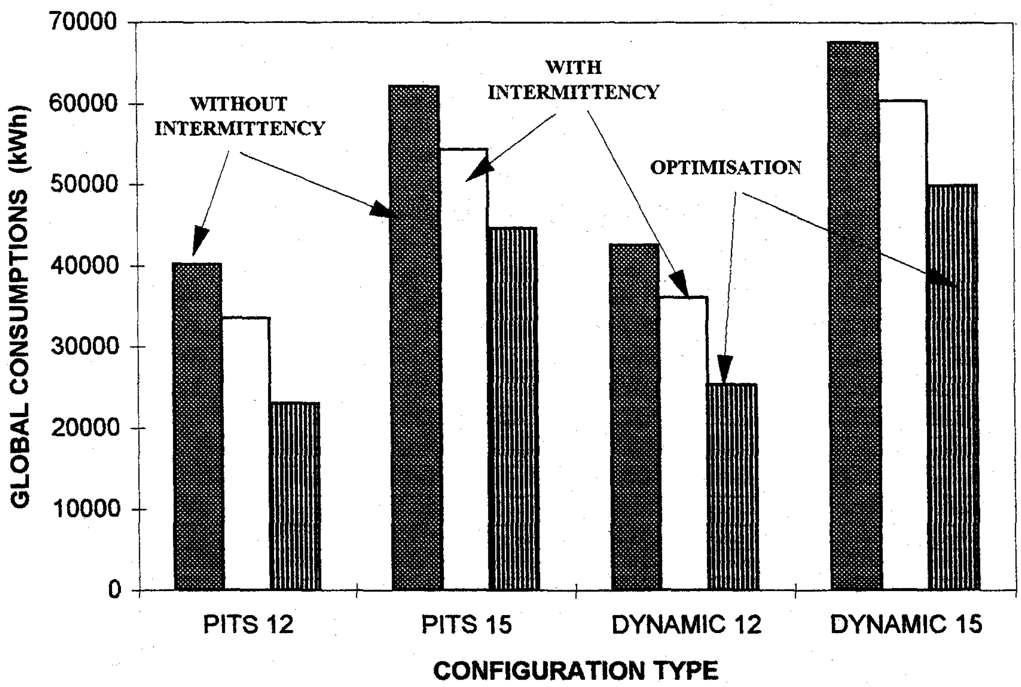


Figure 11: Influence of optimisation on gymnasium global consumptions for the climatic site of MONTPELLIER