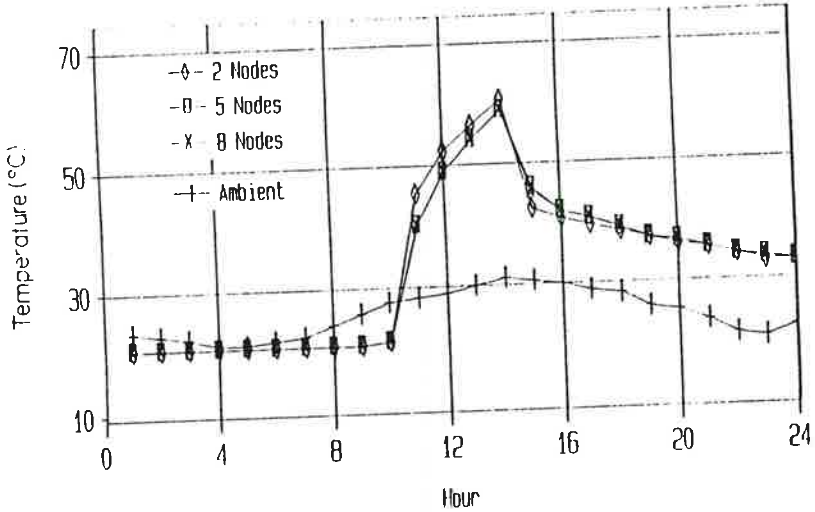
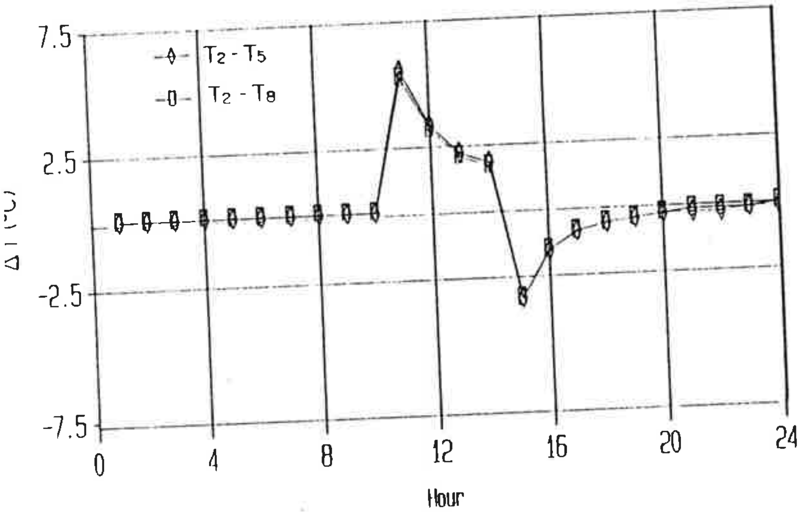


URE 5a: Surface temperature predictions for the high-mass component using increasing numbers of nodes to describe the wall (convection plus solar pulse)



IGURE 5b: Deviations in surface temperature predictions from the two node baseline case for larger nodal representations (convection plus solar pulse)

INTERNAL HEAT TRANSFERS AND HEATING NEEDS OF BUILDINGS

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1. Introduction

Until now, in order to calculate the heating needs of the buildings, unizone models were used*. From these models, simplified methods to predict heating needs have been developed. Recently, multizone codes have appeared. We have tried to answer the question : what is the influence of internal transfer (i.e. of multizone models) on the heating needs computation ?

Before to present the results of this study, we explain how it is possible to characterize the annual thermal behaviour of a building. Then the software ASTEC is briefly described and the choice of an internal configuration is discussed.

At the end, we raise some numerical problems occuring during permanent or transient multizone simulations.

2. Simplified characterization of buildings thermal behaviour

Since 1977, the CSTB has performed a simplified method (1, 2) to calculate a volumic heat loss coefficient : G ($W/m^3.K$). This coefficient characterizes the insulation level of buildings. The annual heat losses, D**, are proportional to this coefficient :

$$D = G\ V\ DH$$

where V represents the heated volume (m^3) and DH the number of degree-hours (K.hr)

* With an unizone model, the temperature distribution and the internal and solar gains repartitions are supposed to be uniform.

** The D letter is used because in French the equivalent of "Heat losses" is "Depertitions thermiques"

This coefficient doesn't take into account neither the passive solar gains available into the heated volume nor the internal gains. The capabilities of a building to collect the passive solar gains and to restitute them (added to the internal gains) with phaselead are included in the volumic heating needs coefficient. B ($W/m^3.K$) (3). The annual heating needs **B*** are proportional to this coefficient

$$\mathbf{B} = B\ V\ DH$$

The French thermal regulation on new buildings assignes the respect of maximum values for G and B coefficients

The simplified methods, to calculate the two coefficients, derived from a lot of simulations performed with CSTBât** (in its unizone version)

The determination of B needs the previous knowledge of G and the calculation of an intermediate parameter, X. This last is the ratio between free gains and heat losses :

$$X = \frac{\text{(Solar gains + Internal gains)}}{G\ V\ DH}$$

The solar gains relate to the energy collected by the building. These gains are evaluated by taking into account the various passive components arranged in the considered building. The internal gains represent a mean thermal power of 4.17 W/m^2***
X coefficients give an idea of building capabilities to collect passive solar gains.

But all the free gains do not take part into heating needs covering (because of overheats). So, knowing X, we have to determine the heating needs ratio covered by the free gains. This ratio is called F and it comes :

$$B = G\,(1 - F)$$

F is obviously less than X. The difference between X and F is dependent on buildings structures. Different behaviours of buildings result from different thermal masses. Usually, we distinguish four classes of thermal mass ****:

- Heavy mass (more than 400 kg/m^2)
- Medium mass (from 150 to 400 kg/m^2)
- Low mass (from 100 to 150 kg/m^2)
- Very low mass (less than 100 kg/m^2)

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* The **B** letter is used because in French the equivalent of "Heating needs" is "Besoins de chauffage"

** CSTBât means "Code de Simulation de la Thermique du Bâtiment". It is a computer program developed by the CSTB to carry out accurate simulations about the thermal behaviour of the buildings and their heating or cooling equipment. When we have began this work, the multizone version of CSTBât was not achieved ; it is one of the reasons for which we have choosen ASTEC

***This value is issued from statistics studies.

**** The computation method of buildings thermal mass classes is included in ref. (3)

3. The ASTEC software

To perform the computations, we use the software ASTEC. This software is not a code especially consecrated to simulation of buildings thermal performances. In fact, it is a solving program which at first has been developed by the CEA* to deal with non-linear electric or electronic problems

Around a numerical processor, using a Gear's algorithm, we find an output-processor, able to carry out arrays or curves, and an interface user/main-program

To describe a problem, a specific language is requested which uses the electricity terminology.

So, to model a thermal system, thermal-electricity analogy technics are required.

The basis components are resistances, capacities, voltage sources and sources of current. With these basis components, the user can work out its own macro-components (for example, a wall, an adiabatic wall, a window ...) which can be stored in a user's librarian. Then macro-components can be connected to form a whole dwelling.

The time step is automatically adjustable in regard of the convergence difficulties.

4. The multizone model

The description of the real partition could be very accurate. But this would induce us to create a lot of complicated models (therefore the running times would be too long).

We have chosen to limit the accuracy (therefore the number of nodes) of the partition to a three-zone model :

- a "day" zone which regroups the reception rooms ;
- a "night" zone which regroups the bedrooms ;
- a "technical" zone which regroups mainly the bathroom and the kitchen.

The choice of a three-zone model is justified by the fact that similar rooms are often located in the same place in the house ; they are used in the same way at the same moments (for example, bedrooms). So the internal transfers between these rooms can be neglected. On the other hand, this choice has been confirmed by another study performed during the development of the software CSTBât 1.3 (4). This study was carried out on the comparison of unizone, 2-zone and 7-zone models. It was restricted to one particular flat in two different climatic stations. These simulations have shown that there is a large difference on instantaneous heating needs computation between 2-zone and 7-zone models. These differences are reduced when considering the annual results - taking as a reference the 7-zone model, they are from 7% to 25% for the unizone model and only from 1% to 6% for a 2-zone model.

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* Commissariat à l'Energie Atomique - France

So a 3-zone model appears to be a good compromise between accuracy and CPU running-times. To give an idea about these last, we can say that, on a VAX 750, an annual simulation, with a maximum time-step of 1 hr, takes from 3 to 30 mn (CPU time) with a unizone model and from 20 to 100 mn with a 3-zone model (inferior values correspond to a simplified model of internal radiative transfers and superior values to a very accurate model of these transfers). The 3-zone description leads us to define space and time distributions for internal gains in each zone. We have performed this work by using investigations carried out to define a time distribution for unizone models (5).

5. Influence of internal transfers on the heating needs

The heat transfers between two adjacent rooms can occur by conduction, convection or radiation. The conduction can be the only occuring transfer (if the dividing wall is opaque and air-tight).

At the opposite, if the dividing wall involves a large opening, convection can be the leading transfer mode. In almost all cases, radiation is negligible as it is shown in the following table.

Mode of transfer	Relative importance
Conduction	100 to 25%
Convection	0 to 70%
Radiation	0 to 5%

Table 1. Relative importance of the three possible modes of heat transfer between two adjacent rooms.

Notice that convection can result both of mechanical ventilation or free convection.

For this study we have supposed that doorways were always closed. So aeraulic transfers are only caused by a mechanical ventilation and there is no radiative transfer between two different zones. The ventilation air flow is time dependent (see fig. 1).

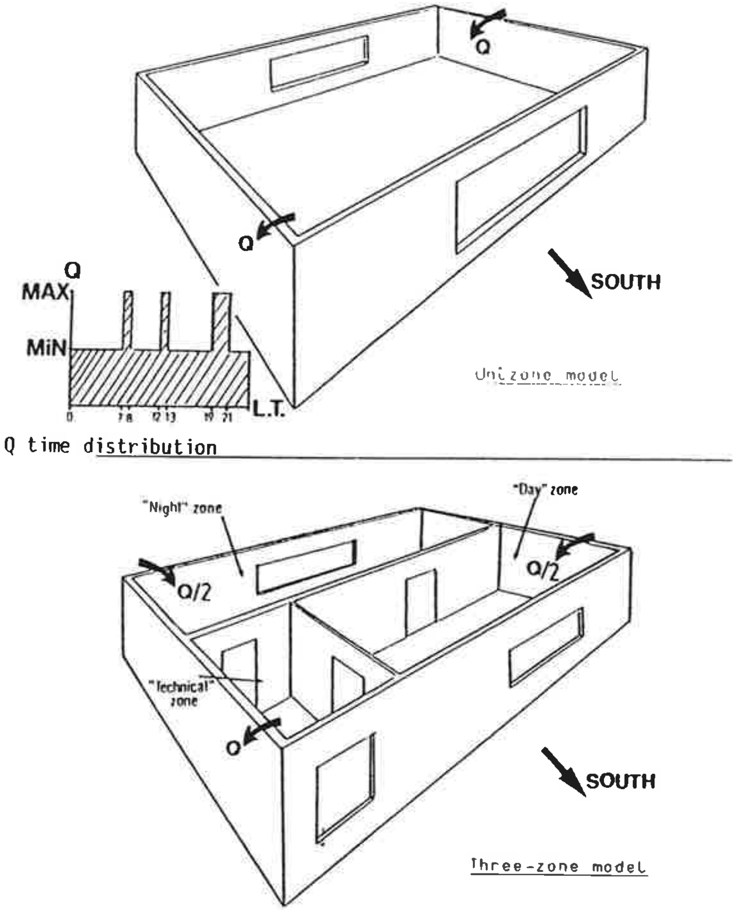

Fig. 1. Unizone and three-zone partitions of a dwelling.
Q is the air flow of a mechanical ventilation.

Numerous simulations have been performed with three climatic conditions (Carpentras and Nice - Southern France - and Nancy - Northern France). The main parameters were the glazed area, the kind of glazing (double or simple) the walls constituents and the thermal mass.

As a conclusion, we can say that an unizone model under-estimates the heating needs of about 15% (see fig. 2). This under-estimation can reach 30% in case of very glazed houses (i.e. 40% of glazed area on the south wall) in sunny climate.

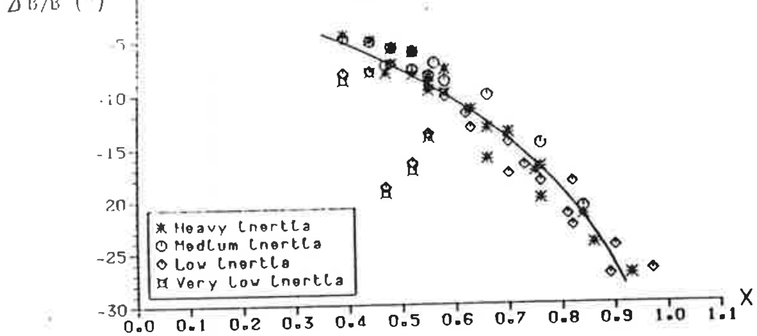

Fig. 2 Relative differences on the computation of heating needs between an unizone model and a 3-zone model.

For each simulation, we have computed the F and X coefficients. On fig. 3, one can see the difference between unizone and 3-zone models in regard of the thermal mass.

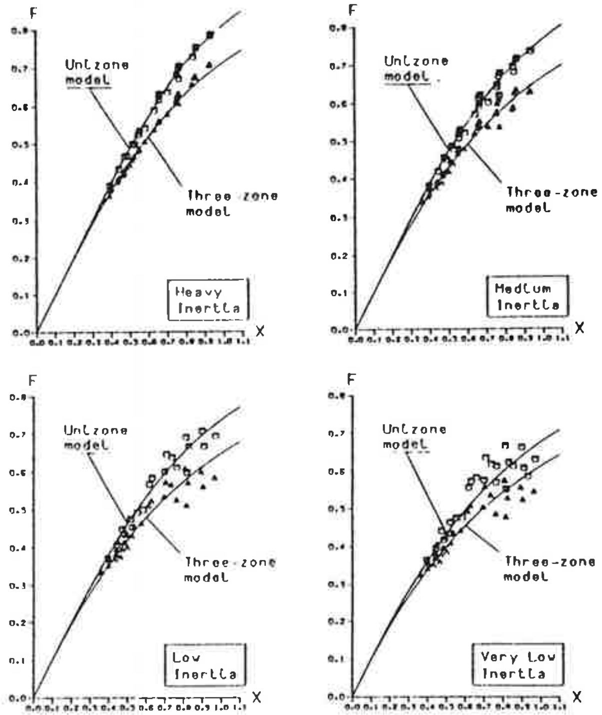

Fig. 3 Comparison of the rates of heating needs recovery (F) computed either with an unizone model (symbol □) or with a 3-zone model (symbol ▵).

We have searched for the determination of analytic formulas to fit at the best the couples (X, F). The general formula is :

$$F = \frac{X - X^r}{1 - X^r}$$

r exponent values depend on thermal masses (see table 2)

Mass class	Heavy	Medium	Low	Very low
Unizone model	5.253	4.210	3.720	3.320
3-zone model	3.500	3.000	2.800	2.590

Table 2. r exponent values of F = f(X) function.

Using the results of this study, the CSTB's B computation simplified method could be modified to take into account the influence of internal transfers on the recovery of free gains.

(Models developed with the software ASTEC have also been used to compare rates of recovery either of internal gains or of solar gains (5, 6))

6. Aeraulic transfer models

Internal heat transfers by conduction or radiation are functions of temperatures. Aeraulic transfers depend on pressures.

To built multizone codes, designers have linked aeraulic and thermal models. So, the number of variables (temperatures and pressures) has greatly increased. Moreover aeraulic flows are non-lineary dependent on pressures. Consequently, numerical problems of convergence can be very important.

We have checked those problems for three codes (TARP*, CSTBât and ESP**). All aeraulic modules are based on the WALTON's model. Difficulties appear mainly when dividing walls include great appertures. They increase for transient simulations and it is worse when inhabitants behaviour is taken into account (opening and closing the doorways).

Those problems are diminished with the sofware ASTEC because of capabilities of its numerical solving processor. Anyway running-times are unacceptable.

To compute heating needs with some accuracy, it is obvious that a multizone description of buildings or dwellings is required. But convective transfers have to be expressed as functions of temperature fields. One of the main problems to solve is : how to model coupled transfers by natural and forced convection through a great apperture ? To answer this question and, at the end, to validate a numerical model, we have built a prototype. This last is equiped to measure air velocities and to make energy balances under various conditions : temperatures in each zone are adjustable and a mechanical ventilabion can provide forced air flows from 0 to 200 m^3/hr.

The first results let us think that for numerous cases, a first order model could be validated.

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** Environmental Systems Performance. University of Strathclyde (GB)

7 Conclusions

3-zone models seems to be an enough accurate descriptions of dwellings real configurations. Time and space distributions for internal gains have been performed according to 3-zone models

The differences on annual heating needs computation between an unizone model and a 3-zone model, assuming that air transfers are caused only by a mechanical ventilation system, can reach 30% On an average, the heating needs under-estimation, made with an unizone model, is about 15%.

According to these comparisons, we have improved the CSTB's B computation simplified method (B is the volumic heating needs coefficient).

A study, to clearly work out influence of models accuracy on the heating needs computation, is actually carried out (comparisons between unizone, 2-zone, 3-zone and 4-zone models are made).

Our software tools have also been used to calculate the rates of recovery of thermal losses of either a hot tank water or a gas generator when these components are in the heated volume (6)

Transient simulations, with a complete description of aeraulic transfers have been undertaken with the codes TARP, CSTBât and ESP. Numerical convergence problems have been displayed, (sometimes even whith permanent conditions for temperatures fields) Main difficulties appear when dividing walls include great appertures (through which aeraulic transfers occur by coupled natural and forced convection). That induces us to try to validate simplified aeraulic models. Our basic tool to do that is an experimental house of 80 m^2.

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THE SENSITIVITY OF SIMULATION MODEL PREDICTIONS TO AUXILIARY HEATING AND CONTROL TEMPERATURE CHARACTERISTIC

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1. Introduction

During an inter-model comparison carried out by the Internationa Agency (1) in the 1970's, it was found that the calculated auxil energy demand of a building was significantly affected by the pr of this energy supplied as convective or radiative heat. Since little further attention seems to have been paid to the subject.

The current interest in buildings which incorporate passive sola features has increased the need to understand this aspect due to that the radiation characteristics of such climatically responsi buildings are so different from those which use a more conventio climate rejecting approach. The large areas of glass mean that:

i. the radiant processes are strongly decoupled from the convective processes due to (a) the high radiant gain (b) the difference in surface temperatures between the the solar heated surface and the unheated surfaces

ii. the radiant environment is highly anisotropic

iii. the radiant heat input varies over a wide range and ca change rapidly as a function of time.

The question addressed by this paper may be stated as follows: the purpose of passive solar design is to use radiant solar ener displace the energy needed to be supplied as auxiliary heat, how the radiative/convective characteristics of the heat input and affect this process?

2. Method

2.1. Model

The study was carried out using HTB2, a dynamic research model developed in the UK (2) to simulate energy efficient buildings. based on an earlier explicit finite difference model HTB (Heat T through Buildings) which has been in use at Cardiff since 1971 has now been completely restructured, extended and documented to it into line with modern programming practice and the needs of