# COMETRES, A SIMPLE TOOL FOR THE IMPROVEMENT OF SUMMER COMFORT IN RESIDENTIAL BUILDINGS

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## ABSTRACT

In summer, it is possible to achieve a satisfactory comfort in residential buildings with purely passive means as thermal inertia, possibility of cross ventilation and solar protection of the external envelope. These parameters have to be taken into account at the earliest stages of building design. Because the maximum cooling power is generally available at night and the maximum temperature occurs in the middle of the day, the calculation tools must take into account in a quite accurate way the non steady state thermal behaviour of the rooms, and the control strategies must compensate this phase displacement, while keeping the indoor climate comfortable during occupancy. We developed, on the basis on a simple RC equivalent network, a thermal dynamic model with a particular attention paid to the impact of the outdoor noise. This model, called COMETres, follows validation procedure of the TC89WG6 of the European Comity of Normalisation (CEN) which works on thermal performance of buildings in summer without mechanical cooling (prEN 13792). This simplified reference calculation method enables to calculate the indoor temperature profile for a reference warm day according to a zoning of metropolitan French territory. Used primarily for new buildings, this tool will be also be a help for retrofitting.

## KEYWORDS

Summer comfort, Residential building, dynamic calculation tool, indoor temperature, reference day.

## INTRODUCTION

In France, mechanical cooling is widely used in office and commercial buildings but not in residential buildings until now. This situation is changing and air conditioning is sometimes considered as the only way to improve summer comfort in residential buildings. Nevertheless, in many cases, it is possible to achieve a satisfactory comfort in summer in residential buildings with purely passive means as thermal inertia, possibility of cross ventilation and solar protection of the external envelope. These parameters have to be taken into account at the earliest stages of building design.

The development of efficient strategies in this field requires to take into account the fact that the maximum cooling power is generally available at night with cross ventilation, and the maximum temperature occurs in the middle of the day. So, the tools must take into account in a quite accurate way the non steady state thermal behaviour of the rooms, and the control strategies must compensate this phase displacement, while keeping the indoor climate comfortable during occupancy.

We developed, on the basis on a simple RC equivalent network, a thermal dynamic model which calculate the indoor temperature profile for a reference warm day according to a zoning of metropolitan French territory, with a particular attention paid to the impact of the outdoor noise (related to the windows opening at night). This model, called COMETres, was primeraly validated by comparing its results to a more detailed one (TRNSYS), and now by validation procedure of the TC89WG6 of the European Comity of Normalisation (CEN) which works on thermal performance of buildings in summer without mechanical cooling (prEN 13792).

Used primarily for new buildings, this tool will be also be a help for retrofitting. The hypothesises and the algorithms of this model were given to the software publishers to product their own codes and to make link with winter thermal calculations.

## 1 - DESCRIPTION OF THE REFERENCE CALCULATION METHOD

While the correlation methods are widely used for the heat requirements assessment with satisfying results, this approach is difficult to apply to the summer comfort assessment. The reason is that transient phenomena play a prominent part in the building behaviour in summer, especially if there is no cooling plant. So, simplified tools based on dynamics models seem appropriate to assess the internal temperature in summer and to evaluate the thermal comfort. The COMETres (COMfort Evaluation Tool for residentials buildings) method is based on a thermal model (equivalent RC network), a ventilation model based on experimental results (opening windows at night) and a reduced set of climatic data.

### *1.1 - thermal model*

The RC model (five resistances, one capacitance) gives hourly values of the internal air and the operative temperatures (see figure 1). The parameters of the model are calculated from the building and operation data. The building data are the area, orientation, tilt angle, thermal resistance and solar factor of each external components (walls, windows, roofs). Additional parameters take into account the effect of overhangings. The room daily inertia is the ratio of the effective mass of building components to the room volume. The sequencial effect of inertia is also taken into account. Most of these data are already used for the heating. Operation data are daily patterns for internal heat gains and ventilation.

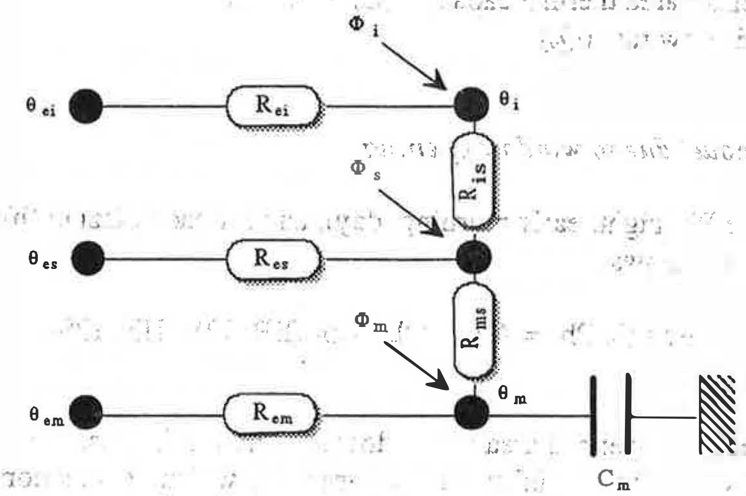


Figure 1 : RC equivalent network

The model based on the simplifications of the hea  transfer between the internal and external environment can be described as follows:

The relevant nodes are defined related to :

$\theta_i$ : indoor air temperature,
$\theta_s$ : Tstar temperature,
$\theta_m$ : mass temperature,
$\theta_{ei}$ : outdoor air temperature,
$\theta_{es}$, $\theta_{em}$ : equivalent outdoor air temperature of external components.

The equivalent resistances (K/W) and thermal capacity (J/K) between the internal and ex ernal environment considered are :

$R_{ei}$ : thermal resistance due to air ventilation,
$R_{es}$, $R_{em}$ : thermal resistances of external components between outside and inside,
$R_{is}$, $R_{ms}$ : thermal resistances which correspond to heat exchanges between internal surfaces and internal air,
$C_m$ : thermal capacity of the enclosure elements.

The heat fluxes (W) considered are :

$\Phi_i$ : heat flux to node $\theta_i$, due to convective part of internal sources, convective par  of direct solar radiation directly transmitted to the air and convective heat flux of ventilated air layer of glazings,
$\Phi_s$ : heat flux to node $\theta_s$, due to radiative part of internal sources and radiative part of direct solar radiation
$\Phi_m$ : heat flux to node $\theta_m$, due to radiative par  of internal sources and radiative part of direct solar radiation

According to an electric representation, the envelope components are divided as below with the required datas :

- light opaque (thickness ≤ 12 cm) and heavy opaque external components : thermal transmittance (U), solar factor ($S_f$), area thermal capacity(C), area (A).
- thermal bridges : thermal transmittance (u), solar factor (s), length (l).
- glazing components : thermal transmittance (U), short wave, long wave + convective and ventilated air layer components of solar factor, area thermal capacity (C), area (Ab)
- internal components : area thermal capacity (C), area (A).
- room : volumic air flow rate ($Q_v$)

### *1.2 - Ventilation model due to window opening*

For each hour range Ph (night, early morning, day), and for each glazing (b), we calculate first an equivalent area as follows :

$$Aeq\ (b, Ph) = Ab\ .\ ROL\ .\ Cpr\ (BR, IPV, IJN, IPS)$$

With :

ROL : ratio between the openned area of window and the whole area,
Cpr : coefficient of air permeability of the opening, which is function of the following parameters :
BR : nocturnal noise level (three levels),

IPV : exposure to breaking and entering,
IJN : status of the associated room (bedroom or other),
IPS : air permeability of shutters.

The sommation of the equilalent areas for each orientation (Or : East, West, North or South) is done :

$$Aeqt\,(Ph, Or) = \sum_{b} Aeq(b, Ph)$$

The conventional volumic air flow rate due to window opening is calculated as follows :

$$D_{fen}\,(Ph) = 100.\left(\sum_{Or} Aeqt(Ph, Or) + 3.\sqrt{\sum_{Or2>Or1} Aeqt(Ph, Or1).Aeqt(Ph, Or2)}\right)$$

where 100 (en m/h) is the equivalent velocity of wind for thermal effects and transversal ventilation.

### *1.3 - Climatic data*

These data have been chosen in order to give the level of indoor air and operative temperature which will be overstepped during five days for an average summer. The calculation is made for a reference warm day. The choice and the values for France of these reduced climatic data has been validated by simulating various buildings on 15 real summers for each of six meteorological stations. French territory have been divided in four climatic zones Ea, Eb, Ec, Ed (see figure 2) with some corrections to take into account the distance to the sea and the altitude.

The climatic datas needed by the model are :

Idn : direct normal radiation (Wh/m²)
Idi : isotropic diffuse radiation (Wh/m²)
T : averaged daily temperature (°C)
Eq : daily semi amplitude (°C)
Eseq : difference beetwen averaged daily and averaged monthly temperatures (°C)


Figure 2 : Summer climatic area

### *1.4 - Example of results*

As an illustration of the influence of different parameters, figure 3 gives results, in term of operative temperature, for a reference dwelling situated in the Gard, when, inertia, solar gains, and night ventilation are modified. In the best conception, operative temperature is always below 26°C, and in the worst, maximum operative temperature is about 35°C.

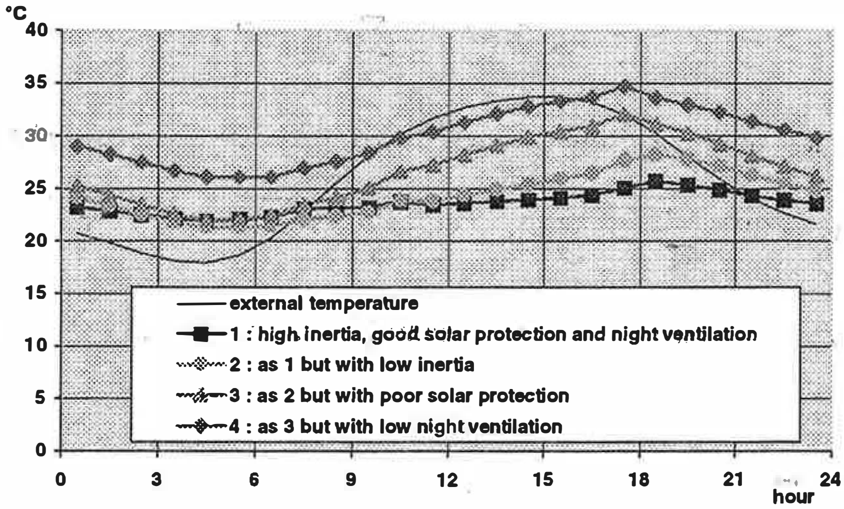


Figure 3 : Example of COMETres results : operative temperatures for a reference dwelling, varying inertia, solar gains and night ventilation.

## 2 - VALIDATION PROCEDURE

### *2.1 - comparison with TRNSYS model*

The results of our model have been primeraly compared to the ones of TRNSYS simulations for a West oriented room with different inputs (climatic data, solar heat gains, thermal inertia, ventilation schedules...). With high ventilation rates, as it happens in summer, the difference between air and operative temperature cannot be neglected. Figure 4 compares the maximum temperatures and the difference between air and operative temperature obtained with the two models. Discrepancies remain less than 0.9°C for the operative temperature and 0.2°C for the difference between air and operative temperature.

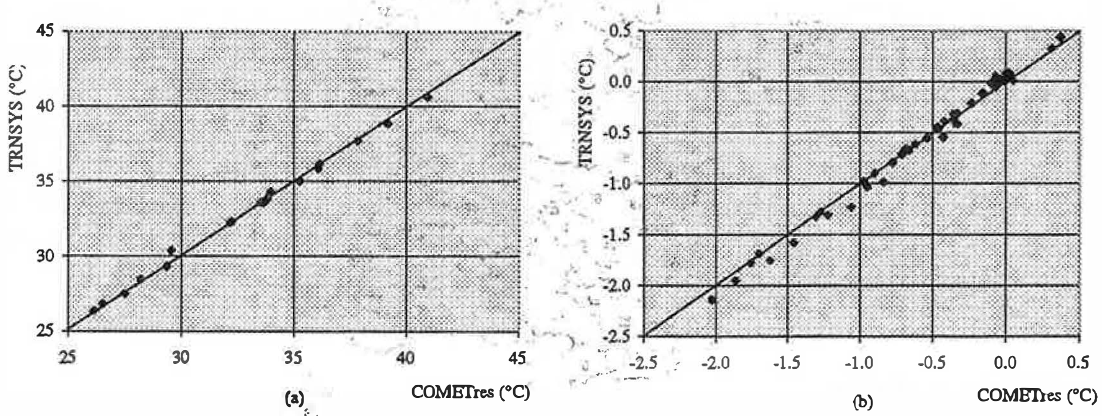


Figure 4 : Comparison between COMETres and TRNSYS results :
(a) : Maximum operative temperature
(b) : Difference between air and operative temperature

### *2.2 - Validation procedure of the TC89WG6*

Our model follows validation procedure of the TC89WG6 of the European Comity of Normalisation (CEN) which works on thermal performance of buildings in summer without mechanical cooling (prEN 13792). This standard sets out the level of input and output data, and describes the boundary conditions required for a calculation method to determine the maximum, average and minimum daily values of operative temperature of a room in a warm period. It doesn't impose any specific calculation method but includes the criteria to be met by a calculation method in order to satisfy this standard. These criteria are a set of test cases (two geometries in two different climatic conditions, with three different types of envelope and ventilation rate : 18 test cases). For each test case, the comparison with reference values given and our model COMETres gives a difference less than 0.4°C, which should be acceptable for the validation of our model (see figure 5).

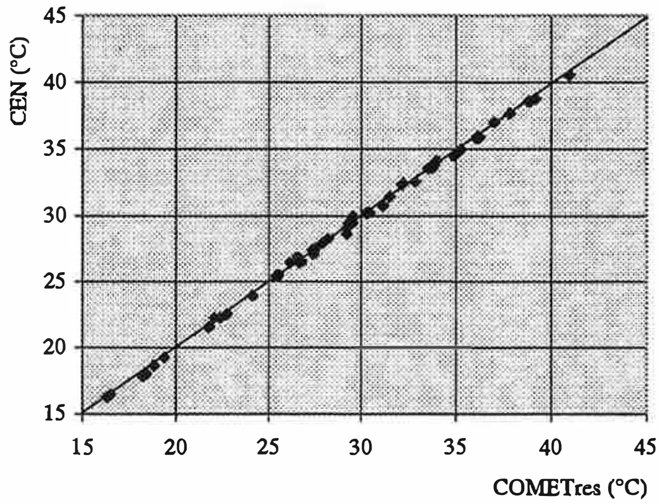


Figure 5 : Comparison between COMETres and CEN results for maximum, average and minimum operative temperatures of validation tests.

## CONCLUSION

Helping building engineers to improve the building design for summer comfort requires to base the tools on dynamic simulations. We have developed for that purpose a simple RC model called COMETres, which proved to be accurate enough compared to reference detailed tools. One important point is that this tool is based on simple input which make it possible to use it at the early stage of the building design, when major changes can still be done. Used primarily for new buildings, this tool will be also be a help for retrofitting. The hypothesises and the algorithms of this model were given to the software publishers to product their own codes and to make link with winter thermal calculations. Works are now in progress to apply the same model for air conditioning system sizing, and calculation of yearly energy needs for air conditioned buildings.


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