# SIM_ZONAL: SOFTWARE EVALUATING INDOOR TEMPERATURE DISTRIBUTIONS AND AIR MOVEMENTS FOR RAPID APPRAISALS - FIRST APPLICATION TO AN CELL.

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## ABSTRACT

This article presents the first application of the Sim_Zonal software, a tool for evaluating indoor temperature and air flow distributions for residential and office buildings. The aim of this EDF (Electricity of France) software developed with the LEPTAB (University of La Rochelle) is to evaluate comfort problems and specially risks of discomfort (risk of draught, indoor gradient temperature, etc..) for rapid technical appraisals. The tool development - under Windows 95 - is in progress. In this paper we present our first application : an evaluation of the air temperature distribution in an cell heated with a heated floor.

## INTRODUCTION

Sim_Zonal simulates the thermal and air flow exchanges inside a room in order to determine comfort conditions. It is a 3-dimensional simulation tool designed to appraise the quality of thermal environments within the framework of short-term studies lasting less than a week. In this article, we first briefly present the models developed in Sim_Zonal. These models are based on the following choices: the zonal method [1,2,3] is used to represent the air flows in the room, the heat exchanges by radiation are modeled by the Walton's method [4] and the heat exchanges by conduction are described with a finite differences model, reduced by Moore's method [5]. The software is then presented through the modeling of a cell 15 $m^2$ in area provided with a heated floor.

## MODELING ASSUMPTIONS

The detail of the models used in Sim_Zonal is described in the reference document [6]. The main modeling assumptions are presented in the following paragraph.

*Zonal models*

The principle of the zonal method is to divide the room considered into a number of cells in which are calculated the air flow characteristics which are assumed to be constant (temperature, pressure, density, etc.). Mass and energy transfers are determined between the different zones. The division's macroscopic character is compensated by an as accurate as possible description of driving airflows. With dominant airflows, specific laws are applied; outside this range the laws are simplified as far as possible to limit calculation times [7]. To analyze the various mass and energy transfers in low-speed zones, a pressure zonal model is considered (*pressure varies hydrostatically*). The laws used are then derived from mass, movement quantity and energy conservation equations. The variables of the problem are the temperature, the pressure and the density at the center of each cell, as well as the density of heat flows exchanged between one cell and its neighbors. In the dominant flow zones, equations are added describing the thermal plumes and boundary layers.

*Conduction models*

The proposed model is an approximation using the finite differences method. To reduce the system, Moore's reduction method [5] is applied. The conduction phenomena in the walls are described in dynamic mode:

$$C. \quad T' = A.T + E.U$$

$$Phi\_Cond = H.T + D.U$$

A system reduced to order 2 is obtained by applying Moore's method.

*Radiation models*

The system of equations accurately describing the heat exchanges through radiation is non-linear. It was thus decided to simplify the radiation flow calculation expression, in order to make it linear and thus consistent with the other models used. For this purpose, the fictitious enclosure method proposed by Walton [4] is used. Its principle is to consider that this area i exchanges with a single fictitious gray area associated with it.

## CELL DESCRIPTION

This cell with an area of 15 $m^2$ is representative of an office or a bedroom. Its dimensions are 2.90 m x 5.15 m x 2.50 m (in the West-East, South-North and Top-Bottom directions); the window is located on the North wall and the door on the South wall.

The plane is shown in Figure 1. In our study, the cell is heated by a heated floor.

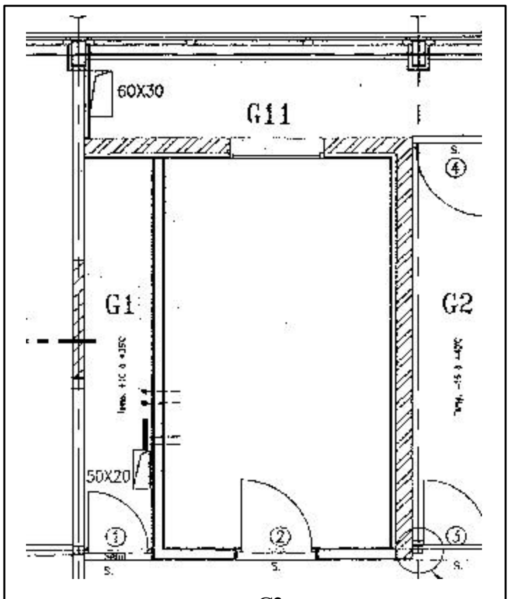


Figure 1: Cell description

***Composition and characteristics of walls***

**Inside walls**

These are the walls in contact with soft seals G1 and G3. They are little insulated and their composition from the inside of the cell to the outside is:

• 26 mm plasterboard

• 108 mm rock wool

• 26 mm plasterboard

The exchange coefficients are taken to be equal on either side of the wall and their value is 9.1 W/m2.°C

The area of the South wall is 7.25 m and the area of the West wall is 12.875 m2.

**Outside walls**

The outside walls are in contact with a seal (G11 and G2) and are well insulated. Their composition from the inside of the cell to the outside is:

• 10 mm plasterboard

•50 mm polystyrene

•200 mm Siporex

**Ceiling**

The ceiling has the following composition:

• 13 mm plasterboard

• 100 mm rock wool

•liquid seal system

**Floor**

Floor composition:

•50 mm concrete

•heating electric cables

•50 mm floormate 200

• liquid floor

**Door**

The door has a thermal resistance of 1 $m^2$.°C/W and its dimensions are 2m x 1m (2$m^2$).

**Window**

The window has double-glazing, its dimensions are 1.2m x 1.25m (1.5 m2) and its statutory characteristics are AC2-TH5.

## CALCULATION OF BOUNDARIES CONDITIONS

The cable heating power and the temperatures outside the cell are considered as boundaries conditions. They are pre-calculated using an energy code (see figure 2). In our case, we used an air node model (single-node model). This initial simulation determined, on an hourly basis, the power delivered by the heated floor in order to obtain an ambient temperature of 19°C.

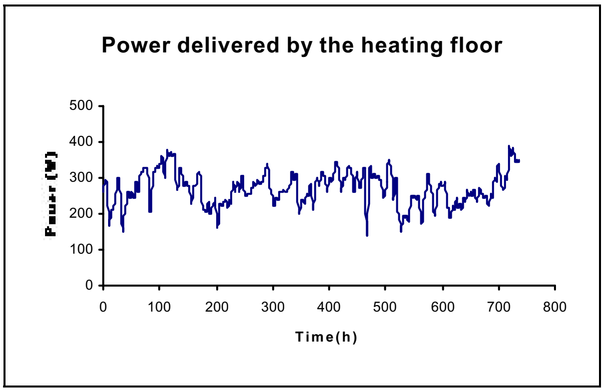


Figure 2: boundaries conditions for calculating the flux delivered by the transmitter.

## SIM_ZONAL USER INTERFACE

In our application, the room was meshed into 18 sub-volumes (see figure 3). The set of data required for the simulation, with the exception of the composition of the walls, was entered through a graphics interface.

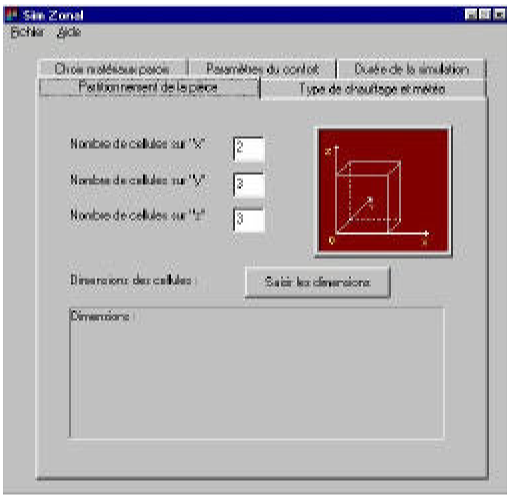


Figure 3: Entering the mesh

## ANALYSIS OF THE SIMULATION

The simulation was carried out in October in Trappes (near Paris).

The initial results obtained are satisfactory.

We regulated at 19 °C tell with the single-node model (boundaries conditions). We obtained an average temperature of 19.1 °C with our 18-nodes zonal model.

The distribution of temperatures over the simulation period is consistent (see figure 4), i.e. less than a degree different from the maximum temperatures. This result corresponds to the temperatures obtained with an heated floor.

The spatial distribution seems correct.

- The distribution in Bottom/Top temperatures is consistent (see Figure 5). The temperature of the lower center cell is higher than that of the center and upper zones.
- The temperatures of the sub-volumes in contact with a seal at 19°C are higher than those in contact with the outside temperature (see Figure 6).

The simulation time is short: less than 30 seconds for this simulation over a complete month.

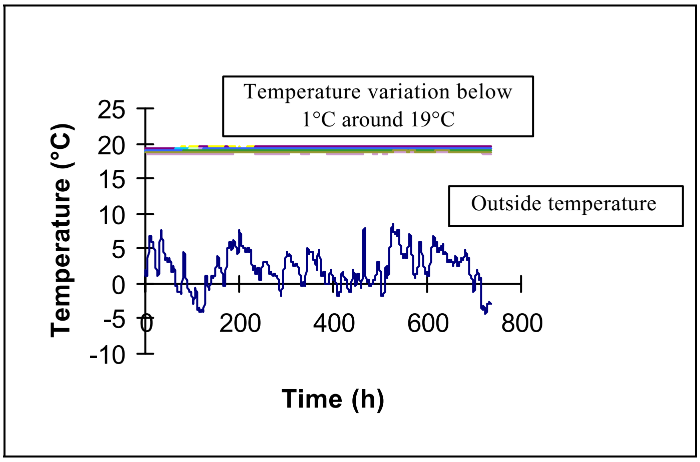


Figure 4: Temperature variations in the cell.

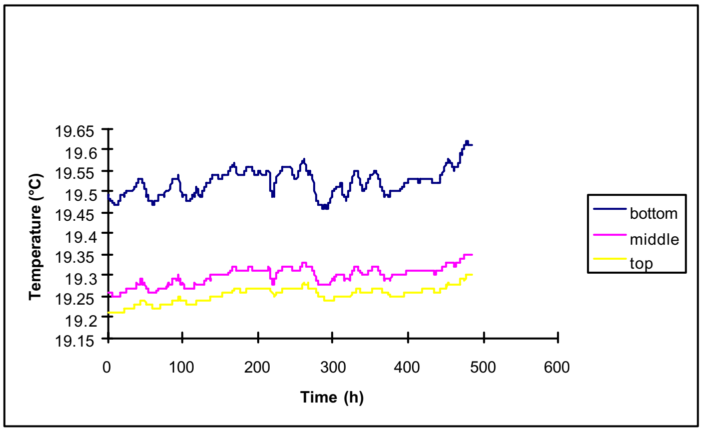


Figure 5: Temperature variations in the three air volumes located in the center zone.

The results of figure 6 shows cross-section planes obtained in the cell. They represent the spatial distribution of the temperatures and flow rates at a given time in the simulation (Mid-October at 3 pm).

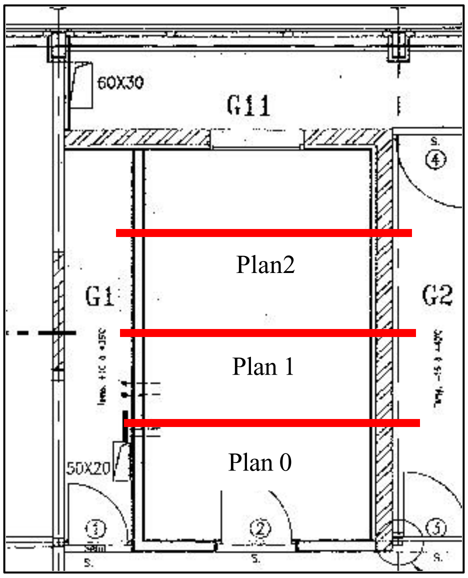


Figure 6: Cross-section planes

The spatial distribution of the temperatures is shown in figures 7.1, 7.2 and 7.3. The zones in contact with the outside walls (right-hand part of the cross-sections) are colder than those in contact with the seals at 19°C. Plane 2, whose North wall is in contact with the outside temperature, is also colder than the other planes.

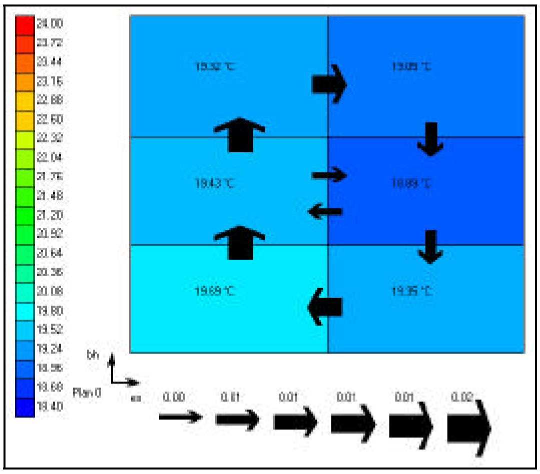

Figure 7.1: Spatial distribution of the temperature fields – Cross-section plan 0.

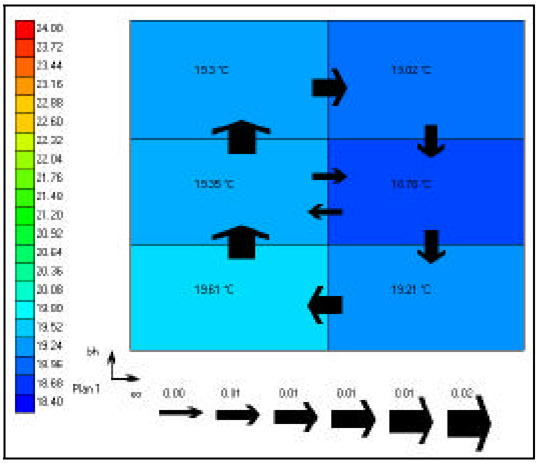

Figure 7.2: Spatial distribution of the temperature fields – Cross-section plan 1.

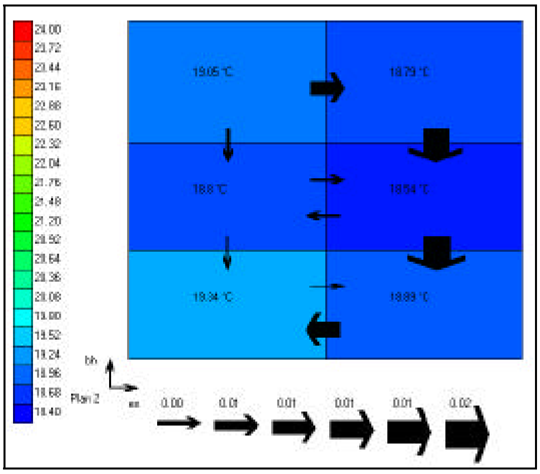

Figure 7.3: Spatial distribution of the temperature fields – Cross-section plan 2.

## CONCLUSION

In this article, we present the initial results obtained using the SIM_ZONAL calculation code. This software will give an estimation of a room's thermal comfort for rapid appraisal (less than 30 seconds for a month simulation). Indeed, an estimation of the risk of non-comfort may be calculated using the different temperatures and the air flow rates. Then parameters such as the head/foot temperature gradient or the risk of draught may be determined.

Forthcoming developments will concern the integration of various transmitter models (convectors, ventilo-convector, split, etc.), the addition of the post-processing module specific to comfort (PMV, PPD calculation) and a validation based on comparisons against CFD codes and experimental measurements.

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## NOMENCLATURE

- C: the matrix of calorific, diagonal capacities defined as positive,
- A: the symmetrical but not positive matrix of the heat exchanges internal to the domain,
- E: the rectangular matrix of the thermal connections between the domain and the outside,
- H, D: vectors applied to the field of temperatures.
- T(t): field of temperatures inside the walls.
- Ph_Cond(t): Conduction flow (Watt) through the wall.
- U(t): Vector of loads. (temperatures outside and inside the walls)