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AN INDOOR AIR QUALITY PREDICTION MODEL

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Various stages, discussed in this paper, enter the design of new heating and ventilation processes:

- social and cultural analysis of users' expectations,
- design of a simulation tool,
- validation of modelling.

Owing to the complexity of comprehension of phenomena acting on air quality inside premises, EDF, GDF and the FNB (National Building Federation) have decided to join forces and skills in an attempt to provide users with better answers regarding control of heat and odour in respect of air quality in occupied premises.

This approach participates in enhancing the quality of new and existing premises by making conditions more suitable for new comfort and health requirements available (requirements which still need be defined). The first stages of thinking, especially modelling, are expressed in the approach set out below.

1 - SOCIO-CULTURAL ANALYSIS

This analysis will be performed by a specialised bureau on a sample of households. Its aim will be to qualify accurately users' reactions from a health and comfort point of view in relation to their accomodation.

This analysis will be broken down into five stages:

- Determination of the type of accommodation under study (lifestyle, type of building and technical equipment).

- Design of a supporting questionnaire for the sample-inquiry.

This questionnaire will include three items:

- a technical heading (simple diagnosis of the construction and equipment);

- a sociological heading (to be specified by an EDF team of sociologists);

- a medical heading;

- in addition to this first sample-inquiry, a second sample-inquiry may be performed to secure a fine analysis of approximately thirty "problem-prone" dwellings selected from the former sample. These dwellings will serve as bases for modelling.

• Field sample-inquiry

• Analysis of initial findings

• More sophisticated analysis (factoral, etc. analysis).

2 - MODELING - THE BILGA SOFTWARE

Since 1981, the Research Division of the National Building Federation (FNB) has been examining the combinaison of the thermal and aeraulic domains. To this end, it has devised a numerical simulation tool of the hygrothermal behaviour of a multi-zone building in variable conditions. This model has then been supplemented with the following modules:

- modelling of pollution in accommodation (in collaboration with GDF),

- modelling of humidity transfers in the walls and furniture (in collaboration with EDF).

This software operates on an AT-compatible micro-computer and an APOLLO workstation.

2.1 - The different modelling parameters

• Internal pollution sources

•• Occupants

In the programme, each individual's activity is given on an hourly basis, room by room. Different scenarios allow users' activities to be taken into account for CO, CO_2, NO_2, HCHO, assuming a constant and continuous 9-minute burning time for a cigarette.

••• Reactions with radicals

The most substantial photo-chemical reaction causes the appearance of radicals O:

$$O + NO \rightarrow NO_2$$

$$O + NO_2 \rightarrow NO + O_2$$

$$O + O_2 \rightarrow O_3$$

••• Other reactions

Only one other reaction has been integrated to the model.

$$O_3 + NO \rightarrow NO_2 + O_2$$

• Physics of the air-pollutant mixing

A distinction is drawn between draughts in a room and between rooms. By definition, the physico-chemical magnitudes of a zone in a dwelling are homogeneous: volume, temperature, chemical reaction speed, etc. Three pollutant transfer modes are possible between each zone: convection, diffusion and gravity.

•• Diffusion

Between 0.2 volume per hour, it has been shown that diffusion need be taken into consideration. Transfers are linked to differences in concentration between two zones. They have been formulated in three-dimensional form from Fick's second law.

•• Convection

It is linked to polluted air transfers between zones. It is formulated from mass conservation of a pollutant in a volume.

•• Gravity

It is linked to the earth's attraction on pollutants. It is taken into account from pollutant particles fall velocities.

• Humidity exchanges

- absorption-disorption in the internal masses,
- absorption-disorption-diffusion in the outside walls of the building.

2.2 - Example of application

A possible application is to compare the efficiency of the different ventilation systems (natural ventilation, controlled mechanical ventilation or hygrocontrollable ventilation).

•• Materials

The materials used for the construction, configuration and decoration can contribute to internal pollution. The main emitting materials to be taken into account in the model are chipboard or fibre panels, wallpaper and related bound materials, painted walls, material on the walls and carpeting.

In the model, emissions and absorptions are taken into account by a first order function with corrective terms for temperature and humidity.

•• Equipment

The main units of equipment examined are unconnected combustion appliances (hot water for hygiène or cooking).

The quantity of pollutant emission from an appliance depends on several parameters:

- test measurement of emission characteristics for each pollutant;
- instantaneous power according to a law assumed to be linear;
- operating conditions (continuous, intermittent, cyclical).

• Outside pollution and its penetration

•• The environment

Typical profiles for each of the seven pollutants taken into account in the model reconstitute the effect of a given environment (natural, semi-urban, urban, etc..., atmosphere). These profiles represent hourly concentrations.

A penetration factor Fp is applied to each pollutant p to take account of the reactivity of certain pollutants during the transfer from outside to inside the premises.

•• Physico-chemical reactions

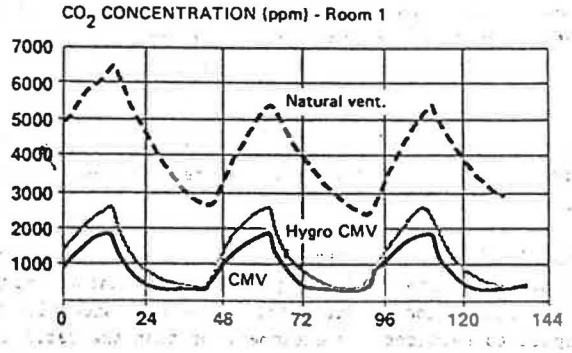
••• Chemical kinetics

Three photo-chemical reactions are taken into account:

$$O_3 + h_\nu \rightarrow O_2 + O$$

$$NO_2 + h_\nu \rightarrow NO + O$$

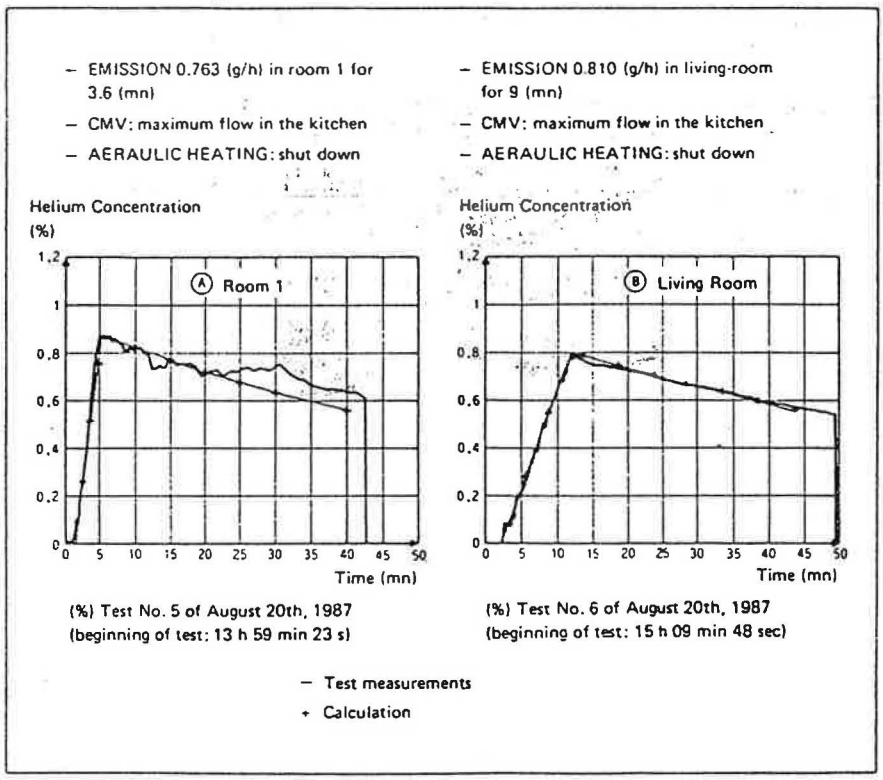
$$HCHO + h_\nu \rightarrow H_2 + CO.$$



This is, for example, the result of a CO_2 concentration simulation of a bedroom occupied at night-time by two non-smokers (winter day in accommodation with a conventional insulated structure).

3 - VALIDATION, CALIBRATION OF THE MODEL

The changes in, on the one hand, measured and, on the other, calculated tracer gas concentrations currently used for the determination of the rates of air flow have been compared.



FOLLOW-UP OF CONCENTRATION IN ROOM 1 AND THE LIVING-ROOM WITHOUT HEATING.

Since the model can take the stratification and heterogeneity of concentrations into account, finer comparisons are under study.

4 - CONCLUSION

The analysis, use and validation of a model has been briefly presented here; it has a broad scope since it covers different professions (engineers, doctors) and skills.

Modelling should afford a better analysis and understanding of the findings of the socio-cultural analysis (simulation using representative cases). Parametrical simulation studies will allow cost specifications to be proposed with respect to services and equipment meeting the desired health an safety criteria.

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