OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

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PAPER 5

THE INFLUENCE OF OCCUPANT BEHAVIOUR ON INDOOR AIR QUALITY - A CASE STUDY

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Synopsis: A balanced ventilation system with heat recovery was designed and installed into an 11 storey prefabricated blockbuilding. Monitoring of the system operation was accomplished during a year. Operational characteristics, quantified energy saving, indoor climate parameters and the effect of occupants'behaviour on those were determined and analysed. Temperature runs during durable window opening and cooking periods were monitored and on the basis of the results comparison between the new experimental and the traditional reference system was made. From the point of view of efficient ventilation, perfect effluent removal and energy saving operation the developed system proved to be better than the reference one.
The need for the more detailed investigation of the occupants' activities and their influences on the indoor air quality has also arisen. Finally proposals for some modifications and the wide utilization of the system were made.

1. Introduction: A five-year research and development project was launched in 1980 in Hungary, financed by the Ministry for Building and Urban Development, to develop a new energy saving ventilation system for multistorey blockbuildings. The presently widely used ventilation systems are of suction type, outlets positioned in the kitchens, bathrooms and lavatories and fresh air supply is realized through the cracks of the windows. Due to the official measures to install and use airtight windows for the sake of energy saving, problems with the decreased ventilation rate had arisen.

   The need for a balanced ventilation originated from this and beside the demands of necessary and enough air change rate, proper flow patterns inside the flat and low noise level, the system had to meet the requirements of the energy saving operation as well.
   The system had to conform to the characteristics of the prefabricated building technology.
   The five-year R and D activity realized through the following steps: system analysis, choice of the most suitable one, draft then detailed design into an experimental house /in that time under construction/, manufacturing and installing, experimental running and comprehensive monitoring during a year, evaluation of the experiments and proposal for wide utilization. Beyond the system analysis, indoor air quality measurements and the examination of the effects of several occupants' activities were also aimed.

2. System description, operation and monitoring

The experimental object was a section of an 11 storey blockbuilding made of prefabricated wall-panels and of other prefabricated elements. The section consisted of 3 flats /see Fig.2./. Among the 33 dwellings each ventilated by the system, 6 of them in 3 storeys were instrumented with sensors for measurements.

For the sake of comparison a neighboring similar section of the building was also measured as reference. In this section the traditional suction-type ventilation system was operated.
The main unit of the experimental system was a rooftop ventilation unit. The Fig.1. shows the plan view of the roof of the section, the ventilation box and the distributing duct network. The pipes were connected to the vertical ducts placed in the ventilation shafts.

The Fig.2. shows the plan views of the dwellings, the distributing network for fresh air supply and the exhausted air outlets. The fresh heated air was supplied into the rooms above the doors, through adjustable inlet grids.
The suction outlets for exhausting were placed in the kitchen, bathroom and lavatory. For the sake of proper inside flow pattern the inner doors were equipped with permeable opening-grids.

In the reference section the suction-type ventilation system was the same as the exhausting part of the experimental one. The fresh air supply there, was provided through the cracks of the windows. The main unit of the experimental system consisted of the following parts: 2 fans, fresh air grid, filter, air-to-air recuperative heat exchanger for recovery, re-heater battery supplied by the warm water district heating system, shutters for by-pass out of the heating season. The ventilation systems operated continuously through the days without interruption. The air change rate was about 0.6, the fresh and exhausted air volumes were balanced in about 100 m3/h (sucked 40 m3/h from kitchen and bathroom, 25 m3/h from lavatory/.

The one-year running of the experimental and reference ventilation systems was monitored. The data acquisition system was automatic in operation and was controlled by a Hewlett-Packard HP-85 desk-top microcomputer.
The temperature-, rel.humidity - and pressure sensors were connected through cables into a scanner controlled by the HP-85.

The collected data in every minute were temporarily stored, then hourly averages were constituted and stored onto the tape-cartridge. Later the data were processed to the necessary form by a suitable program.

3. Results

The measured results were analysed and evaluated from three aspects:

- energetic evaluation,
- examination of indoor air quality produced by the ventilation system,
- effects of the occupants' behaviours on indoor climate.

Since the scope of this paper is intended to focus on the third kind of evaluation the results of the previous ones are presented only in a few words.

From the energetic evaluation the experimental balanced ventilation system proved to be an energy saving one compared to the reference. The measured recovered amount of energy was 90 GJ /Giga-Joule/ per a heating period /180 days in Hungary/.

The average indoor temperatures in the dwellings were in the range of 19-25 centigrade . Unfortunately - due to the badly adjusted central heating system - temperature gradient of 5-6 centigrade through the 11 storeys was found. The inside relative humidity was measured between 35-60 percent.

Beyond the measurement of the temperature and rel. humidity the effect of the air jet blowing from the fresh air inlets was also examined. The air jets coming from the inlets positioned above the doors did not cause unpleasant draught feeling in the occupation zone. The velocities measured within the jet decreased below 0.3 m/s within 0.8 m /distance from the inlet/, i.e. jets decayed rapidly.

To examine the influence of the occupants' behaviour on the indoor air quality some deliberate tests were accomplished. Two kinds of activity were analysed:

- the influence of the durable window opening on indoor temperature run,
- the effect of the cooking on the indoor air,

3.1 The effect of window opening

Fig.3. shows an example to the results, where main characteristic temperature-runs are collected. In this case no window opening occured through the day.

The upper curve shows the change of the warm water temperature going to the radiators /primary temp./. The control is weather and inside temperature dependent and for the sake of energy-saving in night period /from 10 p.m. till 4. a.m./ the system, operates with decreased temperature: about 40-45 centigrade . The lower curve shows the outdoor temperature run.
The curves in the middle show the averaged indoor room temperatures in the staircase, in the flats in 1st, 5th and 11th storeys respectively. The aim of the tests was to determine the changes in room temperature runs caused by deliberate durable window openings.

Fig.4. shows an example. One of the windows of the two rooms of dwellings in the 11th and 1st storeys was open through 1 and 2 hours respectively. Due to the very intensive air change - though the casements of the windows were only partially opened, and the curves represent the average room temperature of the two rooms communicating each other through open doors or permeable openings - remarkable drop /3-6 centigrades/ in the temperatures could be observed.

Decreasing of the opened area of the window to half of the previous setting and on the contrary increasing the duration of the open status /5 hours/, the obtained results could be seen in Fig.5. /reference house, flat in the 1st storey/. Temperature drop is smaller but long-lasting compared to the previous test.

The same opening test was carried out in one of the flats in the 1st storey of the experimental building as well.
The result is presented in Fig.6.
The temperature run and the transitions are smoother compared to the reference.

3.2 The effect of cooking

As can be seen from the Fig.2. the dwellings have relative small kithens. The cooking process for 4 persons - which is the average inhabitant number - can produce large amount of heat, unpleasant vapours and odours.
For the elimination of these ventilation outlets /adjustable valves/ were installed above the cooking stoves. Exhaust hoods above the stoves were not used /unfortunately/.

To obtain sharp differences in the results, Saturdays and Sundays were selected for the tests, because usually in week-ends the families are at home and the cooking activities are also larger.

The observed period was extended from 8 a.m. till 4.pm and indoor kitchen temperature was monitored.

The peak temperature raise - overheating temperature difference - and the decreasing lapse-rate were watched. Comparisons between the two ventilation systems were made.
Some results are shown in figures 7-9. The three curves present the kitchen temperature run for the experiment , the reference building and the outdoor temperature respectively.

4. Conclusions and proposals

The main goal of the presented investigation work was to examine a newly developed balanced ventilation system - with comparison to a reference - and evaluate it's performance, operation and efficiency. However being a well equipped experimental site for comprehensive monitoring, there were possibilities to examine other problems, as well as the consequences of several occupants' activities, measurement of indoor flow patterns etc.

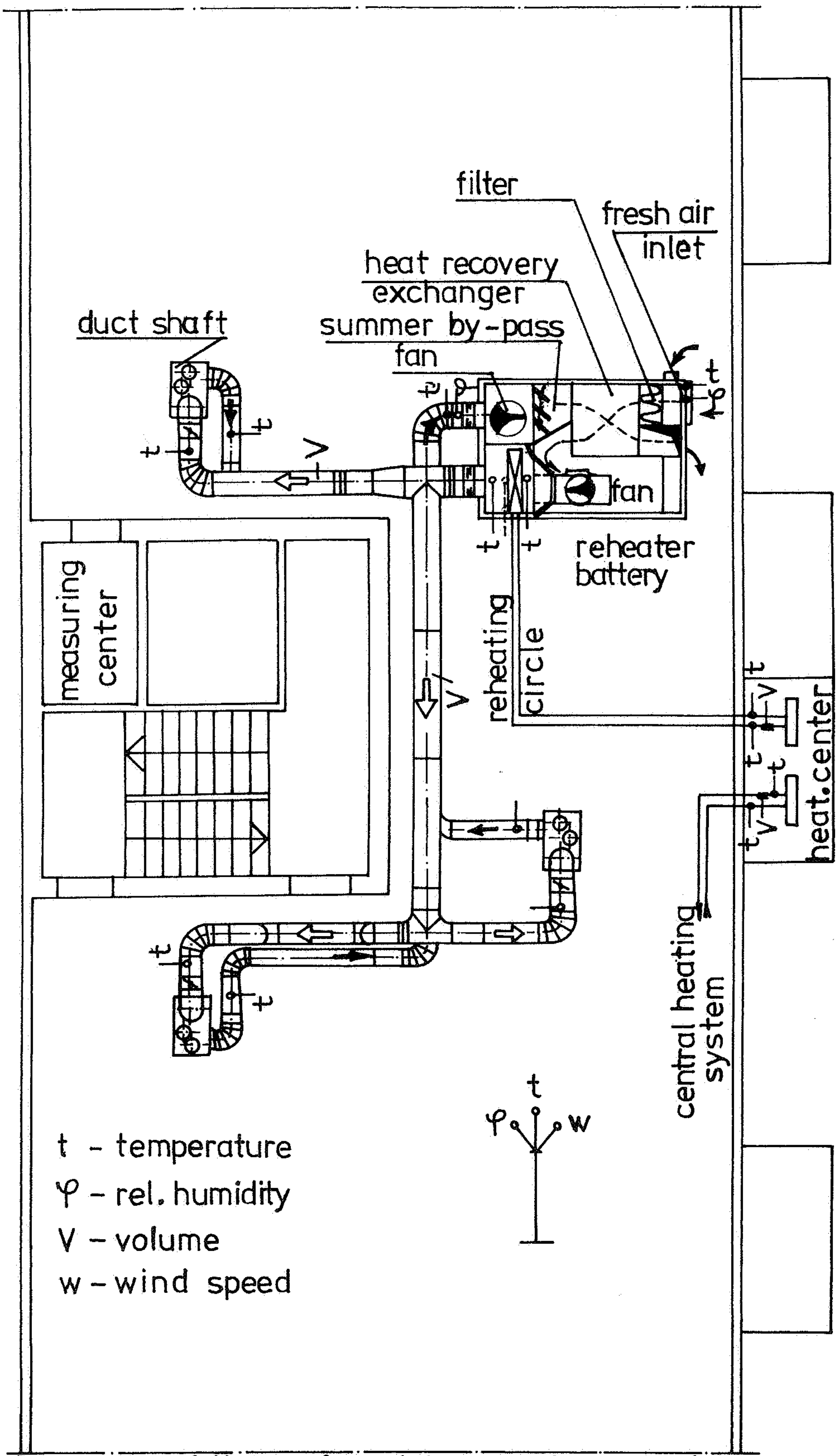
Since the whole monitoring system was installed primarily for the measurement of operational and energetic parameters, therefore more detailed investigation of other phenomena was slightly limited. For example: for the examination of the consequences of window opening and cooking processes more frequent sampling - say in every 15 minutes - would have been needed.

For the more detailed study of the two selected activities the more exact fixing of the several influencing parameters would have been also accomplished e.g. circumstances of the cooking: duration, intensity and detailed program of cooking process, more precise follow up of the decay of the excess heat and contamination etc.
However the measurements carried out produced valuable information on the basic consequences of the examined activities.

Furthermore subjective tests were also made. Some occupants were asked about the ventilation efficiency after cooking and opinions were collected and evaluated. The results of the presented measurements and the responses of the occupants proved the new balanced ventilation system more efficient and perfect compared to the reference one.

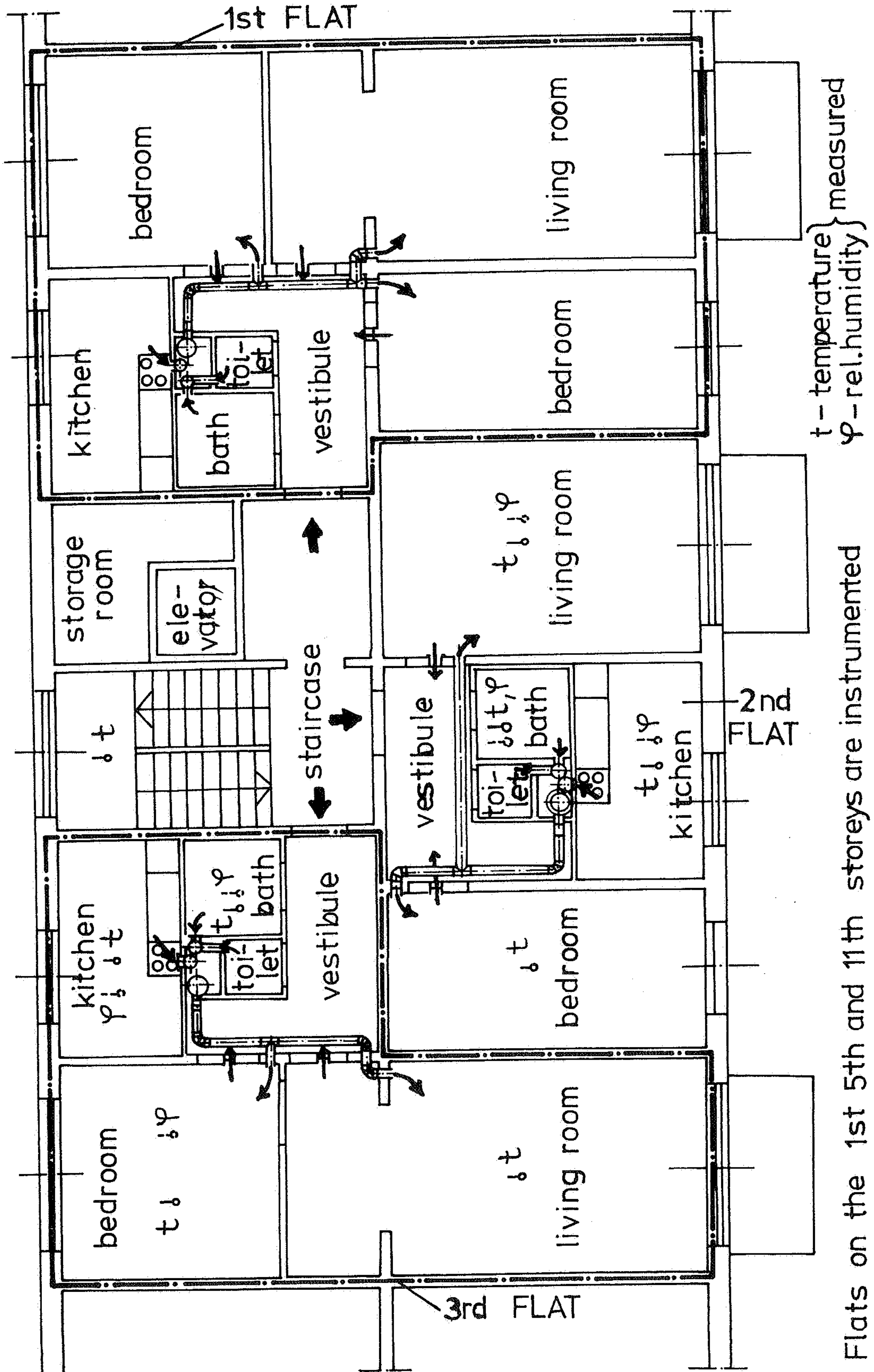
According to the results of the comprehensive examinations the wide-spread utilization of the new system was proposed and the preparation for this has been launched.

The need for the further more detailed investigation of the occupants' activities and their influences on the indoor air quality was also noted.



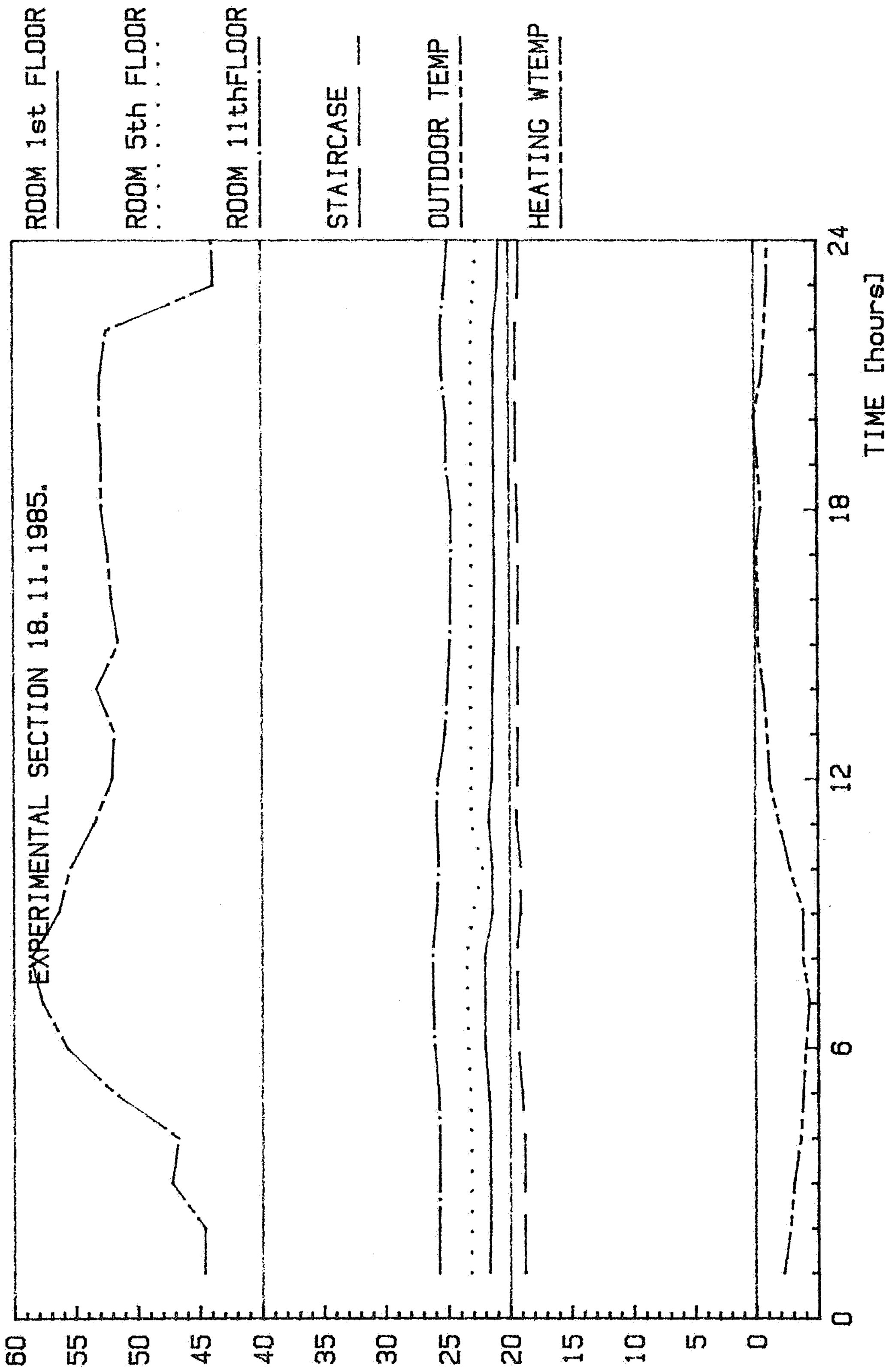
Plan view of the roof, roof-top ventilation unit and duct network

Fig. 1.



Plan view of the experimental flats with ventilation network

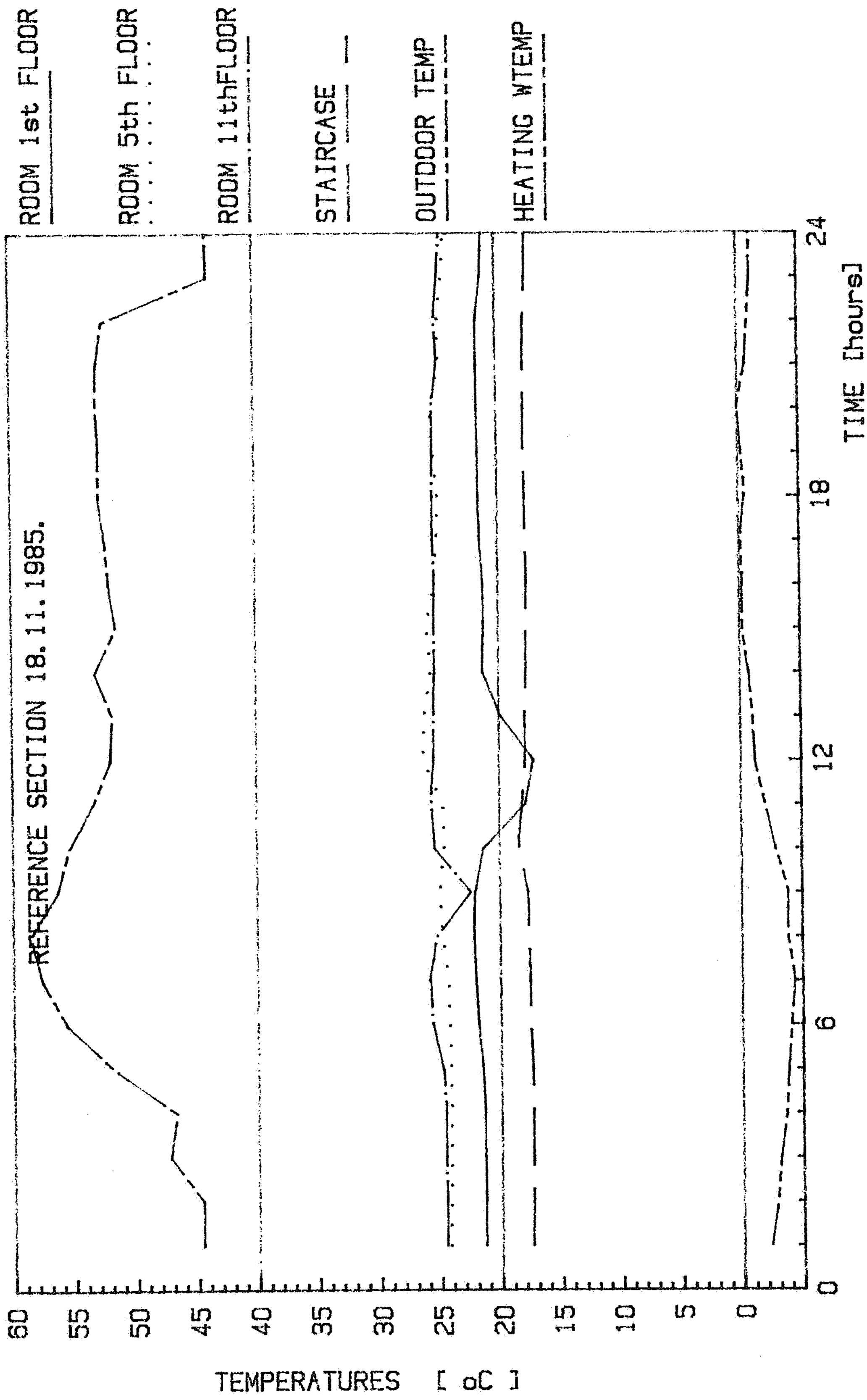
Fig. 2.



TEMPERATURES [oC]

Temperature runs

Fig. 3.



Temperature runs. The effect of window opening

Fig. 4.

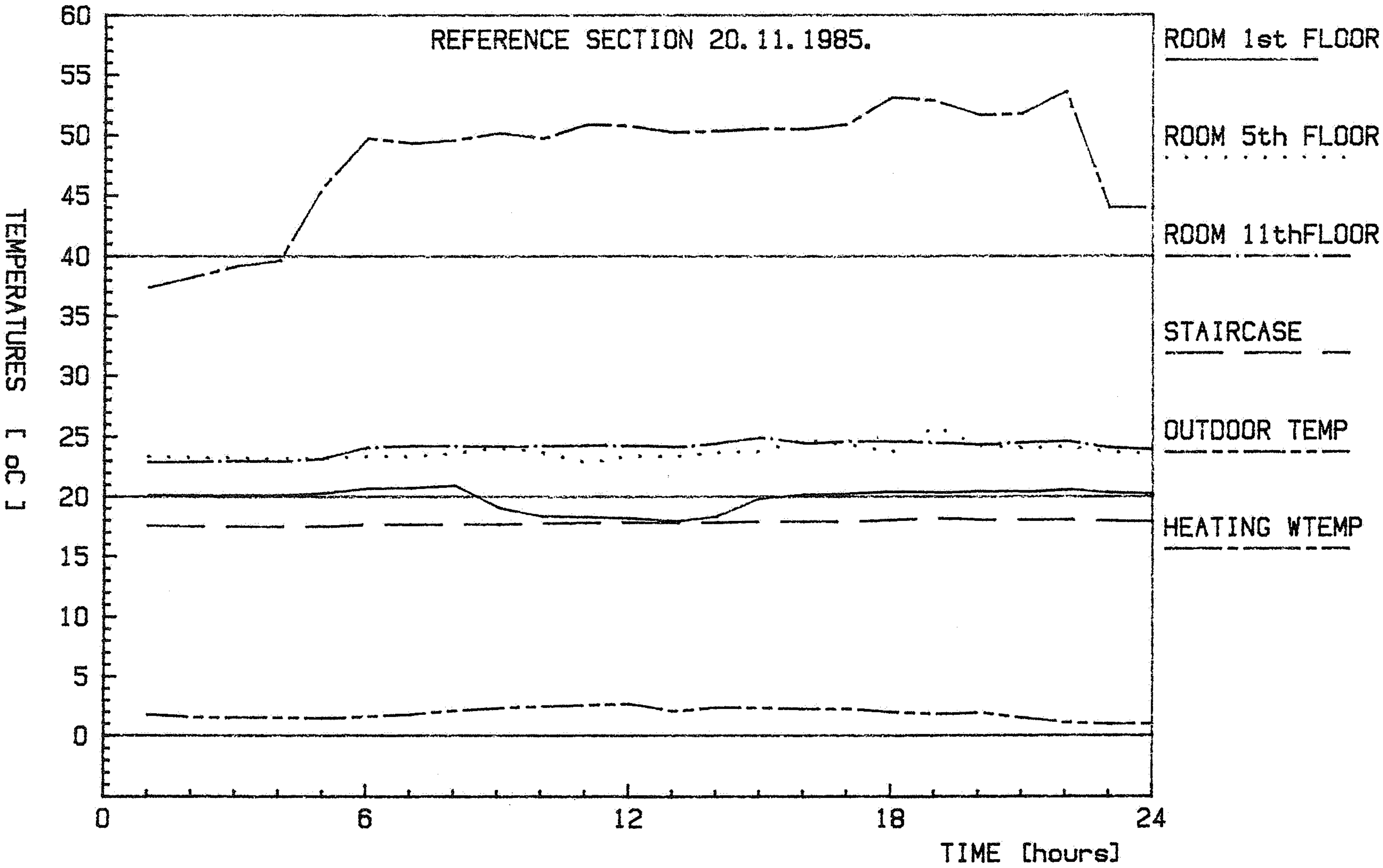
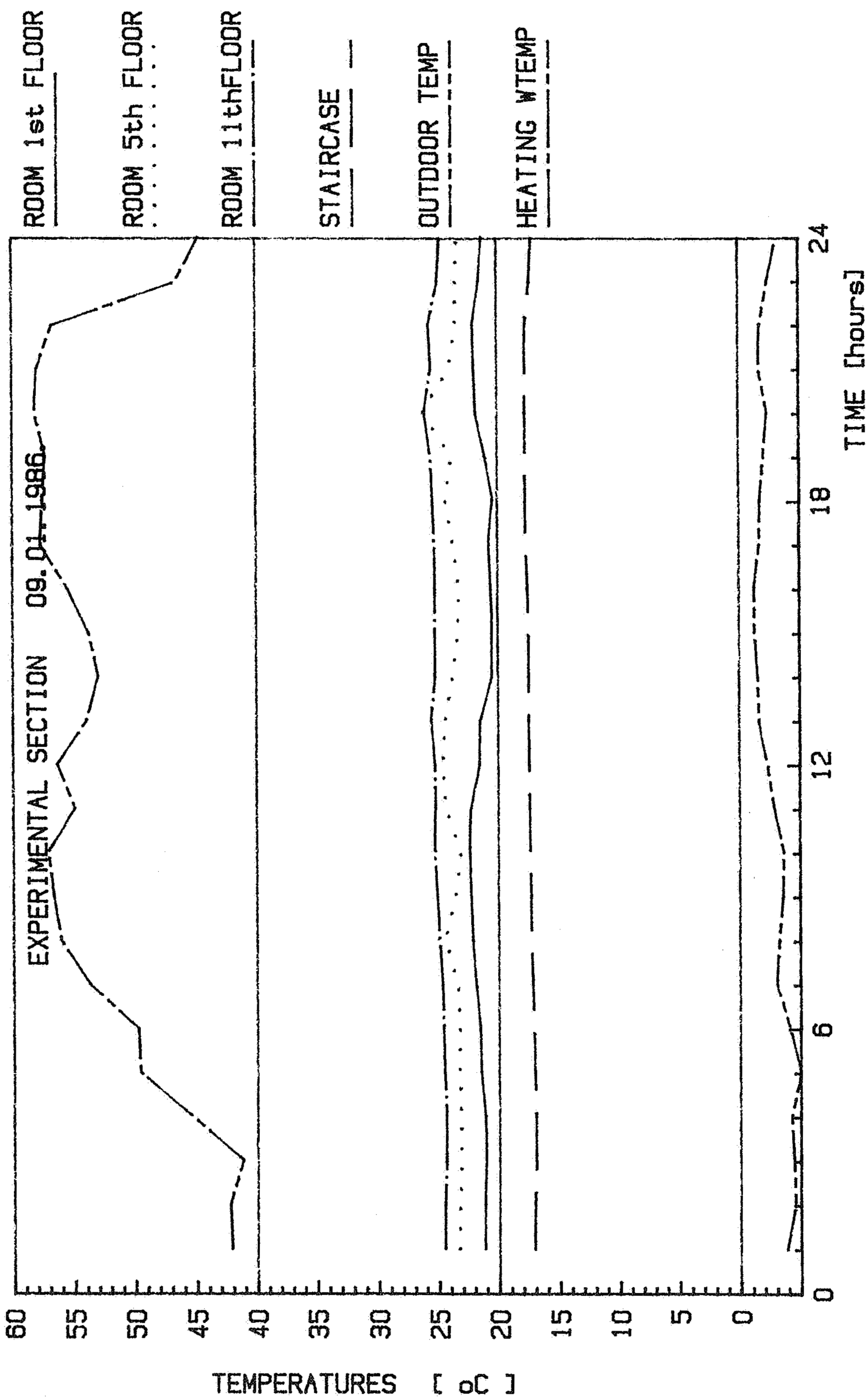
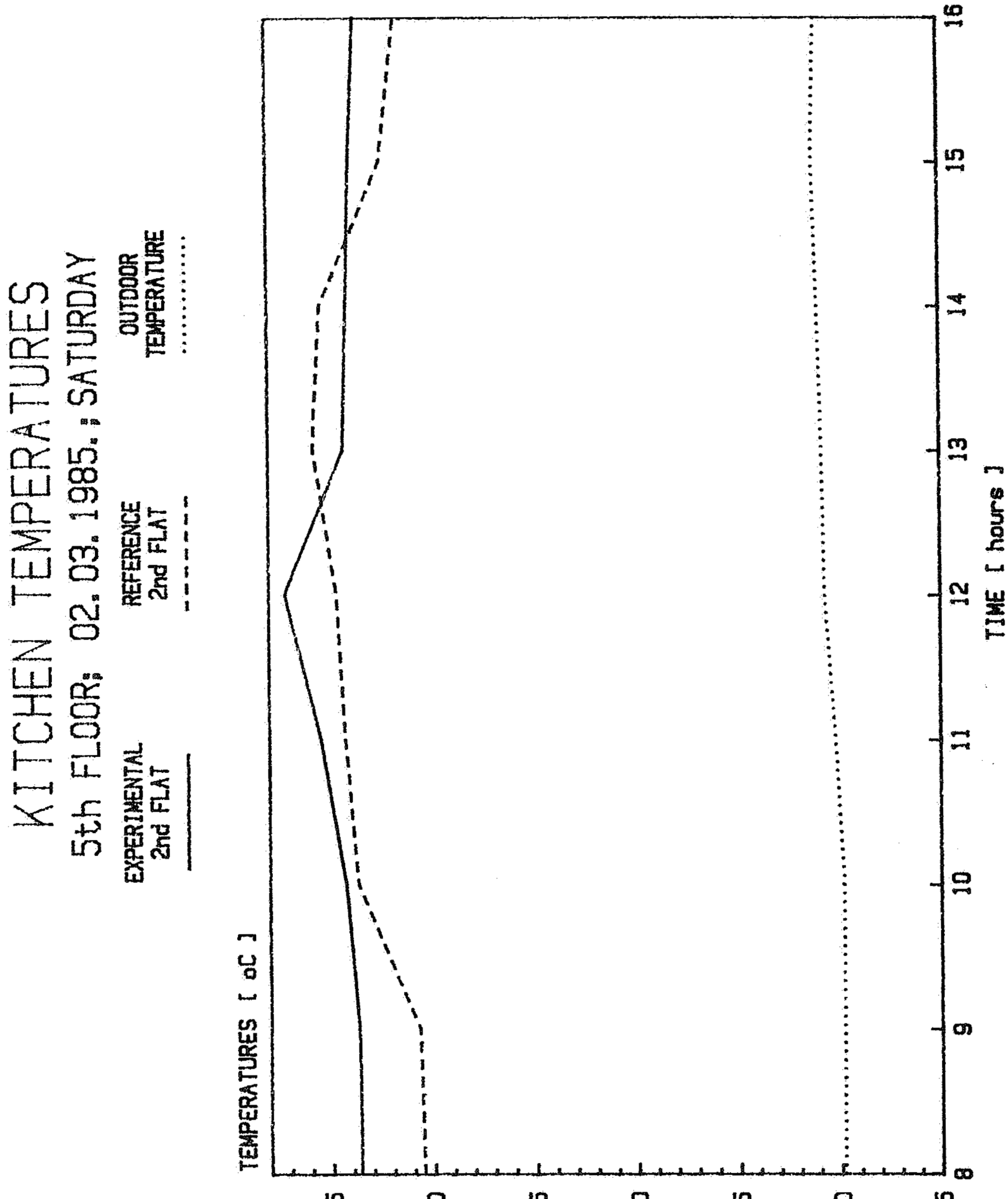


Fig. 5.
Temperature runs.The effect of window opening



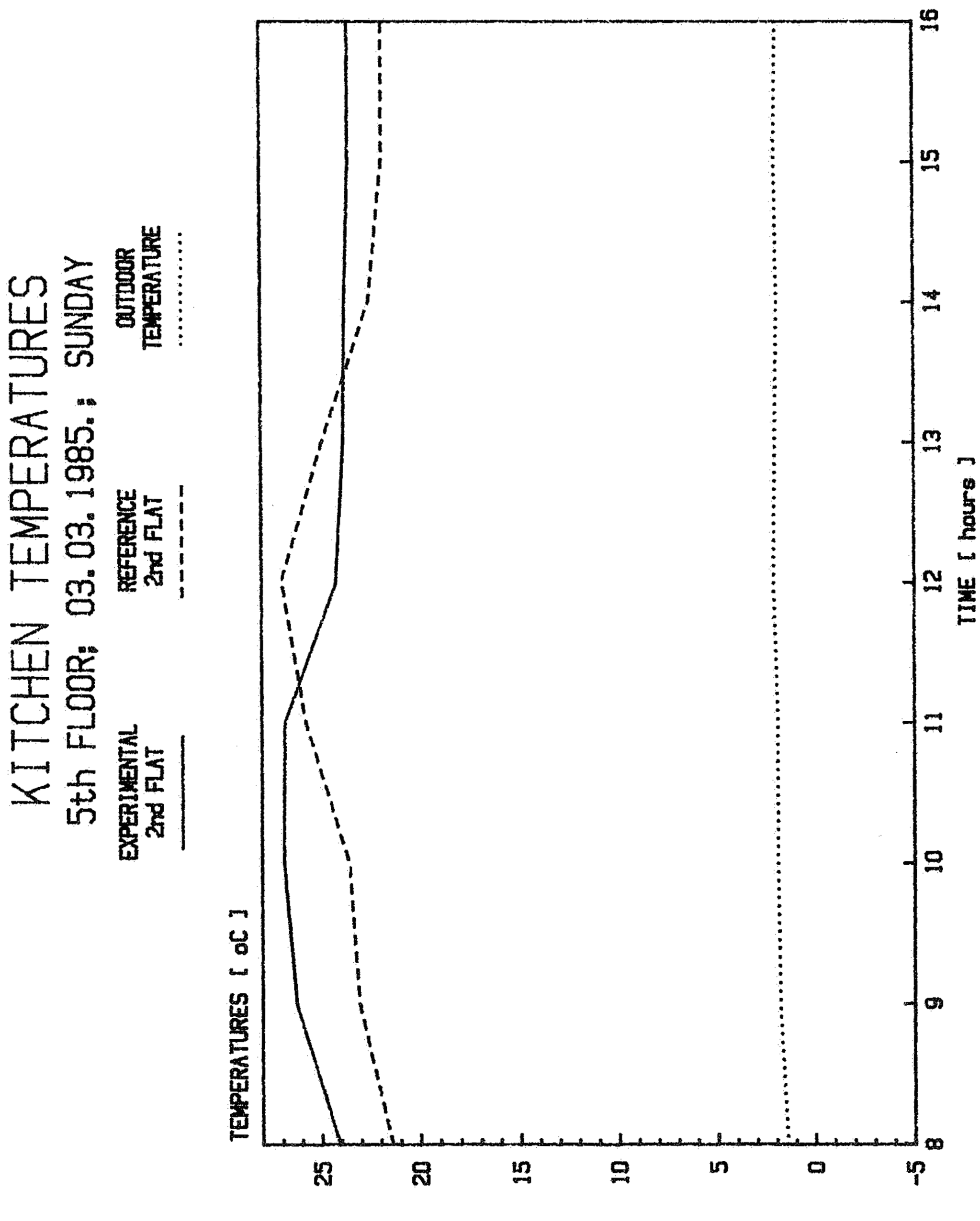
Temperatures runs. The effect of window opening

Fig. 6.



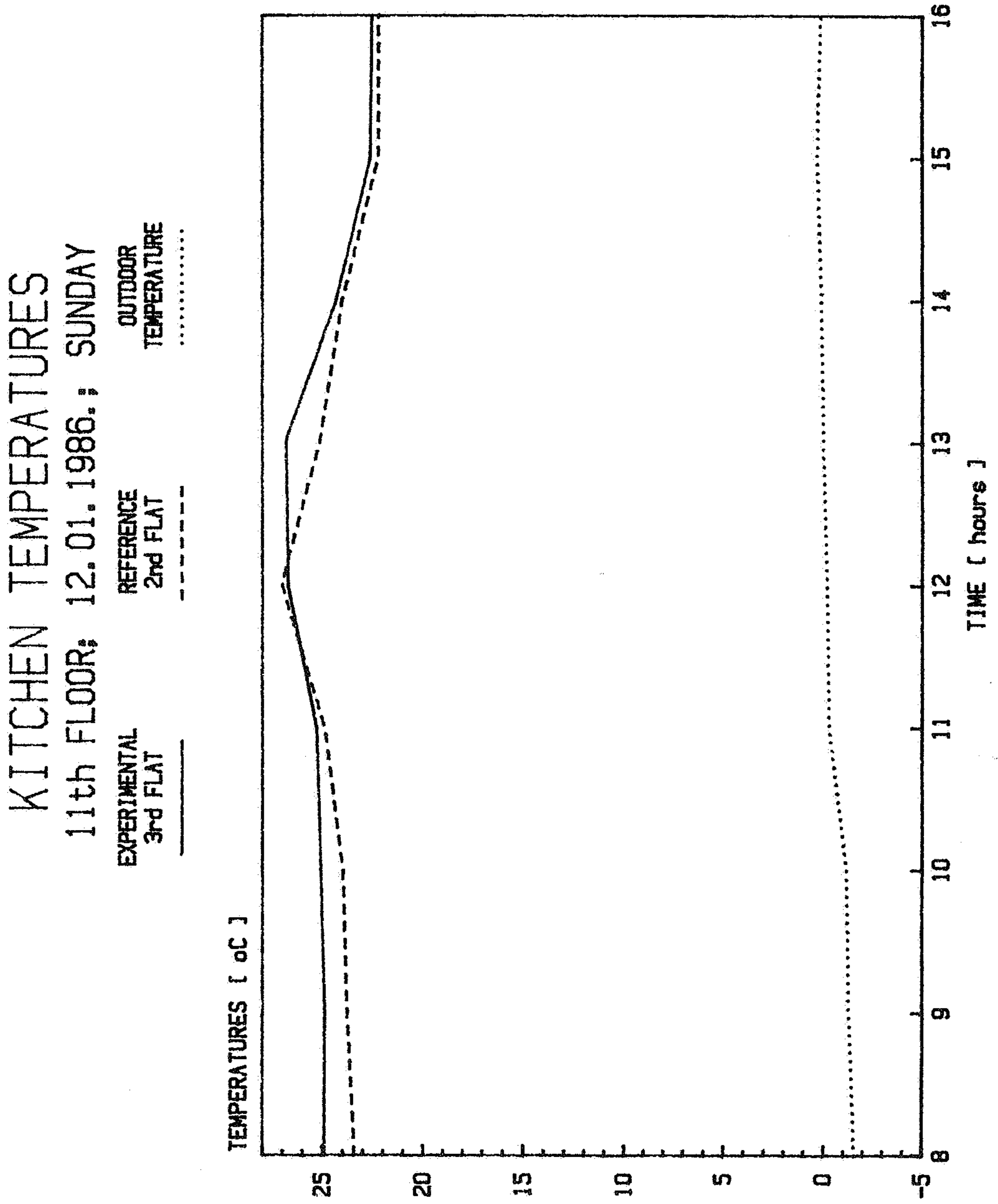
The effect of cooking process

Fig. 7.



The effect of cooking process

<u>Fig. 8.</u>



The effect of cooking process

Fig. 9.