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ROOM AIR TEMPERATURE CONTROL IN DEMAND CONTROLLED VENTILATION SYSTEMS

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1. SUMMARY

The controllability of room air temperature in different heating systems connected to demand controlled ventilation systems was studied. Studied ventilation systems were exhaust, supply and exhaust and a system with exhaust and an individual supply to each apartment.

Studies were made using PIPNET-simulation program package. It is designed to allow detailed simulation of entire building systems: the building shell, heating and ventilating plant and the dynamic thermal interactions among the subsystems.

First single zone calculations were performed. The control of the supply air temperature in warm air heating was studied in case where heating coil was designed for airflow of 1,0 m^3/s. The airflows varied from 1/4 to 1/1. The supply air temperature was controlled using PI-controller. According to the calculations it is possible to control the room air temperature within +/- 1K even if the heating coil is overdimensioned.

The dynamic behavior of a water radiator and a floor heating panel system was studied in an exhaust ventilation system. The control of the room air temperature was also studied with P-, PI- and PID -controllers. Simulations showed that a thermostatic valve is not fast enough if the airflows in the room change rapidly in the exhaust ventilation system, while the supply and extract ventilation system PI- and PID -controllers kept the room air temperature quite well in the set value.

Secondly multizone calculations with an apartment of 89,5 m^2 were done. The heating system consisted of floor heating panels in 4 rooms and water radiators controlled by thermostatic valves in other rooms. The water rate in the floor heating panels was constant and the supply water temperature was compensated according to the outdoor temperature. The duration curves of room air temperature with different ventilation systems were calculated using daily heat load and ventilation profiles.

Based on the calculations recommendations for the range of air flow rates to provide acceptable room air temperature will be given.

2. INTRODUCTION

Many research projects have shown that there are a lot of shortcomings in the operation of ventilation systems and devices. Most of the existing air change systems in residential buildings do not even meet the present requirements of building codes. The biggest problems in mechanical ventilation systems are draught, stuffy indoor air, odours spreading in the flat and between the flats, noice and condensation. Most of the systems are also difficult to use and maintain.

These lacks in the operation have been initiators/stimulators for the project "Ventilation systems of the future residential buildings". Demand controlled ventilation systems that fit in the future way of living are developed. The aims of this project are to achieve

- good ventilation effectiveness,
- a possibility for inhabitants to control the ventilation rate,
- stability of the system,
- low energy consumption,
- a possibility to change the quality level of the system afterwards.

These aims are set so that the ventilation system has technical preconditions to maintain high indoor air quality and good thermal comfort and energy economy as well.

The study of room air temperature control of demand controlled ventilation systems in residential block of flats is discussed in this paper.

3. WARM AIR HEATING

Studies were made using PIPNET-simulation program pagage. The control of the supply air temperature was studied in case where the heating coil was designed for an airflow of 1,0 m³/s. Two connections of the coil were simulated in figure 1. The valve characteristic of the 3-way valve was logarithmic for the main branch and linear for the by branch. Lograrithmic valve characteristic was chosen to make the characteristic of the whole heating coil connection as linear as possible.

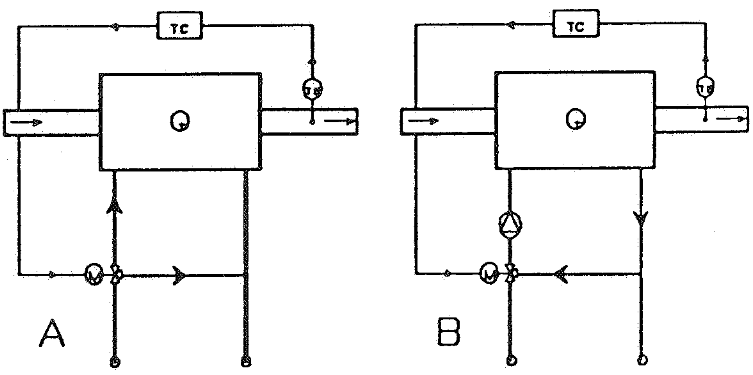


Figure 1. Simulated heating coil connections. Variable water flow control (A) and variable inlet water temperature control (B).

The airflows varied from 1/4 to 1/1 in simulations. The supply air temperature was controlled using PI-controller. The control values K_P and K_I were determined in a situation where the gain of the system was greatest. This was done by making a step response test to the system.

According to the calculations it is possible to control the supply air temperature within ± 1K even if the heating coil is overdimensioned.

4. WATER RADIATOR HEATING

Dynamic behavior of a water radiator was studied using PIPNET-simulation program package. Calculations were made with a single room model. Room air temperature was controlled using thermostatic valves. Some simulations with PI- and PID-controllers were also carried out.

The purpose of these simulations was to study how the room air temperature responds to an increase in the air change rate of the room. The simulated system consists of a single room, radiator, thermostatic valve and an mechanical exhaust ventilation system. Supply air to the room comes through the exterior wall and it's temperature is the same as the outside air's temperature.

If the characteristic of the thermostatic valve is logarithmic, then the characteristic of the whole system (valve, pipe and radiator) is almost linear. This means better controllability of the system than when using a valve with linear characteristic.

While the thermostatic valve is a P-type controller, there is a permanent deviation. The size of the deviation depends on the control curve, the room itself and the loads. In figure 2 there is shown the room air temperature as a function of the proportional position of the value in 4 load conditions. For example in the case 1 the room air temperature settles to 20°C when $H/H_{100} \approx 0{,}46$.

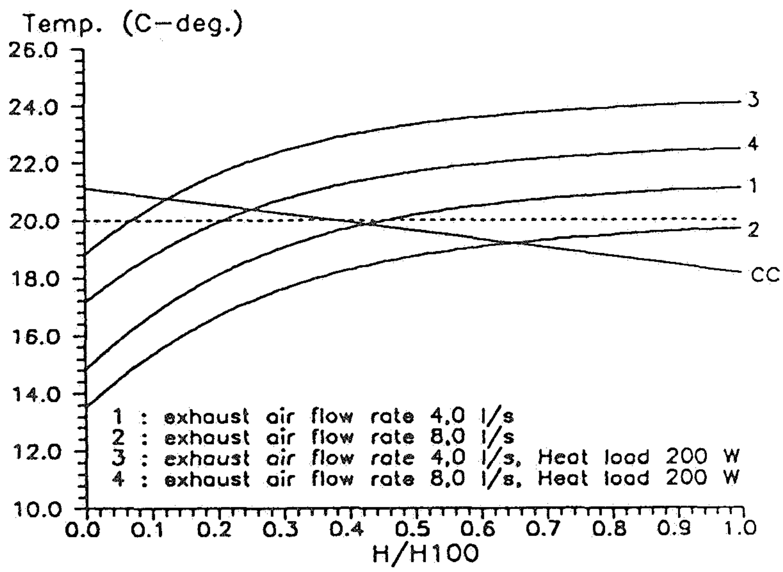


Figure 2. Room air temperature as a function of proportional position of the valve. The outdoor air temperature is 0°C.

The thermostatic valve control curve is set so that the set value 20°C is achieved when the outdoor air temperature is -20°C, exhaust air flow rate is 4 l/s and there are no other heat gains than the radiator. The room air temperature settles in a steady state situation at the intersection of the room air temperature curve and the control curve (CC).

According to the simulations water radiator heating with a thermostatic valve cannot keep the room air temperature in the set value, if the exhaust air flow rate is e.g. doubled and there is no heat load in the room. If there is heat load in the room at the same time then when the exhaust air flow is increased, the room air temperature either decreases or increases depending on wheather the heat loss due to increased air flow rate is greater or smaller than the heat load.

In figure 3 there is shown the room air temperature in different cases. The two outdoor air temperature is the same as the design outdoor temperature, i.e. is -27°C. The supply water temperature to the radiator is 70°C and the radiator 1 is dimensioned for the heating load corresponding to minimum air flow of 6,6 l/s and the radiator 2 for an air flow of 13,2 l/s. The exhaust air flow is increased from 6,6 to 13,2 l/s for 2 hours. The more effective radiator keeps the set value (20°C) better than the smaller radiator. The controllability of a radiator sets requirements for dimensioning the radiator according to the maximum heating load.

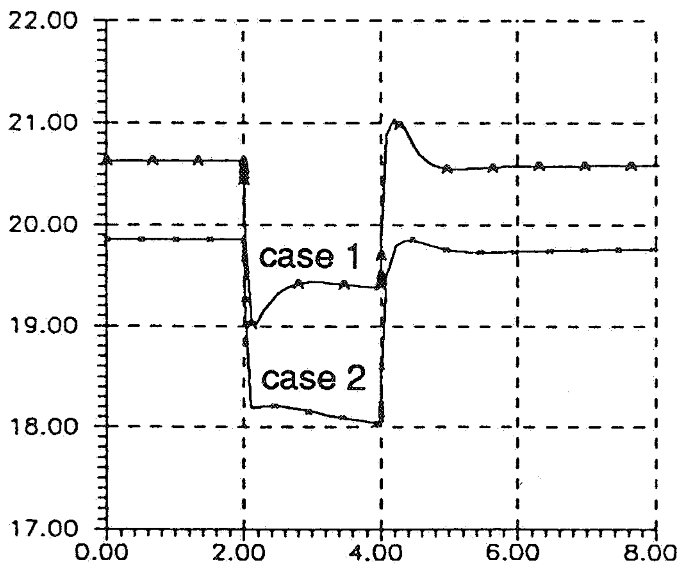


Figure 3. The room air temperature when it is controlled with thermostatic radiator valve (linear characteristic).

In figure 4 there is shown a situation equal to the figure 3 situation with radiator 2 exception with that there are now a PI-controller connnected and 3-way valve instead of thermostatic valve. The control values K_P and K_I were determined in case when the exhaust air flow is 6,6 l/s.

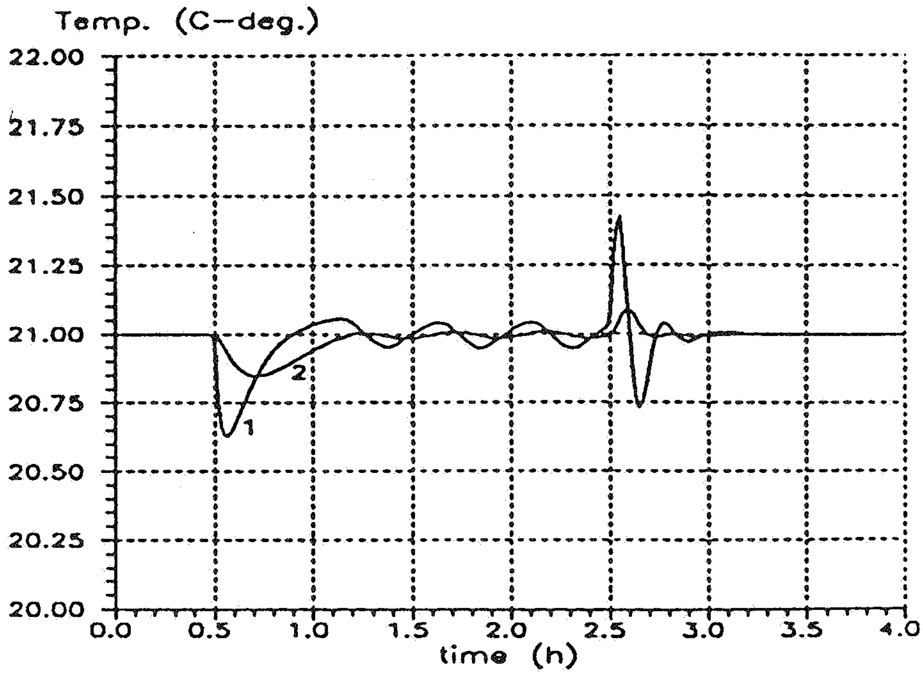


Figure 4. Room air temperature (1) and temperature of the temperature sensor (2) in the room when exhaust air flow is doubled for 2 hours.

5. FLOOR HEATING PANEL

The room air temperature control in a floor heating system and in a combined floor heating and water radiator system were studied using the PIPNET-simulation program package. Calculations were made with a single room model. There was a mechanical exhaust ventilation system.

The calculations showed that the floor heating system doesn't work when the need for heating load varies rapidly. If a radiator is added to the floor panel heating system, the situation gets much better (Fig. 5).

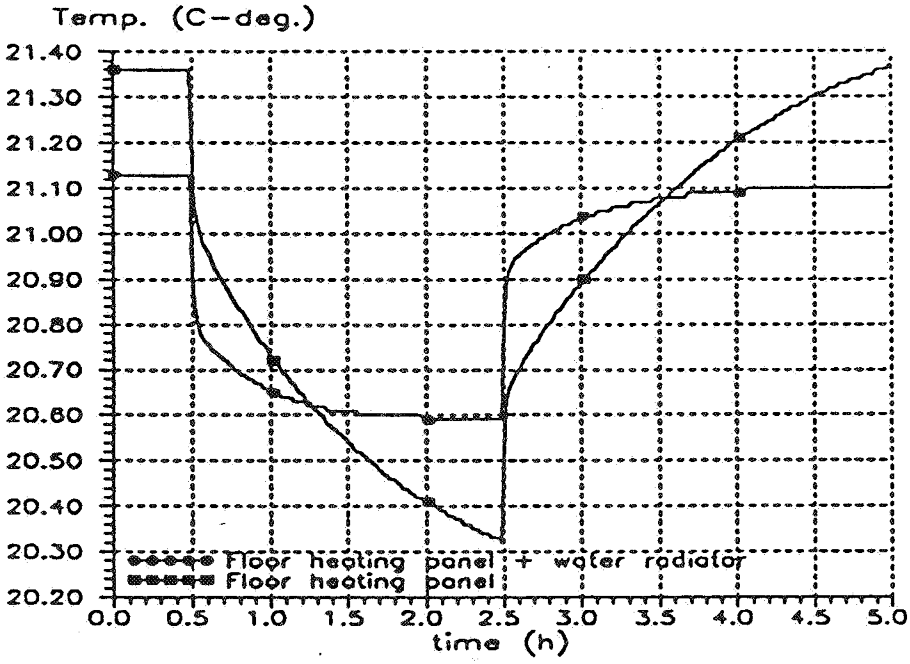
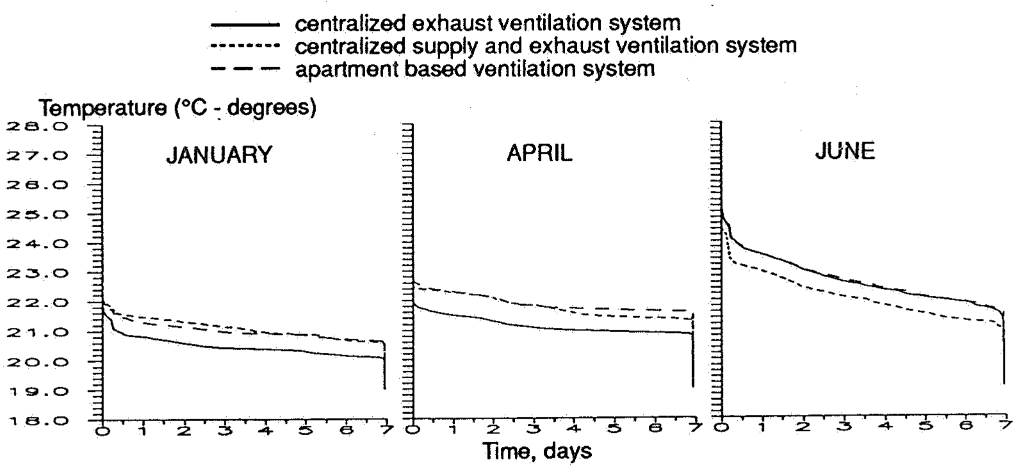


Figure 5. Room air temperature in a floor heating panel system with and without a water radiator when the exhaust air flow is doubled.

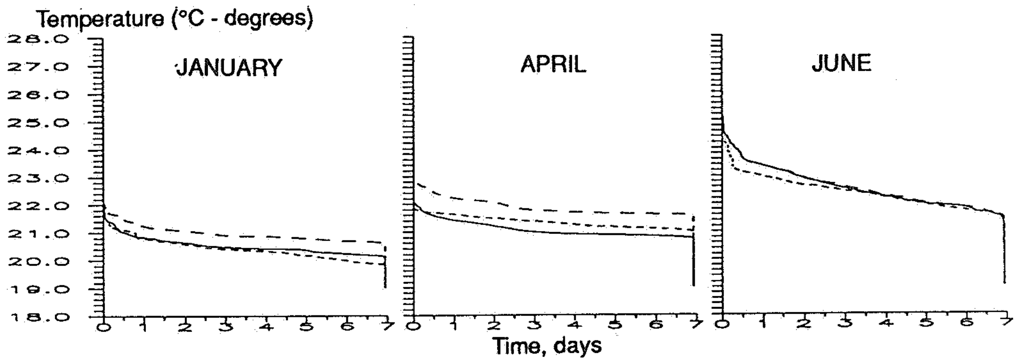
6. MULTIZONE CALCULATIONS

The purpose of the multizone calculations was to compare the performance of the studied ventilation systems. The heating system was selected according to the single zone calculations. The simulated apartment had 3 bedrooms, a living room, a kitchen, a corridor, WC, a sauna and a bathroom. Corridor, WC and bathrooms had floor heating panels and in other rooms there were water radiators. The supply water flow to the floor heating panel was constant. The supply water temperature was outdoor air temperature compensated. The radiators had thermostatic valves.

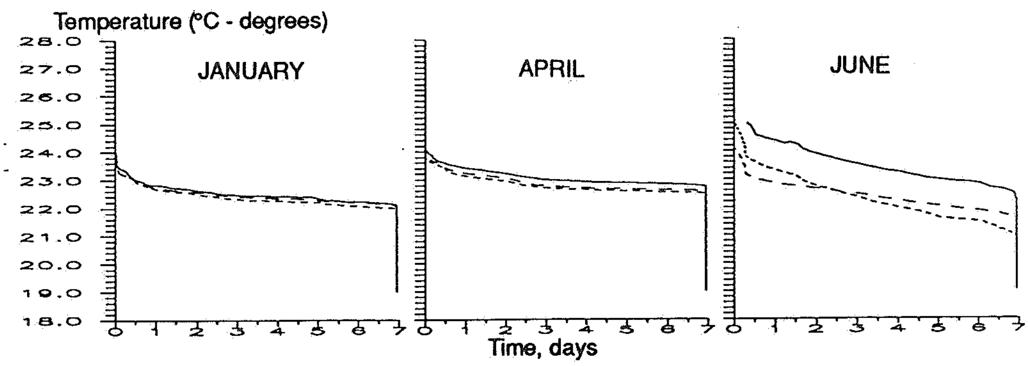
The systems were simulated with 3 different weather periods: January, April and June. The outdoor air temperature varied from 0°C to -25°C in January, from 0°C to +5°C in April and from 10°C to 25°C in June. The maximum solar radiation in June was about 800 W/m^2. The air change rate varied from 0,5 to 1,0 ach.



KITCHEN



BEDROOM 2



BATHROOM

Figure 6. The room air temperature duration curves of kitchen, bedroom 2 and bathroom during the weather periods of January, April and June.

7. RECOMMENDATIONS

According to the calculations the thermal conditions of a single room do not change too much when increasing the air change of the room if the following principles are applied.

Mechanical supply and exhaust and mechanical exhaust and individual supply systems:

- the supply air temperature is over 16°C during the heating season.

Mechanical exhaust systems:

- the maximum air change rate of a room is the basic air change rate (e.g. 0,5 ach.) plus 1,0 ach. This is valid when the outdoor temperature is lower than -20°C.

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