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Development and Investigation of a Combined Ventilation and Floor-Heating System

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Synopsis

The continual reduction of the transmission heat losses of residential buildings causes an increasing importance of the ventilation heat losses. Energy saving can be achieved by using a mechanical ventilation system with heat recovery. A great improvement is the combination of heating and ventilation in one system.

In this project such a combined system was developed to reduce the energy consumption of the fans, the operating expenses and also the investment costs in comparison to existing systems. In future a high market acceptance is expected for combined heating and ventilation systems.

Extensive long time investigations are made for optimization and determination of general operating parameters. The improved results can also be considered as fundamentals of simplified dimensioning- and calculation proceedings.

1. Introduction

Nowadays, when buildings are built tightly-joined because of energy saving issues, a sufficient ventilation of buildings through joints is no longer possible. This prevents the transport of noxious gases and humidity out of the inside of the building. A rather simple method to reach the necessary air change rate is to make use of natural ventilation by opening the windows. Yet this method is not an ideal one, since it reduces the thermal comfort and neglects the aspect of energy saving. These disadvantages can be avoided by the application of mechanical ventilation systems. Especially the use of a warm air heating system that combines ventilation and heating promisses an improvement of thermal comfort and at the same time a reduction of the demand for energy.

The aim of this work was to develop marketable systems for the distribution of heat and air. The emphasis in this project was on the analysis of heat tranfer and flow patterns in rooms being equipped with combinations of floor heating and warm air heating systems. It was intended to derive algorithms for the layout of the systems mentioned above from the results of the investigations.

2. Description of the systems

The developed systems are based on the warm air heating that is characterized by its ease of control, its quick adjustment of heating power and the low level of temperature being necessary to provide the heating energy. Moreover, a warm air heating system allows the application of heat recovery systems which enlarge the energy saving potential especially in highly insulated buildings where a great part of the heat requirement is caused by the ventilation heat losses.

The air conducting components of the developed systems are integrated in the floor construction. Thus part of the heat transfer takes place through the surface of the floor. The amount of the heat transmitted through the floor depends on the construction of the floor and the air conducting components.

The three developed heating systems are all chracterized by a central treatment of the air (filtering, heat recovery, preheating), whereas they differ in the further treatment and conduction of the air.

1st variant: The supply air is heated up to 50 °C by a water/air heat exchanger in the central boiler plant. It is distributed in the building by a system of insulated air ducts. The entrance of the air into the floor is near the internal wall of the room. In the hollow floor the air flows through ducts in the direction of the external roomwall. The ducts are ending in a cavity of one meter length, built with cones, that equalizes gradients in air velocity and temperature. The air flows into the room through outlet grilles that are installed in front of the external wall. In this variant the part of heat transmitted through the floor is quite small. If this heating system is installed in highly insulated buildings, the air change rate necessary due to hygienic reasons is sufficient for the transport of the demanded heat. In buildings that are insulated according to present standards the recirculation of additional air is necessary to reach the required heating capacity.

2nd variant: Depending on the required heating capacity the supply air is heated up to a temperature of 20 °C - 40 °C. Starting on the side of the internal roomwall the air flows through a cavity built with cones, that is situated between the two layers of the floor (fig.1).

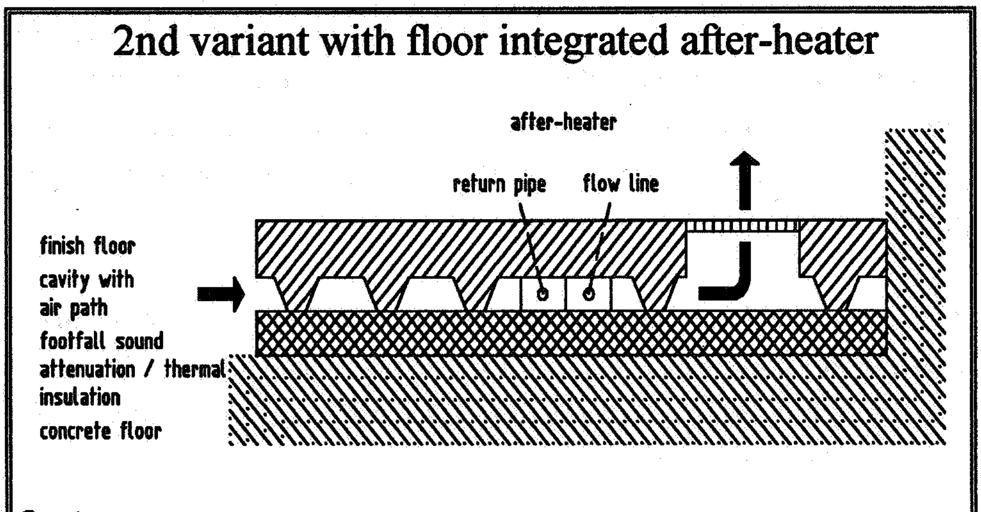

fig. 1

While the air is streaming through the cavity, the heat is transmitted into the room through the upper layer of the floor (the finish floor). So the air is cooled down until it reaches almost the temperature of the room near the air inlet into the room on the side of the outer roomwall. Shortly before it reaches the outlet grilles the air is tempered by an after-heater so that it enters the room with a supply air temperature that is significantly higher than the room temperature so that a draught can be prevented. The 2nd variant represents a warm air heating system that uses the floor as a low temperature heating surface. Because of the floor-integrated after-heater the second variant, in contrast to the first variant, is able to supply the necessary heating capacity for a building with an average standard of insulation without additional costs for the transport of air.

<u>3rd variant:</u> Above the cavity that is built with cones and through which the supply air is streaming a conventional floor-heating with hot water used as heat carrier is installed (fig. 2). The floor-heating works like a heat exchanger with a large surface. The heat is on the one hand transferred from the water through the floor finish to the room and on the other hand it is

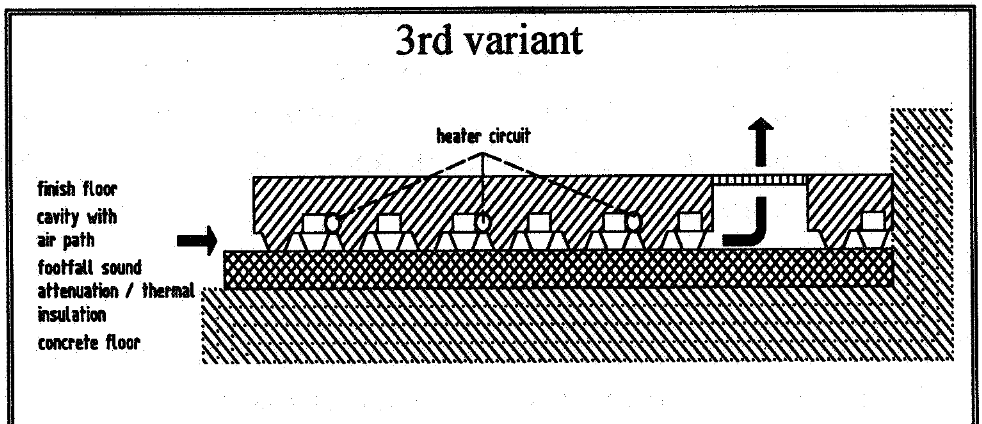

fig. 2

transferred to the pre-heated air flowing in the hollow floor, so that the temperature of the supply air rises to a level above the temperature of the room. As a result of the chosen combination of air heating and floor heating the well known advantages of the floor heating, like a low mean level of temperature and an even distribution of temperature in the heated room, are supplemented by the benefits of the air heating. In comparison to a mere floor heating the temperature level that is necessary for the supply of the heating capacity is even lower, so that good conditions for the use of low temperature heating techniques (heat pump, fuel value boilers) and the integration of generative energy sources are created.

3. Results

To test the three different variants of air heating systems described before three testing rooms with corresponding thermal boundary conditions were built up. An extensive series of measurements was carried out so that an energetic analysis of the different variants became possible.

The inflow technique investigations of the air flow in the cavity have shown that the velocity distribution and the velocity profiles between the two floor layers depend strongly on the geometrical structure of the cavity and the way the air gets into it. Independent from the differences of the shape of flow in the cavity the comparison of the volume of air escaping from the different air vents has shown that the distribution of the air is good enough for practical applications. This result could be reproduced for various heights and distances of the cones. The evaluation of the measurements carried out to determine the heat emission of the different systems as well as the mathematical modelling of the heat transfer shows, that the temperature profile at the floor surface is quite homogenous inspite of the varying thickness of the floor finish. There are almost no temperature gradients at the surface of the floor so that all the systems seem to be well suited for the heating of floor surfaces.

The first variant of warm air heating was used as a sort of reference case and the results of the measurements carried out will not be described here.

The second variant attracts intention as the air is rapidly cooled down until it reaches the after-heater which is installed just in front of the air outlets. Fig. 3 shows which part of the entire heat flow is transferred through the surface of the floor and which part reaches the room with the supply air. If half of the entire heat flow is supplied by the pre-heater and half of it by the after-heater then 57% of the heat reach the room with the supply air. This share of the heat is directly coupled with the part of the heat flow supplied by the after-heater. So this heating system is easily to be controlled by adjusting the heat output capacity of the after-heater. The part of the heat flow supplied by the pre-heater is almost completely transmitted through the floor. About 72% of this heat are supplied to the room by radiation and the remaining 28% by convection.

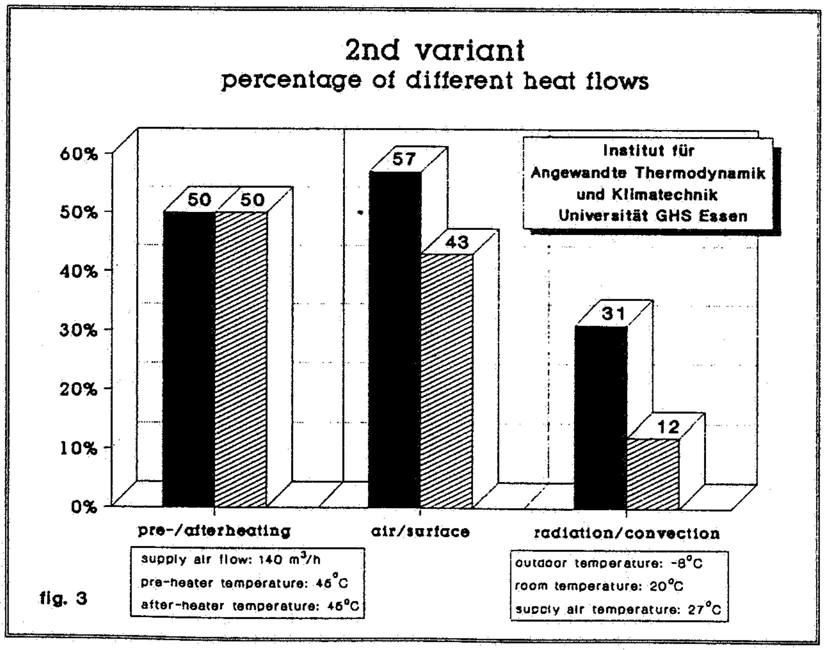

fig. 3

In contrast to the first and second variant, in the third variant the air is heated up while flowing through the cavity, so that when it reaches the outlet, the supply air is significantly warmer than the room. Fig. 4 shows that the heating up of the air in the cavity advances rapidly inspite of the low excess temperature of the heating water. The warming up of the air in the cavity guarantees that besides the part of the heat transmitted through the floor part of the heat is supplied to the room by the supply air.

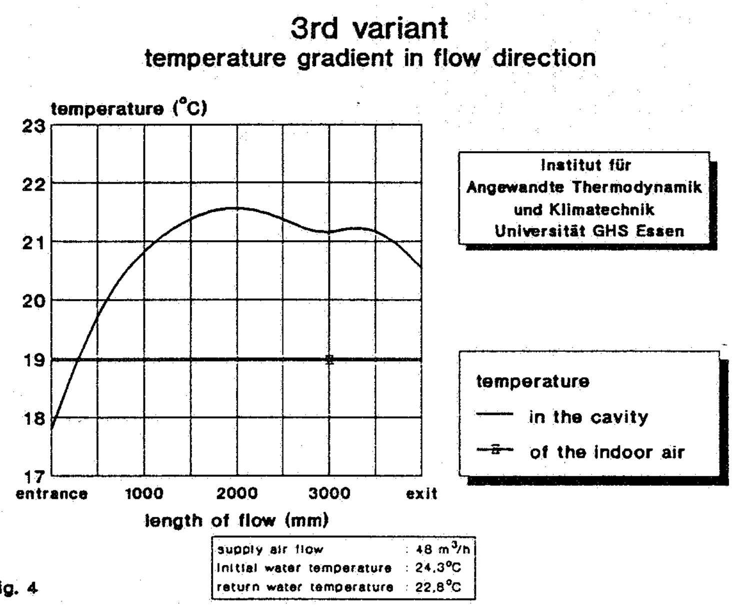

fig. 4

Fig. 5 shows that the temperature-distribution in the floor finish is homogene even if the distance between the tubes with the heating water is big. Because of the excess temperature at the floor surface the part of the heat transferred to the room through the floor is considerably bigger than in the second variant. As shown in fig. 6, 90% of the entire heat flow are supplied to the room by the floor surface. 75% of the heat transfer from the floor to the room are radiation, 25% are convection.

If the air change rate amounts to 1 per hour 10% of the entire heat flow are transmitted to the room by the supply air. As the investigations have shown, the temperature of the supply air remains almost constant if the quantity of supply air is risen. The heat flow through the floor staying almost constant, the part of the heat supplied to the room by the air is increased. So a quick adaptation of the heating capacity is possible.

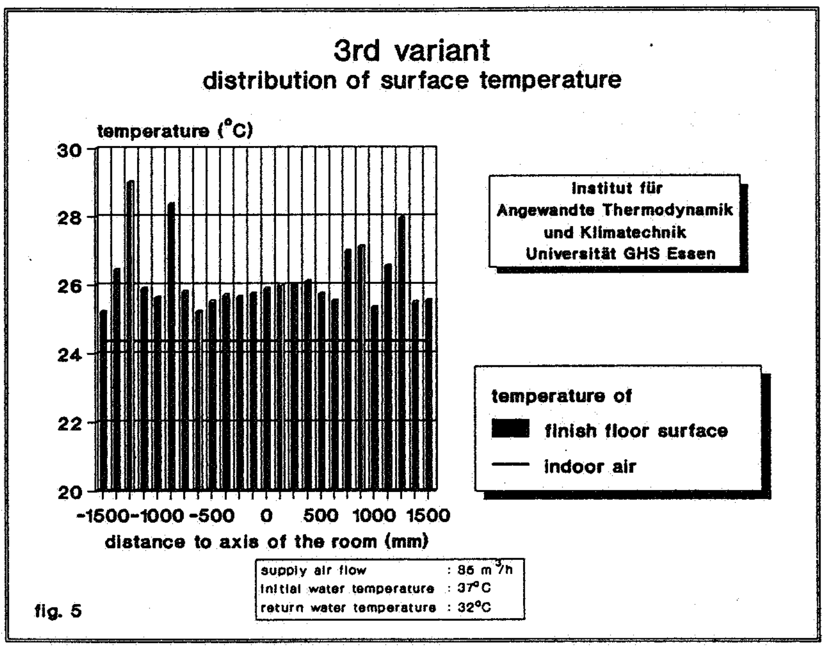

fig. 5

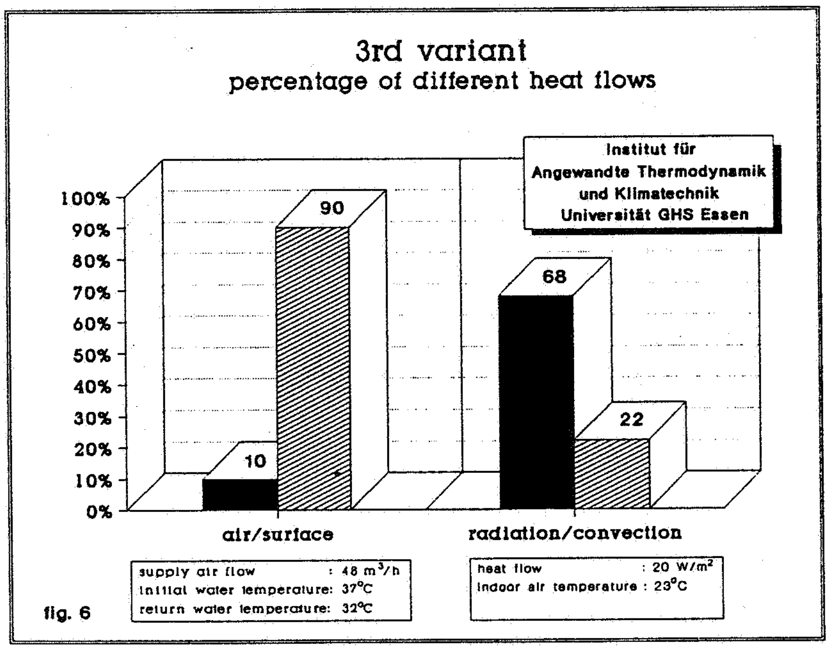

fig. 6

Measurements of temperature and air velocity in the room have shown that both are distributed in a homogene way. This has a positive influence on the thermal comfort as well as on the economic efficiency and on hygienical aspects.

4. Summary

The measurements carried out under operating conditions are obviously in accordance with the mathematical modelling carried out before. Both, the measurements and the modelling, show that the developed heating systems meet the demands concerning thermal comfort and energy efficiency.

Since special demands arised for the components of the installation and for the control equipment due to operating characteristics of the analyzed systems, these components had to be developed or improved in the course of the project.

5. Acknowledgement

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