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Heat transfer and air flow in an air heating and ventilation system

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HEAT TRANSFER AND AIR FLOW IN AN AIR HEATING AND VENTILATION SYSTEM

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SUMMARY

An air heating and ventilation system with suspended ceiling spaces and grilles in sidewall below the window is presented in the paper. The system allows for room heating in winter and cooling in summer with simple use of renewable energy sources, like solar or ground energy. It improves indoor thermal climate and reduces energy demand. Graphical characteristics of system performance, vertical room air temperature gradient and air velocity over the grille are also given.

System concept and description

The system is a connection of panel air heating and forced ventilation. Warm air flows in space between the ceiling and light suspended gypsum board, divided into the ducts of small width, so creating a loopway system. Ventilation air comes from a grille placed below the window. The heating and ventilation air is distributed from building basement through wall ducts. The system scheme is shown by figure 1.

The connected air heating and ventilation system enables simple use of renewable energy sources, like solar or ground energy (heat in winter, cool in summer). Heat energy gained in solar collectors could be directly led to heating-ventilation system because even in winter period, when insolation is very little the temperatures reached in collectors are usually sufficient (1).

Panel heating system enables the full use of ceiling heat capacity to store heat in winter and cool in summer. Accumulated heat could be returned to room with delay, when ambient temperatures are extreme. Room cooling in summer takes place in result of cool storage, coming from ambient night air flowing through ceiling structures. The air could be cooled in ground exchanger, too (2).

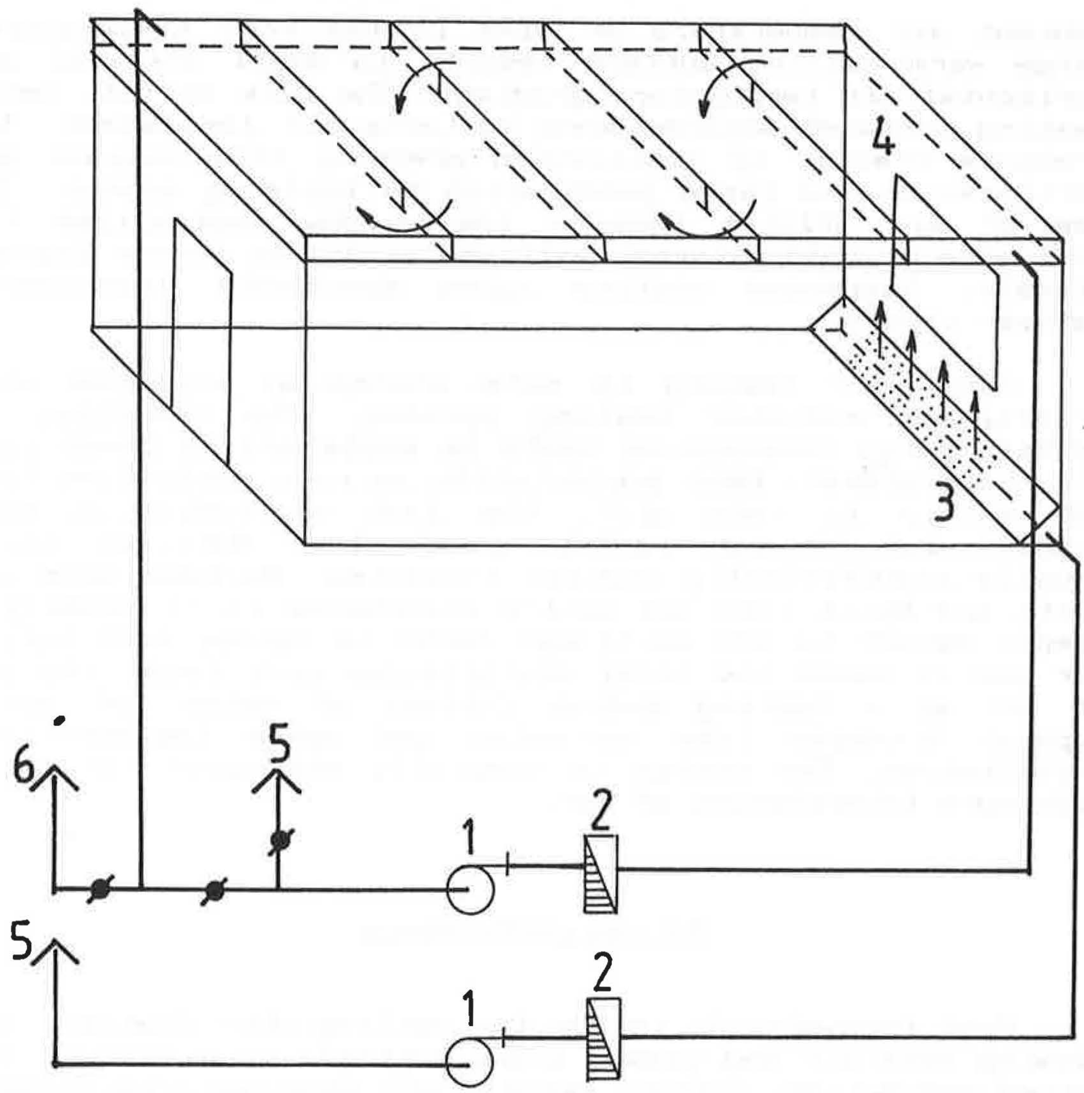

Fig. 1. Air Heating and Ventilation System
1 fan, 2 heating coil, 3 sidewall grille, 4 ceiling duct panel, 5 outdoor air intake, 6 exhaust air outlet

Similar forced warm air panel system, called Panelaire system, is well known in the U.S.A., and was described by Adlam (3). The differences between those systems are in ceiling panel construction, and heating and ventilation air distribution.

System advantages

The system is able to create better indoor climate conditions compared with traditional radiator heating. Ceiling accumulation smoothes the disturbances caused by ambient air temperature or wind in the room temperature. Large warm ceiling surface results in small vertical and horizontal air temperature gradient. The lack of hot, metal heating surfaces assures more suitable air ionization. The pressure created by ventilation prevents from ambient air infiltration and radon penetration to building spaces. The use of air grilles beneath the window neutralizes the influence of cold external wall and window on indoor thermal climate. Suspended ceiling makes soundproof improvement between floors.

Panel air heating is more economical compared with traditional radiator heating systems. The reduction in annual energy consumption could be explained by lower room air temperatures, heat accumulation in room partitions (and not mainly in room air), the lack of radiation heat transmission between radiator and close external wall, usually insufficiently thermal insulated. Because warm air ducts are built into the wall's structures it is usually a simple matter to add aditional ducts to convey ventilation air and it makes the total installation cost less. The use of air as a heating medium instead of water let avoid typical troubles like corrosion and water leakage from installation. The system is specially atractive for rooms with more interchanges of air.

System performance

Heat transmission inside the ceiling duct (between the flowing warm air and gypsum board surface) is a case of the forced convection. Correct results are obtained from Nusselt equation for a gas being cooled within a duct:

(1) $$Nu = 0.023*(Re)^{0.8}*(Pr)^{0.4}$$

This equation can be used downto Re>2100, so it is valid for air movement inside the ceiling duct because the air speed is rather always over 1 meter per second. The film coefficient h_{fc} is calculated from the formula:

(2) $$Nu = h_{fc}*D/k$$

where D - duct diameter, k - air thermal conductivity.

Little resistance to the passing air is very important and essential from heat efficiency point of view. This little resistance, $R = 0.0413\ m^2K/W$, is offered by smooth surface of the gypsum board.

Heat transmission from a warm ceiling surface to the room is due to combined convection and radiation. Parallel convective and radiant film coefficient h_{cr} could be calculated from empirical formulas given by Kwiatkowski (4).

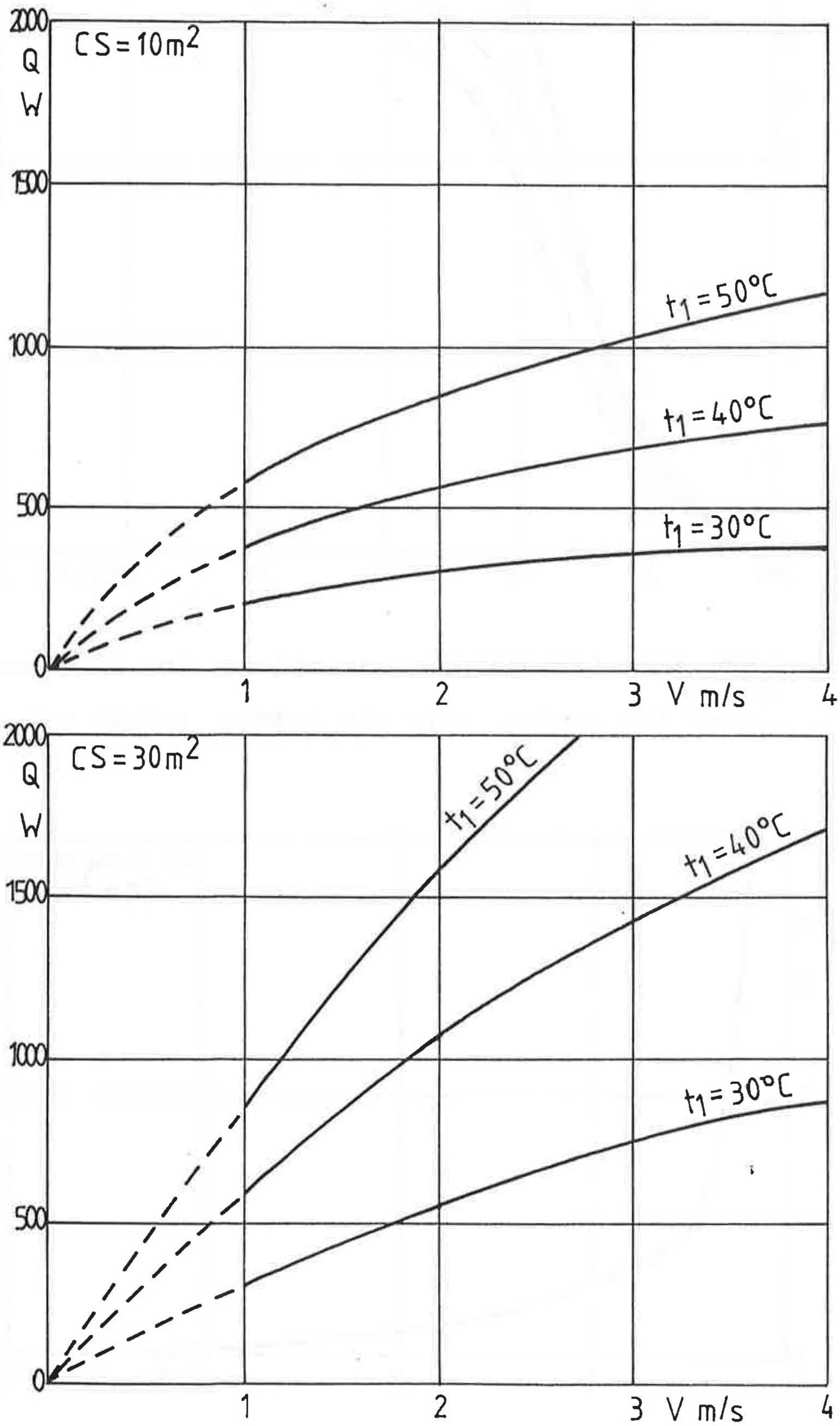

Fig. 2. Heat output of the system Q vs. duct air velocity V, warm air temperature t_1 and ceiling surface CS

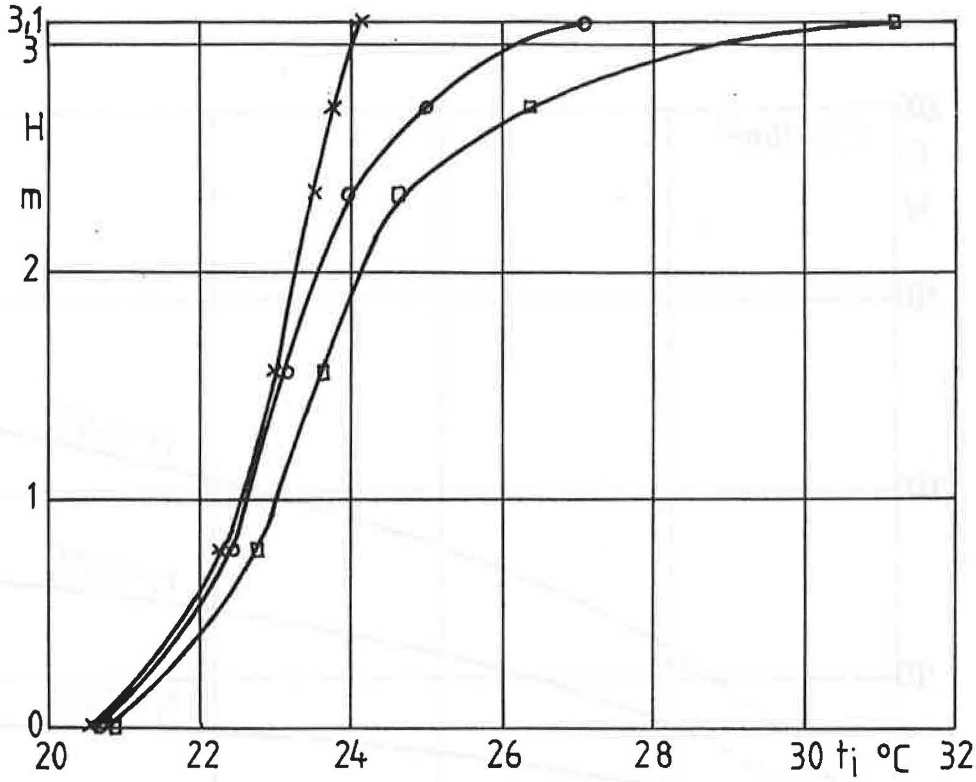

Fig. 3. Room air temperature variations in air heating system
□ near the window, ∘ in the middle, × near the door

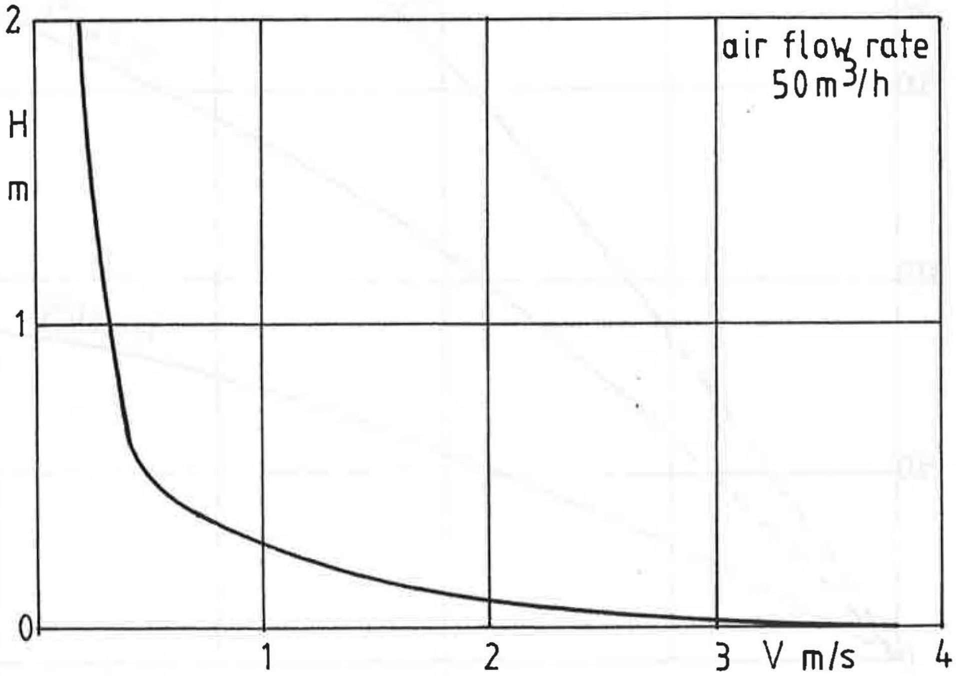

Fig. 4. Warm air velocity over a sidewall grille
t_i room air temperature

For ceiling surface:

(3) $$h_{cr} = 1.163(t_c-t_i)^{1/3}+0.025(t_c-t_i)+0.050t_i+4.047$$

and for floor surface:

(4) $$h_{cr} = 2.163(t_f-t_i)^{1/3}+0.025(t_f-t_i)+0.050t_i+4.047$$

where t_c - ceiling temperature, t_i - room air temperature, t_f - floor temperature.

Figure 2 showes the performance of air heating depending on duct warm air velocity and temperature. Graphs indicate that warm air velocity is of less influence on thermal output of air system than warm air temperature.

Room air temperature is presented by figure 3 in three room sections: near the window, in the middle of the room, near the door. There are only minor room air temperature variations within the occupied zone.

Warm air velocity over the grille could be seen on figure 4. The incoming ventilation air and room air mixing over the grille results in fast air velocity depression. In case of warm air ventilation depression of the room and warm air temperature difference over the grille is also fast.

References

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