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INTEGRATION OF HEATING MODE INTO VENTILATED COOLED BEAM

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ABSTRACT

Nowadays the ventilated cooled beam is one of the most popular air-conditioning system, e.g. in Scandinavia and Central Europe. With such beams, it is possible to create high-quality indoor climate conditions, including thermal comfort and a low noise level within reasonable life-cycle costs. The beam is suitable for spaces with a high cooling requirement, low humidity load and relatively small ventilation requirement. Typically, the beams are used in offices and conference rooms. Although the beam system is quite popular and well-known, there is still limited experience in using these beams for primary heating. The main objective of this paper is to present the results of a study to determine the heating power that can be achieved with the beams. The study comprised several tests carried out in laboratory conditions. In the laboratory measurements, the heating capacity, temperature gradient of the room, and the air velocities were analyzed when the parameters were the temperature of the inlet water and the flow rate of the supply air. The results obtained from the study, show that it is possible to create comfortable indoor conditions with the beams even during winter conditions. The measured air-flow velocities were lower than 0.2 m/s at all the measurement points. An inlet water temperature of 40 °C gives a reasonable temperature gradient in the room of under 3 °C. At the same time, the average air velocity in the occupant zone is under 0.1 m/s.

KEYWORDS

Ventilated cooled beams, heating, laboratory measurements, thermal comfort, air conditioning

BACKGROUND TO COMFORT AND HEATING

The heating and ventilation systems of a room are functions that contribute to comfortable, healthy and productive indoor climate conditions. However, increasingly there are higher expectations of indoor comfort conditions and the ability to control the room temperature, the air quality and limit drafts is now common. The basic guideline for thermal comfort is laid down in the ISO 7730 Standard (1990). The major part of this report concerns thermal comfort in terms of the temperature gradient in the room space and the room air velocities. ISO 7330 recommends the following:

- Air velocity (to avoid draughts):

< 0.15 m/s (winter)
< 0.25 m/s (summer)

- Vertical air temperature difference:

< 3°C from foot to head
when sitting, 0.1 m to 1.1 m, or standing, 0.1 m to 1.7 m.

Figure 1 shows some examples of the temperature gradients of common heating devices, (Heating and Ventilating Engineer 1985). The figure 1 illustrates that, with the traditional heating system, the maximum gradient is typically 3 – 5 °C. Of course, the existing conditions considerably affects a lot for the gradient, e.g. heat losses, positioning of the heating device, surface temperatures, and the sizing temperature levels of the heating device. All in all, the higher the heat losses and temperature level of emitters, the higher the temperature gradient in room space. Furthermore, the installation has a consequential effect on the gradient: it is more difficult to keep the gradient low when the installation height of the emitter is high.

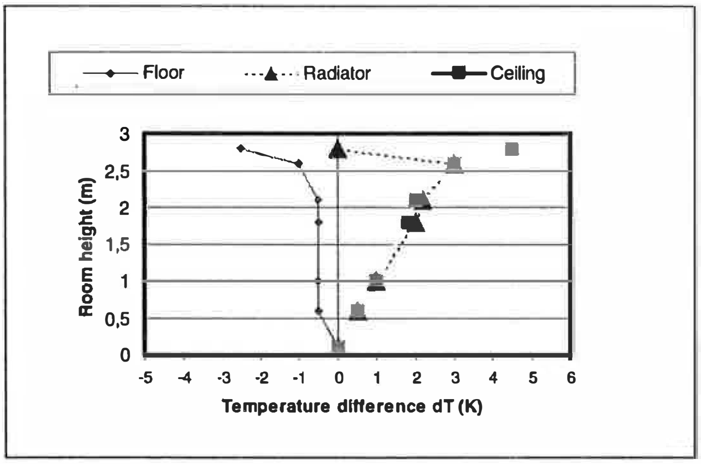

Figure 1: Temperature gradients of common heating systems

The required heating capacity is strongly dependent on the thermal properties of the building and the outdoor climate conditions. Figure 2 shows the required heating capacity as a function of the average thermal conductance and the outdoor temperature. In this case, the room dimensions are 2.8 m (room width), 4.5 m (room depth) and 3.0 m (height), giving a the floor area of 12.6 m^2 and a total external wall area of 8.4 m^2. In this case, the glazing ratio of the total outdoor wall area is fixed to 50 %. In the European case, there is a double-glazed window (U-value 3 W/m^2K) and the U-value of the wall is 0.45 W/m^2K. In the Scandinavian case, there is a triple-glazed window (U-value 2 W/m^2K) and the U-value of the wall is 0.28 W/m^2K. Figure 2 also shows an example which incurs high heat losses: this case is like a European one, except for having a single-glazed window. In addition, a case representing low heating demand is shown. Here, the heat losses are simply fixed 50 % lower than the Scandinavian case

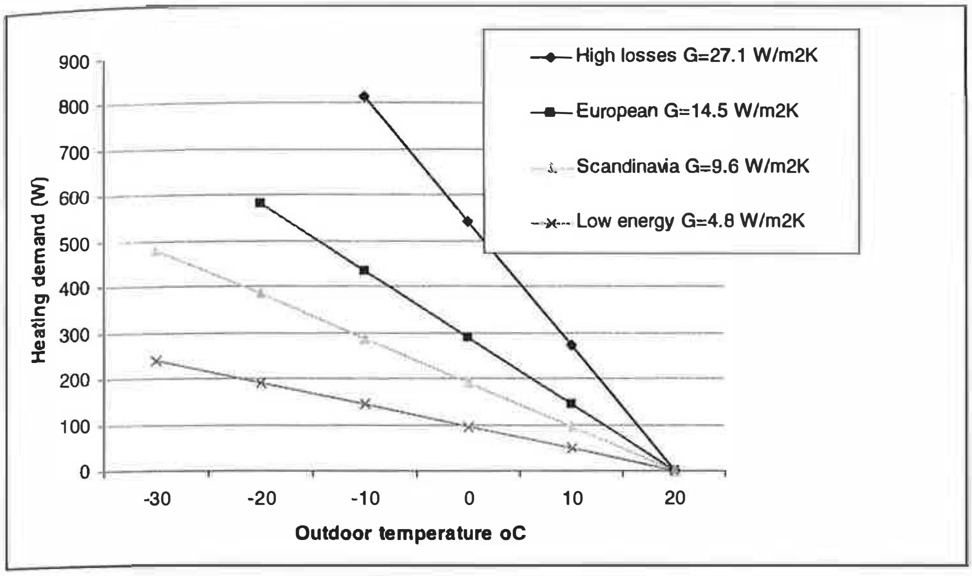

Figure 2. The required heating capacity as a function of thermal conductance and external temperature for a case room-module (room area 12.6 m^2 and external wall area 8.4 m^2).

The main idea of Figure 2 is to show the trend-setting heating capacity for a typical room. Of course, during the design phase the required heating demand should be calculated case by case. Based on this calculation, the required heating capacity of 500 W per room-module is enough for the normal case.

HEATING WITH VENTILATED COOLED BEAMS

Nowadays the ventilated cooled beam is one of the most popular air-conditioning systems, e.g. in Scandinavia and Central Europe. With such beams, it is possible to create high-quality indoor climate conditions including thermal comfort and a low noise level within reasonable life-cycle costs. The beam is suitable for spaces with a high cooling requirement, low humidity load and a relatively small ventilation requirement. Typically, these beams are used in offices and conference rooms.

The ventilated cooled beams can be divided into passive and active types, according to their properties. In passive beams, the heat transfer mainly occurs by means of free convection and partly by radiation. With active beams, the supply air device is integrated in the beam and the heat transfer occurs by forced convection. In active beams, the air-flow supplied through the nozzles induces room air through the heat exchanger of the beam, Figure 3. The mixture of supply air and induced air is directed into the room through the longitudinal slot on one or both sides of the beam. In the open model of the beam, the induced air comes from the upper side of the beam. In the closed model, the induced air enters through the bottom plate under the beam (as shown in Figure 3).

Although the beam system is quite popular and well-known, there is still limited experience in using these beams as a primary heating device. Laboratory measurements were carried out to analyze the properties of the ventilated cooled beams for heating. This paper focuses on the results for the closed beam, which is designed to be installed with a suspended ceiling. In this beam, the heating is achieved by integrating separate cooling and heating water pipes in the same coil.

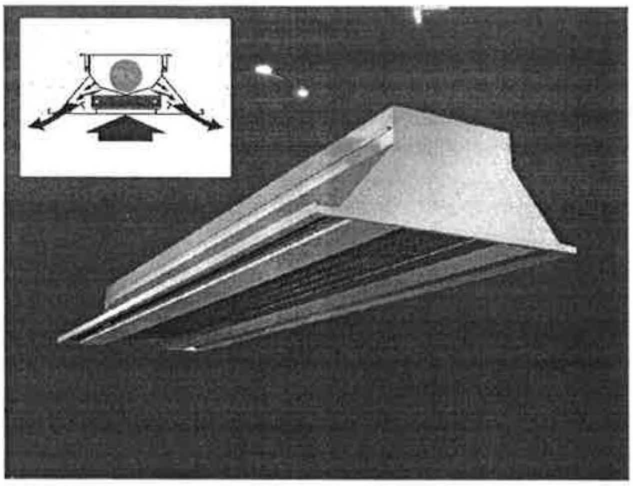

Figure 3: The studied ventilated cooled beam where heating and cooling modes are integrated.

In the laboratory measurements, the heating capacity, and the temperature gradient of the room and air velocities were analyzed when the parameters were the temperature of the inlet water and the flow rate of the supply air. The studied temperature levels of the inlet water were 40 °C, 60 °C and 70 °C, and the studied flow rates of the supply air were 13 l/s and 22 l/s.

The measurements were carried out in laboratory with dimensions of 4.5 m x 2.8 m x 2.7 m (height). The length of the studied beam was 1800 mm long (inside 1500 mm coil) and the width of the beam was 600 mm. The installation height of the beam was 2200 mm. In this measurement, the suspended ceiling was not used. In these measurements the air could freely stratify over the closed beam. In the normal case, when the suspended ceiling is used, the highest temperature is just under the beam. Table 1 gives the measurement results while Figures 4 and 5 show the temperature gradients.

TABLE 1
MEASURED DATA OF THE BEAM IN THE HEATING MODE.

Supply air rate qv(l/s)	Supply Air temp. T_{supp} (°C)	Water output Pw(W)	Output per active length Pw(W/m)	Inlet water temp. Tw1(°C)	Outlet water temp. Tw2(°C)	Water temp. difference dTw(°K)	Water flow rate $Q_{m,w}$ (kg/s)
22.3	18.7	561	373.7	38.6	34.2	4.4	0.0303
22.1	18.7	1154	769.1	60.7	51.4	9.3	0.0299
22.3	18.6	1519	1012.8	73.8	61.7	12.1	0.03
13.0	18.7	426	283.9	38.0	34.6	3.4	0.0301
12.7	18.7	824	549	57.3	50.8	6.5	0.0302
12.7	18.6	1233	822.3	73.2	63.1	10.1	0.0293

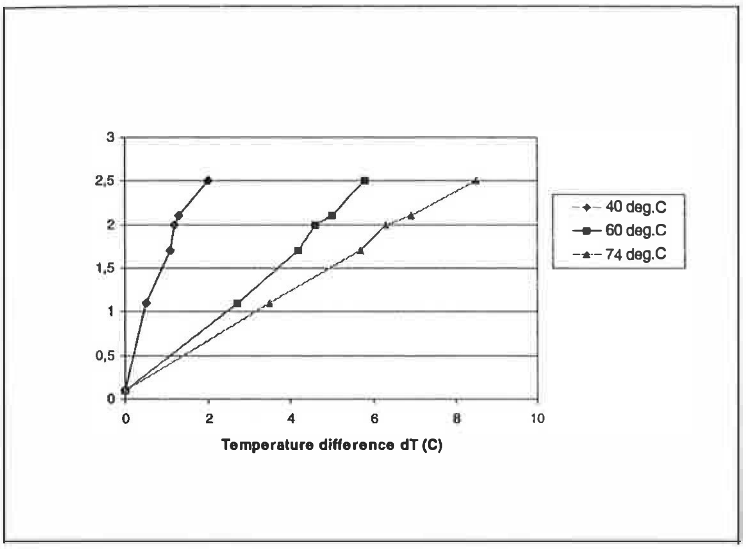

Figure 4: Room temperature gradient with three different inlet water temperature level. The supply air-flow rate is 22 l/s.

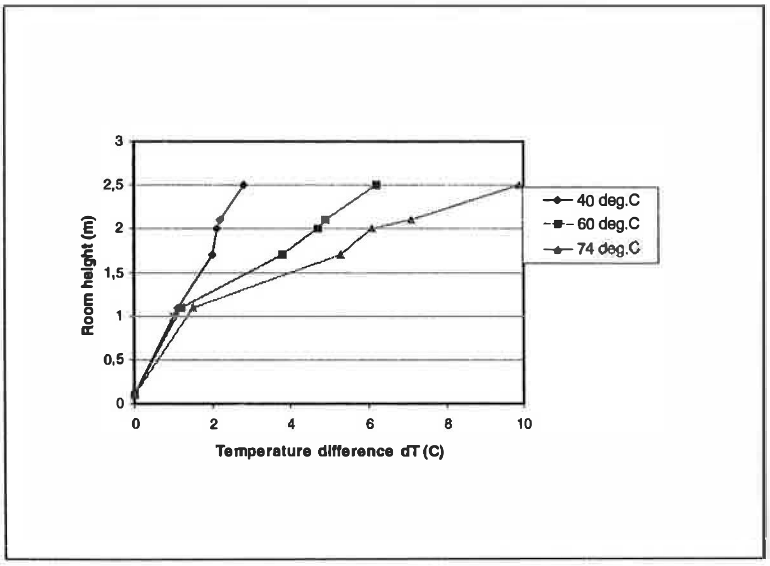

Figure 5: Room temperature gradient with three different inlet water temperature level. The supply air-flow rate is 13 l/s.

The measured data shows the effect of the inlet water temperature level on the temperature gradient. With relatively high temperatures, the gradient in the room rises: the temperature level of 74 °C leads to quite a high gradient 8 – 10 °C in the test room. Reducing the temperature level to 60 °C produces a 5 – 6 °C gradient in the room, which does not fulfil thermal comfort requirements. Using a 40 °C inlet water temperature gives reasonable gradients in the room of under 3 °C. At the same time, the average air velocity in the occupant zone is under 0.1 m/s.

Increasing the supply air-flow rate decreases the temperature gradient. In the measured case, using 22 l/s instead of 13 l/s reduced the gradient only about 1 °C. Therefore, the key factor is to control the inlet water temperature at a reasonably low level. Decreasing the inlet temperature is not a problem for fulfilment of the required heating capacity. With the temperature level 40 °C, it is possible to reach 500 W, which in most cases is enough.

DISCUSSION

Integration of the heating mode in the ventilated cooled beams is a challenging task. The main problem has been to control the temperature gradient at a reasonably low level, and so contribute to creating thermal comfort conditions in room spaces in an energy-efficient way. Increasing the gradient could be problematic for thermal comfort as well as increase energy consumption. On the other hand, meeting the heating capacity requirement is not a big problem in most cases.

The key factor is the temperature level of the inlet water. The lower inlet temperature leads to a lower gradient. Based on the measurements obtained, a temperature level of 40 °C or below, gives a reasonable gradient for the room space. For design practice, this also means the possibility to use low temperature level heating sources.

It should be noticed that these measured gradients show the worst case when there are no solar and internal heat gains. During working hours, there is normally enough or even too much of a heat load to keep indoor temperature within acceptable comfort levels. This means that this worst case exists in the beginning of the working day when the external temperature is also near sizing conditions. When the required heating capacity is lower the gradient is also smaller.

The meaning of the gradient should be analyzed case by case during the design process. If the period of high-heating peak load is short, the relatively high gradient could be acceptable and the inlet temperature could be higher. This analysis should be based on the life-cycle approach.

REFERENCES

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Advances in Floor Heating in Europe. Heating and Ventilating Engineer number 674 1985. Pages 18-22.