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Air-Conditioning by Chilled Indoor Fountains

Problem

To cool and dehumidify indoor air, first of all air-conditioning systems on the basis of air circulation are common according to state-of-the art technology. But the operation of this type of air-conditioning system causes specific noise and sometimes even uncomfortable draughts. This is the reason, why surface cooling elements, e.g. chilled beams or ceilings, have established on the market as an alternative. The advantage of this kind of cooling elements is the double effect. They cool the convective air flow, while simultaneously forming a heat sink for long-wave radiation of persons and objects in a room. Moreover, they neither cause background noise nor air draughts. Yet, the air-conditioning performance of these cooling elements is limited. The surface temperature of a chilled ceiling must be elevated above the dew point of indoor air temperature, in order to avoid favourable conditions for mould growth, i.e. surface humidity must always be kept below 80 % r. h. [1]. Therefore, chilled ceilings are not suited for dehumidifying indoor air, as it is precisely the deposition of water vapour in the air that must be avoided to prevent mould growth.

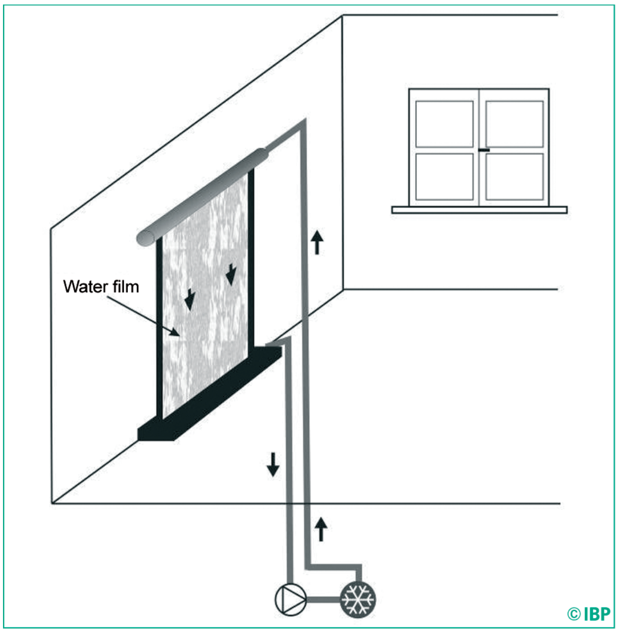

Fig. 1: Schematic diagram of a surface air-conditioning system, where the refrigerant is not conducted in pipes, but is flowing as a film over a surface in direct contact with indoor air.

Alternative Surface Air-Conditioning Systems with Chilled Liquid Films

The risk of condensation or mould growth is not only a challenge for the control of chilled ceilings, but also a considerable limitation to the usable cooling capacity at elevated indoor air humidity. **Fig. 1** shows the schematic diagram of a novel surface air-conditioning system as a possible solution [2]. It consists of a water-distributing plane, which can be mounted to a wall or any other self-supporting object in the room. It is supplied from above with chilled water or any other refrigerant by means of small nozzles so that an even liquid film is formed flowing slowly into the lower receptacle. A chiller, installed outside of the room, is controlling the temperature of the refrigerant, as it is the case with a chilled ceiling.

In contrast to the chilled ceiling, this method is suitable for being operated at temperatures below the dew point of indoor air without any problems. Moreover, the advantage is that the air flow over the water film is not only cooled but simultaneously also dehumidified. If the temperature of the water film is below the dew point temperature of indoor air, indoor air humidity will condensate on the water film and is conducted away. According to the composition of the refrigerant, water absorbed from indoor air can be removed from the cooling cycle by a simple overflow or regeneration device. Boundary conditions may of course be adjusted in a way that indoor air is humidified, if desired.

Testing Cooling and Dehumidification Effects

Two indoor environment test rooms are available for experimental investigations at the outdoor testing site of the Fraunhofer Institute for Building Physics in Holzkirchen. The test rooms have a volume of 50 m³ and are equipped with a calibrated ventilation system providing a constant air change rate (0.5 h^{-1} in this case). The rooms have calibrated ultrasound evaporators, which can simulate moisture generation cycles, characteristic for apartments with high occupancy. The evaporators are controlled by clock timer causing the "digitalisation" of moisture generation. Therefore, characteristics of relative humidity in the test rooms are of saw-tooth nature. The test rooms and the equipment were designed for comparative tests for the humidity-buffering effects of internal linings as described in detail in [3].

A facility was installed according to the schematic in **Fig. 1** in one of the test rooms with normal plaster for interiors on the walls. This "chilled fountain" expanding over almost the total room height consists of a bordered steel sheet with thermal insulation on the backside. The refrigerant (pure water was used in the tests) is distributed to provide a homogeneous water film on the entire surface of the sheet by means of small nozzles at the upper end of a pipe. This water film is collected at the end in a receptacle and led to a chiller installed outside the test room. The open cooling cycle is closed in this way. First testing was carried out at an indoor temperature of 20 °C and summer-like humidity conditions.

Fig. 2 shows in the diagram below the 24-hour-course of relative humidity in the test room with and without operating the chilled fountain. Daily repetitions of periods with elevated moisture generation are presented in the diagram above. Due to a low humidity generation during the night, indoor relative humidity falls from initially 70 % to slightly more than 60 %. The chilled fountain is operated from the beginning of the moisture generation peaks in the morning of the first day. The dehumidification effect of the chilled water is obvious by comparing the two courses: Even during moisture generation peaks, indoor air humidity remains at more than 10 % RH below the reference values without operating the chilled fountain. Only after turning off the chilled water, the air humidity conditions go back to the normal level.

Further investigations of thermal comfort at indoor air temperatures between 25 °C and 30 °C showed that a remarkable improvement of the PMV values can be achieved by the radiation sink effect of the chilled fountain on hot summer days.

Conclusions and Outlook

Noiseless and draught-free operation is the reason for the great popularity of chilled ceilings. The described surface air-

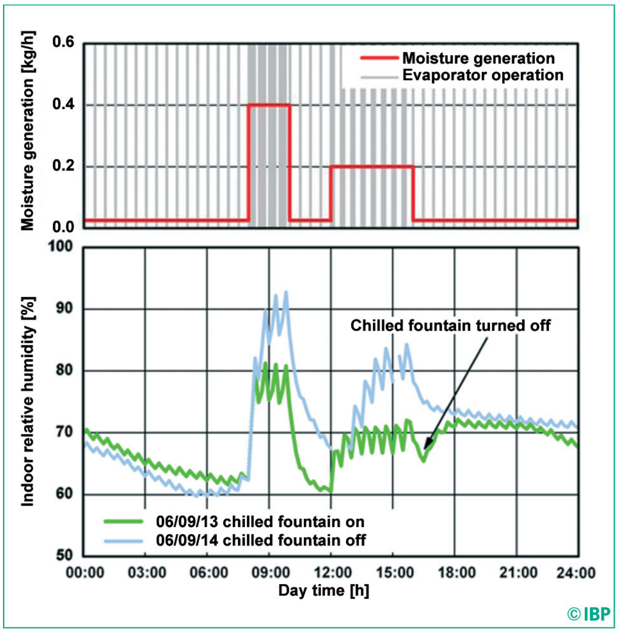

Fig. 2: Time-dependent moisture generation and resulting indoor air humidity measured on two subsequent days with comparable weather conditions. The first day (09/13) the chilled fountain was operating until 16:30; the next day it remained shut down.

conditioning systems possess the same properties. Moreover, they can simultaneously dehumidify indoor air providing thermal comfort in indoor environments on hot and humid days. First testing already verified this double effect to improve indoor air conditions. An essential aspect of indoor air-conditioning by chilled water films is the prompt availability. The effect is immediately perceivable after switching on the device, as is the case with conventional air-conditioning systems with blower in a similar way. In contrast to these devices, however, the presented surface air-conditioning systems do not require any internal heat exchanger of refrigerant-air as well as no additional energy source for the blower. This fact could have a favourable effect on the energy efficiency. In contrast to conventional chilled ceilings, however, the chilled indoor fountain can serve as so-called condensation trap. Therefore its operation would be particularly beneficial in hot and humid climate conditions.

Literature

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