VENTILATION AND COOLING
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Title: **Ventilation and Cooling**

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The main source of humidity in office buildings are the human occupant in the offices. Moisture is therefore a result of heat transmission from the person to the room air.

1. Heat transmission of the human body

The human heat transmission is done by convection, radiation and by evaporation of water to the environment. This physical transmissions cause the following six parameters of thermal comfort:

- activity level
- clothing
- air temperature
- air humidity
- air velocity
- wall temperature

The different heat transmission mechanism take over different parts of the total heat load. The ratio are depending on various parameters. With rising air-temperature the convection is decreasing meanwhile the latent heat by evaporation is increasing. In fig. 1 the influence of the activity level on the different ratios is shown. The total heat losses with an activity level related to 120 W (left part of Fig. 1) is fairly constant over a wide range of temperature. But the ratio between the latent heat and the sensible heat is very different at various air temperatures.

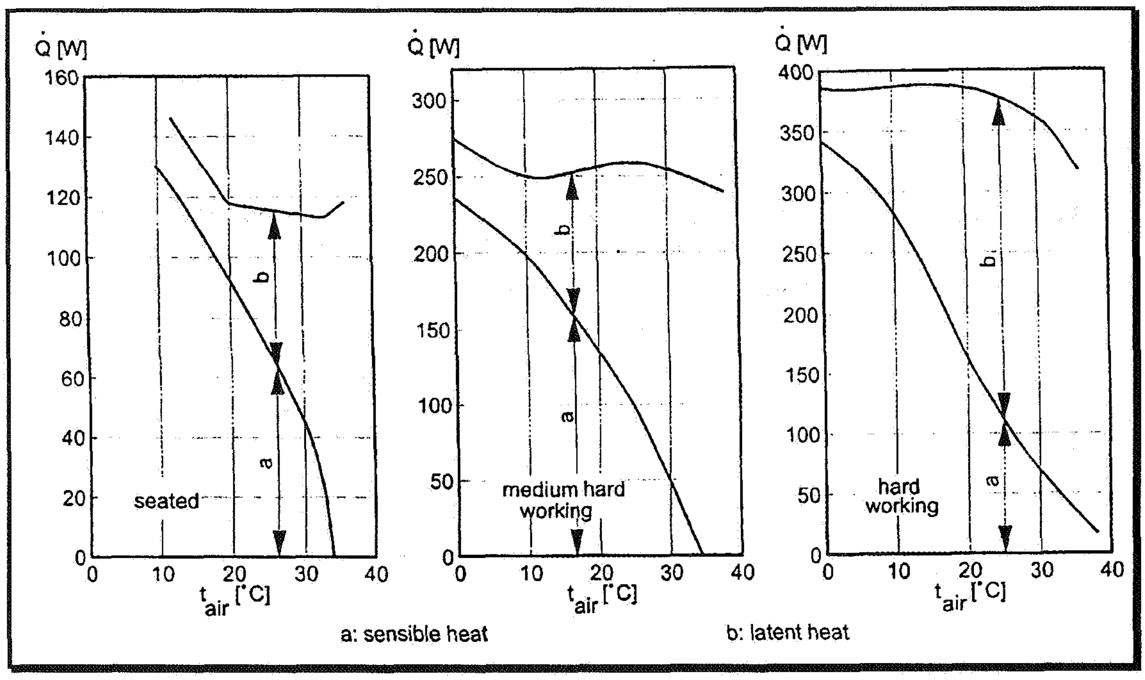

Fig. 1: Heat-transmission of persons in normal clothing /1/

Higher activity level related to 250 W (middle part of Fig. 1) or to 350 W (right part of Fig. 1) shows the same tendency. The sensible heat is always the sum of convection and radiation.

At higher temperatures the evaporation must take over sometimes incomming radiation. In cars e.g. the incoming solar radiation must be considered already at lower room-temperatures because this incoming energy must be bilanced by additional evaporaton. That is the reason why a large amount of water vapour ist transported to the air.

Main standards and regulations are done for offices with fairly the same activity level for all persons in the room. But also in these rooms a different heat transmission to the room can be seen in comparing the different individuals. /2/

Because the parameters of the heat convection are fairly stable, and because of the constant body temperature and a fixed clothing the control mechanism of the body temperature by changing the heat losses can only be done in the latent heat range. The rise of the temperature of the body surface can only be shifted in very small limits and the room air temperature and the air-velocity can not be ajusted individually. A change in the radiation is also not possible at a fixed wall temperature and given room configuration.

Fairly often different activity levels can be found in the same room. Some examples are shown with the following values (Tab. 1).

activity	**range of heat transmission**	**mean value**
1. seated	90 W - 150 W	120 W
2. typewriting	120 W - 170 W	150 W
3. speaker	160 W - 250 W	200 W
4. waiter	200 W - 300 W	250 W
5. dancing	200 W - 400 W	300 W

Tab. 1: Activity levels

These activity levels are very different but we can find them in the same room at the same time and with the same clothing. The distribution of the heat transmission to radiation, convection and evaporation therefore depends also on the room temperature. Calculated values on the bases on some measurements are shown in the next table (Tab. 2).

2. Humidity and comfort

If we regarde a ball-room we will have seated persons, speaker, waiter and dancing groups which have only a small difference in radiation and convection. To be able to meet the heat balance the human body sends water to the surface to reach evaporation cooling. The related amount of water will be at 20°C between 45 g/h and 220 g/h. The relative values at 26°C are 90 g/h and 300 g/h.

This amount of water must be transfered to the air. This can be reached by a high mass transfer coefficient or by a big difference between the absolut humidity at skin level and in the room air. An increase of the mass transfer coefficient will also give an increase of the heat transfer coefficient. This correlation is given in the Lewis law.

When we use the same values of the absolut humidity as in normal office buildings we will get no common comfort in rooms with very different activity levels.

	20°C					26°C			
	Heat	Radiation	Convection	Evaporation	Water	Radiation	Convection	Evaporation	Water
seated	120 W	45 W	45 W	30 W	45 g/h	30 W	30 W	60 W	90 g/h
typewriting	150 W	50 W	50 W	50 W	72 g/h	33 W	33 W	85 W	125 g/h
speaker	200 W	60 W	55 W	85 W	125 g/h	40 W	37 W	123 W	180 g/h
waiter	250 W	65 W	70 W	115 W	170 g/h	43 W	45 W	162 W	230 g/h
dancing	300 W	65 W	80 W	155 W	220 g/h	43 W	50 W	207 W	300 g/h

Tab. 2: Heat distribution with the same clothing and different activity levels

In table 2 we see that at 20°C a seated person will have a convective heat transfer of about 30 W and an evaporation heat of about 60 W. A dancing person, however, will have about 50 W of convective heat and more than 200 W by evaporation. If this will be done by a higher mass transfer coefficient the convective heat losses of a sitting person will increase too and will cause the feeling of draft.

To be able to avoid this the high water mass transfer must be reached with a big difference of absolut humidity instead of an increased transfer coefficient. This means a temperature of 20°C and a low absolut humidity in the air with the standard air velocity will meet the comfort conditions for both groups of the population in the same room. The small temperature difference and a normal heat transfer coefficient will not give any draft for sitting persons and also give enough evaporation potential for people with higher activity level like speakers, waiters and dancers.

The relative humidity in the rooms should not be lower than 30 %. Below this level the nose and the throat can dry out and this must be avoided. In a lot of different materials which are used in buildings a low humidity can also give a high electrostatic load which also cause discomfort. /4/

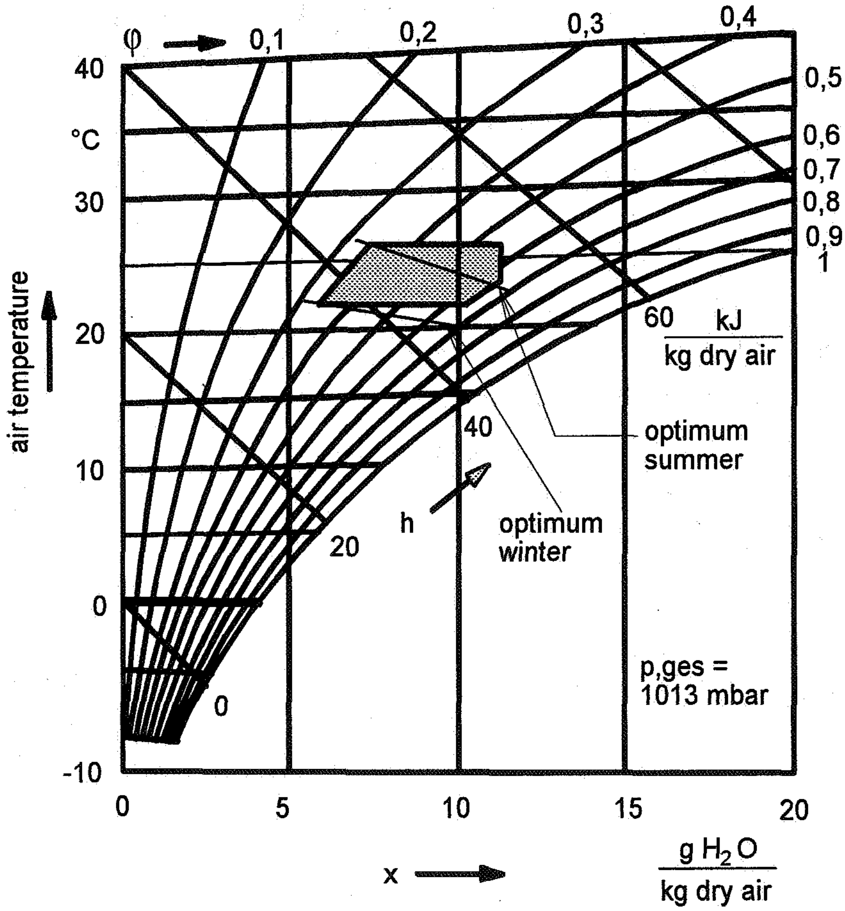

Fig. 2: Comfort zone DIN 1946 pt 2

The investigations of O. Fanger /5/ about the thermal comfort shows a much smaller influence of the humidity, but these values are only valuable for office buildings. The reason of these results is the very small change of activity level, a very simular clothing and a fairly stable air temperature. As shown the activity level is of great influence. It is not possible, therefore, to use the values for office buildings in a much broader scale. In figure 2 the optimal conditions are shown compared with the comfort zone of DIN 1946 part 2. These results can also be shown by experiments.

In air conditioned testrooms a group of about 30 people had to find out which rooms seems to be colder compared with the other one.

Unanimously they stated that a room with 26°C and 30% humidity is definetly cooler than a room with 24°C and 60 % humidity. These tests give the line of optimum conditions for summer (see figure 2).

3. Dehumidification load

The cooling load is not enough to discribe the refrigeration capacity because it is also necessary to consider the air changes. The air change rate cause especially in summertime a different dehumidification load which effects the refrigeration capacity. The minimum air changes are influenced strongly by the material which is used in the interial design. This can be shown in table 3 /6/. This example shows how great the influence of the material can be to the total energy consumption offer building. This influence is somewhat higher than the influence of the insulation.

	ventilation dehumidification		air changes		energy demand heating	
marble floor:	0,1 m^3/m^2h	⇨	0,04 ach	⇨	1 W/m^2	2 W/m^2
carpet floor:	2 m^3/m^2h	⇨	0,8 ach	⇨	25 W/m^2	40 W/m^2
	up to		up to		up to	up to
	8 m^3/m^2h	⇨	3,2 ach	⇨	100 W/m^2	160 W/m^2

Tab. 3: Ventilation rates

In summer everybody is speaking about cooling in air conditioning plants when he is going to degreese the air temperature. For the dehumidification we have to calculate in central Europe an enthalpy difference of about 25 kJ/kg dry air. It is very important to know that the highest enthalpy is not in the area of the highest temperature.

4. Cooling and Dehumidification

During the last years the reduction of energy consumption in buildings became one of the most important aims for the development of new technologies. A significant share of energy consumption in non-residential buildings bases on the requirement of cooling and air conditioning. Due to energy saving issues it is necessary to develop new air conditioning and cooling strategies, that lead to an continious reduction of energy consumption.

One possible starting point for the development of these systems is the separation of cooling and ventilation in air conditioning systems, because it is more effective to transport energy by using water systems than to use only air to deliver the cooling energy to the rooms. This strategy was the basis for the development of hybrid systems. By using these systems, it is possible to reduce the ventilation rates to a minimum, which ensures dehumidification and guarantees a satisfying air exchange due to hygienic aspects. The main part of sensible cooling can be delivered to the room by induction-coils, heat exchangers with free convection or chilled structural elements in the room like chilled ceilings.

During the last few years many chilled ceiling systems and free convective cooling systems were developed and they are nowadays often installed in combination with ventilation systems, which guarantees the necessary ventilation rate. These systems can be installed as well in new as in retrofit commercial buildings. At the beginning of this period, there was no guideline or technical standard available, which regulated or standardized the measurement of the cooling performance. So sometimes the given characteristic data for the design of these systems were related to different operating parameters like room temperature or mean temperature of the cold water, which is mainly used as transport medium to distribute the cooling energy within the building. Also it was possilble, that given data of cooling performance varied within a wide range for systems with nearly the same structure and design.

An accurate planning of these systems during the design period and an objective comparison of different systems is only possible, if the characteristic data for the description of heat transfer and cooling performance were investigated under comparable and clearly defined boundary conditions.

5. Refrigeration capacity

Mainly refrigeration systems for air conditioning are running with a temperature range of 6°C up to 12°C. Nearly all water chillers are designed for this temperature. The 6°C as supply temperature is necessary to reach the dehumidification of the outdoor air used for air renewal.

Normally the same system temperature is used to transport heat from inner heat gains to the central system. In chilled ceiling systems the temperature a the surface must be about 20°C in summertime to avoid condensing water at the surface.

If there is used the same water chiller either for the dehumiditation and for the cooled ceilings the 5°C or 6°C chiller water will be mixed with return water to read the higher supply temperature of about 15°C. If the water chiller will be devided in two parts working on a different temperature level a lot of energy can be saved. In table 4 the C.O.P. for different chiller temperatures are shown. They are measured in a water cooled condenser with 30°C/35°C. Compared with the supply temperature of 5°C the chiller has 38 % increase in C.O.P. at 15°C water supply temperature. This is a very high energy saving which must be considered in new system design.

chilled water temperatures supply/ return	cooling capacity	electrical power input	C.O.P	relative C.O.P
5°C / 10°C	198 kW	42,5	4,6	1
6°C / 12°C	208 kW	43,1	4,82	1,048
10°C / 15°C	250 kW	45	5,55	1,21
15°C / 20°C	298 kW	47	6,34	1,38

Tab. 4: C.O.P.'s for different chiller temperatures

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